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Standard Guide for Design of Equipment for Processing Nuclear and Radioactive Materials[1]

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1. Scope

1.1 *Intent:*

1.1.1 This guide covers equipment used in shielded cell or canyon facilities for the processing of nuclear and radioactive materials. It is the intent of this guide to set down the conditions and practices that have been found necessary to ensure against or to minimize the failures and outages of equipment used under the subject circumstances.

1.1.2 It is intended that this guide record the principles and caveats that experience has shown to be essential to the design, fabrication, and installation of equipment capable of meeting the stringent demands of operating, dependably and safely, in a nuclear processing environment that operators can neither see nor reach directly.

1.1.3 This guide sets forth generalized criteria and guidelines for the design, fabrication, and installation of equipment used in this service. *This service* includes the processing of radioactive wastes. Equipment is placed behind radiation shield walls and cannot be directly accessed by the operators or by maintenance personnel because of the radiation exposure hazards. In the type of shielded cell or canyon facility of interest to users of this guide, either the background radiation level remains high at all times or it is impractical to remove the process sources of radiation to facilitate in situ repairs or carry out maintenance procedures on equipment. The equipment is operated remotely, either with or without visual access to the equipment.

1.2 *Applicability:*

1.2.1 This guide is intended to be applicable to equipment used under one or more of the following conditions:

1.2.1.1 The materials handled or processed constitute a significant radiation hazard to man or to the environment.

1.2.1.2 The equipment will generally be used over a long-term life cycle (for example, in excess of two years), but equipment intended for use over a shorter life cycle is not excluded.

1.2.1.3 The material handled or processed must be retained, contained, and confined within known bounds for reasons of accountability or to minimize the spread of radioactive contamination.

1.2.1.4 The materials handled or processed must be kept and maintained within one or more of the following conditions:

(1) In a specific geometric array or configuration, and

(2) Within a range of conditions that have been determined to be a critically safe set of conditions for that piece of equipment, that is:

(a) In a given and specified operational position where adjacent nuclear criticality interaction conditions are known and unchanging,

(b) For a given and specified set or range of operating conditions, and

(c) For a given and specified process.

1.2.1.5 The equipment can neither be accessed directly for purposes of operation or maintenance, nor can the equipment be viewed directly, for example, without intervening shielded viewing windows, periscopes, or a television monitoring system.

1.2.2 This guide is intended to be applicable to the design of equipment for the processing of materials containing uranium and transuranium elements in any physical form under the following conditions:

1.2.2.1 Such materials constitute an unacceptable radiation hazard to the operators and maintenance personnel,

1.2.2.2 The need exists for the confinement of the in-process material, of dusts and particulates, or of vapors and gases arising or resulting from the handling and processing of such materials, and

1.2.2.3 Any of the conditions cited in 1.2.1 apply.

1.2.3 This guide is intended to apply to the design, fabrication, and installation of ancillary and support services equipment under the following conditions:

1.2.3.1 Such equipment is installed in shielded cell or canyon environments, or

1.2.3.2 Such equipment is an integral part of an in-cell processing equipment configuration, or an auxiliary component or system thereof, even though an equipment item or system may not directly hold or contain nuclear or radioactive materials under normal processing conditions.

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NOTE 1—Upsets, accidents, or certain emergency conditions may be specified (and thus required) design considerations, but not necessarily acceptable or normal operating circumstances under this definition.

1.2.4 This guide is intended to apply to the design and fabrication of any and all types of equipment for radioactive wastes processing when any of the conditions cited in 1.2.1 apply. This would include equipment for waste concentration; for incorporation of wastes in selected host materials or matrices; and for the fixation, encapsulation, or canning of such wastes. It is intended to apply to all such wastes, regardless of the product waste composition or form. The product radioactive waste may have a glass, ceramic, metallic, concrete, bituminous, or other type of host material or matrices (composition), and may be in pelletized, solid, or granular form.

1.3 *User Caveats:*

1.3.1 *This guide does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this guide to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3.2 (**Warning—**This guide pertains to equipment used in and for the handling and processing of nuclear and radioactive materials. These operations are known to be hazardous for a variety of reasons, one being chemical toxicity.)

1.3.3 This guide is not a substitute for applied engineering skills. Its purpose is to provide guidance.

1.3.3.1 The guidance set forth in this guide relating to design of equipment is intended only to alert designers and engineers to those features, conditions, and procedures that have been found necessary or highly desirable to the acquisition of reliable equipment for the subject service conditions.

1.3.3.2 The guidance set forth results from discoveries of conditions, practices, features, or lack of features that were found to be sources of operational or maintenance trouble, or causes of failure.

1.3.4 It is often necessary to maintain the materials being processed within specific chemical composition or concentration ranges, or both. When such constraints apply, it may also be necessary to create and maintain a specific geometric array to minimize the chances of a nuclear criticality incident. Designers and engineers are referred to other standards for additional guidance when such requirements apply.

1.3.5 Equipment usage intent, service conditions, size and configuration, plus the configuration and features of the operating and maintenance environments have an influence on equipment design. Therefore, not all of the criteria, conditions, caveats, or features would be applicable to every equipment item.

1.3.6 It is intended that equipment designed, fabricated, procured, or obtained by transfer or adaptation and re-use of existing equipment, and installed in accordance with this guide meet or exceed statutory, regulatory, and safety requirements for that equipment under the applicable operating and service conditions.

1.3.7 This guide does not supersede federal or state regulations, or both, and codes applicable to equipment under any conditions.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *Industry and National Consensus Standards—*Nationally recognized industry and consensus standards applicable in whole or in part to the design, fabrication, and installation of equipment are referenced throughout this guide and include the following:

2.2 *ASTM Standards:*[2]

C859 Terminology Relating to Nuclear Materials

D5144 Guide for Use of Protective Coating Standards in Nuclear Power Plants

2.3 *ANSI Standards:*[3]

ANS Glossary of Terms in Nuclear Science and Technology (ANS Glossary)

ANSI/ANS 8.1 Nuclear Criticality Safety in Operations with Fissile Materials Outside Reactors

ANSI A14.3 Ladders, Fixed Safety Requirements

2.4 *ASME Standards:*[4]

Boiler and Pressure Vessel Code Section VIII

ASME NQA 1 Quality Assurance Requirements for Nuclear Facility Applications

ASME NOG-1 Rules for Construction of Overhead Gantry Cranes (Top-Running Bridge, Multiple Girder)

2.5 *Federal Regulations:*[5]

10CFR50, Appendix B, Quality Assurance

29CFR1910 Occupational Safety and Health Standards

2.6 *National Electrical Manufacturers Association (NEMA) Standard:*[6]

NEMA 250 Enclosures for Electrical Equipment 1000 Volts Maximum (Type 4)

2.7 *National Fire Protection Association (NFPA) Standard:*[7]

NFPA 70 National Electric Code

3. Terminology

3.1 *Definitions:*

3.1.1 The terminology employed in this guide conforms with industry practice insofar as practicable.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[5] Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.

[6] Available from National Electrical Manufacturers Association (NEMA), 1300 N. 17th St., Suite 900, Arlington, VA 22209, http://www.nema.org.

[7] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

3.1.2 For definitions of terms used in this guide, refer to Terminology C859 and ANS Glossary.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 The terms defined below are of a restricted nature, specifically applicable to this guide.

3.2.2 *accident*—an unplanned event that could result in unacceptable levels of any of the following: *(1)* equipment damage, *(2)* injury to personnel, *(3)* downtime or outage, *(4)* release of hazardous materials (radioactive or non-radioactive), *(5)* radiation exposure to personnel, or *(6)* criticality.

3.2.3 *accountability*—the keeping of detailed records on, and the responsibility, on the part of operations personnel and plant management, of being accountable for the amounts of special nuclear materials entering and leaving a plant, a vessel, or a defined processing step.

3.2.4 *datum connection points*—those locations on equipment where separate auxiliary equipment items such as pumps, agitators, columns, condensers, and other separately removable equipment pieces are mounted, or where process, service, instrumentation, or electrical jumper connections are made.

3.2.4.1 *Discussion*—These datum connection points are positioned by dimensioning from (theoretically) perfectly placed base *X, Y,* and *Z* datum planes; for example, such points or locations are dimensionally located by three-plane coordinate dimensions. Datum connection points are the loci of positioning elements such as dowels, trunnions, trunnion guides, and such other devices or elements that serve to align, position, or locate equipment in a precise position or array, or which serve as a point for the connection or placement of other components.

3.2.5 *engineering responsibility*—an obligation to perform engineering design activities assigned to a specified organization.

3.2.6 *geometrically favorable*—equipment having set dimensions, and a shape or a layout configuration, that provides assurance that a criticality incident cannot occur in the equipment or system under a given set of circumstances or conditions.

3.2.6.1 *Discussion*—The given set of conditions or circumstances requires that the isotopic composition, form, concentration, and density of fissile materials in the equipment or system will not violate those assumed and used for the preparation of the criticality analysis, and that those variables will remain within conservatively chosen limits, and that nuclear criticality interaction conditions will be within some permitted, pre-set range.

3.2.7 *jumpers*—the pipe line, electrical service, or instrumentation service connector assemblies that span the gap between nozzles or connection points on the canyon or cell-mounted equipment and *(1)* nozzles or connection points on adjacent or nearby vessels, or *(2)* service nozzles or connector points on the interior sides of the cell or shield walls.

3.2.8 *owner-operator*—the firm having either legal ownership responsibilities and rights for the nuclear and radioactive materials handling/processing facility where subject equipment is to be installed or used, or both, *or* the firm that has accepted all management, engineering, operation, and maintenance responsibilities and rights (or specified portions thereof) by way of contractual arrangement(s) with the legal owner of the facilities.

4. Significance and Use

4.1 Equipment operability and long-term integrity are concerns that originate during the design and fabrication sequences. Such concerns can only be addressed or are most efficiently addressed during one or the other of these stages. Equipment operability and integrity can be compromised during handling and installation sequences. For this reason, the subject equipment should be handled and installed under closely controlled and supervised conditions.

4.2 This guide is intended as a supplement to other standards, and to federal and state regulations, codes, and criteria applicable to the design of equipment intended for this use.

4.3 This guide is intended to be generic and to apply to a wide range of equipment types and configurations.

4.4 The term *equipment* is used herein in a generic sense. See 3.2.6 for the definition.

4.5 This service imposes stringent requirements on the quality and the integrity of the equipment, as follows:

4.5.1 Leak tightness is required. This implies containment of liquids at all times, and retention of vapors and gases by means of vessel design, or through means of engineered provisions or operational procedures, or both, that ensure the retention, collection, and treatment of vapors and off-gases when the vessel cannot be fabricated or operated with an air-tight vessel configuration. Radioactive materials must be contained.

4.5.2 Equipment must be capable of withstanding rigorous chemical cleaning and decontamination procedures.

4.5.3 Equipment must be designed and fabricated to remain dimensionally stable throughout its life cycle.

4.5.4 Close fabrication tolerances are required to set nozzles and other datum points in known positions.

4.5.5 Fabrication materials must be resistant to radiation damage, or materials subject to such damage must be shielded or placed so as to be readily replaceable.

4.5.6 Smooth surface finishes are required. Irregularities that hide and retain radioactive particulates or other adherent contamination must be eliminated.

4.5.7 Equipment must be capable of being operated virtually unattended, unseen, and trouble-free over long periods.

4.6 It is assumed that the radiation hazards, combined with the need for confinement and containment, will necessitate a shielded enclosure cell equipped for some degree of remote handling and processing capability in the transuranic materials handling, processing, or machining operations (see 1.2.2).

4.7 Equipment intended for use in the processing and incorporation of radioactive wastes in host composites or matrices may operate at high temperatures and pressures and may require engineered provisions for the removal of large heat loads under normal and emergency conditions. The chemical corrosion and erosion conditions encountered in these processes tend to be extremely severe, placing emphasis on design for containment integrity.

4.8 Maintenance records from the plant or from a plant having a similar processing mission may be available for reference. If available and accessible, these records may offer valuable insight with regard to the causes, frequency, and type of failure experienced for the type and class of equipment being designed and engineered.

4.9 The constraints cited herein are intended to help the engineer establish conditions aimed toward the following:

4.9.1 Enhancing radioactive materials containment integrity,

4.9.2 Minimizing the loss of in-process materials or the spread of hazardous radioactive contaminants,

4.9.3 Minimizing equipment blemishes or faults that promote the adherence or retention of radiation sources,

4.9.4 Facilitating the ease and safety of decontamination and maintenance sequences, and

4.9.5 Reducing the failure frequency rate for all types and classes of equipment used in this service.

4.10 *Exclusions:*

4.10.1 In general, this guide is not intended to apply when the conditions set forth in 1.2.1 are irrelevant to the design of equipment or systems.

4.10.2 Given the conditioned exceptions set forth in 4.10.3, this guide is not intended to apply to the following:

4.10.2.1 *Operations*—Operation of equipment or facilities.

4.10.2.2 *Uranium Ore Mining*—Equipment or facilities associated with the mining of uranium ore.

4.10.2.3 *Uranium/Plutonium/Heavy or Reactive Metals Processing Equipment*—Equipment for the processing, machining and handling of uranium, plutonium, or other transuranic materials in metallic or other forms such as solutions, slurries, powders, or pellets when the radiation exposure levels are minimal, or when such operations are carried out in hoods or glove boxes and do not require massive radiation shield walls or enclosures. (See 1.2.2.)

4.10.2.4 *Laboratory/Research and Development/Semiworks Equipment*—Equipment for the above named facilities. The use of this guide in an unrestricted manner would result in equipment that is over-designed and costly for the above service conditions. (See qualification in 4.10.3.)

4.10.2.5 *Ancillary and Support Services*—Equipment and facilities designed for ancillary and service facilities that are located and installed outside shield walls, in spaces that are directly accessible for purposes of operation, maintenance and repair. (Note, however, the exception stated in 1.2.3.)

4.10.2.6 *Nuclear (Fission) Reactors and Auxiliaries Thereof*—Design of nuclear fission reactor vessels and auxiliary components and systems used in, or associated with, power reactor facilities or to nuclear reactors and auxiliaries intended for any other use or purpose. This guide does not apply to any equipment item or complex where the primary equipment design considerations include the dissipation of fission heat, or where the removal of radioactive decay heat loads resulting from reactor shutdown is a necessity, or both. (See qualification in 4.10.3.)

4.10.2.7 *Decommissioning*—Decommissioning of equipment. (See qualification in 4.10.3.)

4.10.2.8 *Nuclear Criticality Safety*—Design for nuclear criticality safety. (See qualification in 4.10.3.)

4.10.3 Given the foregoing non-applicability statement, this guide may be selectively applied to laboratory, research and development, and semi-works equipment when equipment integrity, materials containment, and the need for ease of cleaning are prime design considerations, where it is deemed essential to safety, or when it is otherwise justifiable. Also, many of the design criteria, guidelines, and caveats set forth herein will have applicability to certain equipment items and auxiliaries to be found in a reactor facility environment. Guidance provided herein relative to equipment features and provisions that minimize the retention of radioactive contamination in any form, and that facilitate cleanup and decontamination, will generally satisfy the potential need for equipment cleanup associated with the eventual decommissioning and disposal of the equipment. Specific guidance is provided in instances where design, fabrication, or integrity considerations are essential to the preservation of conditions or dimensions necessary to meet pre-determined and specified nuclear safety requirements.

5. Quality Assurance and Quality Requirements

5.1 *Quality Assurance (QA):*

5.1.1 The owner-operator should have an approved QA program that is traceable to the criteria cited in applicable portions of 10CFR50, Appendix B. The QA program should also meet the requirements of and be in accordance with ASME NQA-1.

NOTE 2—The above-referenced documents are general in format and do not serve as a procedure, instruction, or QA plan or program specific to any one piece or class of equipment, or to any one task associated with equipment design, fabrication, and installation.

5.1.2 Each sub-contractor engineering firm and each vendor involved in equipment design, fabrication, inspection, testing, and installation should have a QA program traceable to both the criteria of 10CFR50, Appendix B and the requirements of the owner-operator's QA program.

5.1.2.1 The vendors or sub-contractor firms should be required to submit their QA programs to the owner-operator client for review and acceptance prior to initiating firm design and engineering work, and before materials procurement and fabrication commences.

5.1.3 An individual QA plan, specifically applicable to the subject equipment (or service), should be prepared early in the conceptual design stage, and implemented throughout the design, fabrication, inspection, and installation phases for the equipment. Complete, definitive, and specific quality assurance methods and procedures should be delineated in this QA plan. The document should be controlled, numbered, or otherwise identifiable to facilitate its being referenced in other documents. Where appropriate, reference to the QA Plan should: *(1)* appear on vessel or equipment drawings or documents, or both, *(2)* be included in applicable fabrication specifications, *(3)* be included in applicable purchase order or procurement documents, *(4)* be included in specifications and procedures covering equipment inspection and testing, *(5)* be included in procedures for the preparation and packaging of equipment for shipment,, and *(6)* be included in specifications and procedures covering equipment installation. This should apply regardless of the origins of the drawings or documents.

5.1.3.1 All specific QA instructions contained in the QA plan should indicate the tasks and responsibilities for which any and all individuals, functions, or groups are to be held accountable.

5.1.4 The individual QA Plan should be written and applied in such a manner as to assign responsibilities both for performing tasks, and for verifying adherence to QA Plan requirements. If the responsibility for verifying specified QA inspections, examinations, analyses, and tests is wholly or partially delegated to equipment vendor or fabricator organizations, rigid back-up verification procedures should be carried out.

5.1.5 The owner-operator or responsible design and engineering organization should reserve the right to visit suppliers' and fabricators' facilities to *(1)* perform audits or surveillance activities, *(2)* witness specified operations, or *(3)* examine pertinent records. It may also propose changes to the QA Plan and relevant procedures.

5.2 *Quality Requirements:*

5.2.1 The quality and integrity of methods, workmanship, and materials associated with the design and fabrication, testing, and inspection of equipment or systems intended for service under the subject conditions must be commensurate with calculated, known, or demonstrable needs. Such needs arise from: *(1)* stated risks and hazards, whether known or perceived, associated with the handling and processing of nuclear and radioactive materials, *(2)* basic physical and chemical principles, and *(3)* applicable codes and regulations. The originating organization for the design and engineering of the equipment should determine such needs, and should then document the calculations or rationale, or both, by which such needs were determined.

5.2.2 The owner-operator, or alternatively the individual or organization defining the service conditions and performance requirements for a piece of equipment or for a system should specify any and all conditions to be met. The individual or group should specify material requirements and determine the need for and specify the tests and inspection requirements, and should establish or state the acceptance criteria by which compliance is to be judged and recognized, and should state what records are required.

5.2.3 The design and engineering records, including calculations, mathematical modeling, stress analysis, test results, and other engineering documents for equipment or systems intended for critical equipment or systems, as may be adjudged by the owner-operator because of service conditions should be cross-checked, verified, and authenticated by an independent analysis. Such analysis should be in accordance with the applicable or specified portions of ASME NQA-1.

5.2.4 Modification of equipment, in any way and at any stage of its life, might contribute to a subsequent failure if the design intent or capabilities of the equipment, or both, are unknown or misunderstood. If any deviations from the original or presently applicable and specified design conditions, configuration, quality requirements, integrity, and other conditions or requirements established for the equipment are contemplated, a documented effort should be made to review and clear changes through the individuals or group having original or equivalent design and engineering responsibility. All such changes themselves should be well documented as to the reasons and the authorizations for making the changes.

5.2.5 Handling, packing, protection, shipping, storage, and installation of equipment destined for service under the subject service conditions should be accomplished with and through the use of procedures and controls that have been included in either the QA program or the individual QA plan specific to the equipment, and which ensure that the quality and integrity of the equipment is not compromised or diminished.

5.3 *Records Retention*—All records of design, fabrication, inspection, and testing should be passed into the custody of the owner-operator. The records should be retained for the useful life of the equipment or system.

5.3.1 All such records generated by sub-contractor design and engineering firms and by equipment vendors or fabricators, or both, on and for the equipment should be furnished, for audit, to the organization having overall primary design and engineering responsibility. The retention requirements for such records should be specified in writing.

5.3.2 Such records should be available for audit purposes at any time during the period of their retention.

5.3.3 Vendors are cautioned to duplicate such records as may be prudent or necessary for their retention, and to protect and preserve such records with the utmost care until they are passed into the custody of the owner-operator.

6. General Requirements

6.1 *Design Caveat:*

6.1.1 No equipment or components having a set performance function should be located in a nuclear and radioactive materials handling and processing environment unless there are no safe, practicable, or cost effective alternatives, or combinations thereof. If the in-cell placement is not necessary, the subsequent decontamination and maintenance need is made much more difficult when operating equipment or functional components are placed in a remote-operated canyon or cell.

6.1.2 The design of nuclear processing equipment shall include provisions to minimize the release of radioactive material from process vessels and equipment (including pipes or lines connecting to vessels or areas that are not normally contaminated with radioactive material, such as cold reagent tanks and instrument air) during normal and foreseeable abnormal conditions of operation, maintenance, and decontamination.

6.2 *Design Features and Constraints for Vessels:*

6.2.1 All equipment fabricated of stainless steel and alloy materials and intended for use in this service should have a very smooth surface finish, one equivalent or superior to a No. 2B bright mill finish as commercially supplied on high quality rolled sheet products. This applies to all surfaces, inside and out, regardless of the location or orientation, or both, of the surfaces. The intent is to discourage the retention of radioactive contaminants and to facilitate ease of decontamination. This provision is also applicable to cast and forged items to the extent that smooth surface finishes can be achieved at an acceptable cost level.

6.2.1.1 The surfaces should be free of gouges, scratches, crevices, cracks (regardless of their origins, causes, or character), voids, weld ripples or overlap, inaccessible surfaces and pits that can capture and retain dirt, moisture, and particulate or deposited radioactive contaminants.

6.2.1.2 Equipment vendors and fabricators should be requested to submit weld samples and surface finish samples typical of those finishes they propose to supply for each piece of equipment on which they are bidding. The purchase order specification should state surface finish requirements in terms of the samples submitted, or in terms that are readily identifiable, achievable, and verifiable.

6.2.2 The inclusion of weep holes or vents in reinforcing pads and collars around flanged openings, nozzles, support trunnions, or lift eyes is not permitted on equipment in this service, irrespective of code fabrication procedural requirements. All such special reinforcement pads or collars should be seal welded around the entire perimeter of the pads or collars. This provision requires that the metal surfaces enclosed be absolutely clean and dry during fabrication.

6.2.3 Impact nut retention provisions such as collars are generally required around bolt holes on the top flange face of flanged joints, when such connections are part of the equipment design configuration. Such nut retention collars must have drain holes or slots that permit run-off and draining of liquids used during decontamination sequences.

6.2.4 The thickness of material used for equipment is critical to its ability to resist bending, flexing, and distortion. The dimensions of plate, structural members, pipe schedule or thickness, positioning members such as dowels, trunnions and guides, and other elements of the equipment should be set at levels that will resist damage once the equipment has been fabricated. A generous metal thickness allowance may often be justified on the basis of preventing distortion and damage to the equipment while it is being transferred and handled during shipment, or during installation in a remote-operated facility. Adherence to this caution can result in a metal thickness over and above that required to meet design basis and operational temperature and pressure conditions. Costs of the extra metal are of minimal concern compared with the assurance of having a dimensionally stable piece of equipment.

6.2.4.1 The prime objective of the caution statement in 6.2.4 is to preserve the accuracy of placement of the nozzles, the positioning dowels and trunnions, the guides and the datum base plates or support points, and such other elements of the equipment as may be necessary in order that when the equipment is placed in its service position the connection points will be at known locations. This contributes to the attainment of leak-tight hookup of pipe jumpers for process and service connections, and secure connection of instrumentation and electrical power supply jumpers. It also assures that flange faces and positioning dowels and guides for the mounting of auxiliaries such as agitators, pumps, condensers, columns, and other components on the base equipment configuration will be at known positions. The service connections for a condenser, an agitator, or a pump may be six to fifteen feet above its mounting flange on the base vessel. Any tilt or distortion of the mounting flange can tilt, throw off, or misposition the datum connection points on the auxiliary equipment item so that the service jumpers cannot be attached. Equipment design based on a minimum adequate metal thickness for given design or operating temperature and pressure conditions is not always acceptable for these reasons.

6.2.5 An as-built record of the precise position of each of the connection and positioning elements, for example, the *X, Y,* and *Z* position coordinates for each nozzle, flange, dowel, bolt, and dowel hole, should be taken and documented prior to the time the equipment is placed in its service location. The measurements recorded should include nozzle, flange, and dowel tilt or cant, including degree and direction with respect to the nominal vessel centerlines and the vessel's support base or legs. The placement accuracy and the alignment of dowels, flanges, and guides with regard to verticality, flatness, tilt, cant, direction of tilt, or cant, should be within required and specified tolerances. If the equipment is destined to operate at temperatures in excess of approximately 150 °C the measurements should be checked after the equipment has been cycled between ambient room temperature and the operating temperature two or three times so that any residual thermal distortion will be accommodated.

6.2.6 All flanged openings and nozzles on equipment intended for liquids handling and processing should be placed at the extreme top of the vessel, or alternately, at a level above the maximum liquid fill level likely to be experienced during the operational cycles for the vessel.

6.2.6.1 A freeboard in the range of 15 to 20 % should be provided for equipment used in non-boiling liquids processing service. The freeboard may need to be increased beyond the suggested level if the equipment has a tall, thin configuration. If the equipment has an overflow nozzle, the overflow nozzle should be placed opposite the vent nozzle location to provide for a vent air sweep across the vessel. The overflow nozzle should turn down and extend to within three inches of the base of the equipment to minimize splashing.

6.2.6.2 The objective of high openings placement is to create a vessel configuration that will minimize chances of accidental overflow and drainage or leakage of radioactive liquids, solutions, or slurries into the processing cell or canyon in the event of gasket, seal, or jumper pipe failure. Accidental overfill of vessels is not common, but it has been known to happen.

6.2.6.3 Anti-siphon protection should be incorporated into the design of the vessel or its jumper, or both, or connecting lines. Such protection is required to prevent accidental transfer of liquids from the vessel to an unintended location. Such siphoning transfers can be caused by variable liquid levels in vessels, due to condensation and collapse of steam pressure in the lines of transfer jet or sparger connections, or from other causes. Equipment and facilities design must provide protection against transfer or suck-back of radioactive materials into occupied operating areas.

6.2.7 Gusseting and reinforcement for the support or stiffening of flanged openings and nozzles, and for stiffening the heads or shells of vessels, should be placed on the external sides of the vessel to facilitate ease of cleanup and decontamination. Placement and configuration of the reinforcement gussets should not create liquid entrapment points. Placement of reinforcement gusseting on the external side benefits calibration accuracy for the vessel.

6.2.8 Lift eyes or trunnions on vessels should be positioned so as to be visible to the operator of the lifting equipment and so as to be clear of all nozzles and openings on the vessel. The lift points must be readily accessible to the hoist hook used to lift and transport the vessel. If equipment design is such that a lift yoke or lift bail suspended from the hoist hook is intended or required to lift and transport the vessel, the placement of the lift points on the vessel shall be such as to allow the yoke or bail to be moved into the lift position with a minimum of interference.

6.2.8.1 Lift eyes, lift bails, or trunnions should be attached to the main shell of the equipment, as opposed to being attached to a heat transfer or insulation cover jacket.

6.2.9 Equipment must be configured and balanced so as to hang vertically and in a stable position when it is suspended from the hoist hook or lift bail or yoke. The constraints with regard to surface finish (see 6.2.1) apply to any ballast added for balancing cell or canyon equipment.

6.2.10 Vessels designed to have a heat transfer jacket or those requiring insulation and an insulation jacket should be subjected to a thorough inspection and to leak tightness and weld integrity tests before the jackets are added. Leak tightness and weld integrity tests for the jacket should be conducted separately.

6.2.11 The insulation (and the insulation jackets) on canyon and cell equipment generally does not abut or cover nozzles, openings, and lift eyes or trunnions, and does not extend to cover the top and bottom of the vessels. The insulation on canyon or cell equipment is most often provided to keep surface temperatures low and thus minimize thermal air currents in the cell environment. The thermal efficiency of the equipment is a secondary consideration. This latter generalization does not apply in the case of furnaces, melters, and other equipment operating at temperatures in excess of 125 °C, or where surfaces must be insulated for process reasons.

6.2.12 Insulation cover jackets should be configured to allow for the free draining of decontamination liquids. The jackets should have a short tube connection or an alternative provision to accommodate vacuum leak testing of the enclosed volume.

6.2.13 Equipment design should be standardized to the extent practicable so that common auxiliaries such as agitators, pumps, condensers, lift bails, lift yokes, and jumpers may also be standardized. In the context used here, standardized means having common dimensions and configurations rather than having duplicate performance characteristics, although those too may be desirable. The purpose is to decrease design costs and minimize maintenance problems and the need to store spare equipment items.

6.3 *Design Constraints for Jumpers, Lift Bails, and Yokes:*

6.3.1 Jumpers should be configured to drain towards the vessel on the receiving end of the connection insofar as is practicable.

6.3.2 Jumpers and lift bails or lift yokes should be configured and balanced so as to hang in a vertical and stable position when suspended from the hook on a lift hoist.

6.3.2.1 Lift bails and lift yokes are low maintenance components that are seldom transferred into areas where adhering surface contamination is a threat to personnel. The materials of construction (Section 7) and the surface finish constraints (6.2) are much less stringent for such components. Two sets of lift bails and lift yokes should be provided, one set being used and stored in the contaminated environment, and the other set used to transfer equipment into and out of the contaminated environment.

6.4 *Equipment Installation—General:*

6.4.1 Equipment received on-site and stored while awaiting installation in the cell or canyon environment should be stored under conditions that preserve the dimensional and operational integrity of the equipment. The equipment should be protected from damage due to heat, moisture, sunlight, or corrosive fumes or materials. The equipment should also be stored under conditions that protect it from damage caused by transfer handling, dropped loads, flying debris, or vandalism.

6.4.2 All precautions should be taken to ensure that marking crayons, inks, paints, and labels having an unacceptable chloride content are not used on stainless steel equipment components during storage or during test, transfer, handling, and installation sequences. See 7.4 regarding chlorides and fluorides as causes of stress corrosion cracking.

6.4.3 Equipment test, inspection, calibration, and checkout sequences should be completed prior to equipment installation in the cell or canyon environment to the extent that this is practicable. Equipment should be immaculately clean and empty when it is installed in place. To the extent required, equipment openings should be sealed to exclude dusts and moisture (and the introduction of apple cores, cigarette butts, and other debris by vandals) during the interval between the final cleaning of the equipment and the installation in place. Precautions should be included in the installation specifications that call for the removal of all such temporary seals as a near-final installation step.

6.4.4 All equipment should be handled with extreme care during transfer handling and installation sequences to ensure against collision damage and dimensional changes damage. Pumps, mixers, agitators, centrifuges, and other rotating equipment should be handled in such a manner as to preserve shaft straightness and rotational balance. Equipment should be handled and moved in an upright position using the same type of handling hooks, lift bails, and yokes as are to be employed in the canyon or cell maintenance procedures to the extent this is practicable.

6.4.5 Installation sequences should be planned and sequenced so that other equipment is not handled above and around previously installed components to the extent practicable. Personnel access to equipment previously installed should be sharply limited and constantly supervised. Equipment previously installed should not be used to rest, support, or