Interlink Systems, Inc.
5116 Bissonnet #341, Bellaire, TX 77401
Telephone and Fax: (713) 663-6361
jamesmcadams@alumni.rice.edu

The Control Simulator (CS4) - Simulated devices

A variety of line configurations and end devices are supported at this time. The following is a list of the devices with a very brief description of each one.

SUPPLY

"Supply" refers to the end of the control line where the control panel is located. This might be a platform, drilling rig, etc. Flow can be into or out of the line at the supply end.

Constant pressure

The simplest device are implemented to supply fluid pressure to the line is a constant pressure supplied through an orifice (simulating the restriction in the control valve). It works well where the response of the HPU is not of interest.

Hydraulic power unit

There are two hydraulic power unit models, each with a reservoir, pump, accumulator, regulator, and output orifice. The simulated pump is turned on and off by simulated pressure switches monitoring accumulator pressure. The accumulator model is quite detailed (see "Accumulators" below). The difference between the two is that one has a constant flow pump and the other has a pump with an output that falls off with an increase in outlet pressure (to simulate an air driven pump that can regulate by stalling, for instance).

Constant flow

To handle TFL cases there is a simple pump that supplies a constant flow rate until a certain trip pressure (measured at the pump) is reached, at which point it cuts off.

CONTROL LINES

Materials

Control lines can be hard (tubing) or a hose. The tubing model assumes linear, elastic expansion of the conduit wall and linear compression of the fluid. The hose model allows nonlinear, time varying (viscoelastic) expansion of the hose wall and allows a small amount of air to be included in the control fluid.

Air in the fluid

Air in the line is simulated in the program by adding additional terms to the fluid density and bulk modulus when calculating the effect of hose expansion on the speed of sound in the line. Due to this, tubing with a small amount of air can be simulated using the hose model.

Friction factor

The friction term is quite significant in subsea control hoses and is handled carefully by The Control Simulator. The friction factor is allowed to vary along the length of the line in addition to varying with time. This gives more accurate simulations when much of the flow occurs near the transition region. The friction factor is calculated using the methods normally used for steady state laminar and turbulent flow. In the transition region, friction factor is continuous and varies from the laminar value to the turbulent value as Reynold's number is increased across the transition region.

SUBSEA DEVICES

There are several discharge devices to go on the " tree "end of a line. They include a plug (for a blocked line), two orifices (one fixed, the other time varying), an accumulator, and three spring return valve operators. There are also three models for use with TFL problems. All of these devices can go at the end of a line. In addition, most of the devices can have a second line attached to their output port. In this manner, line and discharge devices can be cascaded for up to eight lines with any combination of tubing and hoses. This makes it possible to model, for instance, a steel supply line to a subsea pod with an accumulator, a control valve in the pod feeding a hose from the pod to a valve operator on a satellite tree, and then return lines back to the surface.

Valve Operators

The basic valve operator is a complex model. It includes piston area and stroke, a controlled leak (flow-by) bypassing the piston, sticking and running friction, stem dimension and forces, and spring forces. Accumulators are present at the operator inlet and outlet and they include the effect of water depth on the gas. The accumulators and flow-by path can be individually disabled when not needed. The accumulator on the inlet simulates the supply in a piloted system where the control pod is located on the tree. The accumulator on the outlet simulates a surge accumulator and can be used with or without a return line. This model can be used to model tree valves or pilot valves by varying dimensions and forces.

There is a second valve operator that has all of the capabilities of the first, but which can be commanded to actuate several times in a row. For instance, in one simulation it might simulate opening 5 valves at an interval of 30 seconds, then waiting 5 minutes and repeating the 5-valve sequence. This makes it easy to examine the effect on the supply line of opening several wells in succession with a multiplex control system.

Finally, a third valve model, includes a single accumulator and optional regulator. It is meant to handle cases where tree or BOP valves are being operated by a multiplex system with the supply line optionally going on to another tree.

TFL Tools

Three devices are provided for examining TFL problems. One simulates a TFL tool passing through a blast joint. This results in a pressure pulse that then propagates to the other end of the line, changing shape as it goes. The second model simulates the pressure pulse that results from landing a TFL tool at some pumping rate. A constant flow pump that can turn off at a specific pressure complements this model. Finally, there is a model that allows you to apply a pressure pulse of an arbitrary shape to the end of a line and watch the pulse as it propagates toward the source.

All subsea devices except the plug include orifices to simulate the restrictions due to connecting tubing and control valves.

ACCUMULATORS

All accumulator models are based on the Redlich-Kwong empirical equation of state, which corrects for non-ideal behavior of the precharge gas at high pressures. The model keeps track of the precharge gas temperature and its return back to ambient conditions over time. A table of specific heat ratios is included for nitrogen covering a wide range of temperatures and pressures. This results in a model that can closely approximate the behavior of real accumulators for fast and slow changes in fluid volume. The effect of water depth on the absolute pressure in the accumulator is included in the model. The loss of efficiency at high absolute pressures is automatically accounted for.

FLUIDS

There are two fluid models. In the simplest model, the fluid model takes into account density, bulk modulus, and viscosity (all as constants). The second model allows the viscosity to vary as a linear function of the pressure.

"TIME VARYING" DEVICES

The Control Simulator has provisions for storing the state of the control line at the end of a simulation. These data can then be used as the initial conditions for a second simulation. This allows simulation of time varying or nonlinear elements by having end devices in the second simulation that are different from those used in the first. This is useful for simulating such things as a sequenced system being run past two or three shift points in one step, or the operation of a second valve before the supply line transients from another valve operation have had a chance to die out.