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Rueter, F.

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PREPARED BY F. Rueter

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INTRODUCTION

It frequently happens that vertical and horizontal traverses (e.g. total pressure traverses) are made with the measuring points chosen in a more or less arbitrary manner, without making any effort to locate them at the centres of sections of equal area. A simple arithmetic average of the pressures may then give a seriously distorted idea of the average pressure in the duct, and it is necessary, instead, to weight each pressure by the area it represents.

This note describes a method of area-averaging such a set of readings taken in an arbitrary rectangular duct, and using a Hewlett-Packard 9820-A calculator to perform the arithmetic. Clearly, any other programmable calculator or computer could be used instead, and with minor modifications, the method is equally applicable to a circular duct, or to a rectangular one in which only a single traverse is recorded.

Analysis

Figure 1 shows a pair of diagonals dividing the rectangular duct section into four quadrants, numbered arbitrarily from 1 to 4. Each quadrant is treated as a separate entity, and is divided into as many trapezia as there are measuring points within it by the right bisectors of the lines joining adjacent pairs of points.

For clarity, the first quadrant is reproduced to enlarged scale in Figure 2, which also shows the notation used in what follows.

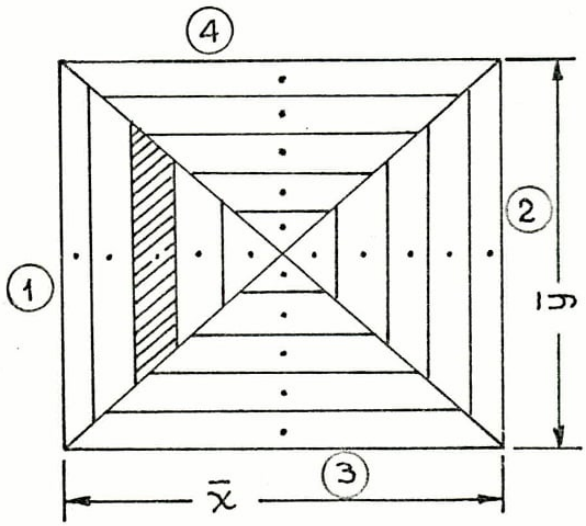

FIGURE 1

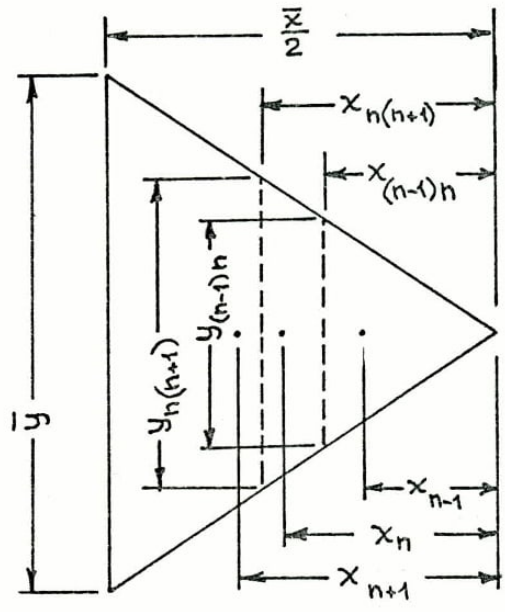

FIGURE 2

Clearly, the area of the n th segment,

$$A_n = (x_{n(n+1)} - x_{(n-1)n}) \cdot \frac{y_{n(n+1)} + y_{(n-1)n}}{2} \qquad (1)$$

Also, $y = 2x \cdot \frac{\overline{y}}{\overline{x}}$

and $x_{n(n+1)} = \frac{x_n + x_{n+1}}{2}$ giving $y_{n(n+1)} = \frac{\overline{y}}{\overline{x}} \cdot (x_n + x_{n+1})$

Similarly, $x_{(n-1)n} = \frac{x_n + x_{n-1}}{2}$ so that $y_{(n-1)n} = \frac{\overline{y}}{\overline{x}} \cdot (x_n + x_{n-1})$

Substituting in (1):

$$A_n = \frac{1}{2}(x_n + x_{n+1} - x_n - x_{n-1}) \cdot \frac{1}{2} \cdot \frac{\overline{y}}{\overline{x}} \cdot (x_n + x_{n+1} + x_n + x_{n-1})$$

$$= \frac{\overline{y}}{4\,\overline{x}} \cdot (x_{n+1} - x_{n-1}) \cdot (2x_n + x_{n+1} + x_{n-1}) \qquad (2)$$

For the first entry (n=1), n-1 = 0. This will be the apex of the triangle forming the first area, so that $x_0 = 0$. For the last entry in the quadrant, $n = \overline{n}$, and $x_{\overline{n}(\overline{n}+1)}$ must be equal to $\overline{x}/2$. To satisfy this condition,

$$x_{\overline{n}+1} = \frac{\overline{x}}{2} + (\frac{\overline{x}}{2} - x_{\overline{n}})$$

$$= \overline{x} - x_{\overline{n}}$$

Program:

Given the dimensions of the duct $\overline{x}$ and $\overline{y}$, the number of readings $\overline{n}$ on each semi-traverse, the distance x_n of each measuring

point from the centre line, and the value P_n of each reading, it is possible to construct a repetitive program based on Equation (2) to compute the area-averaged value of all the P_n readings. The program evaluates the area of each trapezium in turn, multiplies this by its appropriate pressure reading, and accumulates the products. After completion of calculations for the horizontal traverse (second quadrant) the values of $\overline{x}$ and $\overline{y}$ are interchanged, effectively rotating the duct 90° clockwise to repeat the procedure for the second traverse. After completing the second traverse, the required average is found by dividing the accumulated products of area and pressure by the total cross-sectional area of the duct.

A listing of this program written for the H-P 9820-A calculator follows:

```
0:
"A":ENT "X MAX",
X:ENT "Y MAX",Y⊢
1:
0→A→R5⊢
2:
"B":ENT "N MAX",
B⊢
3:
"C":0→C→R0:R5+1→
R5⊢
4:
ENT "X":R1:ENT "
P",R3:C+1→C⊢
5:
IF R1>X/2:X/2→R1
⊢
6:
"D":IF C=B:X-R1→
R2:C+1→C:GTO "E"
⊢
7:
ENT "X",R2:ENT "
P",R4:C+1→C⊢
8:
"E":Y-4X*(R2-R0)
:2R1+R2→R0:R3→R
→A⊢
9:
R1→R0:R2→R1:R4→R
3⊢
10:
IF C<B:GTO "D"⊢
11:
IF R5=2:X→Z:Y→X:
Z→Y:GTO "B"⊢
12:
IF 4>R5:GTO "B"⊢
13:
FXD 2:PRT A/XY:
GTO "A"⊢
14:
END ⊢
R130
```

Register	Variable
A	$A_n \cdot P_n$
B	n
C	n
X	x
Y	y
R Ø	x_{n-1}
R 1	x_n
R 2	x_{n+1}
R 3	P_n
R 4	P_{n+1}
R 5	Quadrant

Program Operation:

After loading or keying in the program, the following steps are executed.

Step	Display	Enter	Step	Display	Enter
1	X MAX	$\overline{x}$	4_2	X	x_2
2	Y MAX	$\overline{y}$	5_2	P	P_2
3	N MAX	$\overline{n}$	:	:	:
4_1	X	x_1	4_n	x	$x_{\overline{n}}$
5_1	P	P_1	5_n	P	$P_{\overline{n}}$

Steps 3 through $5_{\overline{n}}$ are repeated for Quadrants 2, 3, and 4, after which the area-averaged value of P is printed out, and the program returns to Step 1 for the next pair of traverses. It should be pointed out that if, in any one traverse, a reading has been taken on the duct centre line, that reading must be entered twice for the traverse in question, e.g. as the first value in Quadrants 1 and 2.