6821

ROY F. WESTON, INC.

TECHNICAL REPORT FOR EVALUATION OF SLURRY NOZZLES TO SUPPORT THE SUPPLEMENTAL FUELS DEVELOPMENT

Contract No. DACA31-91-D-0079
Task Order 13

Unlimited Distribution
Approved for Public Release

WESTON

TECHNICAL REPORT FOR EVALUATION OF SLURRY NOZZLES TO SUPPORT THE SUPPLEMENTAL FUELS DEVELOPMENT

Contract No. DACA31-91-D-0079
Task Order 13

Prepared for:

U.S. ARMY ENVIRONMENTAL CENTER (USAEC)
SFIM-AEC-RMB
Aberdeen Proving Ground, MD 21010-5401

July 1995

Prepared by:

ROY F. WESTON, INC.
1 Weston Way
West Chester, PA 19380-1499

Work Order No. 02281-012-013

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIST OF FIGURES

LIST OF TABLES

GLOSSARY

atomization —	The process of breaking a liquid into a multitude of tiny droplets.
atomizing air —	That part of the air supplied through the burner that is used to break the fluid into tiny droplets.
centipoise —	A unit of measurement for absolute viscosity = 1/100th of a poise. The absolute viscosity of water at 20 °C is approximately one centipoise.
centistoke —	A unit of measurement of kinematic viscosity = 1/100th of a stoke. The kinematic viscosity in centistokes times the specific gravity equals the absolute viscosity in centipoises.
density —	The weight of a unit volume of a substance in pounds per cubic feet. Also called specific weight.
fluid —	A gas, vapor, or liquid as opposed to a solid.
GPM —	Units of flow expressed as gallons per minute.
heat of combustion —	The heat released by combustion of a unit quantity of fuel, measured either in calories or Btu.
Kinematic viscosity —	The relative tendency of a fluid to resist flow: equal to the absolute viscosity divided by the density. Usually designated in stokes, SSU.
micron —	One-thousandth of a millimeter (.001 mm) or one millionth of a meter. One inch = 25,400 microns.
orifice —	Used to designate a deliberate construction in a passage, circular in shape unless otherwise specified.
propellant —	Munitions that are off specifications or require disposal from a Army Ammunition clean up site.
psig —	Units of pressure expressed as pounds per square inch gauge.

SMD — Sauter mean diameter: A means of expressing fineness of a spray in terms of the surface area produced by the spray. The SMD is the diameter of a drop having the same volume-to-surface ratio as the total volume of all the drops to the surface area of the drops.

specific gravity — The ratio of the density of a liquid to the density of water at 60 °F.

SSU — Saybolt Seconds Universal, a unit of kinematic viscosity.

viscosity — The tendency of a fluid to resist flow. A measure of resistance to flow.

VMD — Volume mean diameter: A means of expressing the drop size in terms of volume sprayed. 50% of the droplets sprayed will have a diameter greater than the VMD and 50% of the droplets will have a diameter less than the VMD.

SECTION 1

EXECUTIVE SUMMARY

The U.S. Army generates significant quantities of off-specification and scrap energetic or explosives materials. Energetic materials are also contained in obsolete and unserviceable munitions. Disposal options for these energetic materials are limited because current methods such as open burning and open detonation are being restricted by environmental regulations. Incineration of explosives in a water slurry is a known method of disposal but it is expensive.

The U.S. Army Environmental Center (USAEC) is investigating technologies to safely and effectively destroy energetic and explosive materials. Previous laboratory-scale testing conducted by USATHAMA has shown that blending explosives with fuel oil and burning the resultant mixture can be completed successfully at Hawthorne Army Ammunition Plant (HWAAP), which is located in Hawthorne, NV. A pilot-scale system was constructed for mixing explosives such as 2,4,6-trinitrotoluene (TNT) and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) in fuel oil and firing the resulting mixture into an industrial boiler to generate steam. During operational testing of the pilot boiler at HWAAP, plugging of the oil/explosive mixture was experienced.

Under Task Order 13, WESTON has been contracted to perform an evaluation of nozzle vendors to meet the specification of processing a supplemental fuel oil mixture. The supplemental fuel mixture consists of trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), or a COMP B (a 40/60 mixture of TNT/RDX) mixed with fuel oil in a solution with a solvent (i.e., toluene, acetone).

Nozzles can vary depending on the ambient conditions, the physical and chemical characteristics of the fluid that is being atomized and material handling before reaching the nozzle. WESTON evaluated a variety of vendors that had the capability to provide a nozzle specified for this application. Several other nozzle vendors were solicited to provide technical and budgetary information; however, they declined to respond because their equipment was not suitable for this application.

Based on the limited number of vendors capable of providing the required nozzle, WESTON suggests that a number of nozzles be tested. The costs and availability of the varied nozzles detailed in this report will prove that the limited nozzles available can be tested in the pilot boiler at Indian Head without much modification to the boiler and/or controls. WESTON has found that it is very useful to have a variety of nozzles on-hand during operation for an efficient change of nozzle because one nozzle may be more suitable than another; for example, to accommodate changes in ambient conditions.

WESTON suggests that each nozzle detailed in this report be purchased and tested on the pilot boiler. Successful testing will prove that the variety of nozzles can be used on a full-scale system without the requirement for extensive modifications. This will also allow AEC to change to a proven nozzle without the need to test the nozzle prior to full-scale operation.

SECTION 2

INTRODUCTION

2.1 BACKGROUND

Significant quantities of waste energetic materials are generated by the U.S. Army as a result of the generation of off-specification materials during production and in the demilitarization of obsolete munitions. Current waste management practices involve either open burning/open detonation or controlled incineration. Because of the potential environmental problems resulting from open burning/open detonation and the high costs associated with incineration, other waste management options are being investigated. One disposal option being evaluated is the use of waste energetic materials as a fuel-oil supplement for industrial boilers. Combustible energetic waste materials represent a significant source of energy that can be recovered by this process.

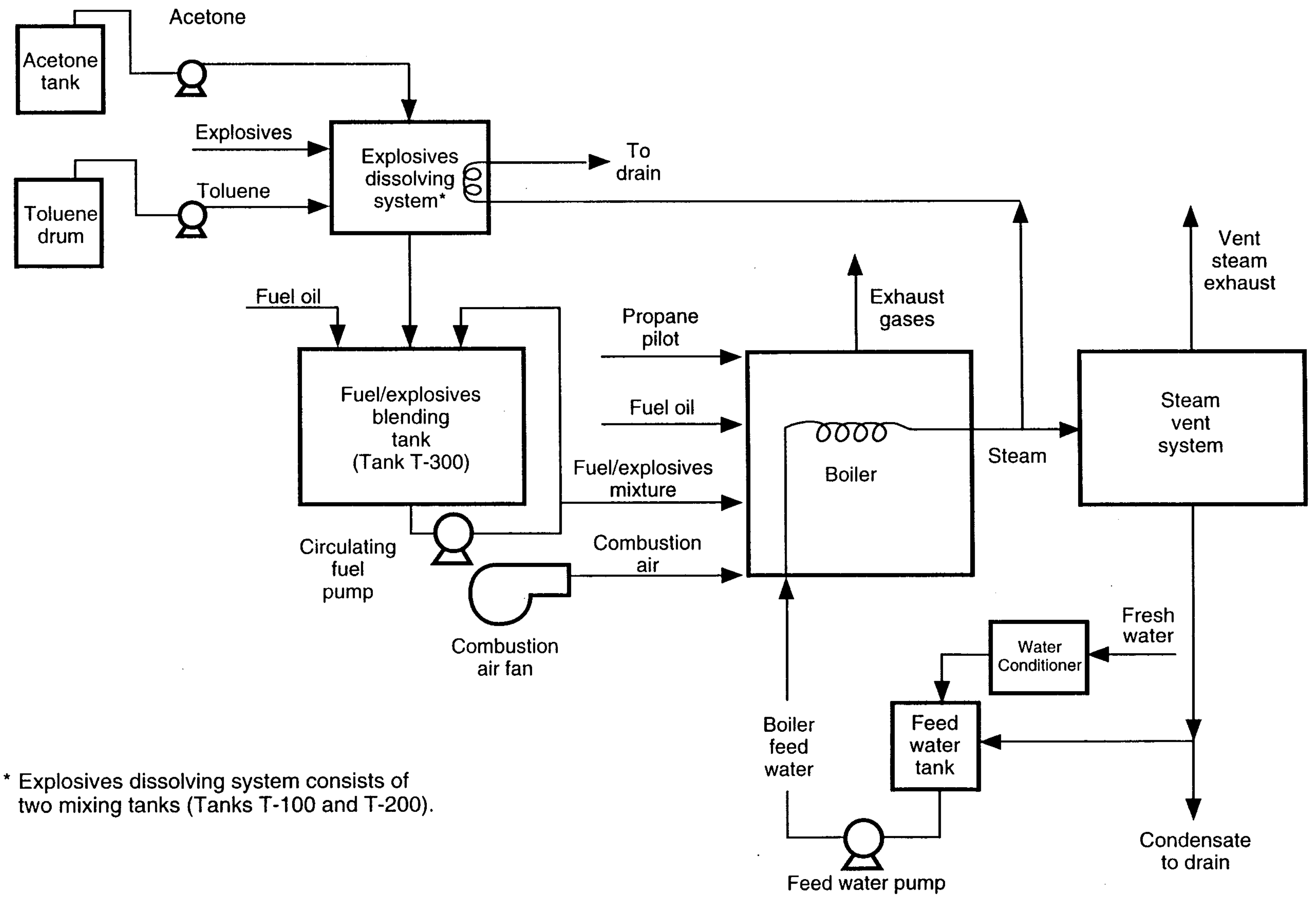
A pilot test was conducted by Roy F. Weston, Inc. (WESTON®) at the Hawthorne Army Ammunition Plant (HWAAP) in Nevada during 1991. The purpose of the pilot study was to determine the feasibility of 1) blending explosives and solvent with No. 2 diesel oil, and 2) safely firing the solvent/explosive/diesel oil in a boiler. A process flow diagram of the boiler system used during the pilot test is shown in Figure 2-1. The technology demonstrated its potential to be an effective method to recover energy from waste explosives.

2.1.1 Summary of Pilot Test Conducted at HWAAP

The pilot test conducted at HWAAP was designed for three test sequences. The three test sequences were distinguished by the type of fuel burned. The test sequences were 1) only fuel oil, 2) fuel oil supplemented by a trinitrotoluene (TNT)/solvent/fuel oil mixture, and 3) fuel oil supplemented by a composition B mixture. Composition B is a solid explosive mixture of 40% TNT and 60% RDX. The test matrix using only fuel-oil consisted of various excess oxygen levels. The test matrix using fuel-oil supplemented with explosives was

Figure 2-1

Process Flow Diagram



* Explosives dissolving system consists of two mixing tanks (Tanks T-100 and T-200).

95P-0004 1/4/95

comprised of various excess oxygen levels and explosive concentrations. The original planned test sequences are shown in Figure 2-2.

Although 18 test runs were scheduled, mechanical problems with the fuel and slurry delivery system during the pilot test limited the trial to five test runs. The five test runs completed were tests T-1, T-2, T-3, T-5, and T-9.

During the five tests, maintaining a consistent flow of blended material was a problem. The slurry material was precipitating out in the transfer piping. Many components within the fuel delivery system were subject to plugging with precipitated explosives. Surprisingly, WESTON did not experience plugging at the nozzle. WESTON made several recommendations in the Final Report for Task Order 6 which included modification to the slurry handling system.

2.1.2 Future Use of the Pilot Test Equipment

The supplemental fuels pilot test equipment has recently been moved from HWAAP to Indian Head Division, Naval Surface Warfare Center (IHDIVNAVSURFWARCEN) in Indian Head, Charles County, Maryland. Following the recommended mechanical modifications that impaired the testing at HWAAP, the complete pilot test (18 test runs) for the unit will be conducted. Modifications to correct mechanical problems based on the HWAAP demonstration are being made to the system. Additional testing on variations of equipment and technologies may be conducted to support applicability of using this technology in industrial-sized boilers at Government facilities.

2.2 OBJECTIVE OF STUDY AND PURPOSE OF REPORT

The objective of this report is to describe the function of a nozzle and how the variation in design can affect the process. This report will describe several types of nozzles that are or could be used for the supplemental fuel application. Section 4 of this report

Test Sequence I

- Fuel oil feed
- Various excess air concentrations (20%, 25%, 30%)

% excess air	
20	T-1
25	T-2
30	T-3

Test Sequence II

- Fuel oil/solvent/TNT feed
- Various excess air concentrations

Weight % explosives in feed

% excess air	1	10	15
20	T-10	T-7	T-9
25	T-12	(T-18)* T-11	T-8
30	T-5	T-6	T-4

Test Sequence III

- Fuel oil/solvent/Comp B feed
- Various excess air concentrations

Weight % explosives in feed

% excess air	1	4	8
20	T-16		T-14
25		T-17	
30	T-13		T-15

95P-1023 2/24/95

*T-18 was a repeatability test.

FIGURE 2-2 ORIGINALLY PLANNED TEST SEQUENCES illustrates that there is an entire industry capable of supplying nozzles; however, only a limited number have experience in the combustion field.

2.3 NOZZLE PURPOSE

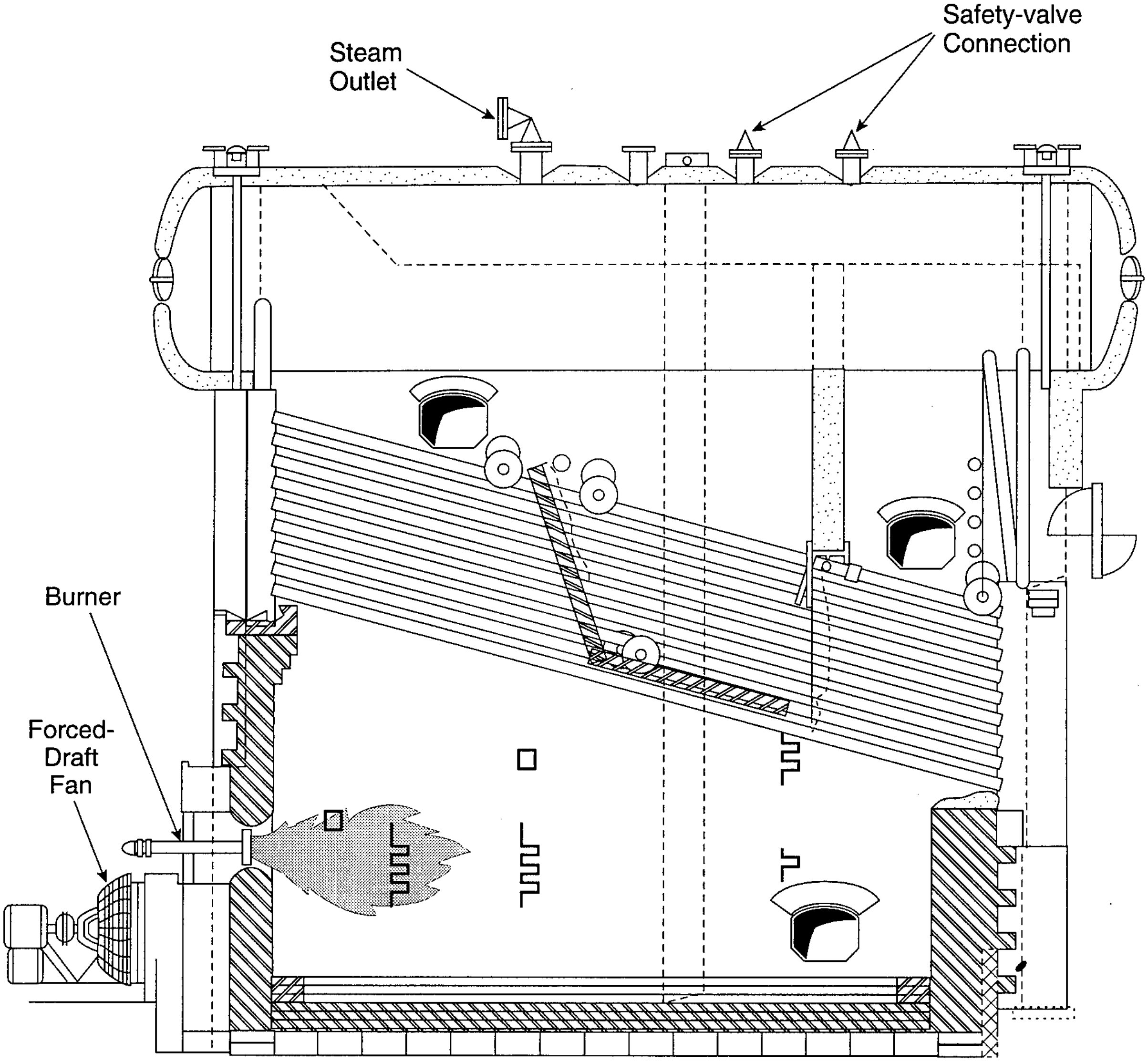
The purpose of the burner is two-fold: 1) to supply the heat necessary to generate steam in the boiler, and 2) to burn the fuel mixture in an environmentally safe manner. Figure 2-3 illustrates a generic steam boiler with a standard burner orientation. The boiler is equipped with a burner and forced draft fan. The fan provides sufficient air to combust the fuel that is injected through the burner.

The spray nozzle is the key mechanical element of the burner. The nozzle atomizes the liquid by breaking the fluid mechanical element into a multitude of tiny droplets. Proper atomization and exposure of the fluid surface to air is the key to an efficient burner. Combustion occurs when the surface of the fuel or liquid is exposed to air. Without atomization the combustion process would be inefficient and in some cases the fuel may not even burn. Inefficient burners are also a source of pollution.

The burner/atomizer selected for the Indian Head Division, Naval Surface Warfare Project must be capable of efficiently atomizing and burning a liquid stream that consists primarily of No. 2 fuel oil and a mixture of solvented explosives.

2.4 BURNER SYSTEM COMPONENTS

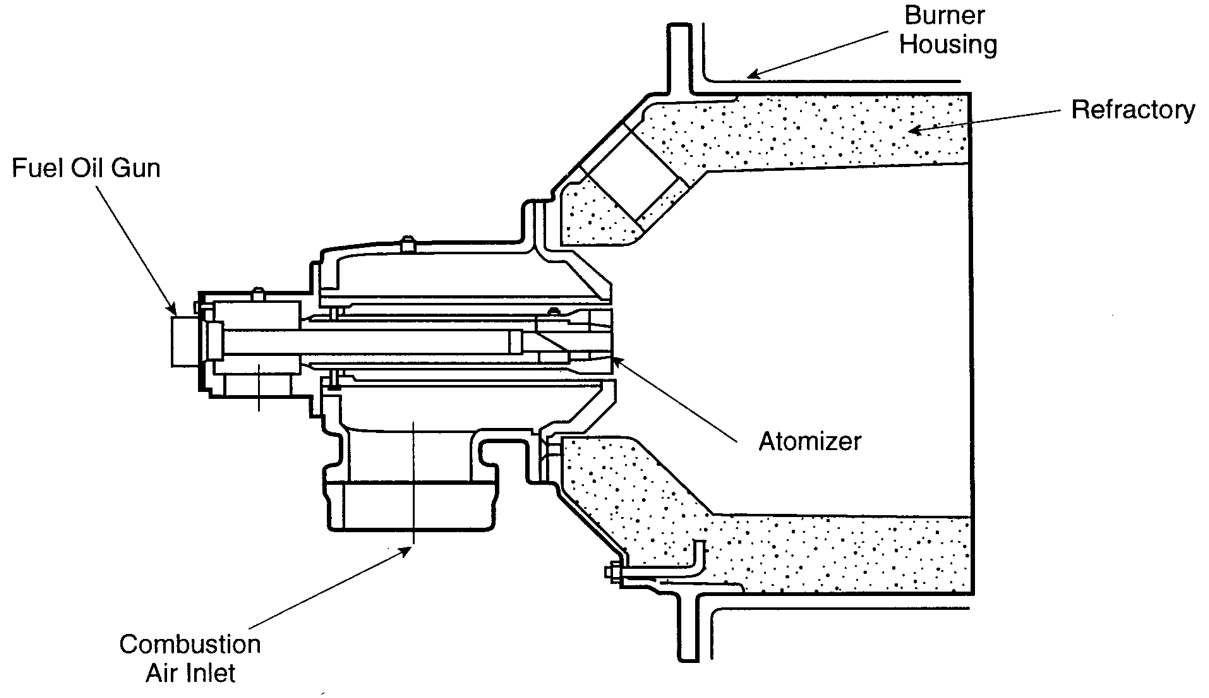
The components of a fuel oil burner system are similar for most commercially available systems. Figure 2-4 is a drawing of a typical burner for fuel oil firing application. The major components of the burner are the following:



95P-0150 1/27/95

Steam – It's Generation and Use
Bobcock & Wilcox Company, 1960 37th Edition.

FIGURE 2-3 TYPICAL BOILER SYSTEM



95P-1565 3/22/95

FIGURE 2-4 FUEL OIL BURNER

- Burner housing — the outer shell of the burner that provides the basic mechanical structure for the burner and is usually constructed of mild carbon steel. Parts of the housing are the combustion air inlet, a nozzle for the fuel oil gun, and other various connections for flame safeguard monitoring.

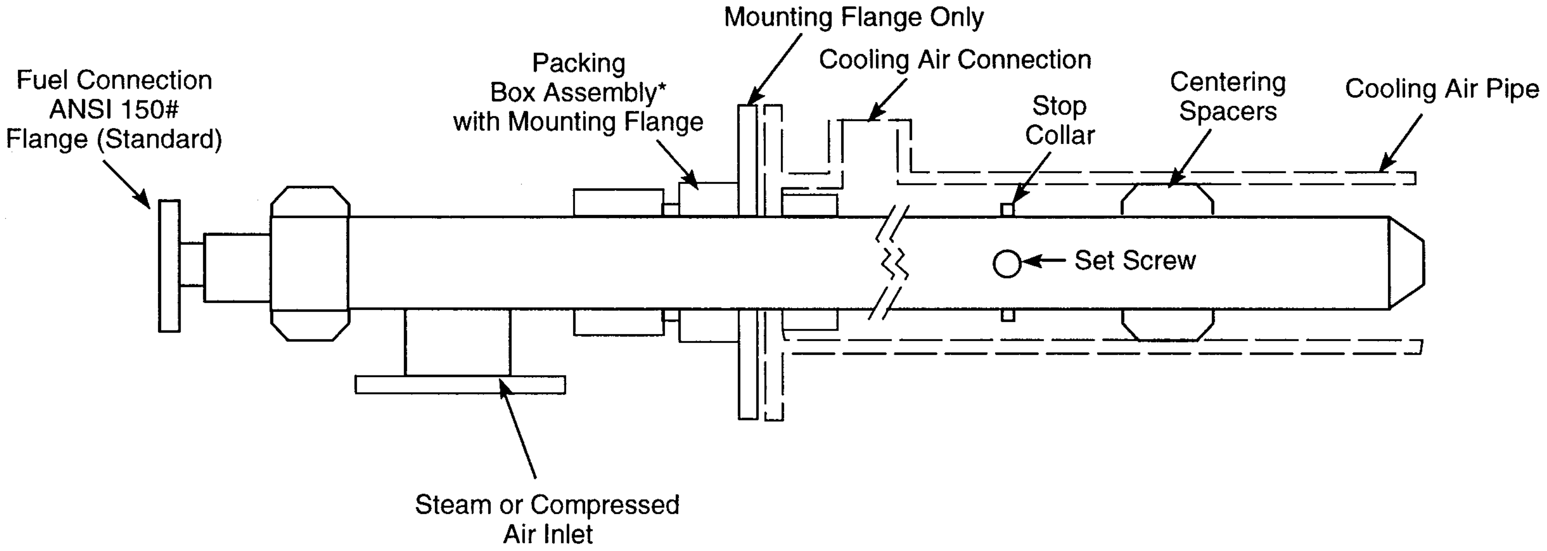
- Combustion air inlet — allows outside air to enter the burner. This air inlet must be sized to provide a sufficient quantity of air to allow proper combustion of the fuel.

- Refractory — an insulating material that is composed of mostly silica and ceramics. Refractory is installed inside the burner housing and is used to protect the carbon steel from the intense heat formed in the combustion process.

- Fuel oil gun — is a removable mechanical assembly where the liquid is introduced into the burner.

- Nozzle or atomizer — located at the end of the fuel gun at the atomizer where mixing of air and liquid takes place.

Figure 2-5 shows the major components of a typical fuel oil gun. As shown in the diagram, a typical fuel gun will consist of a liquid fuel connection and an atomizing fluid connection. The connections are internally piped to the atomizer where the actual mixing of air and liquid occurs. Usually a packing assembly is provided so that the fuel oil gun can be adjusted laterally within the burner housing. The packing gland is constructed such that air leakage through the burner is minimal, and the gun can be adjusted while the burner is operating. Other components of the fuel oil gun are set screws and centering spacers to ensure that the gun is perfectly centered within the cooling air pipe. The cooling air pipe is provided to help cool the atomizer tip as well as the end of the fuel oil gun. Without proper centering, hotspots will form and the fuel gun will deteriorate from heat.



Source: North American Manufacturing Co. - Cleveland, Ohio

95P-1564 3/22/95

FIGURE 2-5 FUEL OIL GUN

SECTION 3

NOZZLE FUNCTIONS

Though spray requirements differ from one application to another, the basic functions of nozzles are to control:

- Liquid flow (metering).
- Spray angle and pattern.
- Quality of atomization.
- Generation of hydraulic momentum or impact.

Nozzle criteria that affect the selection of a particular burner nozzle include nozzle flow rate, spray angle and pattern, and quality of atomization. In this section, each criterion is discussed separately, as it applies to fuel oil burners.

Nozzles are grouped into two major categories, single fluid and dual-fluid nozzles. Single fluid nozzles use only the liquid (fluid) to atomize or disperse the fluid. Dual-fluid atomizers use a supplemental fluid such as steam or air to help atomize the liquid stream. Dual-fluid nozzles also have two subcategories, internal and external mix. The internal mix nozzle has a mixing chamber inside the nozzle where the two fluids mix prior to exiting the nozzle's orifice(s). External mix nozzles do not have fluid contact until the fluids have exited the orifices. Impacts of nozzle construction on nozzle function are also discussed in this section.

3.1 <u>CONTROL OF LIQUID FLOW</u>

Liquid flow rate through an atomizer is determined by the physical design of the atomizer, principally the size of the metering passages, and by the liquid's physical condition. For single fluid or mechanical atomizing nozzles, the liquid flow rate is theoretically proportional to the square root of the nozzle pressure drop across the nozzle orifice.

where:

$$Q = c\sqrt{\Delta P}$$
$$Q = flow\ (gpm)$$
$$c = constant\ for\ nozzle$$
$$\Delta P = pressure\ drop\ (psig)$$

Figure 3-1 shows the effect of the liquid pressure on the flow rate through a fixed orifice in a single fluid nozzle. As the liquid pressure is increased from 10 psig to 100 psig, the flow rate of the liquid increases from approximately 0.7 gpm to 2.1 gallons per minute. For this application the orifice size for the liquid is 3/32 of an inch.

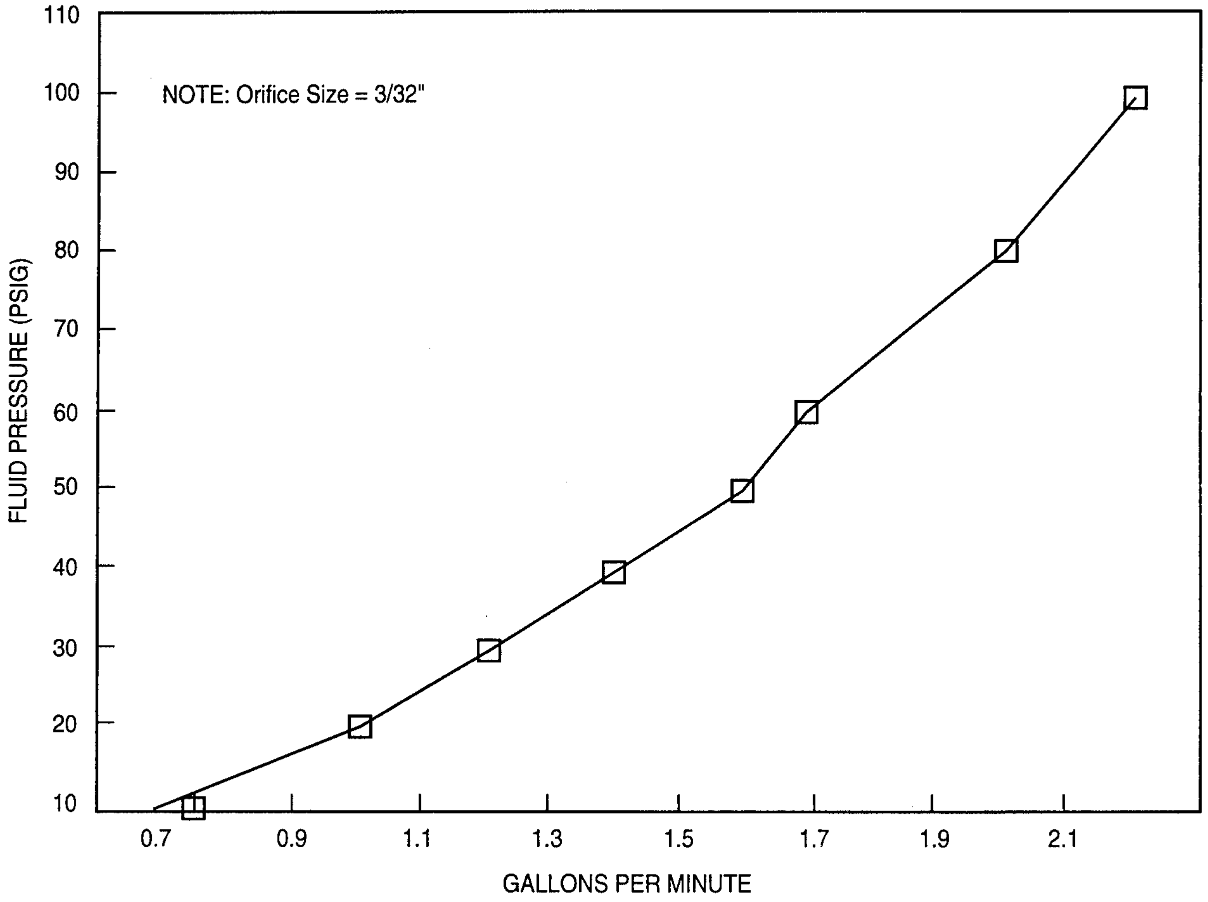
Figure 3-2 illustrates the effect of changing the orifice diameter when a constant liquid pressure is applied to a single fluid nozzle. As the orifice diameter increases, the flow rate increases. With a constant supply pressure of 30 psig, the flow rate is increased from 1 gpm to 15 gpm, as the orifice diameter increases from 0.09 inches to 0.32 inches.

Dual-fluid atomizing nozzles include internal and external mixing types. When evaluating the effects of fluid flow rates, external mixing nozzles have the same properties as a single fluid nozzle, since the two streams do not mix inside the atomizer. For internal mixing nozzles, the liquid and gas flow rates are affected by their respective pressures as well as the balance between their pressures. For example, raising the air pressure while holding the liquid pressure constant will lower the liquid flow rate.

Figure 3-3 shows the effect of varying the air pressure in an internal mix dual-fluid nozzle. With the air and liquid pressure at 10 psig, the flow of liquid is 0.66 gallons per hour. As the air pressure is increased, the flow rate of the liquid decreases linearly. This effect is caused by the back pressure that the atomizing air creates on the liquid at the nozzle's tip.

Figure 3-4 is a graph of the atomizing air flow versus air pressure applied to the same internal mix dual-fluid nozzle as shown in Figure 3-3. As the air pressure is increased from

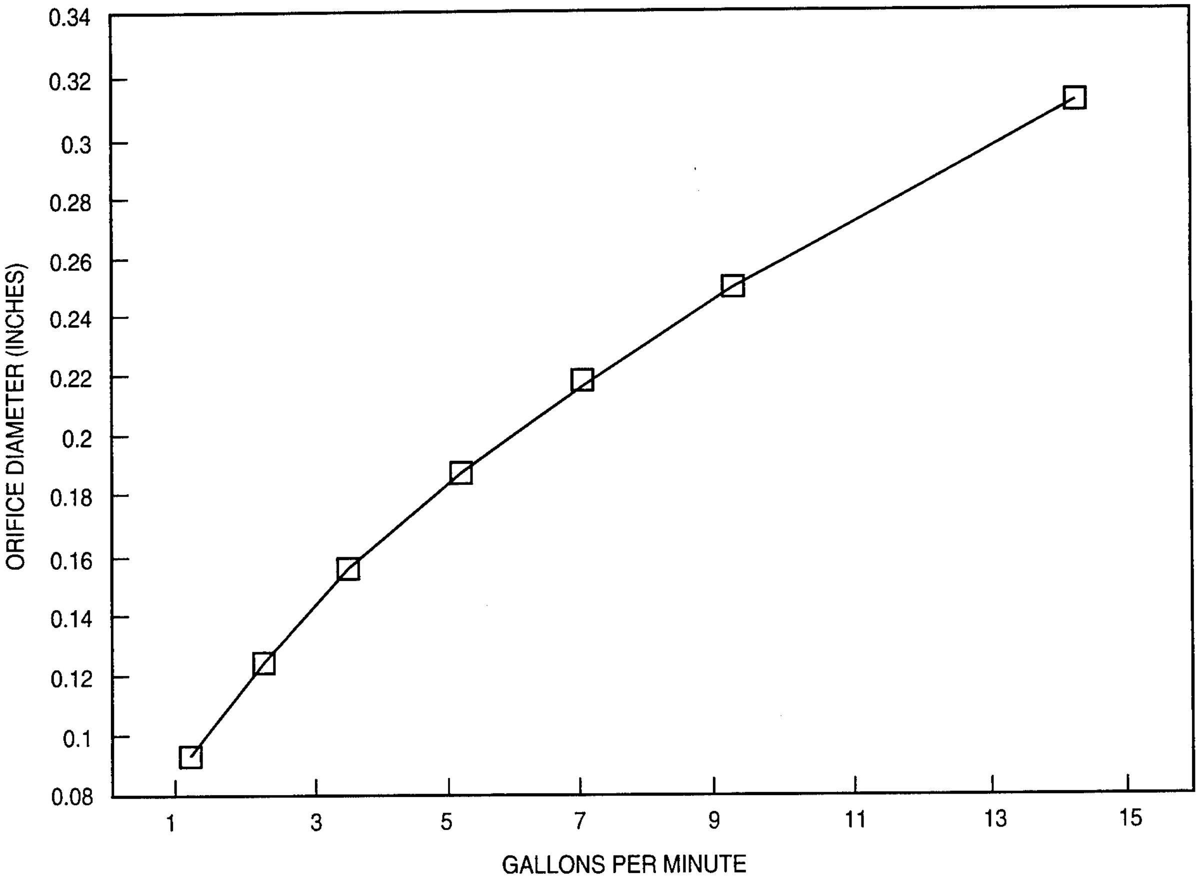
Single Fluid Atomizer



95P-0378 2/28/95

FIGURE 3-1 FLOW VS. PRESSURE

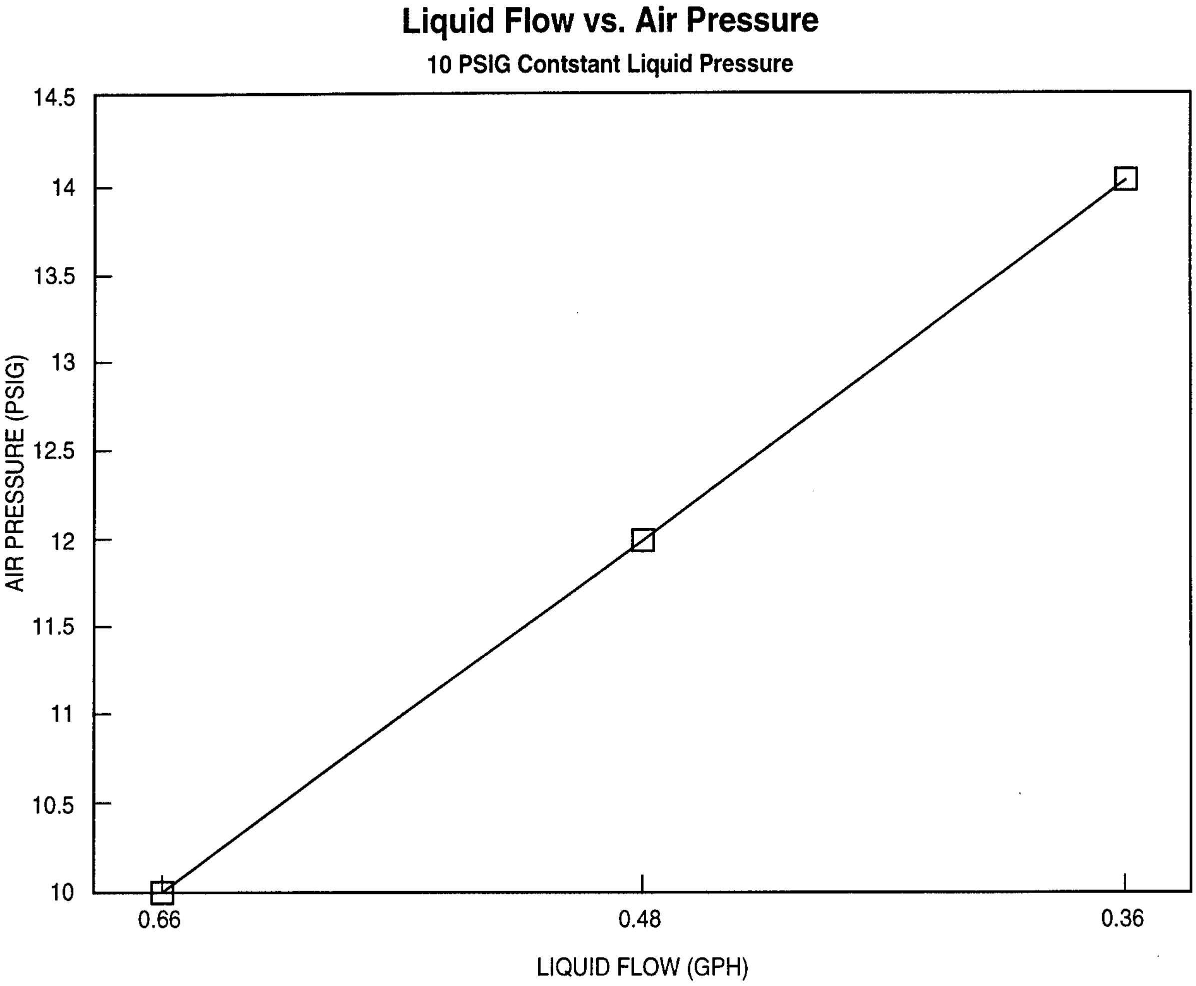
Single Fluid Atomizer



95P-0379 2/28/95

FIGURE 3-2 FLOW VS. ORIFICE DIAMETER

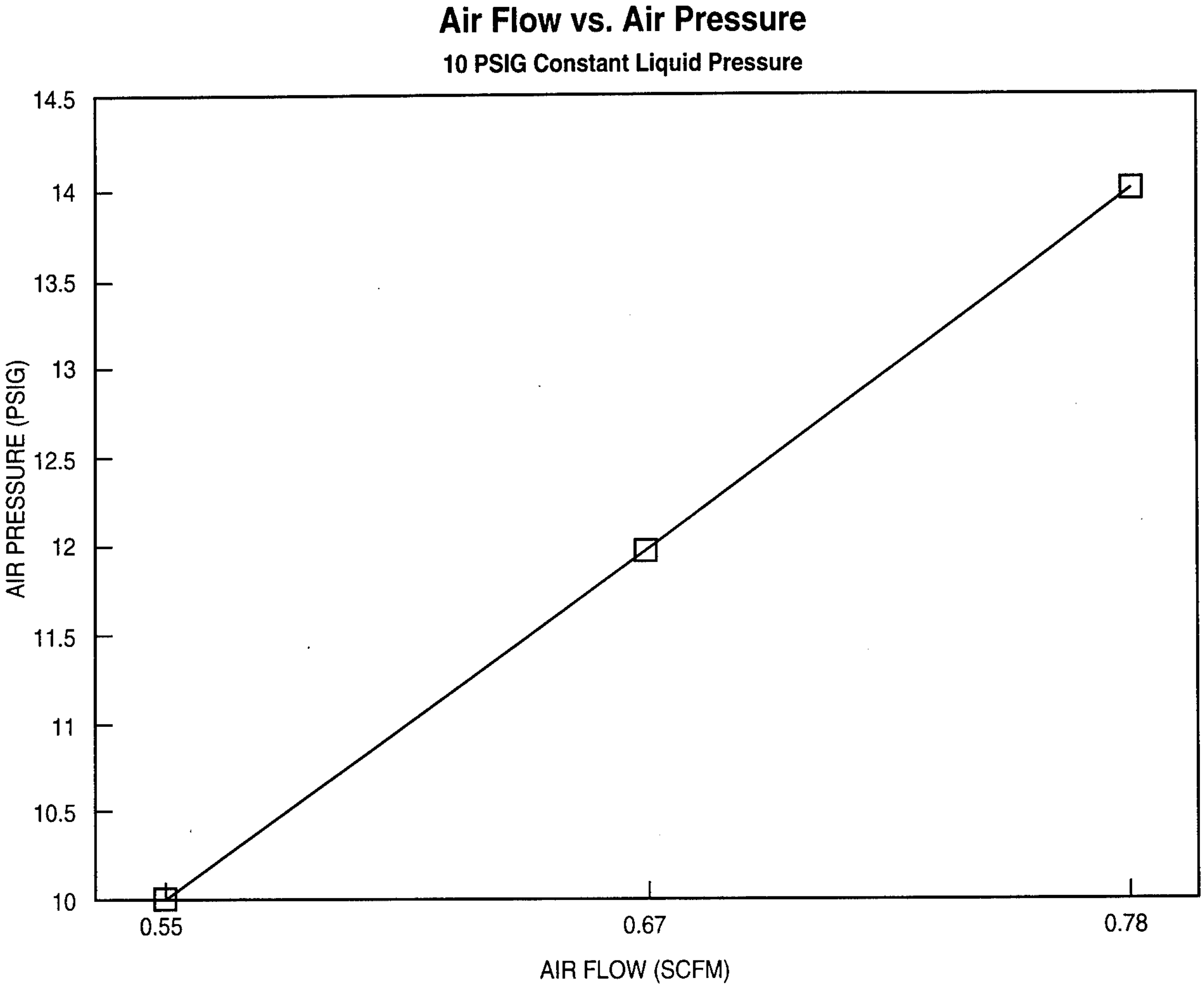
Internal Mix Dual-Fluid Atomizer



95P-1563 3/22/95

FIGURE 3-3 LIQUID FLOW VS. AIR PRESSURE

Internal Mix
Dual-Fluid Atomizer



95P-0381 2/28/95

FIGURE 3-4 AIR FLOW VS. AIR PRESSURE

10 psig to 14 psig, the air flow increases linearly from 0.55 scfm to 0.78 scfm. Liquid flow will decrease as the air flow increases.

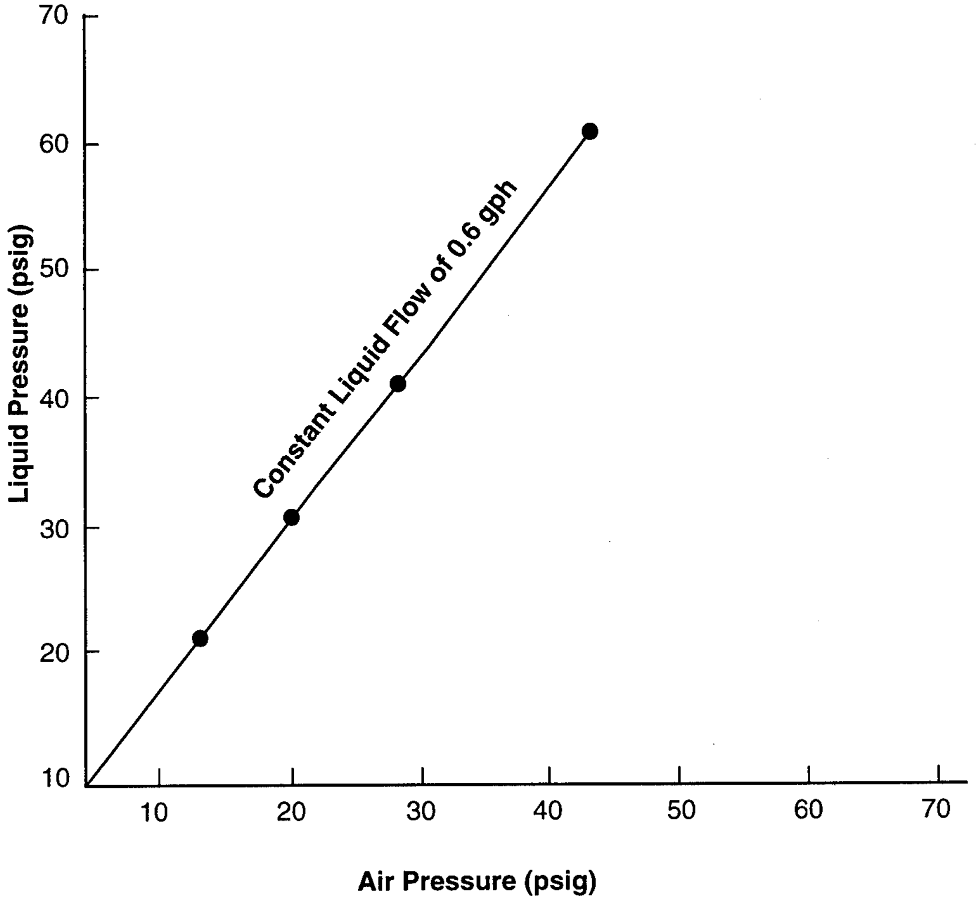
Figure 3-5 plots the effect of varying the liquid pressure with the air pressure for an internal mix nozzle. The graph shows that as the air pressure is increased, the liquid pressure must also be increased for liquid flow to continue. If the pressure of the air is increased by 10 psi (to 20 psi), the liquid pressure must be increased by approximately 5 psi. This is due to the compressibility of air versus the noncompressibility of a liquid.

The liquid physical properties also influence flow through a nozzle. Theoretically, volumetric flow through a nozzle varies inversely with the square root of liquid density. In most applications, however, changes in fluid density are also accompanied by changes in viscosity, and the net change in flow varies with both properties. Viscosity is the tendency of a liquid to resist flow. Volumetric flow through a nozzle varies inversely with the viscosity of the fluid. All nozzle designs are based on the viscosity and density relative to water. As viscosity increases above the properties of water, the flow rate will decrease; alternatively, as the viscosity decreases, the nozzle flow increases. This is also true for the density of a fluid. As the density increases, flow will decrease and flow will increase as density decreases.

Control of liquid flow as it applies to the burner atomizer is a major criterion. The nozzle must be sized to deliver flow rate compatible with boiler system need. The size of the orifices in the passages and the liquid stream physical characteristics for burners are determined by the type of fuel being combusted. Control is usually achieved by pressure regulators and valves providing a constant supply pressure.

3.2 SPRAY ANGLE AND PATTERN

The shape of a pattern developed by the atomized liquid is affected by the physical orientation of orifices and liquid physical characteristics. Nozzles may be designed for



95P-1630 3/23/95

FIGURE 3-5 LIQUID PRESSURE VS. AIR PRESSURE AT CONSTANT FLOW FOR AN INTERNAL MIX (DUAL-FLUID ATOMIZER) various patterns: hollow cone, full cone, flat spray, and solid stream. Figure 3-6 is an illustration of the common spray patterns. The spray angle is the internal angle that is formed when the liquid exits the nozzle. Spray angles for nozzles range from 0 degrees to 250 degrees.

A well-developed pattern requires a certain amount of energy (pressure), usually 10 to 15 psig. Beyond this point, pressure has relatively little effect on the spray angle. Viscosity is key physical parameter relative to spray pattern. An increase in fluid viscosity usually produces a narrow pattern and smaller spray angle. At very high viscosities, the spray may collapse and produce a straight stream or a 0 degree spray angle.

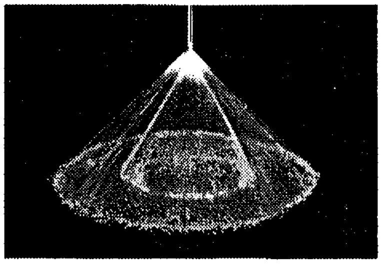
An important consideration in spray nozzle performance is the selection of the nozzle with a spray pattern best suited for the application. Different nozzle types offer different spray patterns and characteristics. The following is a discussion of common spray patterns and performance characteristics.

Hollow Cone

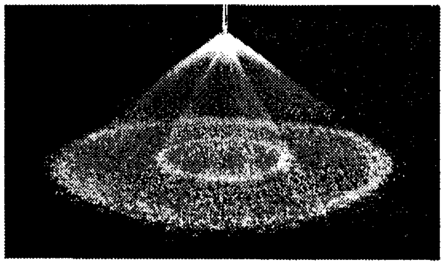
Hollow cone nozzles feature a spray angle that varies from 40 degrees to 165 degrees. The general spray characteristics are available in a wide variety of capacities and drop sizes. There is a good interface between air and drop surfaces. Typical applications for this type of nozzle include:

- Air, gas, and water cooling.
- Product cooling on conveyors.
- Dust control.
- Water aeration.
- Burners

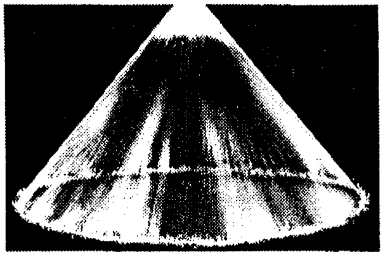
In general, the extensive range and capacities and drop sizes make the hollow cone nozzle useful for a wide variety of applications where a combination of small drop size and capacity is required.



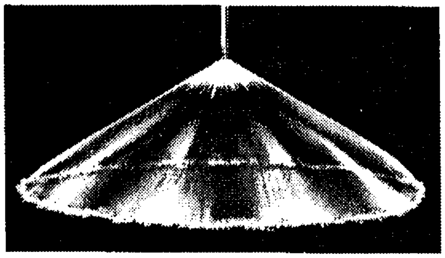
Full Cone 90°



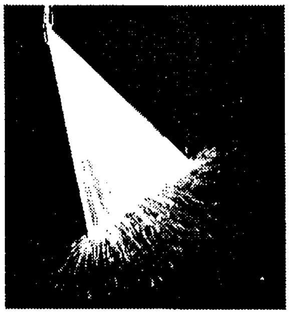
Full Cone 120°



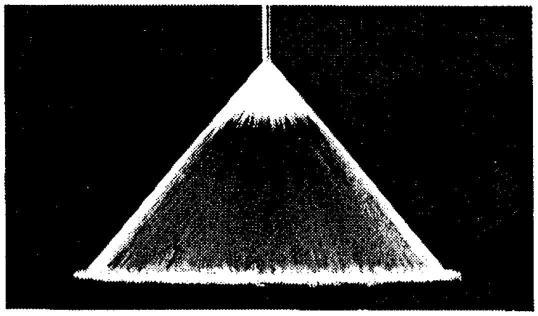
Hollow Cone 80°



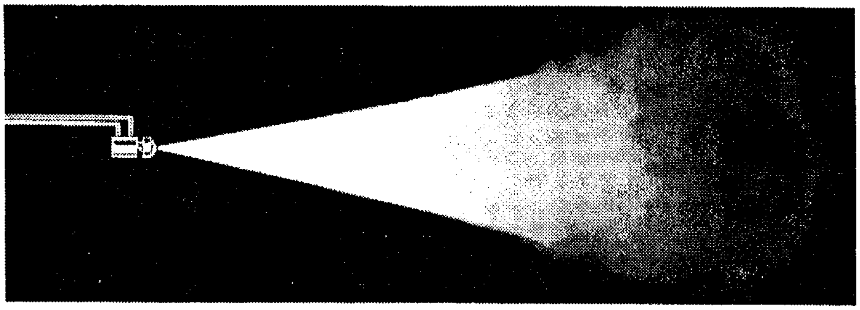
Hollow Cone 120°



Fan 50°



Fan 80°



Air Atomizing

Straight Jet 0°, high impact

Source: Bete Fog Nozzle, Inc.

FIGURE 3-6 SPRAY ORIENTATIONS

Full Cone

Full cone sprays provide a uniform, round, and full spray pattern with medium to large spray droplets. Spray angles are available from 15 to 125 degrees. Typical applications for the full spray nozzle are:

- Washing and rinsing.
- Disbursing drops in chemical reaction process.
- Metal cooling.
- Dust suppression.
- Fire protection.
- Burners

The full cone spray nozzle provides full spray coverage with medium to large flow rates. Spray patterns in an oval shape are also available.

Flat Spray

Flat spray nozzles are available in spray angles from 15 to 150 degrees. They are used to provide an even distribution throughout the entire flat spray pattern. The size of droplet produced is medium to large. This type of spray is ideal where high and uniform spray impact is required. Typical applications for the flat spray nozzle are:

- High pressure washing.
- Descaling (hot rolled steel).
- Label removal.
- Band spraying.

The thin rectangular pattern of this nozzle provides uniform coverage. In manifold set-ups the nozzles are carefully positioned for edge-to-edge pattern contact. This type of nozzle is primarily designed for impact applications.

Solid Stream

A solid stream pattern is shown in Figure 3-6. Note the extremely narrow spray pattern and length that this nozzle produces. The spray pattern as shown in this application is 0 degrees. Typical applications for this nozzle are:

- Product cleaning where complete removal of all dirt and debris is required.
- Decorative spray ponds.
- Laminar flow cooling applications (steel mill runout table).

Summary of Spray Patterns for Burner Applications

A liquid burner requires a nozzle that produces a wide angle spray pattern for two reasons:

- To maximize contact of air with the liquid.
- To produce a flame that will not impinge the walls or boiler tubes within the combustion chamber.

For this reason the solid stream nozzle is not recommended. A flat fan-shaped pattern will usually produce too wide an angle, and experience with this type of nozzle has been poor for burner applications. The flame is not stable and tends to extinguish easily.

The patterns that are acceptable for liquid burners are the full cone and hollow cone sprays. They can produce the flame shape and length required for most applications.

3.3 QUALITY OF ATOMIZATION

Atomization is measured by the size of droplets produced by the nozzle. Atomizers do not generate droplets of equal size; liquid break-up from an atomizer is caused by the collapse of unstable fluid sheets, jets, or ligaments. These mechanisms produce a large spectrum of droplet sizes, often from submicron up to several hundred microns in the same spray.

For a perspective of droplet diameters, consider the following ranges of atmospheric precipitation:

Type of Precipitation	Size Range (microns)
fog	1-30
mist	30-100
drizzle	100-300
light rain	300-1,000
heavy rain	1,000-5,000

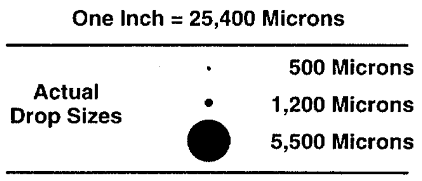
The droplet sizes are expressed in terms of mean volume diameter (MVD). MVD is a value where 50% of the total volume of liquid sprayed is made up of drops with the diameters larger than the median value and 50% are less than the median value. Because nozzles generate droplets that extend over a wide range of sizes, a mean volume diameter is reported. In Figure 3-7, examples of different spray patterns and the droplet size for varying capacities are shown. As Figure 3-7 shows, the finest droplets are produced by an air atomizing nozzle.

From the stand-point of atomization, the two most important liquid properties are the viscosity and the surface tension of the liquid. As viscosity or surface tension increases, larger forces must be overcome by the energy supplied to the nozzle. This detracts from the energy available for droplet break-up, resulting in coarser atomization. For very viscous fluids, dual-fluid atomizers are recommended to achieve proper atomization.

For fuel oil burners it is important to provide a fine atomization that will help vaporize the liquid fuel, and provide maximum contact with air. This is most effectively achieved by atomizing the fuel to a particle size with a range of 30 to 100 microns. For most oil applications this is accomplished by using a dual-fluid atomizer with either air or steam as the atomizing fluid.

Spray Pattern Type	10 psi		40 psi		100 psi	
	CAPACITY gpm	VMD microns	CAPACITY gpm	VMD microns	CAPACITY gpm	VMD microns
Air Atomizing	.005 .02	20 100	.008 8	15 200	12	400
Fine Spray	.22	375	.03 .43	110 330	.05 .69	110 290
Hollow Cone	.05 12	360 3400	.10 24	300 1900	.16 38	200 1260
Flat Fan	05 5	260 4300	.10 10	220 2500	.16 15.8	190 1400
Full Cone	.10 12	1140 4300	.19 23	850 2800	.30 35	500 1720

Based on a sampling of nozzles selected to show the wide range of possible drop sizes available.



95P-0274 2/24/95

FIGURE 3-7 DROPLET SIZES

3.4 GENERATION OF HYDRAULIC MOMENTUM OR IMPACT AND SPRAY COVERAGE

Impact or the impingement of a spray onto a target surface can be expressed in several different ways. The most useful impact value with regard to spray performance is represented in impact per square inch. This value is greatly dependent upon the spray pattern distribution and spray angle. To calculate the theoretical impact (pounds per square inch) the following formula may be used:

$$\text{Theoretical Total Impact Spraying Water} = .0526 \times F \times 0.5P$$

where:

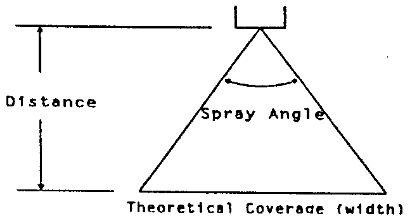
F = Flow in gallons per minute

P = Pressure upstream of the orifice (psi)

The tabulation given in the spray coverage information chart gives theoretical spray coverages, neglecting the effect of gravity and outside influences such as gas flow past the discharge. In actual spraying, the spray angle and resultant coverages will vary with distance. The spray angle tends to be decreased by a liquid of greater viscosity than water; increased by a liquid with lower surface tension than water. See Figure 3-8.

Spray velocity is the speed at which the atomized fluid leaves the orifice of the nozzle. The velocity is proportional to the square root of the pressure supplied at the nozzle. It is also determined by the design characteristics of the specific nozzle. Direct stream nozzles have the highest discharge velocities, wide spray nozzles have the lowest. The impact force of the spray depends upon the flow rate and velocity. Therefore the impact depends upon the supply pressure as well as the nozzle design.

As far as burner design, impact is not desirable because a wide angle is required to achieve proper mixing with air. However, flame shape is developed by adjusting the nozzle angle.



Spray Coverage

Spray Angle Degrees	Width of Spray Pattern at various distances in cm (in.) from nozzle orifice												
cm (in.)	5(2)	10(4)	15(6)	20(8)	25(10)	30(12)	40(15)	50(18)	60(24)	70(30)	80(36)	100(42)	125(48)	150(60)
5°	(.18)	(.35)	(.5)	(.7)	(.9)	(1.1)	(1.3)	(1.6)	(2.1)	(2.6)	(3.1)	(3.7)	(4)	(5)
15	1,3(.5)	2,6(1.1)	3,9(1.6)	5,3(2.1)	6,6(2.6)	7,9(3.2)	11(3.9)	13(4.7)	16(6.3)	18(7.9)	21(9.5)	26(11.1)	33(13)	40(16)
25	2,2(.9)	4,4(1.7)	6,6(2.7)	8,9(3.5)	11(4.4)	13(5.3)	18(6.6)	22(8)	27(10.6)	31(13.3)	35(15.9)	44(18.6)	55(21)	67(24)
30	2,7(1.1)	5,4(2.1)	8(3.2)	11(4.3)	13(5.4)	16(6.4)	21(8)	27(9.7)	32(12.8)	38(16)	43(19.3)	54(22.4)	67(26)	80(32)
40	3,6(1.4)	7,3(2.9)	11(4.3)	15(5.8)	18(7.2)	22(8.7)	29(10.9)	36(13)	44(17.4)	51(21.6)	58(26.2)	73(30.6)	91(35)	109(43)
45	4,1(1.7)	8,3(3.3)	12(4.9)	17(6.6)	21(8.2)	25(9.9)	33(12.4)	41(14.9)	50(19.8)	58(24.8)	66(29.8)	83(34.8)	103(40)	124(50)
50	4,7(1.9)	9,3(3.6)	14(5.6)	19(7.4)	23(9.3)	28(11.2)	37(14)	47(16.8)	56(22.4)	65(28)	75(33.6)	93(39.1)	116(45)	140(56)
60	5,8(2.3)	12(4.6)	17(6.9)	23(9.2)	29(11.4)	35(13.9)	46(17.3)	58(20.8)	69(27.6)	81(34.6)	92(41.6)	116(48.4)	144(55)	173(69)
65	6,4(2.5)	13(5.1)	19(7.6)	26(10.2)	32(12.7)	38(15.2)	51(19.1)	64(22.9)	76(30.5)	89(38.1)	102(45.8)	127(53.2)	159(61)	191(76)
70	7,0(2.8)	14(5.6)	21(8.2)	28(11.2)	35(14)	42(16.8)	56(21)	70(25.2)	86(33.6)	98(42)	112(50.4)	140(59.8)	175(67)	210(84)
75	7,7(3.1)	16(6.1)	23(9.2)	31(12.3)	38(15.3)	46(18.4)	61(23)	77(27.6)	92(36.8)	107(46)	123(55.2)	154(64.2)	192(74)	230(92)
80	8,4(3.4)	17(6.7)	25(10.1)	34(13.4)	42(16.8)	50(20.1)	67(25.2)	84(30.2)	101(40.2)	117(50.2)	134(60.4)	168(72.5)	210(81)	252(100)
90	10(4)	20(8)	30(12)	40(16)	50(20)	60(24)	80(30)	100(36)	120(48)	140(60)	160(72)	200(84)	250(96)	300(120)
100	12(4.8)	24(9.5)	36(14.3)	48(19.1)	60(23.8)	72(28.6)	95(35.8)	119(42.4)	143(57.2)	167(71.4)	191(86)	238(100)	298(115)	357(143)
110	(5.7)	(11.4)	(17.1)	(22.8)	(28.6)	(34.3)	(42.8)	(51.4)	(68.6)	(85.7)	(102.8)	(120)	(137)	(171)
120	17(6.9)	35(13.9)	52(20.8)	69(27.8)	87(34.7)	104(41.6)	139(52)	173(62.4)	208(83)	242(104)	277(125)	346(145.8)	433(166)	520(208)
140	(11)	(22)	(33)	(44)	(54.9)	(65.9)	(82.4)	(98.9)	(131.9)	(164.8)	(197.8)	(230.8)	(263.8)	(330)

This table is based on simple trigonometry and the calculation of these pattern widths does not take into account gravitational effects.

95P-0267 2/27/95

FIGURE 3-8 SPRAY COVERAGE

The narrower the angle, the larger the flame. For example, refer to Figure 3-8 for a nozzle specified to have a spray angle of 30 degrees, and a nozzle with a spray angle of 70 degrees. The width of the spray for the nozzle with the 30-degree angle is 32 inches at a distance of 60 inches from the nozzle, while the 70-degree angle nozzle has a width of 84 inches at the same distance. The nozzle with the wider angle will have a shorter flame since more fluid (oil) is exposed to air for the same distance.

The following table is a summary of physical property changes and how they affect spray nozzle performance.

Factors Affecting Spray Nozzle Performance

	Increase in Operating Pressure	Increase in Specific Gravity	Increase in Viscosity	Increase in Fluid Temperature	Increase in Surface Tension
Pattern Quality	improves	negligible	deteriorates	improves	negligible
Capacity	increases	decreases	*	**	no effect
Spray Angle	increases, then decreases	negligible	decreases	increases	decreases
Drop Size	decreases	negligible	increases	decreases	increases
Velocity	increases	decreases	decreases	increases	negligible
Impact	increases	negligible	decreases	increases	
Wear	increases	negligible	decreases	**	no effect

3.5 NOZZLE BURNER TYPES

There are several types of burner/atomizers commercially available. The burner types range from a standard line of burners such as those available by burner manufacturers to custom designed and fabricated burners for specific applications. It is also possible to retrofit liquid fuel burners with various atomizers to produce the desired flame shape, minimize pluggage, and/or to reduce emissions. Figure 3-9 illustrates various types of burner/nozzles.

The various liquid fuel/burners are grouped into several categories:

- Centrifugal atomizing.
- Low-pressure air-atomizing burner/nozzle.
- High-pressure air or steam atomizing burner/nozzle.
- Mechanical atomizing.

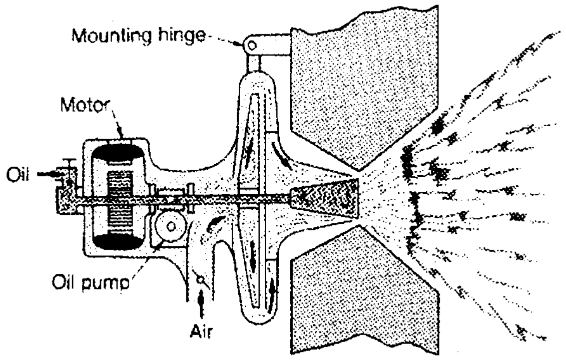
3.5.1 Centrifugal Atomizing Burners

Figure 3-9, picture A, shows a typical rotary cup or centrifugal atomizing burner. This type of burner uses centrifugal force to throw oil from the lip of a rotating cup in the form of a conical sheet of liquid which quickly breaks into spray. Low-pressure air is admitted through an annular space around the rotating cup. If the air velocity is high, it tends to blow the spray into a narrow cone, but if the speed of rotation of the cup is high, this tends to overcome the effect of the air stream, producing a wide angle spray. Shape of the spray is also determined by the relative positions of the cup and air orifice. Horizontal rotary cup burners are still used for boilers but not for high temperature furnaces because they have electric motors and other moving parts immediately adjacent to the burner.

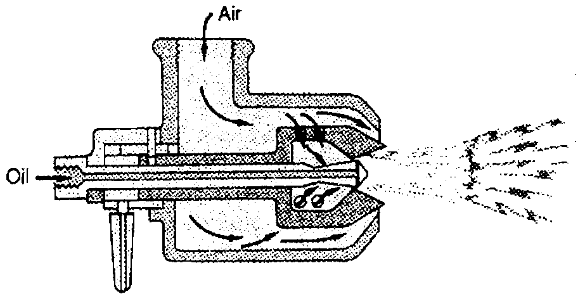
3.5.2 Low-Pressure Air-Atomizing Burner/Nozzle

Low-pressure air-atomizing oil burners use a relatively large quantity of air at 1 to 2 psi as the oil-atomizing medium. A well-designed atomizing unit may use as little as 10% of the total combustion air requirements for atomization. Low-pressure air atomizers are usually designed to handle oil with 100 SSU viscosity. The oil pressure at the burner is usually 1-5 psi, just enough to provide positive delivery to the unit. Low-pressure atomizing oil burners are applicable to a greater variety of uses than any other single type of burner. Some of their advantages are: no high pressures involved, relatively large air and oil orifices that

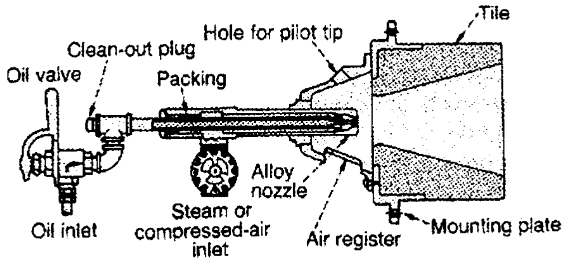
a. Rotary-cup burner



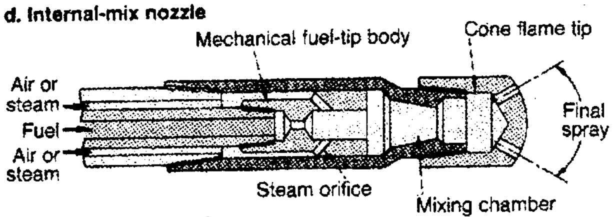
b. Low-pressure, air-atomizing burner



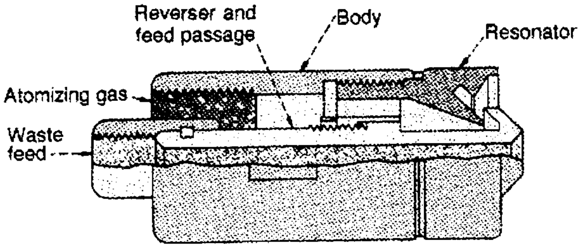
c. High-pressure, steam- or air-atomizing burner



d. Internal-mix nozzle



e. Typical sonic nozzle



95P-0374 2/24/95

Source: "Chemical Engineering", October 12, 1987.

FIGURE 3-9 TYPICAL BURNER TYPES

minimize pluggage, no intricate or delicate parts, simplicity of operation and control, flexibility to changes in loading or fuel, simplicity of installation, no moving parts, and economical operation.

Figure 3-9, picture B, is a schematic of a typical low-pressure air-atomizing burner. Note that the low-pressure air enters the burner through a single inlet. A portion of the combustion air is delivered to the atomizer and the remaining air is diverted to the outside of the tip to shape the flame and provide the remaining air for the fuel. Because of the relatively low air pressure, the orifices in the atomizer will be quite large, minimizing pluggage. Because of the low pressures involved on the liquid and air side of the atomizer, this burner will produce a long and wide spray-angle type of radiant flame. This type of flame pattern is not desirable for the application in the supplemental fuel boiler because of the small combustion space available within the boiler.

3.5.3 High-Pressure Air or Steam Atomizing Burner/Nozzle

High-pressure air or steam atomizing burners use steam or compressed air to tear droplets from the oil stream and propel them into the combustion space. The high velocity of the oil particles relative to air produces quick vaporization of the liquid. These burners can atomize light to very heavy oils, sludges, pitch, and some tars. They are often used for incineration of liquid wastes. Steam or compressed air at pressures ranging from 5 to 150 psi is used. The steam consumption may vary from 1 to 5 pounds per gallon of oil and air consumption from 22 to 100 ft^3 of air per gallon. There are three types of these nozzles: the internal mix, external mix, and the sonic atomizer.

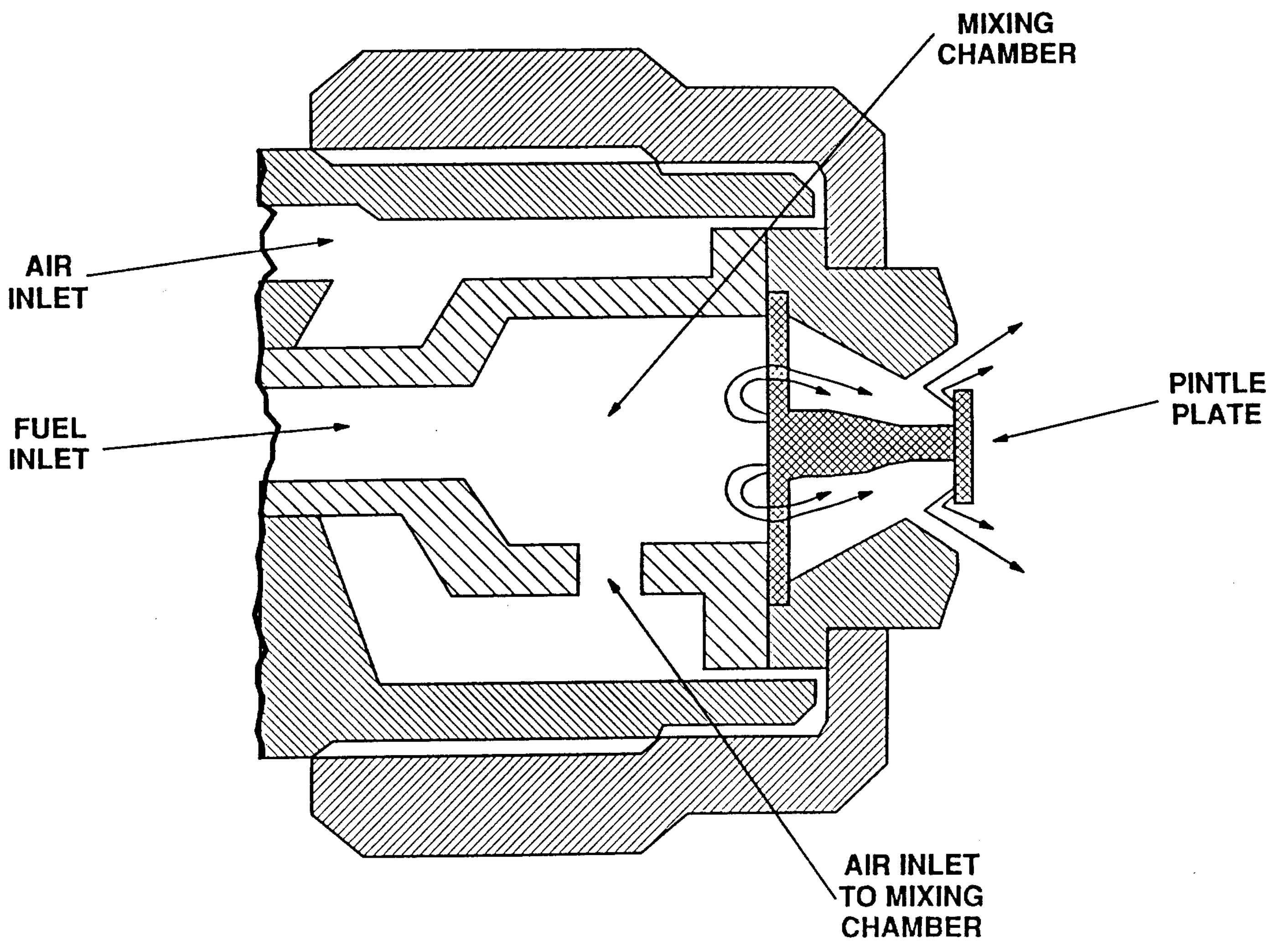
Figure 3-9, picture C, shows the typical view of a high-pressure steam or air atomizing burner. The burner consists of a fuel gun with two connections, one for the atomizing steam or air and one for the liquid. The two streams are mixed at the gun's tip by using either an external or internal mix nozzle. Picture D is a different style of internal mix nozzle where a drilled cap is used instead of a pivot pin at the discharge of the nozzle. The spray pattern can vary, by changing the angle of the exit ports.

Figure 3-10 shows a typical internal mix nozzle. The fuel enters the mixing chamber axially and comes in contact with tangentially introduced streams of air or steam. The interaction of the two streams creates extreme turbulence and mixing. The fuel air mixture impinges against a circular deflector ring or pivot pin plate before leaving the atomizer as a finely atomized spray.

Figures 3-11 and 3-12 are examples of external mix nozzles. In these nozzles the atomization of the liquid occurs outside the nozzle by interaction of the liquid and atomizing fluid stream. Figure 3-12 is a variable spray atomizer that uses two perpendicular atomizing fluid streams to increase the amount of contact of the fluids. By varying the flow rate of each of the atomizing streams, the spray angle can be changed with the burner operating without any modifications to the atomizer.

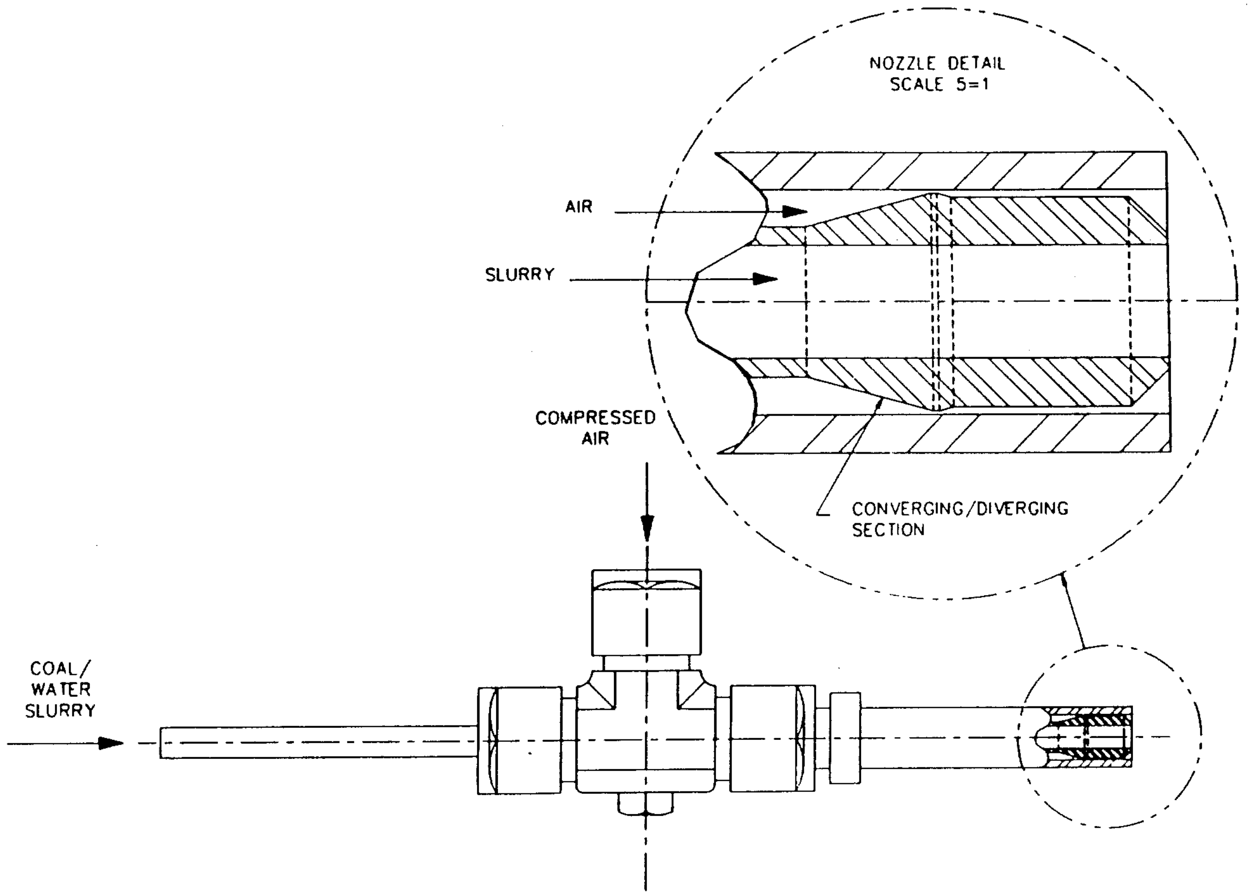
For an exterr mix nozzle, oil pressures of 5 to 30 psi are recommended at the burner, but for an internal nozzle, the oil pressure and the atomizing pressure must be about the same. The slim, compact nature of these atomizers make them readily adaptable for converting gas burners to combination oil/gas.

Figure 3-9 (e) and Figure 3-13 are schematics of a typical sonic atomizer. Sonic and ultrasonic atomizers are also used in high-pressure atomizing burners. These atomizers use an arrangement similar to a vibrating reed to produce a fog of minute liquid droplets. Burners must be specifically designed to transport the fog to the combustion space and mix a high volume of air stream with it. The energy source for sonic atomization is a compressible fluid — usually air. The air accelerates through a converge section and expands through a diverge section into the resonator cavity. This creates a powerful standing sonic shock wave. Fluid delivered to the sonic area is shattered into droplets. As it absorbs and employs the sound, the liquid serves to effectively damp it. Turning the nozzle down from maximum flow produces finer droplets as the ratio of energy to flow is increased even while energy input to the nozzle is decreased.



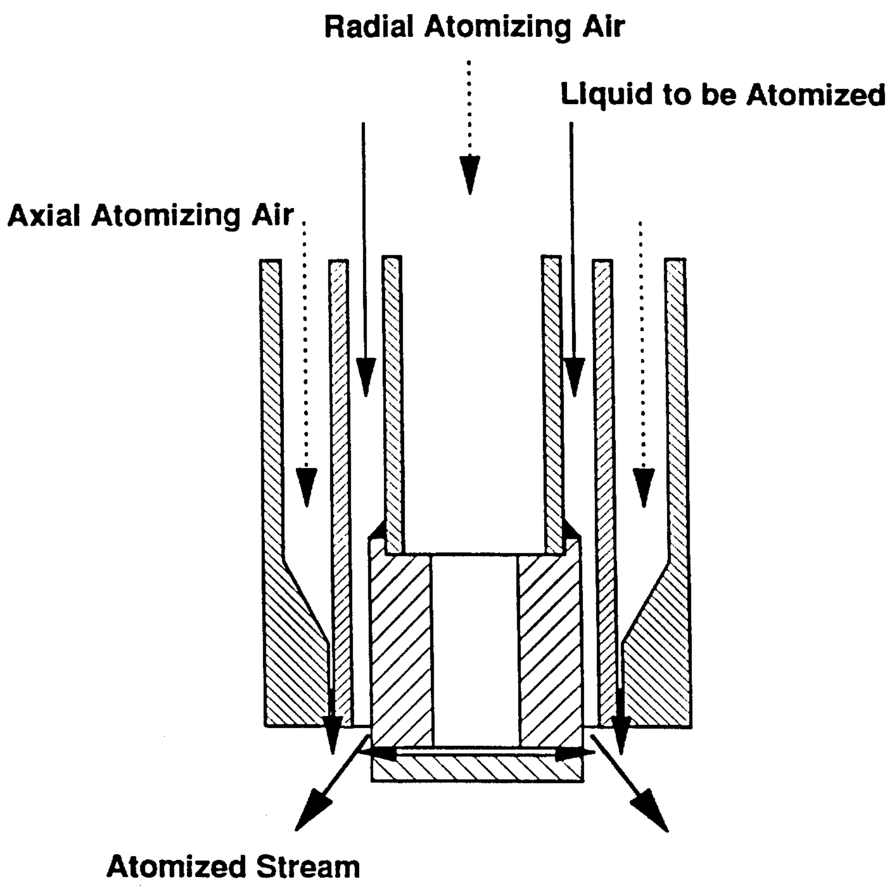
95P-0271 2/27/95

FIGURE 3-10 INTERNAL MIX BURNER/NOZZLE



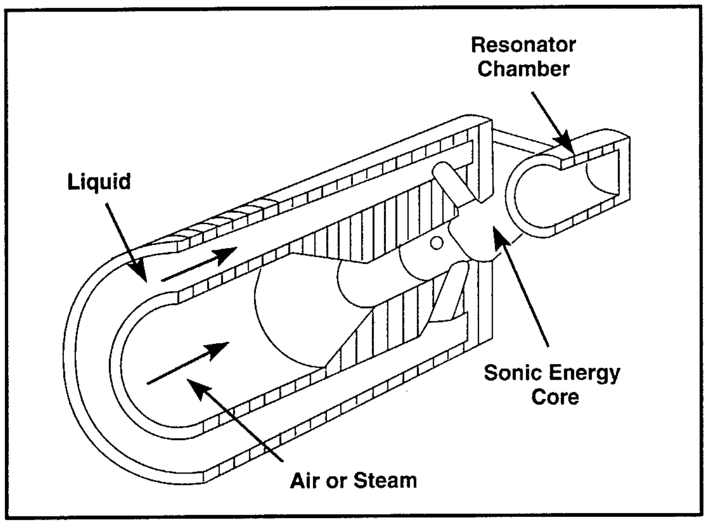
95P-0270 2/24/95

FIGURE 3-11 EXTERNAL NOZZLE



95P-0269 2/24/95

FIGURE 3-12 EXTERNAL MIX BURNER/NOZZLE



The sonic atomizing nozzle is an air driven acoustic oscillator for atomizing liquids by passing them through a field of high frequency sound waves. Air is accelerated beyond the speed of sound through a convergent/divergent orifice and then reflected back to complement and amplify the primary shock wave. Any liquid capable of being delivered to the shock wave is vigorously shattered into very fine droplets. Air bypassing the resonator carries the atomized droplets downstream in a soft, low velocity spray. Large orifices and low pressure virtually eliminate wear and prevent deterioration of the quality of atomization while greatly extending useful nozzle life. The greatest advantage of sonic atomizing nozzles is their ability to provide consistent quality of atomization over a wide flow range.

Source: Sonic

95P-0971

FIGURE 3-13 SONIC NOZZLE

3.5.4 Mechanical Atomizing Burners

Pressure atomizing burners are also referred to as mechanical pressure atomizing burners. These types of atomizers work on the principle that when oil is permitted to expand through a small orifice, it tends to break into a spray of fine droplets. Mechanical atomizers are usually designed to operate at pressures of 100 psig liquid with fluid viscosities less than 50 SSU. Turndown, or flow and pressure adjustments to the nozzle, is poor with this type of nozzle. Mechanical atomizers are typically limited to on/off applications. Large boilers use multiple guns that work on this principle. Their steady load and ability to turn guns off and on alleviate the turndown problem.

Figure 3-14 shows a typical mechanical spray nozzle. These spray nozzles can produce a variety of spray patterns by altering the drilling of the orifices at the outlet. Note that this particular spray nozzle has a single outlet; therefore, the pattern for this spray will be very narrow with a relatively course droplet size.

3.6 NOZZLE SPECIFICATIONS

Liquid fuels must be vaporized before they can be burned. Oil burners generally use two steps to get the fuel into a combustible form — atomization plus vaporization. First the oil is atomized and the large surface area of the atomized particles is exposed to air and heat. To achieve quick vaporization and maximum air contact with the fluid/oil, a fine atomization of the liquid must occur. It is recommended that oil be atomized in the range of 30 to 100 microns for maximum burner efficiency.

The fuel oil/slurry properties are listed in Tables A-1 and A-2 in Appendix A. The tables indicate that the physical properties of the slurry/oil have a higher density and viscosity than No. 2 fuel oil. No. 2 fuel oil has a density of 0.826 g/ml and a viscosity of 4.5 centistokes. At the design conditions of 15% AA2 propellant at 45°C, the physical properties are:

- 9 g/ml density.
- 200 cs viscosity.

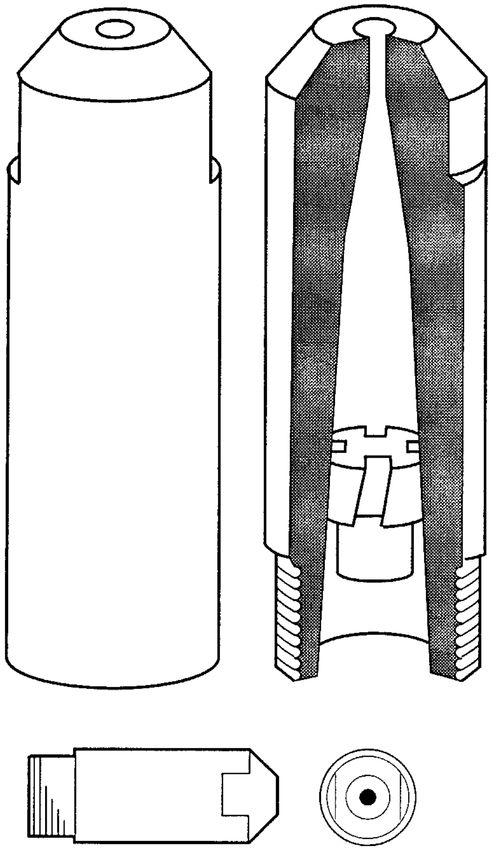


FIGURE 3-14 MECHANICAL SPRAY NOZZLE

Figure A-1 in Appendix A is a graph of the particle size distribution of a 15% mixture of AA2 propellant. The ground particle size has an average particle size of approximately 200 microns.

In summary the atomizer must perform the following:

- Short flame because of combustion space available.
- Circular flame shape (hollow or full cone).
- Atomize a liquid stream to 30 to 100 microns.
- Atomize a viscous fluid.

The best atomizer to provide these functions is a dual-liquid atomizer.

3.6.1 Spray Angle

The spray angle should be no less than 50 degrees and no greater than 75 degrees. This will create a shorter flame that is desirable for the Cleaver Brooks Boiler. With a spray angle meeting this criterion, the flame length inside the combustion chamber should be no longer than five feet, allowing maximum contact of air with the atomized fuel.

3.6.2 Flow Rate

The Cleaver Brooks Boiler has a nominal thermal rating of 2 million Btu per hour. Table 2-5 from Tecogen Technical Report dated March 1994 shows heats of combustion values of wt% explosive and solvent mixed with fuel oil. For a design objective of 15% by weight with fuel oil, the heating value was experimentally determined and reported in Appendix A, Table A-3 to be 16,758 Btu/lb.

To determine the flow rate the following formula is used:

$$Q=m(\Delta H)$$

where:

$Q=$ heat release in Btu/hr

$m=$ mass flow rate of the slurry in lb/hr

$\Delta H=$ heat of combustion of the fuel oil slurry mixture

Therefore, the flow rate of the oil/mixture is:

$$\frac{2.0 \text{ x } 10^{6} \text{ Btu/hr}}{16{,}758 \text{ Btu/lb}}$$

$$=119.34 \text{ lb/hr}$$

The specific gravity from Appendix A, Table A-1 is:

.903

The weight of the fluid is:

8.33 lb/gallon x .903 = 7.521 lb/gallon

Therefore, the flow of oil/slurry is:

$$\frac{119.34 \text{ lb/hr}}{7.521 \text{ lb/gallon}}$$

$$= 15.86 \text{ gallon/hr}$$

$$= .264 \text{ gallon/minute}$$

To provide the finest atomization it is desirable to be able to provide 60 to 80 psig of liquid pressure at the atomizer. The currently installed pump at the Indian Head Division, Naval Surface Warfare Division Project is capable of furnishing 80 psig at the spray tip, therefore the specification will provide the vendor with the maximum available to meet the requirements.

The specification for the liquid side of the atomizer tip will therefore be .27 gpm at 80 psig.

3.6.3 Atomizing Air Pressure

The air pressure available is 100 psig. Most atomizers are designed to operate with the liquid pressure equal to the atomizing air pressure. The pressures may vary as a result of the application or desired flame pattern; however, they usually never exceed a 20 psig difference. Therefore the specification will read 100 psig available air, 80 psig desirable to provide latitude in the event extra pressure is required.

3.6.4 Nozzle Type

Because of the minimal plugging experienced with the preliminary testing, either an external or internal mix nozzle would be acceptable. A sonic atomizing nozzle is not desirable because of the physical construction of the atomizer. The nozzle has a resonator cavity that could easily deteriorate when subjected to heat for long durations.

Table 3-1 is a summary of the complete nozzle specifications for this application.

Table 3-1

Spray Nozzle Specifications

Fluid Atomized	No. 2 fuel oil with 15% by wt. propellant
Specific Gravity	0.9
Viscosity	200 centistokes
Propellant Size	< 200 microns
Droplet Size Desired	30-150 microns
Fluid Pressure	80 psig
Flow Rate	0.26 gpm
Atomization Media	air
Atomization Pressure	80 psig
Spray Angle	55-75 degrees
Type Nozzle	internal/external mix
Spray Pattern	hollow/full cone
Materials of Construction	304 ss

Note: Nozzle will be used for atomizing a mixture of fuel oil and propellant to be burned in a waste heat boiler. Metering orifices should be designed for minimal plugging of the propellant.

SECTION 4

VENDOR EVALUATION SELECTION

4.1 BACKGROUND

The procurement department of WESTON performed an evaluation of available vendors that are capable of supplying nozzles for the type of application discussed in this report. The evaluation involved a vendor search utilizing such reference documents such as the *Thomas Register* and the *Environmental Pollution Buyers Guide - 1995.*

4.2 EVALUATION

The vendors were selected under the keyword "nozzles." Table 4-1 illustrates vendors listed in the above publications that were contacted to participate in this evaluation. These vendors were identified in the publications as able to supply nozzles capable of delivering the desired slurry to a burner assembly. The vendors were sent a specification sheet shown in Table 4-2. As shown in Table 4-3, only 5 of the 14 vendors responded in the specification sheets that they had a standard nozzle capable of delivering the desired slurry being evaluated in this report.

4.3 CONCLUSION

As a result of this investigation, it can be determined that a limited number of vendors are capable of supplying a standard nozzle suitable for the type of application. The detailed evaluation of the five vendors that responded are discussed in Section 5 of this report. The nozzles that the vendors could supply in this evaluation were inexpensive and a test could be performed with the different types of nozzles to demonstrate the capability of the additional, inexpensive nozzles. WESTON recommends that a nozzle from each vendor be purchased with an adapter to allow for easy replacement. During the testing program at Indian Head, each of the nozzles should be installed in the burner to demonstrate the capability of the nozzle.

Table 4-1

Participating Vendors

<u>BEX INC.</u> 37709 School Craft Rd. Livonia, MI 48150 313-464-8282 313-464-1988 FAX Pat	<u>W.M. STEINEN MFG. CO.</u> 29 E Halsey Rd. Parsippany, NJ 07054 201-887-6400 201-887-4632 FAX Joe Stewart
<u>BETE FOG NOZZLE INC.</u> 50 Greenfield St. Greenfield, MA 01301 413-772-0846 413-772-6729 FAX John Lesenski	<u>VULCANIUM CORP.</u> 3045 A Commercial Ave. Northbrook, IL 60062 708-498-3111 708-498-3392 FAX Chris Wilcox
<u>DELAVAN DELTA INC.</u> 20 Delavan Dr. Lexington, TN 38351 901-968-8152 901-968-5376 FAX Cathy Wish Steve Hunnicut	<u>FOGTECH ENVIRONMENTAL CONTROL</u> 1646 E. Jefferson Phoenix, AZ 85034 602-252-1244 602-253-6248 FAX Bob
<u>LECHLER INC.</u> 445 Kautz Rd. St. Charles, IL 60174 708-377-6611 1-800-444-7069 FAX Bill Meyer	<u>ATOMIZING SYSTEMS INC.</u> 1 Hollywood Ave. Ho-Ho-Kus, NJ 07423 201-447-1222 201-447-6932 FAX A.J.
<u>SPRAYING SYSTEMS CO.</u> North Ave Wheaton, IL 60189 Chadds Ford, PA 19317 610-459-5913 610-459-8273 FAX Bob Titchenell	<u>BERGER'S</u> 306 Edgemont Chester, PA 610-876-9444
<u>SRECO-FLEXIBLE</u> Box 1441 Lima, OH 45802 419-991-2065 419-999-2300 FAX Doug Follett	<u>PLUMBER'S SUPPLY</u> 376 S. Center St. Pottsville, PA 17901 717-622-0376

Table 4-1

Participating Vendors
(Continued)

THE RARING CORPORATION 11800 N.E. 95th St. Suite 230-G Vancouver, WA 98682 800-375-7041 206-892-1624 FAX Dave Gilroy	SONIC ENVIRONMENTAL SYSTEMS 141-T New Rd. Parsippany, NJ 07054 800-882-2877 201-882-1486 FAX Brian Hartshorn
BIRD PRECISION 1 Spruce St. Waltham, MA 02254 617-894-0160 800-370-6308 FAX Paul Baillio	FOSTER MFG CO. INC. 2324 W. Battlefield Rd. Springfield, MO 65807 417-881-6600 417-881-3645 FAX Lois Moss
SPRAY TECHNOLOGIES INC. 823 Lincoln Ave West Chester, PA 19380 610-431-6573 610-431-6574 FAX Greg Weber	TERRA PRODUCTS INC. 150 Banjo Dr. Crawfordsville, IN 47933 317-362-7367 800-458-0232 FAX Scott McDonald
TECOGEN 45 First Avenue P.O. Box 8995 Waltham, MA 02254 617-622-1400 Tony Litka	

Table 4-2

Request For Specification Information
USAEC Delivery Order No. 0013
Prime Contract No. DACA31-91-D-0079

Description	Nozzle Specification
Spray Angle	55-75 degrees
Flow Rate	0.256 gpm
Fluid Type	No. 2 fuel oil with 15% by wt propellants
Specific Gravity	0.9
Viscosity	200 centistokes
Propellant Size	Less than 200 microns
Droplet Size Desired	30-100 microns
Fluid Pressure	80 psig
Atomization Media	Air
Atomization Pressure	80 psig
Type Nozzle	Internal/external mix
Spray pattern	Full cone/hollow cone
Material of Construction	304 ss

Background: The nozzle for this application should be capable of atomizing the liquid into a mist in the range of 30-100 micron particles. Liquid fuels must be vaporized before they can be burned. Oil burners generally use two steps to get the fuel into a combustible form-atomization plus vaporization. First the oil is atomized and the large surface area of the atomized particles is exposed to air and heat. The use of high-pressure air is desirable to form tear droplets from the oil stream and propel them into the combustion space. The high velocity of oil relative to air produces the scrubbing action required for quick vaporization.

NOTE: Nozzles will be used for atomizing a mixture of fuel oil and propellants to be burned in a waste heat boiler. Metering orifices should be designed for minimum plugging of the propellant.

Table 4-3

Participating Vendor Responses

Vendor Name	Cost	Type of Nozzle
Atomizing Systems, Inc.	No response	N/A
Berger's	No response	N/A
Bete Fog Nozzle, Inc.	Not available	External Mix
Bex Inc.	No response	N/A
Bird Precision	Declined bid	N/A
Delavan Delta, Inc.	$192.28/nozzle	External mix
Fogtech Environmental Control	No response	N/A
Foster Mfg. Co., Inc.	No response	N/A
Lechler, Inc.	No response	N/A
W.M. Steinen Mfg. Co.	No response	N/A
Plumber's Supply	No response	N/A
Sonic Environmental Systems	$958-1,680/nozzle	External mix
Spray Technologies, Inc	No response	N/A
Spraying Systems Co.	$606.04/nozzle	Internal mix
SPRECO-Flexible	No response	N/A
Tecogen	$7,200/nozzle	External mix
Terra Products, Inc.	No response	N/A
The Raring Corporation	$155/nozzle	External mix
Vulcanium Corp.	No response	N/A

Although during the HWAAP testing program WESTON did not experience problems with material handling at the nozzle, experience with different types of nozzles would be beneficial. Having experience in processing material through various nozzles will enable WESTON to make an easy transfer to an alternate nozzle in the event of problems during full-scale testing. Experience has shown that problems that occur during the pilot-scale testing may not be the same problems that occur during the full-scale application. It would be beneficial to have a variety of proven, demonstrated nozzles available when problems are experienced during full-scale operation.

SECTION 5

VENDOR EVALUATION

Six companies were evaluated for the selection of an atomizing slurry nozzle. The companies were selected on the basis of their experience in the combustion fields, their willingness to participate, as well as their technical capabilities. The companies selected were Delavan Inc., (Delavan) Spraying Systems Co., (Spraying Systems) Bete Fog Nozzle, Inc. (Bete Fog Nozzle), Tecogen, Sonic Environmental Systems, and The Raring Corporation.

All the companies were forwarded the nozzle specification sheet shown in Table 4-2 and asked to provide the best nozzle for the application. It should be noted that Spraying Systems was familiar with the application, and had performed work similar to this application from their Minnesota Branch.

The companies were evaluated on the following performance criteria:

- Atomizing air pressure
- Atomizing flow rate
- Liquid pressure
- Nozzle turndown
- Ease of cleaning
- Droplet size
- Chance of plugging
- Controls required (instrumentation)
- Spray angle
- Spare parts
- Product support
- Available metallurgy
- Cost

5.1 DELAVAN INC.

Delavan quoted an air atomizing nozzle that it has developed and marketed specifically for fuel oil atomization. The type of atomizer is an internal mix and has a proven track record. The nozzle has the following properties.

Atomizing Air Pressure

The pressure required to atomize the fluid as specified is 60 to 80 psig. This is found to be within the specifications and capabilities of the supplemental fuel boiler system.

Atomizing Air Flow Rate

The atomizing air requirements will vary with liquid conditions; however, an average flow rate for the atomizing air is 1.5 scfm. No air flow rates were specified as a nozzle requirement.

Liquid Pressure

Delavan did not require the available 80 psig liquid pressure. The requirements of the nozzle were 60 psig, which is within the specification. Lower pressure is a benefit because of the decreased horsepower requirements of the fuel supply pump.

Nozzle Turndown

None was quoted; however, typical turndowns for a nozzle is at least 3:1 based on flow. The nozzle should be capable of turning down to .08 gallons per minute. This is acceptable for the application.

Ease of Cleaning

The nozzle is relatively easy to clean; the nozzle body must be unscrewed to expose the passages for the air and liquid. This can be difficult after the nozzle has been exposed to heat for a lengthy period of time. Since threaded joints are not allowed for this application, cleaning will be difficult from the exterior of the nozzle.

Droplet Size

The nozzle can produce an atomized stream of 60 to 100 microns.

Chance of Pluggage

The minimum passageway for this nozzle is 0.080 inches. It should easily pass the specified 200 micron particle maximum particle size. Two hundred microns is equivalent to approximately 0.010 inches.

Controls Required

The existing controls will satisfy the requirements for the nozzle.

Spray Angle

The spray angle formed by the tip is 60 to 75 degrees. The type of spray is a full cone. Both are within the specifications.

Spare Parts

Spare parts are available and are stock items for the metallurgy selected.

Product Support

Delavan has a research facility that can support special applications and problems if required. They also have an experienced staff of technical professionals that are available if required.

Available Metallurgy

The tip was specified as a 304 stainless steel metallurgy. The quotation included a tip constructed of 303 stainless steel. Use of 303 stainless steel is an acceptable alternative. Delavan also has many other types of metallurgies available should the application arise.

Cost

The cost for this atomizer is $192.28. This is relatively inexpensive for a spray nozzle.

5.2 SPRAYING SYSTEMS CO.

Spraying Systems quoted an air-atomizing internal mix nozzle. Spraying Systems' selection for this application was catalog number 1/4 JBC air atomizing nozzle, with a modified air cap. The nozzle has the following properties:

Atomizing Air Pressure

This nozzle requires atomizing air pressure of 80 to 100 psig. This is within the specifications.

Atomizing Air Flow Rate

This nozzle requires air flow rates that range from 8.55 scfm to 10.35 scfm. No air flow requirement was specified to the vendor.

Liquid Pressure

The required liquid pressure for this nozzle is a constant 60 psig. As the air pressure increases, the liquid flow rate will vary from 21.4 to 15.3 gallons per hour. (.35 to .255 gallons per minute). This was found to be acceptable and within the specifications.

Nozzle Turndown

The nozzle turndown was not given by Spraying Systems; however, it is industry standard for a nozzle of this type to achieve a 3:1 turndown for the flow of the liquid. For this application, nozzle turndown is not a significant factor.

Ease of Cleaning

As far as the mechanical aspects of the nozzle, cleaning of the tip could be quite cumbersome. The nozzle consists of an air cap, fluid cap and an air/liquid inlet connector. To clean the tip, the air cap and the fluid cap would have to be disassembled with a pipe wrench. After heat is applied to the nozzle, these connections can be quite difficult to remove. This tip is not easily cleaned in this application since screwed fittings are not allowed.

Droplet Size

The droplet size was well within the specification as the nozzle produced a spray droplet size of 25 to 35 microns. This nozzle is an extremely good atomizer; it will ensure good vaporization and mixture of air with the fuel oil/propellant mixture.

Chance of Pluggage

The orifice sizes are quite large with respect to the 200 micron particle size that was specified. The air side holes are 0.052 inches and the liquid side orifice is 0.010 inches. If the particle sizes are as specified the nozzle should not plug.

Controls Required

Existing controls will satisfy the requirements.

Spray Angle

Spraying Systems quoted a full cone spray pattern; however, its selection was a modified hollow cone spray nozzle. Its proposal was to modify a hollow cone spray by drilling a center hole in the tip that "should produce the desired full cone spray." (See Spraying Systems quotation.)

The spray angle was within the specifications. The angle quoted was 70 degrees which should produce a maximum flame length of 5 feet.

Product Availability

All parts as quoted are in stock except for the air cap that is drilled with a special center hole. The air cap is an 8- to 10- week item as quoted; however, an expedited delivery would probably be available for an extra cost.

Product Support

Product support for Spraying Systems is above average and it has an extensive research facility to research and develop product lines or solve difficult applications. Technicians would be available for on-site troubleshooting, if required.

Available Metallurgy

Should different metallurgy be required, Spraying Systems has the ability to machine cast and recommend varying metallurgies. No changes are anticipated for this application.

Cost

The total price for a Spraying Systems' nozzle is $606.04, the majority of the cost being the special application for the drilling of the seventh center hole.

5.3 BETE FOG NOZZLE, INC.

Bete Fog Nozzle quoted two different atomizers for this application, an internal and an external mix spray pattern. The external mix nozzle was Bete's model XA-EF 450A. The external mix nozzle as quoted produced a flat spray pattern. This nozzle was not evaluated because of the flame shape and instability produced by this type of nozzle.

The internal mix was Bete's model XA-PR250A. Although this nozzle has good atomization qualities, the spray pattern is very narrow, 17 to 22 degrees. This type of spray is not desirable for the application. The minimum acceptable pattern would be 50 degrees, which improves mixing of the air with the fuel oil and improves combustion efficiency.

Bete did not meet any of the specifications for this application. Bete informed WESTON that it could custom manufacture a nozzle for this application; however, it would be a lengthy and costly process. A firm price to provide this service was not available.

5.4 TECOGEN

Tecogen was requested to provide a quotation for the atomizer proposed in its Technical Report-Study Services Slurry Burning Project Support dated March 1994. The feature that makes this nozzle attractive is the external atomization design which provides twin shearing streams without requiring high velocities and pressures. The nozzle has the following properties:

Atomizing Air Pressure

Tecogen's atomizing air pressure requirements are within the specifications with anticipated operating pressures between 60 and 80 psig.

Atomizing Air Flow Rate

The atomizing flow rate for this type of nozzle will range from 5.2 to 9.2 scfm depending upon the characteristics of the liquid. The expected atomizing flow rate is approximately 8.0 scfm.

Liquid Pressure

The liquid pressure will be 30 to 50 psig. This is less than the specified pressure of 80 psig. A lower pressure will allow the liquid orifices to be larger, minimizing pluggage.

Nozzle Turndown

The nozzle turndown was not provided. As with the other nozzles, it is industry standard that a nozzle of this type can turndown a minimum of 3:1 for liquid flow. This is found to be satisfactory for this application.

Ease of Cleaning

The nozzle is easily cleaned without mechanical disassembly. The air side and fluid side orifices can be cleaned by removing the fuel gun and accessing the orifices. Should the nozzle require disassembly, however, cleaning will be quite difficult. Screwed fittings are not allowed for this application.

Droplet Size

An external mix atomizer is the least efficient of the dual-fluid type atomizers. This is due to the loss of energy caused by the physical mixing outside of the nozzle. It is expected, however, that a particle size within the range of 75 to 150 microns can be achieved. This is satisfactory for this application.

Chance of Pluggage

The minimum gap for any of the orifices in this atomizer is 1,200 microns. As specified, the 200-micron particle will easily pass through the orifices and pluggage should be minimal.

Controls Required

Additional controls are required for the Tecogen atomizer. This is because the atomizer offers two air streams that can be adjusted to shape the flame into various patterns. This is desirable but no necessary for the application. The extra controls involved are minor and could be retrofitted easily into the system with minimal cost impact should Tecogen be the vendor of choice. The controls consist of a pressure regulator, a pressure indicator, and a needle valve.

Spray Angle

The spray angle is adjustable and will meet the specifications. Because the spray angle is variable with no mechanical adjustments, this nozzle has the least potential for problems during the start-up and initial operations phase of the project. Should the angle ever be changed after initial set-up, however, difficulties could occur.

Spare Parts

Tecogen's nozzle will be custom designed and fabricated for this specific project. For this reason, it is doubtful that spare parts will be in stock at the factory in case of an emergency.

Product Support

Tecogen does not have a specific testing laboratory for nozzles. Tecogen does not have specially trained technicians available for immediate support.

Available Metallurgy

Different types of metallurgy are available through Tecogen.

Cost

A budget price was provided for the nozzle. The cost was approximately $7,200 to custom design and manufacture a product for this application.

5.5 SONIC ENVIRONMENTAL SYSTEMS

WESTON used Sonic Environmental Systems to provide nozzles during the pilot test at HWAAP. The type of atomizer is an external mix which WESTON had good results with during the HWAAP test. The nozzle had the following properties:

Atomizing Air Pressure

The pressure of Sonic nozzles ranged from 0 to 80 psig. This is found to be within the specifications and capabilities of the supplemental fuel boiler system.

Atomizing Air Flow Rate

The atomizing air requirements will vary with liquid conditions; however, an average flow rate for the atomizing air is 1.5 scfm. No air flow rates were specified as a nozzle requirement.

Liquid Pressure

Sonic did not require the available 80 psig liquid pressure. The chart provided by Sonic indicated a lower liquid pressure. Lower pressure is a benefit because of the decreased horsepower requirements of the fuel supply pump.

Nozzle Turndown

None was quoted; however, typical turndowns for a nozzle is at least 3:1 based on flow. The nozzle should be capable of turning down to .08 gallons per minute. This is acceptable for the application.

Ease of Cleaning

The nozzle is relatively easy to clean; the nozzle body must be unscrewed to expose the passages for the air and liquid. This can be difficult after the nozzle has been exposed to heat for a lengthy period of time. Since threaded joints are not allowed for this application, cleaning will be difficult from the exterior of the nozzle. It will be suggested that several nozzle assemblies be available as spare parts once the nozzle selection has been made.

Droplet Size

The desired droplet size specified was 30 to 50 microns.

Controls Required

The existing controls will satisfy the requirements for the nozzle.

Spray Angle

The type of spray is a full cone.

Spare Parts

Spare parts are available and are stock items for the metallurgy selected.

Product Support

Sonic has a research facility that can support special applications and problems if required. It also has an experienced staff of technical professionals that are available if required.

Available Metallurgy

The tip was specified as a 316 stainless steel metallurgy. Use of stainless steel is acceptable. Sonic has also included Hostelloy as an option if extreme heat conditions exist.

Cost

The cost for this assembly is $958 to $1,680. This is an average cost for a spray nozzle.

5.6 THE RARING CORPORATION

The Raring Corporation quoted an air-atomizing external mix nozzle. Raring's selection for this application was Model FP-10 air atomizing nozzle, with a modified air cap. The nozzle has the following properties:

Atomizing Air Pressure

This nozzle specified an atomizing air pressure of 80 psig.

Liquid Pressure

The specified liquid pressure for this nozzle is a constant 80 psig.

Nozzle Turndown

The nozzle turndown was not given by Raring; however, it is industry standard for a nozzle of this type to achieve a 3:1 turndown for the flow of the liquid. For this application, nozzle turndown is not a significant factor.

Ease of Cleaning

The nozzle is relatively easy to clean; the nozzle body must be unscrewed to expose the passages for the air and liquid. This can be difficult after the nozzle has been exposed to heat for a lengthy period of time. Since threaded joints are not allowed for this application, cleaning will be difficult from the exterior of the nozzle.

Droplet Size

The nozzle was specified to provide an atomized stream of 30 to 50 microns.

Controls Required

The existing controls will satisfy the requirements for the nozzle.

Spray Angle

The type of spray is a full cone.

Spare Parts

Spare parts are available and are stock items for the metallurgy selected.

Available Metallurgy

The tip was specified as a 304 stainless steel metallurgy.

Cost

The cost for this atomizer is $155.00. This is relatively inexpensive for a spray nozzle.

SECTION 6

CONCLUSION AND RECOMMENDATION

Of the six companies that were evaluated, five provided a nozzle that entirely met the specifications. Tecogen met all the technical requirements; however, many of the technical questions were left unanswered, probably because of the customized nozzle it intended to supply. Bete Fog Nozzle is not a consideration since it did not offer a nozzle that had the flame shape or the required spray angle for this application. Because of the criticality of flame stability and combustion efficiency, it is not recommended that Bete Fog Nozzle be chosen as the preferred nozzle vendor. Therefore, the final evaluation and recommendations are based on nozzles provided by Tecogen, Spraying Systems, Delavan, Sonic Environmental, and The Raring Corporation.

Atomizing Air Pressure

All the vendors quoted air pressure requirements that were within the specification of 100 psig. Delavan, Sonic, and the Raring Corp. quoted the lowest pressure range of 60 to 80 psig while Spraying Systems required a pressure of 80 to 100 psig. Atomizing air pressure is important in two aspects: the air compressor power and costs will increase, and the air side orifices in the atomizer will be larger (minimizing the chance of pluggage).

Atomizing Flow Rate

The lowest flow rate quoted was from Delavan with an air flow of 1.5 scfm. Spraying Systems anticipated a flow rate of 8.55-10.35 scfm depending upon the conditions. Sonic and Raring did not specify a flow rate. Both flow rates are acceptable; however, the lower flow rate will reduce air compressor costs.

Liquid Pressure

Delavan and Spraying Systems each required a liquid pressure of 60 psig. The external mix atomizer offered by Tecogen requires 30 to 50 psig to operate. The lower pressure requirement is an advantage in that the fuel supply pump will not have to perform as much work, and the liquid orifices will be larger to minimize pluggage. Sonic and Raring did not specify a pressure other than that listed on the specification sheet (80 psig).

Nozzle Turndown

All the nozzles are expected to turndown to a flow rate of 3:1. This is well within the operating conditions required by the process.

Ease of Cleaning

From the aspect of a quick clean-out, Tecogen's external mix nozzle would be the simplest to clean. This is because the liquid side and air side orifices can be cleaned without total disassembly. If a mechanical disassembly is required, Delavan, Sonic, and Raring nozzles would be the easiest. For this application, physical disassembly is not permitted because of the disallowance of screwed fittings. Therefore, Tecogen's nozzle is superior for this application.

Droplet Size

The specification required a droplet size of 30 to 100 microns of atomized spray. All vendors were able to meet this specification except for Spraying Systems' nozzle with a droplet size requirement of <30 microns.

Chance of Pluggage

The nozzle most likely not to plug would be the Tecogen external mix nozzle. This is because the orifices are larger than the other vendors.

Controls Required

All vendors requirements for controls would adapt within the existing control scheme with the exception of Tecogen. However, the modification to retrofit the existing scheme is very minor and would entail adding a pressure gauge, needle valve, and a small amount of piping.

Spray Angle

All vendors met the requirement of a 50- to 75-degree spray angle with a cone spray pattern. Tecogen's nozzle has the added capability of changing the spray pattern without mechanical adjustments to the atomizer.

Spare Parts

Delavan and Sonic are the only vendors that stock all of the nozzle components. Spraying Systems stocks all the material; however, its modification to the nozzle requires extra delivery time. This could be overcome by ordering the stock cap and drilling the required orifice in a local machine shop. Tecogen does not carry the items in stock; therefore, delivery time would be lengthy and possibly expensive.

Product Support

Spraying Systems and Delavan both have research laboratories to support their product requirements. Both are willing to perform testing as required should the need occur. Both also have technicians that are available to troubleshoot systems in the field. Tecogen's product support is minimal in comparison to Delavan and Spraying Systems. Sonic and Raring were not requested to provide support capability; however, it can be expected that both can provide the needed support.

Available Metallurgy

All vendors can manufacture the atomizers to different metallurgies. However the 303 SS atomizer should be adequate for this application.

Cost

The Raring Corporation's atomizer was the least costly of all the tips quoted. This is because the application fit an existing product line and no extra engineering or manufacturing is required. Tecogen's tip was the most costly because of custom design and manufacturing required to furnish this atomizer.

Recommendation

Table 6-1 summarizes the parameters of evaluation for each vendor. Table 6-2 is an evaluation of the vendors on a grading system of all the performance criteria. The criteria are based on the following point system:

0 - Poor
1 - Average
2 - Good

A total point evaluation indicated that Delavan had the highest score of 20 points as opposed to 14 points for Tecogen. It should be noted that Spraying Systems and Tecogen offered technically sound nozzles; however, the extra cost for this application is not warranted. Because of its experience, product availability and technical advantages, Delavan is the preferred vendor for this application. Delavan can provide a standard nozzle for this process that is a proven design, available from the factory stock shelf and of reasonable cost.

Table 6-1

Comparison of Vendor Specifications

	Delavan Corporation	Spraying Systems, Inc.	Tecogen	Sonic Environ. Systems	The Raring Corporation
Atomizing Air Pressure	60-80 psig	80-100	60-80	80 psig	80
Atomizing Flow Rate	1.5 scfm	8.55-10.35	5.2-9.2	1.5	
Liquid Pressure	60 psig	60	30-50	80	
Nozzle Turndown	3:1	3:1	3:1	3:1	
Ease of Cleaning	Difficult	Difficult	Good	Difficult	
Droplet Size	60-100	25-30	100-200	30-50	
Chance of Pluggage	Average	Average	Minimal	Average	
Controls Required	None	None	Modification Required	None	
Spary Angle	60-75	70	35-90	Full cone	
Spare Parts	In stock	In stock except for tip	Special manufacture	Stock	Not Specified
Product Support	Good	Good	Poor	Not Specified	Not Specified
Available Metallurgy	All	All	All	310 Hostelloy	304
Cost	$192.29	$606.04	$7,000.00	$958-1,680	$155.00

Table 6-2

Evaluation of Vendors

	Delavan Corporation	Spraying Systems, Inc.	Tecogen	Sonic Environ. System	The Raring Corporation
Atomizing Air Pressure	2	1	2	1	1
Atomizing Flow Rate	2	1	1	1	1
Liquid Pressure	1	1	2	1	1
Nozzle Turndown	1	1	1	1	1
Ease of Cleaning	1	1	2	1	1
Droplet Size	1	2	1	1	1
Chance of Pluggage	1	1	2	1	1
Controls Required	2	2	0	2	2
Spray Angle	1	1	2	1	1
Spare Parts	2	1	0	2	1
Product Support	2	2	0	1	1
Available Metallurgy	2	2	2	2	1
Cost	2	1	0	1	2
Total	20	17	15	16	15

0 - Poor
1 - Average
2 - Good

SECTION 7

REFERENCES

1. Cosmos, M. et al. 1991. "Phase I: Pilot Test to Determine the Feasibility of Using Explosives as Supplemental Fuel at Hawthorne Army Ammunition Plant (HWAAP) Hawthorne, Nevada." U.S. Army Corps of Engineers - Toxic and Hazardous Materials Agency, Report No. CETHA-TE-CR-91006.

2. Delavan, Inc. 1993. *Delavan Spray Nozzles and Accessories for Spraying Applications*.

3. Spraying Systems Co. 1992. *Industrial Spray Products Catalog 51A*.

4. Tecogen. 1994. "Technical Report - Study/Services Slurry Burning Project Support: AOT Maryland, Inc." Contract No. N00174-92-D002. Waltham, MA.

5. North American. 1978. *North American Combustion Handbook* Second Edition.

APPENDIX A

SLURRY CHARACTERISTICS

Table A-1

Densities[a] of Propellant No. 2 Fuel Oil Slurries At 25 °C, 45 °C, and 65 °C

Propellant	Wt. % Propellant	Density (g/mL)		
		25 °C	45 °C	65 °C
No. 2 Fuel Oil	0.0	0.851	0.826	0.812
Nitroguanidine	5.0	0.875	0.858	0.846
	7.5	0.883	0.870	0.860
	10.0	0.901	0.885	0.871
	12.5	0.920	0.891	0.885
	15.0	0.933	0.908	0.895
Nitrocellulose (Dried at 70 °C)	5.0	0.875	0.855	0.826
	7.5	0.886	0.872	0.840
	10.0	0.898	0.880	0.852
	12.5	0.908	0.886	0.870
	15.0	0.939	0.896	0.883
Nitrocellulose (28% Water Content)	5.0	0.872	0.859	0.847
	7.5	0.880	0.868	0.860
	10.0	0.891	0.878	0.867
	12.5	0.905	0.885	0.874
	15.0	0.910	0.893	0.883
AA2 Propellant	5.0	0.879	0.864	0.854
	10.0	0.899	0.885	0.872
	15.0	0.924	0.903	0.891
	20.0	0.943	0.926	0.911
	25.0	0.968	0.948	0.930
	30.0	0.983	0.966	0.952

All values are the average of three replicates.
*From Reference 1

Table A-2

Viscosities[a] of Propellant No. 2 Fuel Oil Slurries At 25 °C, 45 °C, and 65 °C

			Viscosity (CS)	
Propellant	Wt. % Propellant	25 °C	45 °C	65 °C
No. 2 Fuel Oil	0.0	5.3	4.5	3.4
Nitroguanidine	5.0	9.3	6.5	5.7
	7.5	12.6	9.8	8.8
	10.0	31.4	18.4	16.0
	12.5	78.2	54.5	49.6
	15.0	128.9	74.4	58.6
Nitrocellulose (Dried at 70 °C)	5.0	15.9	10.5	8.7
	7.5	53.5	30.4	25.0
	10.0	156.4	95.6	80.9
	12.5	381.5	203.2	180.5
	15.0	454.8	243.5	220.8
Nitrocellulose (28% Water Content)	5.0	12.4	9.8	7.8
	7.5	29.9	17.7	14.9
	10.0	54.3	40.1	33.6
	12.5	149.9	110.9	98.2
	15.0	341.9	240.5	188.0
AA2 Propellant	5.0	43.8	20.3	17.9
	10.0	51.9	40.5	35.9
	15.0	58.0	52.1	46.4
	20.0	84.7	64.3	54.7
	25.0	92.7	78.3	69.6
	30.0	105.4	87.8	83.9

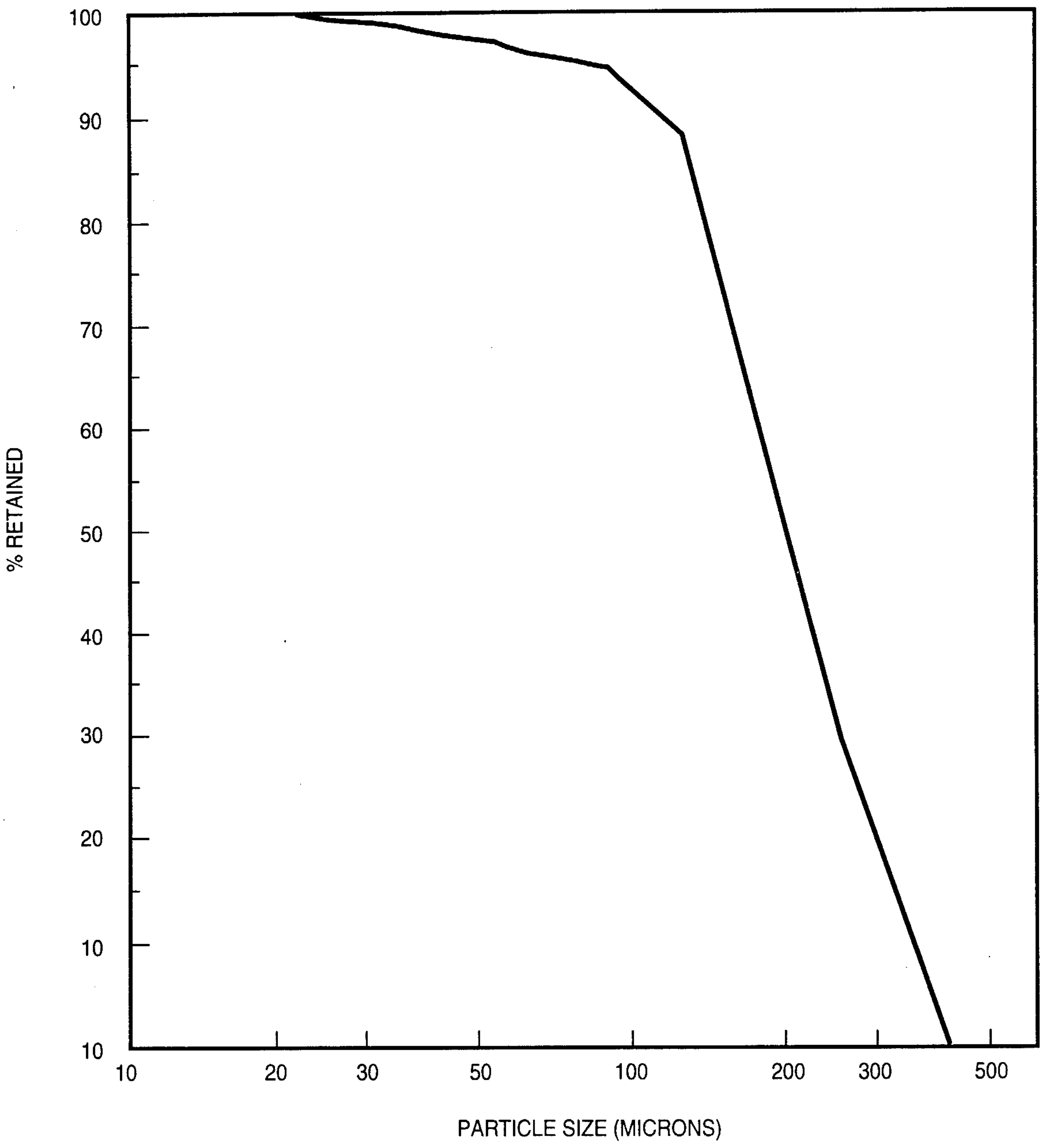
[a] All values are the average of three replicates.

Table A-3

Heats of Combustion* of No. 2 Fuel Oil, Propellants, and Selected Propellant — No. 2 Fuel Oil Slurries

Material	Heat of Combustion (Btu/lb)
Nitrocellulose	4,308
Nitroguanidine	4,016
AA2 Propellant	4,354
No. 2 Fuel Oil	18,947
10% Nitrocellulose-90% No. 2 Fuel Oil	17,483
15% Nitroguanidine-85% No. 2 Fuel Oil	16,707
15% AA2 Propellant-85% No. 2 Fuel Oil	16,758
20% AA2 Propellant-80% No. 2 Fuel Oil	16,029

*Heats of combustion for propellants and No. 2 fuel oil were determined experimentally. Heats of combustion for the propellant-No. 2 fuel oil slurries were calculated from these values.



95P-1566 3/22/95

FIGURE A-1 PARTICLE SIZE DISTRIBUTION OF AA2 PROPELLANT AFTER WET GRINDING

APPENDIX B

VENDOR QUOTATIONS

FAX Transmission

From: David F. Gilroy / Product Mgr.
Questions? Call (206) 892-1659
Fax (206) 892-1624

The Raring Corporation
11807 NE 99th Street, S 1100
Vancouver, WA 98682 USA

To: Brian Randall
Company: Weston , 610 701-3126
Address:
Date: January 20, 1995
Time: 1:43 PM
Pages: 4 (including this one)

Re: USAEC Oder No. 0013 / Atomizing Nozzles
Our Proposal No. P- 012095

The prices are for the nozzle assembly only, and does not include the adapter to mount the nozzle in for delivery of air/fuel. Your adapter needs may require a flange type or other custom design. If so, I will need to see drawings of what we need to fit our nozzle to.

We have supplied specialty adapters before and can assist in their design as well as engineer and supply.

I will be gone Monday Jan. 23, so if you need to talk to someone here, ask for Eng. Sokha Kuch or leave a message for me via fax, phone or voice mail.

Regards

REQUEST FOR SPECIFICATION INFORMATION
USAEC DELIVERY ORDER NO. 0013
PRIME CONTRACT NO. DACA31-91-D-0079

DESCRIPTION	NOZZLE SPECIFICATION	INFORMATION REQUESTED	VENDOR DATA
Spray Angle	55-75 Degrees	Nozzle Model No.	FP-10
Flow Rate	0.256PM		.2 gal pm
Fluid Type	#2 Fuel Oil with 15% by WT Propellants		
Specific Gravity	0.9	Fabrication Point	Vancouver, WA-USA
Viscosity	200 Centistokes		Raring Corp.
Propellant Size	Less than 200 microns		
Droplet Size Desired	30-50 microns	Leadtime Range	
Fluid Pressure	80 psig		Quantity
			(0-100) (100+)
Atomization Media	Air	Price Range	($155.00 ea) (125.00 ea)
Atomization Pressure	80 psig		
		Quantity Price Break	
Type Nozzle	External Mix		
Spray Pattern	Full Cone		
Material of Construction	304 ss	Applicability Range	?

Background: The nozzle for this application should be capable of atomizing the liquid into a mist in the range of 30-100 micron particles. Liquid fuels must be vaporized before they can be burned. Oil burners generally use two steps to get the fuel into a combustible form-atomization plus vaporization. First the oil is atomized and the large surface area of the atomized particles is exposed to air and heat. The use of high pressure air is desirable to form tear droplets from the oil stream and propel them into the combustion space. The high velocity of oil relative to air produces the scrubbing action required for quick vaporization.

NOTE: Nozzles will be used for atomizing a mixture of fuel oil and propellants to be burned in a waste heat boiler. Metering orifices should be designed for minimum plugging of the propellant.

cwj

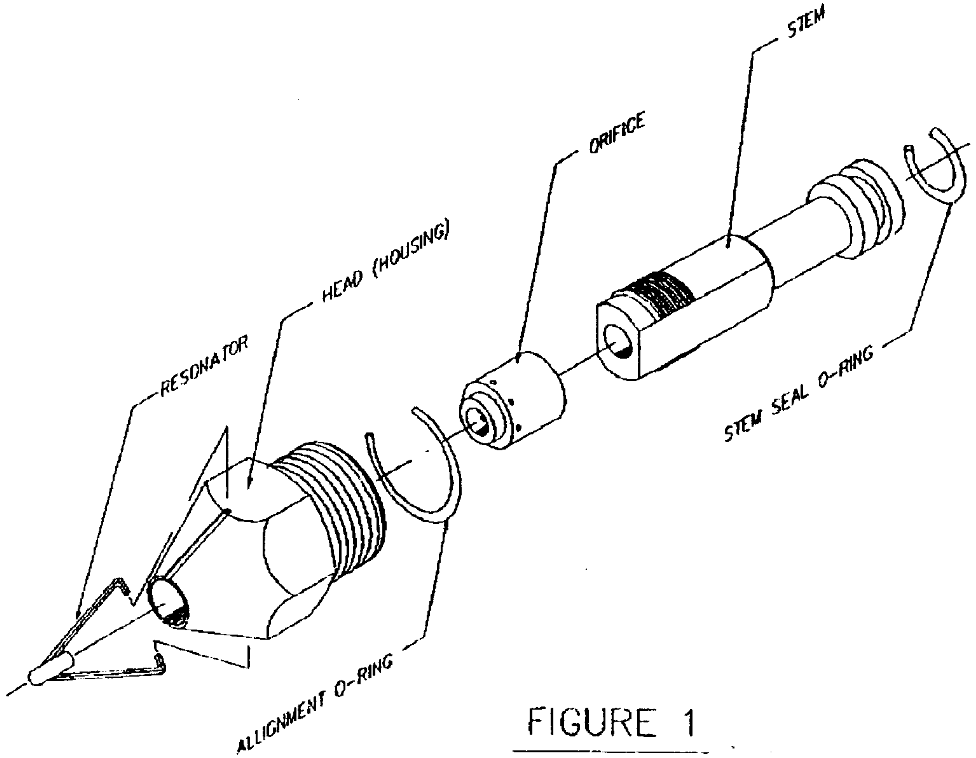


FIGURE 1

The Raring **Coporation**		
TITLE : ADS MICROFOG NOZZLE		
DRAWN : ROSS	DWG NO : ADS-01	REV 0
DATE : 4/26/89		

CAD DWG NAME : NOZ

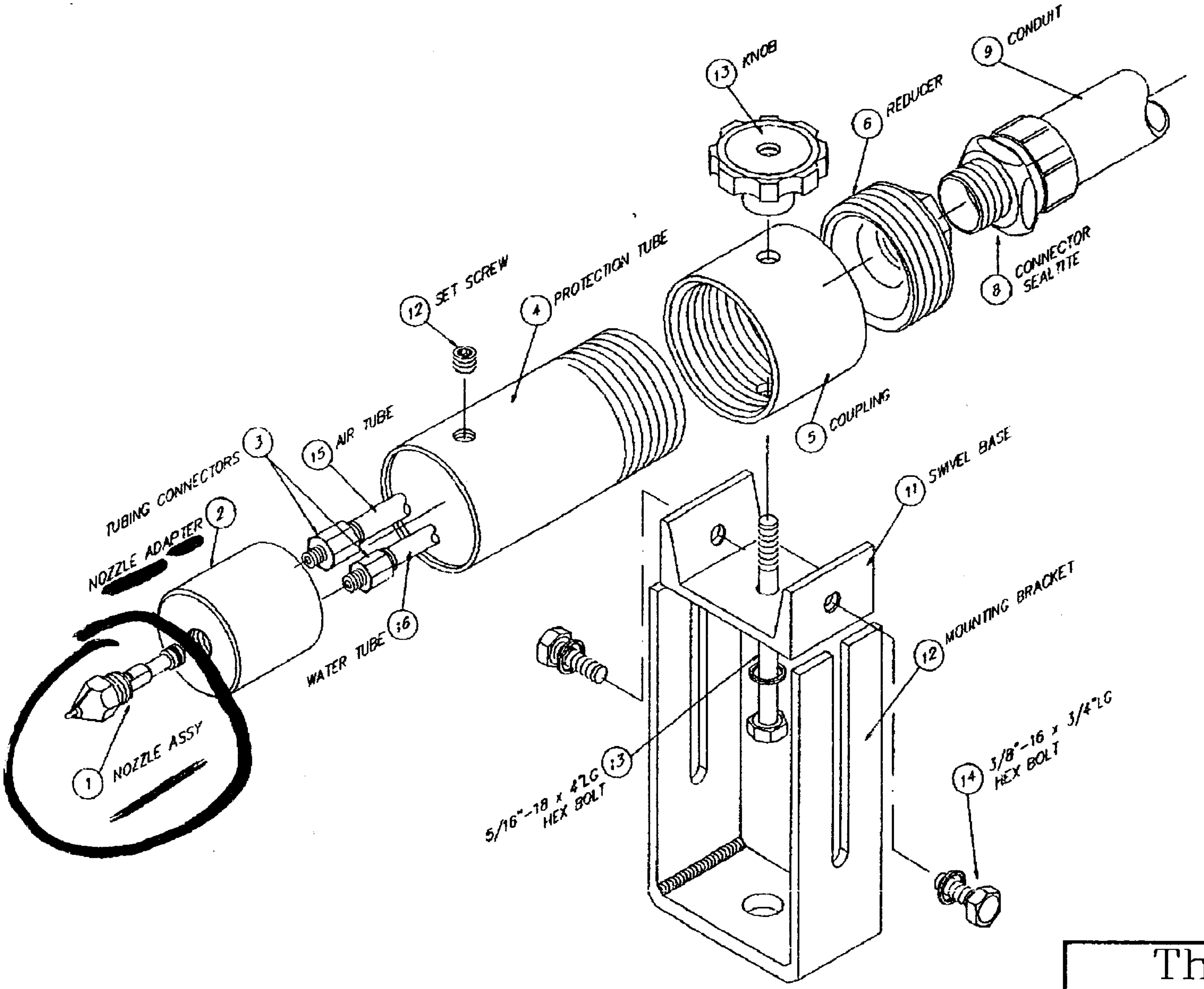


FIGURE 4

The Raring
Coporation

TITLE :
ARMOURED NOZZLE EXPOSION VIEW

CAD DWG NAME : ARMNOZ	DRAWN : ROSS DATE : 4/27/89	DWG NO : ADS—04	REV 0

SONIC
ENVIRONMENTAL SYSTEMS

FAX COVER SHEET

FAX NO: 610-701-3126 DATE: 1/20/95

TO: WESTON ATT: BRIAN RANDALL

YR REF: SONIC REF:

5 Page(s) to follow, excluding cover sheet.
Sonic Fax Number: (201) 882-1486

WE RECOMMEND OUR NOZZLES HIGHLY TO THIS APPLICATION BUT WOULD DECLINE TO DECLARE WHICH MODEL NUMBER BEST SUITS YOUR SYSTEM. WE MAKE GUARANTEES ON OUR NOZZLES WHEN THEY ARE INCORPORATED INTO OUR SYSTEMS BUT WOULD BE HESITANT TO GUARANTEE THEY WOULD BE SUCCESSFUL TO YOUR DESIGN/SPECS.

BEST REGARDS,
BRIAN HARTSHORN

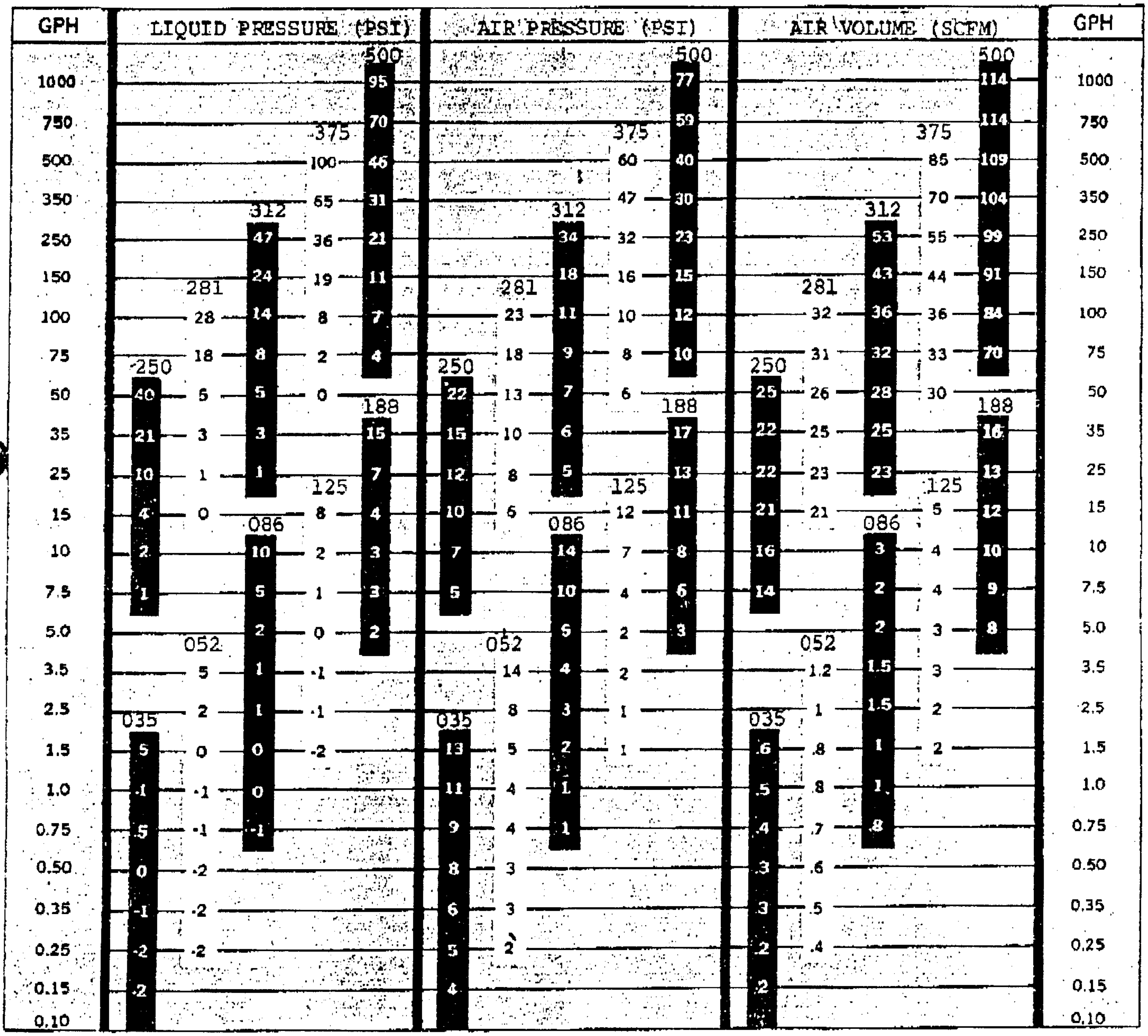
141 New Road ◆ Parsippany, NJ 07054 USA ◆ Phone: 201-882-9288 ◆ Fax: 201-882-1486

FLOW RANGE CHART OF SONICORE® ATOMIZING NOZZLES USED IN THE HIGH PERFORMANCE ATOMIZING SYSTEMS DESIGNED AND MANUFACTURED BY SONIC DEVELOPMENT CORPORATION

This chart is a guide to the flow ranges of Sonicore nozzles for the atomization of liquids. It lists liquid pressure, air pressure and air volume for ten of the most commonly used Sonicore atomizing nozzles. Sonicore part numbers are shown at the top of each bar. Values within each bar represent the appropriate pressure or volume at selected flow rates.

To select a nozzle, first, find the required liquid flow rate in gallons per hour (GPH). Determine which nozzle sizes will satisfy the desired flow rate. Since more than one nozzle size will meet your requirements, final selection will depend on (1) required flow range (2) available air or steam (3) available liquid pressure (4) properties of fluid being atomized.

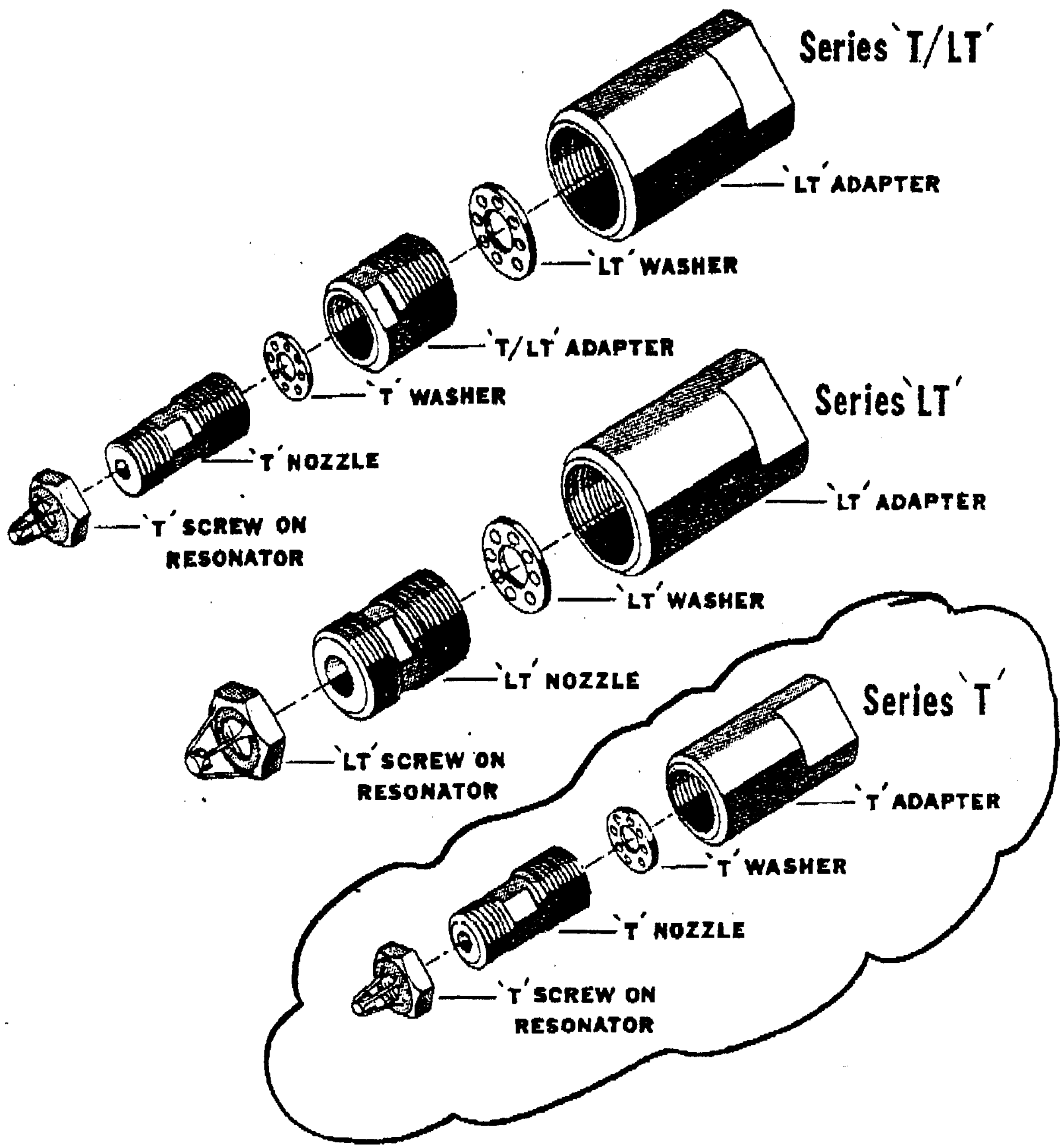
The values shown on this chart are based on the atomizing of oil. For droplet size information on the use of Sonicore nozzles in the atomization of water or fog generation, consult our Engineering Department.



sonic
DEVELOPMENT CORPORATION

SONIC ENVIRONMENTAL SYSTEMS
141 New Road, Parsippany
New Jersey, 07054 U.S.A
TEL 201-882-9288 FAX 201-882-1486

SONICORE® NOZZLES ARE COMPONENTS OF THE COMPANY'S ATOMIZING SYSTEMS AND ARE NOT SOLD SEPARATELY



CUSTOMER:

DRAFTSMAN
DATE
ENGR
DATE
APPROVAL
DATE
ASS'Y'S REQ'D
SCALE

SONIC DEVELOPMENT CORPORATION
ENVIRONMENTAL SYSTEMS
141 NEW ROAD • PARSIPPANY • NEW JERSEY • 07054

THIS DOCUMENT IS THE PROPERTY OF SONIC DEVELOPMENT CORPORATION, AND SHALL NOT BE ALTERED, COPIED, USED FOR MANUFACTURING OR COMMUNICATED TO ANY OTHER PERSON OR COMPANY WITHOUT OUR WRITTEN PERMISSION.

TITLE:

DWG. NO.:

REV

: January 20, 1989
NFL-D3

SONIC
ENVIRONMENTAL SYSTEMS

SONICORE® ATOMIZING NOZZLE
PRICE LIST

NOTE: PRICES ARE FOR STANDARD NOZZLES ONLY (NO DESIGN CHANGE NUMBERS)

HIGH FLOW "T" AND "LT" SERIES
(B) 316SS; (HC) HASTELLOY; (M) 310SS

MODEL	1-4	5-9	10-49	50-99	100+
188TB11	$396.00	$376.00	$334.00	$317.00	$297.00
250TB11	439.00	402.00	374.00	354.00	317.00
281TB11	470.00	458.00	417.00	378.00	332.00
312TB11 (12,13,15,16,19,20)	573.00	504.00	431.00	405.00	340.00
375TB11(12,13)	637.00	582.00	535.00	494.00	415.00
400LTB06	825.00	735.00	624.00	601.00	561.00
500LTB05	825.00	735.00	624.00	601.00	561.00

COMPONENTS PRICE LIST
HIGH FLOW "T" AND "LT" SERIES--RESONATORS
(F) STELLITE 6; (B) 316SS; (HC) HASTELLOY

FOR NOZZLE MODEL NO.	SONIC P/N	1-4	5-24	25-100+
188T	SESNR-188TB01	$158.00	$153.00	$133.00
250T	SESNR-250TB01	158.00	153.00	133.00
281T	SESNR-281TB01	158.00	153.00	133.00
312T	SESNR-312TF05	158.00	153.00	133.00
312T(SHROUD/SUPPORT)	SESNR-312TB30	231.00	222.00	194.00
375T	SESNR-375TF01	158.00	153.00	133.00
400LT	SESNR-400LTF00	209.00	201.00	175.00
400LT(SHROUD/SUPPORT)	SESNR-400LTF31	305.00	294.00	255.00
500LT	SESNR-500LTF10	209.00	201.00	175.00
500LT(SHROUD/SUPPORT)	SESNR-500LTF30SS	305.00	294.00	255.00

HIGH FLOW "T" AND "LT" ADAPTERS
(B) 316SS; (HC) HASTELLOY; (M) 310SS

MODEL	SONIC P/N	1-4	5-9	10-49	50-99	100+
"T"	SESNA-TB02	$404.00	$394.00	$385.00	$363.00	$332.00
"LT" TO "T"	SESNA-RTLTB01	550.00	528.00	509.00	501.00	493.00
"LT"	SESNA-LTB03	513.00	494.00	477.00	454.00	448.00
"LT"	SESNA-LTB09	513.00	494.00	477.00	454.00	448.00

NOTE: Contact Sonic directly for materials of construction other than 316 stainless steel.

1994

EDES: January 20, 1989

-D4

SONIC
ENVIRONMENTAL SYSTEMS

SONICORE® ATOMIZING NOZZLE
PRICE LIST

NOTE: PRICES ARE FOR STANDARD NOZZLES ONLY (NO DESIGN CHANGE NUMBERS)

"T" AND "LT" WASHERS
(B) 316SS; (HC) HASTELLOY; (G) BRASS

MODEL	SONIC P/N	ALL QUANTITIES
"T" WASHERS	SESNW-TG05	$88.00
"T" WASHERS	SESNW-TB02	98.00
"T" WASHERS	SESNW-TB04	98.00
"LT" WASHERS	SESNW-LTB02	98.00

"T" AND "LT" MISC.

MODEL	SONIC P/N	ALL QUANTITIES
"T" WRENCH	SESNX-TX00	$46.00
"LT" WRENCH	SESNX-LTX00	57.00

NOTE:

A. Quantity discounts may only be applied to the model and/or part number that prices shown are respective to. Combination of more than one model or part number in any given category to acquire a higher quantity discount will not be permitted.

B. All prices are "List" and shown in U.S. Dollars, F.O.B. Parsippany, NJ, U.S.A.

REQUEST FOR SPECIFICATION INFORMATION
USAEC DELIVERY ORDER NO. 0013
PRIME CONTRACT NO. DACA31-91-D-0079

DESCRIPTION	NOZZLE SPECIFICATION	INFORMATION REQUESTED	VENDOR DATA
Spray Angle	55-75 Degrees	Nozzle Model No.	
Flow Rate	0.25GPM		
Fluid Type	#2 Fuel Oil with 15% by WT Propellants		
Specific Gravity	0.9	Fabrication Point	
Viscosity	200 Centistokes	PARSIPPANY,	
Propellant Size	Less than 200 microns	NEW JERSEY	
Droplet Size Desired	30-50 microns	Leadtime Range	
Fluid Pressure	80 psig	STOCK	
		ITEMS	
Atomization Media	Air	Price Range	
Atomization Pressure	80 psig	ATTACHED	
		Quantity Price Break	
Type Nozzle	External Mix	ATTACHED	
Spray Pattern	Full Cone		
Material of Construction	304 ss	Applicability Range	

Background: The nozzle for this application should be capable of atomizing the liquid into a mist in the range of 30-100 micron particles. Liquid fuels must be vaporized before they can be burned. Oil burners generally use two steps to get the fuel into a combustible form-atomization plus vaporization. First the oil is atomized and the large surface area of the atomized particles is exposed to air and heat. The use of high pressure air is desirable to form tear droplets from the oil stream and propel them into the combustion space. The high velocity of oil relative to air produces the scrubbing action required for quick vaporization.

NOTE: Nozzles will be used for atomizing a mixture of fuel oil and propellants to be burned in a waste heat boiler. Metering orifices should be designed for minimum plugging of the propellant.

cwp