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Paper

A COMPARISON OF TUBE NOZZLE PERFORMANCE

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ABSTRACT

Tubes in the size range of 5/8" to 2" diameter, ranging in length from 5 to 65 feet, such as are found in heat exchangers, evaporators and coolers, are frequently waterblast cleaned using a technique called flex lancing. Flex lancing uses a nozzle on the end of a flexible hose that is fed into and out of the tubes by an operator. There exist several basic designs of these nozzles that are used in tube cleaning. The goal of these tests was to measure the relative performance of the most common designs of tube nozzles.

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1. INTRODUCTION

Early tube cleaning nozzles consisted of a non-rotating drilled nozzle tip that was attached to the end of the high pressure waterblast hose, with as many as 40 small drilled orifices in an attempt to achieve as much coverage by the jets as possible. These are still quite commonly used today, but due to their improved cleaning rates there are also several designs of rotating nozzles that are displacing the original non-rotating tips. The most likely reasons for the use of the non-rotating designs are their simplicity, the lack of maintenance required and the very low cost of these nozzles. The purpose of this research was to compare the relative performance of several of the common tube cleaning nozzles available and an estimate of operating costs per job.

2. TESTING

Tests were performed in 25 mm (1 in.) and 35 mm (1.37 in.) inside diameter tubes; 75 durometer Buna-N rubber rod matching the inside diameter was inserted into the tubes to simulate plugged conditions. All tests were conducted at 103 MPa (15,000 psi) and total flow rates of 45 to 53 lpm (12 to 14 gpm) per nozzle. Rates of removal were timed for each of the nozzle types.

Table 1 describes the nozzle types. Of the rotating nozzles, all but Nozzle D are high speed spinning nozzles; Nozzle D has a speed control mechanism, high pressure seal and bearings. Spinning Nozzles C and E are of a relatively new design where the water flow path is straight through to the nozzle head, as opposed to Nozzle A with a turbulent flow path to the forward facing jets.

3. RESULTS

3.1 Cleaning Rates

The rate of material removal is shown in Figure 1 in terms of volume to allow comparison between tube sizes. The data from Nozzles B and C was taken from tests in the 25 mm tube size; the other nozzles were tested in the 35 mm tube size. Figure 2 shows the material removed by Nozzles B and C; Nozzle C went 27 times faster. Figure 3 shows the results of nozzles A, D and E; Nozzle D was the fastest of these, at 13.5 times that of Nozzle A and 1.2 times that of Nozzle E.

3.2 Nozzle Efficiency

The efficiency based on the power consumption of the just the forward facing jets of all the nozzles is compared in Figure 4. Nozzles D and E were 26 times more effective than Nozzle A when jet power is included in the comparison; Nozzle C was 23 times more efficient than Nozzle B.

To be successfully used as a hand-held nozzle, all of these tips must have rearward facing jets to balance the front jets. Additionally, Nozzles A, C and E are not positively sealed; they continuously leak during operation, consuming additional power. The efficiency plot in Figure 5 includes the additional pump power for the balancing jets and the leakage; the ratios of performance of Nozzles A and B compared to Nozzles C, D and E did not change much when this was included.

When comparing Nozzles C, D and E to each other, based on their size, there are some differences in efficiency that become visible. Their overall efficiencies and front jet efficiencies are compared in Figure 6. The front jet efficiency of nozzle C is twice that of nozzles D and E. This is likely due to the flow rate and nozzle body diameter being close to optimum for this tube size. When nozzle C was tested in the 35 mm tube, the efficiency did not change but the effectiveness did. This smaller diameter body removed just enough material to allow advancing, as shown in Figure 7. If the nozzle had been fed through at a slower rate, it might have removed more of the material, but this would still be limited by increasing standoff distance to the tube wall in larger tubes, and the efficiency would have been reduced by this slower feed rate.

Another test was conducted using nozzle E to determine the effect on efficiency of increasing flow rate. Figure 8 shows the results for overall efficiency and front jet efficiency. The overall efficiency increased by 50% with a 50% increase in overall flow rate; the front jet efficiency increased by 30% with a 95% increase in front jet flow.

3.3 Operating Costs

This comparison takes the relative performance from these test results and applies them to a job example with 250 plugged tubes, 35 mm diameter, 10 m (33 ft) long. Costs are based on prices of the tools with replacement parts, using a typical drilled orifice life of 30 hours and a rotating nozzle life of 100 hours. Labor and pump operating costs are not included. The results are shown in Table 2. Intuitively, if the operator is charging by the hour, he will be paid more to choose the slowest possible method. Others consider only initial tool cost or operating cost per hour. However, downtime costs to the plant can be on the order of hundreds of thousands of dollars per day, and the operator should use this as leverage to charge more to quickly complete the job. In addition to costs in dollars, the faster completion of a job reduces exposure time and fatigue to the operator, reducing the risk of incurring injuries.

4.0 CONCLUSIONS

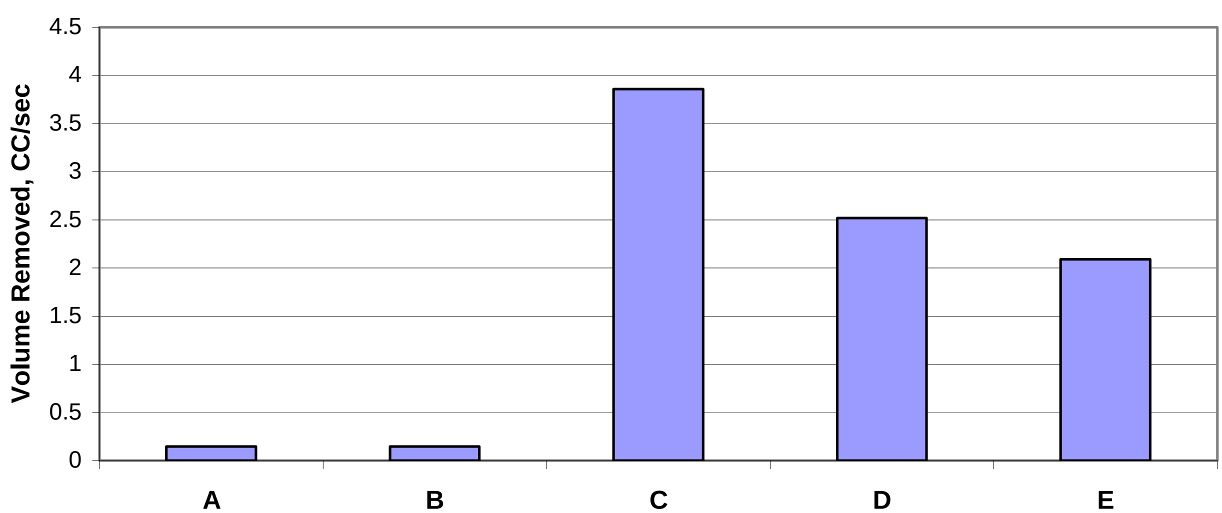
The relative performance of five different tube cleaning nozzles was measured and compared. There was a difference in performance between the rotating nozzles based on design; the designs with a straight through flow path allowed cleaning at a rate 13 times that of the nozzle with a turbulent flow path. The rotating nozzles removed material at a rate of 27 times that of the non-rotating nozzle.

Nozzle	Type	Diameter	Forward Jets	RPM
A	Rotary, leak, free spin	25 mm	2	25000
B	Non-Rotary	19 mm	7	NA
C	Rotary, leak, free spin	18 mm	3	25000
D	Rotary, bearings, seals	23 mm	3	1000
E	Rotary, leak, free spin	24 mm	3	25000

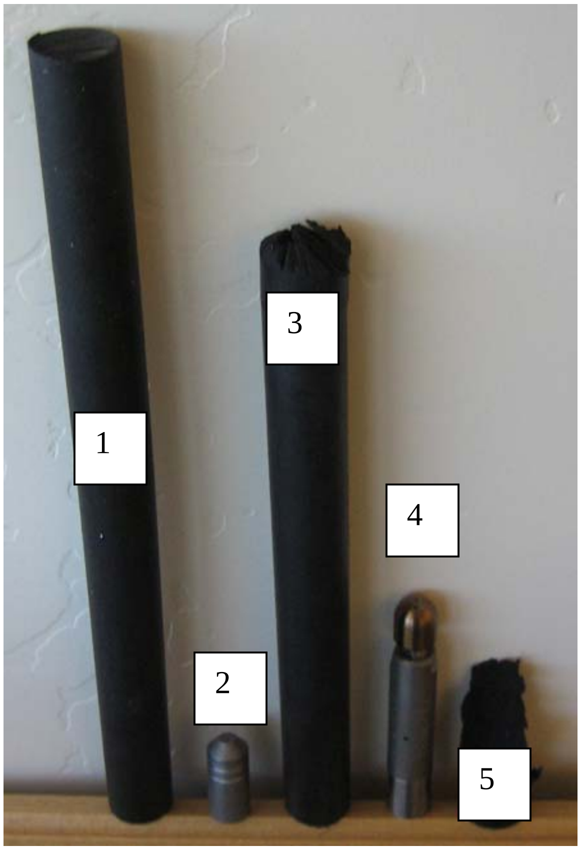
Description of Nozzle Types Compared
Table 1.

Nozzle	Cost/Hour	Total Hours	Total Cost
B	$1.30	2480	$3,224
D	$13.30	257	$3,418
E	$6.60	316	$2,086

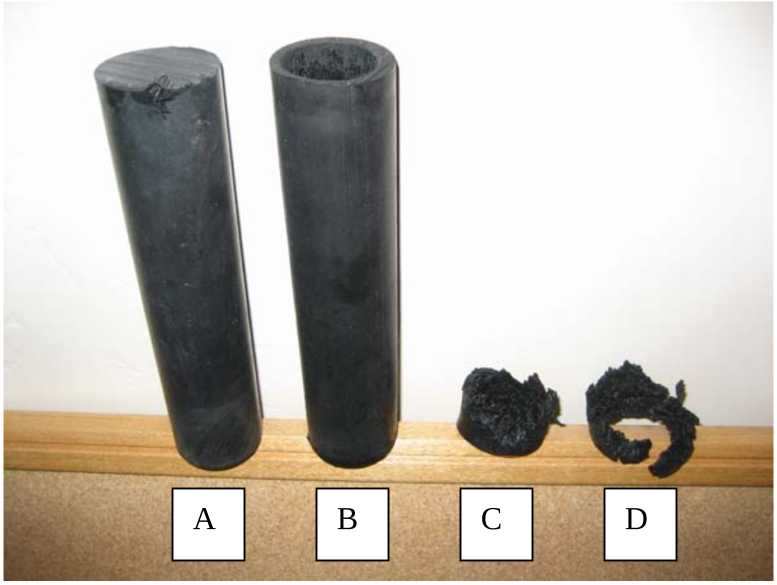
Comparison of Operating Costs per Job
Table 2.



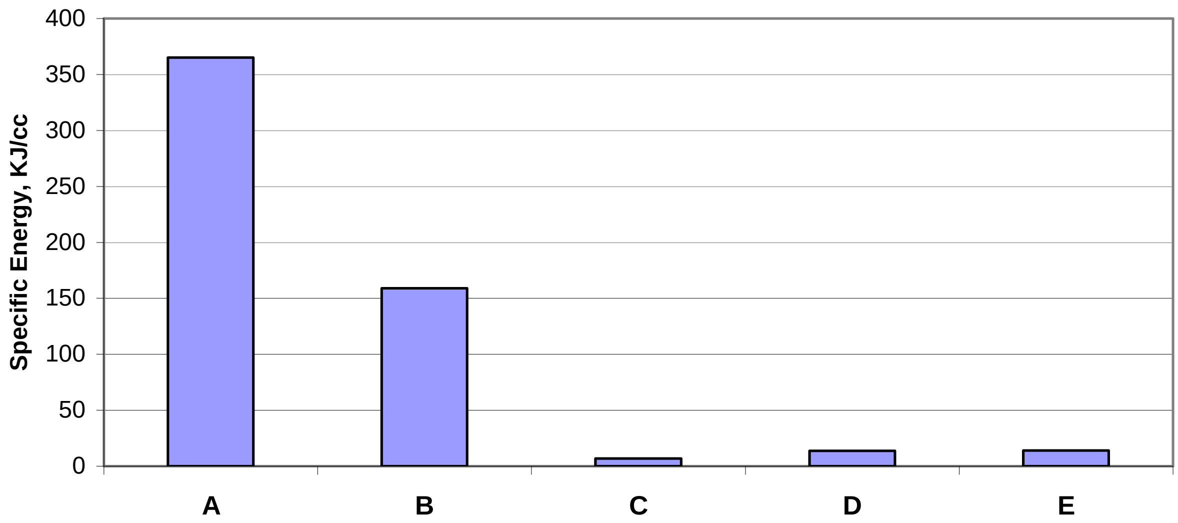
Material Removal Rates for the Nozzle Types Tested
Figure 1.



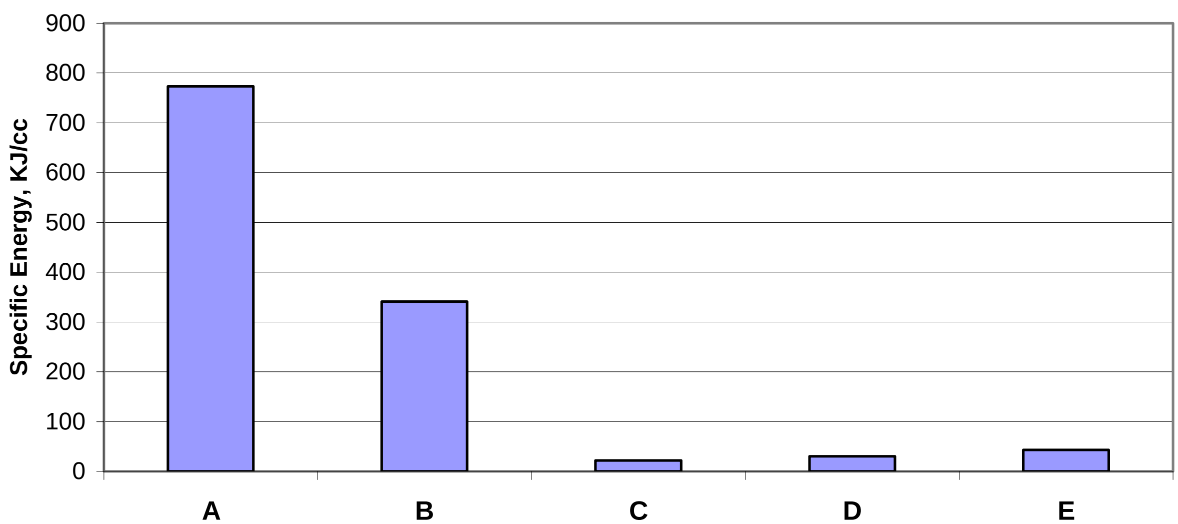
(1) Original 25 mm Test Sample; (2) Nozzle B and (3) Resulting Sample after 4 minutes; (4) Nozzle C and (5) Resulting Sample after 40 Seconds, Right
Figure 2.



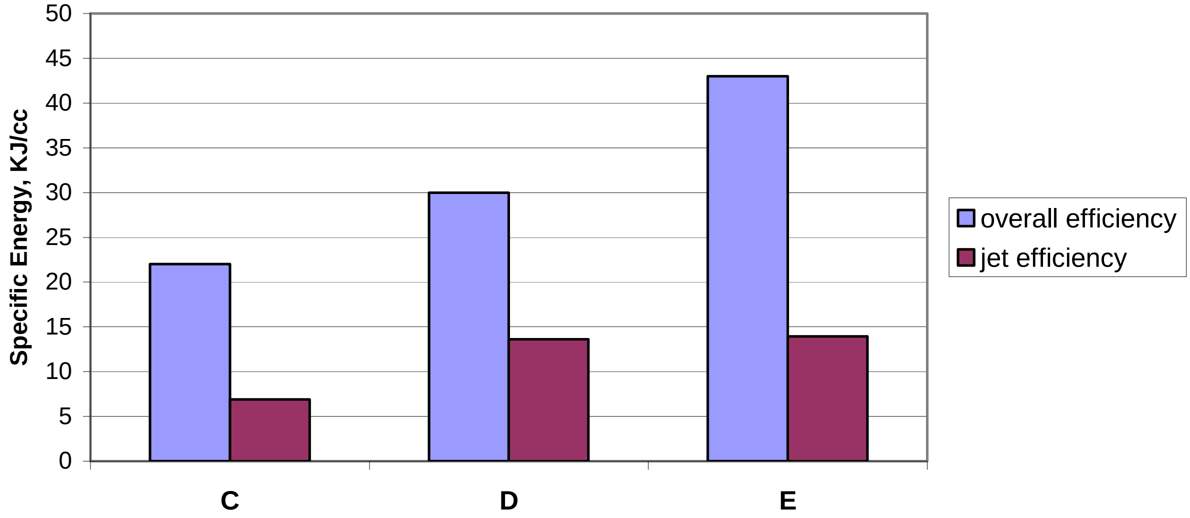
(A) Original 35 mm Test Sample; (B) Results of Nozzle A after 2 Minutes; (C) Results of Nozzle E after 69 seconds; (D) Results of Nozzle D after 57 Seconds
Figure 3.



Efficiency of the Forward Jets
Figure 4.

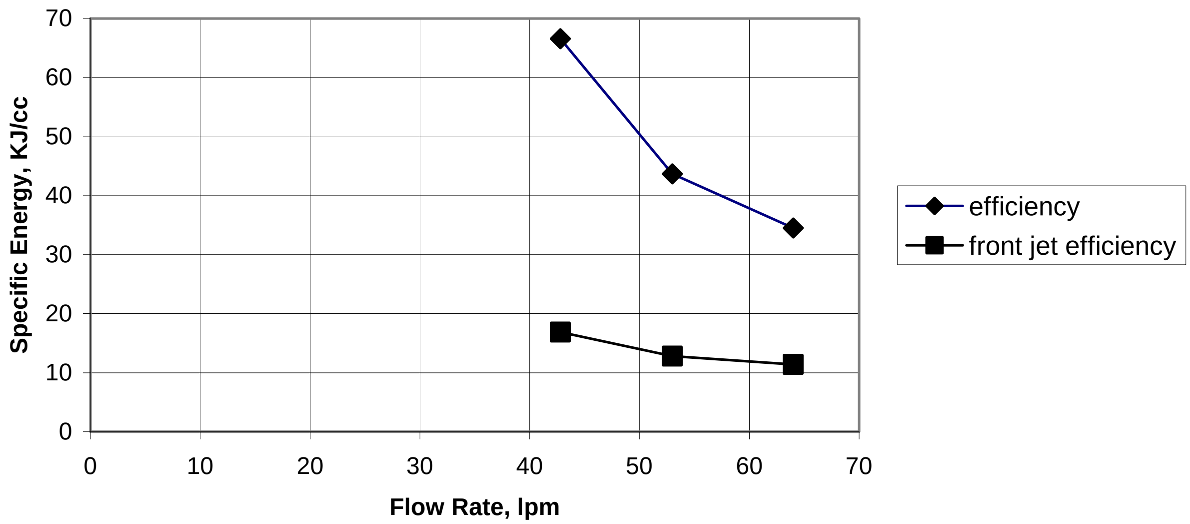


Overall Efficiency Including Back Jets and Leak
Figure 5.



Comparison of Overall Efficiency and Front Jet Efficiency, Nozzles C, D and E
Figure 6.

Material Not Removed by Nozzle C in a 35 mm Tube
Figure 7.



Efficiency with Increasing Flow Rate, Nozzle E
Figure 8.