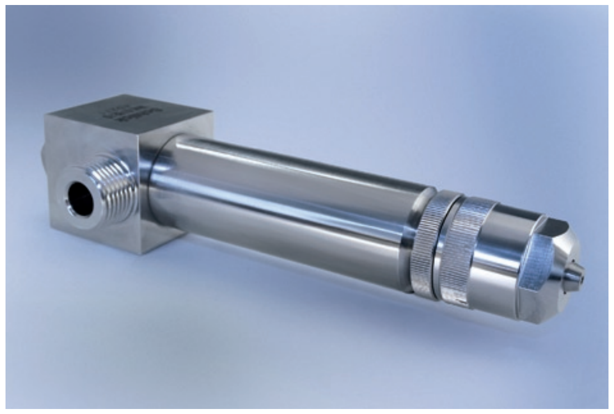
And It Burns!

Nozzle Systems Used in Combustion Processes

In the industry, heating oil and liquid residues are completely incinerated in order to produce or reclaim energy. Due to poor or incomplete combustion of the medium, soot is produced, and at the same time the emission values in the combustion chamber increase. With liquid fuels, combustion always takes place in the gas phase: The liquid fuel is first atomised, then vaporised, mixed with air, and finally burned in the gas phase. This article shows how atomisation can be influenced by various special nozzles.


Pressure nozzles


Two-substance nozzle with external mixing

In order to increase the surface area, and to enable the vaporisation and the mixing of the fuel vapour with air, the liquid is transformed into droplets. Nature strives to achieve the minimum surface area, so therefore a spray represents an unstable condition. The spray either evaporates, whereby the surface area reduces, or many small droplets combine due to collision, forming a few large drops, which again reduces the surface area.

Atomisation Requirements in the Combustion Process

For the complete combustion of the atomised liquid, the nozzle system must fulfil a number of boundary conditions. Experience shows that the volumetric average diameter of the droplets must not exceed a particle size of 40 µm. Depending on the operating rate, the quantity of liquid can be set between 10% and 100% for a given load, with a constant quality of atomisation. Due to the different characteristics specific to the material (density, viscosity, surface tension), the nozzle must be able to influence the quality of atomisation.

Technical Realisation of the Spray

If one considers the nozzle systems used for combustion processes, pressure nozzles or dual-material nozzles, one finds that the stated requirements are only fulfilled to a limited extent. We differentiate between pressure nozzles, nozzles with external mixing, and multi-material nozzles with internal mixing.

Pressure Nozzles

For pressure atomisers, hollow-cone nozzles are used. The expected size of the droplets depends on the cross section of the nozzle and the differential pressure applied to the liquid. The smaller the nozzle cross-section, and the higher the differential pressure applied to the liquid, the finer the spectrum of droplets. Due to this fact, only small liquid controlling ranges are possible (1:3 as a maximum). Hole cross-sections of less than 0.5 mm, and pressures up to 40 bar are necessary in order to achieve droplet sizes below 50 µm.

The materials are selected according to their chemical resistance, and the prevalent temperatures from 800°C to 1,250°C Schlick uses heat-resistant 1.4841 stainless steel. If the operating life of the burner gun is reduced by chemical corrosion, special materials (e.g. Hastelloy or Inconel) are used. Often, highly toxic liquid residues are incinerated. In this case, the burner guns are designed according to the Pressure Equipment Guideline 97/23/EG (Category II to IV). The required permanent operation of the nozzles makes it necessary that they are not prone to clogging.

The fluid is fed to the nozzle under pressure and enters the circulation chamber via tangential slits or holes. Here, the pressure energy is converted into rotational or kinetic energy. A rotating film of liquid is formed around a core of air, which leaves the exit hole as a hollow-cone jet, which disintegrates into a multitude of fine droplets after overcoming surface tension.

The quality of atomisation and the droplet spectrum depend on the diameter of the hole, the pressure, the dispersion cone, the density, the viscosity and the surface tension. Due to the necessary swirl plate, with very small helical slits or holes inside of the nozzle, reliable continuous operation is no longer achieved.

Multi-substance Nozzles

One or more of the liquids fed to the nozzle is torn into droplets by one or more gaseous atomisation media (air, steam, etc.). We generally differentiate between internal and external mixing, according to where the liquid and the gas meet. Because of the better regulating behaviour, advantages with regard to clogging, wear, distribution of droplet size etc., Schlick usually employs external mixing, although at present, patented Schlick developments with improved internal mixing and without these disadvantages are in the course of being tested.

Two-substance Nozzles with External Mixing

In external mixing systems, the liquids and the atomising medium (usually compressed air) are thoroughly mixed shortly after leaving the front face. The exit cone for two-substance nozzles is approximately 30° to 40°. With a volumetric average droplet size of 40 µm, the liquid residue or heating oil is completely incinerated after a distance of 1,000 to 2,000 mm. Due to the tube-in-tube design, the outside layer of compressed air protects the liquid within. This prevents, premature vaporisation due to the high temperatures, and therefore ensures a continuous feed quantity.

Due to the separated feed, this nozzle technology is considerably less prone to clogging than two-substance nozzles with internal mixing. The desired droplet size can be individually adjusted via the mass-ratio of air to liquid. In order to operate with large controlling ranges of liquid, it is necessary to integrate a pre-atomisation at the liquid side, whose flow characteristics prevent clogging. A triple-groove swirl plate was developed, which has a lesser deviation angle compared with other liquid swirl plates. For liquid control ranges of 1:5, a pressure control range of 1:25 is necessary. In practice, the nozzle is designed for a minimum throughput of 0.3 bar and a maximum throughput of 7.5 bar. At present there are five model variants, which cover the throughput range from 1 l/h to 1500 l/h.

Two-substance Nozzle with Internal Mixing

The fundamental concept of the development was the modification of the geometry of the internal mixing zone, in particular to avoid fittings prone to clogging, and to achieve a more thorough mixing of the atomising air and the liquid. This makes it possible to reduce the amount of air which the nozzle requires to produce a constant droplet size, and therefore to minimise the penetration power of the spray. As well as this, the configuration of the holes was designed to greatly increase the spray angle. The stream of liquid impinges centrally onto the tip of a cone in the mixing chamber. The resulting film is then disintegrated into individual drops by the atomising air. The flanks of this cone taper into the nozzle holes. The nozzle holes are inclined to match the angle of the cone. Liquid residues are therefore blown out in a defined manner, and the surface impinged upon is larger. The entire removable front section of the nozzle is referred to as the air cap.

Three- and Four-substance Nozzles

For combustion processes in which heating oil, waste water and liquid residues are burned simultaneously, three- and four-substance nozzle systems with external mixing are used. Schlick multi-substance units provide the possibility of very fine atomisation of several liquids at the same time, using one nozzle, and only one atomising medium (air, gas or steam). At the same time, thorough mixing of the media takes place at the nozzle exit. There is also the possibility of charging one channel with air, gas or steam, in order to create a greater exchange area between the atomising medium and the liquid. Reactions between the different liquids inside the nozzle are ruled out, as due to the external mixing of the media, they only meet at the exit of the nozzle. Multi-substance nozzles generate a full-cone spray pattern.

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Atomisation in the Combustion Chamber

In the combustion of exhaust gases and residual liquids, the nozzles are mainly used in two fields: namely for the injection of residual liquids into the combustion zone or the combustion chamber, and for injection of reduction media for selective non-catalytic reduction (SNCR) in a reaction chamber, in order to convert nitrous oxides into non-hazardous nitrogen.

In both cases, in order to achieve a good reaction result, it is necessary to achieve the most even distribution of the liquid as possible over the available chamber cross-section, together with the finest possible dispersion of the liquids. The incineration of liquids which provide energy is carried out in the highly turbulent swirl burner, the combustor. Due to the type of air supply and the form of the outflow unit, an axial motion is created, which is superimposed on the swirl flow. The result is a thorough mixing of the hazardous substances with the process air/ fresh air and the auxiliary fuel.

The rotary flow created in such a manner that it:

- brings about an extremely rapid mixing of the reactants in the highly turbulent regions, and therefore enables a complete conversion of the hazardous substance and the fuel in the smallest possible space.
- the combustion process is stabilised with regard to flow, and therefore ensures reliable combustion behaviour even under extreme conditions.

The fine dispersion of the residual fluids in the swirl field also ensures the rapid and residue-free conversion of the hazardous substances. The energy content of the liquids compensates for the fuel consumption. If the energy content is high enough, the use of an auxiliary fuel can be dispensed with.

Boundary Conditions for Complete Combustion with the Nozzle System

- The volumetric average droplet diameter should be between 20–40 µm
- Homogeneous distribution of fluid over the entire cross-section
- Liquid control range up to 1:10
- Temperature resistant
- Corrosion resistant
- Not prone to clogging, in order to ensure uninterrupted operation
- Maximum contact area between the spray and the combustion air
- Even distribution of velocity with sufficient exit velocity for optimum utilisation of the combustion chamber geometry.