LASICO APPLICATION NOTES

No. 112085

**WHAT TYPE OF CIRCULAR CHART PLANIMETER,
RADIAL OR SQUARE ROOT, SHOULD BE USED FOR GREATEST ACCURACY ?**

This application note presents a simplified proof, that for greatest accuracy in the computation of flow, a square root planimeter should be used to measure square root terms of the flow equation. These square root terms are static pressure and differential pressure. A similar proof, not included in this note, can show that a radial planimeter should be used to measure first order terms, i.e. temperature,. in the flow equation.

The type of circular chart used, linear or square root, has no bearing on the type of planimeter that should be employed.

The approach used for this proof is to first compute total and average flow for a simplified plot of static and differential pressures. The measurement lines are simple enough so that they can be read exactly by eye; a measurement is not necessary!
Also the chart is simple enough so that it is obvious that the answer is correct.

Next, total and average flow are computed on the basis of square root planimeter readings; then they are computed again on the basis of radial planimeter readings. The results, as well as the structure of the equations, are then compared and the conclusions drawn.

A simplified 24 hour circular chart is shown in figure 1. Plotted on it a static pressure line and a solid differential pressure line. The static pressure line is constant at 50% of full scale for the entire 24 hour chart duration. The differential pressure is constant at 40% of full scale from noon until 6 PM, constant at 80% from 6 PM until midnight, zero from midnight until 6 AM and then constant at 20% of full scale from 6 AM until noon.

Assume that full scale static pressure and full scale differential pressure are 100 psig and 100 inches-of-water, respectively.
If the two measurement lines were plotted on a linear (radial) chart, then the outer circle would naturally be labeled 100. If the two measurement lines were plotted on a square root chart, then the outer circle would be labeled 10, the square root of 100. Each segment of the measurement lines of the example in Figure 1 are labeled with the linear (radial) chart reading, as well as the square root chart reading, shown in parentheses.

Next assume that our system has an orifice flow constant of 123. This orifice flow constant consists of the product of the basic orifice factor, Reynold's number factor, expansion factor, pressure base factor, temperature base factor, etc. The average barometric pressure will be assumed to be 14.7 psia.

The equation for flow rate is:

$$Qh = C' \sqrt{hw}\ \sqrt{pf} = C' \sqrt{hw}\ \sqrt{pf} \; ; \quad (1)$$

where

Qh	=	flow rate in cu.ft./hr
C	=	orifice flow constant
hw	=	differential pressure in inches of water
pf	=	absolute static pressure, psia

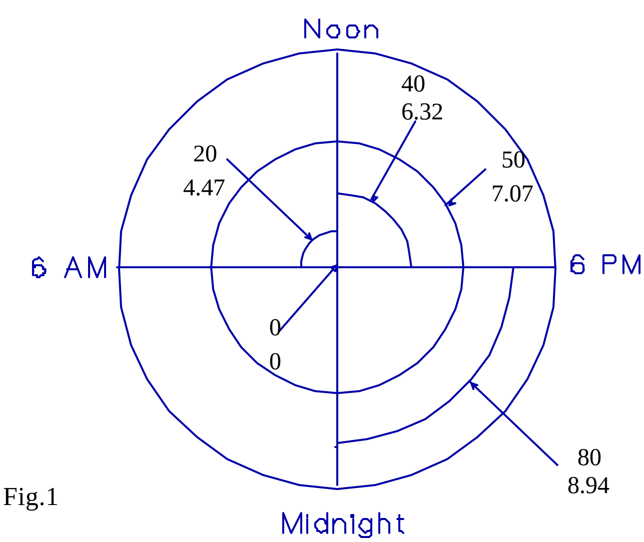

Fig.1

The TOTAL FLOW is the flow rate multiplied by the period of time during which flow is required. For example, if the flow rate is 50 cu.ft./hr, then the total flow during an 8 hour period is (8)(50)=400 cu. ft.

The total flow during the 24 hour period of the chart shown in Fig.l is exactly equal to the sum total of the flows during each 6 hr. period that the differential and static pressures are each constant. From noon to 6 PM the flow rate is

Q = C ŌhwŌpf = 123Ō40Ō64.7 = 6257.3 cu.ft./hr (2)

where pf = 50 psia + 14.7 psia = 64.7 psia;

and the flow is **F = (6 hrs) (6257.3 cu.ft./hr) = 37,543.8 cu.ft.** (3)

From 6 PM to midnight the flow rate is:

Q= 123 Ō80 Ō 64.7 = 8849.2 cu.ft./hr (4)

and the flow is:

F (6 hrs) (8849.2 cu.ft./hr)= 53,095.0 cu.ft. (5)

From midnight to 6 AM, the flow rate is

Q= 123Ō0 Ō64.7 = 0 cu.ft./hr (6)

and the flow is

F (6 hrs) (0 cu.ft./hr) = 0 cu.ft (7)

From 6 AM to noon, the flow rate is

Q= 123Ō20Ō64.7 =4424.6 cu.ft./hr (8)

and the flow F is

F= (6 hrs) (4424.6 cu.ft./hr) = 26,547.5 cu.ft. (9)

Thus the total flow for the 24 hr period is the sum of the flows during each period:

F (TOTAL) = 37,543.8 + 53,095.0 + 26,547.5 = 117,186.3 cu.ft. (10)

and the average flow rate during this period is

$$Q = \frac{\textbf{117.186.3 cu.ft.}}{\textbf{24 hrs}} = \textbf{4882.8 cu.ft / hr} \qquad (11)$$

Our measurement chart is. simple enough so that we know, without any doubts, that this answer is correct.

If the average flow rate over 24 hours were calculated from a single rather than 4 equations, the new equation would be:

$$\mathbf{Q} = \frac{(6)\,(100)\sqrt{40}\sqrt{64.7} + (6)\,(100)\sqrt{80}\sqrt{64.7} + (6)\,(100)\sqrt{0}\sqrt{64.7}}{24} + \frac{(6)\,(100)\sqrt{20}\sqrt{64.7}}{24}\ \text{cu.ft./ht} \qquad (12)$$

or, by factoring out certain terms, it could be rewritten as

$$Q = 123\sqrt{64.7}\ \frac{6\sqrt{40} + 6\sqrt{80} + 6\sqrt{0} + 6\sqrt{20}}{24} = 4882.8\ \text{cu.ft./hr} \qquad (13)$$

which is the same answer as computed before.

If a square root planimeter were used to trace the differential pressure measurement line, then its final answer Rsrp, because of the physical shape of the instrument curve, would be

$$\mathbf{Rsrp} = \frac{6\sqrt{40}}{24} + \frac{6\sqrt{80}}{24} + \frac{6\sqrt{0}}{24} + \frac{6\sqrt{20}}{24} = \frac{6\sqrt{40} + 6\sqrt{80} + 6\sqrt{0} + 6\sqrt{20}}{24} = 4.935; \qquad (14)$$

This " average of square root values" multiplied by the static pressure and orifice flow constant would give

$$\mathbf{Q} = 123\sqrt{64.7}\,(4.935) = 4882.8\ \text{cu.ft./hr} \qquad (15)$$

which is the same answer as that in equation 11 and hence is correct.

If, on the other hand, a radial planimeter were used to trace the differential pressure measurement line, then its final answer Rrp, also because of the shape of the instrument curve, would be

$$Rrp = \frac{6(40) + 6(80) + 6(0) + 6(20)}{24} = 35.0 \qquad (16)$$

and the square root of Rrp would be

$$\sqrt{Rrp} = \sqrt{35} = 5.916 \qquad (17)$$

This " square root of the average values" multiplied by the orifice flow constant and the static pressure gives

$$\mathbf{Q} = 123\sqrt{64.7}\,(5.916) = 5853.2\ \text{cu.ft./hr} \qquad (18)$$

which is different from the value in equation 11 that we know to be correct, and is hence incorrect.

In conclusion, for best accuracy, a square root planimeter should be used to measure the square root terms, static and differential pressure, of the flow equation.
A radial planimeter should be used only to measure the first-order terms, temperature, of the flow equation.

We believe this note to be accurate; however the user must assume responsibility as to his or her agreement or disagreement with the results. We would appreciate any comments regarding this note.

LASICO

LOS ANGELES SCIENTIFIC INSTRUMENT CO. INC.
2451 Riverside Dr., Los Angeles, CA 90039, U.S.A.
PHONE: (323) 662-2128, FAX: (323) 662-0904
E-mail : lasico@worldnet.att.net **Website** : www.lasico.com