Saturated Steam Mass Metering

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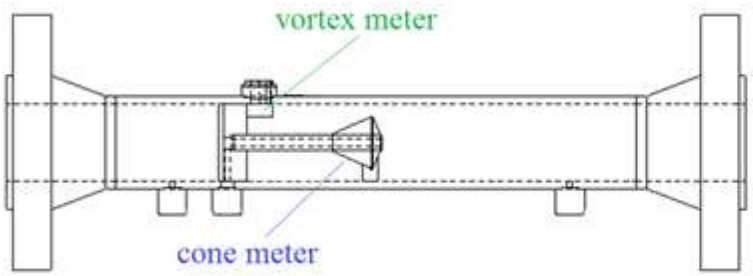

Fig 1. VorCone Meter Design

Fig 2. Inlet View of a VorCone Meter

Fig 3. 2" Meter Saturated Steam Application

Fig 4. Saturated Steam Field Separator Reference

The VorCone meter combines two separate meter technologies, i.e. the vortex and cone DP meters. Both the vortex meter and the cone DP meter are extensively used in steam applications. Combining them to make a hybrid meter (see Figs. 1 & 2) makes the whole greater than the sum of its parts.

The VorCone meter cross references the two meter outputs to predict a saturated steam's quality (see equations below). Once the quality is known the ISO TR 12748 cone meter wet gas correction factor is applied to find the steam mass flow. Figs 3 & 4 show a 2" meter saturated steam flow field trial. Figs 5 & 6 show the results.

$$x = \frac{m_g}{m_g + m_l} \quad \text{-- (1)} \qquad Q_{v,mix} = f/K \quad \text{-- (2)}$$

$$\rho_{\text{hom}} = 2\Delta P_{tp}\left\{\frac{YC_d}{Q_{v,mix}}\frac{A\beta^2}{1-\beta^4}\right\}^2 \quad \text{-- (3)} \qquad x = \frac{\rho_g(\rho_l - \rho_{\text{hom}})}{\rho_{\text{hom}}(\rho_l - \rho_g)} \quad \text{-- (4)}$$

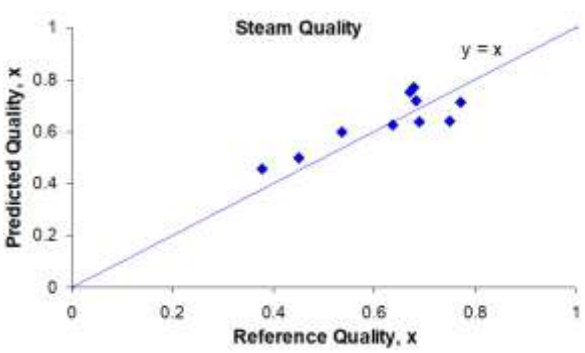

Fig 3. 2" Meter Quality Prediction

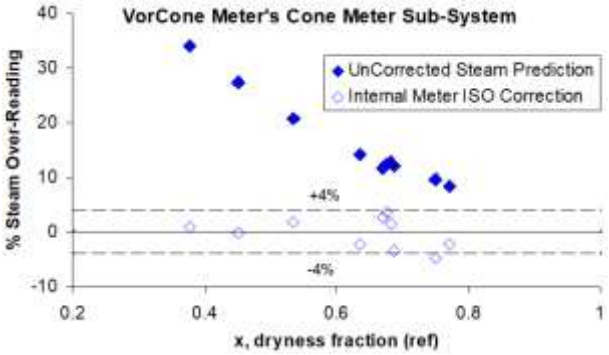

Fig 4. 2" Steam Mass Flow Prediction.

The VorCone meter can read three DPs across the system and use pressure field analysis ('Prognosis™') to monitor the health of the system (see Fig 5). Fig 6 shows the normal Prognosis display for a VorCone meter operating correctly with single phase flow. All points inside the box indicate normal operation.

Fig 7 shows the Prognosis response of the 2" VorCone meter to varying quality when under saturated steam field trial conditions. The VorCone meter Prognosis system monitors and tracks changes in saturated steam quality independently of the meters primary quality measurement technique. This shows quality monitoring redundancy.

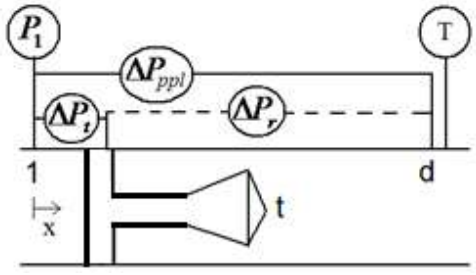

Fig 5. VorCone Meter with 'Prognosis™'.

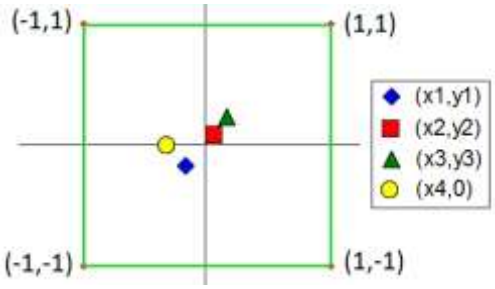

Fig 6. Single Phase Flow Prognosis Dispaly

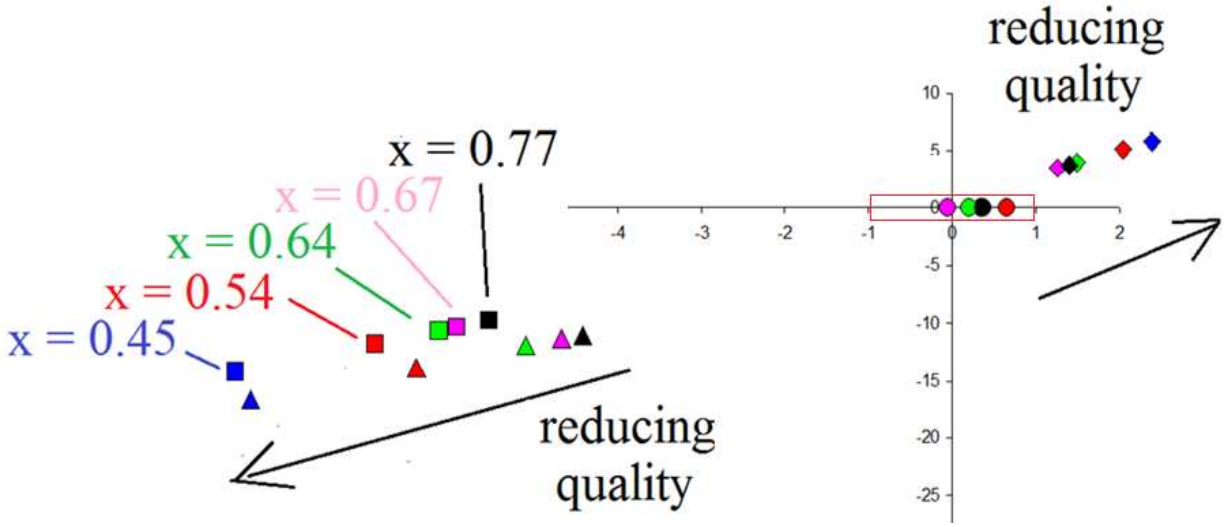

Fig 7. Prognosis Results From Varying Syeam Quality Field Trial.

A second saturated steam quailty prediction test was carried out downstream of a boiler, There was no measured reference quality available but the new boiler setting was 75% quality. The 3" VorCone meter predicted a quality of 73%.

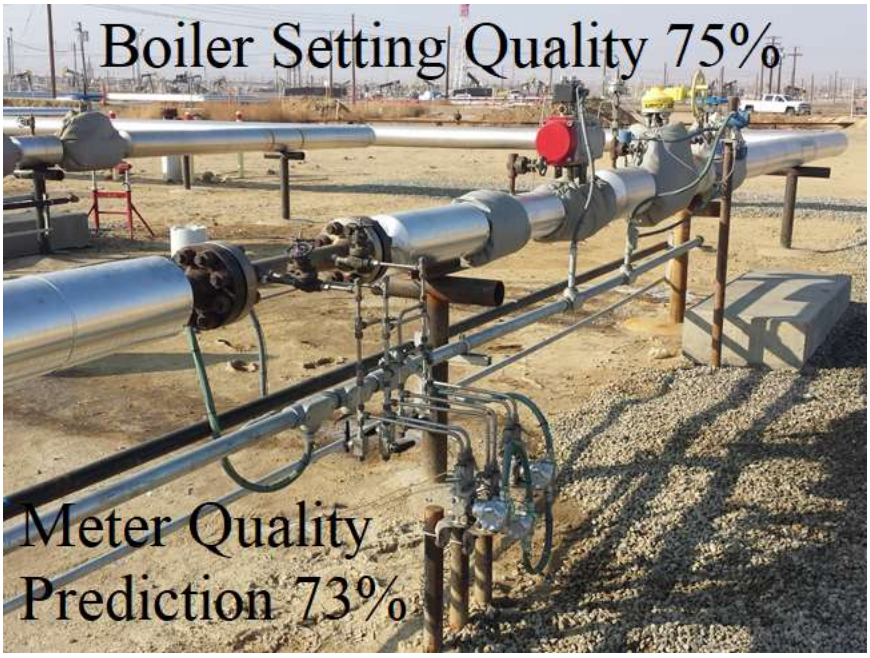

Fig 8. 3" VorCone Meter Downstream of Saturated Steam Boiler Outlet.

The VorCone meter has both a stand alone vortex meter and stand alone cone meter. The hybrid system cross referencess these two sub-system meter outputs to predict the two saturated steam flow unknowns, i.e. the steam quality and the steam (vapor) mass flow. The steam quality calculation routine is wholly theoretical. The steam (vapor) mass flow calculation uses this theoretical steam quality prediction with the published ISO cone meter wet gas flow (e.g. saturated steam flow) orrection factor. The VorCone meter's saturated steam calculation routine is simple, fully disclosed, and shown by field trial to work.