DESIGNING A VENTURI SCRUBBER WITH ADJUSTABLE THROAT SECTION

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The suspended particle trapping performance in a Venturi scrubber is determined primarily [1, 2] by the hydraulic resistance, which is chosen to suit the particle size and cleaning specifications. In turn, that resistance is dependent mainly on the gas flow speed in the throat of the Venturi tube, so if the gas flow speed is variable, a necessary condition for the required performance is maintaining the optimal gas speed in the throat section.

It has become common therefore to use scrubbers with adjustable throat section [1–4]. This organization and the State Industrial Gas Cleaning Institute have devised two modified scrubber designs with adjustable annular throats [3, 4]: containing a conical body designed to carry approximately up to 50,000 m³/h of gas and one with an elliptical body for gas flow rates from 50,000 to 500,000 m³/h.

We now consider the method of designing the Venturi scrubber with conical body (Fig. 1). The conical part is set in the convergent nozzle, and the rod bearing it slides within the jacket. This removes the cone unit from the zone of contact with a dusty gas flow and liquid. The irrigating liquid is injected into the expanding cone (through a truncated cone) at the upper end of that cone. A centrifugal droplet trap is used built into the body to separate the irrigating liquid. Four standard sizes of such Venturi scrubbers have been devised (Table 1).

The data show that the scrubber with conical insert maintains a constant gas speed in the working throat section as the relative gas flow rate varies over the range from 1.3 to 1.8.

The following expression gives the hydraulic resistance $\Delta p$ (Pa) needed for the dust trapping:

$$K = \Delta p + p_l m,$$

where $K$ is the energy loss needed for removing dust from 1000 m³ of gas in kJ, $p_l$ is the pressure of the liquid injected into the scrubber in Pa, and $m$ is the specific irrigation in m³/m³.

The $p_l$ in a Venturi scrubber is usually 0.1–0.2 MPa, while $m$ varies from 0.5 to 3.5 liters/m³ [2]. Then the second term on the right in (1) is small (from 50 to 700 Pa) and has no substantial effect on $\Delta p$, which can be taken as equal to $K$ for practical calculations, particularly for finely divided particles.

The following is [1, 3] the hydraulic resistance of a Venturi scrubber with built-in droplet trap:

$$\Delta p = \Delta p_s + \Delta p_l,$$

where $\Delta p_s$ is the hydraulic resistance of the unirrigated scrubber in Pa and $\Delta p_l$ is the hydraulic resistance due to the irrigating liquid in Pa.

The hydraulic resistance is as follows [4] for a dry scrubber with conical flow section:

$$\Delta p = 0.08M^{-0.643} \frac{v_g^2 p_g}{2},$$

where $M = v_g/v_{ss}$ is the Mach number, $v_g$ is the speed of the gas flow in the throat (usually calculated from the pressure and temperature) at the exit of the gas from the equipment in m/sec, $v_{ss}$ is the speed of sound (at the negative pressures occurring...
in the scrubber throat, one takes \( v_{ss} = 386.5 \text{ m/sec} \), and \( \rho_g \) is the gas density (under the conditions at the exit from the equipment) in kg/m\(^3\).

With conical flow insert:

\[
\Delta p_l = 0.081 - 0.08 \left( \frac{v_g}{386.5} \right)^{-0.643} m^{-0.502} \frac{\rho_l m}{2},
\]

where \( \rho_l \) is the density of the irrigating liquid in kg/m\(^3\).

The liquid flow rate \( V_l \) (m\(^3\)/h) is constant in a scrubber with adjustable throat. When one calculates the working parameters, one must allow for the variation in \( m = V_l / V_g \), in which \( V_g \) is the gas flow rate for the conditions at the outlet from the apparatus in m\(^3\)/h, as there is variation in the gas flow rate.

With \( v_g = V_g / F \), in which \( F \) is the working area of the annular throat in m\(^2\), we multiply together the constant quantities to put (2) as

\[
\Delta p = 2.229 \cdot 10^{-6} \left( \frac{v_g}{F} \right)^{1.357} (12.346 \rho_g + m^{0.498} \rho_l).
\]

The error in this empirical formula (5) does not exceed 1 Pa.

When one chooses the variable-throat scrubber, the following quantities are known: \( \Delta p \) from (1), the maximal and minimal values of \( V_g \), and \( \rho_g \) and \( \rho_l \). It is thus necessary to determine \( F \) and \( m \).

It is found [2] that \( m \) varies from 0.5 to 3.5 liters/m\(^3\). As excessive consumption of liquid is undesirable, we take \( m = 1 \cdot 10^{-3} \text{ m}^3/\text{m}^3 \) for the maximal gas flow \( V_{max} \). Then for \( V_{min} \) we have

\[
m = V_{max} (1 \cdot 10^{-3}) / V_{min}.
\]

We substitute these values of \( m \) into (5) and transform it to give \( F \) to get two expressions giving the maximal working section \( F_{max} \) and minimum one \( F_{min} \) of the adjustable throat:

\[
F_{max} = 5.421 \cdot 10^{-6} V_{max} \left( \frac{\Delta p}{385.05 \rho_g + \rho_l} \right)^{-0.737};
\]

\[
F_{min} = 5.421 \cdot 10^{-6} V_{min} \left( \frac{\Delta p}{385.05 \rho_g + \frac{V_{max}}{V_{min}} \rho_l} \right)^{-0.737}.
\]

### TABLE 1

<table>
<thead>
<tr>
<th>Standard scrubber</th>
<th>Area of working throat section, m(^2)</th>
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<tbody>
<tr>
<td></td>
<td>max</td>
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<tr>
<td>SV 150/90-800</td>
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<tr>
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<td>SV 400/250-2200</td>
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