Orifice plates serve a number of different purposes in various engineering fields. Typical applications include fuel lines, hydraulic systems, air conditioning systems, water pipe systems, steam traps and bubble diffusers. Pressure loss and flow performance data for orifice plates are often used to design openings in more complex applications, such as film cooling holes in gas turbine blades (designed to use a minimal amount of cooling air yet still prevent thermal damage to blade surfaces) or flow control valves (in which flow rates are controlled with the size of the openings). However, due to the versatility, low cost and low maintenance of orifice plates, they are most commonly used as orifice flowmeters for measuring flow in pipes or ducts.

Orifice flowmeters consist of a straight-run pipe with a restriction in the form of an orifice plate, which causes obstruction to the flow. Pressure taps are positioned upstream and downstream of the orifice plate to measure pressure drop. Taps can be installed in different configurations: flange pressure taps, corner pressure taps, and D and D/2 pressure taps. To determine the flow rate across the orifice plate, the discharge coefficient across different sizes of orifice plates must be known. These are available in standards such as ISO 5167, ASME MFC-3M and ANSI/API2530.

While a fair amount of reliable data is available to predict flow performance in turbulent flow in short orifice plates (such as those previously described), data are scarce for long orifice plates and lower Reynolds number flows.

ESDU is an engineering advisory organization that provides validated engineering design data, methods and software to industry professionals and academics. The organization is part of the global information company IHS, which shares insight and analytics in critical areas that shape today’s business landscape. Data developed by ESDU using validated CFD predictions represent an essential source of accurate and reliable information for industrial applications. This information is required, for example, in designing pipelines to select appropriate pumping equipment, to optimize performance of specific components, or to determine the size or length of duct networks. ESDU has carried out extensive studies to validate ANSYS CFX CFD software using different turbulence and transition models.

**FLOW ACROSS ORIFICE PLATES**

Introducing an orifice plate into a pipe system causes a local increase of fluid velocity and, therefore, a rise in kinetic energy and a drop in pressure. A large flow separation occurs downstream of the orifice plate. Smaller recirculation regions may be present upstream and at the orifice wall, depending on the thickness of the orifice plate and the Reynolds number of the flow.

**CFD VALIDATION STUDIES**

ESDU has carried out extensive CFD validation studies for the flow across square-edged and knife-edged orifice plates [ESDU TN 10013]. Guidance is provided on the CFD modeling of pressure loss, discharge coefficient and flow characteristics [ESDU BPG-CFD 11010].

The ESDU CFD predictions were validated across all flow regimes using ANSYS CFX 11.0. Mesh independency solutions were conducted by systematic sensitivity studies until the percentage...
difference in the pressure loss coefficient was less than 1 percent (Figure 2). The flow models used included:

- Laminar flow model
- SST turbulence model with automatic near-wall treatment
- k-ω model with automatic near-wall treatment
- k-ε with scalable near-wall treatment
- SST with the γ-θ transition model

The solution was considered as converged when global RMS residuals were both below $10^{-6}$ and constant (Figure 3).

**RESULTS**

The ESDU CFD predictions for the pressure loss and discharge coefficients were validated against reliable experimental data as well as ISO and ASME standards in the form of correlations (Figures 4 and 5). The predicted discharge coefficients were within 2 percent of the correlations in ISO and ASME standards across the diameter ratio range 0.3 to 0.7.

While the predictions obtained using the laminar flow model are reliable at low Reynolds numbers (Re<100), the most consistent results across the transitional flow regimes were obtained using the SST.
γ-θ transition model. This model’s predictions are closest to the measurements not only in terms of pressure loss and discharge coefficients, but in the prediction of flow recirculation sizes downstream of the orifice plate.

ESDU also found that the predictions obtained using SST and k-ω turbulence models are in a good agreement with experimental data and correlations in the fully turbulent flow regime. However, the ANSYS CFX predictions obtained using the k-ε model with scalable wall treatment significantly differ from the other turbulence models, especially for the prediction of flow separation sizes. Using best practices to appropriately apply the software produces high-quality results that are in good agreement with experiment.

**Figure 4.** Comparisons of ESDU CFD predictions for pressure loss coefficient, with measurements for different diameter ratios $\beta$

**Figure 5.** Comparisons of ESDU CFD predictions for discharge coefficient, with measurements for diameter ratio $\beta=0.5$