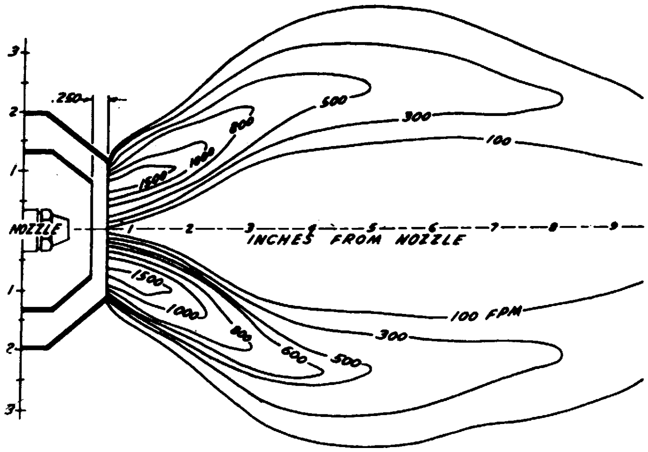

Figure 1. Definitely hollow air pattern for one type of burner. This pattern is from a Shell Head burner.

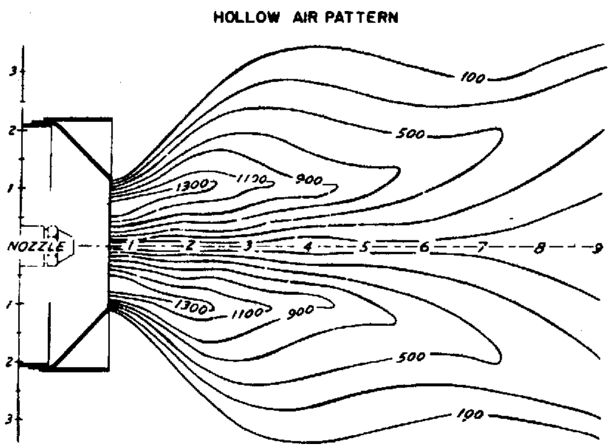

Figure 1A. A modified hollow air pattern.

How to select the right nozzle

A number of things must be considered to match spray pattern to air pattern for quiet, efficient performance

By Eugene O. Olson
Division Engineering Manager
Delavan Manufacturing Company
West Des Moines, Iowa

Matching of the atomizing nozzle spray pattern to the air pattern from an oil burner sounds like a very simple cut and dried procedure. You hear it said that a hollow air pattern must have a hollow spray pattern and that a solid air pattern must have a solid nozzle spray pattern.

This rule may be completely valid, but the fact is that no burner manufacturer does it exactly that way. Field experience in servicing burners also dictates variations from that rule depending upon many things such as the spray angle, the combustion chamber size and shape, furnace or boiler configuration and the noise or pulsation tendency of the unit.

Before we get into a discussion of the subject, it might be well to define our terms so that we can be talking the same language.

The air pattern of a burner is simply a picture of the air velocities (feet per min.) at various points. This tells us where the air is available for combustion. All the air patterns shown here are from actual production burners.

For example, in Figure 1, it is plain that more air is available at the outer edges of the air pattern than in the center. We would define this as a hollow air pattern.

The air pattern from another burner is shown in Figure 1A. This pattern is not as open as the first one, but is still quite definitely a hollow type pattern.

In the first of these patterns, recirculating gases in the center of the pattern are traveling *toward* the burner rather than away from it. There is also some recirculation at the outer edges of the pattern and all of this helps to maintain a stable flame front and high efficiency.

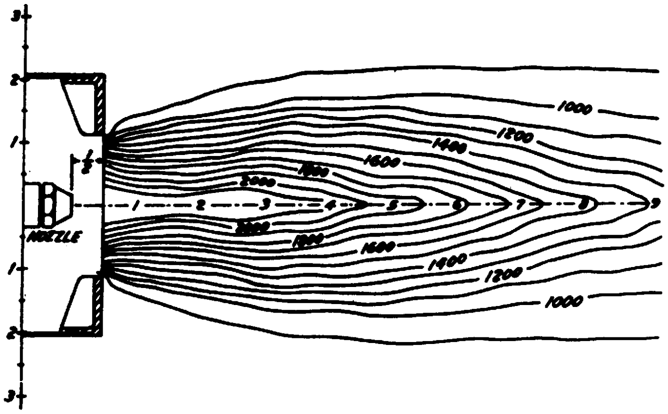

Figure 2. Typical air pattern for a convention burner with a static disc and cast-iron end Cone.

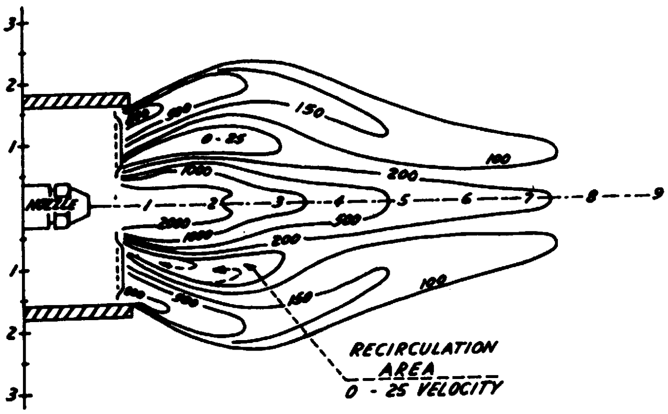

Figure 3. Pattern produced by a flame retention burner.

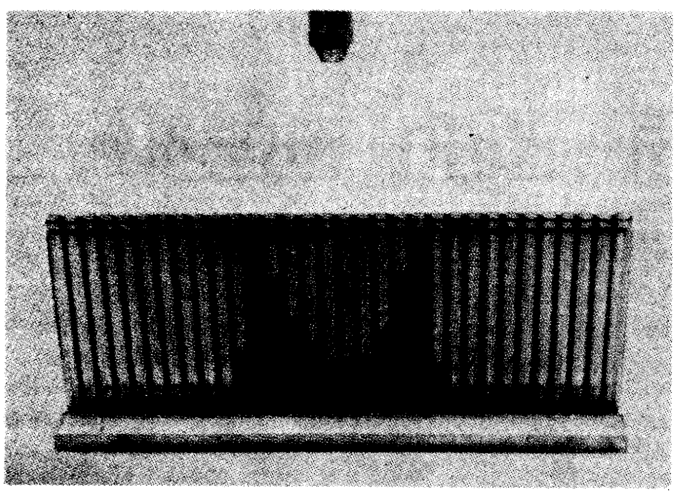

Figure 4. Typical hollow cone spray pattern.

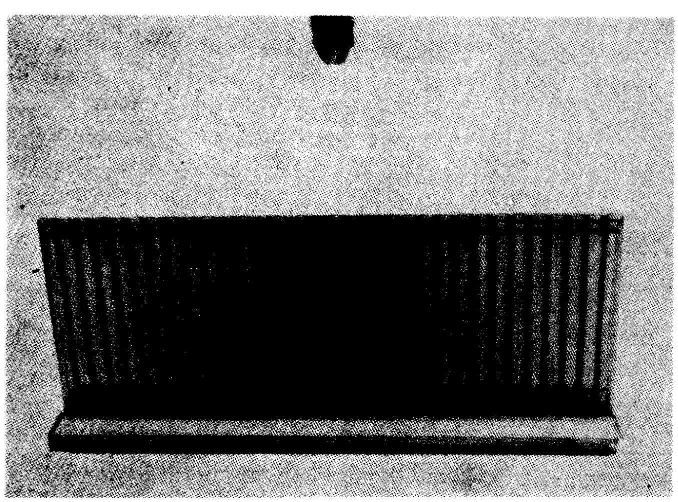

Figure 5. Typical solid cone spray pattern.

The pattern shown in Figure 2 is entirely different in that the air velocity in the center is higher than in other parts of the pattern. This is generally characterized as a solid air pattern. There are variations of this pattern from different burners of the conventional type depending upon the combination of static discs and end cones used. Some have higher air velocities in the center. Others have lower center velocity.

Two common features

Figure 3 shows a pattern from a typical flame retention burner. These burners do not all have the same pattern but on the basis of the few burners we have checked they seem to have two features in common.

1. There are two air patterns, a high velocity, solid stream in the center and a lighter hollow pattern at the outside.

2. Between those two patterns is an annulus of recirculation extending back to the retainer disc. This is apparently what holds the flame at the disc.

In any burner regardless of its air pattern the atomizing nozzle must assist the burner to do certain things:

1. The spray must ignite smoothly.

2. The nozzle must provide a spray that will maintain a steady, quiet fire in the particular air pattern.

3. The nozzle must provide a pattern and droplet size that will burn clean with no smoke.

4. The combination of the air pattern and fuel pattern must provide good efficiency.

To accomplish these things, nozzles are available in different spray patterns and different spray angles. Defining a spray pattern requires that we establish a test procedure. Several different methods are used in the industry, some quantitative and some qualitative. All of these do not produce the same results or interpretation of a spray pattern. For purposes of this discussion, I shall illustrate only one method.

Figure 4 shows the arrangement of the sampling equipment and a hollow pattern. This particular pattern shows that the highest concentration of droplets in the spray is near the outside edge of the pattern.

Figure 5 shows a common solid cone type of spray showing a slight depression in the center of the pattern, but actually with fairly uniform distribution across the cross section of the spray

The classical illustration of hollow cone and solid cone sprays as shown in Figure 6 is strictly schematic. Nobody builds nozzles with that kind of spray pattern. As a matter of fact, it is impossible. The sketches of the cross sections of hollow cone and solid cone sprays in Figure 7 are intended to illustrate the fact that all sprays leave the orifice in a hollow conical film of liquid and further along, liquid droplets.

In a hollow cone spray some droplets are thrown outward on the outside of what could be called the "effective spray angle." At the same time, droplets are also thrown on the inside of the main concentration of droplets, thus giving a greater thickness to the wall of the spray cone than we usually illustrate. This is apparent by the amounts of liquid shown in the tubes for a hollow cone pattern

To make a solid cone nozzle, we simply increase the turbulence of the hollow conical film of liquid leaving the orifice of the nozzle. This throws more droplets outside and especially, inside of the principal cone. It is possible to control the amount of liquid, which is delivered inside of the effective spray angle by nozzle design to obtain different spray characteristics. Thus, a so-called solid cone spray might be heavy in the center or it might lean toward the hollow type with simply a thicker wall in the spray cone, depending upon the requirement.

As flow rate is increased, the hollow cone spray becomes more streamlined and hollow. Likewise, as flow rate increases, the solid cone becomes less solid. For example, at 20 gph it is very difficult to make a true solid cone nozzle without increasing the droplet size and velocity above what could be tolerated in an oil burner.

There are differences in the definitions of hollow cone and solid cone sprays between the various nozzle manufacturers. This usually comes about because of the different test methods used and is influenced also by the interpretation of what the industry can use in the *average* burner of either type. The nozzle manufacturer knows that the serviceman is not a research type individual with laboratory facilities and, therefore, endeavors to supply him a nozzle that will fire the average burner.

What I am saying is that the hollow cone nozzle must be hollow enough to fire the very hollow cone burners and at the same time work well in those not so hollow. The solid cone nozzle must be solid enough to give the desired performance in a burner requiring a solid cone nozzle,

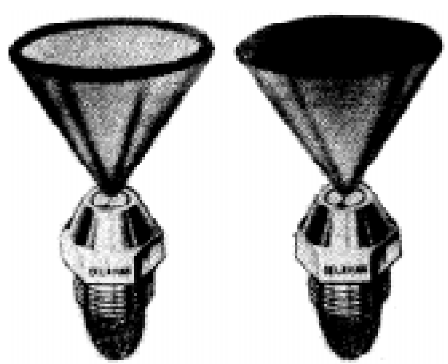

Figure 6. The usual illustration of hollow and solid sprays; right.

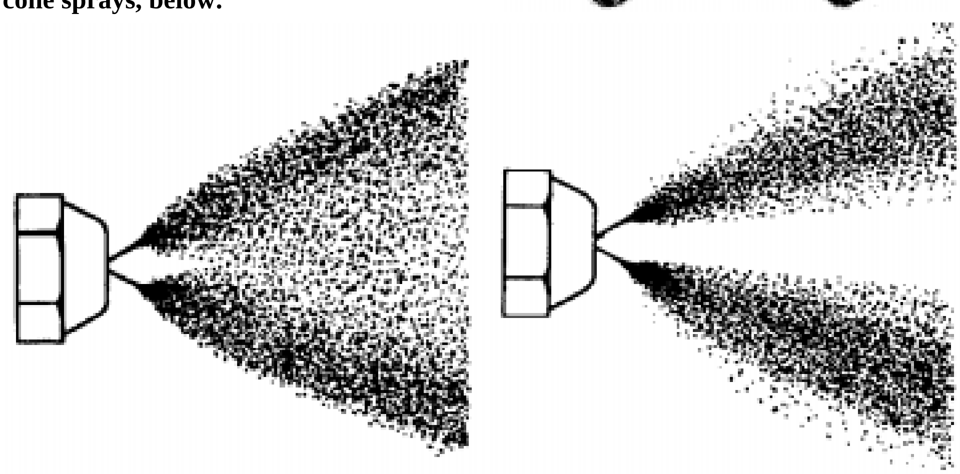

Figure 7. Schematic illustrations of droplet distribution in hollow and solid cone sprays, below.

At the same time it must not produce the objectionable performance characteristics that may be encountered with a heavy center spray. The so-called all purpose patterns are simply compromises to work in the average burner. They are designed to work well in most burners and thus simplify the stock problems and burner analysis problems for servicemen.

Matching patterns

We now face the problem of putting the correct nozzle spray pattern into the burner air pattern for best performance. The majority of installed burners in the field are of the conventional type using a static disc or turbulator and an end cone with or without vanes, producing an air pattern somewhat similar to Figure 2.

If you are trying to achieve maximum efficiency, you could reason that this air pattern should have a solid cone nozzle probably 45° or 60°. If efficiency were the only criterion, this conclusion would probably be true. We must not forget, however, that many of these units are fired into round or square combustion chambers and they are installed in burners or boilers that under certain conditions can pulsate or rumble. It is, therefore, common practice for manufacturers of these burners to specify *hollow cone* nozzles in the small sizes, that is, up to approximately 1.25 gph or 1.5 gph.

Looking at the illustrations it would also seem out of place to use 80° or 90° hollow cone nozzles in this air pattern. That is being done, however, and it is not uncommon to attain CO_2 readings as high as 12% in certain installations with 70° or 80°.

The reason this sort of matching can be done is that with the extremely small droplet sizes in the low flow rates, the air flow moves these droplets rather easily and it is possible, therefore, to attain this good efficiency. A hollow cone spray gives a short bushy fire. A true solid cone nozzle may give a longer fire that would impinge on the target wall of a square or round chamber.

The principal reason that the hollow cone is used in these patterns is the noise factor. It has been demonstrated in practice and documented by research laboratories that pulsation usually emanates from the center of the spray mixture. If there is a concentration of droplets in the center of the fire with insufficient air to burn them, we have a problem.

With a rich mixture in the center of the fire, it has been found that periodic ignition occurs and these periodic flames alternate with areas of no flame. This has been illustrated by high-speed movies. One extensive research project established a definite correlation between the amplitude of pulsation and the degree of "solidness" of the nozzle spray. By going to more hollow type sprays it was possible to eliminate or reduce the periodic ignition and reduce the resultant pulsation..[1,2]

The noise factor

In the lower firing rates, it is possible to get quiet operation and satisfactory efficiency using hollow cone nozzles in the solid air pattern. Higher flow rates, particularly from 3 gph and up, introduce other problems. One of these is ignition. Some burners with a solid air pattern do not start smoothly with hollow cone nozzles. It seems that the ignition zone, being more or less on the surface of the spray cone is chilled and the flame does not spread. This is solved by going to a solid cone type spray or even a relatively solid spray with a greater spray wall thickness than the hollow cone. The ignition seems to penetrate down into the spray and gives perfectly smooth starts.

After ignition, the high velocity of the air in these larger burners will penetrate the spray cone and provide enough air in the center of the fire for smooth, quiet operation and maximum efficiency. Here too, the solid cone spray produces a fire with a longer center.

From what we have shown it becomes evident that there is no hard and fast rule for adapting nozzles to a conventional burner. The problem changes with firing rate. However, if we were to summarize the field practice and experience, it is evident that hollow cone type nozzles in the proper spray angle will give good results in a very high percentage of burners of this type in the smaller sizes. Above 2 gph the nozzle must be selected to fit the requirements of the job on the basis of ignition, noise, combustion chamber dimension and efficiency when firing with a solid air pattern burner.

The hollow air patterns illustrated in Figures 1 and lA, present a rather simple problem. Since the air velocity in the center is approaching zero, it is logical that the hollow cone type of spray should be used and that is the way it works out in practice. This is true of the entire firing range for that type of burner but in some cases, the job may require a different spray angle. Spray angles between 60° and 90° are usually used.

If a solid cone nozzle were used in this particular pattern, there would be insufficient air in the center of the spray for clean combustion. The result is smoke in the center of the fire that cannot be cleared up by any adjustment of the burner air. There is also a tendency for the air pattern to pull the spray to one side or the other and cause a badly unbalanced fire. This is accompanied by considerable rumbling and pulsation

Flame retention burners

The latest addition to the American oil burner scene is the flame retention burner. A look at the pattern in Figure 3 would tell us that it could satisfactorily use a solid cone nozzle. While this is generally true, the manufacturers of this type of burner are recommending hollow cone nozzles in the small sizes, the same as for the conventional burner. The reason is that hollow cone nozzles give quieter operation and satisfactory efficiency.

Even in the larger sizes, hollow cone nozzles are sometimes used with excellent results if the combination of burner and the boiler requires it. In general, however, the larger firing rates should be fired with solid cone nozzles, again choosing the proper spray angle.

I have mentioned above that different nozzle manufacturers use different methods of determining spray patterns and, therefore, come up with different results. It has been pointed out that this fact makes for confusion on the part of the service people who must replace nozzles in the field.

Why not identical designs?

It is, of course, possible to establish spray patterns quantitatively and define them in more accurate terms than merely hollow cone, solid cone, or any other such designation. In order for different nozzle manufacturers to build nozzles with identical distributions, however, it would be necessary that they also use identical designs and dimensions. While this may be an ideal solution for the serviceman, it would tend to eliminate improvements in nozzles and creativity in designs by eliminating competition.

The same thing could be said for oil burners. The air pattern of an oil burner can be determined quantitatively also, but in order to produce identical patterns, which could make for interchangeability with a certain nozzle specification, the burner manufacturers would also have to use identical designs and dimensions. Such a procedure would eliminate creativity in that field also.

Different boiler and furnace configurations may also require different nozzle specifications and burner specifications to give best performance. The nozzle and burner combination that works well in Boiler "A" may not be satisfactory in Boiler "B". Burner manufacturers are faced with this problem quite often. I have no simple rule to solve it without exceptions. There are enough spray patterns and spray angles available, however, that together with the choices available in burner designs there is a combination that will work in practically every job

[1.] Pulsations in Residential Heating Equipment, A. A. Putnam & W. R. Dennis. H. P. A. C. July 1956.
[2.] Oil Burner Pulsations, C. F. Speich & A. A. Putnam, ASHRAE Paper, 1961.