

All About Air #20 **DECAY WITH THE KREHER FORMULA** – WHITE PAPER by Thomas W. Kreher, Applied Pneumatic Controls ©

**If you file tips and time savers here is one you will want to keep.**

A reservoir or storage tank with compressed air discharged to atmosphere will vacate to zero in 5 equal time constants. With an orifice of known diameter we can calculate the initial flow rate. If this rate remained unchanged the time required to vacate the reservoir at the initial pressure and flow rate is the “relaxation time” or time constant,  $T_k$ . This time constant,  $T_k$ , is 1/5 of the time required to vacate the reservoir to zero.

**Assign the following conditions;**

V cu ft Reservoir = 3 Cubic Feet (22.44 gallons).  
Initial Pressure = 100 PSIG = 114.7 PSIA  
Orifice Diameter = .1834

My constant crunched orifice formula to determine the initial flow from the data above is:

$$14.5 \times D^2 \times (100 + 14.7) = 55.9 \text{ SCFM}$$
$$55.9 \text{ SCFM} / 60 \text{ sec/min} = .9317 \text{ SCFS}$$

**.9317 SCFS = initial flow.**

With 3 cubic feet x the Compression Factor,  $C_f$  of  $100 / 14.7 = 6.8^*$   
 $3 \times 6.8 = 20.4 \text{ SCF initial volume.}$

**\*Hold it! If you are ready to set me straight and say the compression factor should be  $(P_1 + 14.7) / 14.7 = 7.8$ , let me explain. When the reservoir has discharged the compressed air and the gauge reads zero there will still be one atmosphere, 14.7 PSIA remaining in the tank. Therefore we are only dealing with the delta volume shown by gauge pressure and  $100 \text{ PSIG} / 14.7 = 6.8$  (Compression Factor).**

**The initial volume divided by the initial flow rate is the Relaxation Time,  $T_k$ .**

Then  $20.4 \text{ SCF} / .9317 \text{ SCFS} = 21.9 \text{ Sec.} = T_k$ .

$21.9 \text{ Seconds} = T_k$ .

$T_k \times 5 = 109.5 \text{ seconds.}$

This is the total time to vacate 20.4 SCF at 100 PSIG to 0 PSIG with an effective orifice of .1834 Dia.  
(FYI the same as a  $C_v$  of 1)

For your amusement and amazement, the pressure at the relaxation time  $T_k$  will be  $.3678 \times P_1 \text{ PSIG}$ . In this case that is  $.3678 \times 100 \text{ PSIG} = 36.78 \text{ PSIG}$ .

The remaining pressure at two time constants, .438 seconds is  $P_1 \times .3678^2$  or  $100 \times .3678 \times .3678 = 13.53 \text{ PSIG}$ .

This follows for three, four and five time constants with the pressure being 4.98 PSIG at 3  $T_k$ , 1.83 PSIG at 4  $T_k$  and .67 PSIG at the end of five time constants.

The formula for ©  $T_k = (V \text{ cu ft} \times P_1 \text{ PSIG}) / 3.55 \times D^2 \times (P_1 \text{ PSIG} + 14.7)$

Select any time T in seconds up to 5 times  $T_k$  and substitute it for “T” to get the remaining pressure at that time. The formula below is the standard exponential “decay” formula adapted to pressure decay by deducing the value for  $T_k$ , the Relaxation Constant, thus:

**The Kreher Formula.**

$$© P_2 \text{ PSIG} = P_1 \text{ PSIG} \times e^{-T/T_k}$$

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