U.S. NUCLEAR REGULATORY COMMISSION

DESIGN-SPECIFIC REVIEW STANDARD FOR mPOWER^{TM} iPWR DESIGN

6.4 CONTROL ROOM HABITABILITY SYSTEM

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of ventilation and air filtration

Secondary - Organization responsible for the review of design basis accident radiological consequence analyses

Organization responsible for the review of chemical engineering

I. AREAS OF REVIEW

This design specific review standard (DSRS) section is applicable to design certification (DC) and combined license (COL) applications submitted under Title 10 of *Code of Federal Regulations* (10 CFR) Part 52. NUREG-0800 is the Standard Review Plan (SRP) upon which this DSRS section is based. NUREG-0800 was originally written for Part 50 license applications. For DC and COL applications submitted under 10 CFR Part 52, the level of information reviewed should be consistent with that of a final safety analysis report (FSAR) submitted in an operating license (OL) application. However, verification that the as-built facility conforms with the approved design is performed through the inspections, tests, analyses, and acceptance criteria (ITAAC) process.

The control room ventilation system and control building layout and structures, as described in the applicant's safety analysis report (SAR) or design control document (DCD), are reviewed to ensure that plant operators are adequately protected against the effects of accidental releases of toxic and radioactive gases and to assure conformance with the requirements of 10 CFR Part 50, Appendix A, General Design Criteria (GDC) 2, 4, 5, and 19, and of 10 CFR 50.34(f)(2)(xxviii), 10 CFR 52.47(b)(1), and 10 CFR 52.80(a). Additionally, review is performed to ensure that the control room can be maintained as the backup center from which technical support center (TSC) personnel can safely operate in the case of an accident. These objectives are accomplished by the following:

The mPower^{TM} control room habitability system includes the following classifications of equipment:

1. Safety-related and risk-significant equipment

2. Safety-related and nonrisk-significant equipment

3. Nonsafety-related and risk-significant Regulatory Treatment of Nonsafety Systems (RTNSS) equipment

4. Nonsafety-related nonrisk-significant equipment.

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The mPower^{TM} application will include the classification of systems, structures, and components (SSCs), a list of risk significant SSCs, and a list of RTNSS equipment. Based on this information, the staff will review according to Design-Specific Review Standard (DSRS) Section 3.2, SRP Sections 17.4 and 19.3 to confirm the determination of safety-related and risk-significant SSCs.

The specific areas of review are as follows:

1. The zone serviced by the control room emergency ventilation system is examined to confirm that all critical areas needing access in the event of an accident are included within the zone (control room, kitchen, sanitary facilities, etc.) and to ensure that those areas not needing access are generally excluded from the zone.

2. The capacity of the control room in terms of the number of people it can accommodate for an extended period of time is reviewed to confirm the adequacy of self-contained breathing apparatus and to determine the length of time the control room can be isolated before CO_2 levels become excessive. The number of people inside the control room assumed for various control room habitability analyses, conducted under the current DSRS and DSRS 9.4.1, should also account for the TSC personnel that may be needed to maintain the control room as the TSC backup center during a design basis accident (DBA).

3. For the control room HVAC system with safety-related passive cooling and heating design features, the site-specific limiting temperatures and humidity levels resulting within the control room envelope due to its complete loss of active cooling or heating are reviewed for the length of time the control room could be isolated under a DBA or an anticipated operational transient. This is to establish that the passive cooling or heating of the control room using its heat sink design and make-up air supply provision can maintain suitable ambient temperature, humidity, and breathing air conditions for the control room personnel and assure the operability of its equipment, under an extended loss of AC power.

4. The adequacy of the various industry standards and utility requirements documents (URDs) on human comfort used in the control room habitability analyses is reviewed.

5. The control room ventilation system layout and functional design is reviewed to determine flow rates and filter efficiencies for input into the analyses of the buildup of radioactive or toxic gases inside the control room, assuming a design basis release. Basic deficiencies that might impair the effectiveness of the system are examined. In addition, the system operation and procedures are reviewed.

6. The physical location of the control room with respect to potential release points of hazardous airborne materials is reviewed. The layout of the control building is reviewed to ensure that airborne materials will not enter the control room from corridors or ventilation ducts, etc.

7. Radiation shielding provided by structural concrete is analyzed to determine the effectiveness of shielding and structure surrounding the control room. The control building layouts are checked to see if radiation streaming through doors or other apertures or from equipment might be a problem.

8. Independent analyses are performed to determine the radiation doses and toxic gas concentrations.

9. Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC). For DC and COL reviews, the staff reviews the applicant's proposed ITAAC associated with the structures, systems, and components (SSCs) related to this DSRS section in accordance with SRP Section 14.3, "Inspections, Tests, Analyses, and Acceptance Criteria." The staff recognizes that the review of ITAAC cannot be completed until after the rest of this portion of the application has been reviewed against acceptance criteria contained in this DSRS section. Furthermore, the staff reviews the ITAAC to ensure that all SSCs in this area of review are identified and addressed as appropriate in accordance with SRP Section 14.3.

10. COL Action Items and Certification Requirements and Restrictions. For a DC application, the review will also address COL action items and requirements and restrictions (e.g., interface requirements and site parameters).

    For a COL application referencing a DC, a COL applicant must address COL action items (referred to as COL license information in certain DCs) included in the referenced DC. Additionally, a COL applicant must address requirements and restrictions (e.g., interface requirements and site parameters) included in the referenced DC.

Review Interfaces

Other SRP and DSRS sections interface with this section as follows:

1. The review of potential sources of hazardous gas is performed under SRP Section 2.2.1-2.2.2. The review will also include the preparation of the sources, source locations, estimated hazardous gas concentrations near the control room building, and probability estimates for accidental releases related to transportation.

2. The review of dispersion of airborne contamination is performed under SRP Sections 2.3.4 and 2.3.5.

3. The review of the protection against missiles generated by tornadoes and extreme winds is performed under DSRS section 3.5.1.4.

4. The review of the emergency standby atmosphere filtration system and iodine removal efficiencies of the control room atmosphere filtration system is performed under SRP Section 6.5.1. The review under SRP Section 6.5.1 should also assess the possible radiological impact of operating the control room atmosphere filtration system on other reactor service building HVAC systems, such as through the pressure coupling due to the safety-related make-up air supply to the control room.

5. The review of the design of the control room ventilation system is performed under DSRS Section 9.4.1.

6. The review of the storage and location of CO_2 or other firefighting materials is performed under DSRS Section 9.5.1.1.

7. The review of the radiation shielding and exposures is performed under DSRS Sections 12.1 through 12.5.

8. The review of the radiation levels external to the control room from design basis accidents (DBAs) is performed under DSRS Section 15.0.3.

9. The review of the Technical Specifications is performed under DSRS Section 16.0.

10. The review of the Probabilistic Risk Assessment is performed under SRP Section 19.3 for potential risk significance of SSCs.

II. ACCEPTANCE CRITERIA

Requirements

Acceptance criteria are based on meeting the relevant requirements of the following Commission regulations:

1. GDC 2, “Design Bases for Protection Against Natural Phenomena,” as it relates to system capability to withstand the effects of earthquakes.

2. GDC 4, “Environmental and Dynamic Effects Design Bases,” as it relates to SSCs important to safety being designed to accommodate the effects of and to be compatible with the environmental conditions associated with postulated accidents.

3. GDC 5, “Sharing of Structures, Systems and Components,” as it relates to ensuring that sharing among nuclear power units of SSCs important to safety will not significantly impair the ability to perform safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining unit(s).

4. GDC 19, “Control Room,” as it relates to maintaining the nuclear power unit in a safe condition under accident conditions and providing adequate radiation protection.

5. 10 CFR 50.34(f)(2)(xxviii), as it relates to evaluations and design provisions to preclude certain control room habitability problems.

6. 10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAAC that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a facility that incorporates the design certification has been constructed and will be operated in conformity with the design certification, the provisions of the Atomic Energy Act, and the NRC's regulations.

7. 10 CFR 52.80(a), which requires that a COL application contain the proposed inspections, tests, and analyses, including those applicable to emergency planning, that the licensee shall perform, and the acceptance criteria that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, the facility has been constructed and will operate in conformity with the combined license, the provisions of the Atomic Energy Act (AEA), and the U.S. Nuclear Regulatory Commission’s (NRC's) regulations.

DSRS Acceptance Criteria

Specific DSRS acceptance criteria acceptable to meet the relevant requirements of the NRC’s regulations identified above are set forth below. The DSRS is not a substitute for the NRC’s regulations, and compliance with it is not required. Identifying the differences between this DSRS section and the design features, analytical techniques, and procedural measures

proposed for the facility, and discussing how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria, is sufficient to meet the intent of 10 CFR 52.47(a)(9), “Contents of applications; technical information.” The same approach may be used to meet the requirements of 10 CFR 52.79(a)(41) for COL applications.

1. Control Room Emergency Zone

   The control room emergency zone should include the following:

   A. Instrumentation and controls necessary for a safe shutdown of the plant, i.e., the control room, including the critical document reference file;

   B. Computer room, if it is used as an integral part of the emergency response plan;

   C. Shift supervisor's office; and

   D. Operator washroom and the kitchen.

   The control room emergency zone should conform to the guidelines of Regulatory Guide (RG) 1.196, January 2007, "Control Room Habitability at Light-Water Nuclear Power Reactors," and Regulatory Guide (RG) 1.197, May 2003, "Demonstrating Control Room Envelope Integrity at Nuclear Power Reactors."

2. Ventilation System Criteria. The ventilation system should include the following design features:

   A. Isolation dampers used to isolate the control zone from adjacent zones or the outside should be low leakage dampers or valves. The degree of leaktightness should be documented in the SAR.

   B. Single failure of an active component should not result in loss of the system's functional performance. All the components of the control room emergency filter train should be considered active components. See Appendix A to this DSRS for criteria regarding valve or damper repair.

3. Pressurization Systems. Ventilation systems that will pressurize the control room during a radiation emergency should meet the following criteria:

   A. Systems having pressurization rates of greater than or equal to 0.5 volume changes per hour should be subject to periodic verification (every 18 months) that the makeup is $\pm$ 10% of design value. During plant construction or after any modification to the control room that might significantly affect its capability to maintain a positive pressure, measurements should be taken to verify that the control room emergency zone is pressurized to at least to the value used in the accident analysis relative to all surrounding air spaces while applying makeup air at the design rate.

   B. Systems having pressurization rates of less than 0.5 and equal to or greater than 0.25 volume changes per hour should have identical testing requirements as indicated in acceptance criteria 1 above. In addition, at the combined license, or standard design certification stage, an analysis should be provided (based on the planned leaktight design features) that ensures the feasibility of maintaining the tested differential pressure with the design makeup airflow rate.

C. Systems having pressurization rates of less than 0.25 volume changes per hour should meet all the criteria for acceptance criteria 2 above, except that periodic verification of control room pressurization (every 18 months) should be specified.

4. Emergency Standby Atmosphere Filtration System. Iodine removal for this system should be in accordance with the guidelines of RG 1.52. Protection of control room personnel from releases of chlorine or other toxic gases is addressed in RG 1.78 as discussed in the criteria below.

5. Relative Location of Source and Control Room. The control room inlets should be located with consideration of the potential release points of radioactive material and toxic gases. Specific criteria as to radiation and toxic gas sources are as follows:

   A. Radiation sources. As a general rule the control room ventilation inlets should be separated from the major potential release points by at least 31 meters (100 feet) laterally and by 16 meters (50 feet) vertically. However, the actual minimum distances should be based on the dose analyses (Ref. 18).

   B. Toxic gases. The minimum distance between the toxic gas source and the control room is dependent upon the amount and type of the gas in question, the container size, and the available control room protection provisions. The acceptance criteria for the control room habitability system are provided in the regulatory positions of Regulatory Guide 1.78 with respect to postulated hazardous chemical releases in general.

6. Radiation Hazards

   10 CFR Part 50, Appendix A, GDC 19 “Control Room,” requires that adequate radiation protection shall be provided to permit access and occupancy of the control room under accident conditions. Applicants for and holders of construction permits and operating licenses under 10 CFR Part 50, applicants for design certifications under 10 CFR Part 52, or applicants for and holders of combined licenses under 10 CFR Part 52, shall meet the requirements of GDC 19.With regard to control room access and occupancy, adequate radiation protection shall be provided to ensure that radiation exposures shall not exceed 0.05 Sv (5 rem) total effective dose equivalent (TEDE) as defined in 10 CFR 50.2 for the duration of the accident.

   In accordance with GDC 19, these doses to an individual in the control room should not be exceeded for any postulated design basis accident. The dose consists of contributions from airborne radioactivity inside and outside the control room, as well as direct shine from all radiation sources.

7. Toxic Gas Hazards. Three exposure categories are defined: protective action exposure (2 minutes or less), short-term exposure (between 2 minutes and 1 hour), and long-term exposure (1 hour or greater). Because the physiological effects can vary widely from one toxic gas to another, the following general restrictions should be used as guidance: there should be no chronic effects from exposure; acute effects, if any, should be reversible within a short period of time (several minutes) without benefit of any measures other than the use of self-contained breathing apparatus.

   The allowable exposure limits should be established on the basis that the operators should be capable of carrying out their duties with a minimum of interference caused by the gas and subsequent protective measures. The limits for the three exposure categories normally are set as follows:

A. Protective action limit (2 minutes or less): Use a limit that will ensure that the operators will quickly recover after breathing apparatus is in place. In determining this limit, it should be assumed that the concentration increases linearly with time from zero to two minutes and that the limit is attained at two minutes.

B. Short-term limit (2 minutes to 1 hour): Use a limit that will ensure that the operators will not suffer incapacitating effects after a 1-hour exposure.

C. Long-term limit (1 hour or greater): Use a limit assigned for occupational exposure (40-hour week).

The protective action limit is used to determine the acceptability of emergency zone protection provisions during the time personnel are in the process of fitting themselves with a self-contained breathing apparatus. The other limits are used to determine whether the concentrations with breathing apparatus in place are applicable. They are also used in those cases where the toxic levels are such that emergency zone isolation without use of protective gear is sufficient. Self-contained breathing apparatus for the control room personnel should be on hand. The adequacy of the number of self-contained breathing apparatus maintained in the control room is reviewed for the number of individuals expected inside the isolated control room under a chemical or a radiological DBA. A 6-hour onsite bottled air supply should be available with unlimited offsite replenishment capability from nearby location(s). As an example of appropriate limits, the following are the three levels for chlorine gas:

protective action:	15 ppm by volume
short-term:	4 ppm by volume
long-term:	1 ppm by volume

RG 1.78 provides a partial list of protective action levels for other toxic gases.

Technical Rationale

The technical rationale for application of these acceptance criteria to the areas of review addressed by this DSRS section is discussed in the following paragraphs:

1. GDC 2, as to system capability to withstand the effects of earthquakes, requires that SSCs important to safety be designed to withstand the effects of a design-basis earthquake without loss of capability to perform safety functions.

   The function of the control room habitability system is to provide a controlled environment for the comfort and safety of control room personnel during normal operation, anticipated operational occurrences, and during and after postulated accidents, including the coincidental loss of offsite power. This requirement ensures that the control room will remain functional in the event of a design basis earthquake. Regulatory Guide 1.29 provides guidance acceptable to the staff for meeting these control room occupancy protection requirements.

Meeting the requirement of GDC 2 provides assurance that the habitability of the control room area will be maintained and that equipment in the control room will operate as designed, thereby minimizing the potential for loss of function.

2. Compliance with GDC 4 requires that structures, systems, and components important to safety be designed to accommodate the effects of, and be compatible with, environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents (LOCAs). These structures, systems, and components shall be appropriately protected against dynamic effects (e.g., the effects of missiles, pipe whipping, and discharging fluids) that may result from equipment failures and from events and conditions outside the nuclear power unit.

   The function of the control room habitability system is to provide a suitable and controlled environment for the control room and equipment located therein during normal operation, anticipated operational occurrences, and during and after postulated accidents, including LOCAs. GDC 4 applies to this DSRS section because the reviewer verifies that the control room will remain functional throughout the course of operating and accident events and that operators will be able to carry out their responsibilities without being subject to undue stress.

   Meeting the requirements of GDC 4 provides assurance that the control room habitability system will function as designed, thereby providing protection to plant operators against the effects of accidental releases of toxic and radiological gases.

3. Compliance with GDC 5 requires that structures, systems, and components important to safety not be shared among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown in the remaining units.

   For a multiple-unit facility in which there is a common control room, components of the control room habitability system will necessarily be shared; whereas, for a multiple-unit facility in which there are separate control rooms, components of the control room habitability system need not be shared. For either design, it should be demonstrated that the operating environment of control areas for each unit remains within specified limits in the event of an accident or toxic gas release, thereby ensuring that control room operators and essential equipment in the control room will be able to continue functioning effectively throughout the course of the event. In this manner, an event at one unit will be prevented from propagating to another unit.

   Meeting the requirements of GDC 5 provides assurance that a failure in one unit of a multiple-unit site will not affect an orderly shutdown and cooldown in remaining units.

4. Compliance with GDC 19 requires provision of a control room from which actions can be taken (a) to operate the nuclear power unit safely under normal conditions and (b) to maintain the plant in a safe state under accident conditions, including LOCAs.

   The reviewer verifies that adequate radiation protection and protection from hazardous chemical releases will be provided to permit access to and occupancy of the control room under accident conditions.

   RG 1.196 and 1.197 provide acceptable guidance for meeting control room habitability requirements. With respect to control room habitability dose analyses for the mPower™ design, as discussed in DSRS 15.0.3 the dose assessment guidance of RG 1.183 is

generally applicable, as justified by the applicant. RG 1.52 and 1.78 present methods acceptable to the staff for meeting control room occupancy protection requirements.

Meeting the requirements of GDC 19 provides assurance that adequate protection will be maintained to permit access to and occupancy of the control room under accident conditions.

5. Compliance with 10 CFR 50.34(f)(2)(xxviii) requires the evaluation of potential pathways for radioactive materials that may lead to problems related to control room habitability under certain accident conditions; it also requires making necessary design provisions to preclude such problems.

   The requirements of 10 CFR 50.34(f)(2)(xxviii) apply to this DSRS section because the review evaluates issues involving isolation of the control room, pressurization to assist in preventing inleakage, filtration of the control room air, and location of ventilation intakes. Collectively, these criteria are designed to mitigate the radiological consequences of accidents in the control room.

   Meeting the requirements of 10 CFR 50.34(f)(2)(xxviii) provides assurance that, in the event of an accident, radiation doses to operators will not exceed acceptable limits and, consequently, will not prevent operators from performing required functions.

III. REVIEW PROCEDURES

These review procedures are based on the identified DSRS acceptance criteria. For deviations from these acceptance criteria, the staff should review the applicant's evaluation of how the proposed alternatives provide an acceptable method of complying with the relevant NRC requirements identified in Subsection II of this document.

For the review of DC or COL applications, the procedures are used to verify that the initial design criteria and bases have been appropriately implemented in the final design as set forth in the final safety analysis report. The review procedures include a determination that the content and intent of the technical specifications prepared by the applicant are in agreement with the criteria for system testing, and minimum performance developed as a result of the staff review as indicated in Subsection I of this DSRS section.

1. Programmatic Requirements - In accordance with the guidance in NUREG-0800 "Introduction," Part 2 as applied to this DSRS Section, the staff will review the programs proposed by the applicant to satisfy the following programmatic requirements. If any of the proposed programs satisfies the acceptance criteria described in Subsection II, it can be used to augment or replace some of the review procedures. It should be noted that the wording of "to augment or replace" applies to nonsafety-related risk-significant SSCs, but "to replace" applies to nonsafety-related nonrisk-significant SSCs according to the "graded approach" discussion in NUREG-0800 "Introduction," Part 2. Commission regulations and policy mandate programs applicable to SSCs that include:

   - Maintenance Rule, SRP Section 17.6 (DSRS Section 13.4, Table 13.4, Item 17, Regulatory Guides 1.160, "Monitoring the Effectiveness of Maintenance at Nuclear Power Plants." and RG 1.182; "Assessing and Managing Risk Before Maintenance Activities at Nuclear Power Plants".

- Quality Assurance Program, SRP Sections 17.3 and 17.5 (DSRS Section 13.4, Table 13.4, Item 16).

- Technical Specifications (DSRS Section 16.0 and SRP Section 16.1) – including brackets value for DC and COL. Brackets are used to identify information or characteristics that are plant specific or are based on preliminary design information.

- Reliability Assurance Program (SRP Section 17.4).

- Initial Plant Test Program (RG 1.68, "Initial Test Programs for Water-Cooled Nuclear Power Plants, "DSRS Section 14.2, and DSRS Section 13.4, Table 13.4, Item 19).

- ITAAC (DSRS Chapter 14).

2. In accordance with 10 CFR 52.47(a)(8),(21), and (22), for new reactor license applications submitted under Part 52, the applicant is required to (1) address the proposed technical resolution of unresolved safety issues (USIs) and medium- and high-priority generic safety issues (GSIs) that are identified in the version of NUREG-0933 current on the date 6 months before application and that are technically relevant to the design; (2) demonstrate how the operating experience insights have been incorporated into the plant design; and, (3) provide information necessary to demonstrate compliance with any technically relevant portions of the Three Mile Island requirements set forth in 10 CFR 50.34(f), except paragraphs (f)(1)(xii), (f)(2)(ix), and (f)(3)(v). These cross-cutting review areas should be addressed by the reviewer for each technical subsection and relevant conclusions documented in the corresponding SER section.

3. Control Room Emergency Zone: The reviewer verifies that the control room emergency zone includes the areas identified in the acceptance criteria of subsection II.1 of this DSRS section. The emergency zone should be limited to those spaces needing operator occupancy. Spaces such as battery rooms, cable spreading rooms, or other spaces not needing continuous or frequent occupancy after a design basis accident (DBA) generally should be excluded from the emergency zone. Inclusion of these spaces may increase the probability of smoke or hazardous gases entering the emergency zone. They may also increase the possibility of infiltration into the emergency zone, thus decreasing the effectiveness of the ventilation system in excluding contamination. It is advantageous to have the emergency zone located on one floor, with the areas included in the zone being contiguous.

4. Control Room Personnel Capacity: A control room designed with complete isolation capability from the outside air to provide radiation and toxic gas protection is reviewed to determine if the buildup of carbon dioxide could present a problem. The air inside a 2830 m^3 (100,000 cubic foot) control room would support five persons for at least six days. Thus, CO_2 buildup in an isolated emergency zone is not normally considered a limiting problem. However, the resulting CO_2 levels are reviewed for the number of individuals expected inside the control room envelope for the length of time the control room could be isolated under a chemical or a radiological DBA. This is to ensure that the carbon dioxide levels inside the control room remain within acceptable limits throughout the isolation period. Any make-up air supply to the control room under isolation, credited as a mitigating factor for the carbon dioxide build-up, is also reviewed.

5. Ventilation System Layout and Functional Design. The reviewer evaluates the control room ventilation system in order to establish appropriate parameters to be used in the control room dose calculations. The control room ventilation system design and performance is evaluated in accordance with DSRS Section 9.4.1. The reviewer should use Rg 1.52. The procedures are as follows:

   A. The type of system proposed is determined. The following types of protection provisions are currently being employed for boiling water reactor (BWR) or pressurized water reactor (PWR) plants:

      i. Zone isolation, with the incoming air filtered and a positive pressure maintained by the ventilation system fans. This arrangement is often provided for facilities having high stacks. Airflow rates are between 190 and 1900 L/s (400 and 4000 cfm).

      ii. Zone isolation, with filtered recirculated air. This arrangement is often provided for PWRs with roof vents. Recirculation rates range from 950 to 14,200 L/s (2000 to 30,000 cfm).

      iii. Zone isolation, with filtered recirculated air, and with a positive pressure maintained in the zone. This arrangement is essentially the same as that in (2), with the addition of the positive pressure provision.

      iv. Dual air inlets for the emergency zone. In this arrangement, two widely spaced inlets are located outboard, on opposite sides of potential toxic and radioactive gas sources. The arrangement ensures at least one inlet being free of contamination, except under extreme no-wind conditions. It can be used in all types of plants. Makeup air supplied from the contamination-free inlet provides a positive pressure in the emergency zone and thus minimizes infiltration.

      v. Bottled air supply for a limited time. In this arrangement, a flow rate of 190 to 290 L/s (400 to 600 cfm) is provided from compressed air containers for about 1 hour to assist in preventing inleakage. It is used in systems having containments whose internal atmospheric pressure becomes negative within an hour after a DBA (subatmospheric containments).

   B. The input parameters to the radiological dose model are determined. The parameters are emergency zone volume, filter efficiency, filtered makeup airflow rate, unfiltered inleakage (infiltration), and filtered recirculated airflow rate.

   C. The ventilation system components and the system layout diagrams are examined. As noted earlier the reviewer will determine if the system meets the single failure criterion as well as other safety requirements under DSRS Section 9.4.1. Damper failure and fan failure are especially important. The review should confirm that the failure of isolation dampers on the upstream side of fans will not result in too much unfiltered air entering the control room. The radiation dose and toxic gas analysis results are used to determine how much unfiltered air can be tolerated.

   D. The iodine protection factor (IPF) methodology of Reference 18 may not be adequately conservative for all DBAs and control room arrangements because it models a steady-state control room condition. Since many analysis parameters

change over the duration of the event, the IPF methodology should only be used with caution.

E. The following information may be used in evaluating the specific system types (see Ref. 18 for further discussion):

i. Zone isolation with filtered incoming air and positive pressure. These systems may not be sufficiently effective in protecting against iodine. The staff allows an IPF, which is defined as the time-integrated concentration of iodine outside over the time-integrated concentration within the emergency zone, of 20 to 100 for filters built, maintained, and operated according to Rg 1.52. An IPF of 100 needs deep bed filters. Such systems are likely to provide a sufficient reduction in iodine concentration only if the source is at some distance from the inlets. Thus, the staff consider that in most cases, only plants with high stacks (about 100 meters) would meet GDC 19 with this system.

ii. Zone isolation with filtered recirculated air. These systems have a greater potential for controlling iodine than those having once-through filters. IPFs ranging from 20 to over 150 can be achieved. These are the usual designs for plants having vents located at containment roof level. A system having a recirculation rate of 2400 L/s (5000 cfm) and a filter efficiency of 95% would be rated as follows:

Infiltration L/s (cfm)	IPF[3]
100 (200)	25
50 (100)	49
24 (50)	96
12 (25)	191

Infiltration should be determined conservatively. Measured gross leakage is used to determine the infiltration rate that will be applied in the evaluation of the radiological consequences of postulated accidents. This rate is determined in accordance with the guidance of RG 1.197. "Demonstrating Control Room Envelope Integrity at Nuclear Power Reactors," May 2003.

The base infiltration rate is augmented by adding to it the estimated contribution from opening and closing of doors associated with such activities in accordance with by the plant emergency plans and procedures. Normally, 5 L/s (10 cfm) is used for this additional contribution.

iii. Zone isolation with filtered recirculated air and a positive pressure. This system is essentially the same as the preceding one. However, an additional operational mode is possible. Makeup air for pressurization is admitted. It is filtered before entering the emergency zone.

[3] Within the range of interest, the iodine protection factor is directly proportional to recirculation flow rate multiplied by efficiency.

Pressurization reduces the unfiltered inleakage that is assumed to occur when the emergency zone is not pressurized. Assuming a filter fan capacity of 2400 L/s (5000 cfm) and a filter efficiency of 95%, the following protection factors result (flows in L/s (cfm)):

Makeup Air	Recirculated Air	IPF (Assuming No Infiltration)	IPF (Assuming Infiltration[4])
190 (400)	2200 (4600)	238	159
350 (750)	2000 (4250)	128	101
470 (1000)	1900 (4000)	96	80

For method of operation, the following methods have been considered:

(1) automatic isolation with subsequent manual control of pressurization.

(2) automatic isolation with immediate automatic pressurization.

The first is advantageous in the case of external puff releases. Simple isolation would maintain the buildup of the unfilterable noble gases. It would also protect the filters from excessive concentrations in the case of a chlorine release. However, the second method does ensure that infiltration (unfiltered) is reduced to near zero immediately upon accident detection. This would be beneficial in the case where the contamination transport path to the emergency zone is mainly inside the building. Method (i) should be used in the case of a toxic gas release and either method (i) or (ii) should be used in the case of a radiological release, provided GDC 19 can be satisfied.

A substantial time delay should be assumed where manual isolation is assumed, e.g., 20 minutes for the purposes of dose calculations.

iv. Dual air inlets for the emergency zone. Several plants have utilized this concept. The viability of the dual inlet concept depends upon whether or not the placement of the inlets ensures that one inlet will always be free from contamination. The assurance of a contamination free inlet depends in part upon building wake effects, terrain, and the possibility of wind stagnation or reversal. For example, in a situation where the inlets are located at the extreme edges of the plant structures (e.g., one on the north side and one on the south side), it is possible under certain low probability conditions for both inlets to be contaminated from the same point source. SRP Section 2.3.4 presents the position for dealing with the evaluation of the atmospheric dispersion (χ/Q) values for dual inlet systems.

[4] Normally 5 L/s (10 cfm) infiltration is assumed for conservatism. This flow could be reduced or eliminated if the applicant provides assurance that backflow (primarily as a result of ingress and egress) will not occur. This may mean installing two-door vestibules or equivalent.

Because damage to the ducting might seriously affect the system capability to protect the operators, the ducting should be seismic Category I and should be protected against tornado missiles. In addition, the number and placement of dampers should be such as to ensure both flow and isolation in each inlet assuming one single active component-failure (see Appendix A for information on the damper repair alternative). The location of the intakes with respect to the plant security fence should also be reviewed. Evaluation of the design options described above depends on the physical characteristics of the site as well as the plant design and, thus, can be finalized only at the COL stage of review.

v. Bottled air supply for a limited time. In some plant designs, the containment pressure is reduced below atmospheric within a pre-determined time period after a DBA, as short as 1 hour. This generally ensures that, after that time, significant radioactive material will not be released from the containment. Such a design makes it feasible to maintain the control room above atmospheric pressure by use of bottled air. Periodic pressurization tests are necessary to determine that the rated flow, normally about 150 to 300 L/s (300 to 600 cfm), is sufficient to pressurize the control room emergency zone. The system should also be composed of several separate circuits, one of which is assumed to be inoperative to account for a possible single failure. At least one nonredundant, once-through filter system for pressurization as a standby for accidents of long duration should be provided.

Compressed air bottles should be protected from tornado missiles or internally generated missiles and should be placed so as not to cause damage to vital equipment or interference with operation if they fail.

6. Atmosphere Filtration Systems. The primary organization responsible for ventilation and air filtration evaluates the iodine removal efficiency of the atmosphere filtration systems under SRP Section 6.5.1, determines the appropriate credit to be given, and advises the organization responsible for the review of design basis accident radiological consequence analyses. The review by the primary organization responsible for ventilation and air filtration should include evaluation of the testing proposed for the filtration system and should use applicable positions of RG 1.52 for guidance.

7. Relative Location of Source and Control Room. SRP Sections 2.2.1 and 2.2.2 provide guidance on identifying potential sources of toxic or otherwise potentially hazardous gases. The organization responsible for the review of SRP Sections 2.2.1 and 2.2.2 will provide its findings to the organization responsible for ventilation and air filtration for its toxic gas estimates for use in the control room habitability analysis. There are three basic categories: Radioactive sources, toxic gases such as chlorine, and gases with the potential for being released inside confined areas adjacent to the control room. Evaluation of the relative locations of sources and airborne transport of toxic or otherwise potentially hazardous gases depends on the physical and meteorological characteristics of the site, and plant design and, thus, can be finalized only at the COL stage of review.

A. Radiation Sources. The organization responsible for the review of design basis accident radiological consequence analyses will use DSRS Section 15.0.3 to determine the DBA source terms that are routinely used to evaluate the radiation levels external to the control room envelope. Contamination pathways internal to

the plant are examined to determine their impact on control room habitability. Other DBAs are reviewed to determine whether they might constitute a more severe hazard than the LOCA.

B. Toxic Gases. The organization responsible for the review of materials and chemical engineering will review and identify those toxic substances stored or transported in the vicinity of the site which may pose a threat to the plant operators upon a postulated accidental release. The method used to determine whether the quantity or location of the toxic material is such as to need closer study is described in RG 1.78. This guide also discusses the methods for analyzing the degree of risk and states, in general terms, the various protective measures that could be instituted if the hazard is found to be too great. In the case of chlorine, specific acceptable protective provisions are provided in RG 1.78.

In summary, the facility should include the following provisions or their equivalent for the emergency zone ventilation system:

i. quick-acting toxic gas detectors,

ii. automatic emergency zone isolation,

iii. emergency zone leaktightness,

iv. limited fresh air makeup rates, and

v. breathing apparatus and associated bottled air supply.

The best solution for a particular case will depend on the toxic gas in question and on the specific ventilation system design.

C. Confined Area Releases. The reviewer in the organization responsible for the review of ventilation and air filtration studies the control building layout in relation to potential sources of radiation and toxic gases inside the control building or adjacent connected buildings. The following is considered:

i. Storage location of CO_2 or other firefighting materials should be such as to eliminate the possibility of significant quantities of the gases entering the emergency zone. The review will be coordinated with the organization responsible for the review of materials and chemical engineering.

ii. The ventilation zones adjacent to the emergency zone should be configured and balanced to preclude airflow toward the emergency zone.

iii. All pressurized equipment and piping (e.g., main steam lines and turbines) that could cause significant pressure gradients when failed inside buildings should be isolated from the emergency zone by multiple barriers such as multiple door vestibules or their equivalent.

8. Radiation Shielding. Control room operators as well as other plant personnel are protected from radiation sources associated with normal plant operation by a combination of shielding and distance. The review of the adequacy of this type of protection for normal operating conditions is coordinated with the review done in DSRS

Chapter 12 by the organization responsible for the review of health physics issues and the review done in DSRS Section 15.0.3 by the organization responsible for the review of design bases accident radiological consequence analysis. To a large extent, the same radiation shielding (and missile barriers) also provides protection from DBA radiation sources. This is especially true with respect to the control room walls, which usually consist of at least 46 cm (18 in) of concrete. In most cases, the radiation from external DBA radiation sources is attenuated to negligible levels. The following items should be considered qualitatively in assessing the adequacy of control room radiation shielding and should be coordinated with the organization responsible for the review of design basis accident radiological consequence analyses, which will be requested to provide assistance as necessary.

A. Control Room Structure Boundary. Wall, ceiling, and floor materials and thickness should be reviewed. 46 to 61 centimeters (Eighteen inches to two feet) of concrete or its equivalent will be adequate in most cases.

B. Radiation Streaming. The control room structure boundary should be reviewed with respect to penetrations (e.g., doors, ducts, stairways). The potential for radiation streaming from accident sources should be identified, and if deemed necessary, quantitatively evaluated.

C. Radiation Shielding from Internal Sources. If sources internal to the control room complex are identified, protective measures against them should be reviewed. Typical sources in this category include contaminated filter trains, or airborne radioactivity in enclosures adjacent to the control room. Evaluations of radiation shielding effectiveness with respect to the above items should be performed using simplified analytical models for point, line, or volume sources such as those presented in References 21 and 22. If more extended analysis is necessary, analytical support from the organization responsible for the review of design basis accident radiological consequence analyses should be requested. The applicant's coverage of the above items should also be reviewed in terms of completeness, method of analysis, and assumptions.

9. Independent Analyses. Pursuant to GDC 19, the applicant is required to calculate doses to the control room operators. Independent analyses are made by the organization responsible for the review of design basis accident radiological consequence analyses because of the diversity of control room habitability system designs and the engineering judgment involved in their evaluation. Since this analysis involves site-related characteristics, it can be finalized only at the COL stage of review. Using the approach indicated in RG 1.183 or other methods found acceptable to the staff through its review pursuant to DSRS 15.0.3, the source terms and doses due to each DBA are calculated. The dose for each DBA is then compared with the requirements of GDC 19. If the guideline values are exceeded, the applicant will be requested to improve the system.

10. Design Certification and COL Applications Review. For review of a DC application, the reviewer should follow the above procedures to verify that the design, including requirements and restrictions (e.g., interface requirements and site parameters), set forth in the final safety analysis report (FSAR) meets the acceptance criteria. DCs have referred to the FSAR as the design control document (DCD). The reviewer should also consider the appropriateness of identified COL action items. The reviewer may identify additional COL action items; however, to ensure these COL action items are addressed during a COL application, they should be added to the DC FSAR.

For review of a COL application, the scope of the review is dependent on whether the COL applicant references a DC, an early site permit or other NRC approvals (e.g., manufacturing license, site suitability report or topical report).

For review of both DC and COL applications, SRP Section 14.3 should be followed for the review of ITAAC. The review of ITAAC cannot be completed until after the completion of this section.

IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the staff's technical review and analysis, as augmented by the application of programmatic requirements in accordance with the staff's technical review approach in the DSRS Introduction, support conclusions of the following type to be included in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

The staff concludes that the design and expected performance of the control room area ventilation system is acceptable and meets the applicable requirements of GDC 2, 4, 5, 19, and of 10 CFR 50.34(f)(2)(xxviii).

1. These conclusions are based on the staff's review and evaluation that the control room habitability systems meet the regulatory positions of RG 1.52, Revision 3, June 2001, "Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Post-Accident Engineered-Safety-Feature Atmosphere Cleanup Systems in Light-Water-Cooled Nuclear Power Plants," RG 1.78, Revision 1, December 2001, "Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release," RG 1.183, July 2000, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," RG 1.196, January 2007, "Control Room Habitability at Light-Water Nuclear Power Reactors," and RG 1.197, May 2003, "Demonstrating Control Room Envelope Integrity at Nuclear Power Reactors."

   If special protection provisions for toxic gases are not necessary, the following statement or its equivalent is made:

   The habitability of the control room was evaluated using the procedures described in RG 1.78. As indicated in Sections 2.2.1 and 2.2.2, no offsite storage or transport of chemicals is close enough to the plant to be considered a hazard. There are no onsite chemicals that can be considered hazardous under RG 1.78. A sodium hypochlorite biocide system will be used, thus eliminating an onsite chlorine hazard. Therefore, special provisions for protection against toxic gases will not be necessary. In accordance with plant emergency plans and procedures, self-contained breathing apparatus is provided for assurance of control room habitability in the event of occurrences such as smoke hazards.

   If special protection provisions are necessary for toxic gases, compliance or noncompliance with the guidelines of RG 1.78 should be stated. Since toxic gas risk is related to site characteristics, this part of the evaluation will be completed at the COL stage of review.

   In meeting the positions of these regulatory guides, the applicant has demonstrated that the control room will adequately protect the control room operators and will remain habitable in accordance with 10 CFR 50.34(f)(2)(xxviii).

For DC and COL reviews, the findings will also summarize the staff's evaluation of requirements and restrictions (e.g., interface requirements and site parameters) and COL action items relevant to this DSRS section.

In addition, to the extent that the review is not discussed in other SER sections, the findings will summarize the staff's evaluation of the ITAAC, including design acceptance criteria, as applicable.

V. IMPLEMENTATION

The staff will use this DSRS section in performing safety evaluations of mPower™-specific DC, or COL, applications submitted by applicants pursuant to 10 CFR Part 52. The staff will use the method described herein to evaluate conformance with Commission regulations.

Because of the numerous design differences between the mPower™ and large light-water nuclear reactor power plants, and in accordance with the direction given by the Commission in SRM- COMGBJ-10-0004/COMGEA-10-0001, "Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews," dated August 31, 2010 (ML102510405), to develop risk-informed licensing review plans for each of the small modular reactor reviews including the associated pre-application activities, the staff has developed the content of this DSRS section as an alternative method for mPower™ -specific DC, or COL submitted pursuant to 10 CFR Part 52 to comply with 10 CFR 52.47(a)(9), "Contents of applications; technical information."

This regulation states, in part, that the application must contain "an evaluation of the standard plant design against the SRP revision in effect 6 months before the docket date of the application." The content of this DSRS section has been accepted as an alternative method for complying with 10 CFR 52.47(a)(9) as long as the mPower™ DCD FSAR does not deviate significantly from the design assumptions made by the NRC staff while preparing this DSRS section. The application must identify and describe all differences between the standard plant design and this DSRS section, and discuss how the proposed alternative provides an acceptable method of complying with the regulations that underlie the DSRS acceptance criteria. If the design assumptions in the DC application deviate significantly from the DSRS, the staff will use the SRP as specified in 10 CFR 52.47(a)(9). Alternatively, the staff may supplement the DSRS section by adding appropriate criteria in order to address new design assumptions. The same approach may be used to meet the requirements of 10 CFR 52.79(a)(41) for COL applications.

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, GDC 2, "Design Bases for Protection Against Natural Phenomena."

2. 10 CFR Part 50, Appendix A, GDC 4, "Environmental Dynamic Effects Design Bases."

3. 10 CFR Part 50, Appendix A, GDC 5, "Sharing of Structures, Systems and Components."

4. 10 CFR Part 50, Appendix A, GDC 19, "Control Room."

5. 10 CFR 50.34(f), "Additional TMI-Related Requirements."

6. NUREG-0737, "Clarification of TMI Action Plan Requirements," Item III.D.3.4, "Control-Room Habitability Requirements," November 1980.

7. RG 1.29, “Seismic Design Classification.”

8. RG 1.52, Revision 3, June 2001, "Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Post-Accident Engineered-Safety-Feature Atmosphere Cleanup Systems in Light-Water-Cooled Nuclear Power Plants."

9. RG 1.78, Revision 1, December 2001 (Reviewed December 2011), "Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release."

10. RG 1.68, Revision 3, March 2007, "Initial Test Programs for Water-Cooled Nuclear Power Plants."

11. RG 1.160, Revision 3, May 2012, "Monitoring the Effectiveness of Maintenance."

12. RG 1.182, May 2000, "Assessing and Managing Risk Before Maintenance Activities of Nuclear Power Plants."

13. RG 1.196, Revision 1, January 2007, "Control Room Habitability at Light-Water Nuclear Power Reactors."

14. RG 1.197, May 2003, "Demonstrating Control Room Envelope Integrity at Nuclear Power Reactors."

15. RG 1.183, July 2000, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors."

16. RG 1.206. June 2007, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

17. RG 1.215, Revision 1, May 2012, "Guidance for ITAAC Closure Under 10 CFR Part 52."

18. K. G. Murphy and K. M. Campe, "Nuclear Power Plant Control Room Ventilation System Design for Meeting General Design Criterion 19," 13th AEC Air Cleaning Conference, August 1974.

19. "Leakage Characteristics of Openings for Reactor Housing Components," NAA-SR-MEMO-5137, Atomics International, Div. of North American Aviation, Inc., June 20, 1960.

20. R. L. Koontz, et al., "Leakage Characteristics of Conventional Building Components for Reactor Housing Construction," Trans. Am. Nucl. Soc., November 1961.

21. R. G. Jaeger, et al., eds., "Engineering Compendium on Radiation Shielding," Vol. 1, "Shielding Fundamentals and Methods," Springer Verlag (1968).

22. N. M. Schaeffer, "Reactor Shielding for Nuclear Engineers," TID-75951, U.S. Atomic Energy Commission, January 1973. (Re-released by the Organization for Economic Co-Operation and Development, Nuclear Energy Agency, June 4, 2008)

23. NRC Inspection Manual Chapter IMC-2504, "Construction Inspection Program - Inspection of Construction and Operational Programs," issued October 15, 2009.

APPENDIX A

SECTION 6.4

ACCEPTANCE CRITERIA FOR VALVE OR DAMPER REPAIR ALTERNATIVE

Pursuant to GDC 19, the control room ventilation system should function properly, even with a single failure of an active component. In certain cases, complex valve or damper configurations should meet the single failure criterion. For example, assurance of the isolation and operability of each leg of a dual inlet system at various times after a postulated accident could necessitate a four-valve arrangement in which two pairs of series valves are connected in parallel. The mechanical, power, and control components of such arrangements combine to form a rather complex system. Credit will be allowed for an alternative system that allows the failed valve to be manually repositioned so that it will not interfere with the operation of the system. For example, in the case of a dual inlet system, if credit for repair is given, then two valves in series in each leg of the dual inlet would be acceptable. Where a valve fails closed but meets the criteria given below, credit would be allowed for the valve to be repositioned and locked in an open position.

The approval of the repair option is contingent upon the intrinsic reliability of the internal components of the valve or damper and also upon the ease and ability to overcome the failure of the external actuating components (electrical relays, motors, hydraulic pistons, etc.). The facility should meet the following criteria or their equivalent.

1. The valve or damper components should be listed as to which are considered internal (nonrepairable) and which external (repairable). These should be designed to meet the following criteria.

   A. Internal valve components (i.e., components that are difficult to repair manually without opening the ductwork) should be judged to have a very low probability of failure. The component design details will be reviewed and characteristics such as simplicity, ruggedness, and susceptibility to postulated failure mechanisms will be considered in arriving at an engineered judgment of the acceptability of the internal component design with respect to reliability. For example, a butterfly valve welded or keyed onto a pivot shaft would be considered a high reliability internal component. Conversely, multiple blade dampers, actuated by multi-element linkages or pneumatically operated components internal to the ducts, would be viewed as being subject to failure.

   B. External valve components (i.e., components including motors and power supplies that are to be assumed repairable or removable) should be designed to ensure that the failed valve component can be bypassed easily and safely and that the valve can be manipulated into an acceptable position. The electronic components should be isolated from other equipment to ensure that the repair operations do not result in further equipment failure.

2. The location and positioning of the valve or damper should permit easy access from the control room for convenient repair, especially under applicable DBA conditions.

3. Appropriate control room instrumentation should be provided for a clear indication and annunciation of valve or damper malfunction.

4. Periodic manipulation of the valve or damper by control room operators should be required for training purposes and also to verify proper manual operability of the valve or damper.

5. The need for manual manipulations of the failed valve or damper should not be recurrent during the course of the accident. Manipulation should not occur more than once during the accident. Adjustment or realignment of other parts of the system should be possible from the control room with the failed valve in a fixed position.

6. The time for repair used in the computation of control room exposures should be taken as the time necessary to repair the valve plus a one-half hour margin. No manual correction will be credited during the first two hours of the accident.

7. Compliance with the above criteria should be documented in the SAR whenever the repair option is used.