Steam Quality Meter Technology Review

1.) Theory of Operation – Installed System configuration

2.) Installed Steam Meter Designs – Generation 2 – Typical Performance 28/64 Choke

3.) Operations Issues/Solutions – Routine Scale handling, Plugging Solutions (by Exception)

4.) Flow Control & Automation – Control Metric & Methods
Critical Flow Choke Equation for Wet Steam. Many steam injection wells for shallow EOR reservoirs use a critical flow choke to control injection flow rate. The advantage of using a choke or other critical flow device is that the flow rate will remain constant regardless of the change in the pressure downstream of the choke. There are a number of equations that describe the critical flow rate of steam \(^3\). The form of the flow equation adopted in this work is one proposed by Napier and modified by King and Crocker\(^4\),

\[
 w = a \frac{d_c^2 \frac{p}{X}}{k} . \quad \quad \quad (1)
\]

where \( w \) is the steam flow rate, \( d_c \) is the diameter of the critical flow meter, \( p \) is the pressure, and \( X \) is the steam quality. The value of \( a \) and \( b \) in Eq.1 are to be determined from experimental data to calibrate for a particular critical flow device, flow regime and pressure range.

Orifice Flow Equation for Wet Steam. The orifice flow equation is an adaptation of the general orifice flow equation, i.e.,

\[
 w = 1888.56 C_o F_o Y_2 \frac{d_o^2}{1-\beta^4} \sqrt{\frac{p}{v_{exp}}} \quad \quad (2)
\]

where \( d_o \) is the orifice diameter, \( \beta \) is the ratio of orifice diameter/pipe diameter, \( \phi \) is the orifice pressure drop, \( v_{exp} \) is the two-phase specific volume of the steam as it flows through the orifice, and \( C_o \), \( F_o \), and \( Y_2 \) are the discharge coefficient, thermal expansion coefficient, and vapor expansion coefficient, respectively. These coefficients are calculated according to Miller\(^5\).

The mathematical form of \( v_{exp} \) used in Eq.2 is as proposed by James\(^6\),

\[
 v_{exp} = A (v_{fg}) \left( \frac{X}{100} \right)^B + v_f , \quad \quad (3)
\]

where \( X \) is the steam quality, \( v_{fg} \) is the specific volume of vaporization, and \( v_f \) is the specific volume of saturated liquid. The steam properties, \( v_{fg} \) and \( v_f \), can both be expressed as functions of the steam pressure\(^7\). The values of \( A \) and \( B \) in Eq.3, which differed from those determined by James, are established experimentally for a specified range of steam pressure and flow regime.
Generation 2 - Steam Quality Meter

O-Plate Downstream – Concentric design

Gate Valve Assembly

Cage Nipple Press Recovery Choke

Concentric Orifice Plate

Dimensions:
- 6.125
- 5.00
- 3.375
- 15.50
- 30.75
Flow Regime Map

Generation 2 - Steam Quality Meter

O-Plate Downstream – Concentric design

Steam Inlet

Steam Outlet

Annular/transient Flow Regime

Mist-Phase Flow Regime

Transition Flow Regime

Annular Flow Regime

Flow Regime Map

Generation 2 - Steam Quality Meter

O-Plate Downstream – Concentric design

Steam Inlet

Steam Outlet

Annular/transient Flow Regime

Mist-Phase Flow Regime

Transition Flow Regime

Annular Flow Regime

1-19-2018 DHH
O-Plate Downstream of Choke: 28/64 Choke

Orifice DP Range 125 in-wc (515 - 390 in-wc) in Quality range 45% - 100%
Gen 2 Meters

> Installation
> Operator Maintenance (routine)
> Choke Plugging Remedy (by exception)
Steam Quality Meter Assembly – As provided to Customer
Typical Steam Quality Meter Installation In Well Head Piping

Adjustable Choke

Mainline Valve

3 Valve manifold

To Injector
Recommended Additional Fittings for Maintenance Procedures

2” Tee, Valve, BullPlugs
Normal Steam Flow Conditions

Steam Supply

To Injector
Adjustable Choke - Routine Scale Purge Operations

Step 1: Open Vent Valve
Adjustable Choke - Routine Scale Purge Operations

Step 2

Cycle Adj Choke
Choke Cleanout – By Exception

Step 1

Insert Tool – Clean Choke Bore
Choke Cleanout – By Exception

Step 2

Brief Backflow

Note: This Step May Not Be necessary
Return to Normal Steam Flow Conditions
Steam Quality Meter Downstream of 3 Valve Manifold
Allows Full Range Performance Validation

Adjustable Choke

3 Valve Manifold

Steam Supply

Steam Meter

To Wellhead
Flow Control System Configuration & Logic

1.) Control Metric – MMBTU/D – Modbus Write Register
2.) Fail Open – Loss of Steam Flow
3.) Fail in Last Position - Loss Of Control Signal