The purpose of this Application Note is to provide some guidance when simulating existing pipe systems and making comparisons between *FluidFlow3's* model results and direct measurements in the field.

For both liquids and gases pipe friction losses are based on an expanded form of the Darcy –Weisbach equation. The friction factor term in the Darcy equation **f** is found from the Haaland equation which gives better than 2% agreement with the well-known Colebrook-White equation.

The absolute roughness of the pipe, k, is used in the Haaland equation when determining **f**. *FluidFlow3* detects laminar flow. A modified form of the Darcy equation is used for compressible flow to account for velocity and density changes as the fluid expands.

The use of the Darcy equation implies that the fluid is Newtonian with a coefficient of dynamic viscosity that changes only with variation in temperature (so all aspects of this note may not necessarily apply to slurry flow simulations). *FluidFlow3* provides an accurate solution to the in-built equations if this is the case. However, in the field there may be many circumstances that will affect flows and pressures that *FluidFlow3* cannot predict. For instance …

- Scaling of pipes may mean a greater field value of k than in the model.
- The fluid may not be Newtonian.
- Low pressure at the inlet to pumps may cause cavitation in the field and affect the performance of the pumps.
- Vapourisation of liquids due to elevation or to excessive pressure drop across a fitting.
- Poor pipework design, especially on the suction side of pumps.
- Valves may be locked into positions which are unknown and orifice plates and other measuring devices may have deteriorated or be out of calibration.
- Control valves may have been inappropriately selected and operating outside the manufacturer's recommended range.
- In systems where pipe lengths are short or there are a considerable number of fittings (valves, bends etc), the so-called "minor losses" become significant. The selection of the correct fitting coefficient is crucial. The difficulty here can be seen by referring to Crane which gives values of K' for globe or angle valves varying from $55f_t$ to $340f_t$. For lift check valves, K' values range from $55f_t$ to $600f_t$ depending on the style of the valve.
- Site data may simply be wrong!

All the issues described above mean that a model developed on the basis of new pipes and equipment and standard fittings' coefficients may not simulate actual site conditions. Results from the *FluidFlow3* model may differ from measurements and/or anecdotal information from the field.

We can address each of the above issues in turn. Essentially, what needs to be achieved is a modification or "calibration" of model data to equate to field conditions.

Pipe Scaling: *FluidFlow3* allows the internal diameter and roughness of pipes to be varied within a model. This can be achieved by globally updating groups of pipes so it is very easy, for instance, to provide a 10% scale to all pipes and determine how this affects the model.

Cavitation: *FluidFlow3* cannot model the effect of cavitation on pumps although it does calculate and display the NPSH available at the inlet to any pump in the system and flag a warning if insufficient NPSH is detected.

Vapourisation: *FluidFlow3's* calculated values of flows and pressures at every node in the system should be inspected to see if negative pressures occur which may have an influence on flow that *FluidFlow3* cannot predict. Remember, before actual vapourisation occurs, low pressures may bring air or gas out of solution. This can significantly influence the performance of a pump in reality if the vapour release is on the suction side; an effect which the software cannot simulate.

Poor Pipework Design or Layout: High points in pipe systems can cause problems that a software simulation will not necessarily detect. In the simplest case, air or vapour becomes trapped at the high point reducing the cross sectional area of flow in the pipe. Air relief valves should be installed to exhaust the trapped gas.

If the pipe centreline at a high point rises above the hydraulic grade line this will result in localised negative pressures. Air can come out of solution at these points long before absolute zero pressure occurs.

Suction pipework can be particularly problematical. Negative pressures in the suction line will not only cause air to come out of solution, but will draw air in via leaks in the pipework. High points (even high points arising from the use of concentric reducers) can localise air blockages. Air in a suction system can become trapped within the eye of the impeller of a centrifugal pump causing a lowering of performance.

Equipment Deterioration: Site measurements/inspection required. *FluidFlow3* allows a fixed head drop to be entered at any location in the model so such head losses can be tested, perhaps to accord with site pressure measurements.

Control Valves Operating out of Recommended Range: *FluidFlow3* detects and warns of two conditions: (a) if the valve is operating outside user-specified recommended operational limits, and (b) if the valve is operating outside the limits of manufacturer's test data.

Equipment Head Loss Coefficients: Site-specific data required. *FluidFlow3* has a wide range of options for simulating the head loss across junctions, fittings and equipment including the methods of Crane and Idelchick. *FluidFlow3* allows fittings data to be entered in the Crane fashion (K') or in the more traditional way of $K = u^2/2g$. If the K method is used, the values of K supplied for a 100mm fitting will not necessarily be correct for a 200mm fitting. So, in any simulation, adopting the correct head loss coefficient for a fitting can be difficult. Is it certain that a fitting is actually performing in accordance with manufacturer's data? Over time the internals of the fitting may have deteriorated, causing a higher or lower pressure drop than the coefficient would indicate. Finally, most coefficients are provided for fittings tested in isolation from other line equipment. How closely spaced fittings interact with each other is often uncertain.

Site Data: Obtaining accurate site data with which to compare the model simulation may be difficult. Are site-metering devices accurate; have they been recently calibrated? Is the actual pump or fan performance compatible with the curve supplied – without witness testing a pump could legitimately be operating within 5% of the manufacturer's curve - with wear the discrepancy could be much higher; is the specified impeller actually installed? Have extensions to the system been added and not documented; could there be other demands on the system which have not been detailed?

Despite the above issues, FluidFlow3 can be effectively utilised in the simulation of an existing pipe network. The computer simulation allows the engineer to identify problem areas by comparing model values with site-measured values and then "calibrating" the model to agree with site conditions.

SUMMARY

When comparing *FluidFlow3's* results to field results it should be kept in mind that *FluidFlow3* solves a set of equations based on input data. Circumstances in the field may be different. Although *FluidFlow3* comes with a database of fittings, the only accurate source of head loss data for a particular fitting is the manufacturer or actual test data.

Existing systems have often been upgraded and extended. Documentation of these past changes often does not exist. *FluidFlow3's* flowsheet representation of the pipe network with its choice of colours for different pipes provides an excellent schematic of the pipe network in the absence of proper drawings. The working model with its ability to provide instantaneous “what if” calculations is an effective tool for developing an understanding of how the system operates, perhaps in discussion with field operators and maintenance staff. This type of discussion can lead to a calibration of the model to close agreement with site conditions.

This possibility of tuning a *FluidFlow3* network to achieve agreement with field results should be considered, say by varying pipe roughness values, partially closing valves, simulating leaks, etc. Having tuned or calibrated the model it would then be reasonable to accept that percentage changes in flows and pressures resulting from changes in the calibrated model would be very similar to the percentage changes in the existing system the field.

When comparing *FluidFlow3's* results with site you should check the following:

- Adequate NPSH available at all pumps.
- Flashing not occurring downstream of orifice plates and other fittings.
- Fittings are performing on site as indicated by the coefficient used in the model.
- Pipes are not scaled or scaling is properly simulated.
- Control valves are properly selected
- Leaks in air flow systems.

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