

MACHINE FOR INJECTING LIQUIDS

BACKGROUND OF THE INVENTIONFIELD OF THE INVENTION

5 This invention relates to a machine for injecting liquids into materials having the consistency of foodstuffs.

DESCRIPTION OF THE RELATED ART

 United States patent no. 5,053,237 of Deloy G. Hendricks and Conly L. Hansen provides an apparatus for
10 the needleless injection of injectate into meat.

 According to lines 33 through 40 in column 4 of that patent, "[A] nozzle injection apparatus causes the injectate to travel from a reservoir under pressure
15 through a valve and out of a nozzle. Sufficient pressure must be provided such that the injectate can travel completely through the cut of meat, if desired. At the same time, temperature controls must be provided so that the injectate leaves the nozzle at a temperature within a
20 desired temperature range."

 Lines 41 through 48 of column 6 and lines 3 through 26 of column 7 consistently explain:

 "... The injection apparatus 10 will, in most cases, include a temperature control feature, such as a water
25 bath 12, for controlling the temperature of the fluid to be injected ("injectate"). The actual injectate fluid

will be contained within reservoir 14 disposed within the confines of water bath 12. It is crucial that the temperature be controlled within certain ranges in order to provide for proper injection.

5 "The apparatus of the present invention also includes a pump 16 and an adjustable relief valve 18 or pressure control assembly. Thus, the injectate can be pumped in a controlled manner from the reservoir through a nozzle assembly 20.

10 "Also useful in the present apparatus is an electric solenoid valve 22, which may be placed in communication with an adjustable timer to control duration of the bursts of injectate. Thus, the volume of injectate can be carefully controlled as can the amount of injectate
15 which leaves the system. This apparatus can then be connected to a starter and relay to operate the valve 22.

 "The injection apparatus will include a nozzle assembly 20. The nozzle assembly will function to direct the injectate in the proper direction and to maintain the
20 stream of injectate at the proper volume. The nozzle assembly 20 may include a plurality of individual nozzles 24.

 "The various components of the apparatus are placed in fluid communication by lines including recycle line
25 26, a feed line 28, and reservoir line 30.

 "Finally, the apparatus illustrated in FIG. 9

includes an injection table 32 to provide support for the meat being injected."

United States patent no. 6,165,528 of Yoshihiko Tanaka et al. discloses another apparatus for the
5 needleless injection of injectate into meat, which it terms a "pickle injector." This patent asserts, on line 66 of column 9 through line 8 of column 10:

"The pickle injector of the invention is a device for injecting the liquid substance into the green meat.
10 The pickle injector is provided with a high-pressure liquid generator, a liquid-substance injecting section, and a pressure controller which can control the injection pressure while injecting the liquid substance when the liquid substance is injected from the injecting section
15 to the green meat."

"The high-pressure liquid generator in the pickle injector the invention may be any mechanism, as long as it can increase the pressure of the liquid substance to a high level...."

20 No recognition is given in patent no. 6,165,528 is given to the fact that the injectate will be heated by passing through the pump and the pressure controller; nor is there any discussion concerning reclaiming injectate that does not find its way into the meat.

25 The apparatus of patent no. 6,165,528 does, however, preferably employ a manifold, as described in line 33

through 60 of column 10:

"... the high-pressure liquid substance is transferred from the high-pressure liquid generator via the high-pressure piping to the injecting section, and it is preferable to use the injecting section which has a member called a manifold for branching a single flow from the high-pressure piping to plural flows. The manifold is preferably placed on the tip end of the injecting section, but can be placed midway in the piping as the case may be.

"The injecting section of the conventional high-pressure liquid generator is of a single-hole type or has a form in which the piping in the manifold is branched radially. The present inventors have manufactured a manifold especially suitable for a pickle injector for meat, piping in the manifold is branched and the branched pipes are parallelly arranged. Here, the parallel arrangement includes not only the arrangement where the pipes are arranged parallel in a row but also the arrangement where the pipes are arranged zigzag or parallel in multiple rows. By arranging nozzles parallel, a nozzle interval can be narrowed to 10 mm or less, e.g., 5.6 mm for injection. Therefore, a highly dense and uniform injection is feasible. Further preferably used is a manifold which has multiple coherent stream injection nozzles arranged parallel in this

manner.

"When the manifold is used, the high-pressure liquid substance is injected as the coherent stream from the nozzle on the tip end of each piping. The liquid
5 substance is injected simultaneously from the parallel arranged nozzles to the green meat. ..."

Subsequently, patent no. 6,165,528 explains, in lines 44 through 47 of column 17, "The liquid substance is injected as a coherent stream from the tip end of the
10 injection nozzle of the manifold 7 in contact with the green meat." Thus, the nozzle actually touches the meat, creating an increased risk of contamination.

In lines 42 through 45 of column 18, similar language describes another embodiment. Also for this
15 other embodiment, however, lines 34 through line 36 of column 18 indicate, "The manifold 7 is ... lowered from above to hit against the green meat."

Although in lines 10 through 11 of column 17 and in line 16 of column 18, patent no. 6,165,528 states that
20 high-pressure piping 6 is "constituted of a flexible hose," no purpose is given for this flexibility. Thus, it is logical to assume that the flexibility is for the traditional purpose in high-pressure lines, viz., absorbing forces associated with the pressure that could
25 damage a more rigid line.

Finally, in its Description of the Related Art,

patent no. 6,165,528 provides a summary of needleless injectors and related devices.

To the best of the inventors' knowledge, all previous needleless injectors have utilized pumps, such as positive displacement pumps, which must run continuously in order to maintain the fluid to be used as an injectate under constant high pressure. Heat generated by such continuous operation is transferred to the injectate as it passes through the pump.

Moreover, in the practical implementation of United States patent no. 5,053,237, once the pressure in the system reached the desired level, a pressure relief valve 18 would prevent the continuously running pump 16 from further raising the pressure. This was accomplished by allowing the injectate to flow from the pump 16, through the pressure relief valve 18, and back to the reservoir 14 that supplied the pump 16 with injectate. A solenoid valve 22 allowed the injectate to flow to the nozzles 24 of the nozzle assembly 20 when desired. The re-circulation of the injectate through the continuously running pump 16 tended to raise the temperature of the injectate even more.

Not only is a cooling system necessary to keep the injectate within the required temperature range, but the added volume in plumbing necessary to provide the recycling and the additional capacity within the

reservoir 14 to account for the injectate that is being cooled within the water bath 12 requires a greater quantity of injectate than would otherwise be necessary. This, in turn, mandated the use of a larger pump 16. More
5 energy was required both because of the larger capacity of the pump 16 and because of the continuous operation. And since injectate is purged when it is desired to use another fluid as the injectate, the cost of injectate was higher.

10 Further, there is an interest in a needleless injection apparatus that can inject a liquid into a subject with minimal damage to the subject itself. There is also an interest in a needleless injection apparatus that can be easily maintained and cleaned in accordance
15 with applicable governmental food safety standards. In addition, there is a need for a needleless injection apparatus that is capable of operation within an existing continuous food preparation/production manufacturing facility without a significant investment in additional
20 equipment and without significant modification of an existing manufacturing process.

Accordingly, reducing exposure of machine components to moisture in the production environment is required to minimize maintenance of the machine. Further, minimizing
25 exposure of the threading on key machine components to the injection fluid or a cleaning solution is required to

enhance longevity of the machine and to reduce possible contamination of the injection subjects.

In addition, operation in a continuous environment requires immediate reaction to subtle changes in
5 production process variables. For example, an injection spray that is substantially uniform, without any hesitation during or between injection bursts is required. Accordingly, a method to ensure steady and consistent injection bursts is needed. In addition, the
10 ability to automatically refresh the fluid supply is also desirable.

SUMMARY OF THE INVENTION

The present inventors recognized the preceding disadvantages of the systems in the prior art and developed a needleless injection apparatus that utilizes
5 one or more commercially available air booster pumps. Such a pump generates less heat by operating only when necessary to maintain a desired pressure.

One aspect of the present invention provides a machine for injecting liquids comprising: at least one
10 manifold head, adapted to receive high-pressure injection fluid, including a fluid entry port and a plurality of injection nozzles, each of said injection nozzles having an injection orifice; and at least one filter assembly comprising a liquid inlet, a liquid outlet, and a liquid
15 passageway connecting said liquid inlet and liquid outlet, said filter assembly in non-threaded engagement with said fluid feed port of said manifold head.

The Machine also employs a head which preferably, but not necessarily, has injectate introduced into the head
20 through apertures in the walls of a hollow tube inside the head that is in fluid communication with the air booster pump. The head has apertures for one or more nozzles. The apertures are preferably, but not necessarily, designed so that an input end of the nozzle lies within the head at a
25 point with enough distance to the interior of the wall of

the head that any particles within the injectate will tend to fall to a level below the input end of the nozzle and not enter and thereby clog the nozzle.

5 The head is preferably, but not necessarily, designed so that upon installation one point of the inside of the head will be at substantially the highest elevation. Near such point the head has an escape aperture so that any gas within the injectate that enters the head will tend to
10 flow to and through such escape aperture. Furthermore, a return line preferably, but not

necessarily, takes injectate that flows through the escape aperture to the low-pressure side of the air booster pump. And also, a drain, in a work surface to which the head is preferably, but not necessarily, mounted, preferably, but
5 not necessarily, reclaims injectate and transports it to the low-pressure side of the air booster pump.

In order to improve performance of the Machine and minimize outgassing from the injectate, either the source
10 of the injectate is pressurized or a pump is inserted between the source and the air booster pump.

Preferably, but not necessarily, a main injectate filter is located between the source of the injectate and the air booster pump; and, preferably, but not
15 necessarily, the design of the Machine permits this main injectate filter can be replaced while the Machine is operating.

A cleaning aperture is preferably, but not necessarily, located in each end of the head.

20 A conveyor belt is preferably, but not necessarily, in a work surface to which the head or heads are, preferably, but not necessarily, mounted and has an endless belt containing so that the head or heads can be mounted either above or below the conveyor belt. The
25 conveyor belt is preferably, but not necessarily, one which may operate at different speeds.

Ozone may be added by the Machine to the injectate or applied to the subject of the injection.

And a computer device preferably, but not necessarily, controls many of the components and functions
5 of the Machine.

An alternate aspect of the present invention provides a machine for injecting liquids comprising: an injection component adapted to receive high-pressure injection fluid comprising: a tubular manifold having a first open end, a
10 second open end, and a plurality of injection nozzles; a first end cap including a fluid entry port, a first cavity having circumferential mating surface, said first cavity coaxially extending out from said fluid entry port and mateably configured to removably retain said first end of
15 said manifold; a first flexible sealing component positioned adjacent to said first mating surface within said first cavity to sealably join said first end of said manifold to the first end cap; a second end cap including a second cavity having a second circumferential mating
20 surface, mateably configured to removably retain said second end of said manifold; a second flexible sealing component positioned adjacent to said second mating surface within said second cavity to sealably join said second end of said manifold to the second end cap; and at
25 least one high-pressure pump in fluid communication with said fluid entry port of

said injection component.

In addition, stand-alone, easily removable filters are provided within the injection heads over the feed entry ports to remove particulate matter from the
5 injection fluid and to increase the turbulence of the entering fluid. These filters also are positioned within the injection head so as to prevent the injection fluid from contacting any threading present in the injection head.

10 Further, fast acting solenoid valves are attached to the escape apertures for quickly and automatically releasing any air build-up located within the injection

heads. The solenoid valves are located within the enclosure and away from the wet working production environment, thereby improving the ability to clean the machine during production downtime.

5 In addition, the air pumps are mounted within the enclosure and provide the high-pressure liquid to the injection heads. A controllable, high-pressure regulator is used to automatically adjust the output pressure of the air pumps thereby ensuring that the injection spray is
10 substantially uniform and the air pumps function without any hesitation during or between injection bursts.

Further, the injection fluid coming out of the high-pressure air pumps is first directed to an injection manifold system which includes a number of high-pressure
15 solenoid valves. The manifold system further ensures the fluid and going to each manifold head during an injection burst is substantially similar in pressure and volume.

Another aspect of the present invention provides a machine for injecting liquids comprising: an enclosure
20 having a top; at least one manifold head movably mounted to said enclosure and adapted to receive high-pressure injection fluid, comprising a fluid entry port, an escape aperture and a plurality of injection nozzles, each of said injection nozzles having an injection orifice; and
25 at least one solenoid valve in fluid communication with

1 said escape aperture, said valve mounted within said
2 enclosure.

3 A further aspect provides a machine for injecting
4 liquids comprising: at least one manifold head adapted to
5 receive high-pressure injection fluid, comprising a fluid
6 entry port, and a plurality of injection nozzles, each of
7 said injection nozzles having an injection orifice; and
8 at least one high-pressure air pump having an inlet and
9 an outlet in fluid communication with said fluid entry
10 port of said manifold head; at least one pressure sensor
11 in fluid communication with said outlet of said pump; and
12 an air pressure regulator connected to said pump and
13 electronically linked to said pressure sensor.

14 Another aspect of the present invention provides a
15 method for needleless injection of subjects with a liquid
16 comprising: providing a fluid to be injected; drawing the
17 fluid into at least one high-pressure pump; supplying the
18 fluid from the pump to at least one injection head; and
19 delivering at least one constant, high-pressure injection
20 burst of fluid to a subject.

21 Yet another aspect of the present provides a method
22 for needleless injection of subjects with a liquid
23 comprising: providing an injection fluid to be injected;
24 drawing the fluid into at least one air pump; supplying
25 the fluid to at least one injection head and filtering the

1 fluid as it enters each injection head; monitoring the
2 output fluid pressure of the pump with a pressure sensor
3 linked to a remotely located control panel; adjusting the
4 air pressure delivered to the pump to ensure the output
5 pressure of the fluid provides the required injection
6 effect on the subject; and delivering at least one
7 constant, high-pressure injection burst of fluid to a
8 subject.

9 A further aspect provides a method for the needleless
10 injection of subjects with a liquid comprising: providing
11 an injection fluid to be injected into a subject;
12 replenishing the fluid as needed during operation of the
13 machine; drawing the fluid into at least one air pump;
14 supplying fluid to at least one injection head and
15 filtering the fluid as it enters the injection head;
16 delivering at least one constant, high-pressure injection
17 burst of fluid to the subject; providing a controller for
18 storing process variables for a given injection subject;
19 and controlling process variables to achieve a
20 predetermined injection result.

21 It may therefore be seen that the present invention
22 teaches both a machine for needleless injection of
23 liquids into a subject, and a method of injecting
24 subjects using high-pressure injection bursts that do not
25 contact the injection subjects. Further, the machine for

26 injecting liquids of the present invention provides for
27 improved injection of subjects by reducing the risk of
28 contamination of the injection subject and simplifying

cleaning of the machine. Further, automatic control of the machine by an operator and easy integration into a production facility are also features of the improved machine for injecting liquids of the present invention.

5 The machine for injecting liquids of the present invention is of a construction which is both durable and long lasting, and which will require little or no repair to be provided by the user throughout its useful lifetime. The machine of the present invention is also
10 of relatively inexpensive construction to enhance its market appeal and to thereby afford it the broadest possible market. Finally, all of the aforesaid advantages and objectives of the machine for injecting liquids of the present invention are achieved without
15 incurring any substantial relative disadvantage.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 represents in schematic form the Machine for Injecting Liquids in an embodiment with no reservoir and no recycling of injectate;

5 Figure 2 represents in schematic form the Machine for Injecting Liquids in an embodiment with one reservoir but no recycling of injectate;

Figure 3 represents in schematic form the Machine for Injecting Liquids in an embodiment with one reservoir
10 and recycling of injectate;

Figure 4 represents in schematic form the Machine for Injecting Liquids in an embodiment with two reservoirs and recycling of injectate;

Figure 5 represents in schematic form the Machine
15 for Injecting Liquids in an embodiment with the capability of adding ozone to the injectate;

Figure 6 shows the exterior of the Machine for Injecting Liquids in an embodiment having a drain;

Figure 7 illustrates the exterior of the Machine for
20 Injecting Liquids in an embodiment having a catch basin in conjunction with the drain;

Figure 8 is an isometric view of the injection apparatus of the present invention, showing a front side thereof;

25 Figure 9 is top plan view of the injection apparatus shown in Fig. 8;

Figure 10 a plan view of the injection apparatus shown in Figs. 8 and 9, showing a back side of the cabinet;

Figure 11 is side plan view of a portion of the injection apparatus shown in Figs. 8 through 10, showing a channel and a conveyor system mounted within the channel;

Figure 12 is a bottom plan view of an injection head of the injection apparatus shown in Fig. 11 taken along line 12-12;

Figure 13 is a cross-sectional view of an injection head of the needleless injection apparatus shown in Figs. 8 through 12, showing a tubular filter disposed therein;

Figure 14 is a vertical section of a fluid-in end cap of the injection apparatus shown in Figs. 8 through 13;

Figure 15 is a partial cross-sectional view of an injection head of the injection apparatus shown in Figs. 8 through 13, showing a disk filter disposed therein; and

Figure 16 is a plan view of the injection apparatus shown in Fig. 8, showing a back side thereof with doors removed.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Figures 1 through 8 illustrate several embodiments of a needleless injection systems constructed in accordance with the present invention. Accordingly, the present invention is a needleless injection apparatus 30 that utilizes one or more commercially available air booster pumps 32 which employs relatively low-pressure compressed air typically less than 150 psi) to generate an output pressure sufficiently intense to propel injectate efficiently and without imparting any substantial heat to the injectate. Rather than operating continuously to maintain a desired pressure, the air booster pump 32 stops once that pressure has been attained. Each air booster pump 32 is connected to one or more heads 34. And preferably, but not necessarily, control valve 36 in a feed line 38 going from the high-pressure side 40 of the air booster pump 32 to one or more heads 34 opens to allow injectate on the high-pressure side 40 of the air booster pump 32 to flow through the nozzle or nozzles 42 of the one or more heads 34. When this occurs, the pressure is lowered, and the air booster pump 32 operates only long enough to re-establish the desired pressure.

Preferably, but not necessarily, the control valve 36 is capable of directing injectate from the air booster pump 32 to the specific head or heads 34 which a user

wishes to provide injection; alternately, however, a separate valve is located between the air booster pump 32 and each head 34 supplied with injectate by that air booster pump 32 so that a user may determine which heads
5 34 will be used for injection.

Alternatively, in lieu of either the control valve 36 or the separate valve between the air booster pump 32 and each head 34 supplied with injectate by that air booster pump 32, a separate pilot valve activates,
10 deactivates, and controls the pressure provided by a given air booster pump 32.

The air booster pump 32 holds only a small quantity of injectate and preferably, but not necessarily, receives such injectate from a nearby supply reservoir
15 46, minimizing the total quantity of injectate that must be within the machine.

Each head 34, itself, has a number of unique features.

The head 34 is a hollow body having apertures 48
20 near the bottom into which one or more nozzles 42 may be releasably connected. Each nozzle 42 has an input end and an output end. Preferably, but not necessarily, the input end lies within the head 34 at a point with enough distance to the interior of the wall of the head 34 that
25 any particles that may be within the injectate will tend to fall to a level below the input end of the nozzle 42

and, therefore, be unlikely to enter and clog the nozzle 42.

The interior diameter of the nozzles 42 is preferably, but not necessarily, selected to be such that surface tension of a liquid injectate will preclude the injectate from passing through a nozzle 42 unless the air booster pump 32 has pressurized the injectate above atmospheric pressure. This diameter is preferably less than .025 inch.

Within the head 34 is, preferably, but not necessarily, located a hollow tube 52 which communicates with the feed line 38 from the air booster pump 32 so that any injectate entering the head 34 must do so through the tube 52. Multiple apertures exist in the wall of the tube 52 that is perpendicular to the longitudinal access of the tube 52; preferably there is an aperture in the vicinity of each nozzle 42 in order to tend to equalize the pressure of the injectate at each nozzle 42. Introduction of the injectate into a head 34 at multiple locations, rather than from a single location, tends to increase turbulence within the injectate inside the head 34 and, therefore, to minimize the tendency of any particles within the injectate to accumulate and block a nozzle 42.

Again preferably, but not necessarily, a filter is located between the feed line 38 and any nozzle 42

associated with that head 34. When the hollow tube 52 is employed, such hollow tube 52 communicates with such aperture; and the hollow tube 52, preferably, but not necessarily, has, as the filter, a screen which removably
5 surrounds the wall of the hollow tube 52 that is parallel to the longitudinal access of the hollow tube 52.

The head 34 is preferably, but not necessarily, designed so that upon installation one point of the inside of the head 34 will be at substantially the
10 highest elevation. Near such point the head 34 has an escape aperture 60 so that any gas within the injectate that enters the head 34 will tend to flow to and through such escape aperture 60. Removal of gas from the injectate within the head 34 is important because,
15 although liquid injectate is essentially incompressible, gas can be compressed; so, when the air booster pump 32 stops, injectate would not be forced through any nozzle 42 by the air booster pump 32 but would be by any entrapped, expanding compressed gas.

20 A return line 62 is preferably, but not necessarily, attached to the escape aperture 60 in order to return any liquid injectate that is forced through the escape aperture 60 by entrapped, compressed gas to the reservoir 46.

25 Preferably, but not necessarily, the feed line 38 and the return line 62 are flexible in order to

facilitate moving the head or heads to alternate locations. The feed line 38 and the return line 62 could, however, be inflexible.

Preferably, but not necessarily, a valve 64 is
5 located in the escape aperture 60 (or the return line 62). This valve 64 may be a manually operated valve but is preferably an electronically actuated valve.

Each head 34 is preferably, but not necessarily, mounted to a surface termed the "work surface," 66 which
10 is preferably, but not necessarily, the top of a cabinet. Preferably, but not necessarily, the mounting is such that the head 34 may be rotated about one or more axes and preferably about three orthogonal axes. This is accomplished through any means that is well known in the
15 art, such as by securing the head with a clamp that can be opened and then closed or loosened and then tightened. Additionally, it is preferable to have the height of the head above the work surface 66 adjustable. Again, this is accomplished through any means that is well known in the
20 art, such as mounting the clamps on a bracket that can be raised or lowered, e.g., with a hydraulic cylinder or a rotatable screw.

When there are multiple, independently orientable heads 34, a variety of optional techniques for injection
25 exist. For example, injection can occur from multiple directions simultaneously or in timed succession; the

angle of entry for the injection from one or more heads 34 can be changed simultaneously or in timed succession; offsetting forces of two or more injection heads 34 can be utilized to stabilize the position of the subject of the injection, precluding or minimizing the movement of the subject that can be caused when injection occurs from a single direction; and the pattern of injection produced by the nozzles 42 of different heads 34 can be overlapped to achieve a higher injection density at one time than could be obtained by using just one head 34, because of physical limitations dictating the space required between adjacent nozzles 42.

The top of the work surface 66, which, as noted above, is preferably, but not necessarily, the top of a cabinet, is preferably, but not necessarily, sloped to collect excess injectate and use gravity to cause it to flow through a drain 68 and preferably, but not necessarily, a screen. The screen can be upstream from the drain 68 or within the drain 68. Optionally, instead of just relying upon gravity, a reclamation pump could be placed in or adjacent to, and in fluid communication with, the drain 68. And the drain 68 optionally could include a catch basin into which injectate reclaimed from the work surface 66 would first flow.

There exist a variety of options for providing injectate to the air booster pump 32. Of course, a

source 44 of injectate is connected to and in fluid communication with the input side 70 of the air booster pump 32.

Preferably, but not necessarily, a filter 72
5 designated the main injectate filter is located between the source of injectate 44 and the air booster pump 32, especially if pre-filtered injectate is not used.

If it is not desired to have a return line 62 from the head 34 and if it is not desired to reclaim injectate
10 from the work surface 66, either a container in which the injectate is delivered or a reservoir 46 into which the injectate is placed can serve as the source 44 of injectate. Gravity can cause the injectate to flow from the source to the air booster pump 32. Preferably, but
15 not necessarily, however, either the source is pressurized, by any means 74 that is well known in the art, with gas to cause the injectate to flow or a pump 76 is inserted between the source and the air booster pump 32. This improves performance of the Machine for
20 Injecting Liquids 30 and tends to preclude outgassing from the injectate which is caused when the air booster pump 32, in the absence of a pressurized source 74 or a pump 76 between the source and the air booster pump 32, creates a vacuum on its low-pressure side 70.

25 When a pump 76 is inserted between the source and the air booster pump 32 and when there is a return line

62 or a drain 68 from the work surface 66 or both the return line 62 and the drain 68, it is preferable, but not necessary, to have the return line 62 and the drain 68 flow into the container or the reservoir 46, whichever serves as the source 44. In this case, were the source pressurized, check valves could be employed in the return line 62 and the drain line 78, in any manner that is well known in the art; but the reclamation pump would have to provide flow from the drain line 78. And, as a further alternative when the reclamation pump stimulates flow from the drain line 78, a line from the source could combine with the return line 62 and the drain line 78 utilizing check valves in any manner that is well known in the art with the combined line proceeding to the pump 76 between the source and the air booster 32 if such a pump 76 is employed and otherwise going to the low-pressure side 70 of the air booster pump 32.

It is further preferable, but not necessary, to have the ability to remove the main injectate filter 72 while the Machine 30 is still operating. This would permit the main injectate filter 72 to be cleaned or replaced without interfering with production.

One example of a structure for accomplishing this is to have a line 80 from the source that branches into two parallel lines, each having a main injectate filter 72. A valve at the point of branching or on-off valves 82 in

each parallel line prior to the main injectate filter 72 select which parallel line will operate. The parallel lines could rejoin prior to or upon entering any pump. An alternate exemplary structure has an auxiliary reservoir 84 located downstream from the main injectate filter 72 prior to any pump. This permits the main injectate filter 72 to be removed when there is no injectate in the first reservoir 46 while sufficient injectate remains in the second reservoir 84 to supply the needs of the Machine 30 at least for the time that is required to replace the main injectate filter 72.

Each head 34, preferably, but not necessarily, has a first end 86 and a second end 88 as well as an aperture 90 designated the "cleaning aperture," which is preferably, but not necessarily, located in either the first end 86 or the second end 88 of the head 34 or, most preferably, both ends 86 and 88 of the head 34. As its name implies, the cleaning aperture 90 facilitates cleaning of the head 34. A brush, a high-pressure flush, or a spray may be introduced to the inside of the head 34 through the cleaning aperture 90. The cleaning aperture 90 is closed preferably, but not necessarily, with a valve located within the cleaning aperture 90. Optionally, a cap designated the "end cap" is removably attached to the head 34 over the cleaning aperture 90. This may be done in any manner that is well known in the

art, such as by having mating threads in the cleaning aperture 90 and on the end cap.

Within or adjacent to the top of the work surface 66 is, preferably, but not necessarily, located an endless-
5 belt conveyor 94. The conveyor 94 moves subjects near the head or heads 34 so that such subjects can be injected. Preferably, but not necessarily, the belt 96 of the conveyor contains apertures 98 so that a head or heads 34 can even be mounted below the belt 96 as well as above or
10 substantially even with the belt 96.

Preferably, but not necessarily, the speed of the conveyor 94 is variable; movement of the conveyor 94 can be continuous or incremental; and preferably the conveyor 94 employs electronic braking to insure that the conveyor
15 94 is stopped rapidly and completely when desired.

Although the Machine 30 can be operated manually, it preferably, but not necessarily, includes a computer device such as a programmable logic controller.

The computer device, thus, preferably utilizes
20 programmable microprocessors and includes the traditional features of a computer, such as a memory.

The length of the injection burst, injection pressure, and the delay between bursts can be programmed into the computer device by a user, although optional
25 default settings can be placed into the computer device at the factory. The computer device is preferably, but

not necessarily, capable of storing multiple programs that can be used when desired. Preferably, but not necessarily, the length of the injection burst can be varied from no injection to a continuous injection.

5 The computer device, furthermore, is preferably, but not necessarily, capable of controlling the movement of the conveyor 94 and synchronizing such movement with the injection burst in order to select the desired effect of the injection. For example, the computer device can,
10 preferably, but not necessarily, cause injection to occur only when the conveyor 94 is stopped and thereby create virtually unnoticeable points of entry for the injectate into the subject; or, alternatively, the computer device can cause injection to transpire while the conveyor 94 is
15 moving to create a slit in the subject that will result in mechanical tenderizing when the subject is material such as meat.

Optionally, the computer device may also be interfaced with various sensors, such as a sensor that
20 detects the thickness of the subject. A program in the computer device then adjusts one or more injection parameters to accomplish a pre-selected goal with regard to the subject, e.g., attainment of a selected concentration of injectate within the subject.

25 Additionally, all valves in the Machine, including but not limited to, the valve in the cleaning aperture 90

and the valve in the escape aperture 60 can preferably, but not necessarily, be controlled by the computer device. When this is done for the valve in the escape aperture 60, the computer device is preferably, but not
5 necessarily,
programmed to open the valve in the escape aperture 60 for a specified duration after a specified number of injections. Experience with the Machine 30 will enable a user successfully to predict the rate of accumulation of
10 gas and, therefore, the number of injections after which the valve in the escape aperture 60 should be opened as well as the duration for such opening, although again default settings can be placed into the computer at the factory. Alternatively, the computer device can be
15 programmed with algorithms based upon formulae that are well known in the art to calculate the theoretical pressure anywhere on the high-pressure side 40 of the air booster pump 32, *e.g.*, in the feed line 38. A pressure sensor then measures the actual pressure. The computer
20 device is programmed to compare the actual and theoretical pressures. Since air within the portions of the Machine 30 that are in fluid communication on the high-pressure side 40 of the air booster pump 32 is generally responsible for the actual pressure being lower
25 than the theoretical pressure, the computer device is programmed with a range below the theoretical pressure

within which the actual pressure must be. The computer device is further programmed to actuate, i.e., open, the valve in the escape aperture 60 one or more times until the actual pressure has risen so that it is above the lower limit of the acceptable pressure range. And in a still further option when the electronically actuated valve is employed in the escape aperture 60, a sensor is located in the head 34 near or, preferably, in the escape aperture 60. This sensor may be any sensor that is capable of distinguishing between liquid and gas, such as an optical sensor or a pressure sensor. The sensor is connected to the electronically actuated valve and causes the electronically actuated valve to be in the open position whenever gas is detected by the sensor.

Also, when there are multiple heads 34, some or all of the parameters can, preferably, but not necessarily, be varied independently for each head 34. This may be done with or without a computer device, but it is more practical to employ a computer device for such purpose.

Preferably, but not necessarily, input by the user to the computer device is accomplished with a sealed touch panel because this can withstand a wet environment. Any other input device that can withstand a moist environment is also acceptable. And any input device known in the art could be used if kept a sufficient distance from the moist environment associated with the

Machine.

Preferably, but not necessarily, the mounting of each head 34 is accomplished with gears and motors that are well known in the art so that each head 34 is moved
5 in three axes as well as raised and lowered using the motors and gears. Such motors and gears are preferably, but not necessarily sealed as are their connections to power, using any technique that is well known in the art, so that they will not be impaired by a moist environment.
10 Also preferably, but not necessarily, using any technique that is well known in the art, such as wires, radio frequency communication, or infrared communication, such motors and gears are remotely controllable. As is well known in the art, this can be done directly through the
15 input device, preferably, but not necessarily, a touch panel or through an input device and the computer.

All features of the Machine 30 except the work surface 66, the heads 34, the motors and gears, and the lines are preferably, but not necessarily, contained
20 within a sealed cabinet 100. Moreover as discussed above, the work surface 66 is preferably, but not necessarily, the top of a cabinet; and, in the preferred embodiment, this would be the sealed cabinet 100.

Anything which enters the sealed cabinet 100, e.g.,
25 wires or lines, such as a line to fill an non-pressurized reservoir, preferably, but not necessarily, enter through

apertures which are sealed, preferably, but not necessarily, with rubber gaskets. For maintenance, one or more doors 102 preferably, but not necessarily, exist in the outer surface of the cabinet 100; but these doors 102 and the sealed cabinet 100 incorporate a seal, preferably, but not necessarily one or more gaskets, around the opening or openings formed when the door 102 is not closed.

Optionally, in order to minimize the presence of microorganisms in the injectate, a source of ozone 104 is connected to a non-pressurized reservoir in any manner that is well known in the art. The ozone 104 is then allowed to bubble through the injectate in such reservoir. This may, for example, be accomplished by connecting the source of ozone 104 through a pressure regulator and valve to the reservoir near the bottom of such reservoir. And, as indicated above, this valve and, indeed, every valve associated with the Machine 30 are, preferably, but not necessarily controlled by the computer device.

Because the introduction of ozone 104 is somewhat consumptive of time, it is preferable, but not necessary, to have a non-pressurized reservoir in each of two parallel lines and to have one or more valves control which reservoir is receiving ozone and which is being used to supply injectate. This is done in a similar

fashion as discussed above for the use of two main injectate filters.

Also, as discussed with respect to the main injectate filter, the two reservoirs could be in series with the upstream reservoir being used for introduction of ozone 104 into the injectate while the downstream reservoir supplies the operational needs of the Machine for injectate.

Similarly, the subject of injection is preferably, but not necessarily, treated with ozone 104 prior to injection. In the same manner as described above for the injectate, ozone 104 is bubbled through a water reservoir containing water. Then there are three options. The subject can be passed through the water reservoir, the water containing ozone can be transferred by any method that is well known in the art to a holding reservoir through which the subject is passed, or the water containing ozone can be sprayed on the subject by any method that is well known in the art.

Preferably, but not necessarily, any portion of the Machine 30 that will contact either the subject or the injectate must meet the food grade specifications that are well known in the art.

Also preferably, but not necessarily, a removable safety shield 106 covers the working surface 66 and heads 34 to such an extent that a user cannot touch the nozzles

42 or the stream of injectate.

Preferably, but not necessarily, this safety shield 106 is transparent. And preferably, but not necessarily, sensors or interlocks, in any manner that is well known in the art, determine when the safety shield 106 has been installed and preclude the Machine 30 from injecting whenever the safety shield 106 has not been installed.

It can be seen that the above-described needleless injection apparatus can take several preferred forms, depending on the application of use for the machine. However, in food manufacture or production facilities, there is an interest in a needleless injection apparatus and method for using that can be incorporated into a continuous production line. In addition, the needleless injection apparatus of the present invention must also incorporate features that permit the machine to be easily operated, maintained and cleaned within a continuous production environment. Further, the improved needleless injection apparatus of the present invention minimizes down time for cleaning between runs and reduces potential contamination of the injection subjects by eliminating exposure of the injection fluid to threaded connection points within the manifold head.

In light of the foregoing, Figs. 8 through 16 illustrate a further embodiment of a needleless injection

apparatus 130 of the present invention. Fig. 8 illustrates a front side of the needleless injection apparatus 130 which includes a cabinet 134, a large catch basin 136, an endless-belt conveyor system 138, injection heads 140 and a control panel 142. Further, the apparatus includes a primary fluid reservoir 144 that is removably connected to the cabinet 134. It will be understood that the needleless injection apparatus 130 of the present invention can further include a safety shield attached to the cabinet 134 for protecting an operator from contacting the moving components or the injection spray while the apparatus is operating.

As shown in Figs. 8 and 9, the cabinet 134 is of a generally box-like construction and includes a front 146, a back 148, a right end 150, a left end 152, a top 154 and a bottom 156. Further, the cabinet 134 can include casters 158. The cabinet 134 also contains a channel 160 formed integrally in the top 154 for capturing and directing excess fluid to the catch basin 136. The catch basin 136 is integral with the cabinet 134 and extends outward from the right end 150 of the cabinet 134 to collect excess injection fluid.

The catch basin 136 contains a drain 162 which releases the collected injection fluid directly back into the primary reservoir 144, or alternatively, to a drain line which is piped directly to a floor drain. Also, the

catch basin 136 can instead be removably attached to the right end 150 of the cabinet 134 in any manner known to those skilled in the art that prevents any excess injectate from spilling onto unwanted surfaces or
5 equipment.

Turning for the moment to Fig. 10, the back side of the injection apparatus 130 is shown. The back 148 of the cabinet 134 contains large doors 164, door hinges 166, a door sealing and locking mechanism 168, a main
10 power inlet 170, multiple quick-connect air outlet ports 172 for powering external air actuated pumps or valves, and a feed inlet port 174 through which fluid pumped from the primary fluid reservoir 144 to the injection heads 140 must travel. The back 148 of the cabinet 134 further
15 includes a compressed air inlet port 175 for supplying compressed air to the cabinet 134. Further, it can be seen that the control panel 142 is mounted to the back 148 of the cabinet 134 with mounting post 177.

Best shown in Fig. 11, the conveyor system 138 is
20 mounted within the channel 160 in order to move injection subjects through the apparatus 130, from the right end 150, past the injection head 140, to the left end 152 of the injection apparatus 130. The conveyor system 138 includes a conveyor belt 176 having a plurality of
25 apertures 178 (best shown in Fig. 9) formed therein so that excess injection fluid can pass through the conveyor

belt 176 to the channel 160. Further, the apertures 178 allow a subject to be injected by an injection head 140 positioned at a point below the conveyor belt 176.

The conveyor system 138 is mounted to the cabinet 134 using a support structure 180 and drive mechanism 182 (shown in Fig. 16). While Fig. 11 illustrates the conveyor system 138 mounted within the channel 160, the conveyor system 138 can be mounted on top of or onto the cabinet 134 in any manner known to those skilled in the art that permits movement of the injection subject past the injection heads 140. In addition, the conveyor system 138 may contain a sensor, such as an optical sensor, for sensing the location of the injection subjects along the conveyor belt 176. These sensors can be remotely linked to a controller or computer to indicate when the subjects are in position to be injected or in position to be off-loaded from the conveyor belt 176.

The injection heads 140 are affixed to the top 154 of the cabinet 134 by a mounting system 184. The mounting system 184 includes a mounting post 186 and a bracket 188 which movably support each injection head 140, permitting the injection head 140 to be raised or lowered to any vertical position along the mounting post 186, including below the conveyor belt 176. Preferably, the injection heads are positioned to be no more than two

inches from the injection subject; however, any injection height may be used.

The mounting system 184 further permits each injection head 140 to be rotated about its center axis 190, allowing the angle of the injection bursts to be varied. In addition, the mounting system 184 can be provided with set-screws 192 or other adjustment mechanism for further elevating the height of the injection head 140.

Alternatively, the injection heads 140 may be mounted to the cabinet 134 in any location or in any manner that allows each injection head 140 to be moved about three orthogonal axes, including electronically automated mounting systems that are controllable via a remote controller or computer. In addition, while two injection heads 140 are shown, it will be appreciated that a single injection head 140 or more than two injection heads 140 may be required for a given injection application.

Referring next to Figs. 12 and 13, a detailed view of the injection head 140 is shown. The injection head 140 includes a hollow, tubular member 194, a plurality of injection nozzles 196 and end caps 198, 200. The injection head and related components are preferably constructed of stainless steel; however, the injection head may be constructed of any material known to those

skilled in the art capable of withstanding the high system pressures required to needlelessly inject subjects.

As illustrated in Fig. 13, the tubular member 194 has cylindrical, outer surface 202, a top portion indicated generally at 204, a bottom portion indicated generally at 206 and opposing open ends 208 and 210. The open ends 208, 210 of the tubular member 194 include threads 212 for removably attaching the end caps 198, 200 to the tubular member 194. The tubular member 194 further includes injection apertures 214 disposed along the bottom portion 206. When the nozzles 196 are removed from the tubular member 194, the injection apertures 214 and the open ends 208, 210 in the tubular member 194 can be used as cleaning apertures when cleaning of the apparatus 130 is required. Alternatively, cleaning of the nozzles 196 and the injection head 140 can occur with the nozzles 196 in place on the manifold.

The tubular member 194 further includes an escape aperture 216 disposed on its top portion 204 of near the end 210. The escape aperture 216 is used as an air bleed/pressure relief port to prevent build-up of air within the injection head 140 during operation of the apparatus 130; thus, the escape aperture 216 is preferably at the point of highest elevation along the injection head 140. A quick-connect fluid line 218 is

attached to escape aperture 216 to evacuate air build-up in the injection head 140 during operation.

Best shown in Fig. 13, the injection nozzles 196 are removably attached to each of the injection apertures 214 by a retaining screw 197. While the nozzles 194 are shown secured into the injection apertures 214 using a retaining screw, the nozzles 196 may be integral to the injection head 140 or otherwise removable attached to the injection apertures 214 in any manner known to those skilled in the art.

Referring again to Fig. 12, each injection nozzle 196 has an orifice 220 for delivery of the injection fluid to the subject. The orifice 220 in each injection nozzle 196 is preferably less than 0.025 inches and more preferably approximately 0.006 inches. The nozzles 196 and set screw 197 are removable for cleaning and can be easily changed depending on the subject to be injected and the desired injection objectives. In addition, consistent with the teachings of the present invention, it will be apparent to one skilled in the art that the orifice 220 in the injection nozzles 196 may be greater than 0.025 inches depending on the type and/or the thickness of the subject to be injected.

The nozzles 196 are constructed of sapphire, or any material known to those skilled in the art capable of withstanding the high-pressure fluid bursts required for

the needleless injection of subjects.

Fig. 14 illustrates the fluid-in end cap 198 which is used to removably seal the open end 208 of the tubular member 194 closed. The end cap 198 includes a feed port 222 having a threaded inlet 224 and a threaded outlet 226 through which the injectate fluid pumped to the injection head 140 is first received. The threaded inlet 224 is sized to receive a fluid feed connection. The threaded outlet 226 is sized to receive open end 208.

In addition, the end cap 198 includes a small compartment 228 bored into the feed port 222, adjacent to the threaded outlet 226. The end cap 198 further includes an O-ring 230 (shown in Fig. 15) positioned within the threaded outlet 226 to ensure a tight seal between the end 208 of the tubular member 194 and the end cap 198.

Likewise, an end cap 200, shown in Figs. 12 and 13, is used to removably seal the open end 210 of the tubular member 194 closed. The end cap 200 includes a threaded cavity 232 in the center of the end cap 200 and is sized to receive the end 210 of the tubular member 194. Further, the end cap 200 includes an O-ring 234 to ensure a tight seal between the end 210 of the tubular member 194 and the end cap 200.

The ends 208, 210 of the tubular member 194 are sealed for a production run by threading and hand

tightening end caps 198, 200 onto the tubular member 194 so that the peripheral edge of each end 208, 210 abuts or contacts the O-rings 230, 234, as shown in Fig. 13.

Accordingly, during a production run, the incoming fluid
5 does not contact any threading, grooves or pitting that may be present in either the end caps 198, 200 or the ends 208, 210, thereby making cleaning easier to perform.

Further, because residual injection fluid does not become trapped within the threading or pass through it,
10 the risk for fluid contamination is decreased. In addition, the configuration of the injection head 140 may increase the useful life of the injection head 140, as threads or grooves exposed to acidic conditions (cleaning fluid or injectate) tend to pit easily and rust.

15 The O-rings 230, 234 can be constructed of a material such as those sold under the trademark TEFLON by DuPont, Inc. or its licensees, EPDM (Ethylene Propylene Diene Monomer), silicone, rubber, or any other material appropriate for the particular application and known to
20 those skilled in the art that can seal the ends 208, 210 of the tubular member 194 closed.

Referring back to Fig. 13, a first filter 236 is shown. The filter 236 is generally a hollow tube having a cylindrical exterior surface 238 and opposing ends 240
25 and 242. The end 240 is open to channel the fluid entering through the feed port 222 in the end cap 198

directly into the filter 236 when it is installed within the injection head 140. The length and width of the filter 236 are selected to permit the filter 236 to fit within the injection head 140.

5 The filter 236 includes apertures 244 formed in the surface 238 along the length of the filter 236. The apertures 244 can be located anywhere along the longitudinal or circumferential extent of the filter 236. The number and placement of the apertures 244 in filter
10 236 is dependent on the flow volume required for a given injection run, which is in turn also affected by the number of injection nozzles used, the type of injectate fluid used, the required injection time, the required burst pressure or a combination thereof.

15 The filter 236 further includes an O-ring 246 near the end 240 for removably sealing the filter 236 relative to the feed port 222 when the filter 236 is installed within the injection head 140.

Typically, the filter 236 is installed into the
20 injection head 140 with the end cap 200 already in place over the open end 210 of the tubular member 194. The end 242 of the filter 236 is inserted into the tubular member 194 and is positioned such that it rests on and is maintained within the cavity 232 in the center of the end
25 cap 200, as shown in Fig. 13. When the end cap 198 is installed on the end 208 of the tubular member 194, the

end 240 of the filter 236 rests and is maintained within the small compartment 228 over feed port 222. The O-ring 246 in the end 240 of the filter 236 threadlessly seals the injectate filter 236 in place.

5 The filter 236 can, alternatively, be installed into the injection head 140 before the end caps 198, 200 are installed on the injection head 140 with the end caps 198, 200 being positioned on to the injection head 140 after the filter 236 has been placed inside.

10 The injectate filter 236 prevents nozzle plugging without being integral to the fluid-in end cap and without requiring a steel mesh encasing or another filter-type material affixed to the filter 236. Further, the filter 236 is a stand-alone filter that rests within
15 the injection head 140, allowing easy change-out of the filter 236 during breaks in a continuous operation or during cleaning.

In addition, the filter 236, by virtue of the O-ring 246 seal, reduces the risk of contamination of the
20 injectate fluid and the needleless injection apparatus 130 by preventing the fluid from contacting any threading present in the filter 236, the end caps 198, 200, or the tubular member 194. The filter 236 may also increase the useful life of the injection head 140 and/or the end caps
25 198, 200 over other filter configurations, as threads or grooves exposed to acidic conditions (cleaning fluid or

injectate) tend to pit easily and rust.

Referring next to Fig. 13, there is shown a second, alternate filter 248 for the needleless injection apparatus 130 of the present invention. The filter 248 is generally a disk-shaped element having a front side 250 and a back side 252. The filter 248 includes a flat, peripheral edge 254 and a plurality of apertures 256 formed within the filter 248.

To install the filter 248 into the injection head 140, the back side 252 of the filter 248 is placed into the end cap 198, without O-ring 230 present within the end cap 198, such that the feed port 222 is covered by the filter 248. The O-ring 230 is then placed over the disk filter 248 so that the O-ring 230 engages the filter's peripheral edge 254. The end cap 198 is then threaded onto the end 208 of the tubular member 194, thereby threadlessly sealing the filter 248 in place within the injection head 140. During operation, injectate fluid passes through the apertures 256 in the filter 248 to remove particulate in the injection fluid.

It will be appreciated by those skilled in the art that the injection head 140 may be of any shape or size, provided that adequate fluid pressure can be achieved at the outlet of the nozzles 196 to provide for the needleless injection of the subject. For example, the injection head 140, rather than being tubular in shape,

can be round or generally cylindrical in shape having apertures within any surface of the cylinder. In addition, the injection head 140 can have injection nozzles that are formed integrally therein, rather than including a tubular member with apertures for removable nozzles. Therefore, the injection head can be a single piece component, lending itself to easier cleaning and assembly.

Further, the injection head 140 may contain apertures 214 and/or nozzles 196 configured in any pattern desirable for a given injection application. For example, the nozzles may be concentrated in a circular pattern or a rectangular pattern, depending on the type of injection subject.

Turning next to Fig. 16, the primary reservoir 144 is a generally rectangular container having four sides 258, an open top 260 and a bottom 262 supported by casters 264. The bottom 262 of the primary fluid reservoir 144 is sloped downward to the center 266 of the bottom 262 such that the center 266 is the lowest point in the bottom 262 of the reservoir 144. Accordingly, any particulate matter present in the injectate fluid will accumulate at the center 266 of the bottom 262. A cleaning aperture 268 is formed within the center 266 of the bottom 262 of the reservoir 144. Further, a cleaning valve 270 is attached to the cleaning aperture 268 to

facilitate draining and cleaning of the reservoir 144.

A fluid-feed aperture 272 is formed within the sloped bottom 262 of the primary fluid reservoir 144 at a point higher up along the bottom 262 than the center 266 to minimize the introduction of unwanted particulate into the system. A fluid-feed air pump 274 is attached to the fluid-feed aperture 272. The air pump 274 draws fluid from the primary reservoir 144 and pumps the fluid to a main injectate filter 276 via a fluid line 278.

The fluid leaving the main injectate filter 276 enters the cabinet 134 via a fluid line 280, ultimately feeding the injection head 140. The main injectate filter 276 may be mounted to the reservoir 144, to the cabinet 134, may be free standing or may be mounted to the apparatus 130 in any way known to those skilled in the art. Further, there may be more than one main injectate filter, as described above, that permits filter change-out during continuous operation of the injection apparatus 130. For added food safety and to prevent clogging, additional fluid filters can be positioned anywhere within the fluid path of the apparatus 130.

The primary fluid reservoir 144 further contains a float valve 282 for replenishing the volume of injectate fluid within the reservoir 144. The float valve 282 may automatically open to refresh the injectate supply within the primary fluid reservoir 144 via another injectate

source or a secondary reservoir when the fluid level within the primary fluid reservoir 144 reaches a specified level. Alternatively, the float valve 282 may be combined with a level sensor that will indicate via the control panel 142 that the level of fluid in the primary fluid reservoir 144 is low, permitting an operator to replenish the fluid remotely via the control panel 142.

Further, while both the primary fluid reservoir 144 and the cabinet 134 are shown generally rectangular in shape, it is apparent that the shape of either the primary fluid reservoir 144 or the cabinet 134 or both can be cylindrical or any geometrical shape.

Fig. 16 further illustrates the back 148 of the cabinet 134 showing the doors 164 open. As can be seen, the fluid line 280 feeds two high-pressure air pumps 284 mounted within the cabinet 134. In turn, the air pumps 284 feed injectate to a high-pressure manifold system 286 which includes multiple fast-acting, electronically actuated solenoid valves 288. A pressure sensor 290 for monitoring the pressure output of each air pump 284 is also located within the manifold system 286.

The solenoid valves 288 are used to control the timing and duration of injection bursts and evenly distribute the injectate fluid between the injection heads 140. It will be appreciated by those skilled in

the art that the number of air pumps 284 and the number of solenoid valves 288 will vary depending on the number of injection heads 140 used in the machine. Further, the need to ensure a steady stream of fluid to the injection subject without experiencing a pressure drop or supply hesitation during an injection burst also will dictate the number of air pumps used in the machine.

Further shown in Fig. 16, an air pressure regulator 292 and a filter assembly 294 are mounted within the cabinet 134 for regulating the compressed air supply used to operate the air pumps 284. The pressure regulator 292 permits an operator to adjust the pressure of the air going to the air pumps 284 thereby influencing the outlet fluid pressure from the air pumps 284. In addition, the valves 293 control the air flow to the pumps 284. In addition, a second air pressure regulator 295 is included within the cabinet 134 for regulating the air pressure supply to the external pump 274, or any additional external equipment requiring compressed air.

Pressure regulator 292 may be electronically actuated and linked with the pressure sensor 290, allowing an operator to automatically adjust the injection burst pressure via the control panel 142, or recall a saved program which automatically adjusts the regulator 292 for a given injection subject or at a given output pressure. Further, the air pressure regulator 292

allows an operator to correct both an unsteady injection stream or variations in compressed air supply pressure while the machine is running. In addition, pressure sensor 290 and pressure regulator 292 can be used to
5 automatically adjust the air pressure. In this instance, the required air pressure will be maintained and controlled automatically via the controller, requiring no operator intervention.

Fig. 16 further shows how the fluid lines 218 from
10 each escape aperture 216 of the injection head 140 enter the cabinet 134. As can be seen, a fast-acting solenoid valve 296 is connected to each line 218 for quickly releasing any air build-up in the injection head 140 during operation. Since injection fluid may also be
15 released through the escape aperture 216, fluid exiting the valves 296 may be piped to a drain or recycled back into the primary reservoir 144 or another injectate source. Importantly, the valves 296 are not located within each escape aperture 216; rather, the valves 296
20 are located within the cabinet 134 at the end of fluid lines 218, thereby eliminating exposure of the valves to a damp working environment. Also, the valves 296 can be automated and programmed to open at predetermined intervals for a given injection subject without requiring
25 an affirmative action by the operator, simplifying operation of the injection apparatus 130.

The conveyor drive mechanism 182 is positioned within the cabinet 134 along with any components of the conveyor support structure 180 necessary for using the conveyor system 138.

5 Referring back to Fig. 8 for the moment, the control panel 142 is shown attached to the cabinet 134. The control panel 142 includes a sealed touch screen 298 which is linked to a programmable logic controller (PLC) 300 within the cabinet 134 (shown in Fig. 16) for storing
10 and controlling operational information. A button 302 is also included on the control panel 142. The button 302 is rotated in the clockwise direction to turn the machine on. The button 302 is also an emergency stop button that instantly stops the machine when depressed. Also, when a
15 production run is over, the button 302 will be depressed to stop the machine.

The PLC 300 may control all process variables including complete synchronization of the conveyor system 138 with the injection bursts to be delivered to the
20 subject. This can include automatic control of the injection pressure, duration of the bursts, spacing between injection bursts and timing of the injections. Further, every valve used in the injection apparatus 130 may be automated using the PLC 300. Variables such as
25 the air pressure supplied to the air pumps 284, the output pressure of the air pumps 284, the direction of

injection spray, the orientation of the injection heads 140 or the fluid level in the reservoir 144 may be monitored and controlled by the PLC 300, thereby simplifying both operation of the machine and integration
5 of the machine into a continuous production line. While a programmable logic controller is disclosed, one skilled in the art will appreciate that any computer control device may be used to store injection and process variables and/or operate the machine.

10 It can be seen that the present invention includes a method of using a substantially uniform, high-pressure injection burst to needlelessly inject a subject with injectate fluid. In this way, damage to the external surfaces of the subject is minimized. The present
15 invention also includes a method of delivering injection fluid to a subject using substantially uniform, high-pressure injection bursts of a sufficient pressure to needlelessly add flavor, color, preservatives, binders, antimicrobial solutions and/or tenderize an injection
20 subject without significant damage to the external surfaces of the injection subject.

Accordingly, referring to Figs. 8 through 16, operation of the needleless injection apparatus 130 of the present invention will now be described. First, an
25 operator uses the touch screen 298 to retrieve from the PLC 300 a stored set of process variables for a given

injection subject or for a given injection effect. The preprogrammed process variables can include control of the injection pressure, duration of the injection bursts, spacing between injection bursts, timing of the
5 injections, the output pressure of the air pumps 284, the direction of injection spray, the orientation of the injection heads 140, the number of injection subjects or any other information necessary to inject a given type of subject. If no predetermined program exists for the
10 production run, an operator may enter variables via the touch screen 298 and/or adjust the variables during the production run in accordance with the required injection effect to be achieved by the machine.

The reservoir 144 is filled with the desired
15 injection fluid. In addition, if a secondary reservoir is used, the secondary reservoir must be also filled with injection fluid. When the primary reservoir reaches a low level, the controller may be programmed to automatically replenish the primary reservoir from the
20 secondary reservoir. Accordingly, no operator intervention will be required to maintain a high level of fluid within the primary reservoir.

Alternatively, if the primary reservoir 144 becomes low, the touch screen 298 may indicate to the operator
25 that the level is low and will permit the operator to refresh the injectate fluid automatically using the

controller. In addition, the operator can pause the operation of injection apparatus 130 and manually refill the primary reservoir 144.

During operation, injection fluid will be pumped
5 from the reservoir 144 through the fluid feed aperture
272 to the main injectate filter 276 by the feed pump
274. The fluid then flows from the main injectate filter
276 to the low-pressure side of the injection air pumps
272 within the cabinet 134. The air pumps 284 pump the
10 fluid to the injection manifold system 286. At this
time, the output pressure of the fluid is measured by the
sensor 290 to determine if the required injection
pressure has been attained. If not, the program
automatically adjusts the air pressure to the pumps 284
15 using the air pressure regulator 292, or the operator may
adjust the regulator 292 via the touch screen 286. The
fluid is evenly distributed among the injection heads 140
by the injection manifold 286 which directs fluid to the
high-pressure solenoid valves 288, ensuring that each
20 injection head 140 receives an adequate and substantially
equal flow of fluid.

Injection subjects are placed on the conveyor belt
176 near end 150 either manually by an operator, or
preferably, automatically by another conveyor system or
25 machine in the production line. The injection subject is
moved towards the injection heads 140 and is injected

according to the desired results. When the subject is in place, solenoid valves 288 in the manifold system 286 open allowing fluid to be delivered to the subject through the nozzles 196 on each injection head 140.

- 5 After an injection burst is complete, the valves 288 are closed.

Periodically, the fast-acting solenoid valves 296 connected to the escape apertures 216 are opened to relieve any air build-up within the injection heads 140.

- 10 If the valves 296 are not programmed to open at a given interval, the operator can use the touch screen 298 to cause the valves 296 to open periodically.

- Subjects can be injected in place, with the conveyor belt 176 stopped, or the subjects can be injected while
15 the conveyor belt 176 is moving relative to the injection heads 140, depending on the desired results.

- Excess injection fluid flows into the channel 160 and then into the catch basin 136. If recycling of the injection fluid is desired, the catch basin may drain
20 directly back into the primary reservoir 144 or into a reserve reservoir. Alternatively, the excess injection fluid may be piped directly to a drain.

- After injection, the injection subjects may be off-loaded automatically from the conveyor belt 176 for
25 further processing and/or packaging. However, off-loading of subjects can be performed manually.

CLAIMS

We claim:

- 1 1. A machine for injecting liquids comprising:
 - 2 at least one manifold head, adapted to receive high-
 - 3 pressure injection fluid, including a fluid entry port
 - 4 and a plurality of injection nozzles, each of said
 - 5 injection nozzles having an injection orifice; and
 - 6 at least one filter assembly comprising a liquid
 - 7 inlet, a liquid outlet, and a liquid passageway
 - 8 connecting said liquid inlet and liquid outlet, said
 - 9 filter assembly in non-threaded engagement with said
 - 10 fluid feed port of said manifold head.
- 1 2. A machine for injecting liquids as defined in Claim 1,
 - 2 wherein said filter assembly comprises:
 - 3 a tubular member having a first end portion
 - 4 configured to mate with said fluid entry port of said
 - 5 manifold head, a second end portion, and a body portion
 - 6 therebetween;
 - 7 a plurality of apertures in said body portion of
 - 8 said tubular member, said apertures in fluid
 - 9 communication with said injection nozzles; and
 - 10 a flexible sealing component positioned on said
 - 11 first end portion of said tubular member for removably
 - 12 and sealingly engaging said first end portion of said
 - 13 tubular member with said fluid entry port of said

14 manifold head.

1 3. A machine for injecting liquids as defined in Claim
2 2, wherein said flexible sealing component is an O-ring.

1 4. A machine for injecting liquids as defined in Claim
2 3, wherein said O-ring is constructed of TEFLON, EPDM
3 (Ethylene Propylene Diene Monomer), silicone, rubber,
4 VITON or any combination thereof.

1 5. A machine for injecting liquids as defined in Claim
2 1, wherein said filter assembly comprises:
3 a disk-shaped filter element having a liquid inlet
4 portion configured to engage said fluid entry port of
5 said manifold head, an apertured portion, a
6 circumferential edge about said apertured portion, and a
7 liquid outlet portion in fluid communication with said
8 injection nozzles; and
9 a flexible sealing component engaging said
10 circumferential edge of said filter element with said
11 fluid entry port of said manifold head.

1 6. A machine for injecting liquids as defined in Claim
2 5, wherein said flexible sealing component is an O-ring.

1 7. A machine for injecting liquids as defined in Claim
2 6, wherein said O-ring is constructed of TEFLON, EPDM

3 (Ethylene Propylene Diene Monomer), silicone, rubber,
4 VITON or any combination thereof.

1 8. A machine for injecting liquids as defined in Claim
2 1, wherein said injection orifice has an interior
3 diameter of less than 0.025 inches.

1 9. A machine for injecting liquids as defined in Claim
2 8, wherein said injection orifice has an interior
3 diameter of 0.006 inches.

1 10. A machine for injecting liquids as defined in Claim
2 1, further comprising:
3 at least one air pump having a low pressure inlet
4 and a high-pressure outlet in fluid communication with
5 said fluid entry port of said manifold head.

1 11. A machine for injecting liquids as defined in Claim
2 10, further comprising:
3 a manifold system having an inlet connected to said
4 high-pressure outlet of said air pump, a plurality of
5 valves connected to said inlet of said manifold system
6 adapted to receive high-pressure injection fluid from
7 said pump, and at least one outlet in fluid communication
8 with said fluid feed port of said manifold head.

1 12. A machine for injecting liquids as defined in Claim

2 1, wherein said manifold head further comprises an escape
3 aperture.

1 13. A machine for injecting liquids as defined in Claim
2 6, further comprising:

3 at least one valve in fluid communication with said
4 escape aperture of said manifold head.

1 14. A machine for injecting liquids as defined in Claim
2 11, wherein said valve is a fast-acting solenoid valve.

1 15. A machine for injecting liquids as defined in Claim
2 1, further comprising:

3 a fluid source in fluid communication with said
4 manifold head.

1 16. A machine for injecting liquids comprising:

2 an injection component adapted to receive high-
3 pressure injection fluid comprising:

4 a tubular manifold having a first open end, a
5 second open end, and a plurality of injection
6 nozzles;

7 a first end cap including a fluid entry port, a
8 first cavity having circumferential mating surface,
9 said first cavity coaxially extending out from said
10 fluid entry port and mateably configured to
11 removably retain said first end of said manifold;

12 a first flexible sealing component positioned
13 adjacent to said first mating surface within said
14 first cavity to sealably join said first end of said
15 manifold to the first end cap;

16 a second end cap including a second cavity
17 having a second circumferential mating surface,
18 mateably configured to removably retain said second
19 end of said manifold;

20 a second flexible sealing component positioned
21 adjacent to said second mating surface within said
22 second cavity to sealably join said second end of
23 said manifold to the second end cap; and

24 at least one high-pressure pump in fluid
25 communication with said fluid entry port of said
26 injection component.

1 17. A machine for injecting liquids as defined in Claim
2 16, wherein said first and said second flexible sealing
3 components are O-rings.

1 18. A machine for injecting liquids as defined in Claim
2 17, wherein said O-rings are constructed of TEFLON, EPDM
3 (Ethylene Propylene Diene Monomer), silicone, rubber,
4 VITON or any combination thereof.

1 19. A machine for injecting liquids as defined in Claim
2 16, wherein said high pressure pump comprises a air pump.

1 20. A machine for injecting liquids as defined in Claim
2 16, wherein said injection component further comprises an
3 escape aperture.

1 21. A machine for injecting liquids as defined in Claim
2 20, further comprising at least one valve connected to
3 said escape aperture.

1 22. A machine for injecting liquids as defined in Claim
2 21, wherein said valve is a fast-acting solenoid valve.

1 23. A machine for injecting liquids as defined in Claim
2 16, wherein said injection component is movably mounted
3 in three orthogonal directions to a work surface.

1 24. A machine for injecting liquids as defined in Claim
2 23, further comprising:
3 a sealed control panel mounted to said work surface.

1 25. A machine for injecting liquids as defined in Claim
2 23, further comprising:
3 a safety shield mounted to said work surface.

1 26. A machine for injecting liquids as defined in Claim
2 16, further comprising:
3 a filter assembly removably mounted within said
4 injection component, comprising:
5 a tubular member having a first end portion

6 configured to mate with said fluid entry port of
7 said first end cap, a second end portion, and a body
8 portion therebetween;

9 a plurality of apertures in said body portion
10 of said tubular member, said apertures in fluid
11 communication with said injection nozzles; and

12 a flexible sealing component positioned on said
13 first end portion of said tubular member for
14 removably and sealingly engaging said first end
15 portion of said tubular member with said fluid entry
16 port of said first end cap.

1 27. A machine for injecting liquids as defined in Claim
2 16, further comprising:

3 a disk-shaped filter element having a liquid inlet
4 portion configured to engage said fluid entry port of
5 said first end cap, an apertured portion, a
6 circumferential edge about said apertured portion, and a
7 liquid outlet portion in fluid communication with said
8 injection nozzles; and

9 a flexible sealing component engaging said
10 circumferential edge of said filter element with said
11 fluid entry port of said first end cap.

1 28. A machine for injecting liquids as defined in Claim
2 16, further comprising:

3 a primary fluid reservoir in fluid communication
4 with said injection component.

1 29. A machine for injecting liquids as defined in Claim
2 28, further comprising:

3 a secondary fluid reservoir in fluid communication
4 with said primary reservoir.

1 30. A machine for injecting liquids comprising:

2 an enclosure having a top;

3 at least one manifold head movably mounted to said
4 enclosure and adapted to receive high-pressure injection
5 fluid, comprising a fluid entry port, an escape aperture
6 and a plurality of injection nozzles, each of said
7 injection nozzles having an injection orifice; and
8 at least one solenoid valve in fluid communication
9 with said escape aperture, said valve mounted within said
10 enclosure.

1 31. A machine for injecting liquids as defined in Claim
2 30, wherein said solenoid valve is a fast-acting solenoid
3 valve.

1 32. A machine for injecting liquids as defined in Claim
2 30, wherein said injection orifice has an interior
3 diameter of less than 0.025 inches.

1 33. A machine for injecting liquids as defined in Claim
2 32, wherein said injection orifice has an interior
3 diameter of 0.006 inches.

1 34. A machine for injecting liquids as defined in Claim
2 30, further comprising:
3 at least one air pump having a low pressure inlet
4 and a high-pressure outlet in fluid communication with
5 said fluid entry port of said manifold head.

1 35. A machine for injecting liquids as defined in Claim
2 34, further comprising:
3 a manifold system having an inlet connected to said
4 high-pressure outlet of said air pump, a plurality of
5 valves connected to said inlet of said manifold system
6 adapted to receive high-pressure injection fluid from
7 said pump, and at least one outlet in fluid communication
8 with said fluid feed port of said manifold head.

1 36. A machine for injecting liquids as defined in Claim
2 30, further comprising:
3 at least one filter assembly having a liquid inlet,
4 a liquid outlet, and a filter element connecting said
5 liquid inlet and liquid outlet, said filter assembly in
6 non-threaded engagement with said fluid feed port of said
7 manifold head.

1 37. A machine for injecting liquids as defined in Claim
2 30, further comprising:
3 a catch basin attached to said enclosure.

1 38. A machine for injecting liquids as defined in Claim
2 30, further comprising:
3 a primary fluid reservoir removably linked to said
4 enclosure.

1 39. A machine for injecting liquids as defined in Claim
2 30, further comprising:
3 a sealed control panel mounted to said enclosure
4 including a touchscreen, an emergency stop button.

1 40. A machine for injecting liquids as defined in Claim
2 30, further comprising:
3 a channel formed with said top of said enclosure;
4 and
5 a conveyor system mounted to said enclosure for
6 moving injection subjects.

1 41. A machine for injecting liquids as defined in Claim
2 30, further comprising:
3 a safety shield mounted to said enclosure.

1 42. A machine for injecting liquids comprising:
2 at least one manifold head adapted to receive high-

3 pressure injection fluid, comprising a fluid entry port,
4 and a plurality of injection nozzles, each of said
5 injection nozzles having an injection orifice; and
6 at least one high-pressure air pump having an inlet
7 and an outlet in fluid communication with said fluid
8 entry port of said manifold head;

9 at least one pressure sensor in fluid communication
10 with said outlet of said pump; and

11 an air pressure regulator connected to said pump and
12 electronically linked to said pressure sensor.

1 43. A machine for injecting liquids as defined in Claim
2 42, further comprising:

3 a manifold system having an inlet connected to said
4 outlet of said air pump, a plurality of valves adapted to
5 receive high-pressure injection fluid from said pump, and
6 at least one outlet in fluid communication with said
7 fluid feed port of said manifold head.

1 44. A machine for injecting liquids as defined in Claim
2 42, further comprising:

3 at least one filter assembly having a liquid inlet,
4 a liquid outlet, and a filter element connecting said
5 liquid inlet and liquid outlet, said filter assembly in
6 non-threaded engagement with said fluid feed port of said
7 manifold head.

1 45. A machine for injecting liquids as defined in Claim
2 42, further comprising:

3 a primary fluid reservoir in fluid communication
4 with said inlet of said pump.

1 46. A machine for injecting liquids as defined in Claim
2 45, further comprising:

3 a secondary fluid reservoir in fluid communication
4 with said primary reservoir.

1 47. A method for needleless injection of subjects with a
2 liquid comprising:

3 providing a fluid to be injected;

4 drawing the fluid into at least one high-pressure
5 pump;

6 supplying the fluid from the pump to at least one
7 injection head; and

8 delivering at least one constant, high-pressure
9 injection burst of fluid to a subject.

1 48. A method for needleless injection as defined in
2 Claim 47, wherein said supplying step includes filtering
3 the fluid as it enters the injection head.

1 49. A method for needleless injection as defined in

2 Claim 47, further comprising:

3 conveying the fluid under pressure to an injection

4 manifold system positioned at the outlet of the pump;
5 monitoring the output fluid pressure of the pump;
6 and
7 equalizing and disbursing the fluid to the injection
8 head such that the pressure and volume of the fluid is
9 substantially evenly distributed among all injection
10 heads.

1 50. A method for needleless injection as defined in
2 Claim 47 further comprising:
3 monitoring the output fluid pressure of the pump
4 with a pressure sensor linked to a remotely located
5 control panel; and
6 adjusting the air pressure delivered to the pump to
7 ensure the pressure of the fluid at the outlet of the
8 pump provides the required injection effect on the
9 subject.

1 51. A method for needleless injection as defined in
2 Claim 47 further comprising:
3 filtering said injection fluid.

1 52. A method for needleless injection of subjects with a
2 liquid comprising:
3 providing an injection fluid to be injected;
4 drawing the fluid into at least one air pump;
5 supplying the fluid to at least one injection head

6 and filtering the fluid as it enters each injection head;
7 monitoring the output fluid pressure of the pump
8 with a pressure sensor linked to a remotely located
9 control panel;
10 adjusting the air pressure delivered to the pump to
11 ensure the output pressure of the fluid provides the
12 required injection effect on the subject; and
13 delivering at least one constant, high-pressure
14 injection burst of fluid to a subject.

1 53. A method for needleless injection as defined in
2 Claim 52, further comprising:
3 conveying the fluid under pressure to an injection
4 manifold system positioned at the outlet of the pump;
5 monitoring the output fluid pressure of the pump;
6 and
7 equalizing and disbursing the fluid to the injection
8 head such that the pressure and volume of the fluid is
9 substantially evenly distributed among all injection
10 heads.

1 54. A method for needleless injection as defined in
2 Claim 52 further comprising:
3 filtering said injection fluid.

1 55. A method for the needleless injection of subjects
2 with a liquid comprising:

3 providing an injection fluid to be injected into a
4 subject;
5 replenishing the fluid as needed during operation of
6 the machine;
7 drawing the fluid into at least one air pump;
8 supplying fluid to at least one injection head and
9 filtering the fluid as it enters the injection head;
10 delivering at least one constant, high-pressure
11 injection burst of fluid to the subject;
12 providing a controller for storing process variables
13 for a given injection subject; and
14 controlling process variables to achieve a
15 predetermined injection result.

1 56. A method for needleless injection as defined in
2 Claim 55, wherein said controlling step comprises:
3 moving an injection subject into place for injection
4 with a conveyor system;
5 adjusting the orientation of at least one injection
6 head about three orthogonal axis to achieve the required
7 injection position for a given run;
8 synchronizing the timing, duration and spacing of
9 the injection bursts delivered to the subject by the
10 injection heads with the conveyor system;
11 monitoring the output pressure of the fluid exiting
12 the pump;

13 adjusting the air pressure delivered to the pump to
14 ensure the output pressure of the fluid provides the
15 required injection effect on the subject; and
16 periodically releasing trapped air from the
17 injection heads; and
18 saving the process variables for a given production
19 run.

1 57. A method for needleless injection as defined in
2 Claim 55, wherein said providing step comprises using a
3 computer memory device to store and recall programs
4 containing production process variables and a touch
5 screen for indicating process parameters and for changing
6 process variables.

1 58. A method for needleless injection as defined in
2 Claim 55, further comprising filtering the fluid.

1 59. A method for needleless injection as defined in
2 Claim 55, further comprising:
3 conveying the fluid under pressure to an injection
4 manifold system; and
5 equalizing and disbursing the fluid to the injection
6 head such that the fluid is substantially evenly
7 distributed all the injection heads.