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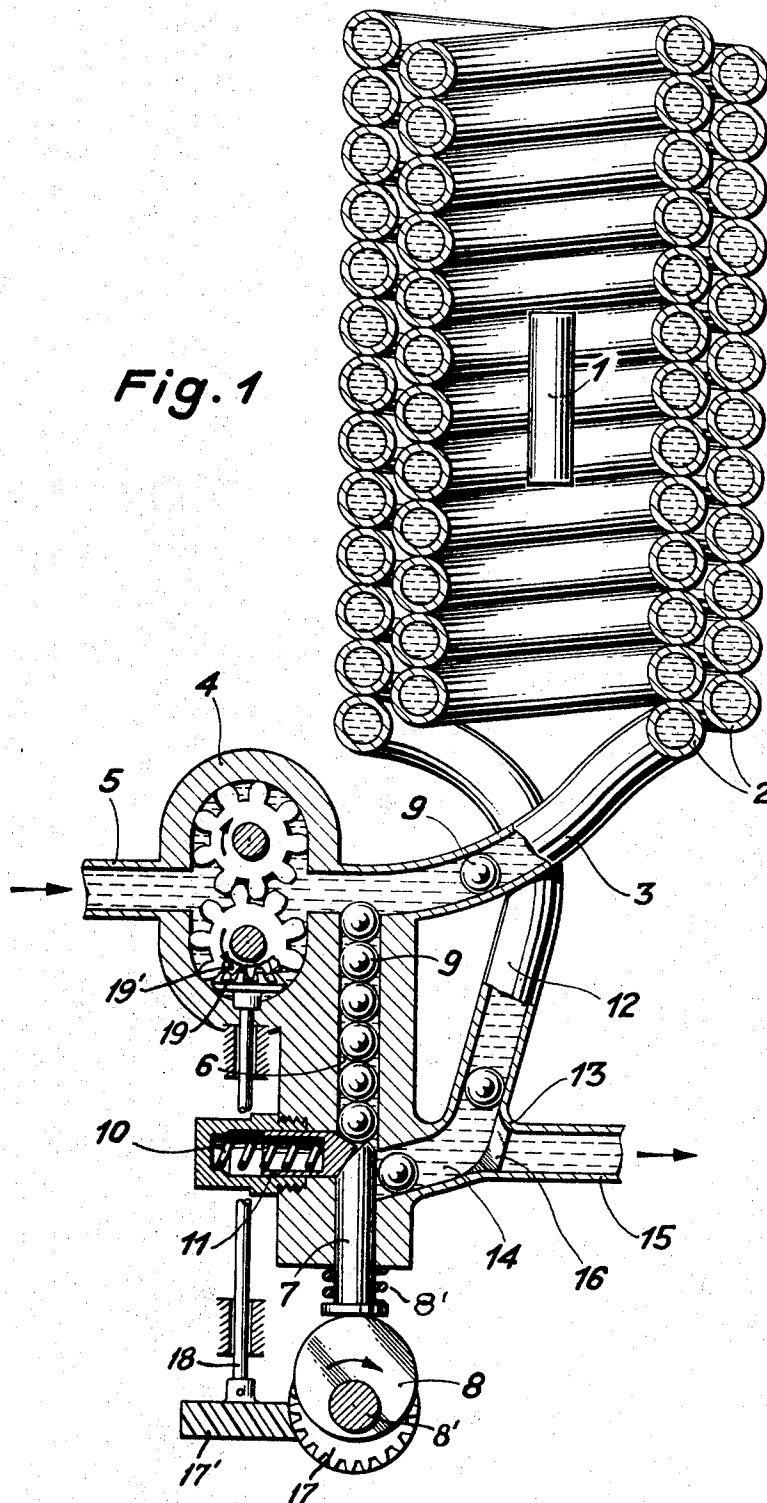
A. BRUNNER
APPARATUS AND METHOD FOR IRRADIATING CONTINUOUSLY
FLOWING LIQUIDS

3,519,817

Filed Feb. 16, 1968

2 Sheets-Sheet 1

Fig. 1



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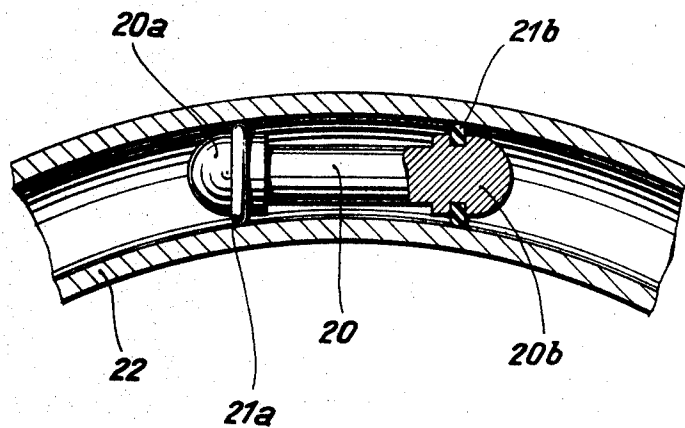
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2 Sheets-Sheet 2

Fig. 2



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APPARATUS AND METHOD FOR IRRADIATING CONTINUOUSLY FLOWING LIQUIDS

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5 Claims

ABSTRACT OF THE DISCLOSURE

The bulbous elements are periodically introduced into the liquid stream downstream of the radiation field to define individual liquid containing chambers. The liquid in the chambers is mixed in a manner to cause equal sojourn time of all the liquid particles through the radiation field by the action of the bulbous elements to achieve homogeneous irradiation of all liquid particles.

This invention relates to an apparatus and method for irradiating continuously flowing liquids. More particularly, this invention relates to an apparatus and method for irradiating continuously flowing liquids in pipelines.

In chemical process technology, the treatment of liquids including those of relatively high viscosity as well as those which in some instances require treatment in a pasty form frequently require exposure to radioactive radiation, for example, for causing polymerization in plastics. However, with such treatments, it is necessary for the production of a desired effect for the irradiation dose received by every particle of the liquid to be the same. This requires each liquid particle to have the same sojourn time during its passage through the radiation field of a radioactive radiation source.

In order to achieve equal sojourn times for particles passing through a radiation field, it has been known to place the material to be irradiated in individual charges such as containers and to pass the individual charges by means of a rotation means about a radiation source. By suitably designing the rotation means, the most uniform possible irradiation of the individual charges has been achieved.

However, where the irradiation operation is incorporated in a continuous manufacturing process wherein a continuously flowing liquid is to be exposed to radioactive irradiation, a problem arises in that, due to the non-uniform flow distribution normally occurring in a flow channel, the liquid to be irradiated cannot be passed through an irradiation field in a pipe which would otherwise be the obvious solution. That is, since the liquid would flow at a higher speed through the axial center of the pipe than at the boundary layers along the pipe walls where the liquid would creep forward, the liquid flowing through the axial center would receive a much smaller radiation dose due to the shorter sojourn time in the radiation field than the liquid in the boundary layers.

In order to overcome such problems, it has been proposed in the field of the heat treatment of plastics flowing in a pipe to insert mixing elements in the flow channels of the pipe to guide into the middle currents that are near the pipe walls. These mixing elements are rigidly positioned in the pipes and oriented to form skew passages some of which connect the central zone of the face cross-section of an element with the border zone of the rear cross-section while others connect the border zone of the face cross-section with the central zone of the rear cross-section. However, the occurrence of stationary eddy currents at the outlet side of the elements is unavoidable

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with these mixing elements. Consequently, liquid particles would become stored in these eddy currents for varying lengths of time so that the sojourn time of the individual particles would still vary in passing through a radiation field.

Accordingly, it is an object of the invention to pass a liquid through a radiation field in a manner to ensure an equal sojourn time for all the liquid particles in the radiation field.

It is another object of the invention to pass a liquid through a pipe in a manner to avoid occurrence of boundary layers.

It is another object of the invention to pass a liquid through a pipe in a manner to continuously mix the liquid particles to achieve a uniform passage of the liquid particles through the pipe.

Briefly, the invention irradiates a continuously flowing liquid by introducing a series of spaced bulbous elements into a stream of liquid to form a plurality of liquid containing chambers in the stream and by subsequently passing the compartmentized stream through a radiation field. Thereafter, the bulbous elements are removed from the irradiated stream.

The apparatus of the invention includes at least one flow duct which is constructed so as to conduct a stream of liquid through a radiation field of a radiation source. The flow duct is connected with a supply means downstream of the radiation field which periodically introduces bulbous elements into the flow duct. The supply means is operated in conjunction with the flow rate of the stream of liquid so that the bulbous elements are introduced into the stream in spaced relation in order to define a substantially self-contained liquid chamber between each pair of introduced bulbous elements. In addition, a means for removing the bulbous elements from the irradiated stream is connected downstream of the flow duct so that the bulbous elements can be recycled or otherwise discharged outside the radiation field.

The method of the invention includes the steps of subdividing a stream of liquid to be irradiated into a series of self-contained chambers by means of a periodic injection of bulbous elements into the stream, passing the subdivided stream through an irradiation field, and removing the bulbous elements from the irradiated stream. During passage of the subdivided stream through the radiation field some eddying takes place within the individual chambers since the flow velocity in the region of the boundary wall is much less than in the middle. Further, during this passage, the liquid particles in the region of the boundary wall are peeled off the wall by the rear bulbous element defining a chamber, as viewed in the direction of flow, and conveyed to the middle of the chamber. The liquid particles are then moved onto the front bulbous element of the chamber at a high speed of advance. The currents on the front face of the chamber are thus forced from the middle back into the border zone. In this way, the eddy zones formed in the individual chambers move at a practically constant speed through the radiation field. Consequently, an extremely homogeneous irradiation of the liquid results from the constant exchange of layers from the border zone to the middle of the chamber occurring in the eddy zones.

The bulbous elements can advantageously be made of spherical metal balls since balls constitute bulbous members with the smallest volumes. A cheap and accurate manufacture of spherical bulbous elements is possible where balls of the kind used for ball bearings are employed. Further, such spherical bulbous elements absorb relatively little radiation. Alternatively, the bulbous elements can also be made of dumb-bell-like elements having end pieces into which sealing rings of resilient material are inserted. In this case, the cross-section of the

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flow duct need not satisfy strict standards of accuracy since the sealing rings are able to compensate for small differences. Moreover, such bulbous elements can be made of a not very absorbent material, for example, aluminum or magnesium, without taking account of the sliding properties in the flow duct when the flow duct is made, for example, of aluminum.

In one embodiment, the supply means for injecting the bulbous elements into the flow path of the liquid to be irradiated includes a shaft connected to the flow duct for receiving a row of bulbous elements, an axially oscillated push-rod disposed at the bottom of the shaft, and a catch which prevents the bulbous elements for returning on a downward movement of the push-rod. Where the liquid is conveyed through the flow duct by means of a pump, for example, a gear pump, the push-rod can be advantageously coupled on the drive side with the drive of the pump. The ratio of the speeds of the pump and push-rod drive then determines the distance between the bulbous elements in the flow duct.

The bulbous elements which are cyclically introduced into the liquid stream and ejected after irradiation of the liquid stream can be recycled into the liquid stream downstream of the radiation field for reuse. In one such embodiment, for such recycling, a connection duct is connected downstream of the flow duct at one end and at the other end which defines an ejection position is connected to a pipeline for carrying away the irradiated liquid and a pipe section which communicates with the base of the supply means for introducing the bulbous elements into the liquid stream. The pipe section is sized to convey the bulbous elements from the irradiated stream back to the supply means. In this embodiment, the bulbous elements circulate in a cycle from the supply means through the flow path of the liquid in the radiation field and are sluiced into the supply means after ejection from the irradiated liquid.

These and other objects and advantages of the invention will become more apparent from the following detailed description and appended claims taken in conjunction with the accompanying drawings in which:

FIG. 1 illustrates a longitudinal cross-section of a coiled pipe arranged in a radiation field wherein bulbous members in the form of spherical balls are introduced into a liquid flow passing through the pipe according to the invention; and

FIG. 2 illustrates a modification of the bulbous members of the invention.

Referring to FIG. 1, the irradiation apparatus includes a double pipe spiral 2 acting as a flow duct and irradiation channel which encompasses a cylindrical radiation source 1, for example, a CO 60 radiator. The inlet of the pipe spiral 2 is connected via a connecting duct 3 with a gear pump 4 to which a liquid to be irradiated flows via a connection piece 5. Alternatively, any suitable means (not shown) can be used to deliver the liquid to the pipe spiral 2, for example, the liquid can be forced by means of compressed air from a container through the pipe spiral 2. In addition, a supply means for injecting bulbous elements into the connecting duct 3 and pipe spiral 2 is connected to the duct 3. The supply means includes a hollow calibrated shaft 6 which communicates with the duct 3 and which is filled from the bottom with a column of bulbous elements such as balls 9. The shaft 6 cooperates with a push-rod 7 which is reciprocally mounted in the shaft 6 to inject the balls 9 into the duct 3. The push-rod 7 is driven by means of an eccentric 8 against the bias of a spring 8' to periodically introduce the balls 9 from within the shaft 6 into the liquid stream in the connecting duct 3 in order to form individual liquid containing chambers between adjacent balls 9. The push-rod 7 need not necessarily be in the form of a piston that fills the hollow cross-section of the shaft 6 but can also be of a smaller diameter. The distances between the balls 9 introduced into the connecting

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duct 3 and therefore the length of the liquid containing chambers defined by each pair of neighboring balls 9 are substantially determined by the speed ratio of the gear pump 4 with respect to the eccentric 8. Thus, it can be advantageous to couple the eccentric 8 to the drive of the pump 4 via a transmission. For example, the transmission includes a screw gear 17 mounted on the shaft 8' of the eccentric 8 which meshes with a screw gear 17' on one end of a suitably supported shaft 18 which also carries a bevel gear 19 at the other end. The bevel gear 19 in turn meshes with a bevel gear 19' on a shaft 4' of the pump 4 so that the eccentric 8 is driven with the pump 4.

The eccentric 8 is operated so that each revolution of the eccentric lifts the column of balls 9, for example, six, in the shaft 6 to inject the top ball into the connecting duct 3 and the liquid stream flowing through the duct 3. A catch 11 is mounted above the push-rod 7 and is biased by a spring 10 to project into the path of the push-rod 7 and balls 9 to prevent the column of balls 9 from descending in the shaft upon return of the push-rod 7 to its lowermost position.

The outlet of the pipe spiral 2 is connected to a connecting duct 12 which leads to an ejection position 13 for the balls 9 from the liquid stream. A pipe section 14 having an enlarged inside cross-section with respect to the pipe spiral 2 and connecting duct 12 connects with the connecting duct 12 at the ejection position 13 to receive the ejected balls. The pipe section 14 is inclined downwardly to connect with the lower end of the shaft 6 to allow the ejected balls to slide down the pipe section 14. A pipeline 15 is also connected to the connecting duct 12 at the ejection position 13 to receive the liquid discharged from the connecting duct 12. The pipeline 14 conveys the liquid out of the apparatus either as an end product or for further conveyance to an adjoining apparatus for further treatments.

In order to prevent passage of the balls 9 through the pipeline 15, a rib 16 is disposed at the ejection position 13 across the mouth of the pipeline 15.

In operation, the eccentric 8 is driven in relation to the pump 4 to move the push-rod 7 in an upward direction in order to move the ball column by a ball diameter to inject the top ball of the column of balls into the connecting duct 3. During this upward movement, the bottom ball of the column is moved against the bottom inclined face of the catch 11 to push the catch 11 against the bias of the spring 10 out of the plane of the ball column. The bottom ball thus moves past the catch 11. After the top ball is injected into the connecting duct 3, the eccentric 8 continues to rotate towards the lowermost position relative to the push-rod 7 to allow the spring 8' to move the push-rod 7 downwardly. As the catch 11 is below the newly delivered bottom ball of the column, as the push-rod 7 moves downwardly, the catch 11 is spring biased into the path of the balls to prevent the ball column from descending with the push-rod 7. Upon reaching its lowermost position, the push-rod 7 exposes the pipe section 14 to the shaft 6 so that the ball positioned at the end of the pipe section 14 rolls into the shaft 6 on top of the push-rod 7. In order to accommodate the ball on top of the push-rod 7, the top surface of the push-rod 7 is inclined in a direction downwardly away from the pipe section 14 so that the ball will be prevented from rolling back into the pipe section 14. Also, this inclined surface facilitates cooperation of the push-rod 7 with the catch 11 during mutual movement.

As the top ball of the column moves into the connecting duct 3, the stream of liquid delivered by the pump 4 moves the ball toward the pipe spiral 2. The balls 9 are of a diameter substantially equal to the internal diameter of the connecting duct 3 and pipe spiral 2 so that as subsequent balls are injected at spaced intervals into the liquid stream, chambers of liquid are formed between each pair of spaced adjacent balls. As the compartment-

ized liquid stream subsequently flows through the pipe spiral 2 through the radiation field of the radiation source 1, some eddying takes place within the individual chambers due to the greater flow speed at the axial center of the stream. However, during movement the rear ball of each chamber, as viewed in the direction of flow, peels off the liquid particles of the boundary layer of the stream from the pipe spiral walls and directs the particles forwardly to the center of the chamber. These peeled particles then move towards the forward ball of the chamber at a high speed of advance. Upon reaching the forward ball, the liquid particles are forced from the center back to the boundary layer. This causes eddy currents to be formed in each chamber which move at substantially constant speed through the radiation field. Thus, an extremely homogeneous irradiation of the liquid results from the constant exchange of layers from the boundary layer to the center of the chamber in the eddy zones.

The shaft 6 also forms a bypass for the pipe spiral 2. That is, due to the unavoidable clearances between the ball column and the shaft wall, a certain amount of liquid enters the connecting duct 12 from the connecting duct 13. This liquid is conveyed in an opposite direction to the periodic upward movement of the ball column in the wedge-shaped spaces between individual balls. However, by controlling the clearance between the shaft walls and the balls, the flow between the ends of the shaft 6 can be kept negligibly low.

Referring to FIG. 2, dumb-bell-like bulbous elements 20 can be used in the irradiation apparatus in place of the bulbous spherical balls of FIG. 1. Each element 20 has a pair of interconnected end pieces 20a, 20b which mount annular sealing rings 21a, 21b of resilient material in the outer surfaces in sliding contact with the curved walls of an irradiation channel 22. In order to inject and eject these bulbous elements 20 into and out of the liquid stream, a means for supplying and ejecting such similar to that described above for the balls can be provided with slight modifications.

It is noted that the shaft 6 can be connected to the connecting duct 3 at an angle to the vertical and can be washed transverse by means of a small amount of liquid withdrawn from the connecting duct 3. This amount of liquid can be ejected from the apparatus above the point of connection of the pipe section 14 used to bring forward the bulbous elements separated from the irradiated liquid. Also, the shaft 6 can, where appropriate, be connected horizontally to the connecting duct 3. In this latter case, at least one additional catch would be disposed above the top bulbous element to prevent the elements from entering the connecting duct 3 without controlled propulsion.

It is further noted that the bulbous elements need not be recycled into the non-irradiated liquid after ejection from the irradiated liquid.

Having thus described the invention, it is not intended that it be so limited as changes may be readily made therein without departing from the scope of the invention. Accordingly, it is intended that the foregoing Abstract of the Disclosure and the subject matter described above and shown in the drawings be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Apparatus for irradiating liquids comprising:
 - a flow duct for disposition in a radiation field to convey a stream of liquid through the radiation field; means for passing a continuous stream of liquid into said flow duct;
 - supply means connected upstream of said flow duct including a shaft in communication with said flow duct for containing a row of bulbous elements there-

in, a push rod reciprocally mounted in one end of said shaft opposite said flow duct, means for reciprocating said push rod in said shaft to inject the bulbous elements into said flow duct in spaced relation within the stream of liquid to define a plurality of liquid containing chambers between spaced adjacent elements, and a catch means disposed in said shaft between said push rod and the row of elements to maintain the row of elements out of contact with said push rod upon retraction of said push rod in a direction out of said shaft; and

means connected downstream of said flow duct for removing the bulbous elements from the stream of liquid.

2. An apparatus as set forth in claim 1 wherein said supply means includes a shaft in communication with said flow duct for containing a column of bulbous elements therein; a push-rod mounted in said shaft below the column of elements; means for moving said push-rod in a reciprocating manner in said shaft, said means including an eccentric for moving said push-rod upwardly to eject the top element of the element column into said flow duct; and a catch resiliently mounted in said shaft between said push-rod and the element column for projecting into the path of the element column to prevent downward movement of the element column upon downward movement of said push-rod.

3. An apparatus as set forth in claim 2 wherein said eccentric is coupled to said means for passing a continuous stream of liquid into said flow duct for moving said push-rod with respect to the flow rate of the stream of liquid to eject the elements into the stream of liquid in spaced intervals to effect formation of the liquid containing chamber between each pair of spaced adjacent elements.

4. An apparatus for irradiating liquids comprising:

- a flow duct for disposition in a radiation field to convey a stream of liquid through the radiation field;
- means for passing a continuous stream of liquid into said flow duct;

supply means connected upstream of said flow duct for introducing bulbous elements into said flow duct in spaced relation within the stream of liquid to define a plurality of liquid containing chambers between spaced adjacent elements; and

means connected downstream of said flow duct for removing the bulbous elements from the stream of liquid including a connection duct connected downstream of said flow duct to convey the stream of liquid and bulbous elements therefrom, a downwardly inclined pipe section connected to said connection duct at an ejection position downstream of said flow duct for receiving ejected bulbous elements from the stream of liquid, and a pipeline connected to said connection duct at said ejection position for receiving the stream of liquid.

5. An apparatus as set forth in claim 4 wherein said means for removing the bulbous elements further comprises a rib disposed across the mouth of said pipeline to prevent passage of the bulbous elements into said pipeline.

References Cited

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RALPH G. NILSON, Primary Examiner

D. L. WILLIS, Assistant Examiner

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250—106

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,519,817 Dated July 7, 1970

Inventor(s) Alfred Brunner

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, line 31, "elected" should be --ejected--

Column 5, line 43, "transverse" should be --transversely--

Column 6, line 64, "3,045,116 7/1962/ Wiesemann et al"
should be--"3,263,081 7/1966 Wiesemann et al--

Column 6, line 65, "3,263,081 7/1966 Gant" should be
--3,045,116 7/1962 Gant--

SIGNED AND
SEALED
OCT 20 1970

(SEAL)

Attest:

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Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents