FLOW RATE CORRECTION FOR THE MODEL 3790 ENGINE EXHAUST CONDENSATION PARTICLE COUNTER (EECPC)

APPLICATION NOTE EECPC-001

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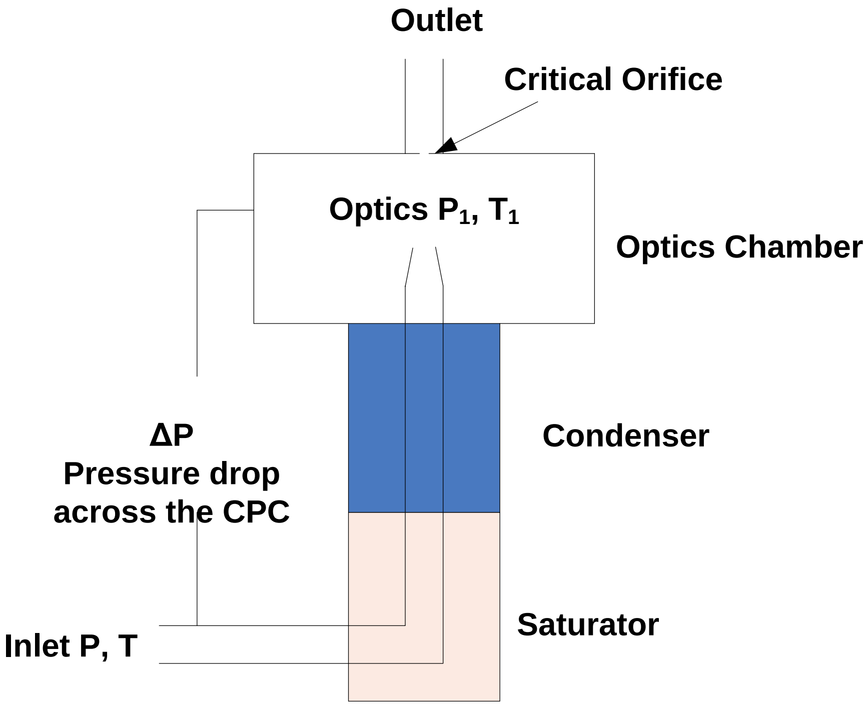

The critical orifice in the Engine Exhaust Condensation Particle Counter (EECPC) is selected such that the inlet flow is 1 lpm at TSI standard conditions (T_0=294.3 K and P_0=101.3 kPa) when the EECPC is warmed up (T_1 = 313.2 K). Typically the pressure drop from inlet to the nozzle outlet is 2.3 kPa. Therefore at TSI standard condition, the pressure upstream the critical orifice is P_0=101.3 – 2.3 = 99.0 kPa, and the temperature upstream of the orifice is T_1 = 313.2 K (optics temperature).

Next we calculate the volumetric flow rate at the critical orifice inlet, when the EECPC inlet conditions are T_0=294.3 K and P_0=101.3 kPa. Because the mass flow rate at the inlet is the same as that at the orifice Q_1, we have

$$1\times\frac{P_0}{T_0}=Q_1\times\frac{P_0-\Delta P}{T_1}.$$

Then $$Q_1=1\times\frac{P_0}{T_0}\times\frac{T_1}{P_0-\Delta P}=1\times\frac{101.3}{294.3}\times\frac{313.2}{99.0}=1.089\ lpm$$

This is the volumetric flow rate set by the orifice, which ideally will always be constant, independent of EECPC inlet temperature and pressure.

When the EECPC inlet pressure and temperature change to P and T, the volumetric flow rate at the orifice is still 1.089 lpm, but the volumetric flow rate at the EECPC inlet will change slightly. Again, according to constant mass flow rate, we can calculate the inlet volumetric flow rate as

$$Q\times\frac{P}{T}=Q_1\times\frac{P-\Delta P}{T_1}.$$

Then $$Q=Q_1\times\frac{P-\Delta P}{T_1}\times\frac{T}{P}=1\times\frac{P_0}{T_0}\times\frac{T_1}{P_0-\Delta P}\frac{P-\Delta P}{T_1}\times\frac{T}{P}=1\times\frac{P-\Delta P}{P_0-\Delta P}\times\frac{T}{T_0}\times\frac{P_0}{P}.$$

The flow rate at standard conditions (273.2 K and 101.33 kPa) is then

$$Q_{std}=1\times\frac{P-\Delta P}{P_0-\Delta P}\times\frac{T}{T_0}\times\frac{P_0}{P}\times\frac{P}{T}\times\frac{T_{std}}{P_{std}}=1\times\frac{P-\Delta P}{P_0-\Delta P}\times\frac{P_0}{T_0}\times\frac{T_{std}}{P_{std}}.$$

In summary, when the EECPC inlet pressure is P and temperature T, the **volumetric flow rate** at the inlet is

$$\boxed{Q(lpm)=1\times\frac{P-\Delta P}{P_0-\Delta P}\times\frac{T}{T_0}\times\frac{P_0}{P}\quad,}$$

and the **flow rate at standard conditions** (273.2 K and 101.33 kPa) is

$$\boxed{Q_{std}(slpm)=1\times\frac{P-\Delta P}{P_0-\Delta P}\times\frac{P_0}{T_0}\times\frac{T_{std}}{P_{std}}\quad,}$$

where P_0 = 101.3 kPa, T_0=294.3 K, P_{std} = 101.33 kPa, T_{std}=273.2 K, ΔP is the nozzle pressure which can be read from the EECPC.

Note that ΔP is relatively small compared to P or P_0 in most cases. Then the volumetric flow rate is independent of the inlet pressure, but proportional to the inlet temperature. The standard flow rate, on the other hand, is proportional to the inlet pressure, but independent of the inlet temperature because the optics temperature is constant.

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