

Bench-Scale Annular Reactors

Carollo maintains BioSurface Technologies annular reactors for conducting distribution system studies. These reactors have the unique capability of allowing separate control of the detention time and shear stress within the system. The reactors consist of a rotor inside a stationary outer cylinder. Hydraulic conditions within the reactor, such as shear stress and water velocity, depend on the rotational speed of the rotor. A rotational speed of 50 rpm is commonly used in drinking water studies, as it creates a shear stress of 0.25 N/m² at the outer wall, which corresponds to a flow of approximately 1 foot per second (0.3 meters per second) in a 4-inch-diameter (100 mm) smooth pipe. Four draft tubes inside the inner cylinder enhance liquid mixing.

The reactors allow the collection of both water samples and coupons from which biofilm growth and the extent of corrosion may be determined. Polycarbonate coupons are often used to evaluate biofilm growth without the presence of corrosion or corrosion by-products. Coupons manufactured from common pipe materials such as ductile iron may also be used. The influent flow rate determines the

Carollo's annular reactor studies offer the following benefits:

- ▼ Permit independent control of detention time and shear stress.
- ▼ Require small sample volumes (few gallons).
- ▼ Allow pipe wall corrosion and biofilm growth to be quantified, in addition to water quality parameters.

water residence time inside the reactor, simulating the residence time in the distribution system.

In most bench-scale experiments, the reactor is assumed to approximate a finite section of a distribution system. A common set up for drinking water experiments

consists of pumping the test water into the annular reactor. Test waters may be augmented by adjusting water quality parameters such as pH or the level of background organic material, or seeded with specific consortia of microorganisms. Additional nutrients, disinfectants, corrosion inhibitors, or other constituents may also be pumped into the reactor depending on the specific experimental objectives.

Annular reactors may also be used in combination with batch incubation bottles to differentiate the effect of the pipe wall from the effect of water age. For batch incubation, a clean bottle is filled with reactor influent water. The bottle is kept under the same conditions of temperature and darkness as the reactors. After a period of time equivalent to the reactor residence time, water is sampled from the incubation bottle and from the reactor effluent. A comparison of the results allows the impact of biofilm growth and corrosion at the pipe wall to be distinguished from

the effect of water age.

The reactors are readily transportable, and can be shipped along with other required equipment such as a feed water pump, chemical dosing pumps, and instrumentation for basic water quality parameters.



Carollo has used the annular reactors to evaluate the effectiveness of scale inhibitors for preventing scale formation in a reverse osmosis brine disposal pipeline. These reactors have also been used to evaluate biofilm formation and regrowth in distribution systems with varying levels of available biodegradable organic matter. Carollo has also used the annular reactors to study the formation and decay of specific disinfectant by-products in distribution systems for various water quality conditions.

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Application Table

Parameter	Value and Notes
Reactor Volume, each	1,150 mL
Typical Range of Pipe Detention Times Simulated	2 hours to 1 week
Typical Range of Rotational Speeds	50 to 250 rpm
Electrical Requirements	Single-phase, 60 Hz, 120-volt
Typical Rental Fee	\$250 per month