The National Institutes of Health | Division of Technical Resources | Office of Research Facilities

Design Requirements Manual **News to Use**

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The formulae $\frac{\partial \rho U_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho U_i U_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial U_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ *for building* $\frac{\partial}{\partial x_j}(\rho \overline{U}_i \overline{U}_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial \overline{U}_i}{\partial x_j}-\rho\overline{u_i' u_j'}\right)+g_i(\rho-\rho_0)$ *state of the art* $\frac{\partial}{\partial x_i}(\rho \overline{U}_i \overline{H})=\frac{\partial}{\partial x_i}\left(\lambda\frac{\partial \overline{T}}{\partial x_i}-\rho\overline{u_i' h'}\right)$ *biomedical research facilities.*

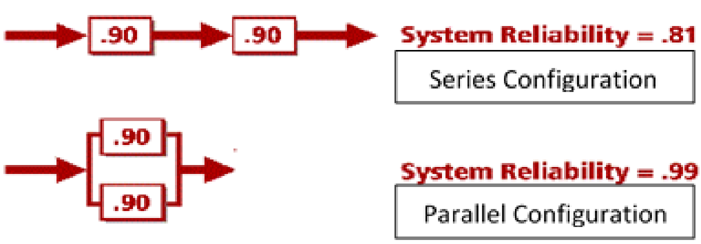
Reliability in Mechanical Systems Design

Mechanical reliability emphasizes the ability of a system or component to function without failure, under specified conditions, and for a specified time period. The Design Requirements Manual (DRM) addresses reliability in various chapters, as an entire system's failure can occur from a system component up to a utility service failure or interruption.

Definition and General Methodology

Failure rate is the frequency at which an engineered system or component fails; it is expressed in failures per unit of time. In any given system, overall reliability can be determined by reviewing the reliability of the system's components. This process requires generating reliability block diagrams using the reliability configuration of each component. These system components can be configured either in a series or in parallel.

Example 1 shows reliability block diagrams, one with a series configuration and another with a parallel configuration. In the series configuration, each component has a 0.90 reliability (90%) and the system reliability is estimated to be 0.81 or 81% using the equation $Rs=R_{C1}xR_{C2.}$ When using a parallel configuration with the same component reliability, the system has a reliability of 0.99 or 99%, based on $Rs=1-(1-R_{C1})$ x $(1-R_{C2})$, assuming both configurations have the same operational time period. The failure rate may not remain constant over the operational lifecycle of a system due to the number of components that may fail.



Example 1: Reliability block diagrams

There are various methods to estimate and create reliable mechanical systems which can be applied at a component or system level. For example, using better materials and advanced lubricants allows for improved system component reliability, and diversity or redundancy can reduce system failure for safety and critical systems.

Although redundancy can minimize single points of system failure, it may require serious consideration of factors such as cost-benefit return, also known as return on investment (ROI), and potential system service interruptions due to extended maintenance periods, which can negatively impact cutting-edge animal research facilities as well as the overall safety of NIH operations. Section 1.15 of the DRM states the above and expands on other requirements.

Design Requirements

There are several basic criteria that shall be maintained when designing reliable systems at NIH:

- The designer must consult with all stakeholders to determine the value of uninterrupted operations. This decision is the result of risk assessment and can vary from laboratory to laboratory at NIH, depending on the types of research conducted in the laboratory.
- Designers must establish a baseline of reliability requirements with all stakeholders to better understand the systems that require high reliability considerations.
- The budget/cost for implementing the required level of reliability must be established early on and based on risk assessment.
- The designer shall select system equipment with high reliability, quality, and durability. This may include equipment replication or redundancy.
- A required maintenance plan must be established to ensure reliable and safe system operation, assisted by the Building Automation system (BAS). For example, the BAS can notify personnel of a system component failure and enact an automatic switch to a redundant component to keep the system functional. See Chapter 7 of the DRM.

Additional Design Requirements and Considerations

Certain systems and facilities will require considering additional parameters to ensure maximum mechanical reliability. Per Section 6.1.2 of the DRM, HVAC systems require operational flexibility, adaptability, scalability (allowance for future program renovation and expansion), and serviceability, including the ability to perform routine maintenance due to single point failure. The DRM addresses the higher level of reliability design considerations necessary for designing Level 3 Biosafety Laboratory (BSL) and Animal Biosafety Laboratory (ABSL) in Chapters 6 through 12, and Chapter 13 covers reliability requirements for Aseptic Production Facilities (APFs).

Conclusion

The reliability engineer must apply an analysis method that best represents the expected systems failure for each component type and application. It is also important to keep in mind that the DRM requirements for reliability must be coordinated with the stakeholder for each given project. Adequate methodology must be applied when the reliability estimate does not accurately reflect the required system's operation.

Resources

NIH Design Requirements Manual (DRM) Revision 1.5: 03/26/2020
RBDs and Analytical System Reliability, Chapter 3
http://reliawiki.org/index.php/RBDs_and_Analytical_System_Reliability