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Enhancement Of Batch Operations Based On A Contamination Free Valve Design

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ABSTRACT: Process industry involves large plants; mainly operating in continuous form, to achieve economic mass production output. However in some situations process vessels and tanks are used, where batch processes, take place. These tanks often contain reactants and products in the liquid state. After treatment or processing, valves are opened to allow the product to drain and vessels may receive the next batch. However, with conventional valves there will always be an amount of fluid trapped between the valve closing element and the tank or vessel, especially for those which are jacketed to allow heating or cooling. This amount is usually untreated, that is to say has not undergone the changes or processing taking place on the fluid bulk in the vessel. Moreover, no matter how accurately this amount is estimated to be isolated from the processed amount leaving the vessel, it will still contaminate with the processed product. From hygiene point of view, this may not be accepted. In this work a valve design is introduced; where no fluid is trapped between a process tank and the valve closing element. When the valve is opened the fluid flows to the outlet flow line without any contamination with unprocessed fluid. Thus a contamination free valve design is utilised to achieve hygiene design tanks or vessels used in batch based processes. Thus cheap equipment acquiring the hygiene requirements necessary for food and some other products that only can be achieved using expensive mass production lines is obtained.

Keywords : Process tanks, valve design, equipment hygiene design, flush bottom tanks, contamination free.

1 INTRODUCTION:

Food and pharmaceutical industries involve the use of various mechanical equipments. In such applications mechanical design should account for special hygiene requirements. Extensive efforts [1], [2], and [3]; have been performed to check and outline such requirements. Normally such industries require mass production units which constitutes huge plants in order to obtain economic products [4], [5], [6], [7]. Large production plants can accommodate technological requirements to control the production processes and obtain an economic production. This is generally the case in all chemical; i.e. process, industry. Food and pharmaceutical industries are sectors of process industry where additionally hygiene conditions are to be met which require special material selection, special design and complicated process control. A clear example of this is HTST (high temperature short time) systems [8], used in the pasteurization of milk. Fig.1 shows a schematic diagram for the process [8].

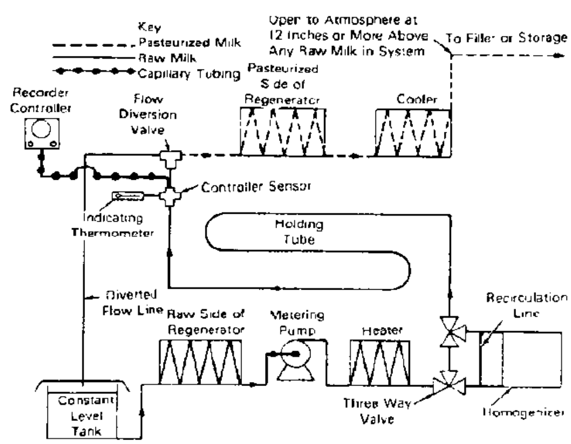

Fig. 1 *Milk-to-Milk Regeneration--Homogenizer Upstream from Holder*

The flow diversion valve; as shown in fig. 1, is operated through accurate controller sensor which senses the temperature at the end of a holding tube. The process requires that the temperature of the milk is kept constant (or within a specified range); after heating to the required temperature, for a limited period of time. The metering pump delivering the exact flow rate; results in holding the output for that period of time when it passes through the length of the holding tube with its known cross sectional area. If the temperature detected, (by the sensor), at the end of the holding tube was correct, then the sensor actuates the flow diversion valve to pass the output milk to flow to cooling then storage, thus the product is accepted. However if the sensor detects a temperature out of the specified range it controls the valve as to redirect the milk to the constant level tank to begin the process again. In this manner; no single drop is allowed to pass as accepted product unless it is pasteurized as described by the temperature limits precisely specified and accurately governed. The instrumentation supplied, namely; the metering pump, the controller sensor and the flow diversion valve, achieve the guarantee that the output is fully controlled to the acceptance requirements. The pasteurization process with HTST system; described, requires continues operating system, where the raw milk enters from one side and the product is obtained at the other side. The raw material undergoes several processing operations governed with the required control, while flowing from the input side to the output side. In practice such equipment are expensive and the product is economic only in case of mass production producing huge amounts. Batch processing; using process vessels or tanks, will not be able to perform the above idea; of returning the unpasteurized amount to the beginning of the process. Other difficulties facing the processing in tanks and vessels concerning drain (to obtain the output), processing, and control may cause the product to fail to meet the hygiene requirements. However, there are manufacturers, especially in poor

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countries or societies which still need to obtain [9], [5]; approved product while using cheap equipment. In this paper a valve design is introduced which aims to make the product of batch processing in vessels accepted thus a cheap processing unit is obtained whose product may compete with mass production units' product.

2 The Problem

Process tanks or vessels are used in batch processing in chemical, food and pharmaceutical industries. After the process takes place the products has to be taken out of the vessels in order that another charge is started. When it is not suitable to withdraw the product using drum pumps, or it is not convenient to empty the tank from above using buckets and the tank is not that small to be tilted to pour the product, it becomes a must that the product should be drained from underneath or a side opening near the bottom. To drain the products from the tank a valve is fitted at the bottom of the tank. No matter how the valve is close to the tank bottom plate or inner shell there is an amount that is considered to be trapped between the vessel and the valve closing element; preventing the flow to the outside of the tank, until the valve is opened. This amount would be rather considerable in the case of using jacketed tanks; where the trapped amount is increased by the jacket thickness out of which the valve is fitted. This amount may not undergo the processing taking place inside the vessel. Referring to the above concept; of the pasteurization example, the trapped amount should be not allowed to flow with the product. In such configuration i.e. batch processing using vessels or tanks in pasteurization, for example, it will not be possible to divert this amount to the container containing the raw material to start the process again. In some process or chemical industries; fertilizers industry for example, where contamination with unprocessed material is ineffective to the processed material; manufacturers estimate the volume of this amount and drain it to a certain container then place another container where the processed material is collected. In sectors of process industries as, food and pharmaceutical industries the design introduced in this paper represents a solution for such a problem. A contamination free valve is designed where nothing is trapped between the vessel and the closing element of the product outlet valve. The product outlet valve, as will be shown is not the main valve closing the process vessel. In the following section the details of the contamination free valve are given. Using such valves on small or medium size process tanks enables small manufacturers in poor societies to obtain healthy products using a cheap piece of equipment. This can replace expensive production units for relatively small quantities meanwhile acquiring hygiene requirements.

3 The Design

It is necessary in equipments used in food and pharmaceutical industries to avoid any source of corrosion and/or the build up of bacteria and undesired organisms. This is expressed from the engineering point of view in the proper material selection and careful design. The design should avoid any irregular surfaces, poor surface finish, or sharp corners, and other crevices. For this reason a flat annular disc is welded to the tank bottom from outside. It is designed and manufactured such that its upper surface becomes a part of the tank bottom plate which is flat too. This is the upper side of the outlet neck which is the main part of the valve. The valve; fig.2, consists of 16 parts, designed to achieve the task of discharging the vessel contents without any development of trapped amount that may be unprocessed then its contamination with the product may cause the product not to be accepted. The sealing disk 2, in closed position coincides with the tank bottom. This means all the solution above it is inside the tank and is being processed. Moreover, absolutely nothing is trapped below it, i.e. between it and the outside of tank through the product outlet valve; part 9. This requires the proposed configuration with the 16 parts described below:

1- Outlet neck
2- Sealing disk
3- O-ring
4- Rod (valve stem)
5- Jacket seal
6- Locking nut
7- Extension joint
8- Tee junction
9- Product outlet valve
10- Extension joint (optional) or nipple.
11- Rod guide
12- Valve Spring
13- Spring Seat
14- Pin
15- Threaded Bushing
16- Valve handle

1- The outlet neck; material and geometry play the most critical role in achieving the valve objective. The material is a non-corrosive; stainless steel for example, with the grade required according to the vessel content. Normally is the same as the vessel material. The surface is machined to high precision required for hygiene conditions. The cut in the neck outer rim have a depth equal to the thickness of the tank bottom plate. This allows both the tank bottom and the outlet neck to have the same flat level (surface) from the tank inner side when the neck is welded to the tank from underneath. With a circular opening cut into the neck centre just to fit a sealing disk, all of the three; the sealing disk, the outlet neck outer rim, and the vessel bottom, will be as flat and smooth as one part. Therefore the depth of cut in the outlet neck is adjusted to the thickness of the sealing disk taking account for the spring pull against the O-ring laying under it to achieve relatively absolute sealing. The O-ring is seated in an under-cut machined concentrically in the outlet neck. The outlet neck is hollow with inside diameter just less than the inside diameter of the O-ring. At further lower depth the inside diameter is adjusted as to fit with the pipe; part 7, whose size is chosen to be capable to discharge the vessel contents in the required time. The outside diameter is determined by adding a reasonable thickness that allows for inner and outer thread. The outer thread for tightening the valve to the vessel bottom using the locking nut; part 6, thus the size of the locking nut is determined.

2- Sealing disk; is a circular stainless steel disk to which a rod; part 4, (valve stem), is welded. Although the outlet neck is the most important part in the assembly, the

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sealing disk is the real valve; because it is the closing element, and thus its dimensions govern the dimensions of the outlet neck and the rest of the parts consequently. Starting with the vessel volume and dimensions, the contents volume, viscosity, ...etc., and the required discharge time as implied by the production capacity, the size of the opening diameter can be estimated. The sealing disk diameter is thus determined and relative concentric diameters of the outlet neck are obtained taking manufacturing requirements into consideration.

3- O-Ring is a standard part, its material is chosen to agree with the vessel contents; food grade rubber in case of food for example. Its size is chosen from standard tables, e.g. [10] according to the sealing disk diameter which is already determined.

4- Rod (valve stem) is welded to the bottom of the sealing disk. Its material should be the same as that of the sealing disk and the outlet neck and the tank shell material. This is required to agree with the conditions required for the medium being in the vessel, as the rod will get in touch with the product. The rod should be long enough to reach the control handle which will be used to raise the sealing disk, and to be thin enough as not to block the passage where the product flow to the outlet valve. Buckling should be accounted for, as a limitation on its design, since it is required to be as thin as possible.

5- Jacket Seal: is a circular rubber seal, whose inside diameter is fitted to the outside diameter of the outlet neck, its outside diameter should be greater than the diameter of the opening in the bottom plate of the jacket. Its thickness should fill the gap between the product vessel and the bottom of the jacket. Such that the jacket water will be sealed as the locking nut; part 6, is tightened around the outer thread of the outlet neck.

6- Locking nut: is a nut whose thread is cut to mate the outside thread of the of the outlet neck; part 1, that when fastened the outlet neck together with the product vessel are pulled down pressing on the jacket seal; part 5, to prevent jacket water from leakage.

7- Extension Joint: is a piece of standard pipe, one of its functions is to determine the vertical level of the product outlet valve; part 9, from the ground or below the jacket bottom; thus the level of the collection (drain) of the product. This is determined by the length of the extension joint; 7, as a tee junction; part 8, will be assembled to its lower terminal to which the product outlet valve; part 9, is fitted. Its other function is acting as an adaptor between the outlet neck part 1 and the tee junction; part 8, both having an internal thread. The extension joint being a piece of pipe with external threads from both ends its upper end is fitted to the bottom internal thread of the outlet neck while the tee junction is assembled to its lower end. The material of the extension joint is the same as that of the outlet neck and that of the rod as it will be in contact with the product. The size of the extension joint that is to say diameter and thus the thread is determined with the size of the product outlet valve according to the time allowed to discharge the quantity of the product from the vessel.

8- Tee Junction: A standard fitting from the NPT piping tables [11] chosen to fit the product outlet valve; part 9, size which may be chosen as to be a ball valve. The tee junction and the outlet product valve are of course in contact with the product. Therefore the material should agree with the product requirements.

9- Product Outlet Valve: Is a standard valve; a ball valve type may be a choice. The material should be which agree with the product requirements. The size is determined from the drain time calculations obtained from the product capacity.

10- Nipple (or extension joint): The material is that required by the product. This part acts mainly as an adaptor between the tee junction and the valve both having internal threads. If the valve need to be fitted at a longer distance from the vessel an extension joint with the appropriate length is used rather than a nipple.

11- Rod Guide: The rod guide is another key part of the proposed design. Concerning the material it is the last part in terms of the order of assembly for which high grade material is required because it is the last part that comes in contact with the product. All parts assembled towards the tank bottom side above the rod guide come in contact with the product; thus require material which agree with the product considerations except the locking nut part 6 and the jacket seal part 5. The rest of the parts below the rod guide doesn’t come in contact with the product; however high grade material fulfilling the product requirements may be an option as will be seen later. The rod guide is machined from a hexagonal or square bar in order to be hold by assembly tools; spanners etc. Otherwise two parallel surfaces can be shaped for tightening purpose. Two cylindrical equal parts are cut upper and lower sides of the hexagonal original shape which is kept in the middle of the rod guide. The cylindrical parts’ diameter is such that an external thread can be machined having the size diameter and length which fits to the internal thread of the tee junction part 8. It will be assembled to the lower end of the tee junction. At the centre of the rod guide a hole is machined throughout its length. The surface finish required for this machining should be smooth enough for a minimum clearance or transition fit with the rod (valve stem) part 4. The rod will pass through this hole thus the name of the part; rod guide. The rod guide prevents the valve stem (rod; part 4) from lateral misalignment.

12- Valve Spring: The valve spring is a helical compression spring which acts to pull the rod (valve stem); part 4, and thus the sealing disk; part2, welded to it, against the O-ring; part 3, to keep the valve closed. It rests on the rod guide and on a spring seat part 13. Another seat between the spring and the rod guide may be introduced as an option if it leads to better stability of spring movement. The length of the spring, number of turns, coil diameter, etc, are to achieve the required stiffness of the spring. It is initially compressed so it pulls down the rod thus sealing the product in the vessel. When the handle part; 16, is turned the spring is further compressed while the rod is raised to

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open the valve to allow the product to flow to the product outlet valve 9.

13- Spring Seat: It is introduced to carry the valve spring which rests on it so it guides the movement of the spring. A hole is machined through its center where the rod (valve stem); part 4, can pass slightly below the seat under the lower end of the spring.

14- Pin: : A small hole is machined in the rod perpendicular to its axis to accommodate a pin which may be taper or straight with a length quite smaller than the outer diameter of the spring seat. The location of the hole on the rod; (thus the pin), is such that there is an initial compression in the spring just enough to acquire valve sealing by pulling the sealing disk downward against the O-ring.

15- Threaded Bushing: Is a hollow cylinder having an internal thread that fits to the external thread of the rod guide part 11, to which it is assembled. It is threaded internally throughout its length. Its length should cover the lower part of the rod guide and the rest of the length of the rod with the spring and its seats and allowing two or three thread turns just to hold the valve handle; part 16.

16- Valve Handle: Mainly a solid cylindrical part having an external thread that fits with the internal thread of the threaded bushing; part 15, it is assembled to the lower most two or three turns of part 15, when the valve is in the closed position. The rest of its height is out of the bushing 15 and is enough for the stroke required to open the valve. A small handle; thus the name, is threaded or welded to the cylindrical part to help in turning it thus moving upwards inside the threaded bushing; 15, pressing on the rod; 4, causing the pin; 14, to push the spring seat against the spring until the sealing disk is raised to the required open position. When the handle is turned back to move downwards until its lowest position the spring pulls the rod downwards to get the sealing disk to its closed position.

4 DESIGN VERIFICATION

The valve with the proposed design was manufactured and attached to a jacketed vessel, fig 3, of about 140 litres in capacity. The valve was tested for normal operation, sealing ability, and leakage, as follows. The vessel was filled with water while the valve handle 16, was completely unthreaded thus the valve spring 12, pulls the rod 4 (valve stem), completely downwards so that the sealing disk 2 closes the valve by resting on the O-ring 3. The valve is kept in this position while the product outlet valve 9, is kept open. For normal operation the valve handle; 16, is turned such that the sealing disk is moved upward to the open position and the water flows out through the product outlet valve; 9. This was done for several times without any problems in collecting the water in buckets and containers while flowing out of the valve; 9. For sealing ability, during each cycle; of filling – discharging – refilling, of the normal operation described, each time the sealing disk was kept in the closed position for a longer period of time before it is opened to allow the water to discharge. No leakage was observed during the periods in which the vessel is full and the sealing disk 2 is in the closed position. The longest

Fig. 2 The contamination free valve, parts' assembly

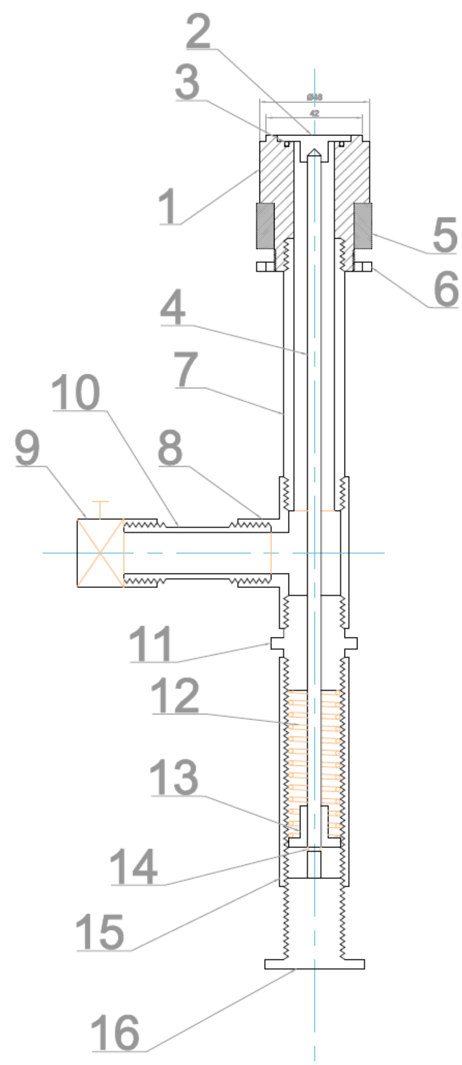

Fig. 3: The jacket of the vessel with the opening through which the valve is assembled shown.

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dwell period reached 10 hours where no leakage is observed. The other test was to check how much of the fluid will leak through the clearance between the rod 4, and the rod guide 11, whether it will flow completely out or will be kept within the threaded bushing 15. The vessel was filled with water while the sealing disk 2 is in the closed position and the product outlet valve; 9, is fully open. The valve handle 16 was turned completely so that the rod 4 is pushed upwards and the sealing disk is in the fully open position. The water flows out through the product outlet valve the time period to discharge the 140 litres completely was measured. The vessel was completely refilled and while the product outlet valve is closed the valve handle 16 was completely threaded so that the sealing disk 2 is in open position and the water head was allowed for a similar period of time to leak through the clearance between the rod 4 and the rod guide 11. A beaker was placed beneath the valve handle 16, droplets was collected. After the time period that was enough to discharge the full capacity has elapsed, the product outlet valve was opened allowing the full capacity to discharge through its normal path. The valve handle 16 was completely unthreaded and the leaked amount was collected. The same procedure was repeated and the leaked amount was collected and measured where no more than 0.05% leakage was observed.

5 Discussion and conclusion

A great number of manufacturers; whose output is in the order of magnitude of thousands of litres per day, can use the above equipment to obtain a product with hygiene (healthy) requirements as obtained using huge plants producing products in mass production. The smallest production line for an HTST pasteurization plant working as a continuous process will be at least ten times in capital cost for a batch operating system depending on the valve design proposed. Process industry using batch processes may vary in their requirements therefore it was enough to verify the operation of the design as described above. In practice it will be necessary that the amount of fluid in vessel kept sealed for the time required for the process. In food industry a batch process may need several hours to be completed. In pasteurization; [8] for example, the product should be kept at a certain temperature for few minutes or for few seconds at another specified temperature. In both cases the fluid need to be kept sealed for heating the amount till the required temperature. The time required for the 140 litres to flow out is not specific as several products may be required to flow at a rate that is to be specified by the process designer according to the product specifications, etc. Therefore it is enough to give relative leakage quantity in a time equal to the time required to flow the total amount out with the chosen sizes of the piping attached. Further work will be performed to determine the optimum jacket size for vessel size, heating sources and heat transfer and agitation would all lead to a well designed cheap piece of equipment that would help small manufacturers in poor countries to obtain economic healthy products that compete; in price and quality, with that obtained from mass production expensive plants.

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