AGA Report No. 3

ORIFICE METERING OF NATURAL GAS AND OTHER RELATED HYDROCARBON FLUIDS

PART 4

Background, Development, Implementation Procedure, and Subroutine Documentation for Empirical Flange-Tapped Discharge Coefficient Equation

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FOREWORD

AGA Report No. 3, *Orifice Metering of Natural Gas and other Related Hydrocarbon Fluids*, consists of four parts. **This one is Part 4 – *Background, Development, Implementation Procedure, and Subroutine Documentation for Empirical Flange-Tapped Discharge Coefficient Equation.*** Other parts are:

Part 1 – *General Equations and Uncertainty Guidelines*

Part 2 – *Specification and Installation Requirements*

Part 3 – *Natural Gas Applications*

Each of the four parts is published separately to facilitate future changes, allow immediate use, and reduce the size of the applicable part needed by most users. Although for many applications each part can be used independently, users with natural gas applications are advised to obtain Parts 1, 2 and 3.

This report applies to fluids that, for all practical purposes, are considered to be clean, single phase, homogeneous, and Newtonian, and the Part 4 of the report describes the background and development of the equation for the coefficient of discharge of flange-tapped square-edged concentric orifice meters, and recommends a flow rate calculation procedure. The recommended procedures provide consistent computational results for the quantification of fluid flow under defined conditions, regardless of the point of origin or destination, or the units of measure required by governmental customs or statute. The procedures allow different users with different computer languages on different computing hardware to arrive at almost identical results using the same standardized input data.

This report has been developed through the cooperative efforts of many individuals from industry under the sponsorship of the American Gas Association, the American Petroleum Institute, and the Gas Processors Association, with contributions from the Chemical Manufacturers Association, the Canadian Gas Association, the European Community, Norway, Japan and others.

It may become necessary to make revisions to this document in the future. Whenever any revisions are advisable, recommendations should be forwarded to the Operations and Engineering Section, **American Gas Association**, 400 N. Capitol Street, NW, 4th Floor, Washington, DC 20001, U.S.A. A form has been included at the end of this report for that purpose.

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4.1 Introduction and Nomenclature

4.1.1 INTRODUCTION

This part of the standard for Concentric Square-Edged Orifice Meters provides the background and history of the development of the standard and recommends a method to solve the flow equations for mass and volumetric flow.

4.1.2 NOMENCLATURE

The symbols used have, in some cases, been given a more general definition than that used in other parts of API 2530. Some symbols have a different meaning than that defined elsewhere in the standard. Care should therefore be given to the meaning of variables used in this document.

Symbol	Represented Quantity
α_1	Linear coefficient of thermal expansion of the orifice plate material.
α_2	Linear coefficient of thermal expansion of the meter tube material.
β	Ratio of orifice plate bore diameter to meter tube internal diameter (d/D) calculated at flowing temperature, T_f.
β_m	Ratio of orifice plate bore diameter to meter tube internal diameter (d/D) calculated at measured temperature, T_m.
β_r	Ratio of orifice plate bore diameter to meter tube internal diameter (d/D) calculated at reference temperature, T_r.
C_d	Orifice plate coefficient of discharge.
C_d(FT)	Coefficient of discharge at a specified pipe Reynolds number for flange-tapped orifice meter.
C_{d_0}	First flange-tapped orifice plate coefficient of discharge constant within iteration scheme.
C_{d_1}	Second flange-tapped orifice plate coefficient of discharge constant within iteration scheme.
C_{d_2}	Third flange-tapped orifice plate coefficient of discharge constant within iteration scheme.
C_{d_3}	Fourth flange-tapped orifice plate coefficient of discharge constant within iteration scheme.
C_{d_4}	Fifth flange-tapped orifice plate coefficient of discharge constant within iteration scheme.
C_{d}_f	Orifice plate coefficient of discharge bounds flag within iteration scheme.
d	Orifice plate bore diameter calculated at flowing temperature T_f.
D	Meter tube internal diameter calculated at flowing temperature T_f.
d_r	Orifice plate bore diameter calculated at reference temperature T_r.
D_r	Meter tube internal diameter calculated at reference temperature T_r.
d_m	Orifice plate bore diameter calculated at measured temperature T_m.
D_m	Meter tube internal diameter calculated at measured temperature T_m.
D_c	Orifice plate coefficient of discharge convergence function derivative.

ΔP Orifice differential pressure.
e Napierian constant, 2.71828.
E_v Velocity of approach factor.
F_c Orifice plate coefficient of discharge convergence function.
F_I Iteration flow factor.
F_{I_c} Iteration flow factor pressure—independent factor.
F_{I_p} Iteration flow factor pressure—dependent factor.
F_{mass} Mass flow factor.
G_i Ideal gas relative density (specific gravity).
G_r Real gas relative density (specific gravity).
GCN Real relative density (specific gravity), % carbon dioxide, and % nitrogen.
k Isentropic exponent.
m Mass.
μ Absolute viscosity of flowing fluid.
Mr_{air} Molar mass (molecular weight) of dry air.
M Dimensionless downstream dam height.
n Number of moles.
N_c Unit conversion factor (orifice flow).
N_{I_c} Unit conversion factor (Reynolds number).
N_3 Unit conversion factor (expansion factor).
N_4 Unit conversion factor (discharge coefficient).
N_5 Unit conversion factor (absolute temperature).
P_b Base pressure.
P_f Static pressure of fluid at the pressure tap.
P_{f_1} Absolute static pressure at the orifice upstream differential pressure tap.
P_{f_2} Absolute static pressure at the orifice downstream differential pressure tap.
$P_{m_{air}}$ Measured air pressure.
$P_{m_{gas}}$ Measured gas pressure.
π Pi, 3.14159... .
q_m Mass flow rate.
Q_b Volume flow rate per hour at base conditions.
q_v Volume flow rate flowing (actual) conditions.
R Universal gas constant.
Re_D Pipe Reynolds number.
ρ_b Density of the fluid at base conditions, (P_b, T_b).
$\rho_{b_{air}}$ Air density at base conditions, (P_b, T_b).
$\rho_{b_{gas}}$ Gas density at base conditions, (P_b, T_b).
ρ_s Density at standard conditions, (P_s, T_s).
$\rho_{t,p}$ Density at flowing conditions, (P_f, T_f).
T_b Base temperature.
T_{d_m} Measured orifice plate bore diameter temperature.
T_{D_m} Measured meter tube internal diameter temperature.
$T_{m_{air}}$ Measured temperature of air.
$T_{m_{gas}}$ Measured temperature of gas.
T_f Flowing temperature.
T_r Reference temperature of the orifice plate bore diameter and/or meter tube internal diameter.
T_d Downstream tap correction factor.
T_s Small meter tube correction factor.