

The formulae $\frac{\partial \mu_i}{\partial \alpha} + \frac{\partial}{\partial \alpha_j} (\rho \mu_i) = -\frac{\partial \rho}{\partial \alpha_j} + \frac{\partial}{\partial \alpha_j} \left(\mu \frac{\partial \mu_i}{\partial \alpha_j} \right) + g_i (\rho - \rho_i)$ for building $\frac{\partial}{\partial \alpha_j} (\rho \mu_i \bar{V}_i) = -\frac{\partial \rho}{\partial \alpha_j} + \frac{\partial}{\partial \alpha_j} \left(\mu \frac{\partial \mu_i}{\partial \alpha_j} - \rho \mu_i \bar{V}_i \right) + g_i (\rho - \rho_i)$ state of the art $\frac{\partial}{\partial \alpha_j} (\rho \mu_i \bar{V}_i) = \frac{\partial}{\partial \alpha_j} \left(\lambda \frac{\partial \mu_i}{\partial \alpha_j} - \rho \mu_i \bar{V}_i \right)$ biomedical research facilities.

Maintaining Water Systems from Construction Through Occupancy

Maintaining water systems from construction completion to building occupancy and use is a critical but often overlooked element of renovation and new construction projects. It's important for construction teams and engineers to be aware of water system hazards; potential issues must be identified during design and planning, which should follow DRM guidance to ensure good water management practices. Establishing a water start-up plan can also help project teams ensure potable water systems maintain residual disinfectant levels and mechanical water systems maintain required corrosion protection levels.

Risks and Recommendations for Low-Use/Stagnant Water Systems

In buildings which are not readily occupied, low-use and stagnant water systems can be potential breeding grounds for microorganisms, which can cause corrosion of metals and their alloys up to 100 times faster than normal corrosion occurs,¹ and lead to growth of undesirable pathogens, such as *Legionella*.² Water chemistry changes may also increase corrosion as well as metal and alloy leaching.³ Post-hydrotest conditions where water is not fully drained or dried can lead to stagnant water, resulting in potential biofilms and piping corrosion.

The DRM encompasses requirements from the 2018 IPC Section 610 – *Disinfection of Potable Water Systems*. Guidance in DRM 8.3: *Water Systems*, along with applicable codes and industry guidance can prevent uncontrolled levels of piping biofilm, bacteria proliferation, and corrosion that occur in stagnant/wetted piping systems. In particular, Section 8.3.12 provides water management requirements to maintain the integrity of water systems, and Section 8.3.16 provides guidance on pressure testing, flushing, disinfecting, commissioning, and water quality testing of new and renovated water systems. Project specifications must contain requirements for important continuous control measures for wetted systems (cleaning, disinfection, treatment, flushing, etc.)² and should also include defined testing and reporting criteria. It's important to note that there are standards for flushing large public water mains, but no consensus standard for flushing and disinfecting plumbing systems within buildings.^{4,5} Once water piping construction is complete, tested, and flushed, an appropriate hand-off to building maintenance is necessary to ensure continued turn-over and maintenance of water systems throughout building occupancy.

To combat low or no use water systems, the Environmental Protection Agency (EPA) recommends proactive measures to minimize piping degradation and public health risks.³ The Centers for Disease Control (CDC) recommends that construction in retrofit projects should avoid excess vibrations and rapid changes in water pressure, which can cause biofilm in pipes to dislodge, freeing sediment into water systems.⁶ As water temperature influences the growth of *Legionella* between 77°F and 113°F, hot water systems shall be maintained above 120°F and cold-water systems maintained below 77°F at all points (growth slows below optimal range).² Other considerations include evaluating if proactive chemicals or high-temperature disinfection are necessary, along with establishing a Water

Management Program (WMP) for water systems and associated water devices per *ASHRAE Standard 188-2018*. *ASHRAE Building Readiness – Domestic Water Systems* provides industry guidance related to building shutdowns and re-opening.⁷

Water System Maintenance During Construction and Renovation

For shutdown of dry systems, where water is drained in an offline state, care should be taken to ensure low points and dead legs are fully drained. A compressed air blowout system (dry, oil-free air) can be used to force water out of low points. Once fully dried, piping systems should be kept closed using valves and end caps until start-up. For a standby (wet) state, water shall be replaced and flushed in returning to service, including a pre-flush baseline to compare to the post-flush water quality.⁵ Construction must confirm that appropriate level of biocides and corrosion inhibitors are added to non-potable systems.² Refilling systems may result in destabilization of sediments and biofilm or introduction of external contaminants; in these cases, flushing the system before and after disinfection may improve results.⁸ Start-up teams should verify and validate that appropriate disinfectant levels reach all piping outlets and are maintained in the pipes for a specified duration. Follow-up water testing should be performed to confirm water systems are ready for service.

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