<u>WATER INJECTION CALCULATIONS</u>

15 Oct. 1998

<u>SAE J-2051</u>

Basis agreed at the SAE meeting of 27 Aug. 1998:

- Water injection to be 5 times the amount required to saturate 70°F air at the test pressure (90 psig), when flowing air at the test cycle rate (300 cpm), to fill and empty twice the test chamber volumes, in a 4 hour period, once a day.

Equations for specific and relative humidity are:

$\gamma = (0.622)\, p_w / p_d$ (1)

$\phi = \gamma\, p_d / (0.622)\, p_s$ (2)

Where:

γ = specific humidity

ϕ = relative humidity

p_d = partial pressure of dry air, abs.

p_w = partial pressure of water vapor, abs.

p_s = saturation pressure of water vapor, abs.

If water is to saturate the air, the relative humidity is 100%. Then, $\phi = 1.00$ and

equation (2) becomes: $(0.622)\, p_s = \gamma\, p_d$

equation (1) becomes: $(0.622)\, p_w = \gamma\, p_d$

and $p_s = p_w$ at saturation.

From steam tables for saturation at 70° F: $p_s = 0.3631$ psia $= p_w$

From Dalton's law for partial pressures:

$p = p_d + p_w$ where: p = total pressure of the mixture, abs.

$P_d = p - p_w$ = (90 psig + 14.696 atmos. press) - 0.3631 = 104.33 psia = p_d

Returning to equation (1):

$\gamma = (0.622)\, p_w / p_d$ = (0.622) (0.3631) / (104.33) = 0.002165 # H_2O / # dry air (3)

From the perfect gas law: p v = R T and 1/ v = weight density

The weight density of dry air in the mixture is:

$$weight\ density = \frac{p_d}{RT} = \frac{(104.33\frac{\#}{in^2})(144\frac{in^2}{ft^2})}{(53.34\frac{ft}{{}^\circ R})(529^\circ R)} = 0.5324\frac{\#\ \text{dry air}}{ft^3}$$

Combining this with equation (3), the amount of water vapor in the mixture is:

(wv) = (0.002165 # H_2O/ # dry air) (0.5324 # dry air /ft^3) = 0.001153 # H_2O /ft^3

(Note: For higher elevations where the atmospheric pressure is only 12.0 psia, the calculation for the amount of water vapor in the mixture results in the same value.)

The flow rate of the mixture is (one test chamber in each port, and twice each volume):

Q = 2 (2 V cc) (300 cpm) where: V = volume of one test chamber

For the requirement of 5 times the saturation amount in 4 hours, the total amount of water injected becomes:

$$\text{W} = \frac{5(\text{wv})\text{Qt}}{(\text{density of water})} = 5(0.001153\frac{\#\,\text{H}_2\text{O}}{\text{ft}^3})(4\text{V cc})(300\ \frac{\text{cycles}}{\text{min}})(4\text{hr})(\frac{1\ \text{ft}^3}{62.4\ \#})(\frac{60\ \text{min}}{1\ \text{hr}})(\frac{1\ \text{litre}}{1000\ \text{cc}})$$

W = (0.0266)(V) liters where V is in cc units.

It is proposed to modify the test chamber volumes of table 5 in the present SAE standard by rounding off the metric volumes to Renard series values. Then a modified table 5, with new water quantities to be injected in a 4 hour period becomes:

Automotive Series	ISO Series	Test Chamber Volume cc	Test Chamber Volume in^3	Water Injected liters in 4 hrs.
075	1	16	(0.98)	0.5
125	2	50	(3.05)	1.3
250	3	100	(6.10)	2.7
500	4	200	(12.2)	5.3
1000		320	(19.5)	8.5