Permanent Storage Areas in CANDU Nuclear Power Plants

Eric L. Williams, MASc, P.Eng, SFPE,
Bruce Power (Retired)
"Canoe-About Inc", RR#2 Tiverton, Ontario, Canada

Abstract

Historically less than adequate attention was paid to the transient (up to four months) and permanent (longer term) combustible and flammable materials (does not include permanent station cabling, electronic, and mechanical equipment) needed to operate the plant over its life at the design stage. This has resulted in operations and station engineering staff having to accommodate these necessary materials during the operations phase. This paper discusses the challenges and proposes a methodology to redesign the station to safely accommodate these materials on a permanent basis.

1. Introduction:

This paper is not an attempt to justify permanent storage areas in CANDU nuclear power plants. As an industry we must continue to be vigilant in our approval of the quantity, type, and location of the combustible and flammable materials authorized to be in our stations. It is a fact that some materials not included in the original design basis are required, and that these permanent storage areas can be safely engineered into our current stations. Future CANDU designs are including permanent storage areas in their initial design concepts.

Numerous nuclear safety and fire protection reviews over the years have confirmed the robust nature of CANDU nuclear power plants design and construction. While the original designers no doubt recognized that operators and maintainers would be required to operate their ingenious creations, it has become obvious that the amount of equipment and material to required to support day to day operations, maintenance, outages, modifications, and refurbishment greatly exceeds the original design intent for the stations. This is especially true for combustible and flammable materials, and hot work operations. Nuclear safety requirements must be maintained at all times, including during shutdowns, outages, modifications and refurbishment activities. Recent operating experience has proven that these much needed materials and equipment may at times be stored in such a way as to subtly compromise the nuclear and life safety requirements so important to our industry. An inadvertently parked pallet of computer paper in a seemingly open place in the station, as an example, can easily short circuit the designed separation between safety system channels and or systems.

The purpose of the process described herein is to ensure that CANDU nuclear power plants are not inadvertently transformed into long term material storage facilities. While some permanent storage areas are no doubt required in the existing stations, and will be designed into the new generation of CANDU reactors, it remains essential to ensure that the material that is determined absolutely essential for effective long term station operation is appropriately considered in the

station design and maintenance with respect to fire protection, environmental protection, seismic design considerations, and security, emergency operations, emergency response, radiation protection and maintenance.

2. Permanent Storage Areas in CANDU Nuclear Power Plants

Fig. 2.0.1. Design Vision 615 Elevation Turbine Building

Fig. 2.0.2. Design Vision 693 Elevation Turbine Auxiliary Bay

Fig 2.0.3 Turbine Hall (Unit 2 Foreground)

2.1 Culture

The original design and construction of the stations was excellent with respect to nuclear, life and fire protection safety, and met or exceeded the requirements of the day. Slowly, and gradually, over time the day to day maintenance requirements began to introduce the equipment and supplies necessary to maintain and operate the station. To maximize the effectiveness of the operators and maintainers materials had to be close at hand and convenient, and supplied in sufficient quantifies so as to not cause delays. Over time the original reason for the vast open spaces in the stations (Figs. 2.0.1, 2.0.2, 2.0.3) was forgotten, and station staff gradually began to claim these areas for the storage and field work necessary to maintain the stations. The lack of serious early events lead to the idea that such materials as floor cleaners, tow motors, tool carts, welding machines, consumable item storage (plastic suits, rubber area shoes and gloves), etc. was normal and safe. It is not unusual for current day owners of existing storage areas to be surprized when they learn that the contents of their storage areas, needed as they are for day to day operations, violate the original design intent of the stations, and even jeopardize the design of the station with regards to nuclear and life safety.

2.2 Legacy

The material stored historically can be categorized as follows:

2.2.1 The legacy of wood construction support materials such as wood scaffold, wood shipping pallets, wood cribbing, wood cable reels (Fig 2.2.1). Wood was even used as the

construction material for the central distribution frames (CDF) in the Control Equipment Room in Main Control Rooms in some early stations, and remains to this day. Reactor Maintenance Equipment (Fig 2.2.2) is another example where woods qualities to not scrape or damage reactor surfaces while in storage was employed. While there were many good reasons for using wood, the fire loading it introduced into the nuclear units is now viewed as totally unacceptable. Vast improvement has been achieved in this area over the past few years, with the result that most nuclear units are now wood free to a very great extent.

Fig. 2.2.1 Staged for Project Start

Fig 2.2.2 Reactor Maintenance Equipment

2.2.2 Material was stored because it was surplus from previous work, and may still contain some useful parts which may be required in the future (Figs 2.2.3, 2.2.4). Example: obsolete instrumentation and electronic equipment. Most Stores and procurement systems did not want to take the equipment back, which forced insightful technicians to store it themselves for the perceived future good of the station. And quite often such material proved useful in future repairs and maintenance.

Fig 2.2.3 Equipment Storage

Fig 2.2.4 Equipment Storage

2.2.3 Some material was radioactive / contaminated, and hence could not be removed from the licensed 'storage' space inside the plant in a timely fashion. Reactor Maintenance equipment is an example. For the safety of the fragile maintenance equipment much of this equipment continues to be stored in wood / plywood boxes.

2.2.4 Material leaving the plant needs to be analyzed or surveyed to ensure it is not contaminated and or that it's chemical make up known to facilitate safe disposal and shipping. These processes require special waste processing areas to handle these items until they can leave the station. Used oils and solvents may be contaminated, and their make up possibly unknown. Hence the need for testing before removal from the station. The chemical sampling processes involved take time.

2.2.5 Outages produce considerable amounts of waste and redundant materials at a time when the human resources to survey and analyze them prior to leaving the station are the scarcest.

2.2.6 The need for additional general work areas and storage areas (Figs 2.2.5, 2.2.6, 2.2.7) were identified once the station was in service. These needed to be convenient to the work group and task at hand.

Fig 2.2.5 Chemistry Lab Storage

Fig 2.2.6 Day Crew Operations Storage

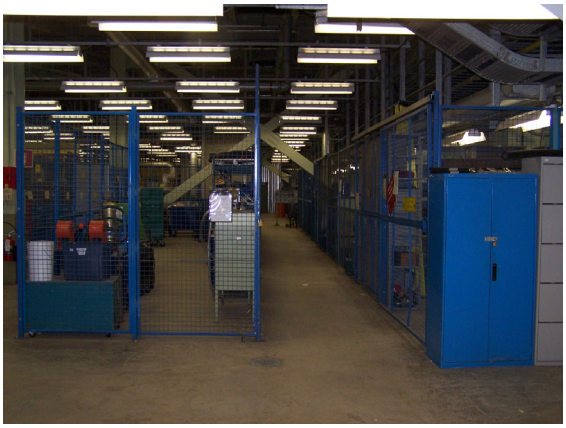


Fig 2.2.7 Control Maintenance Storage

2.2.7 Great improvements have been made in reducing packaging to the greatest degree achievable without compromising the safety of the equipment or material as it is transported to its final use location. This avoids large efforts to monitor the outgoing 'waste' material, and large amounts of costly landfill where the material is not recyclable.

2.2.8 Radiation clothing, including plastic suits, coveralls, gloves, footwear, hoods, and hoses is combustible by nature, and required in significant quantities to facilitate effective outage planning and execution. A supply of such material is usually maintained near reactor building air locks, which are also usually Fire Safe Shutdown Analysis Screen 3 areas. (Fig 2.2.8, 2.2.9.)

Fig 2.2.8 Radiation Areas Supplies

Fig 2.2.9 Plastic Suit Storage

2.2.9 Little things add up. Lunch wastes, discarded newspapers, cardboard coffee machine cups, are other innocuous items that quickly add up to voluminous expensive disposal items when viewed at the unit or station level. 'Waste free lunches', reusable coffee cups, and banning newspaper disposal in the protected area (stations) have all led to vast reductions in waste accumulation in the station, and similarly reductions in the human resources required to monitor and get it out of the stations.

The above are noted herein to inspire readers to evaluate their own station performance in these areas.

2.3 Integrated Independent Performance Assessment – Fire Protection

The Integrated Independent Operational Performance Assessments and Fire Hazards Assessment / Fire Safe Shutdown Analyses performed at many of our plants in the late 1990s abruptly reminded us of the original design intent and purpose of the many seemingly barren areas of our plant. Considerable effort has been made over the past several years to educate all staff as to the design intent and requirements for the various special areas of the station. Constant reminders are required to keep the design intent foremost in all station staff minds.

Previously the fire hazard associated with wood scaffold, wood pallets, and wooden cable reels was not fully appreciated. Over the past decade the actual presence of the materials in the station has been greatly reduced. Where combustible and flammable material is required, great care and analysis is required to ensure its transport, storage, installation, and use while in the station does not inadvertently compromise any of the assumptions in the station Fire Safe Shutdown Analysis (FSSA)

2.4 Change Control

Change Control processes have evolved to enable us to remind ourselves of the original design intent of the station, the impact of the proposed change(s), and to anticipate all potential conflicts with the design intent of the stations, before we inadvertently violate them. The Engineering Change Control (ECC) processes now includes links to change review forms which itemizes how specific changes may impact the station fire protection features and assumptions. The process requires that if the originator is in doubt, the change will be reviewed in detail by the appropriate design authority for fire. Even if the originator can sign the change off as having no impact, it is reviewed by design to ensure they concur with the conclusion of the change originator. Third party review processes ensure that nothing is missed. The processes are much more attuned to specific needs of fire protection than they were even a few short years ago.

2.5 Transient material permits

For many years the industry has recognized the need to manage materials that were not originally intended to be in the station. When materials are required to be in the station for maintenance or modification work, the location of the actual work and temporary storage locations for the 'transient' materials are well thought out in advance, and managed during their total life in the station. Transient material permits require close scrutiny by those familiar with the fire safe shutdown analysis and emergency response team concerns.

Examples of such transient materials include:

2.5.1 Packaging materials for sensitive equipment as it is staged for maintenance and or modification work. While the current trend is to reduce the packaging as much as possible before entering the zoned areas of the protected areas, some packaging may still be required to protect the equipment until it is installed.

2.5.2 Cables and wiring material for the most part continues to be shipped on reusable wooden cable reels. The wood provides protection for the cable sheath during shipment, temporary staging storage, and cable installation. Quite often the cable staging area is in an area with fire safe shutdown analysis implications.

2.5.3 Transport equipment including large trucks, tow motors, fork lifts and trucks that are required to move the material into / out of the storage areas.

2.5.4 One characteristic of storage areas is that they tend to accumulate other not so needed materials, and often the owner and purpose of these materials is not clear.

2.6 Hot Work Operations

Cutting and welding operations, and their support equipment and material, can also obviously introduce combustible material and ignition sources to an area. Grinders, welding machines / gas bottles, and anything that can result in ignition sources and products (hot slag dropping onto combustible materials) are included in this area of concern. Strict requirements apply to such

operations, including the need for a continual fire watch during the operation and the need to inspect for several hours following the completion of the work. The station emergency response teams are usually part of the scrutiny of such operations.

2.7 Permanent?

When does Transient Become Permanent? Understanding this distinction is the latest phase in the effort to manage materials and processes not originally designed into the station. Delayed outages or maintenance, changed plans, and rotating personnel result in materials being left in the stations to the point where the original use, conditions of storage, and even the owner can become forgotten. In some cases the material has been in the stations for as long as many employees can remember, and is accepted as normal. To reduce this abuse, some stations have ***defined 'transient' or 'temporary' as not exceeding four (4) months.*** When equipment or material is required to be stored in the station longer than four months a "Permanent Storage Approval" is required.

2.8 Permanent Storage.

The underlying goal in this process is to maintain the original design intent of the nuclear stations. For the most part the stations were conceived, designed and built to be nuclear power stations. They were not intended to be permanent storage areas or warehouses. To achieve these goals the material that may be considered for long term storage in the station must:

2.8.1 Be eliminated if possible. Can the materials be stored outside of the protected area, or in additions to the station specifically designed and equipment for such storage? "Radiologically Zoned" permanent storage areas, located immediately adjacent to and connected to existing stations, are being considered by some utilities to help eliminate long term storage items from the stations.

2.8.2 Be minimized to the greatest extent achievable in quantity, combustibility, flammability, and explosiveness. Shipping (pallets) and packaging materials (cardboard, styrofoam) must be minimized to the greatest extent possible, and preferably eliminated.

2.8.3 The long term storage areas must not interfere with emergency Operator field actions, emergency security operations, or emergency response team operations. In the case of the latter the ability to respond in a smoke filled area with a charged fire hose must be considered.

2.8.4 Not exceed the civil design basis for the station.

2.8.5 Not jeopardize the environmental and seismic requirements of the station.

2.8.6 Maintain the designed separation in the station. CANDU design counts on physical separation between safety related systems and or their respective channels. Un-analyzed modifications and ill conceived storage areas may inadvertently short circuit the design intent of the station. Where the original design of the station 'used' the area to ensure that a single fire event would not jeopardize redundant channels or equipment, unanalyzed storage areas may located so as to endanger the back up equipment. It could be as simple as a forklift load of computer paper headed to an office area, a spill of

flammable liquids in an un-diked area, or a re-locatable structure being introduced to the area.

2.9 Permanent Material Storage Approval Process

Because considerable legacy equipment and material is already located in our stations, there must be two phases to this project. The first applies to existing materials stored in the stations, the second to new requests.

2.9.1 Existing Areas

2.9.1.1 Culture Established

Senior Station Management must make known and support the need to reduce the presence of materials not designed to be in the station as much as reasonably possible. This is a essential part of the current station culture change.

2.9.1.2 Identify Area

The first task is to identify the legacy storage areas that may be in the station. In some cases the station Transient Material Permit (TMP) system may have identified and be tracking the storage area. A thorough plant walk down is required to ensure that all storage areas not originally designed for that specific purpose are identified. Experience has proven that it is not easy to identify the owners of such material, and hence informed and supportive senior line management is a real asset. Management plant inspections, audits, OPEX reviews, and the station exception reporting system may well have identified such areas previously.

The station Fire Hazard Assessment should also note the combustible and flammable contents of each fire zone in the station, and comment as to the fire protection impact of the material. Fire Hazard Assessments must be maintained to reflect the current status of the station fire zones. While Transient Material Permits can effectively manage the station short term life cycles of combustible and flammable materials in the station, another process is required for the longer term materials.

The location of these areas can be assisted and confirmed by the following methods. If the material is not directly and obviously linked to an installed station system or process, then it probably was not designed to be in the station. Installed and 'live' electrical cables, electrical panels, pumps, instrumentation etc. were properly engineered and installed in the stations. The required station Fire Hazard Assessment (FHA) (previously referred to as the Fire Safe Shutdown Analysis (FSSA)) has analyzed this equipment and confirmed it meets the stringent fire protection design requirements for CANDU nuclear power stations.

The following station processes may be helpful in identifying areas used for the storage of material not intended to be in the stations:

- Station Fire Hazards Assessment (FHA)
- Transient material permit(TMP) process
- Station Planned Inspection Process
- Audit Results (fire protection, other)
- Housekeeping Tours
- Station Management Inspections
- Significant Event Reports /Station Condition Reports

An online computer database could be used to manage the Permanent Storage Area Approval process once it has commenced.

2.9.1.3 Identify Owner

The next challenge is to identify the owner or group that has responsibility for the storage areas, and hold them accountable for the required disposition and management of the rea. Once again the un-waivering support of senior station management is required to minimize the number of areas ultimately deemed acceptable.

2.9.1.4 Determine Proposed Need, Duration, Contents

Working with the existing owner or group, identify the need for the station to contain as little combustible / flammable material as possible, maintain accessibility, and the other design intents for the area. The review of each area should begin with the ideal of eliminating the area all together, and then modifying the ideal as little as possible to support the absolute needs of the station.

2.9.1.5 Senior Station Management Approve Need For The Area

Senior Station Management are well aware of the need to reduce the number and content of station storage areas, and usually have the large picture view of the concern. Audits, Peer Reviews, and Authority Having Jurisdiction (AHJ) reports will all remind them of the large scale impact of their existing practices in this regard. On the other hand specific storage space owners and requestors usually focus on their specific needs and requests, and believe them valid and of top priority. Before the review process goes any further, the Station Manager / Director / Station Vice President must concur with the need reach specific permanent storage area. The final location may still be unsure, but senior management is on record as having concurred agreed with the need for the material / equipment to be in their station. And it follows that once approved, station management will provide the resources to reduce the materials requiring permanent storage, to relocate

the materials to a more appropriate area (preferably outside the station), and or redesign the station to accommodate the permanent storage area.

2.9.1.6 Preliminary Approval

Now that the concept for the storage area has senior management approval, the permanent storage area verification process enters the station design change process. This process is extensive, requires funding, will involve the input of many groups, and takes time. Such projects may have difficulty in being recognized as having high priority. Therefore there is a need for a Preliminary, or an interim, Permanent Storage Area Approval. This will help manage the area until the design change incorporating the storage area into the approved station design basis is complete.

The Preliminary Permanent Storage Area Approval (PPSAA) has the following features:

2.9.1.6.1 It is initiated by the person or work group responsible for the material.

2.9.1.6.2 The responsible manager or supervisor ensures that only essential material is proposed to remain in the station, that its proposed location is as good as it can be with respect to fire prevention and other safety requirements, and that a process is defined and approved to maintain the proposed area in an acceptable and specified condition.

2.9,1.6.3 The responsible manager or supervisor obtains senior station management approval for the specific long term storage area. If senior station management approval is not obtained, it is the responsibility of the responsible manager or work group to get it out of the station in a timely manner. Senior station management approval also requires that adequate funding be made available for the engineering design change required in the formal design of the area into the station approved design. This is best accomplished by initiating the Design Change Package (DCP) to permanently change the station approved design to accommodate the permanent storage area. This will require the identification of a Modification Team Leader (MTL), and the completion of the initial steps in the Engineering Change Control (ECC) process to start the change process going. We recommend requiring that the Design Change Package (DCP) number be registered to document the formal start to the change process. To get this far project approval, resourcing, and funding may be required.

2.9.1.6.4 Once senior management has concurred with the need for the material and or equipment to be in the station, the responsible manager or supervisor requiring the storage area determines that the proposed storage area is acceptable to the other station users and requirements as noted below. The Preliminary Permanent Storage Area Approval (PPSAA) approval may include / list the other documents and or forms that the originator must consider:

- Floor Loading – Civil Engineering – structural drawings which list the acceptable floor loadings for each area.

- Seismic Considerations – Civil Engineering – station checklists to ensure proposed changes do not adversely impact.
- Environmental Qualifications – EQ Engineering - station checklists to ensure proposed changes do not adversely impact.
- Fire Protection – Fire Protection Design Engineering – checklist to ensure proposed change impact on fire protection understood.
- Fire Protection Operations – Site Emergency Services – to ensure storage area will not impact emergency response operations.
- Operator Emergency Operations – Station Operations – to ensure storage area will not adversely impact emergency field operations.
- Security Operations – Station Security - to ensure storage area will not adversely impact emergency field operations.
- Radiation Protection – to ensure the establishment of the storage area does not compromise the Radiation Protection requirements.
- Maintenance – to ensure the permanent storage area does not interfere with possibly infrequent but necessary maintenance operations, such as the withdrawal of a generator or pump shaft.
- There may be other considerations at other stations.

2.9.1.6.5 Conditions for the storage are generated during the above approval process. They will include, but not be limited to:

- Exact location of the storage area (unit, elevation, column line) coordinates
- Maximum load allowed in the storage area. This will include the weight of the transport equipment needed to service the storage area such as fork lifts, trucks, tow motors.
- Maximum amount (weight) of each type of combustible or flammable material allowed in the area. Number of plastic suits, number of boxes (cardboard or wood) of material, number of feet of hose or cables, sizes of material.
- Name of the owner and work group.
- Ongoing inspections required.

2.9.1.6.6 The responsible design or support organization managers or supervisors concurs with the assumptions and conditions noted above, including the ongoing inspection and maintenance activities, to ensure the ongoing compliance of the area with the above granted approvals.

2.9.1.6.7 Once all the above are in place the Shift Manager responsible for the proposed area / unit approves the establishment and or continuance of the

proposed areas subject to the specified conditions and ongoing inspection and maintenance activities, and signs the Preliminary Permanent Storage Area Approval (PPSAA) to reflect the same.

2.9.1.6.8 The responsible manager or supervisor establishes and maintains the storage area as per the conditions and inspection requirements of the approved Preliminary Permanent Storage Approval.

2.9.1.6.9 The responsible manager or supervisor initiates and provides funding for the Design Change Package (DCP) for the permanent design change to incorporate the storage area into the permanent design of the station.

2.9.1.6.10 The Preliminary Permanent Storage Area Approval (PPSAA) approval is issued, posted at the storage area, and documented in a station database of all permanent storage areas. Copies of the approved approvals are also provided to the station Shift Manager and the Station Emergency Response Manager.

2.10 Design Change Package / Notice for the Permanent Storage Area

The design change is initiated, planned and executed as per the station's design change process. The design change will incorporate detailed engineering analysis, human factors engineering, and operations / security / emergency measures input to the permanent storage area design change.

The design change will result in:

2.10.1 Design documentation being revised to reflect the permanent storage area. As a minimum this will require the update of the station civil engineering drawings, station layout flow sheets, and the station pre-fire plans. Where a Permanent Storage Area is required in an area of the station where it will impact other station requirements, additional fire rated structures, suppression systems, detection systems and or other features may need to be designed, constructed, and commissioned to ensure the nuclear, life and asset safety of the station with the addition of the Permanent Storage Area.

2.10.2 The station routine inspection plan will need to be updated to reflect the new station feature.

2.10.3 The permanent storage areas must be posted to reflect the purpose of the area, the type and quantity of the allowable contents, and the owner. This could done through permanent signage or painted instructions on the floor. Such information is required to allow management inspection teams, audits, and housekeeping to understand the purpose of the area, the fact that it is a designed station feature, and who to contact for further information or to resolve discrepancies.

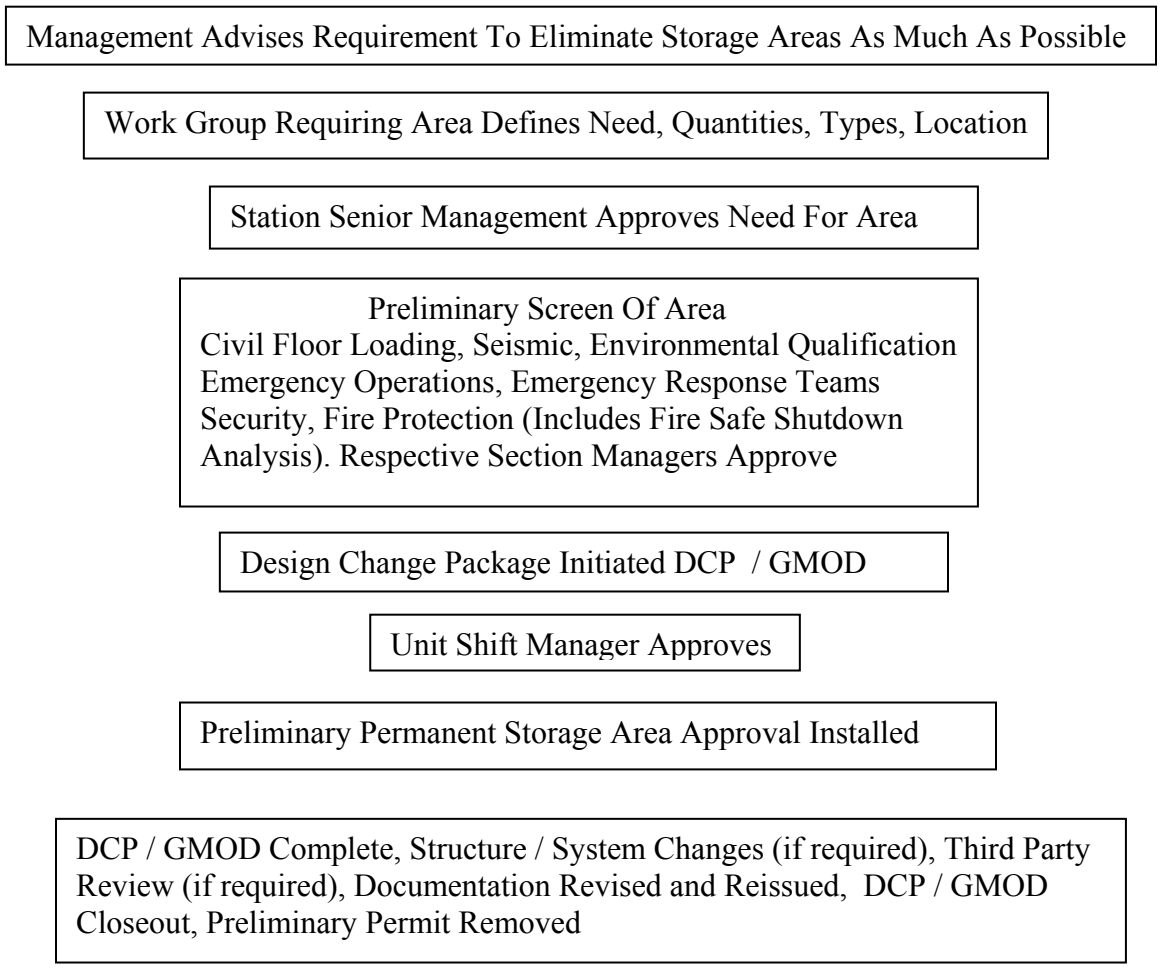
2.11 Proposed New Areas

The process will follow the Station Engineering Change Control (ECC)/ Modification process in its entirety.

New storage areas must not be set up or occupied until the change control process is complete.

3. Wide Diagrams or Tables

Permanent Storage Area Approval Process



4. Definitions:

4.1 Fire Hazards Assessment: Includes the Fire Hazards Assessment (FHA), Fire Safe Shutdown Analysis (FSSA) , and Code Compliance Review (CCR).

4.2 FSSA Screen 3 Fire Zone: Fire Zones Containing FSSA equipment and or cable where one or more of the fire safe shutdown performance goals can not be met if all of the FSSA equipment and or cable in the fire zone is assumed to be unavailable.

4.3 Protected Area: The area inside the security fence that surrounds the nuclear power reactor and its associated supporting infrastructure, as defined or referenced in the station Power Reactor Operating License.

5. Acronyms:

CCR – Code Compliance Review
CDF – Central Distribution Frame
FHA – Fire Hazard Assessment
FSA – Fire Safety Assessment
FSSA – Fire Safe Shutdown Analysis / Assessment
OPEX – Operating Experience
TMP – Transient Material Approval
TPR – Third Party Review

6. Conclusion

While introducing material not included in the design basis must be minimized to the greatest degree possible, it is accepted that some material and equipment is justified in the stations on an ongoing basis and can be safely accommodated in a revised approved design basis.

7. References:

Canadian Standards Association (CSA) Standard N293 – 07 “Fire Protection for CANDU Nuclear Power Plants”

8. Acknowledgements:

The author wishes to acknowledge the ongoing support of his previous employer, Bruce Power, in the preparation and review of this paper.

Specifically the author wishes to recognize and thank those who reviewed and commented on the paper. Thanks to Ms. Louise Jack, P.Eng, Senior Technical Specialist, Fire Protection, Plant Design Engineering and to Steve Cannon, Investor and Media Relations.