A LIFELONG LEARNING EXERCISE (ABET REQUIRED) IN AN UNDERGRADUATE FLUIDS COURSE

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Abstract

Students were asked to investigate pump designs that would accommodate the pumping of maraschino cherries from a tank into the container in which they would be sold. This is a complex mixture of low viscosity liquid and large, soft solids whose integrity must be maintained. The only pumps students knew about at the time were centrifugal and positive displacement (piston/gear) pumps typically used in the chemical process industries. They had no instruction, except to find a pump that would do the job, and hence this counted as a "lifelong learning" exercise, where the student is on his/her own carrying out the investigation. Needless to say, they used the internet almost exclusively, had some fun doing so, and found a variety of pumps that would work.

Introduction

Integrating ABET goals into the undergraduate curriculum has occupied many engineering departments over the last ten years. In a recent rearrangement of our chemical engineering curriculum, the department decided to incorporate some of these goals throughout the course of study. One of those was a "lifelong learning" exercise for our sophomore-level fluids course.

At first this was a daunting assignment, but it rapidly became clear that a number of investigations could be proposed that would satisfy the experience. Pumps are fluid moving devices, of which there are a very large variety of designs meant for special occasions. In fluids we emphasize only two of these because of their wide use in the chemical industry – centrifugal pumps and positive displacement pumps. These are not the only kind of pumps available and only work with clear fluids of low viscosity in the first case and high viscosity in the second.

So, very simply stated, the student assignment was to come up with a pump that could pump maraschino cherries from a source to the container in which they will be sold. Neither the centrifugal pump nor the positive displacement pump (piston or gear) could be used, as they would squish the cherries. The sophomores had no idea what other kinds of pumps there were, and were not given any special guidance. Hence this was a "lifelong learning" assignment which they had to do on their own. They were given two weeks to do it and had to hand in a short, written report describing the operation of the pump. They were encouraged to use figures or other graphical information to better explain how the pump could do the job.

Results and Discussion

Figures 1 and 2 show several existing pump designs.[1] Fig. 1 shows some unacceptable pump designs, including a centrifugal pump, a gear pump and a double screw pump. The centrifugal pump (top of Fig. 1) has a vaned impeller that turns at high speed. It throws the liquid against the wall where pressure is developed according to Bernoulli's principles. The turbulence, high shear and sudden decelerations work against the integrity of the solids. The gear pump (middle of Fig. 1) clearly squeezes too far and would crush soft solids. The double screw pump is a bit better, but, depending on the squeezing and shear (moving boundary), it may not be desirable for the situation at hand either. All these designs would squish and mash the cherries – a very undesirable outcome.

By contrast, some acceptable designs are shown in Fig. 2. These designs include the progressing cavity "Moyno" pump (the middle of Fig. 2), which was the one I expected them to choose (about 1/3 of the class found this), the flexible diaphragm pump (top left entry of Fig. 2) - of which almost half of the class did choose, and a single screw pump (bottom of Fig. 2) - of which about 15% chose, in various guises. All of these pumps avoid severe turbulence in their action. They all involve some kind of moving boundary, more or less sealed off in sections, to move complex, two-phase (solid/liquid) fluids.

The "Moyno" pump design uses a helically shaped, highly polished metal rotor, turning in a helically shaped, rubber or flexible stator. The motion of the rotor is actually eccentric, moving slightly up and down in order for the outer walls of the rotor to stay in contact with the outer walls of the stator to maintain a moving cavity. These cavities, clearly illustrated in Fig. 2 – top end of the rotor, transport the complex liquid, in this case a two-phase mixture of soft solids and low viscosity liquid, without turbulence or violent mixing, and so the integrity of the mix is preserved.

The single screw pump does somewhat the same thing, but the liquid is moved primarily by wall shear and, consequently, is not as desirable for the operation as the Moyno pump.

The flexible diaphragm pump is one of the designs actually used by the industry for this task. It, too, does not subject the mixture to violent turbulence and preserves the integrity of the mix. The size has to be appropriate for the cherries, however, which are about 1 - 2 cm in diameter. Because the solids are relatively large, normal ball-type check valves cannot be used. Fig. 2, top, shows a typical single acting diaphragm pump with ball valves. The double diaphragm is basically two of these put together opposite each other and operated on the same shaft, which can be air-driven or machine driven.

The "Moyno" pump and the single screw pump do not require check valves, but the diaphragm pump does. On the suction stroke, the diaphragm creates vacuum, the suction check valve has to open and the discharge check valve has to close. Similarly, the reverse has to happen on the discharge stroke of the diaphragm shaft. The large majority of the students picked this kind of pump, actually an AODD (air operated double diaphragm) pump – primarily because a manufacturer in Brooklyn, NY used this pump to fill their maraschino cherry jars. (How they got to this site, I have no idea). However, there was an interesting subtlety that only some of the students caught. The check valves have to be flexible, flap type check valves. The more typical ball-type check valves will not work. They'll get stuck and not close, or they will crush the cherries. One type of flap valve is illustrated in Fig. 2, top right. This is like a tri-lobe heart valve[2]. The two-lobe "duck-bill" flexible valve[3] would also work, but it is not as strong as the tri-lobe, and may be too weak for the application.

Conclusions

In this exercise, students found three pumps that would work, including the one I picked as the solution – the Moyno pump or progressing cavity pump. Many missed the important subtlety of flexible check valves when using the diaphragm pump. These must be used in order to make the operation successful, and so the reports the students handed in could be graded on those points of understanding in addition to the writing and presentation. In conclusion, everybody seems to have learned something useful from the exercise and had a positive experience in "lifelong learning" and what is required for that.

Bibliographic Information

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2. http://www.defender.com
3. http://zycon.com/Profile/Day-Pro-Rubber-Inc/Duckbill-Check-Valves.html

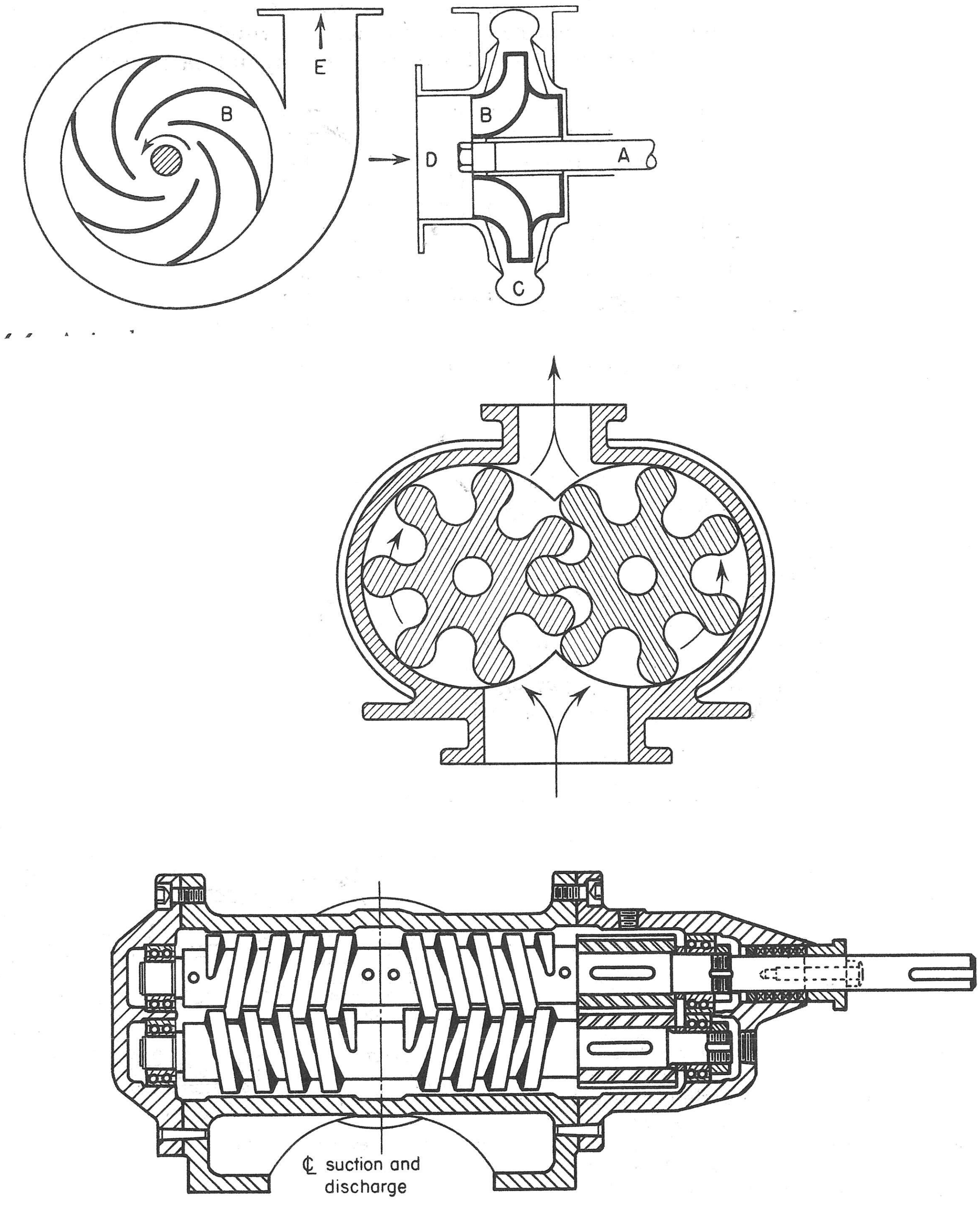

Figure 1: Unacceptable pump designs for pumping maraschino cherries in light syrup.

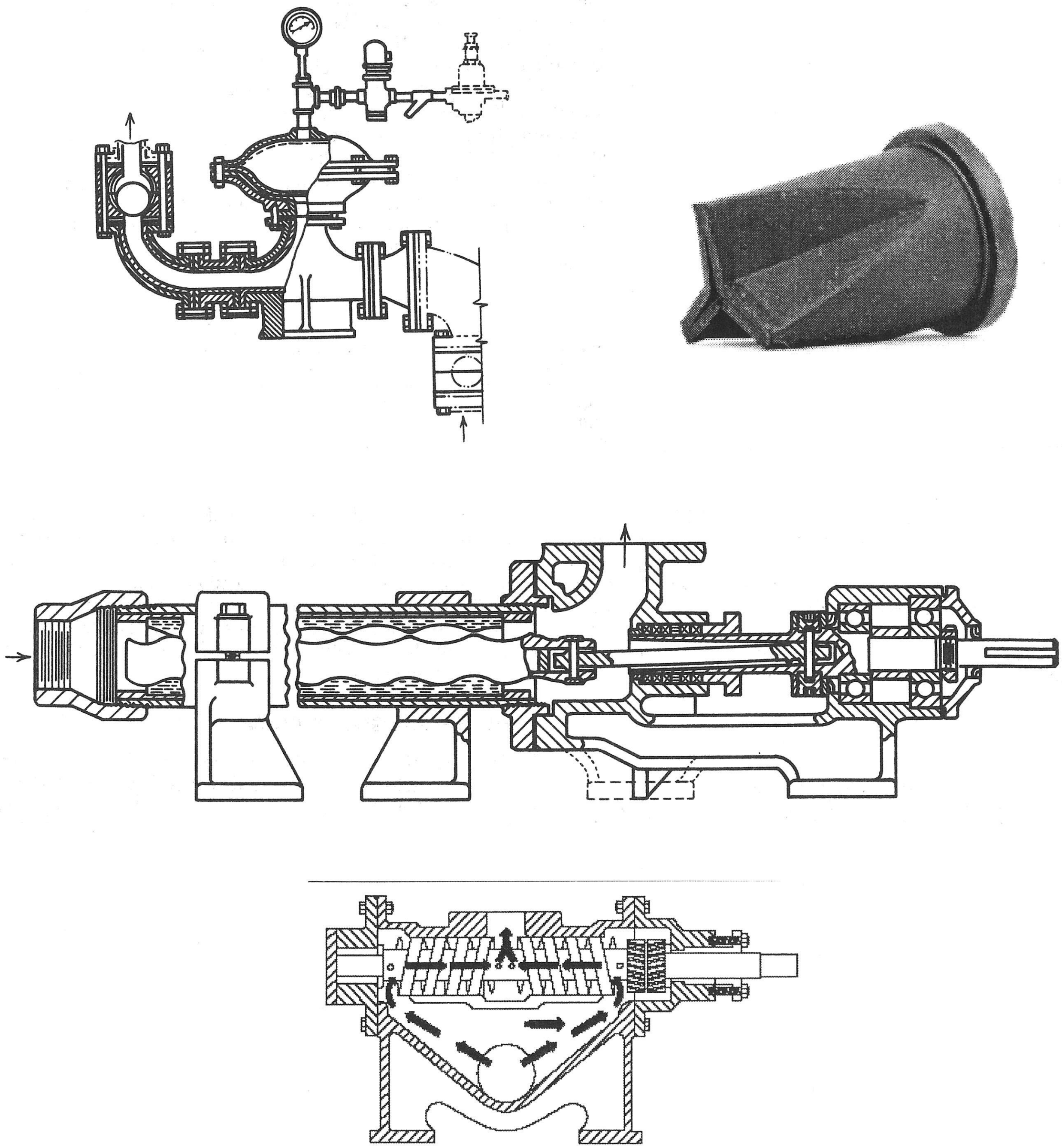

Figure 2: Acceptable pump designs for pumping maraschino cherries in light syrup.