OPTIMIZING WATER BLAST POWER

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ABSTRACT

Efffective waterblasting requires a minimum combination of pressure and flow to clean a surface. To achieve cleaning at further distances, or to complete the job faster, additional power in the form of greater flow or pressure is needed. The purpose of this research was to determine if there is an optimum combination of pressure and flow for a given power at various standoff distances.

Jet power deteriorates as the jet moves through the air. The rate of deterioration of the jet is a function of the nozzle diameter. Total power is the combination of pressure and flow. Therefore, at the same power, there exists the choice of a large jet at low pressure or a small jet at high pressure. At a given standoff distance, the large jet will not have deteriorated as much as the small jet, but the small jet started with a higher pressure at the nozzle.

Jet penetration was measured at various standoff distances in two materials with different properties. Pressures from 21 to 231 MPa (3,000 to 33,000 psi) and flows from 19 to 170 lpm (5 to 45 gpm) were used. In all cases a clearly defined optimum pressure and flow was found. Additionally, it was found that the optimum nozzle size at a given standoff held constant over a range of powers.

1. INTRODUCTION

The power of a waterblast system is the combination of the water pressure and the flow rate. Once a jet exits the nozzle orifice, the water pressure is converted to velocity. The velocity of the jet is then converted into a stagnation pressure at a surface; this stagnation pressure along with the mass flow rate of the jet will determine the effective cleaning power or impact of the jet on a surface.

Since the pressure of a system is much easier to measure than the velocity or the stagnation pressure of the jet, the power of the jet is commonly referred to in terms of the system pressure. For example, we refer to the "threshold pressure" of a material. The pressure value in this case is the pressure the operator reads off the gauge on the pump. In most materials, a minimum threshold pressure must be reached before any material is removed. In many materials there appears to be an optimum pressure, above which increased power is best applied with increased flow.

Ideally, the distance from the jet to the surface being cleaned, referred to as standoff distance, should be kept as small as possible, since a jet loses power as it travels through the air. However, in many waterblast operations, large standoff distances are common, and cannot be efficiently avoided. The rate at which a jet loses power as it travels through the air is dependent on the size of the nozzle. Therefore, at a given standoff distance, a larger jet will have deteriorated less than a smaller jet.

If two jets of equal powers are considered, one a large jet at a lower pressure, and the other a small jet at a higher pressure, the higher pressure jet will have a greater effect at the surface at a short distance. As the standoff distance is increased, the continual deterioration of this jet will result in an impact equal to, and finally less than the larger jet at the lower initial pressure. Meanwhile, the larger jet has been deteriorating as well, but not as rapidly. However, since this jet started out at a proportionally lower pressure to the minimum required threshold pressure to attack the material, it cannot be allowed to deteriorate as much.

This paper explores the effect of the proportions of the pressure and flow to determine if there is an optimum combination at various standoff distances.

2. TEST PROCEDURE

The tests consisted of series of constant power values divided proportionally into pressures ranging from 35 to 231 MPa (5,000 to 33,000 psi), and flows from 19 to 170 lpm (5 to 45 gpm). Carbide nozzles with flow straighteners, all of the same design, were used. Orifice sizes ranged from .71 to 3.96 mm (.028 to .156 in.) A 25 cm (10 in.) straight pipe was used upstream of the nozzle.

Test samples consisting of machineable wax, with a threshold pressure between 35 and 42 MPa (5,000 and 6,000 psi), and a cement and sand mixture with a threshold pressure of 10.5 MPa (1,500 psi) were used. Single jets were traversed at standoff distances from 5 to 127 cm (2 to 50 in.) Passes were made at the constant rate of 30 cm/sec (1 ft/sec). The jet kerfs were measured for depth and volume.

3. RESULTS

3.1 Constant Power, Increasing Standoff Distance

The first series of tests were conducted at 71 Kw (95 hp), with combinations of pressure and flow from 36 MPa, 121 lpm to 231 MPa, 19 lpm (5,100 psi, 32 gpm to 33,000 psi, 5 gpm). The results are shown in Figure 1. At a 5 cm (2 in.) standoff, the depth of cut increased with an increase of pressure, although the trend leveled off between 147 and 231 MPa (21,000 and 33,000 psi), about 5 times the threshold pressure of the material. As the standoff distance increased, the maximum pressure for optimal effect decreased to between 70 and 84 MPa (10,000 and 12,000 psi), and occurs on a narrow peak, where the jet power reaching the surface exceeds the minimum required threshold pressure.

Figure 2 shows the results of an identical 71 Kw (95 hp) test conducted at the 127 cm (50 in.) standoff distance with a cement and sand mixture. Even though this material was much more easily attacked by a jet, and had a much lower threshold pressure, the optimum condition at this standoff distance occurred at nearly the same pressure, between 70 and 77 MPa (10,000 and 11,000 psi). This indicates that the optimum conditions at larger standoffs are not strongly dependent on the threshold pressure of the material.

3.2 Depth compared to Volume

The results of the 71 Kw (95 hp) tests in terms of volume removed are shown in Figure 3. This shows similar results, with the exception of the optimum at close standoffs occuring near 105 MPa (15,000 psi), while higher pressures show decreasing efficiency. The higher pressure conditions resulted in greater depth of cut, but the smaller nozzle diameters did not create as wide of a kerf as the lower pressures with larger orifice diameters. The curves at larger standoffs resemble those produced by depth of cut, with the optimums occuring between 70 and 84 MPa (10,000 and 12,000 psi).

3.3 Increasing Power, Fixed Standoff Distance

Tests were also conducted at 106 Kw (142 hp), at standoffs of 20, 51, and 127 cm (8, 20, and 50 in.). These results are shown in Figure 4. The optimum pressures shifted upward, with the optimum at 127 cm (50 in.) occurring between 105 and 140 MPa (15,000 and 20,000 psi). This upward trend is illustrated in Figure 5, which shows powers of 71, 86, 98, 106 and 135 Kw (95, 116, 131, 142 and 181 hp) at a standoff of 127 cm (50 in.). This trend is due to the increase in orifice size at each pressure with the increasing power. The standoff distance in nozzle diameters is decreasing, resulting in less deterioration of impact at the surface.

If the optimum pressures at each power are used, and a nozzle diameter calculated to match the pressure and power, the resulting orifice diameters at each standoff are approximately the same. These orifice diameters are plotted versus the standoff distance in Figure 6. The standoff distance divided by nozzle diameter is plotted against the standoff distance in Figure 7. The relationship of optimum orifice size at a given standoff distance is expressed in Figure 8, where depth of cut versus the orifice diameter at a standoff distance of 127 cm (50 in.) is plotted for powers ranging from 71 to 135 Kw (95 to 181 hp). These charts show the optimum performance is dependent on orifice size for a given standoff distance. An optimum orifice size should be selected based on standoff distance, and increased power should be applied through increased pressure and flow while keeping this orifice diameter constant.

4.0 CONCLUSIONS

The results of these tests showed an optimum pressure and flow combination for a given power at a given standoff distance. The optimum does not appear to be dependent on the threshold pressure of the material. As standoff distances increase, the optimum conditions become more sharply defined.

In addition, these tests showed that the optimum conditions occur at a fixed value in terms of nozzle diameters at each standoff, and an increase in power should be applied by increasing pressure and flow through the optimum orifice size, defined by the standoff distance.

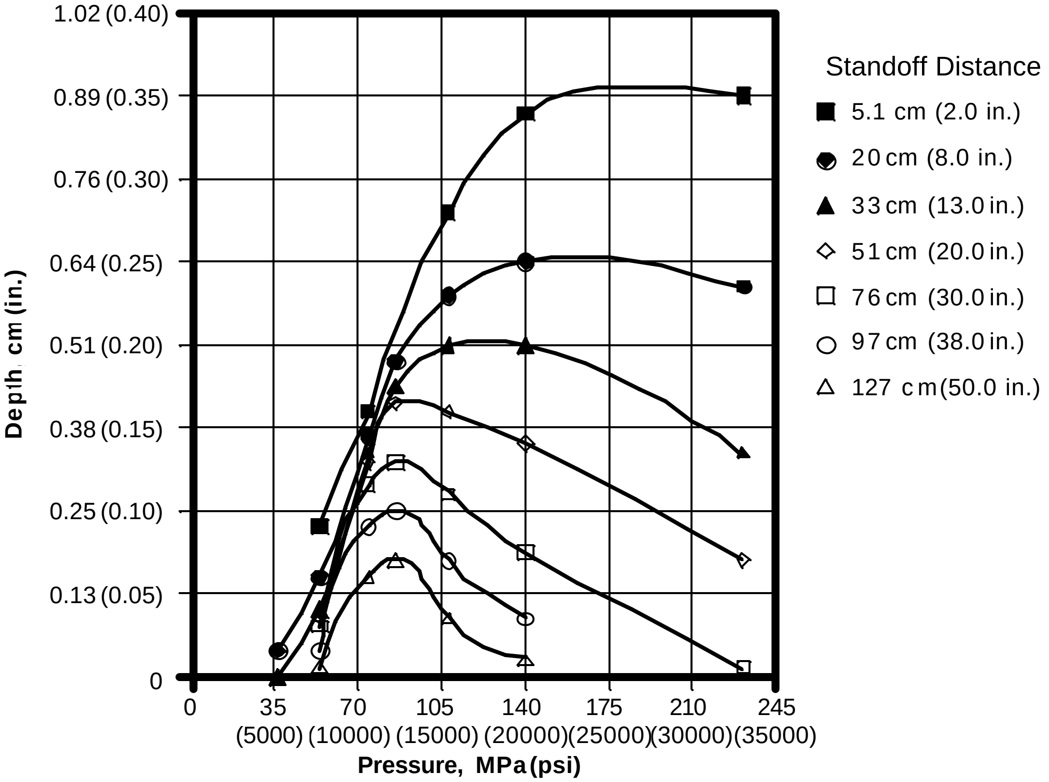

Figure 1. Depth of Cut in Wax at 71 kw (95 hp), vs. Pressure

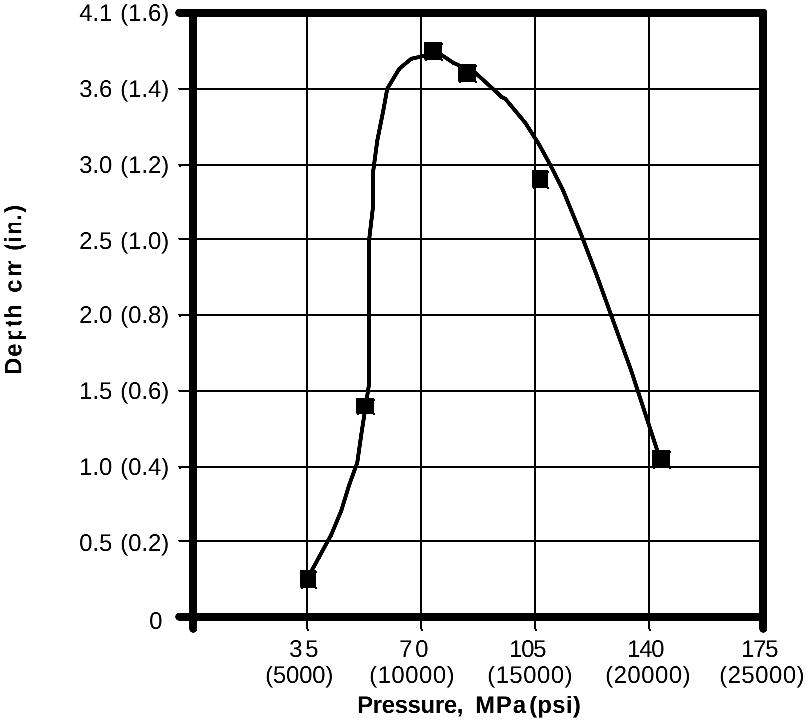

Figure 2. Depth of Cut in Cement/ Sand Mixture at 127 cm (50 in.) Standoff

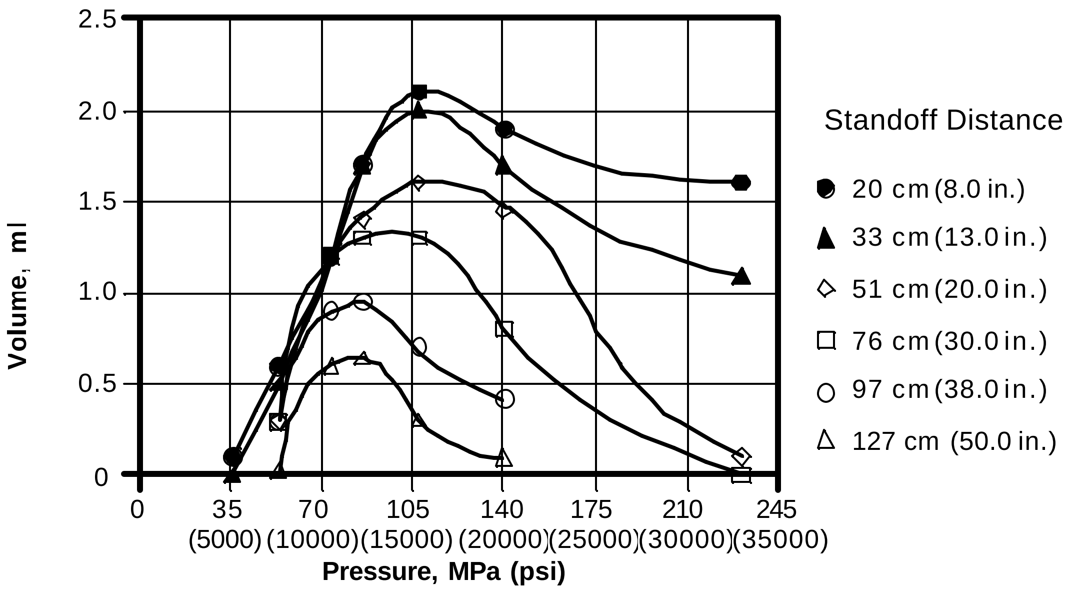

Figure 3. Volume Removed in Wax at 71 Kw (95 hp), vs. Pressure

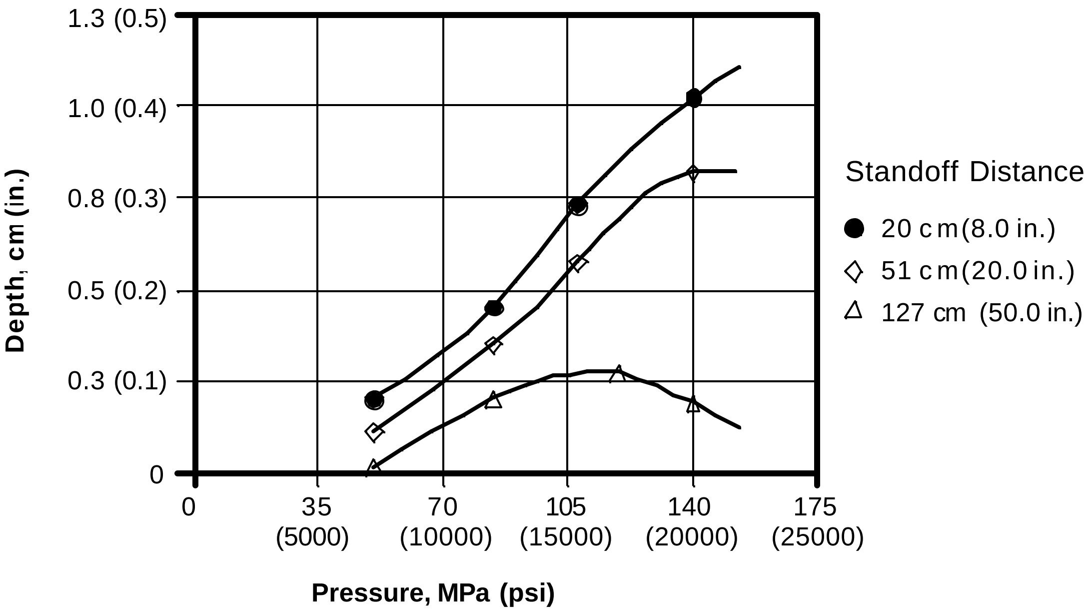

Figure 4. Depth of Cut in Wax at 106 Kw (142 hp), vs. Pressure

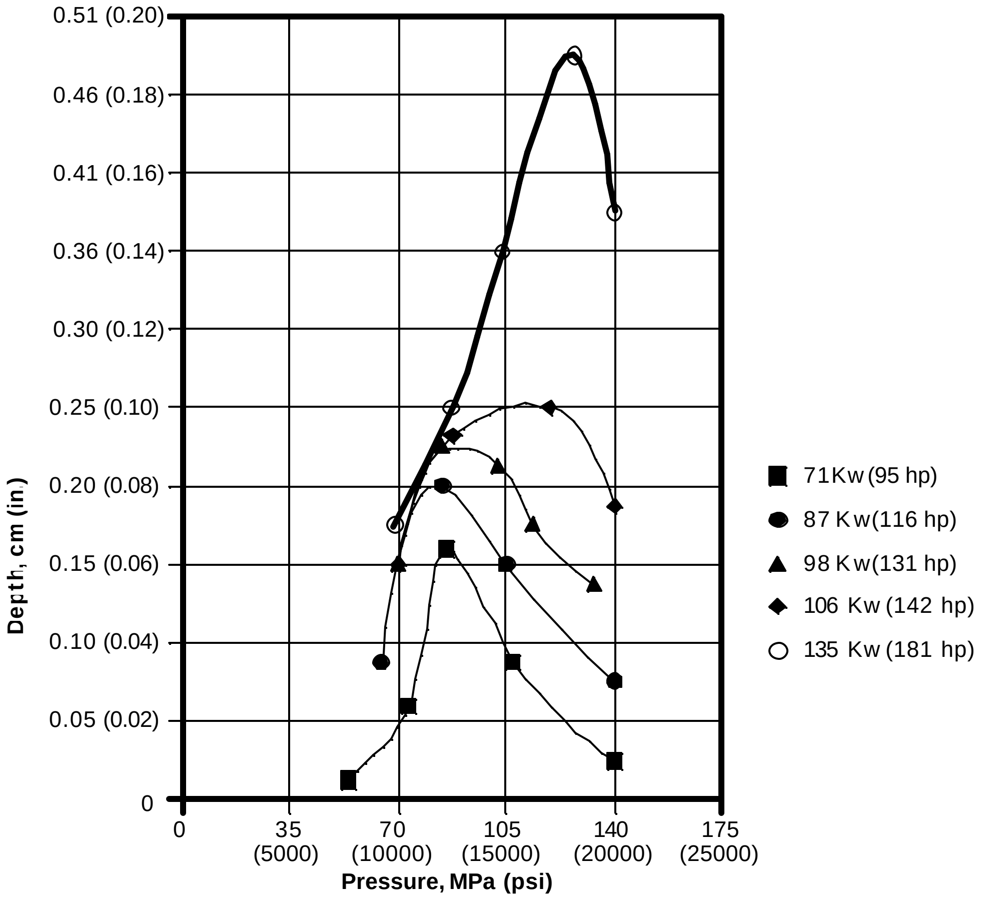

Figure 5. Depth of Cut in Wax at 127 cm Standoff (50"), vs. Pressure

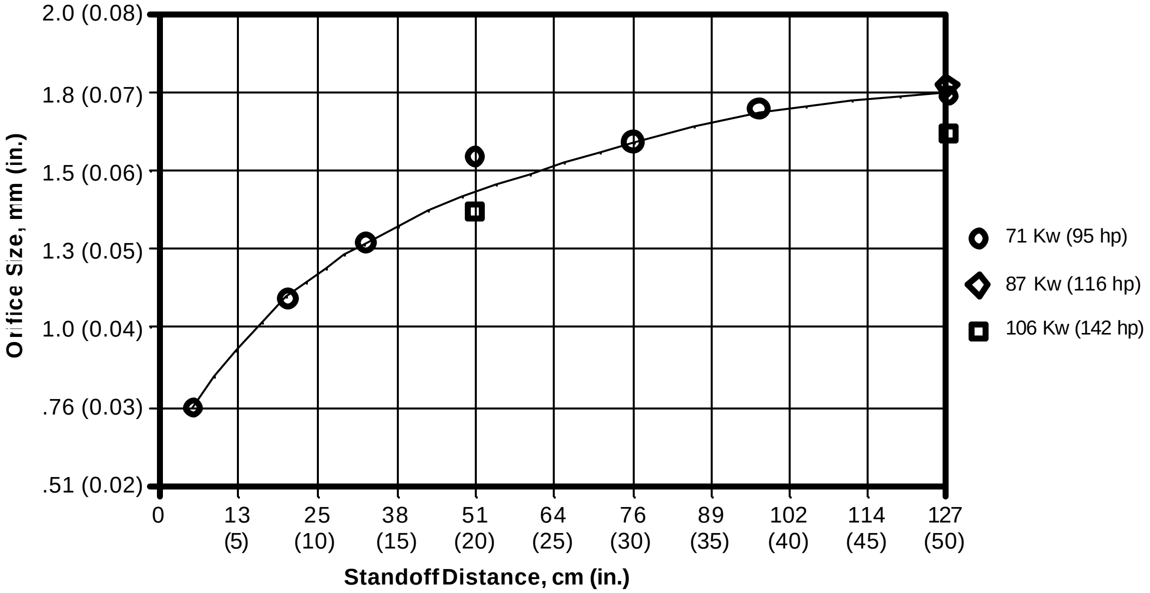

Figure 6. Optimum Orifice Diameters at Standoff Distances

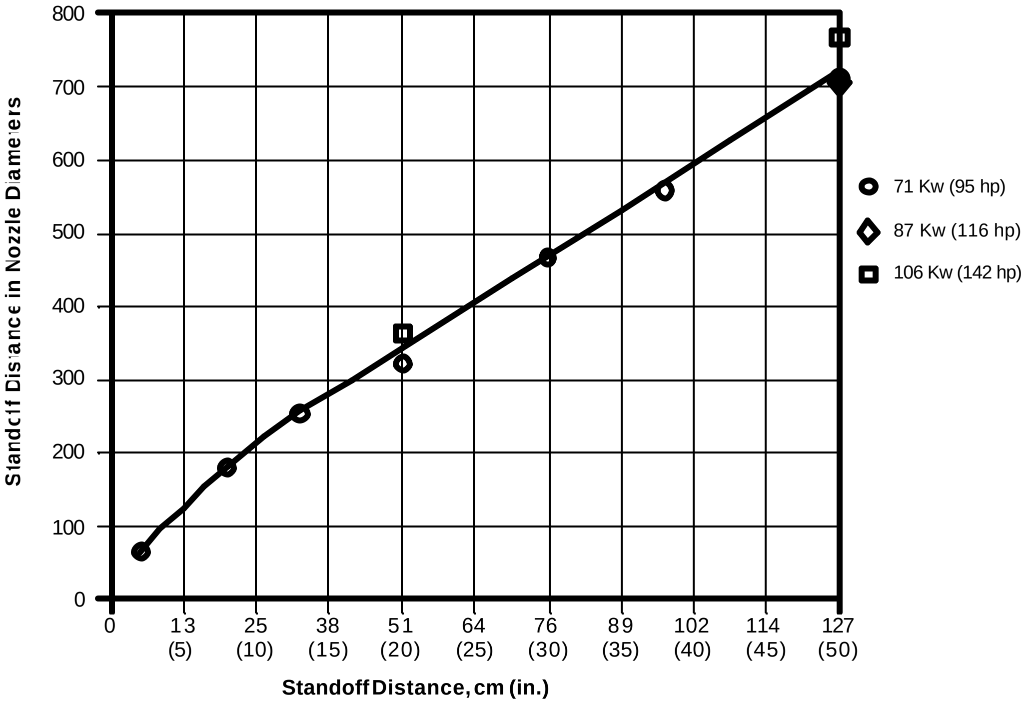

Figure 7. Optimum Nozzle Diameter Standoffs

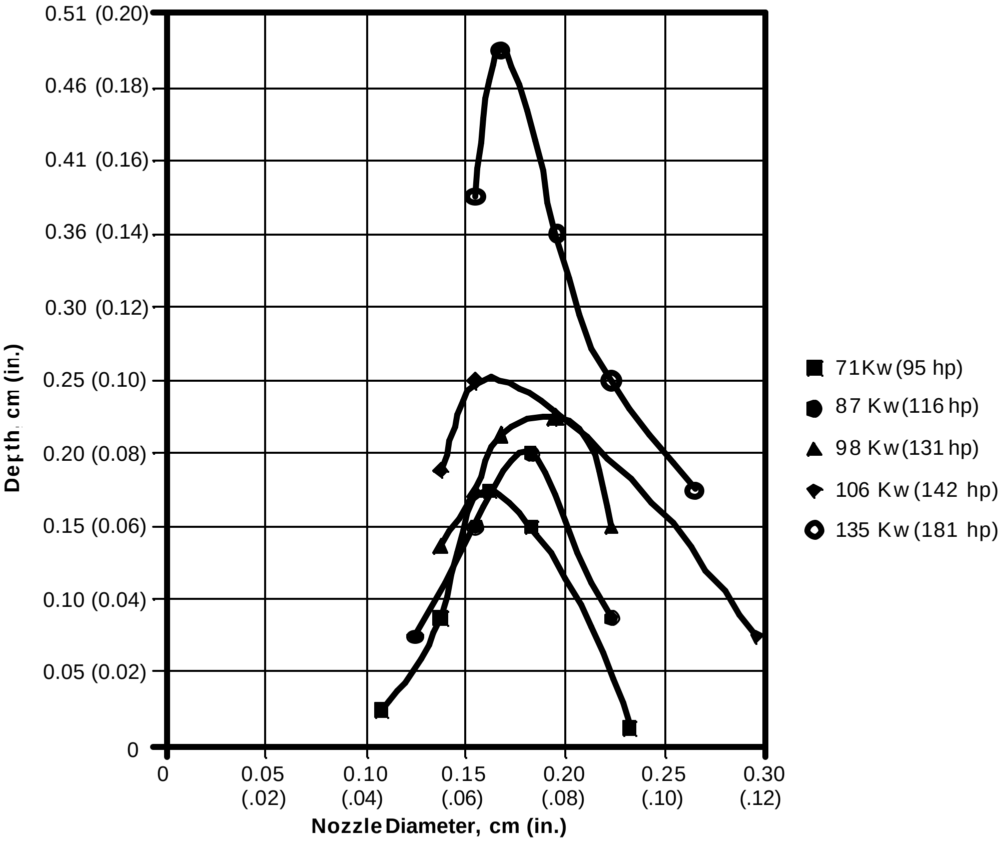

Figure 8. Depth of Cut in Wax at 127 cm Standoff (50"), vs. Nozzle Diameter