Aquila Nuclear Engineering Ltd

# Glove Boxes, Containment & Isolators

## AQUILA WHITE PAPER 001 V02 - November 2015

A guide to meeting customer needs and regulatory requirements.

### Aquila White Papers

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# 1. Introduction

This guide is aimed at people who are relatively new to nuclear containment or new to the capabilities of Aquila Nuclear Engineering. Designing and manufacturing nuclear containment is a skilled task. This guide details some of the areas of high importance when selecting a supplier.

This white paper provides an insight into the requirements of containment and the philosophy applied by Aquila Nuclear Engineering, based on over 25 years of design and build of integrated containment systems.

The main driver for containment technologies, is the requirement to provide protection for personnel, product and the environment. Operation of a process, within a contained environment, is restrictive and can have a big impact on the process functionality and efficiency.

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This White Paper is one of a series of four prepared by Aquila Nuclear Engineering.
The complete series comprises:

001 Glove Boxes, Containment & Isolators
002 Shielded Facilities
003 Remote Handling
004 Transport & Packaging

# 2. Containment Applications

## In the case of nuclear applications, containment confines the material being worked upon and prevents the spread of toxic or radioactive contamination to the worker's environment. In a radiopharmaceutical application, the containment also offers an environment whereby, the medical product is protected from human or environmental contamination.

Containment local to the process, allows the surrounding operating area to be treated as a near normal working environment, depending on the industry and product.

Containment systems are also used in cases where experiments with trace quantities of radioactive and/or toxic material, may result in cross contamination of another part of the process.

In certain processes, the atmosphere inside the containment may need to operate under special parameters, for example; inert gas environment, low relative humidity, stable temperature.

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# 3. Process is King

## It is important to undertake any containment type project with a clear statement of intent.

This statement of intent is sometimes called a Functional Requirement Specification (FRS) and it is the function or process that should be used as the basis for design and the process from which all other items are developed.

No element in the design, specification, manufacture, assembly or verification can be taken in isolation; the best solutions are fully integrated and fully considered, adopting an iterative, open approach with full stakeholder buy in.

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# 4. Develop the Specification

## After the prime processes and operation requirements have been identified, the design parameters must be established to assess what form of containments are the most appropriate.

In doing this, the specification will begin to develop, since this information will start to address the applicable European and national safety codes and regulations, design specification, operational standards and site regulations and codes of practice. The specification may address the following:

- Requirement to control exposure of hazardous materials during normal operations and provide maximum safety under failure conditions, for example; breach flow.
- Human factors or ergonomic assessment.
- Integration with internal and external service requirements.
- Aspects for downstream maintenance activities.
- Operator and environment protection to cater for unplanned incidents which may include malpractice and/or malfunction within the process.
- Containment layout which is generally a compromise between functionality, access, maintainability, exposure rate and other process activities. No item can be taken in isolation and the design process will be iterative and subject to constant review and verification against applicable standards and the functional requirement specification.
- Routine housekeeping and maintenance including the criteria for decontamination of internal and external surfaces.
- Post operation decommissioning, decontamination and size reduction.

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# 5. Safety Criteria and Key Features

## Critical items of the structure, shielding, equipment, extract and service items need to be designed to provide containment under normal operational and accident conditions.

All designs should be formally reviewed and risk assessments undertaken. Points to be considered may include as a minimum:

- Size and shape
- Structural strength
- Use of existing proven designs where possible
- Access and interconnections with containment
- Size, shape, and position of windows
- Number and position of glove and transfer ports and generic glove safety
- Use of manipulators
- Maintenance access and services
- Materials of construction
- Radiological protection, fire, atmosphere etc., safety devices
- Accident conditions

# 6. Inlet & Extract Systems

## The extract system is primarily required to control the atmosphere and air flow in the containment. It also provides for safe breach conditions in the event of loss of containment. Air flow patterns in containment are used to control contamination spread within and between containments. Filters can be used to mitigate contamination spread.

Containment can be purged with air or protecting gas, to create a controlled atmosphere under normal operating and emergency conditions. Nuclear medicine gradings require constant monitoring and alarm when they fall outside prescribed conditions.

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# 7. Materials of Construction

## Materials used in the construction of the containment equipment must be compatible with the results of the safety assessments. Factors to be considered:

- Structural strength
- Corrosion resistance
- Contamination levels
- Sealing arrangements
- Viewing requirements
- Finishes
- Flammability of materials used

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# 8. Classification of Containments

## Containment philosophy varies between the nuclear and nuclear medicines industry; containment classification is influenced by various factors:

- The safety assessment and conclusions
- Whether the containment is primary or secondary containment
- Whether the box is free standing or part of a suite

Integrity Class I containments are described as a primary containment with a leak rate allowance of 0.05% volume per hour (Vol/hr) at ± 10mbar.

Integrity Class II containments are described as a secondary containment where the possibility of it becoming primary is considered unlikely by the safety assessment. The allowable leak rate is 0.5% Vol/hr.

In defining the required integrity, it is necessary to assess and specify many aspects:

- Levels of cover gas contamination within the glove box
- Cover gas rate of change
- Cover gas inflow velocities
- Operational pressure
- Reliability of emergency extract arrangements
- Ability of the system to accommodate fluctuations within the containment pressure
- Efficiency of inlet and extract filters

The above listing is not exhaustive and only serves to show a sample of variables that have to be considered.

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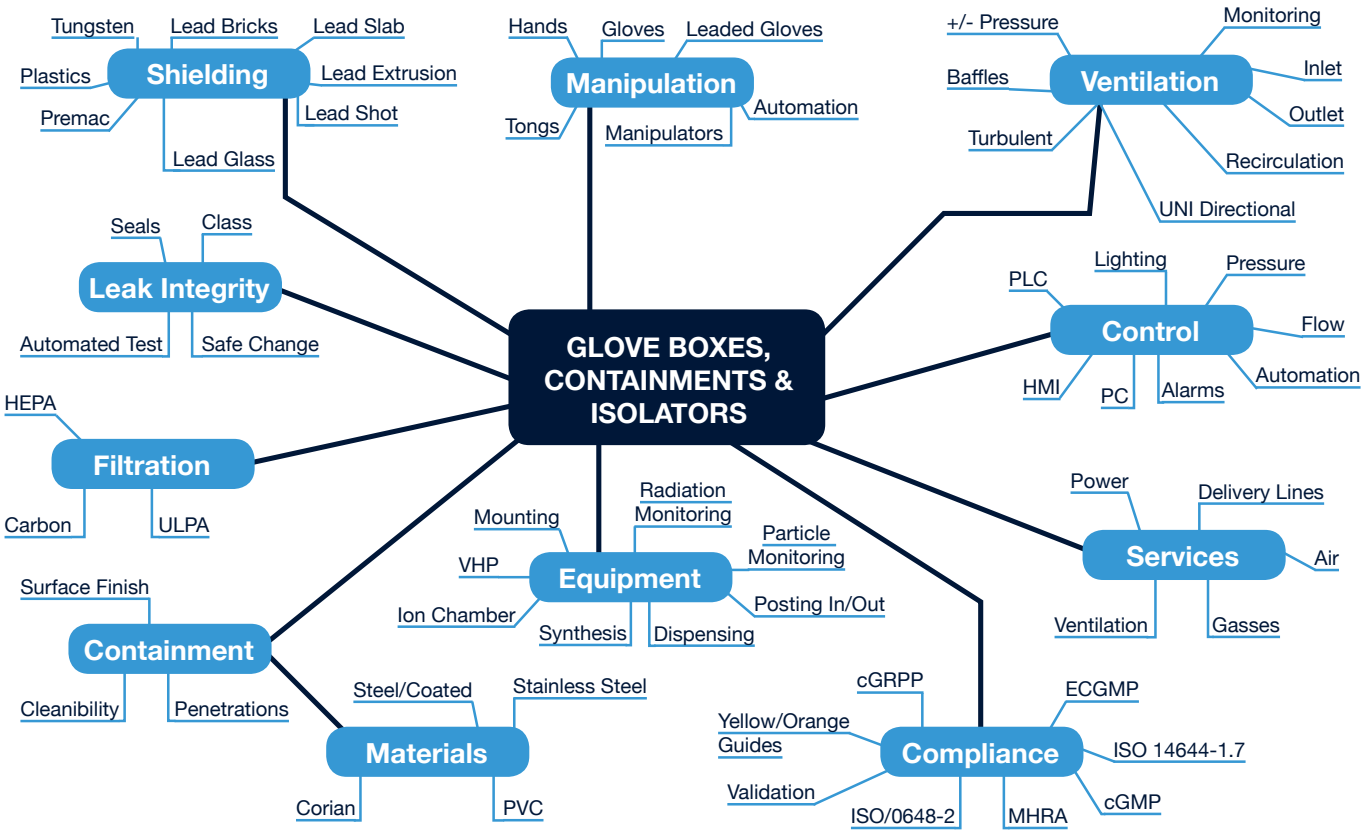
# 9. Aquila Influence Diagram

## The Aquila Influence Diagram, below, is used to identify areas which may be required to meet the Functional Requirement Specification provided by the client. This diagram covers both nuclear and nuclear medicines applications and combines any shielded requirements, since this has a major impact on the design of a complete system.




In our experience, this diagram has served us well as a tool to address every aspect of the containment system solution, employing it throughout the design and risk assessment phase of the project. Certainly, within the nuclear medicines arena, this recorded process is used as part of the validation procedure.

# 10. Design and Manufacturing Philosophy

The containment carcase or shell is obviously a key aspect of the design. Tried and tested design employing the latest manufacturing technology, is the key to providing robust commercial solutions. At Aquila, having over 25 years' experience in the design and manufacture of containment systems, has allowed us to fine tune the process, adopting the latest CNC techniques for production.

**Typical stainless steel containment specification**

- 4mm thick, full radius and welded carcase construction; this provides a ridged construction which can be profiled, bent, formed and welded with reliable outcomes.
- Material is readily available, ex stock, from suppliers and can be specified as Stainless Steel 304L or 316.
- Sheet at 4mm thick can be purchased in a cold rolled 2B condition; this provides a clean hard base material with a good surface finish of generally better than 0.5µ. Sheets to be supplied with surface protection film.
- All sheets are profiled on a CNC laser or water jet cutter, minimising heat affected zones. Weld preparations are ground on in the flat condition.
- The containment carcase CAD model should be developed with the forming and welding requirements in mind. Containment features are used to determine the sheet profile relative to bend lines and the location of welds.
- Minimise welding requirements, located adjacent to corner details, and avoid welding in the centre of flat panels.
- Welding process TIG, controlled by process and procedure. Non-coded welding offers cost reduction and can be validated by inspection and test (subject to use and client acceptance).
- At Aquila, we believe the standardised 20mm corner radius provides the best overall design solution in terms of operational decontamination, minimising welding and distortion and post welding cleaning. From a practical point, the larger radius also impinges on the available operational working area on the base of the containment. 20mm corner radius can be folded on a break press using dedicated tooling. Protection slips are used to minimise marking. All welds are ground and polished flush back to base material surface finish, after final welding.
- For applications which require heavy duty base plates, a mild steel or stainless steel plate can be secured to the bottom of the containment carcase. Base frame details are typically, mild steel powder coated box section construction. Alternative sheet and angle options can be used if appropriate. In high integrity applications, leak tightness of the welded box section is carried out to ensure there is no risk of contamination ingress.
- Aquila standardised on window seal arrangements many years ago. This design utilises an extruded seal section bonded to form a continuous seal. The seal is achieved effectively by an 'O' ring detail which can be viewed through the viewing panel. The seal is retained by the seal section, wrapping around the edge of the containment carcase.

- There are a number of window clamp bar systems which vary considerably in price. At Aquila, we developed a proprietary window clamp bar system which requires only weld studs to be fired directly to the carcase; this is controlled with processes and procedure using a capacitive discharge welder.

- Standard type, double grooved glove rings, traditionally used in the UK, are manufactured from solid PVC, CNC machined, providing an 'O' ring seal detail. These come in a range of diameters and oval configurations.

- Standard service plates or bulk heads can be bolted on or fixed with studs within the containment carcase, mitigating the requirement for welding. Service bulkheads are also supplied as CNC machined components providing for 'O' ring sealing arrangements onto the carcase.

- Standard Aquila surface finish is a random satin "Scotchbrite" Crush. It is applied by orbital sanding pad and will provide a better than 1µ surface finish. The finished carcase is cleaned with a proprietary mild acid wash to remove manufacture oils and debris.

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# 11. Inspection and Testing

## Should faulty components find their way to the assembly stage of a contract or even the pre commissioning stage, the consequential delays and costs are prohibitive and generally cannot be redeemed, it is therefore vital that the key components are inspected and validated.

The key component is the containment carcase, as all other items are built up from this. Manufacture defects can also not be apparent and only manifest themselves with time. Examples would be, poor weld fusion or contamination within the surface finishing.

Carcase manufacture is not a black art, rather an application of technology, specification, process and control. All manufacturing resources have to be verified as operating to defined quality procedures to mitigate careless and unforeseen outcomes. Manufacturing process has to be specified, controlled and validated at each step of the process. Each carcase will have a deliverable quality document package with routing card, material certification, weld batch certification, weld qualification, dimension inspection print, NTD results and surface finish etc.

**Principal validation activities for a containment carcase:**

- Quality Plan and route card generation defining requirements and inspection/hold points.

- Inspection of raw material and certification prior to release for manufacture.

- Profile and forming intermediate inspection.

- Welder, equipment and consumables verification.

- Carcase tack up and inspection hold point for dimension verification.

- Fully weld, form corner details and visual inspection prior to clean up.

- Clean back welds, polish and apply crush finish, 100% Dye Penetration Inspection of all welds, surface finish measurement and validation.
- Verify Capacitive welder verification on test samples, fix studs.
- Dimensional and visual inspection.

The manufactured item and documentation is then passed on for effectively, a third party inspection sign off and test. Aquila engineers and technicians undertake a full review and undertake pressure and leak integrity tests on the carcase as a single manufactured item, blanking off the apertures and applying pressure/depression and measuring loss/gain against pre-determined test specification. It is important to have this baseline; when a carcase is assembled into a hot cell configuration access is not available to chase leaks. Identifying incremental small leaks can take considerable time and cost.

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# 12. Assembly and Testing

Great care and attention should be taken when assembling containment systems as each feature and seal detail can contribute small leakages which build up to a system that cannot be validated to the required standards.
Aquila has developed a range of seal applications that are “engineered” solutions rather than the traditional flat gasket type applications to ensure assembly is reliable and mitigate seal leakage.

Dependent upon complexity and location, features and assemblies will be tested in order to mitigate whole assembly variables.

Air flow patterns are designed into the containment arrangements. These have to reflect the process and are determined by the operation and failure mode identified during risk assessment. Air flow can be calculated, modelled and ultimately verified by smoke trials and testing.

Leak integrity test methods employed can vary from application to application and will be specified to be best practice. Many clients also have a preferred methodology that has to be followed. Aquila preferred methods of testing of standard applications are:

- Pressure Rise Method
- Parjo Method

# 13. Summary

The above text provides a small insight into the requirements of containment and the philosophy applied by Aquila which has been based upon 25 years of design and supply. It is important to come back to the idea that Process is King and project success is entirely dependent upon appropriate specification, standards and design.

No element in the design, specification, manufacture, assembly or verification can be taken in isolation; the best solutions are fully integrated and considered. This requires an iterative open approach with full stakeholder buy in.

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