

FLOW RATE MEASUREMENT FOR ALL FLUIDS WITHOUT VISCOSITY

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To understand flow rate measurement, you must start at the beginning by knowing the Laws.

BOYLES LAW: The volume of a definite quantity of dry gas is inversely proportional to the pressure, provided the temperature remains constant. Mathematically BOYLE 'S law can be expressed as

$$P_1 V_1 = P_2 V_2$$

- V_1 is the original volume.
- V_2 is the new volume.
- P_1 is original pressure.
- P_2 is the new pressure.

1. **CHARLES LAW:** The volume occupied by any sample of gas at a constant pressure is directly proportional to the absolute temperature.

$$V/T = \text{CONTANT}$$

V is the volume

T is the absolute temperature
(measured in Rankine)

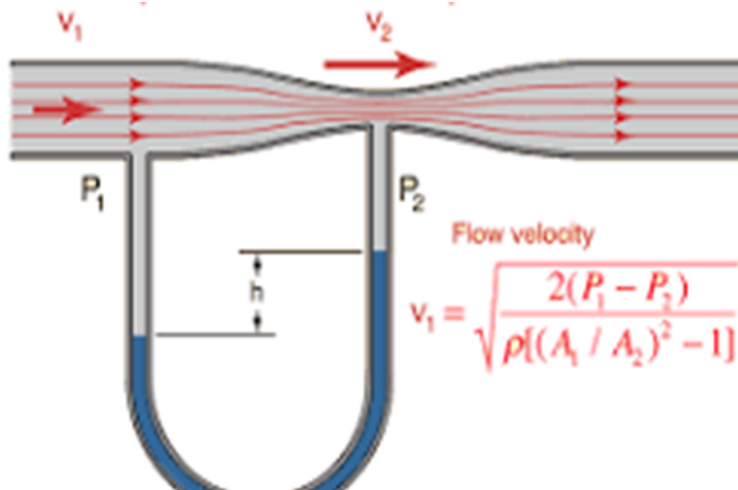
**IMPORTANT: Charles' LAW ONLYWORKS
WHEN THE PRESSURE IS CONSTANT.**

NOTE: CHARLES'S LAW is fairly accurate
But gases tend to deviate from it at
Extremely high and low pressures.

2. **COMBINED LAW:** The combined gas law is a combination of BOYLE'S LAW and Charles' law. Hence its name is the combined gas law. In the combined gas law, the Volume of gas is directly proportional to the absolute temperature and inversely proportional to the pressure.
This can be written as $PV/T = \text{constant}$. Since for a given amount of gas there is a constant then we can write

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

- P_1 is the initial pressure.
- V_1 is the initial volume.
- T_1 is the initial temperature (in Rankine).
- P_2 is the final pressure.
- V_2 is the final volume.
- T_2 is the final temperature (in Rankine).



(FIGURE 1) VENTURI



(FIGURE 2) USED ORIFICE PLATE

There were two companies involved in making primaries, FOXBORO and The Metric Iron Works. Early meters were referred to as “VELOCITY or FLOW METERS.

Most information began to surface in the 1900s and later.

1913 was the year the orifice was beginning to be widely used and studied.

New formulas were being developed such as:

Working from: CONSTANT TO QUANTITY TO COEFFICIENT

Testing continued which is referenced in AGA 1985 which included.

1925 larger meter runs,

1926 Effects of disturbances,

1928 Deviation from BOYLES LAW

1929 Deviation from BOYLES LAW PRESSURES over 600psi

Standard Cubic Foot (SCF)

- ☐ 14.73 Pressure Base
- ☐ 519.67° R Temperature Base
- ☐ 519.67° R Flowing Temperature
- ☐ 1.000 Gravity (real) (exactly)

Differential Pressure Measurement has been unchanged since 1913. Measurement Technology has gone through many changes in meter styles and tap locations. This search resulted in calculations searching for the correct way to measure all fluids (GAS and LIQUIDS). In 1983-2022 Dr. Zaki Husain, through testing, had a hand in developing the V-Cone, Coriolis, Ultrasonic meter from different aspects of development. However, the calculation for flow remained the same.

Studies in U. S. and Europe identified deficiencies in previous standards for orifice measurement to be inadequate to achieve the degree of accuracy required.

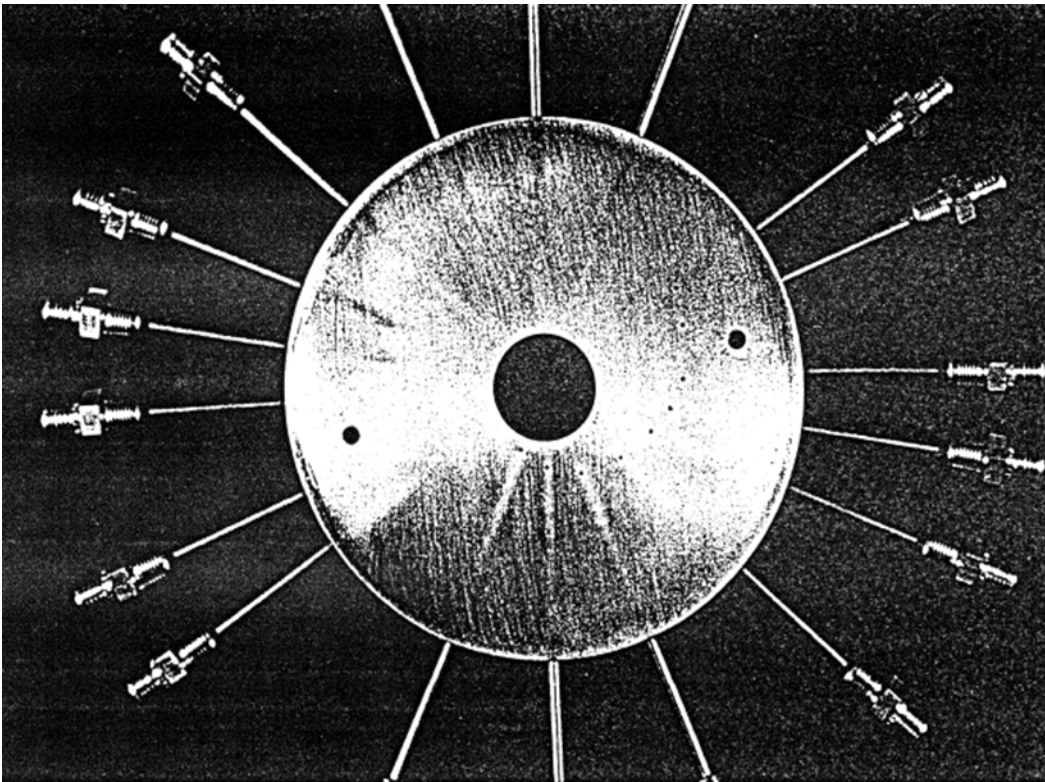
James Gallagher and Dr. Michael Reader-Harris through many hours of work and brain power were able to develop the current calculation on orifice plates. As shown below.

CALCULATIONS

Instructions for computing flow through an orifice

$$Q = C' [h_w p_f]^{5/2}$$
$$C' = F_b F_r Y F_{pb} F_{tb} F_{tf} F_{gr} F_{pv}$$

In 1983 Dr. Ray TEYYSANDIER and Dr. ZAKI HUSAIN did a test to determine the pressure distribution on an orifice plate and the pressure in the bore of the plate



(FIGURE 3) ORIFICE PLATE PRESSURE DISTRIBUTION

This test resulted in finding the bore pressure was the lowest and highest velocity, but most stable differential pressure reading. This started the development of the CENTER TAP TECHNOLOGY. It was published in multiple standards however, no one utilized it until it was installed in a TORUSWEDGE AND TESTED AT CESSI ON three different size meters 2, 3, and 4" and three

different orifice bores 0.3, 0.5, 0.75. The tests at CESSI brought Dr. Husain to the conclusion that there was a better way to calculate the flow of all fluids. During the period of COVID Dr. Husain developed the ENERGY CORRELATION CALCULATION with the CENTER TAP TORUS. We sent many different size meters to different flow labs, and the results all showed the same.

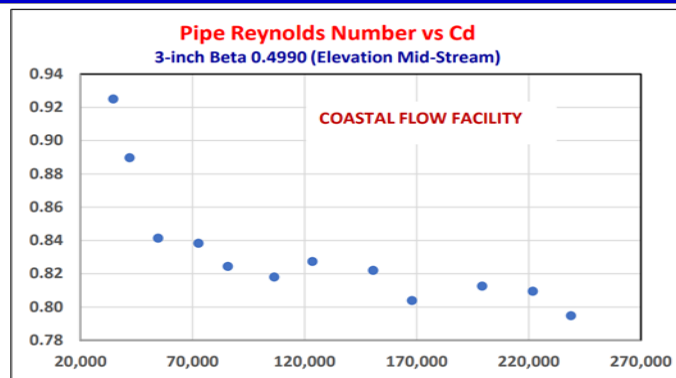
TO DISPLAY THE IMPROVEMENTS OF MEASURED FLOW RATE EMPLOYING THE ENERGY CORRELATION METHOD, FLOW CALIBRATION DATA OF DIFFERENTIAL PRESSURE TYPE FLOWMETERS ARE PLOTTED IN THE TRADITIONAL **DISCHARGE COEFFICIENT AS A FUNCTION OF THE REYNOLDS NUMBER** AND THE FLOW RATE DATA IN THE ENERGY CORRELATION FORMAT OF

$$\frac{Q_{fv}}{d^2} \propto \int (D,d) * \sqrt{\frac{DP}{w_f}}$$

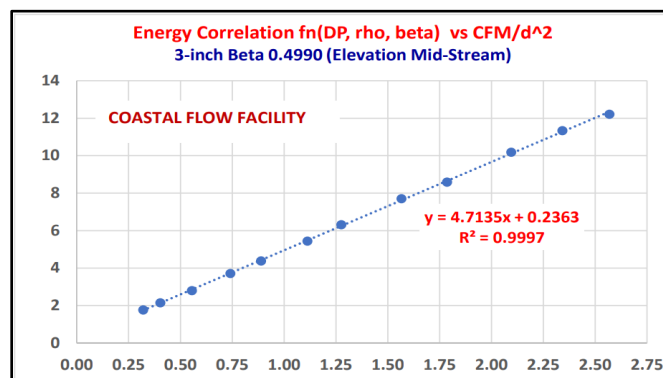
DIMENSIONAL UNITS OF THE **ENERGY CORRELATION** PLOTS ARE

$$Q_{fv} [=] \frac{ft^3}{min} \quad D, d [=] inch \quad DP [=] inches \text{ of Water Column} \quad w_1 [=] \frac{lb}{ft^3}$$

TRADITIONAL DISCHARGE COEFFICIENT PLOT vs ENERGY CORRELATION PLOT



TOP (FIGURE4) TRADITIONAL CHART



TOP (FIGURE4) TRADITIONAL CHART

BOTTOM (FIGURE5) ENERGY CORRELATION CALCULATION

Through flow physics and understanding of FLUID ACTION and CURISOITY Dr. Husain was able to develop this theory and then proved it under all types of fluid conditions. Drilling Muds(multiphase)to very low flow rate and constant viscosity changes (Beer Brewery fermentation pots which produce CO_2), 1" thru 20" Differential devices, pressures and temperatures.

VALIDATION OF THE ENERGY CORRELATION METHOD

IF THE CONCEPT OF ENERGY CORRELATION IS TRUE,

CALIBRATION DATA OF ANY DIFFERENTIAL PRESSURE TYPE FLOWMETER MUST DISPLAY LINEAR RELATIONSHIP OF THE FLOW RATE TO THE SQUARE ROOT OF THE DIFFERENTIAL PRESSURE AND THE FLOWING DENSITY, INDEPENDENT OF THE FLUID VISCOSITY.

DP LIMIT FOR COMPRESSIBLE FLUIDS

When the pressure at the low-pressure port is significantly lower than the pressure at the high-pressure port of the CTT flowmeter, the change in local density of the compressible fluid between the two pressure ports will result in over-registration of the flow rate using the Energy Correlation method.

Above a critical pressure ratio,

$$\Delta P/P,$$

where, ΔP is the differential pressure reading, and P is the pressure at the high-pressure port, the change in fluid density at the low-pressure port must be accounted for in the Energy Correlation function or change the CTT flowmeter with a larger bore to achieve DP/P value below the critical pressure ratio at the highest flow rate through the meter.

SECOND PHASE OF DEVELOPMENT (SAMPLER)

LOCATION PROVIDED DATA THAT SUPPORTED A NEW LOCATION OF A SAMPLING PROB.

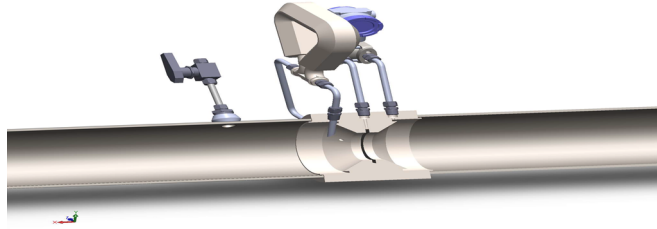
NEW LOCATION:

SAMPLING PROBE CAN BE INSTALLED CLOSER TO THE CTT FLOWMETER BORE TO COLLECT BETTER REPRESENTATIVE SAMPLES OF RICH GAS or MULTIPHASE FLOWS.

CENTER TAP TORUS MASS METER WITH DENSITOMETER,

DIFFERENTIAL PRESSURE TRANSMITTER

AND NEW LOCATION OF SAMPLER PROBE



(FIGURE 6) CENTER TAP TORUS MASS METER

THIRD PHASE OF DEVELOPMENT

DIAGNOSTICS

The **CENTER TAP TORUS TECHNOLOGY** allows a second transmitter to be installed on the meter body which provides a second linear scale (P_1 to P_2) compared to the first transmitter reading of (P_1 to $P_{\text{center tap}}$), any deviation from parallel will set off an operator alarm. Thus, setting up a diagnostics signal.

FOURTH PHASE OF DEVELOPMENT

COST OF CALCULATION

Under review of data for orifice, v-cone, center tap, venturi, of different sizes and pressure zone he discovered that in the calculation with the disappearance of viscosity, Reynolds numbers, coefficient of discharge the calculation is simply a four Step calculation which reduced the need for the expensive electronics flow computer.

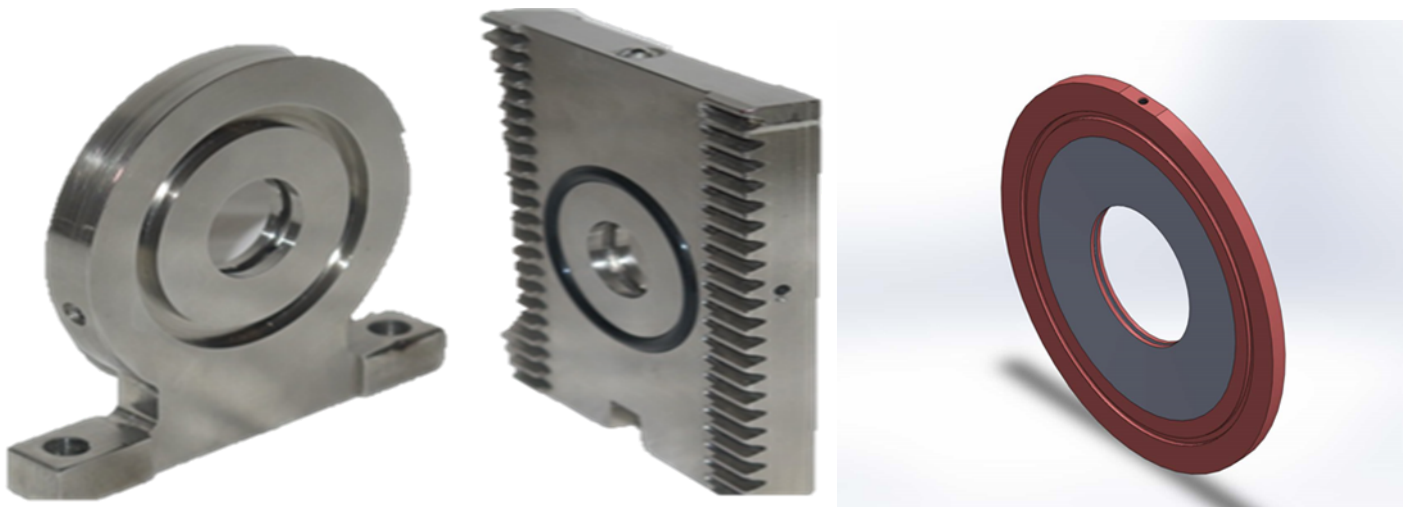
FIFTH PHASE OF DEVELOPMENT

RETROFIT OLD FITTING TO MASS MEASUREMENT

As equipment gets old and worn, we review it's worth seeing if it needs to be replaced. The development of new technology such as the **CORIOUS FOR LIQUIDS, ULTRASONIC FOR GAS** provided a more accurate way to measure flow, cannot operate in each other's fluids efficiently with the highest accuracy. Our current world of wet gas and multiphase fluids and the current **CALCULATION** has problems operating with less uncertainty. When fluids get upset our current flow technologies are interrupted in their reporting cycle until the process begins to be settled. Then they return to operation. It's that time frame that affects our cash registers and the safety of our people.

CENTER TAP TECHNOLOGY allows all fittings for gas to be retrofitted with carrier plates and orifice plate in orifice flange unions and the calculation to be used for **MASS MEASUREMENT**.

SOLID CARRIER FOR SINGLE CHAMBER FITTINGS RETROFIT INSERTS



MODERNIZATION OF BI-DIRECTIONAL PIPELINE (FIGURE 7,8,9)



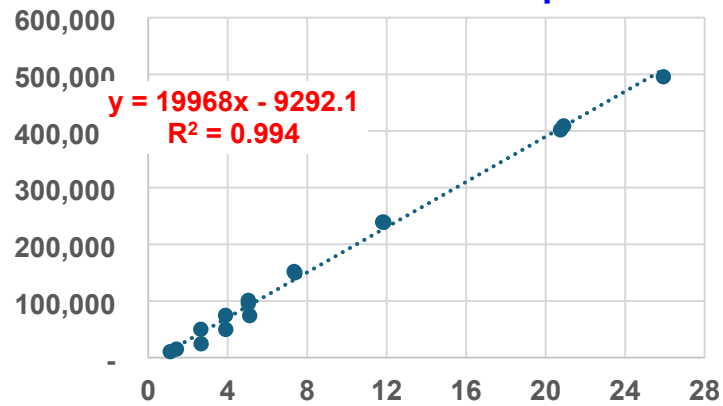
(FIGURE 10)

20" BIDIRECTIONAL PIPELINE

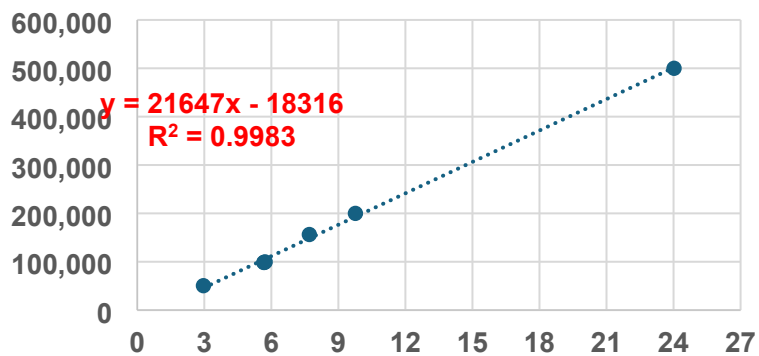
**REPLACEMENT OF TWO 10" ORIFICE METER RUNS, PRODUCED
COMPRESSOR CONTROL ON PIPELINE AT A VERY LOW COST.**

FLARE GAS FLOW RATE MEASUREMENT
CALIBRATED AT CLIENT'S FACILITY IN NORTH DAKOTA

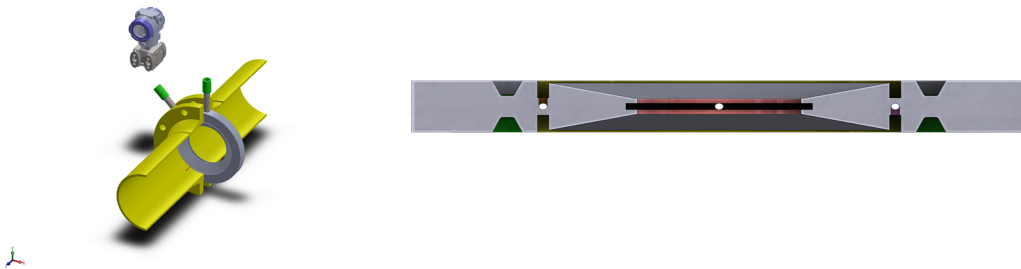
FLARE GAS – Propane

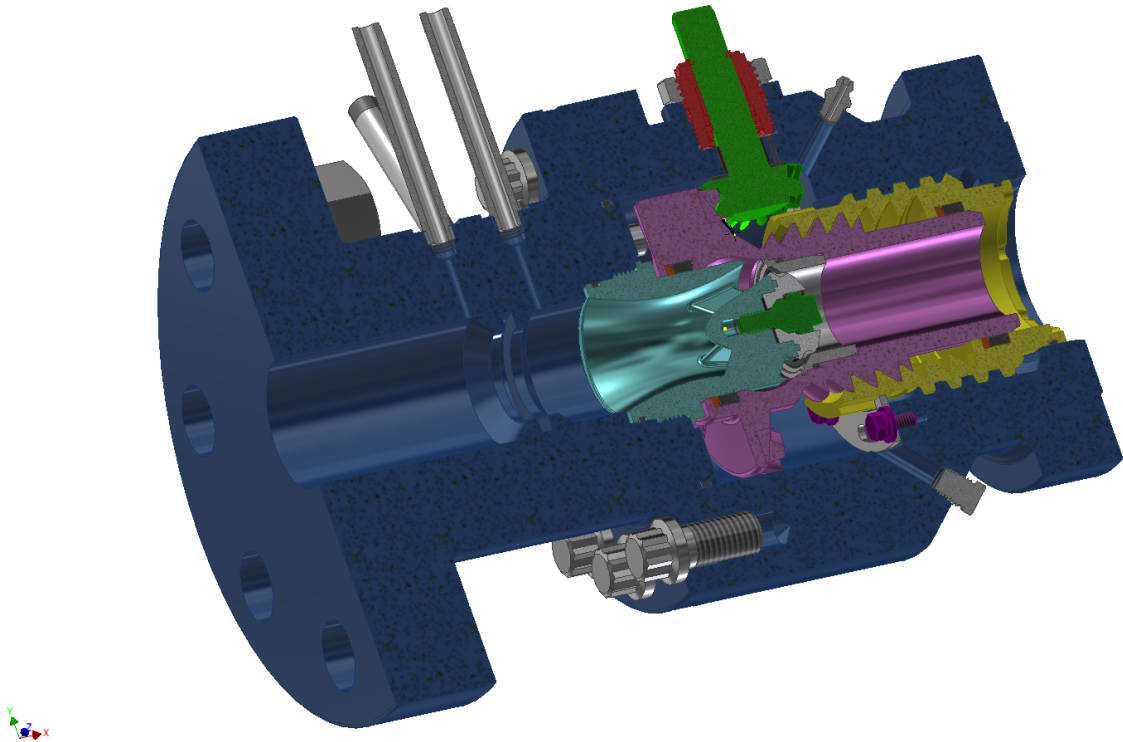


FLARE GAS - Methane



**THE CENTER TAP TECHNOLOGY SOLUTION CAN BE COME THE METER
STATION OF THE FUTURE WITH ALL THE WRIGHT ACCESSORIES**





METER STATION OF THE FUTURE

IF YOU CAN'T MEASURE IT, YOU CAN'T CONTROL IT

GAS AND LIQUID METER STATION OF THE FUTURE