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TECHNICAL NOTES

- TURBINE FLOWMETER -
SIZE SELECTION FOR GAS MEASUREMENT

GENERAL

In order to correctly size a turbine flowmeter for a gas measurement application, it is necessary to:

1. Obtain information about the expected service conditions.
2. Perform a series of calculations to obtain the flow rate in ACFM and the operating density in pounds/ft3.
3. Examine suitable data sheets to choose correct meter size.
4. Determine materials compatibility and bearing type. (Consultation with factory staff is required for this latter step.)

The turbine flowmeter measures the actual volume of fluid or gas passing through the meter. The range of useful operation is determined largely by the density of the gas being measured.

The total measurement capability of a gas flowmeter series is represented by a family of curves that depict the measurement range of each nominal flowmeter size as a function of the flow rate in ACFM. See Curve G-143. Also indicated on this family of curves is some indication of the operating range as a function of the density of gas flowing through the flowmeter.

For each nominal flowmeter size there are several turbine flowmeter designs which have optimized performance and life over a portion of the range covered by that meter size.

I. Preliminary Data Required

1. Required Flow Rates
2. Line Size
3. Type of Gas
4. Operating Pressure
5. Operating Temperature
6. Density and Super Compressibility Data, if available (See Note 1).

II. Conversion of Physical Parameters

1. TEMPERATURE

Perform a conversion to temperature in degrees Rankine (°R) using standard conversions listed below:

°R = °F + 460	Rankine ← Fahrenheit (°F)
°R = (1.8° X C) + 492	Rankine ← Centigrade (°C)
°R = 1.8° X K	Rankine ← Kelvin (°K)

NOTE: Super compressibility charts show the deviation from the ideal gas laws. Whenever possible, obtain this data from the manufacturer of the gas.

2. PRESSURE

Perform a conversion of the pressure to increments of PSIA using the standard conversion listed below for gauge pressure to PSIA.

PSIA = PSIG + 14.7

PSIA = (KG/M2 X .001422) + 14.7

PSIA = (g/cm2 X .01422) + 14.7

PSIA = (Pascals X .0001422) + 14.7

III. Gas Turbine Flowmeter Sizing for Constant Density Applications

In application where the conditions of temperature and pressure are nearly constant, the following procedure may be used to estimate the required flow rate in ACFM.

1. Determine Gas Density

The approximate density of the gas can be determined by either of the following equations:

$$\text{Eq. (1) Density} = \frac{144 \times \text{Pressure}}{\text{UGC} \times \text{Temperature}}$$

$$\text{Eq. (2) Density} = \text{Density @ STP} \times \frac{\text{Pressure}}{\text{Temperature}} \times 36$$

Where: Density is in pounds/cubic feet

Pressure is in PSIA

Temperature is in °Rankine

Universal Gas Constant, UGC and the Density @ STP is obtained from Table 1

2. Determine Flow Rates

The approximate flow rates of the gas can be determined by one of the following equations. Sizing a meter requires that both the maximum and minimum flow rates be known.

$$\text{Eq. (3) ACFM} = \text{SCFM} \times \frac{\text{Temperature in °R} \times 1}{\text{Pressure in PSIA} \times 36}$$

$$\text{Eq. (4) ACFM} = \frac{\text{Lbs Per Min}}{\text{Density}} = \frac{\text{Lbs Per Hr}}{60 \times \text{Density}} = \frac{\text{Lbs Per Sec} \times 60}{\text{Density}}$$

3. With the maximum and minimum flow rate in ACFM and the density in pounds per cubic foot known, determine the most suitable transducer from the family of curves for the gas turbine flowmeter. Alternately, tabulated ranges for the respective flowmeters may be examined to choose a suitable transducer.

4. Determine the actual flow range available if density limitations are indicated on the family of curves. Iterate Step 3 if necessary. If possible, choose a nominal meter size that is the same as the proposed line size. Observe all installations recommendations during layout planning.

   An estimate can be made of the error imposed by varying temperature and pressure by substituting in for pressure, pressure + pressure, and for temperature, temperature + temperature into equation (3).

GAS TURBINE SIZING FOR VARYING DENSITY APPLICATIONS

In applications where the conditions of temperature and pressure are varying during normal operation, the following procedure may be used to obtain the worst case flow rate conditions.

The maximum and minimum flow rates and densities are necessary to properly estimate the measurement rate of the turbine flowmeter.

1. Minimum Density

   Use the maximum temperature in °R and the minimum pressure in PSIA in Equation (1) to obtain the minimum density.

2. Maximum Density

   Use the minimum temperature in °R and the maximum pressure in PSIA in equation (1) to obtain the maximum density.

3. Minimum Flow Rate

   Calculate the minimum flow rate using equation (3) or equation (4). Where density is a parameter, use the maximum density. Where pressure is a parameter, use the maximum pressure. Where temperature is a parameter, use the minimum temperature.

4. Maximum Flow Rate

   Calculate the maximum flow rate using equation (3) or equation (4). Where the density is a parameter in an equation, use the minimum density. Where pressure is a parameter, use the minimum pressure. Where temperature is a parameter, use the maximum temperature.

5. Using the calculated minimum and maximum flow rates in ACFM, choose the optimum flowmeter size from the family of flow range curves for the gas turbine flowmeter.

   Using the family of flow range curves for the gas turbine flowmeters, determine if the selected flowmeter will operate over the flow range if the density varies from the maximum to the minimum density.

   At the lower flow rates, if a higher density is indicated on the curves than the minimum density calculated, the flowmeters operation is outside of its operational limits. Either a derating of the desired flow range specification or an alternate meter size selection is necessary.

REGARDING FLOWMETER CALIBRATION FOR GAS SERVICE

The selected flowmeter is calibrated on air or nitrogen. The density is adjusted to simulate that of the expected service conditions.

The facility performing the calibration provides calibration data which is traceable to the National Bureau of Standards.

The standard accuracy statement for the gas turbine flowmeter provides for accuracy of +/- 1% of reading. This accuracy is over the flow range estimated from any density limitations imposed by the expected service conditions, or by maximum turndown range limit.

FLOWMETER SIZE SELECTION ASSISTANCE

The Engineering Department welcomes request for assistance in choosing a proper meter size.

Bearing selection will be determined when sufficient information is available.

An electronics line is available from simple signal conditioners to complete small systems to use with the gas turbine flowmeter.

TABLE 1 – PHYSICAL PROPERTIES FOR SEVERAL GAS TYPES

GAS	SYMBOLIC NAME	LB/FT3	SPECIFIC GRAVITY	UNIVERSAL GAS CONST.
ACETYLENE	C_2H_2	.06914	.9057	59.4
AIR	–	.075188	1	53.9
AMMONIA	NH_3	.04425	.5970	90.8
ARGON	Ar	.10341	1.38	38.7
BUTENE	C_4H_{10}	.15626	2.076	–
CARBON DIOXIDE	CO_2	.1142	1.521	35.1
CARBON MONOXIDE	CO	.7236	0.9678	55.2
CARBON TETRA FLOURIDE	CF_4	.22727	3.0227	–
ETHANE	C_2H_6	.078125	1.047	–
FLUORINE	F_2	.09804	1.696	–
HELIUM	He	.010352	0.137	386
HYDROGEN	H_2	.005217	.06952	767
KRYPTON	Kr	.2169	2.818	–
METHANE	CH_4	.042184	.5549	96.4
NATURAL GAS	*	.04494	.5977	–
NEON	Ne	.052192	.6941	–
NITROGEN	N_2	.07236	.9624	55.2
OXYGEN	O_2	.082645	1.0992	48.3
PROPANE	C_3H_8	.11765	1.5503	–
PROPYLENE	C_3H_6	.110375	1.476	–
SULFUL DIOXIDE	SO_2	.16573	2.264	24.1

*COMPOSITION OF NATURAL GAS VARIES WITH GEOGRAPHICAL SOURCE.
GAS ANANLYSIS IS ESSENTIAL FOR ACCURATE MEASUREMENT.

APPENDIX 1

MISCELLANEOUS CONVERSION FACTORS – DENSITY IS IN #FT

METRIC SYSTEM

$$\text{ACFM} = \frac{\text{CM}^3}{\text{MIN}} \times 0.00003531$$

$$\text{ACFM} = \frac{\text{CM}^3}{\text{SEC}} \times 0.002118$$

$$\text{ACFM} = \frac{\text{G/SEC} \times 0.1323}{\text{DENSITY}}$$

$$\text{ACFM} = \frac{\text{KG/MIN} \times 2.2046}{\text{DENSITY}}$$

$$\text{ACFM} = \frac{\text{KG/HOUR} \times .03674}{\text{DENSITY}}$$

$$\text{ACFM} = \frac{\text{KG/SEC} \times 132.3}{\text{DENSITY}}$$

ACFM = LITER/MIN X .03531

ACFM = LITER/SEC X 2.119

ACFM = M^3/MIN X 35.31

ACFM = M^3/SEC X 2119

ENGLISH SYSTEM

$$\text{ACFM} = \frac{\text{FT}^3}{\text{SEC}} \times 60$$

$$\text{ACFM} = \frac{\text{IN}^3}{\text{MIN}} \times 0.0005787$$

$$\text{ACFM} = \frac{\text{IN}^3}{\text{SEC}} \times 0.03472$$

$$\text{ACFM} = \frac{\text{PPH} \times 0.0167}{\text{DENSITY}}$$

$$\text{ACFM} = \frac{\text{PPM}}{\text{DENSITY}}$$

$$\text{ACFM} = \frac{\text{PPS} \times 60}{\text{DENSITY}}$$

$$\text{ACFM} = \frac{\text{SCFM} \times 4}{\text{DENSITY} \times \text{U.G.C.}}$$

$$\text{ACFM} = \frac{\text{SCFM} \times .06667}{\text{DENSITY} \times \text{U.G.C.}}$$

HO BASIC SIZE - BLADE ANGLE - BEARING - END FITTING

ESTIMATED USABLE FLOW RANGE OF ________________ TO ______________ ACF/M.

ESTIMATED LINEARITY +/-1% OF READING (FOR FLOW RANGE ABOVE OR FOR 10:1 TURNDOWN WHICH EVER IS LESS).

ESTIMATED REPEATABILITY OF +/-.2%.

OPERATING CONDITIONS:

FLOW RANGE ________ TO ________ OF _________ GAS

AT A PRESSURE OF _________________________ PSIG

AND A TEMPERATURE OF ______________________ °F

CORRESPONDING TO A DENSITY OF ___________ #/FT3

PERFORMANCE FEATURES:

MAXIMUM OUTPUT FREQUENCY ________________ HZ

ESTIMATED "K" FACTOR _______________ CYCLES/FT3

ESTIMATED PRESSURE DROP ________________ PSID

VARIABLE RELUCTANCE PICKOFF _________________

CALIBRATION FOR ABOVE PERFORMED UNDER SIMULATED CONDITIONS OF DENSITY ON AIR AS FOLLOWS:

FLOW RATE _____________ TO _____________ ACF/M

DENSITY __________ #/FT3

RECORD PRESSURE DROP, CYCLES/FT3, FREQUENCY AND FLOW RATE DATA REDUCED TO OBTAIN MEAN "K" FACTOR CYCLES/FT3.