DELAVAN®

A TOTAL LOOK AT OIL BURNER NOZZLES

ISO 9001 CERTIFIED

A Reference Guide for the Burner Service Technician

The complete oil heating system begins at the tank and ends at the chimney. At the heart of the system is a tiny, yet important piece of hardware — the nozzle. It performs the vital functions that keep the flame generating warm, comfortable heat. In fact, it plays such a significant role in the entire system that we feel the technician should know all about the nozzle.

In this reference guide, we'll explore how the nozzle works with other components of the system and give you some oil nozzle facts that can help you maintain a clean, reliable and economical heating system.

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NOTE

The information in this pamphlet is based on experience and is to be used as a general guide only.

WARNING

Improper modification to combustion units may create a fire hazard resulting in possible injury. Contact the original equipment manufacturer before modifying the combustion unit.

Why Use Nozzles?

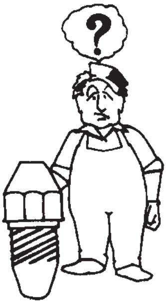
For a better understanding of how a nozzle fits into the performance of an oil burner, let us first review the steps in the process of efficient combustion.

> Like all combustible matter, the oil must first be vaporized—converted to a vapor or gas—before combustion can take place. This is usually accomplished by the application of heat.
>
> The oil vapor must be mixed with air in order to have oxygen present for combustion.
>
> The temperature of this mixture must be increased above the ignition point.
>
> A continuous supply of air and fuel must be provided for continuous combustion.
>
> The products of combustion must be removed from the combustion chamber.

The simplest way to burn fuel oil is the old vaporizing pot type burner in which heat is applied to a puddle of oil, thus vaporizing the fuel. These vapors are then burned after mixing with the proper amount of air.

In most applications, this method of vaporizing is too slow for high rates of combustion and cannot be controlled in the low rates, which leads back to the original question of why nozzles are used. One of the functions of a nozzle is to atomize the fuel, or break it up into tiny droplets which can be vaporized in a much shorter period of time when exposed to high temperatures. This booklet will be concerned primarily with the high-pressure atomizing nozzle since it is the most common in the Oil Heat Industry.

What the Nozzle Does



The atomizing nozzle performs three vital functions for an oil burner:

1. Atomizing As just discussed, it speeds up the vaporization process by breaking up the oil into tiny droplets…something like 55-billion per gallon of oil at a pressure of 100-psi (standard in the industry). The exposed surface of a gallon of oil is thereby expanded to approximately 690,000 square inches of burning surface. Individual droplet sizes range from .0002 inch to .010 inch. The smaller droplets are necessary for fast quiet ignition and to establish a flame front close to the burner head. The larger droplets take longer to burn and help fill the combustion chamber.

2. Metering A nozzle is so designed and dimensioned that it will deliver a fixed amount of atomized fuel to the combustion chamber…within approximately plus or minus 5% of rated capacity. This means that functional dimensions must be controlled very closely. It also means that nozzles must be available in many flow rates to satisfy a wide range of industry needs. Under 5.00 GPH, for example, over 20 different flow rates and 6 different spray angles are considered standard.

3. Patterning A nozzle is also expected to deliver the atomized fuel to the combustion chamber in a uniform spray pattern and spray angle best suited to the requirements of a specific burner. More details on patterns and angles later.

How A Nozzle Works

Now that we know what a nozzle is supposed to do, let's see how it does it.

But before we do, let's take a look at the cutaway showing the functional parts of a typical Delavan nozzle (Fig. 1). The flow rate, spray angle and pattern are directly related to the design of the tangential slots, swirl chamber and orifice.

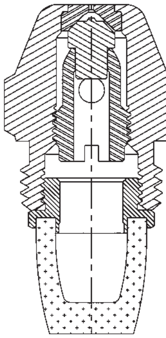


FIGURE 1 *Cutaway view of a Delavan nozzle.*

First, a source of energy is needed to break up the oil into small droplets. Therefore pressure is supplied to the nozzle, usually from a motor-driven pump at 100-150 psi (Fig. 2). But pressure energy alone doesn't do the job. It must first be converted to velocity energy and this is accomplished by directing the pressurized fuel through a set of slots which are cut in the distributor at an angle, or tangentially, to create a high velocity rotation within the swirl chamber. At this point, about half of the pressure energy is converted to velocity energy.

As the oil swirls, centrifugal force is exerted against the sides of the chamber, driving the oil against the orifice walls, leaving a void or core of air in the center. The oil then moves forward out of the orifice in the form of a hollow tube. The "tube" becomes a cone shaped film of oil as it emerges from the orifice, ultimately stretching to a point where it ruptures and throws off droplets of liquid.

How a Nozzle Works

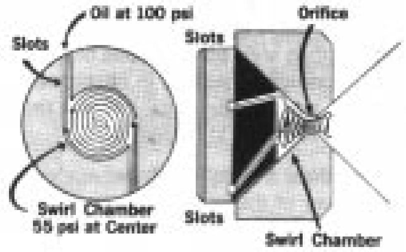
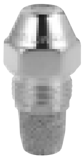


FIGURE 2 *How a nozzle works.*

Nozzle Selection

To match a nozzle to a burner takes field-service experience, trial-and-error, or a good foundation of understanding angles, rates and patterns.

Nozzle Ratings and Testing



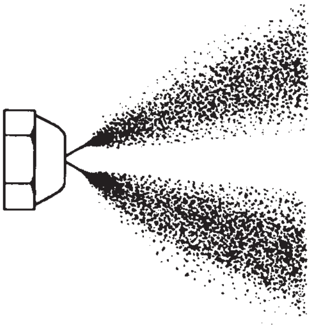
To insure consistent quality, every Delavan nozzle is tested for flow rate and spray angle on modern, high instrumented test stands. Spray quality is observed during testing for uniformity, balance and flutter.

Delavan Nozzles

Nozzle Type	Vial Color
A	Red
Del-O-Flo A	Black
B	Royal Blue
Del-O-Flo B	Gold
W	Green

Test oil is mixed to nominal no. 2 oil specifications. The viscosity is maintained within:1±.04 centistokes (.03 SSU), gravity to a total spread of 11/2° APl and temperature at 80°F ±2° F. Test pressure is set at 100 psi. These conditions are continuously monitored and instrument accuracy is maintained within ±.5% or better. Nozzle testing is conducted in an air-conditioned, controlled environment, with a temperature variation of 4° F maximum.

Nozzle Types



Type A
Hollow Cone
(Creates stable flame at low flows)
Figure 3

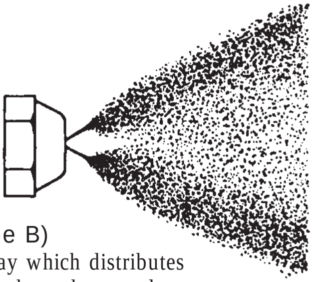
Hollow Cone Nozzle (Type A)

Hollow cone nozzles can be used in burners with a hollow air pattern and also for use in small burners (those firing 1.00 GPH and under), regardless of air pattern. Hollow cone nozzles generally have more stable spray angles and patterns under adverse conditions than solid cone nozzles of the same flow rate. This is an important advantage in fractional gallonage nozzles where high viscosity fuel may cause a reduction in spray angle and an increase in droplet size.

Type A nozzles produce a spray which delivers fine droplets outside the periphery of the main spray cone. These fine droplets greatly enhance ignition and create a stable flame for use with flame retention burners.

For Type A Del-O-Flo® low flow nozzles (see page 5).

Type B
Solid Cone
(For larger burners & where air pattern is heavy in the center or for long fires)
Figure 4

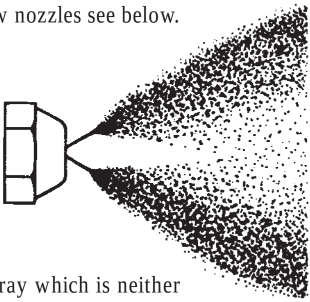


Solid Cone Nozzle (Type B)

Type B nozzles produce a spray which distributes droplets fairly uniformly throughout the complete pattern. This spray pattern becomes progressively more hollow at high flow rates, particularly above 8.00 GPH. These nozzles may be used in larger burners (those firing above 2.00 or 3.00 GPH) to provide smoother ignition. They can also be used where the air pattern of the burner is heavy in the center or where long fires are required.

For Type B Del-O-Flo low flow nozzles see below.

Type W
(Can be used in place of A or B types in reducing specific problems)
Figure 5



Type W Nozzle

Type W nozzles produce a spray which is neither truly hollow nor solid. These nozzles frequently can be used in place of either solid or hollow cone nozzles between .40 GPH and 8.00 GPH, regardless of the burner’s air pattern. The lower flow rates tend to be hollower. Higher flow rates tend to be more solid.

Del-O-Flo® Nozzle

U.S. Patent #4,360,156; Belgian Patent #889,019; U.K. Patent #2,076,696

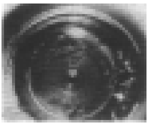


Figure 6
Standard hollow-cone

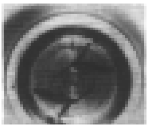


Figure 7
Delavan Del-O-Flo

Del-O-Flo® nozzles are low-capacity nozzles designed to minimize the usual Nozzle plugging problems associated with low flow rates. Del-O-Flo® nozzles are available in A and B types.

Delavan performed a test in which a .50 gph Del-O-Flo® nozzle and a .50 gph standard hollow cone nozzle were run continuously for 23 hours from a double adapter using the same oil supply. Engineers contaminated clean oil with a controlled amount of iron oxide, rust and sand. The pictures to the left show the nozzles after the test (these views are looking inside the nozzle body from the filter end). You can see the iron oxide contamination build up in the standard nozzle (Fig. 6).

Fig. 7 shows the same view of the Del-O-Flo® nozzle. Although the dark streaks show a discoloration from sand, there is no contamination build up.

Burner Manufacturer’s Recommendations*

Manufacturer	Model	Delavan Nozzle	
Aero Burner	F-AFC	80° W, A or B	
	HF-US	80° W, A or B	
	HF-AFC	80° W, A or B	
	SV-SSV	70° or 80° B	
R.W. Beckett	AF/FG (F)	60°, 70° or 80° A or B (100-150 PSI)	
	AF/AFG (M)	60° or 70° A or B (100-150 PSI)	
	AFII (FB)	45°, 60° or 70° A, W or B (140-200 PSI)	
	AF II (HLX)	45°, 60° or 70° A, W or B (140-200 PSI)	
The Carlin Co.	99 FRD (Std.)	.50-.75 GPH	60°A
		.85-3.00 GPH	45°A, 60°A or B
	100 CRD (Std.)	.50-.75 GPH	60°A
		.85-2.25 GPH	45°A, 60°A or B
		.75-1.10 GPH	60°
	Elite EZ-1	.50-1.00 GPH	70°A
		.50-.85 GPH	60° SS
		1.00-1.65 GPH	60° or 70°
	Elite (EZ-2,3)	All Flow Rates	60° A, B or SS
Riello Burners	Mectron 3M 5M	600 W, B, or Del-O-Flo A (Up to to .85 GPH)	
	F3, F.5	.40-1.25 GPH	60° or 80° W or A
	F10	1.25-2.50 GPH	60° or W or B
	F15, F20	2.00-5.00 GPH	45° or 60° W or B
	R35.3, R35.5	.50-1.25 GPH	60° or 80° W or B
	Press Series	2.00-12.00 GPH	60° or 45° B or W
Intertherm	MAC 1265	P/N 6601-181 or .55 GPH 90° W or .579 MH	
	MSH 066	.50 - 80°A	
	MSH 086	.65 - 80° A	
Wayne Home Equipment	P100	.50-1.00 GPH	60°, 70°, 80° A or B
	EHASR	.75-3.00 GPH	80°, 70°, 60° **
	MSR	.75-2.75 GPH	80°, 70°, 60° **
	HS	.50-2.50 GPH	80°, 70°, 60° **
	HS	.50-3.00 GPH	80°, 70°, 60° B
	EG-1	.50-3.00 GPH	88°, 70°, 60° **
		**Under 1.00 GPH use A; above 1.00 use B.	
Weil-Mclain	QB180 (150 PSI)	.55-1.80 GPH	45°, 60°, 70°, 80° A or B
	QB300 (140 PSI)	1.75-3.00 GPH	45°, 60°, 70°, 80° B

*Effective February 1997. Subject to updating by burner manufacturers. For models not listed, contact burner manufacturer. Always follow the appliance manufacturer’s instructions for the correct nozzle specification.

Nozzle Interchange

Delavan Recommended Interchange

Nozzle Interchange Chart

Spray Angles 30° through 90°

HAGO/SID HARVEY	DELAVAN
H	A
SS (up to 2.0)	SS
SS (over 2.0)	A or W
ES/P	B*
B	B*
MONARCH	**DELAVAN**
NS/PL	A
R/AR (up to 2.0)	R-D/AR-D
R/AR (over 2.0)	A/A or W
PLP	B*
DANFOSS	**DELAVAN**
AS	W or B
AH	A

Replacing a nozzle of one make with another sometimes presents problems. This is partly due to unique design differences among the various makes, plus the fact that the nozzle manufacturers use different methods for evaluating spray angles, patterns and spray quality.

***When interchanging a Delavan A, B or W with a Hago, it may be necessary to try the next wider spray angle.**

****Del-O-Flo A and B nozzles will interchange whenever standard A or B nozzles are called for.**

Flow Rate

Atomizing nozzles are available in a wide range of flow rates, all but eliminating the need for specially calibrated nozzles. Between 1.00 GPH and 2.00 GPH, for example, seven different flow rates are available. Generally, with hot water and warm air heat, the smallest firing rate that will adequately heat the house on the coldest day is the proper size to use and the most economical. Short on-cycles result in low efficiency. Another guideline is to select the flow rate that provides a reasonable stack temperature regardless of the connected load. (According to the New England Fuel Institute, aim for a stack temperature of 400°F or lower on matched packaged units or 500°F or lower on conversion burners.) If the boiler or furnace is undersized for the load, it may be necessary to fire for the load and ignore the efficiency.

Proper Flow Rates

The proper size nozzle for a given burner unit is sometimes stamped on the nameplate of the unit.

The following guidelines may be used for determining the proper flow rates:

If the unit rating is given in BTU per hour input, the nozzle size may be determined by…

$$\text{GPH} = \frac{\text{BTU Input}}{140{,}000}$$

If the unit rating is given in BTU output…

$$\text{GPH} = \frac{\text{BTU Output}}{(\text{Efficiency \%}) \times 140{,}000}$$

On a steam job, if the total square feet of steam radiation, including piping, is known…

$$\text{GPH} = \frac{\text{Total Sq. Ft. of Steam} \times 240}{(\text{Efficiency \%}) \times 140{,}000}$$

If the system is hot water operating at 180° and the total square feet of radiation, including piping, is known…

$$\text{GPH} = \frac{\text{Total Sq. Ft. of Hot Water} \times 165}{(\text{Efficiency \%}) \times 140{,}000}$$

Determination of Proper Firing Rate for a House

Two procedures for determining the optimum nozzle size have been developed. One is the standard heat loss calculation method and the other is the K-factor sizing formula.

1. Standard Heat Loss Calculations Method If the amount of heat loss is known, the amount of replacement heat (heat load) needed is also known. From this information, the proper size of a boiler or furnace can be determined, thus the correct nozzle size. This method can be used for determining the proper nozzle size in new construction, a new heating system in an existing house, or a new oil burner installation. This method requires extensive measurements of the house and other construction details. For more information, refer to recommended resource material listed below.

   Recommended Resource Material:

   "Cooling and Heating Load Calculation Manual," American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc. (ASHRAE).

   "Heat Loss Calculation Guide," The Hydronics Institute (IBR), 35 Russo Place, Berkeley Heights, NJ 07922.

2. The K-Factor Sizing Formula This is a sizing calculation that meets oil dealer and heating contractor needs for a quick procedure to determine the proper nozzle size for existing heating systems. The K-factor calculation uses oil dealer records of degree days (a measure of "coldness") and oil used, plus other information, but does not require any measurements of the house. For more information, refer to recommended resource material listed below.

   Recommended Resource Material:

   "Handbook and Product Directory — Fundamentals,"

   American Society of Heating, Air Conditioning and Refrigeration Engineers, Inc. (ASHRAE).

   "The Professional Serviceman's Guide to Oil Heat Savings,"

   R.W. Beckett Corp., 38251 Center Ridge Road, PO. Box D, Elyria, OH 44035.

Spray Angle

Spray angles are available from 30° through 90° in most nozzle sizes to meet the requirements of a wide variety of burner air patterns and combustion chambers.

Usually it is desirable to fit the spray angle to the air pattern of the burner. In today's flame retention burner, it is possible to fire more than one spray angle with good results. Generally, round or square combustion chambers should be fired with 70° to 90° nozzles. Long, narrow chambers usually require 30° to 60° spray angles.

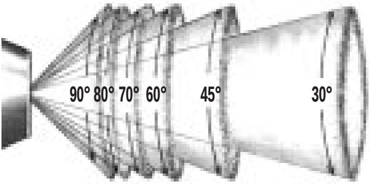
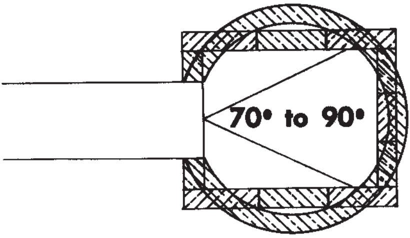
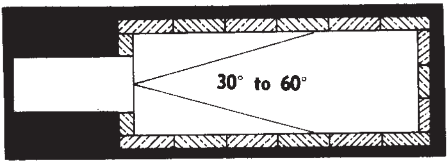


Figure 8
Spray angles available



70° to 90° spray angles for round or square chambers



30° to 60° spray angles for long, narrow chambers

Figure 9

Spray Pattern

Spray pattern is another consideration in determining which nozzle to use. There's a great difference between the solid pattern on the left and the hollow pattern on the right. (See Fig. 10) These patterns were photographed as a laser light beam passed through the spray. Lasers are used at the Delavan test laboratory to study patterns and spray characteristics.

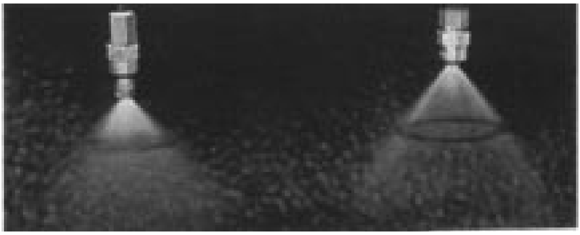
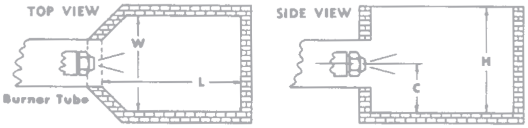


Figure 10 *(Left) Solid cone pattern, (Right) Hollow cone pattern*

Burner Air Patterns

Burner air patterns are much like nozzle spray patterns in that they fall into the same general classifications, either hollow or solid. As you would expect, a burner with a hollow air pattern generally requires a hollow cone fuel nozzle. A burner with a solid air pattern will give highest efficiency with a solid cone nozzle, but the flame will probably be longer.

Recommended Combustion Chamber Dimensions



Nozzle Size or Rating (GPH)	Spray Angle	Square or Rectangular Combustion Chamber				Round Chamber (Diameter in Inches)
		L Length (In.)	W Width (In.)	H Height (In.)	C Nozzle Height (In.)	
0.50 – 0.65	80°	8	8	11	4	9
0.75 – 0.85	60°	10	8	12	4	*
	80°	9	9	13	5	10
1.00 – 1.10	45°	14	7	12	4	*
	60°	11	9	13	5	*
	80°	10	10	14	6	11
1.25 – 1.35	45°	15	8	11	5	*
	60°	12	10	14	6	*
	80°	11	11	15	7	12
1.50 – 1.65	45°	16	10	12	6	*
	60°	13	11	14	7	*
	80°	12	12	15	7	13
1.75 – 2.00	45°	18	11	14	6	*
	60°	15	12	15	7	*
	80°	14	13	16	8	15
2.25 – 2.50	45°	18	12	14	7	*
	60°	17	13	15	8	*
	80°	15	14	16	8	16
3.0	45°	20	13	15	7	*
	60°	19	14	17	8	*
	80°	18	16	18	9	17

*Recommend oblong chamber for narrow sprays.

NOTES: These dimensions are for average conversion burners. Burners with special firing heads may require special chambers.

Higher back wall, flame baffle or corbelled back wall increase efficiency on many jobs.

Combustion chamber floor should be insulated on conversion jobs.

For larger nozzle sizes, use the same approximate proportions and 90-sq. in. of floor area per 1 gph.

Effects of Excess Air On Nozzle Performance

Excess air in the system can be a trouble spot. Of course the burner must have sufficient air to provide good mixing of air and fuel oil, or you get incomplete combustion and smoke. Unfortunately, as the amount of air is increased, the transfer of heat is reduced.

A delicate balance must be achieved between smoke problems (caused by insufficient excess air) and reduced heat transfer (caused by unnecessary excess air).

An air leak in the system also causes lost efficiency. It cools down combustion gases, lowers temperature, and raises stack temperature.

What Affects Droplet Size?

It is sometimes assumed that the smallest possible droplet size is the most desirable for all applications. While this may be true in some cases, it doesn't apply across the board. The safest generalization that can be made is to find the droplet size and distribution that produces the quietest, most efficient combustion. Here are some of the major factors affecting the droplet size.

- **Higher Flow Rate Nozzles** usually produce larger droplets, assuming pressure, fuel properties and spray angle remain the same. A 10.00 GPH nozzle, for instance, will produce larger droplets than a 5.00 GPH nozzle.
- **Wider Spray Angles** produce smaller droplets
- **High Viscosity** fuel produces larger droplets in the spray at the same pressure.
- **Heating Fuel** reduces its viscosity and produces smaller droplets.
- **Increasing Fuel Pressure** reduces droplet size.

Effects of Pressure On Nozzle Performance

Normally, 100 psi is considered satisfactory for the fixed pressure supplied to the nozzle, and all manufacturers calibrate their nozzles at that pressure.

It is interesting to observe the sprays of a nozzle at various pressures. See Figures 11-13. At the low pressure, the cone-shaped film is long and the droplets breaking off from it are large and irregular. Then, as the pressure increases, the spray angle becomes better defined. Once a stable pattern is formed, any increase in pressure does not affect the basic spray angle, measured directly in front of the orifice.

At higher pressure, however, you will note that beyond the area of the basic spray angle, the movement of droplets does make a slight change in direction—inward. That's because at this point the air pressure outside the spray cone is higher than that on the inside, which deforms the spray inward.

Pressure has another predictable effect on nozzle performance. As you would expect, an increase in pressure causes a corresponding increase in the flow rate of a nozzle, assuming all other factors remain equal. This relationship between pressure and flow rate is best shown in the table on page 13.

Increasing pressure also reduces droplet size in the spray. For example, an increase from 100 to 300 psi reduces the average droplet diameter about 28%. One last word on the subject: if pressure is too low, you may be under-firing the burner. Efficiencies may also drop sharply because droplet size is larger and the spray pattern changed. If pressure isn't carefully checked,* the marking on the nozzle becomes meaningless. Pressures of more than 100 psi are sometime desirable, but rarely do burners operate at anything less.

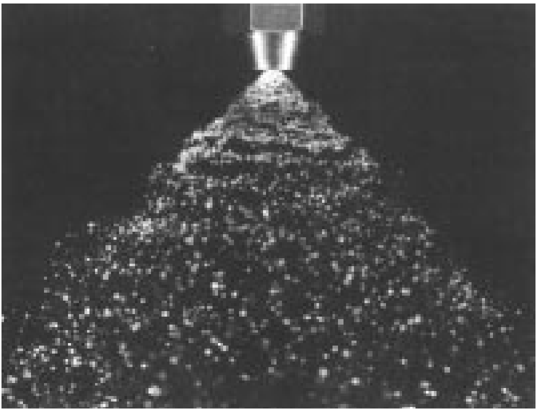


Figure 11 *Spray at 10 psi pressure*

* Pressure can be reduced between the pump and the chamber by clogged filters in the line or the nozzle. Check pressure whenever reduced, not just at the pump.

Effects of Pressure On Nozzle Flow Rate

Nozzle Rating at 100 PSI	Nozzle Flow Rates In Gallons Per Hour (Approx.)					
	120 PSI	145 PSI	160 PSI	175 PSI	200 PSI	300 PSI
0.40	0.44	0.48	0.51	0.53	0.57	0.69
0.50	0.55	0.60	0.63	0.66	0.71	0.87
0.60	0.66	0.72	0.76	0.79	0.85	1.04
0.65	0.71	0.78	0.82	0.86	0.92	1.13
0.75	0.82	0.90	0.95	0.99	1.06	1.30
0.85	0.93	1.02	1.08	1.12	1.20	1.47
0.90	0.99	1.08	1.14	1.19	1.27	1.56
1.00	1.10	1.20	1.26	1.32	1.41	1.73
1.10	1.20	1.32	1.39	1.46	1.56	1.91
1.20	1.31	1.44	1.52	1.59	1.70	2.08
1.25	1.37	1.51	1.58	1.65	1.77	2.17
1.35	1.48	1.63	1.71	1.79	1.91	2.34
1.50	1.64	1.81	1.90	1.98	2.12	2.60
1.65	1.81	1.99	2.09	2.18	2.33	2.86
1.75	1.92	2.11	2.21	2.32	2.47	3.03
2.00	2.19	2.41	2.53	2.65	2.83	3.46
2.25	2.46	2.71	2.85	2.98	3.18	3.90
2.50	2.74	3.01	3.16	3.31	3.54	4.33
2.75	3.01	3.31	3.48	3.64	3.89	4.76
3.00	3.29	3.61	3.79	3.97	4.24	5.20
3.25	3.56	3.91	4.11	4.30	4.60	5.63
3.50	3.83	4.21	4.43	4.63	4.95	6.06
4.00	4.38	4.82	5.06	5.29	5.66	6.93
4.50	4.93	5.42	5.69	5.95	6.36	7.79
5.00	5.48	6.02	6.32	6.61	7.07	8.66
5.50	6.02	6.62	6.96	7.28	7.78	9.53
6.00	6.57	7.22	7.59	7.94	8.49	10.39
6.50	7.12	7.83	8.22	8.60	9.19	11.26
7.00	7.67	8.43	8.85	9.26	9.90	12.12
7.50	8.22	9.03	9.49	9.92	10.61	12.99
8.00	8.76	9.63	10.12	10.58	11.31	13.86
8.50	9.31	10.24	10.75	11.24	12.02	14.72
9.00	9.86	10.84	11.38	11.91	12.73	15.59
9.50	10.41	11.44	12.02	12.57	13.44	16.45
10.00	10.95	12.04	12.65	13.23	14.14	17.32
11.00	12.05	13.25	13.91	14.55	15.56	19.05
12.00	13.15	14.45	15.18	15.87	16.97	20.78
13.00	14.24	15.65	16.44	17.20	18.38	22.52
14.00	15.34	16.86	17.71	18.52	19.80	24.25
15.00	16.43	18.06	18.97	19.84	21.21	25.98
16.00	17.53	19.27	20.24	21.17	22.63	27.71
18.00	19.72	21.67	22.77	23.81	25.46	31.18
20.00	21.91	24.08	25.30	26.46	28.28	34.64
22.00	24.10	26.49	27.83	29.10	31.11	38.11
24.00	26.29	28.90	30.36	31.75	33.94	41.57
26.00	28.48	31.31	32.89	34.39	36.77	45.03
28.00	30.67	33.72	35.42	37.04	39.60	48.50
30.00	32.86	36.12	37.95	39.69	42.43	51.96
32.00	35.05	38.53	40.48	42.33	45.25	55.43
35.00	38.34	42.15	44.27	46.30	49.50	60.62
40.00	43.82	48.17	50.60	52.92	56.57	69.28
45.00	49.30	54.19	56.92	59.53	63.64	77.94
50.00	54.77	60.21	63.25	66.14	70.71	86.60

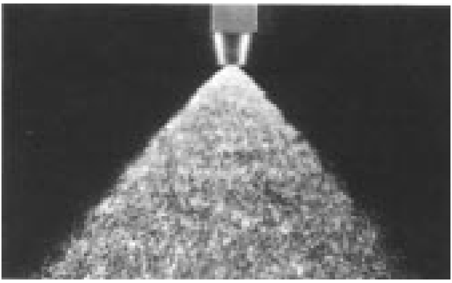


Figure 12 *Spray at 100-psi pressure*

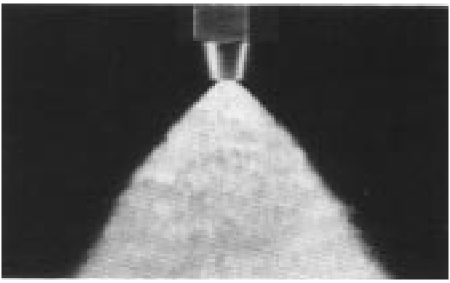


Figure 13 *Spray at 300-psi pressure*

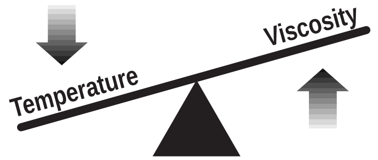
Effects of Viscosity On Nozzle Performance *(Also see page 26)*

One of the most important factors affecting nozzle performance is viscosity, technically defined as a measure of resistance to flow within a liquid. More commonly, viscosity is thought of in terms of "thickness." For example, a gallon of gasoline can be poured through the spout of a can much faster than a gallon of tar. That's because the tar has a much higher viscosity than gasoline, or greater resistance to flow.

Strangely enough, the opposite is true to nozzle applications. As we will see in a minute, with an increase in viscosity, nozzle flow rate also increases.

Temperature is the main factor in changing oil viscosities. It works something like a scale (Fig. 14). As the temperature goes down, the viscosity goes up. Take No. 2 fuel oil for example: at a temperature of 100°F, it has a viscosity of 35 SSU (Seconds Saybolt Universal). But when the temperature drops to 20°F, the viscosity increases to 65 SSU.

An outside storage tank may contain cold oil, and cold oil can cause problems. Here's what happens: the thick oil passes into the nozzle, through the slots, and into the swirl chamber. Since it is more viscous, the rotational velocity is slowed down. This causes a thickening of the walls in the cone of oil as it emerges from the orifice, so the nozzle actually delivers more fuel and larger droplets (see Figures 15 and 16). And as a result, the flame front moves away from the burner head. In severe cases, atomization may be so poor that the fuel cannot be ignited. Or if it is ignited, it often produces a long, narrow and noisy fire that burns off the back wall of the combustion burner.



Temperature F	100	80	30	20
Viscosity (SSU)	35	37	52	65

Figure 14 *How temperature affects viscosity.*

Although such situations are not widespread, it is good to know how to diagnose the problem and find a solution for it. While some success has been reported with special nozzles, most service technicians have found that the surest solution is to increase the energy input. This is done by increasing pump pressure from 100 psi to 120-125 psi. And since increased pressure means increased flow rate, it may be desirable to use the next size smaller nozzle. As the burner ignites, it acts as an oil pre-heater and the viscosity problem will disappear in 10 to 15 minutes. The burner can be left at this increased pressure without harm to the pump. In extreme cases of high viscosity due to cold oil it may be necessary to pre-heat the oil to get ignition.

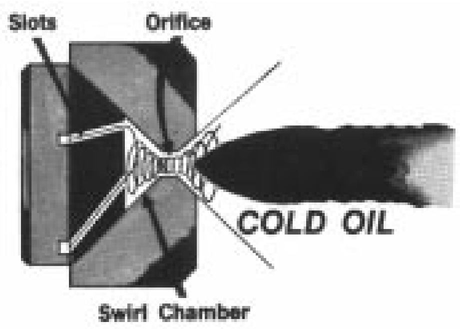


Figure 15 *Cold Oil*

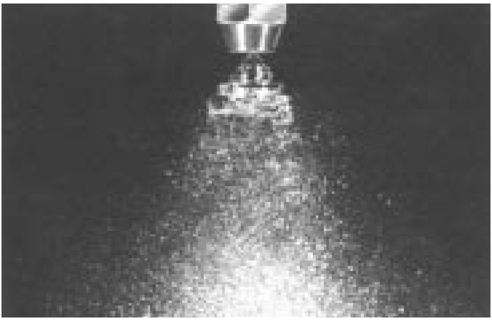


Figure 16 *High viscosity spray*

Examples of Proper Nozzle Selection

The following recommendations are solidly based on many years of field experience and laboratory testing. But, like most recommendations, they are subject to exceptional cases or conditions.

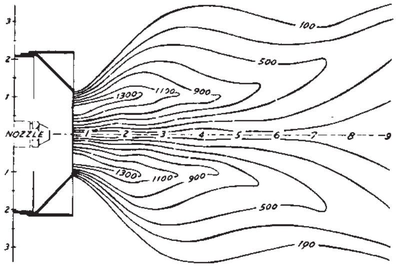


Figure 17 *Hollow Air Pattern*

Burners with Hollow Air Pattern The burner air pattern shown above produces a very definite hollow "air spray," with no measurable air velocity at the center of the pattern. The angle of this particular air spray shows it will require a 70° to 80° hollow cone nozzle for good matching. A solid cone nozzle, or one with a narrow angle, would produce a poor match and probably create smoke in the center of the flame, which couldn't be cleaned up by any adjustment of air.

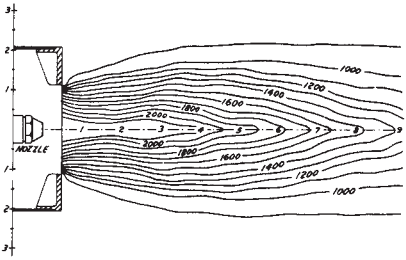


Figure 18 *Solid Air Pattern*

Burners with Solid Air Patterns The burner air pattern shown above produces a moderate form of solid "air spray." In actual tests this burner would show a slightly better CO_2 reading with a solid cone nozzle. This would become even more pronounced in burners showing higher air velocities at the center of the pattern.