Selective Development of ISO 9001 Quality Management Documents for the use at a Volume Reduction Facility

by

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Executive summary

NLM is a division of Necsa. Their primary focus is to reduce the amount of waste that needs to be cared for in the long run. This includes the reduction of volume by compressing drums containing radioactive waste in a large press. This is done in the VRF. The VRF was operated for several years but became dysfunctional due to outdated technology.

Quality is one of the most important aspects of the VRF and therefore the ISO 9000 principles for quality will be applied at the facility. In order to obtain the required level of quality; the existing QMS needs to be amended by creating work instructions, process descriptions and specifications.

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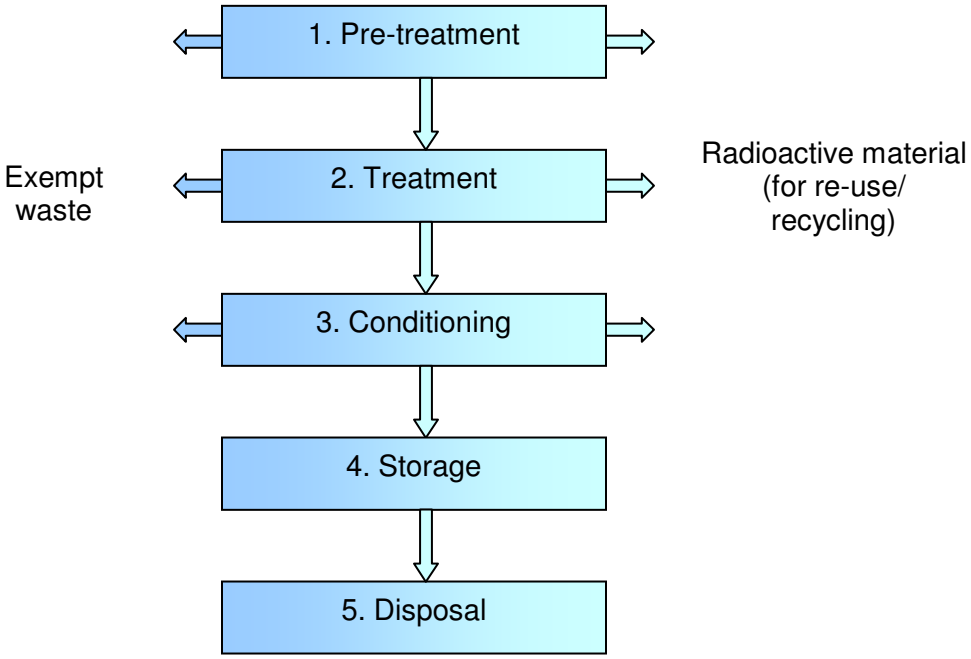
1. Introduction and background

1.1 Division background

According to a NLM brochure: NLM (Nuclear Liabilities Management) is a division of Necsa. NLM's primary focus is to reduce the amount of waste that needs to be cared for in the long term. This is achieved according to the following model:



1. Pre-treatment: consist of collection, segregation, chemical adjustment and decontamination.
2. Treatment: includes **volume reduction**, removal of radioactivity and change of composition e.g. melting, evaporation and filtration.
3. Conditioning: involves immobilisation of the radioactive waste and the placing of the waste into durable containers, suitable for transport, storage and/ or disposal.
4. Storage: is an interim step, providing containment of radioactive waste under controlled conditions prior to final disposal.
5. Disposal: is the final step in the radioactive waste management process. Since different types of waste have different levels of radioactivity, they are disposed of in different ways.

The NLM division performs its task in accordance with the requirements of the South African national policy and strategy on radioactive waste management.

1.2 Terminology:

1.2.1 What is radioactive waste?

This is waste that is contaminated with radioactive matter at concentrations greater than those deemed to be safe for normal disposal and for witch no further use is foreseen.

Unlike other types of waste, radioactive waste can be measured in the minutest quantities with simple radiation measuring instruments. Radioactive waste can be classified as very low level waste (VLLW), low level waste (LLW), intermediate level waste (ILW) or high level waste (HLW) in accordance with the concentration and type of radioactivity found within the waste.

The solid waste operations department's goal is to manage the solid radioactive waste at Pelindaba. The waste comes from mines, hospitals the private sector and from the previous activities at Pelindaba. The waste is stored in drums that are sealed to prevent any contamination of the environment where after the waste is disposed off at a long term storage facility.

The waste is classified as liquid or solid. The solid waste is separated into two groups, compressible and non-compressible. Compressible waste may consist of cloth, sponges, rubber gloves, paper etc. Non-compressible waste is things like wood, steel, sand etc.

To minimize the volume of the waste the compressible waste will be compacted to about one fifth of their original volume. The compacted drums are packed into larger drums that are sealed off by filling the excess space with concrete and after that sealed with a lid.

1.2.2 Definitions and abbreviations:

- Pucks: the compressed drums are called pucks.
- Radioactivity: described by the decay rate (radioactive decay per second) of a material and is measured in Becquerel (Bq).

- Natural back ground radiation: this radiation occurs naturally in the natural environment and comes from outer space, the earth and the air.
- Radioactive radiation: also called ionising radiation because it has the potential to ionise certain materials when it goes through it. This mainly poses an external radiation threat.
- Radioactive contamination: this is fine loose powder of radioactive material where we don't want it. If this powder gets consumed it poses an internal radiation threat.
- Radioactive dose: the effective dose is measured in milli-Sievert (mSv); the yearly permitted dose is 50 mSv.
- Radiological classification: the same colour classification is used for radiation and contamination; however both are indicated separately at the entrance to a radiation area. Four colours are used to indicate the four different levels of exposure:

Table 1: Area classification description

Area classification	Colour code	Possible radiation dosage.	Level of control
Uncontrolled	White	No substantial dose above the natural background dose	None
Surveillance	Blue	Not more than yearly dose. Average not more that 20% of yearly dose due to strict control.	Strict
Controlled	Red	Not more than yearly dose due to strict control. Without control the dose can be exceeded.	Very strict
Limited	Purple	Not more than yearly dose due to extremely strict control. Without control the dose would most likely be exceeded.	Extremely strict

- Criticality: a chain reaction of atom splits resulting from neutrons expelled from one split, that in turn cause new splits. This will only occur under ideal circumstances. A lot of heat and ionising radiation is expelled during criticality.
- Necsa: South African Nuclear Energy Corporation.
- NLM: Nuclear Liabilities Management division of Necsa.
- NNR: National Nuclear Regulator.
- VRF: Volume Reduction Facility.
- PLC: Programmable Logic Controller.
- SCADA: Supervisory Control And Data Acquisition.
- Bq: Becquerel (disintegrations per second).
- QMS: Quality Management System.
- MRI: NLM Master Record Index.
- NCR: Non-Conformance Report.

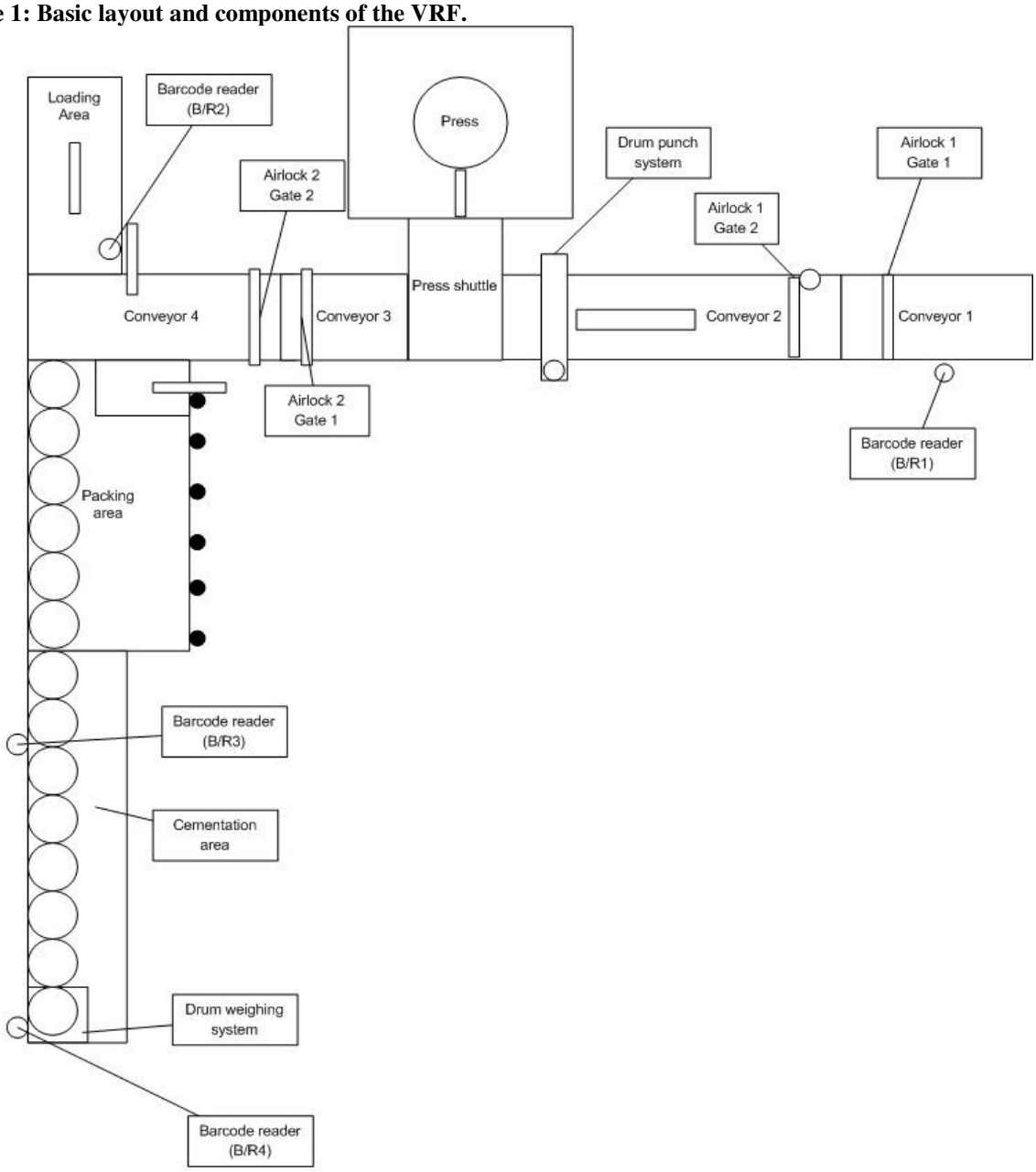
1.3 The Volume Reduction Facility

1.3.1 Process overview:

According to NLM – TECH – 08/001 Basis of design for Volume Reduction Facility, the VRF (Volume Reduction Facility) was operated for several years but became dysfunctional due to outdated technology. The equipment must be upgraded and a new PLC must be installed to automate the control of the system.

The basic layout of the VRF is shown in figure 1. The drums with radioactive waste are placed on conveyor 1. After the drum has been accepted by the system it moves through airlock 1 onto conveyor 2 that takes it to the drum punching system which punches some holes in the drum. After the holes have been punched the drum is pushed onto the press shuttle which in turn moves the drum into the press.

Figure 1: Basic layout and components of the VRF.



It is important to note that when the drum moves through the airlock, both doors may not be open simultaneously. This is to prevent a loss of negative pressure with the associated risk of contamination spreading.

The press compresses the drum to the pre-set pressure to form a puck. The puck must then be visually inspected by the operator in the control room. If it is rejected the puck is pushed off at the back of the press into another drum designated for rejected pucks. A puck is rejected when it burst and the content is spilled. If it is accepted the puck is taken out of the press by the shuttle.

The puck on the shuttle is pushed onto conveyor 3 by the next drum that is pushed onto the press shuttle. The drum then moves through airlock 2 onto conveyor 4. When the puck reaches the end of conveyor 4 it is pushed onto a grab which packs it into the 210L drums at the packing area.

The PLC must calculate the optimal packing strategy to maximise the amount of space utilised. This is done according to the following constraints:

1. The Alpha activity concentration in the cemented drum may not exceed 400 Bq per gram.
2. The Uranium-235 level may not exceed 250 grams per 210L drum.
3. Packed pucks may not exceed a certain height.

The Grab moves the puck to the related 210L drum. The puck is then pushed onto a frame that will be disposed with the drum. The frames are attached to a mechanical lowering device that will lower the frame into the drum as they receive the pucks. This ensures that the pucks do not just fall into the 210L drum which action may damage the drum or result in pucks being in the wrong position. The frame also maintains the correct space between the bottom of the 210L drum and the pucks. This space is filled with concrete at the cementation area.

When the 210L drums are filled they are moved to the cementation area where the cavities in the drum and between the pucks are filled with cement. After curing, the drums are sealed with a lid and moved to the storage area.

The liquid which escapes from the drums in the pressing cycle is collected in the sump of the press. The sump drains into tanks in the lower level of the VRF. This liquid may consist of water and oil that needs to be separated. The total uranium-235 content of the water in the tank may

not exceed 250g. It is therefore assumed that the U-235 content of the water collected from each drum is the same as the total U-235 content inside the drum being pressed. The total theoretical uranium content of a tank is the sum of the U-235 in the drums that have been pressed.

When the theoretical uranium level in the tank reaches the maximum allowable level, the inlet valve is closed and the water diverted to the next tank. The actual U-235 content of the tank is then determined. The nuclide and uranium levels are also monitored. This is done by sampling and testing of the water. Before the water is tested it is collected in a tank where it circulates for a predetermined time. If there is unused volume in the tank and the uranium levels are below the maximum the tank may again be opened to receive water until the theoretical level of uranium is equal to the maximum permitted level or until the volume capacity has been reached. The water is tested again for the actual quantity of uranium present.

Theoretical uranium-235 level (T_t) = $\sum_{1}^{n} X_i + T_{t-1}$

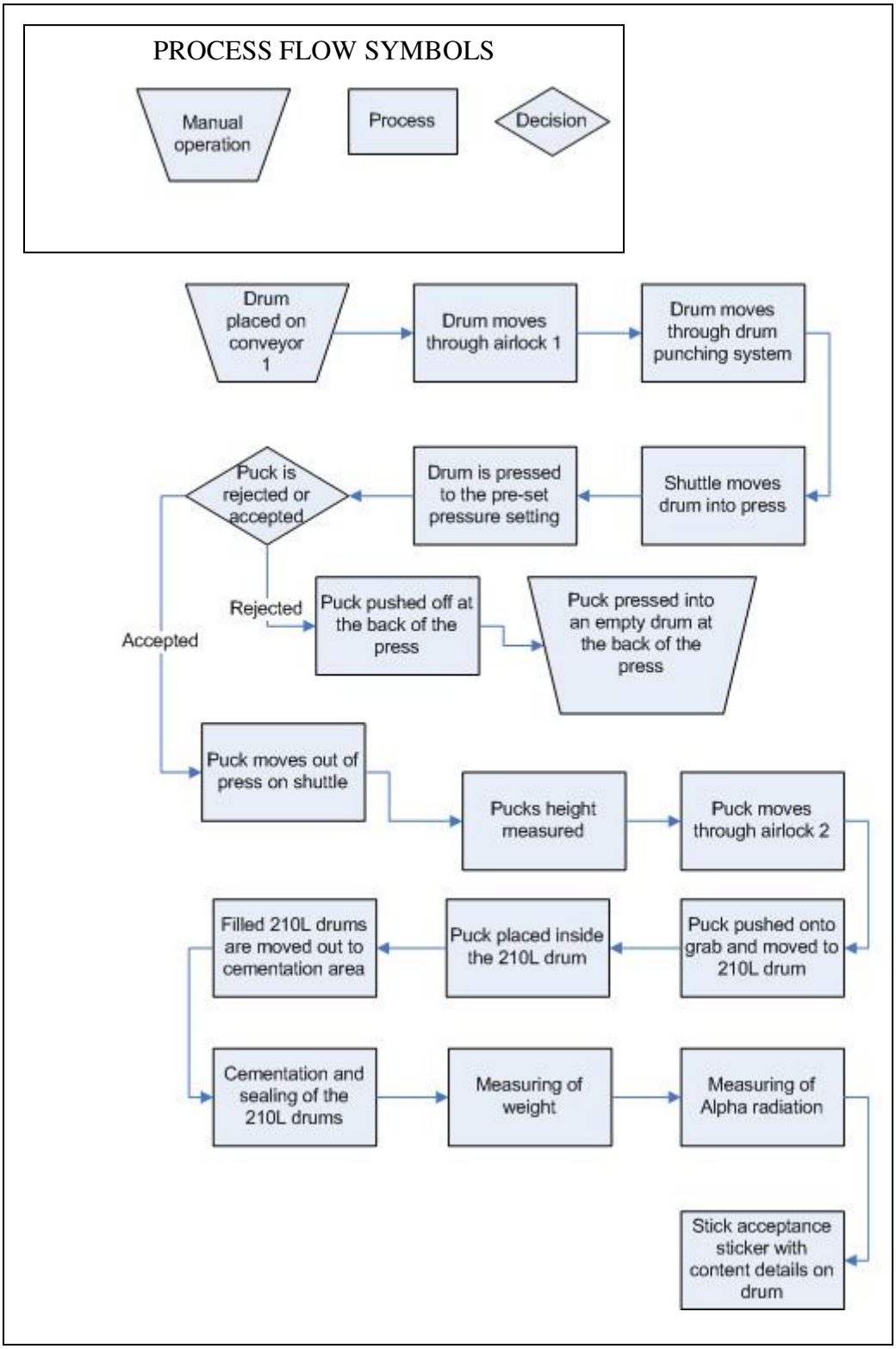
Where X_i is the quantity of uranium in drum i. and T_{t-1} is the starting level. The actual Uranium-235 level must be entered into the data base as a new value for T_{t-1}

$T_0 = 0$ since the tank is empty when of the filling process commences.

$T_t \leq 250$ grams of uranium-235.

Figure 2 shows an overview of the processes at the VRF.

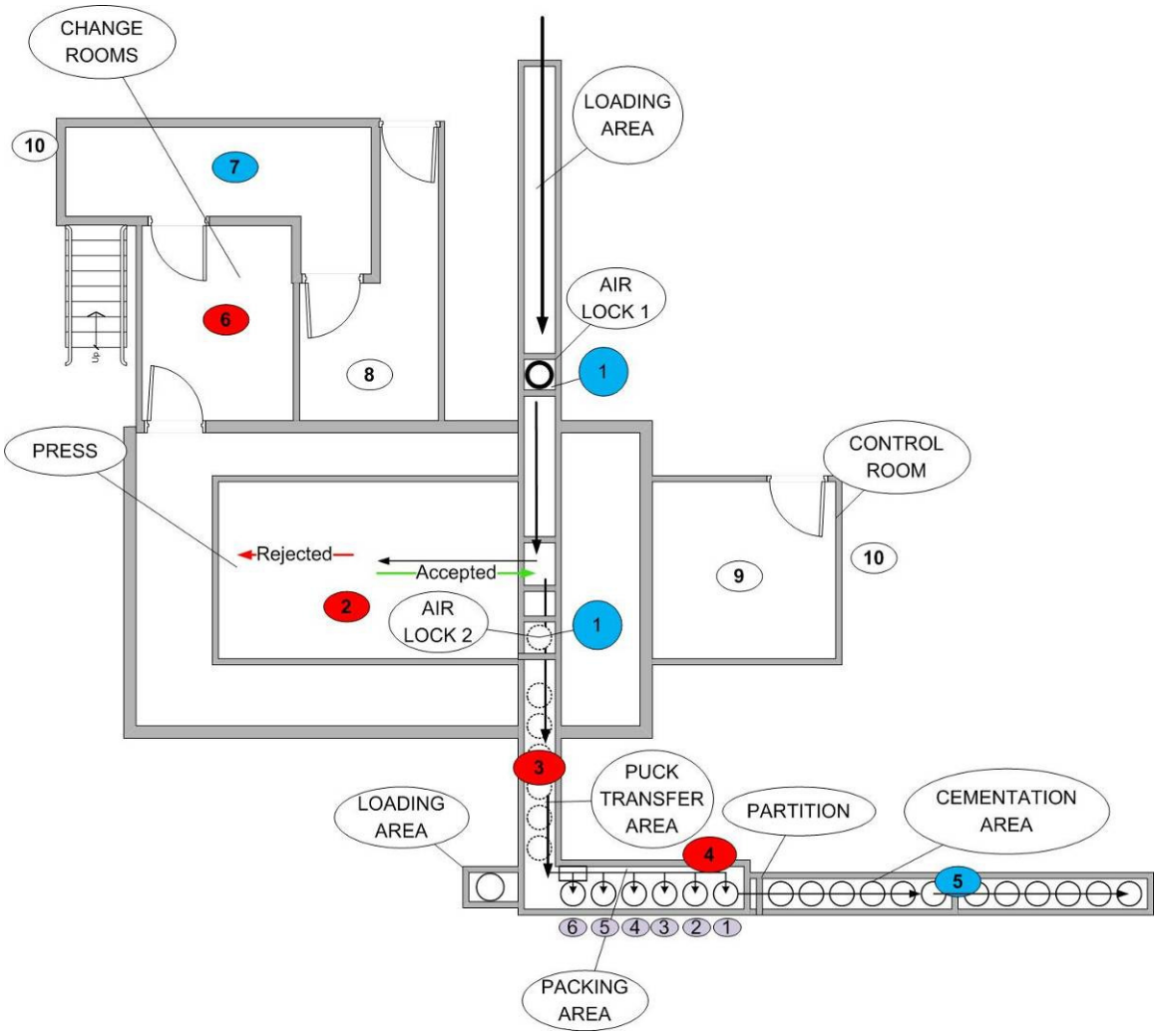
Figure 2: Overview of the process.



1.3.2 Layout of the VRF:

According to: Doc.: Preliminary Design Volume Reducing Facility, prepared by Africon. The VRF consists of an upper and lower level. The upper level is where the main activities take place. This is where the press, control room and change rooms are as shown in figure 3.

Figure 3: Upper level of the VRF.



The lower level of the VRF houses the water effluent tanks and a small hand press that is used to press the rejected pucks into the drum at the back of the press. The description and classification of the zones in figure 3 and 4 are given in table 2.

Figure 4: Lower level of the VRF.

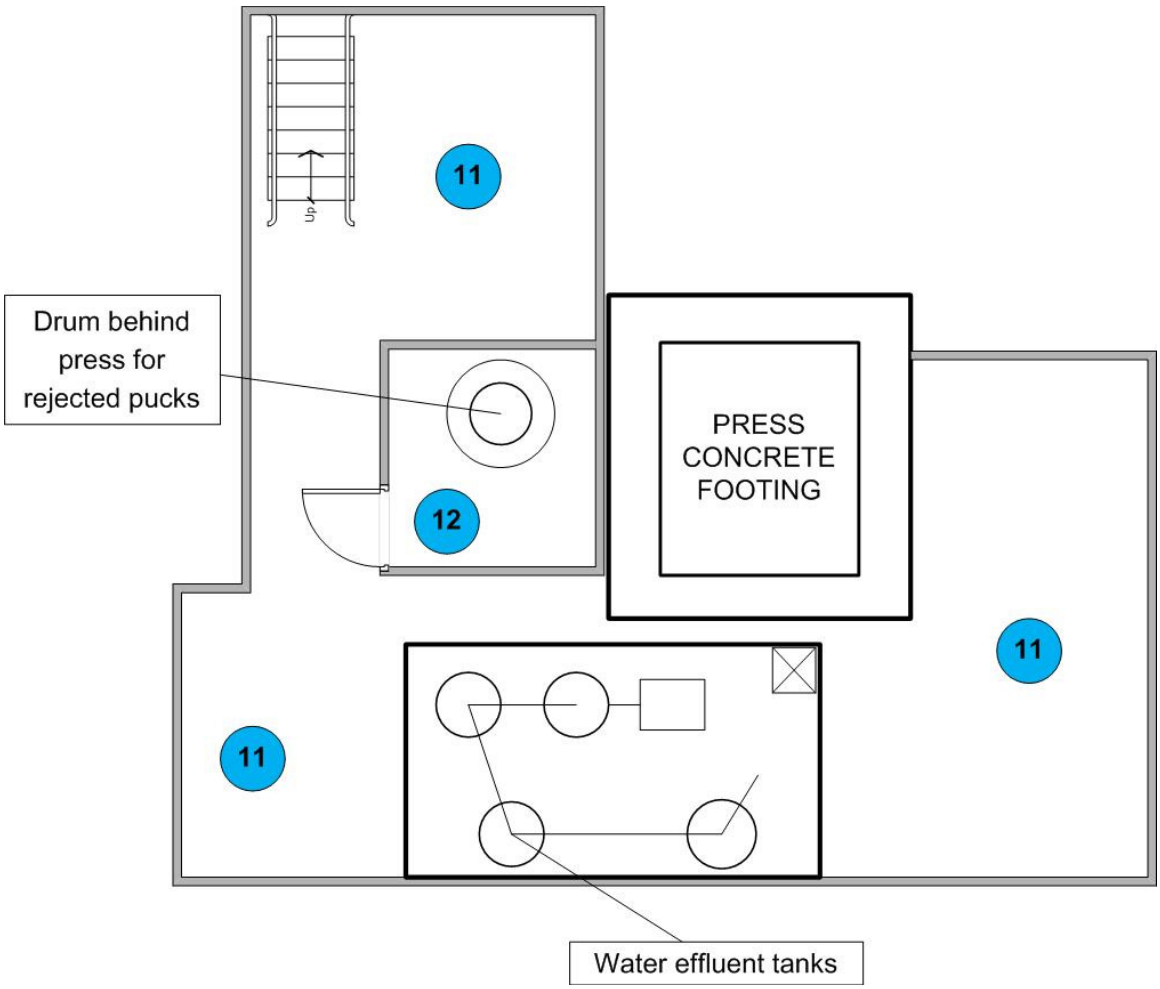


Table 2: Zone classification and description

Upper level of the VRF		
Zone	Description	Area classification (contamination)
1	Airlock gate 1 and 2	Blue
2	Press area (open to zone 3 and 4)	Red
3	Puck transfer area (estimate)	Red
4	Packing area	Red
5	Cementation area	Blue

6	Change room	Red
7	Change room (open to lower level of the VRF zone 11)	Blue
8	Change room	White
9	Control room	White
10	Pelstore (natural ventilated area)	White
Lower level of the VRF		
11	Enclosed area from whole Pelstore basement. Area for effluent receiving and monitoring tanks. Open to zone 7	Blue
12	Small press area	Blue

1.4 The existing Quality Management System

NLM currently has a generic QMS that is used as an overall system for their activities. This QMS consists of three generic tiers. The Nuclear Liabilities Management Quality Manual (NLM-QAM-001) describes the tiers as follows:

Table 3:Generic 1st Tier procedure matrix

ISO 9001 Clause No.	QUALITY MANAGEMENT SYSTEMS	NLM-
1st Tier		
4.2.2	NLM Quality Manual	QAM-001
5.3	NLM Quality Policy	QP-001
5.4.1	NLM Objectives	OB-001

Table 4: Generic 2nd Tier procedure matrix

ISO 9001 Clause No.	QUALITY MANAGEMENT SYSTEMS	NLM-
2nd Tier		
4.2.3	Control of Documents	PROC-001
4.2.4	Control of Records	PROC-002

8.2.2	Control of Internal Audits	PROC-003
8.3	Control of Non-conforming Product	PROC-004
8.5.2	Control of Corrective Action	PROC-005
8.5.3	Control of Preventive Action	PROC-006
5.6 & 7.4	Procedure for Management Responsibility	PROC-007
4.2.3	Procedure for Document Changes	PROC-008
4.2.3	Procedure for creating a document	PROC-009
8.3	Procedure for Control of Design and Development	PROC-010
7.1	Criteria for setting liability management priorities	PROC-011
7.0	Procedure for Product Realization	PROC-012
8.4 & 5	Procedure for Purchasing Control	PROC-013
7.5.4	Procedure for Customer property	PROC-014
7.6	Procedure for Control of Monitoring and Measuring Devices	PROC-015
7.5.5	Procedure for Preservation of Product	PROC-016
5.4	Procedure for Planning	PROC-017
8.2.4	Procedure for Monitoring and Measurement of Product	PROC-018
8.2.3	Procedure for the Monitoring and Measurement of Processes	PROC-019
6.2.2	Procedure for training	PROC-020
7.1	Developing and Implementing Quality Plans for Projects	PROC-021
7.5.3	Procedure for identification and traceability	PROC-022
7.5.1	Control of Production and Service Provision	PROC-023

Table 5: Generic 3rd Tier procedure matrix

ISO 9001 Clause No.	QUALITY MANAGEMENT SYSTEMS
3rd Tier	
7.0	Operational procedures, Work Instructions, Forms, Checklists, Specifications, Route Charts, Criteria's

2. Project aim

The first aim is to develop quality management documents specifically for the VRF. This will ensure that the existing QMS is applied to the specific requirements of the VRF. Keeping record of the waste, pucks and the final product will help to eliminate reoccurring problems. The tracking of pucks is of prime importance because of the nature of the contents. It must be known where each puck is in the system and where it is finally packed.

The second aim is to develop a heuristic to optimise the volume usage in the 210L drums at the packing station. This will be done by making use of Operations Research methods which will be incorporated into the QMS.

3. Project scope

Firstly, the development of quality management documents for the VRF. The documentation will consists of Work Instructions, Process Descriptions and Specifications. The following points are important when considering the development of the documentation:

- Waist handling; both liquids and solids.
- Final product; that is the cemented and sealed 210L which is ready for storage.
- When is a product classified as non-conforming,
- Data tracking; keeping track of the specific drums that go into the final product.
- Optimal use of the volume in the 210L drums.

The focus will be on developing Work Instructions, Process descriptions and Specifications to add to the existing procedures for use at the VRF. The maintenance of the VRF will not be considered since the VRF is not yet built and the detail design of the parts to be used has not been finalised.

Secondly, the development of a heuristic to optimise the volume usage in the 210L drums.

4. Literature review

A literature review was done to gain further insight into the solution/ design techniques that may be used to solve the problem to produce a design. First of all a review of the ISO 9000 standard was done after which a review of operations research methods to develop a heuristic for the optimal use of space in the 210L drums was done. After these the literature review concluded with a look at different product tracking devices.

4.1 ISO 9001:2008

The ISO 9001:2008 quality management system was chosen by the management of NLM since NLM is ISO 9001 registered and would like all of their activities to comply with it. The ISO standards are also recognised internationally which is necessary when dealing with foreign countries.

The adoption of a quality management system should be a strategic decision of an organization. It is important to remember that ISO 9001 is a business tool to help top management to improve the quality of services or products. It only is effective when it is properly set up and properly implemented. It is important to make all employees aware of and part of the implementation to ensure that they accept it as part of their responsibility and not only an additional nuisance tool for management. This will ensure the success of the ISO 9001 implementation.

4.1.1 Benefits

According to *The 9000 Store, quick start guide: benefits of ISO 2008* and *Wikipedia* the benefits include:

- “Improved consistency of service and product performance”.
- “Higher customer satisfaction levels”.
- “Improved customer perception”.
- “Improved productivity and efficiency”.
- “Cost reductions”.
- “Improved communication, morale and job satisfaction”.
- “Competitive and increased marketing and sales opportunities”.
- “Reduced waste”.

4.1.2 Basic principles

According to the ISO 9001:2008 document. “This International Standard promotes the adoption of a process approach when developing, implementing and improving the effectiveness of a quality system, to enhance customer satisfaction by meeting customer requirements”.

The process approach is an important aspect of the international standard. For an organization to function effectively it is important that they manage the numerous linked activities and their transformation of inputs into outputs, which is called a process (ISO 9001:2008 document)

“An advantage of the process approach is the ongoing control that is provided over the linkage between the individual processes within the system of processes, as well as over their combination and interaction”.

According to the ISO 9001:2008 document, this approach when used in a quality management system, will emphasize the importance of:

- “understanding and meeting requirements,
- the need to consider processes in terms of added value,
- obtaining results of process performance and effectiveness, and
- continual improvement of processes based on objective measurements”.

“In addition, the methodology known as “Plan-Do-Check-Act” (PDCA) can be applied to all processes. PDCA can be described as follows:

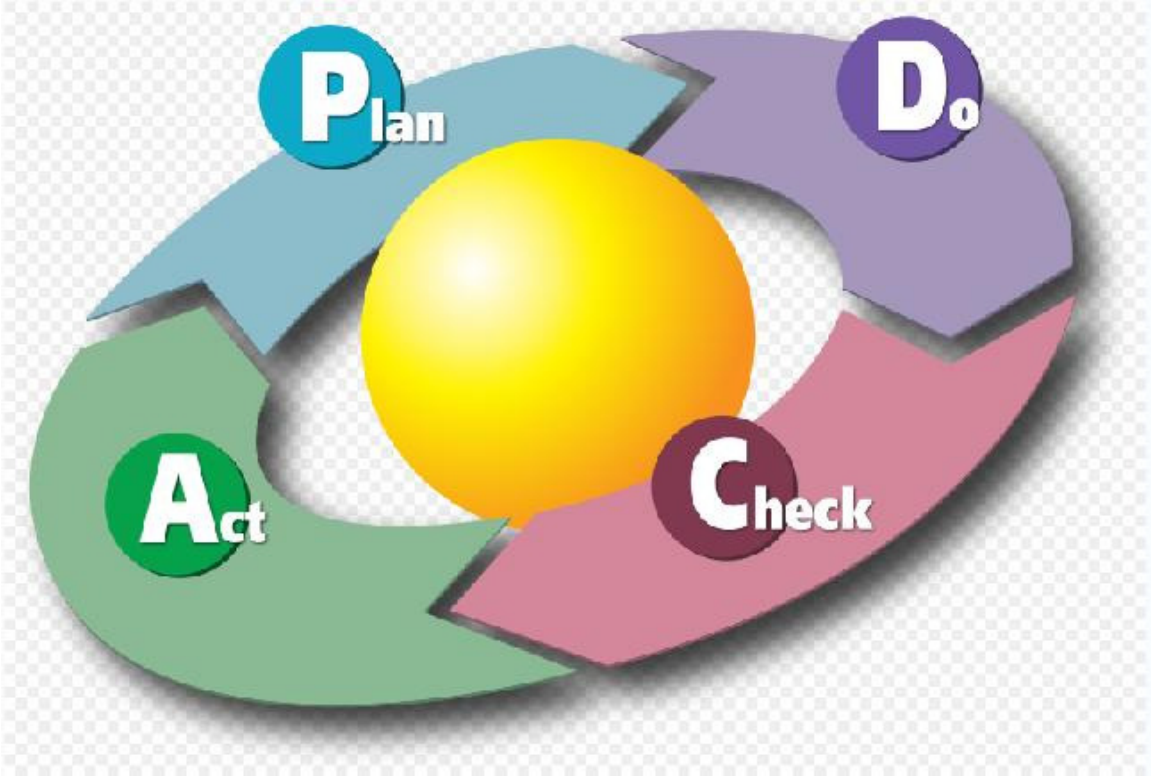
Plan: establish the objectives and processes necessary to deliver results in accordance with customer requirements and the organisation’s policies.

Do: implement the processes.

Check: monitor and measure processes and product against policies, objectives and requirements for the product and report the results.

Act: take actions to continually improve process performance”.

Figure 5: The Plan-Do-Check-Act cycle



Courtesy of wikipedia (http://en.wikipedia.org/wiki/File:PDCA_Cycle.svg).

4.1.3 Key points

According to the ISO 9001:2008 document the following points are important for the development of a QMS:

1. **quality management system:** "the organisation shall establish, document, implement and maintain a quality management system and continually improve its effectiveness in accordance with the requirements of the International Standards".
2. **management responsibility:** management must show their commitment to the QMS and communicate it to the organisation. They must establish a quality policy and objectives. They must ensure that management reviews are performed and the availability of resources. Customer satisfactions plays a most important part in the abovementioned points.

3. **resource management:** management must provide the necessary resources for the implementation and maintenance of the QMS. This must be done to enhance customer satisfaction.
4. **product realisation:** "the organisation shall plan and develop the processes needed for product realisation". It is important to consider the customer requirements for the product before developing the processes. Process mapping can be used to simplify the task of identifying the processes and their relationship with one another.
5. **measurement, analysis and improvement:** the organisation should plan and implement the monitoring, measuring, analysis and improvement processes needed to demonstrate conformity of the product and the QMS and to continually improve the effectiveness of the QMS. "Internal audits shall be conducted at planned intervals to determine whether the QMS (a) conforms to the planned arrangements and (b) is effectively implemented and maintained". Statistical process control can be used to improve the process's performance and continually improve it.

4.1.4 Implementation steps

The following steps should be followed to ensure that the implementation takes place according to plan: (*The 9001 Store: implementing ISO 9001:2008)*

- Inform all employees of the initiative to implement ISO 9001 principles and what their responsibilities are
- "Train employees on the basics of ISO 9001:2008"
- Set up task teams
- Identification of what procedures need to be developed
- "Internal auditors are trained for the internal audit program"
- "The new QMS procedure are used for several months while records are collected and improvements are made"
- "The registrar conducts an audit of the system"

4.1.5 Steps for setting up the documentation

The following steps will be followed in order to set up the documentation for the QMS system:

1. management shall define a quality policy,
2. define the scope of the QMS,

3. identify the customer needs and regulatory requirements,
4. identify the resources needed in order to meet the customer needs and regulatory requirements,
5. identify the processes and their sequence and interaction for the QMS by setting up process maps,
6. set up the required procedures,
7. define the performance measurements to ensure customer satisfaction,
8. keep the required records to prove that the resulting product meets requirements

4.2 Procedure writing

Procedure writing is one of the documentation requirements of the international standard. According to *The 9001 Store: Document control 2008* good documentation must be:

- "clear
- concise and
- user friendly".

To make it user friendly one must

- "use short sentences starting with a verb
- avoid using the passive voice and make it clear who is performing the task
- use white spaces for easy reading".

According to John Robert Dew the ground rules for procedure writing is:

- Be specific, short and to the point
- The person reading it is a customer
- They must be readable and useable under stress
- Use simple numbering system
- Place procedures where the users can get them.

If two employees would perform a task the same way from reading the procedure then it is documented well.

4.3 Heuristic

According to Winston and Venkataramanan (2003, pp2-5), Introduction to mathematical programming, operations research: volume one, fourth edition the components of a mathematical model may include:

- objective function(s),
- decision variables, and
- constraints.

"An optimisation model seeks to find values of the decision variables that optimise (maximise or minimise) an objective function among the set of all values for the decision variables that satisfy the given constraints".

"The variables whose values are under our control and influence the performance of the system are called the decision variables". "Restrictions on the values of decision variables are called constraints".

"When operations research is used to solve an organisations problem, the following seven step model-building procedure should be followed:

1. formulate the problem
2. observe the system
3. formulate a mathematical model of the problem
4. verify the model and use the model for prediction
5. select a suitable alternative
6. present the results and conclusions of the study to the organisation
7. implement and evaluate recommendations".

A heuristic/ mathematical model must be developed to maximize the volume utilization inside the 210L drums. The following constraints hold:

1. The alpha radiation per gram of the total weight of cemented drum may not exceed 400Bq.
2. The uranium-235 level of content may not exceed 250g per 210L drum.

3. The packed pucks may not exceed the predetermined maximum height in the 210L drum.

4.4 Product tracking

The drums have barcodes on their sides to identify them. All of the relevant data can be obtained by scanning the barcode. The problem is that once the drum has been pressed, the barcode can no longer be scanned due to the sides of the drum collapsing making it inaccessible. The puck can thus no longer be identified, and is thus of first importance that an alternative tracking system be found. However it is important to test an alternative tracking system before implementation. This can only be done after licensing and thus the old tracking system will be used when writing documents on the tracking and traceability of products.

4.4.1 Configuration

One way of keeping track of the position of a puck in the system is to remember the order in which they where put into the system and assume that they will emerge at the other end in the same order. This method has problems i.e. what if a puck falls off a conveyor or the pucks must be removed from a conveyor for maintenance? When the order is changed the pucks may be packed into the wrong 210L drum; which may result in a final product that is out of specification and must thus be rejected. This will have a serious impact on the quality of the final product.

4.4.2 Radio Frequency Identification (RFID)

According to http://www.explainthatstuff.com/rfid.html, passive radio frequency identification tags contain a small antenna that responds to incoming radio waves send by a transmitter. There is sufficient power in such radio waves to activate the RFID tag. Passive tags can send and receive signals over a few metres.

A radio frequency identification tag can be used very effectively if they can be fitted to the drum where it will not be destroyed during the pressing cycle. RFID will ensure the traceability of the pucks through the system and even after cementation. This will play a major role in verifying the contents of the 210L drum.

5. The quality management system

NLM currently has a QMS that is based on the ISO 9001:2000 requirements, as described in the introduction. This however is a generic system used overall at NLM. It is therefore necessary to develop new documents for the specific requirements of the VRF.

The existing QMS is described and a broad overview of its operation is given. The overview focuses on the relationship between the most important Procedures and the role of the Procedure for Management Review. This is followed by a description of the Auditing process and its role in the QMS, after which the benefits of Auditing are listed.

A more detailed approach will be followed which will focus on the processes of the VRF and the specific requirements of the documentation for the VRF.

5.1 Overview of the relationship between the procedures

5.1.1 Role of management reviews

In this section an overview of the existing QMS is given, which focuses on the relationship between the most important Procedures within the QMS and the role played by the Management Review Procedure.

The QMS comprises of a set of interactive Procedures and Work Instructions that are in accordance with the requirements of the ISO 9001:2000 standards for QM systems. It is important to understand the relationship between the specified procedures of the QMS in order to understand the working of the QMS. The Management Review Procedure is one of the most important procedures and will thus be discussed first.

The Procedure for management review can be found in the Procedure for Management Responsibility (NLM-PROC-007, section 6.7) where the following points are discussed:

1. General information regarding management reviews.
2. Establishing a management review team.
3. Establishing an agenda, which includes a description of the review inputs and review outputs.

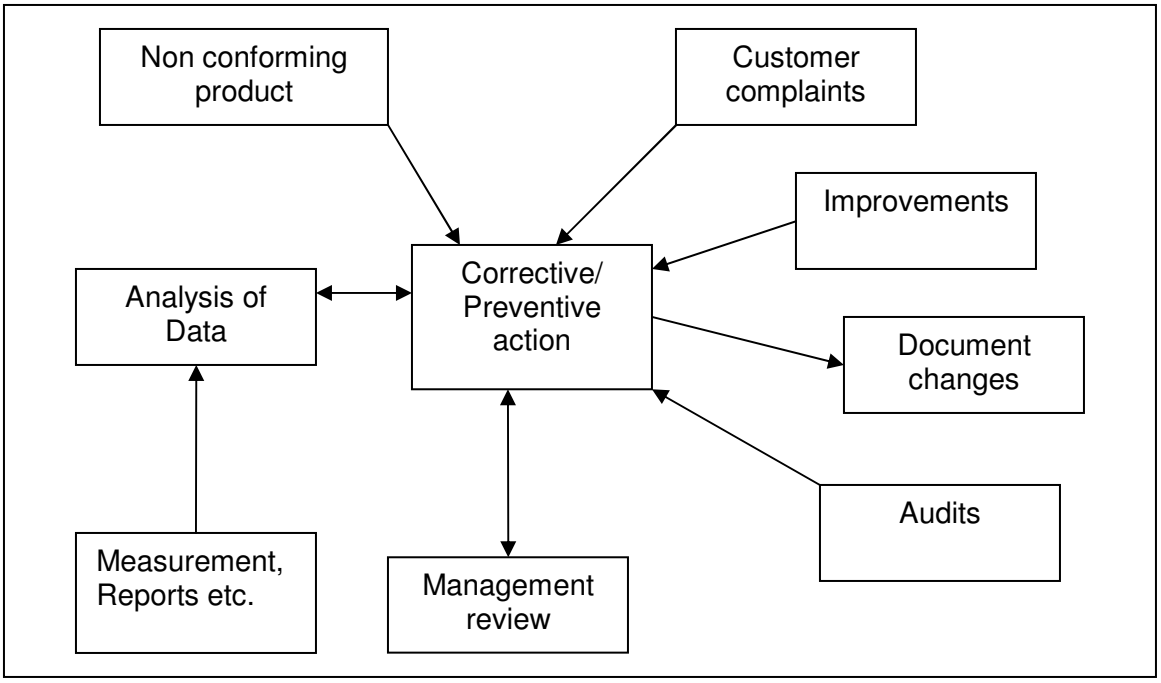
It does not describe the relationship with the other procedures of the QMS. It was therefore decided to describe the relationship between the most important Procedures. The following description can be used as an amendment to the above mentioned Procedure to assist in understanding the QMS and its procedures.

The diagram below illustrates the relationship between the most important Procedures within the QMS. The management review process plays a most important part in the QMS. It ensures that:

1. the QMS is functioning as it should,
2. any non-conformities are discussed and corrective actions are proposed,
3. checks of corrective actions are performed, and that
4. the QMS is continually improved and used from day to day.

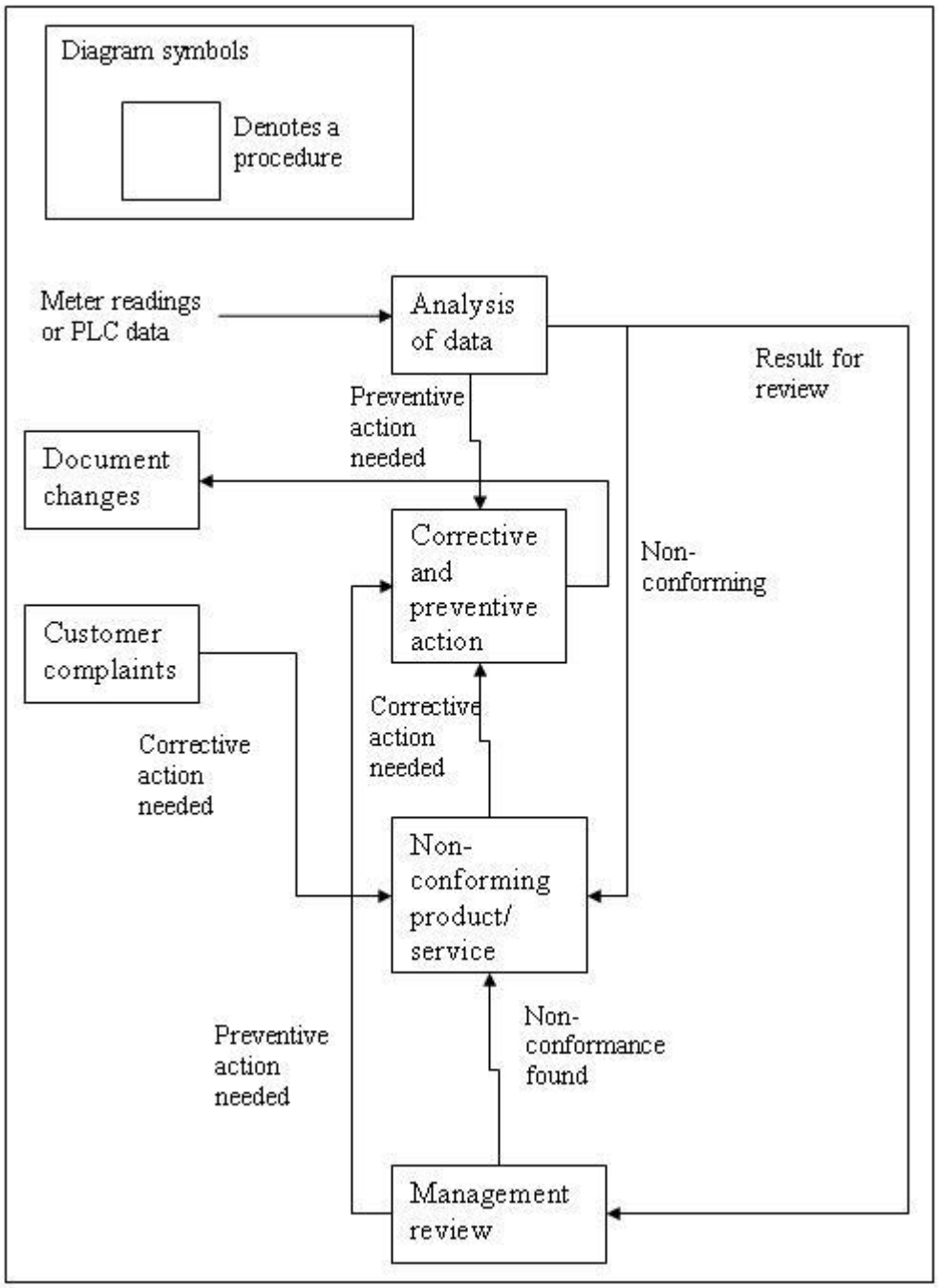
When an audit is performed, the auditors typically inspect the records of the management reviews that have been performed. Management reviews consider how corrective and preventive actions are performed and whether they have been successful. Corrective and preventive action will typically influence the data obtained from measuring devices and may result in changed documents, procedures and processes. The effectiveness of preventive and corrective action can be determined by analysing the data from the measuring devices.

The following diagram gives an overview of the interaction between the most important Procedures of the QMS.



The following diagram shows the interaction of the following procedures between one another and the route that must be followed according to the Quality Management System.

Figure 6: Interaction between the procedures.



By following the above mentioned Procedures of the QMS, continuous improvement of the QMS will be assured. It ensures that data is analysed correctly and any non-conformance corrected or prevented. Results from the data analysis may be requested by management for reviewing.

When reviewing the results, management must report any non-conformances and ensure that preventive steps are followed where necessary.

It is important that any non-conformances be reported and handled according to the Procedure for Non-conforming Products (NLM-PROC-004). When a non-conformance has been reported and recorded, corrective action must be planned and executed according to the Procedure for Corrective Action (NLM-PROC-005). All customer complaints must be dealt with as a non-conformance. While corrective or preventive actions are performed, it may become necessary to change the documented procedures according to the Procedure for Document Changes (NLM-PROC-008).

5.1.2 Role of auditing

Ensuring that the abovementioned system is kept active is important in that regular internal audits are executed according to the Procedure for the Control of Internal Audits (NLM-PROC-003). According to the Procedure for carrying out internal quality audits (P0822E02) of the Department of Industrial and Systems Engineering at the University of Pretoria, this is done by ensuring that:

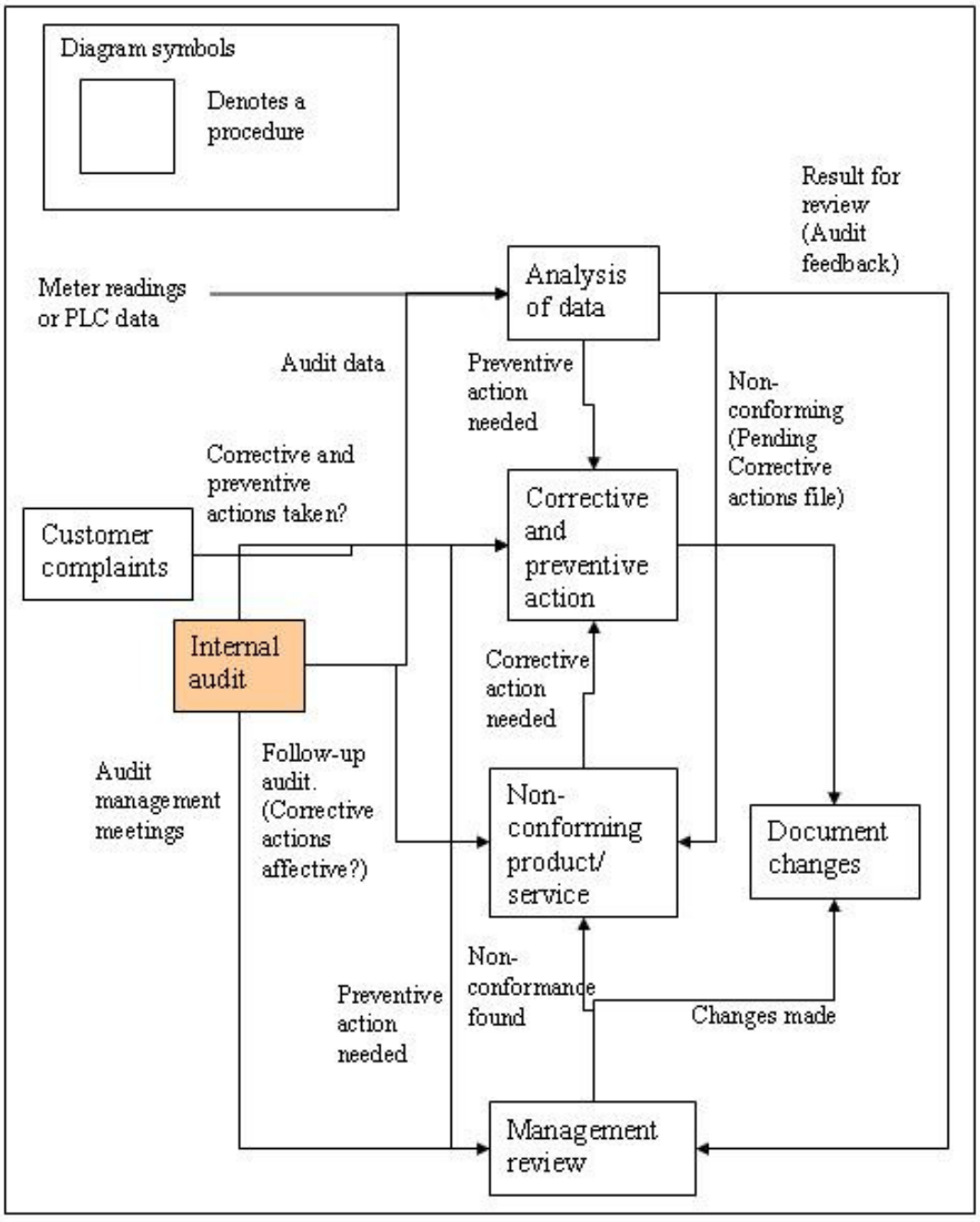
- “all quality activities comply with planned arrangements,
- the quality system is effective and maintained,
- corrective and preventive actions are implemented and effective, and
- all elements of the quality system are reviewed as planned at regular intervals to ensure that the National and International Quality Standards are adhered to”.

According to the Procedure for Control of Internal Audits (NLM-PROC-003). The interval between internal audits should not be greater than 12 months to ensure that corrective and preventive actions are regularly performed. The audit results form an integral part of the input to management review activities and should be in report format and are to be reviewed at management review meetings. Non-Conformance Reports (NCR) shall be closed-out within a period of 3-6 months.

The auditor must ensure that the appropriate corrective actions are taken. This must be done during a follow-up audit. Until the corrective actions are verified the NCR remains open and

registered on the applicable MRI system, after which it may be closed. Unscheduled audits may be conducted at any time deemed necessary. The internal audit procedure is shown in the following flow diagram.

Figure 7: The role of Internal Auditing.



In the above diagram it can be seen that when performing an internal audit, many of the relevant Procedures of the QMS are reviewed. The procedure for data analysis is described in the Procedure for Control of Internal Audits (NLM-PROC-003) must be reviewed to ensure that it is correct with the passage of time. The procedure for Control of Corrective action (NLM-PROC-005) and the Procedure for Preventive Action (NLM-PROC-006) must be audited to ensure that they are done according to the prescribed procedure. Non-conforming product/ service reporting must be audited to ensure that it is reported and documented and that corrective actions will be taken. When auditing the Management it is important to consider their commitment toward the QMS. Regular meetings should be held where the QMS is discussed. When considering the management reviews it is important to refer to previous reviews to ensure that corrective action has been taken to eliminate previous problems identified. It is also important to ensure that the necessary changes are made to Procedures as needed for corrective and preventive actions. The Procedure for Document Changes (NLM-PROC-008) should be followed when a document requires alteration.

When management is committed and the Procedures are followed the QMS will be effective and continual quality improvements will be possible.

5.2 Processes at the VRF

In this section the processes for product realisation at the VRF and the documentation requirements will be discussed.

According to *figure 2: overview of the processes* the following table was set up to identify the mechanisms involved with the processes.

Table 6: VRF process descriptions

Action no.	Description	Who responsible	Measure	Data stored
1	Drums placed on conveyor and scanned	Employee	Scanned and accepted by PLC	Yes, drum information stored in data base
2	Drum moved through air lock 1	PLC	Sensors confirm	No
3	Drum moved through drum punching system	PLC	Sensors confirm	No

4	Shuttle moves drum into press	PLC	Sensors confirm	No
5	Drum is pressed	PLC	Sensors confirm	No
6	Decision to reject or accept	Control room operator	Visual inspection (burst or not)	Yes, decision recorded in data base
7	Puck pushed off at back of press	PLC	Sensors confirm	No
8	Puck pressed into empty drum	Employee	Visual inspection	No
9	Puck moves out of the press	PLC	Sensors confirm	No
10	Pucks height measured	Height sensor	Sensors confirm	Yes, height stored in data base
11	Puck moves through air lock	PLC	Sensors confirm	No
12	Puck moved onto grab and moved to 210L drum	PLC	Sensors confirm	No
13	Puck placed inside 210L drum	PLC	Sensors confirm	Yes, destination recorded in data base
14	Filled 210Ldrums are moved to cementation area	PLC	Sensors confirm	Yes, position of 210L drum changed. marked as “full” and content stored in data base
15	Cementation and sealing of 210L drums	Employee	Visual inspection	Yes, marked as sealed in data base
16	Measuring of weight	Scale	Scale output	Yes, weight stored in data base
17	Measuring of Alpha radiation	Measuring device	Machine output	Yes, radiation measurement stored
18	Stick acceptance sticker with content details on drum	Employee	Visual	Sticker printed confirmation

For the application of the generic Procedures of the existing QMS, it is important to identify the specific requirements of the VRF. For example the Procedure for Control of Records (NLM-PROC-002) states that records must be kept and defines format but does not specify which data must be recorded.

In the Data stored column in the above table a short description is given of the data that needs to be stored. A detailed description of the data is as follows:

- **Action 1:** The following data must be stored in the data base when the drum is scanned:
    1. Drum ID number.
    2. Uranium-235 content in grams.
    3. Alpha radiation activity in Bq.
- **Action 6:** The control room operator must do a visual inspection of the puck when the pressing cycle is completed. The puck must either be accepted or rejected and this decision together with the resulting route of the puck must be recorded.
- **Action 10:** The puck's height is measured and recorded and added as an attribute to each respective puck's data string.
- **Action 13:** The attributes of the puck must be linked to the ID number of the 210L drum into which the puck is packed. This means that the content of the 210L drum must be obtainable when its barcode is scanned.
- **Action 14:** Pucks are packed into the 210L drum until it is full. The 210L drum must then be marked as "full".
- **Action 15:** After cementation and sealing of the drum it is scanned out and recorded as cemented and sealed in the data base.
- **Action 16:** The drum is weighed and its weight recorded in the data base.
- **Action 17:** The drums alpha radiation is measured and recorded in the data base.

5.3 The heuristic

A heuristic must be formulated to ensure that the required quality of the final product is met in a cost effective way. The heuristic must be programmed into the PLC to govern the packing of the pucks into the 210L drums.

The PLC must calculate the optimal packing strategy to maximise the amount of space utilised. This is done according to the following constraints:

1. The Alpha radiation activity per gram of the total weight of the cemented drum may not exceed 400 Bq.
2. The Uranium-235 level may not exceed 250 grams per 210L drum.
3. Packed pucks may not exceed a certain height.

The objective function:

$$\text{Max } z = \sum_{i=1}^{n}\sum_{j=1}^{6} X_{ij} \qquad [1]$$

The decision variables:

X_{ij} = the height in centimetres (cm) of puck i where i = {1, 2,…, n} put into 210L drum j where j = {1, 2,…, 6}.

L = the maximum permitted height of pucks in each 210L drum.

A_{ij} = the given alpha radiation (Bq) per puck i, i = {1, 2,…, n} packed into 210L drum j, j = {1, 2,…, 6}.

U_{ij} = the given amount in gram (g) of uranium-235 in puck i, i = {1, 2,…, n} packed into 210L drum j = {1, 2,…, 6}.

The constraints:

$$\sum_{i=1}^{n} X_{ij} \leq L \qquad \forall j \ni \{1, 2,\ldots, 6\}. \qquad [2]$$

$$\sum_{i=1}^{n} U_{ij} \leq 250 \qquad \forall j \ni \{1, 2,\ldots, 6\}. \qquad [3]$$

$$\sum_{i=1}^{6} A_{ij} \leq 400 \qquad \forall j \ni \{1, 2,\ldots, 6\}. \qquad [4]$$

$$\sum_{j=1}^{6} Y_{ij} \leq 1 \qquad \forall i \ni \{1, 2,\ldots, n\}. \qquad [5]$$

$Y_{ij} = 1$ if $X_{ij} \geq 0$ $\qquad \forall j \ni \{1, 2,\ldots, 6\}$

0 otherwise $\qquad \forall i \ni \{1, 2,\ldots, n\}.$ [6]

Equation [1] maximises the volume usage in each 210L drum. Inequality [2] constrains the height of the puck in the 210L drum to a pre-determined height. Inequality [3] constrains the maximum total uranium-235 content in each 210L drum to 250g. inequality [4] constrains the maximum alpha radiation to 400Bq per 210L drum. Inequality [5] ensure that a puck i, i = {1, 2,…, n} can only be packed into one 210L drum j, j = {1, 2,…, 6}. Equation [6] serves as a binary counter.

6. References

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13. Nuclear Liabilities Management Quality Manual (NLM-QAM-001)
14. Procedure for Management Responsibility (NLM-PROC-007)
15. Procedure for Non-conforming Products (NLM-PROC-004)
16. Procedure for Corrective Action (NLM-PROC-005).
17. Procedure for Document Changes (NLM-PROC-008).
18. Procedure for the Control of Internal Audits (NLM-PROC-003)
19. Procedure for carrying out Internal Quality Audits (P0822E02) of the Department of Industrial and Systems Engineering at the University of Pretoria
20. Procedure for Control of Records (NLM-PROC-002)

7. Attachments

7.1 Work instructions

It was deemed necessary to create the following Work Instructions to ensure that the specific requirements of the VRF are adhered to according to the generic Procedures. The work instructions were created according to the Procedure for Creating a Document (NLM-PROC-009) as far as possible. This means that the structure of the document was followed but without the document number, revision number, logos, Necsa copyright statement or classification. This will be done by Necsa on the appropriate template designed for creating new documents.

According to the Procedure for the Control of Documents (NLM-PROC-001) Work Instructions are of level 3 of controlled QMS documents. Work Instructions shall be identified with the following number: NLM-WKI-XXX where the XXX represent the unique number. For the purpose of this document the unique numbering starts at 001. The numbering should however be changed when implementing the Work Instruction at the VRF. The following table shows the 3rd tier documents developed for use at the VRF.

Table 7: 3rd Tier Work Instructions for the VRF.

Quality Management System	NLM-
3rd Tier	
Ensuring Product Traceability	WKI-001
Identification of Non-conforming Product	WKI-002
Product Realisation	WKI-003

7.1.1 Work Instruction for Ensuring Product Traceability (NLM-WKI-001):

1. Purpose:

The purpose of this Work Instruction is to specify the programming requirements for the product and WIP data tracking and storage system at the VRF. The main purpose is to aid the programmers of the data base and the PLC to comply with the requirements.

2. Scope:

This document specifies the format and type of data that must be stored in the data base of the VRF in order to comply with the Procedure for Identification and Traceability (NLM-PROC-022). Data relating to the material flow through the VRF and the final product leaving it must be stored.

3. References:

The following documents are referenced in this document:

1. NLM-PROC-002: Procedure for the Control of Records.
2. NLM-PROC-022: Procedure for Identification and Traceability.

4. Definitions and abbreviations:

4.1 Definitions:

4.2 Abbreviations:

VRF: Volume Reduction Facility.
PLC: Programmable Logic Controller.
NLM: Nuclear Liabilities Management Department.
QMS: Quality Management System.
Bq: Becquerel.

5. Responsibilities:

The responsibilities for ensuring product traceability are as follows:

1. the management and programmer of the PLC and its data base is responsible for ensuring that it complies to this document,

2. the control room operator is responsible for ensuring that the PLC and data base is working properly,

6. Work instruction:

According to the Procedure for Identification and Traceability (NLM-PROC-022) section 5.1 point h, “bar codes shall be obtained from the waste tracking system and identified on each waste package”. It is therefore necessary that each final product has its own unique bar code. When the final product’s barcode is scanned or the drum’s ID number in entered into the system the following data must be available:

ID number:
Total weight:
Content:

Puck ID number:	Uranium-235 (g)	Alpha radiation (Bq)	Nuclide content summary	Pucks height (cm)
Total:				

Filled confirmation: “Full”
Total Uranium-235 content (g):
Cemented and sealed confirmation:
Total height of packed pucks:
Total alpha radiation (Bq):
Number of pucks in drum:
Intermediate storage location:
Final destination:
Conforming to specifications: “yes” or “no”.
Sticker printed: “yes” or “no”.
Remarks: (any notes or remarks can be inserted here)

The abovementioned information must be printed on a sticker which must be placed on the side of the drum. According to the Procedure for the Control of Records (NLM-PROC-002) it is important that the abovementioned information is available in report format.

To comply in full with the requirements of the Procedure for identification and traceability (NLM-PROC-022), it is important that the location of each drum that enters the VRF is known and traceable. The following data should thus be available when the ID no. is entered into the waste tracking system:

ID number:
Content:

Uranium-235 content (g)	Alpha radiation (Bq)	Nuclide content summary

Route: “rejected” or “accepted”
In the system: “yes” or “no”
Final destination reached: “yes” or “no”
When the final destination has been reached:
Final destination ID no.: (210L drum ID)
Intermediate storage location:
Final destination:
Remarks: (any notes or remarks can be inserted here)

7. Records:

See NLM-PROC-002: Procedure for the Control of Records, section 7 or NLM-PROC-022: Procedure for Identification and Traceability, section 8.

7.1.2 Work instruction for the Identification of Non-conforming Product (NLM-WKI-002):

1. Purpose:

The purpose of this document is to define the minimum product requirements and what a non-conforming product is, to ensure that it is identified and recorded.

2. Scope:

This document specifies the minimum requirements of the final product leaving the VRF. Any product not conforming to the minimum requirements should be identified and recorded as non-conforming.

3. References:

1. NLM-PROC-004: Procedure for the Control of Non-conforming Product.
2. NLM-PROC-005: Procedure for the Control of Corrective Action.
3. NLM-PROC-006: Procedure for Preventive Action.

4. Definitions and abbreviations:

4.1 Definitions:

a. **Product:** the final product leaving the VRF i.e. the sealed and cemented 210L drum.
b. **Pucks:** the drums after being pressed.
c. **Product non-conformance:** is product that does not conform to the documented acceptance criteria or requirements.
d. **Corrective action:** is the action required to eliminate the cause of non-conformance or other undesirable situation in order to prevent reoccurrence.

4.2 Abbreviations

VRF: Volume Reduction Facility.
PLC: Programmable Logic Controller.
NLM: Nuclear Liabilities Management Department.
QMS: Quality Management System.
Bq: Becquerel.

5. Responsibilities:

See the Procedure for the control of non-conforming product (NLM-PROC-004) section 6 for responsibilities.

6. Work instruction:

The Procedure for the control of non-conforming product (NLM-PROC-004) describes the process in which a non-conforming product should be handled. However it is important to know what a non-conforming product is before a non-conformance can be reported. A product is non-conforming when it does not conform to the following acceptance criteria:

1. the content must be verifiable,
2. properly cemented (the cement level should be sufficient to completely cover the top puck with cement grout and allow for the proper closure with an airtight lid),
3. the lid must seal airtight,
4. the uranium-235 content is within the allowable limit (< 250 gram/ drum),
5. the alpha radiation is within the allowable limit(< 400 Bq/ total weight of drum), and
6. the weight (kg) of the drum is known.

When a reoccurring non-conformance has been identified the Procedure for corrective action (NLM-PROC-005) or preventive action (NLM-PROC-006) should be followed to prevent the reoccurrence of the non-conformance.

7. Records:

See NLM-PROC-004: Procedure for the Control of Non-conforming Product, section 10, NLM-PROC-005: Procedure for the Control of Corrective Action, section 7 or NLM-PROC-006: Procedure for Preventive Action, section 8 for the applicable documents.

7.1.3 Work Instruction for Product Realisation (NLM-WKI-003):

1. Purpose:

The purpose of this document is to define the requirements and processes that must be adhered to for product realisation.

2. Scope:

This document defines the requirements of the following:

1. product requirements,
2. waste water and oil handling.

3. References:

1. NLM-PROC-012: Procedure for Product Realisation.
2. NLM-WKI-001: Work Instruction for Ensuring Product Traceability.
3. NLM-SPEC-004: Specification for Waste Water Handling.

4. Definitions and Abbreviations:

4.1 Definitions:

a. **Product:** the final product leaving the VRF i.e. the sealed and cemented 210L drum.
b. **Pucks:** the drums after being pressed.

4.2 Abbreviations:

VRF: Volume Reduction Facility.
PLC: Programmable Logic Controller.
NLM: Nuclear Liabilities Management Department.
QMS: Quality Management System.
WIP: Work in Progress.
Bq: Becquerel.

5. Responsibilities:

It is the responsibility of management to ensure that the requirements for product realisation at the VRF are met and that it is consistent with the other processes of the QMS.

6. Work instruction:

According to NLM-PROC-012 section 6.2.1 it might be necessary to determine additional requirements related to the product. The following additional requirements related to the final product have been identified:

1. The alpha radiation per gram of the total weight of cemented drum may not exceed 400Bq.
2. The uranium-235 level of content may not exceed 250g per 210L drum.
3. The packed pucks may not exceed the predetermined maximum height in the 210L drum.
4. The pucks and the final product should be identifiable and traceable. See Work Instruction for Ensuring Product Traceability (NLM-WKI-001).
5. Records on the final product and WIP should be obtainable.
6. Waste water handling. See Specification for Waster Water Traceability (NLM-SPEC-004).

7. Records:

See NLM-PROC-012: Procedure for Product Realisation, section 6.10, NLM-WKI-001: Work Instruction for Ensuring Product Traceability, section 8 or NLM-SPEC-004: Specification for Waste Water Traceability, section 10.

7.2 Process Descriptions:

It was deemed necessary to create the following Process Descriptions to ensure that the specific requirements of the VRF are adhered to according to the generic Procedures. The Process Descriptions were created according to the Procedure for creating a document (NLM-PROC-009) as far as possible. This means that the structure of the document was followed but without the document number, revision number, logos, Necsa copyright statement or classification. This will be done by Necsa on the appropriate template designed for creating new documents.

According to the Procedure for the Control of Documents (NLM-PROC-001) Process Descriptions are of level 3 of controlled QMS documents. Process Descriptions shall be identified with the following number: NLM-PD-XXX where the XXX represent the unique number. For the purpose of this document the unique numbering starts at 001. The numbering should thus be changed when implementing the Process Description at the VRF. The following table shows the 3rd tier documents developed for use at the VRF.

Table 8: 3rd Tier Process Descriptions at the VRF

Quality Management System	NLM-
3rd Tier	
Waste Water Handling System	PD-001
PLC System	PD-002

7.2.1 Process Description for Waste Water Handling System (NLM-PD-001):

1. Purpose:

The purpose of this document is to describe the Waste Water Handling System at the VRF.

2. Scope:

This document describes the logic that governs the Waste Water Handling System at the VRF. This includes the control of the circulation pumps and stirrers and the inlet and outlet valves on the tanks.

3. References:

The following documents are referenced in this document:

1. NLM-SPEC-001: Specification for the SCADA system.

4. Definitions and Abbreviations:

4.1 Definitions:

1. Waste Water: the water escaping from the drum being pressed, this water may be contaminated with oil and uranium-235.
2. Low Low level: Tank regarded as empty.
3. Low Level: A level just higher than the top of the circulation pump.
4. High High Level: Tank regarded full.
5. High Level: Range between Low Level and High High Level.
6. Isolation mode: pump and valves on tank in isolation mode can not be started or switched in manual or automatic mode. Section head password needed to change from and to isolation mode.
7. Manual mode: Actions controlled manually.
8. Automatic mode: All actions controlled by the PLC system.
9. Theoretical uranium content: it is assumed that the total amount of uranium in the effluent is equal to the total amount of uranium in the drum being pressed. The total theoretical uranium level is thus equal to the sum of the uranium levels of the drums that have been pressed. When the tank is empty the starting level is zero. When the tank is partly filled the starting level will be the actual level determined by testing.
10. Actual uranium content: The actual amount of uranium determined by testing.

4.2 Abbreviations:

VRF: Volume Reduction Facility.

PLC: Programmable Logic Controller.

NLM: Nuclear Liabilities Management Department.

QMS: Quality Management System.

SCADA: Supervisory Control And Data Acquisition.

Bq: Becquerel.

5. Responsibilities:

The programmers of the PLC and all employees working on the PLC system or with the Waste Water tanks must be aware of the working of the Waste Water Handling System. Management must ensure that the system is working properly and that it is used correctly.

6. Process description:

The liquid which escapes from the drums in the pressing cycle is collected in the sump of the press. The sump drains into tanks in the lower level of the VRF. This liquid may consist of water and oil that needs to be separated. The nuclide and uranium levels are also monitored. This is done by sampling and testing of the water. Before the water is tested it is collected in a tank where it circulates for a predetermined time. The total uranium content of the water in the tank may not exceed 250g. It is therefore assumed that the uranium content of the water collected from each drum is the same as the total uranium content inside the drum being pressed. The total theoretical uranium content of a tank is the sum of the uranium in the drums that have been pressed.

When the theoretical uranium level in the tank reaches the maximum allowable level, the inlet valve is closed and the water diverted to the next tank. The actual uranium content of the tank is then determined by testing. If there is unused volume in the tank and the uranium levels are below the maximum level the tank may again be opened to receive water until the theoretical level of uranium is equal to the maximum permitted level or until the volume is fully utilised. The water is tested again for the actual quantity of uranium present.

Theoretical uranium-235 level (T_t) = $T_{t-1} + \sum_{1}^{n} X_i$

Where X_i is the quantity of uranium in drum i. and T_{t-1} is the starting level. The actual Uranium-235 level must be entered into the data base as a new value for T_{t-1}

$T_0 = 0$ since the tank is empty when the filling process commences.

$T_t \leq 250$ grams of uranium-235.

After obtaining the actual uranium level by testing, the theoretical uranium-235 level must be changed to the actual level as indicated by the test.

6.1 Circulation pumps and stirrers on tanks*:*

The circulation pumps and stirrers must be able to run (start/ stop) in manual mode or in automatic mode depending on what the requirements are.

Automatic mode:

- Low level on tank must switch the circulation pump off.
- When the tank theoretically reaches its maximum allowable level of uranium the circulation pumps must be switched on.
- High level on the tank must switch circulation pumps on.
- After sufficient circulation the SCADA system must show the message “tank ready for sampling” and the tanks number. (For more information on the SCADA system see the Specification for the SCADA system (NLM-SPEC-001))

Manual mode:

- The circulation pumps can be switched on and off as required.

6.2 Inlet/ outlet valves on the tanks:

- The control on the valves must be as such that the valves are in a “fail safe” mode. This means that in the event of the failure of electrical power or plant air, the valves must move to the closed position.
- It must be possible to open or close the valves manually.

- It must be possible to isolate a tank to ensure that the inlet and outlet valves of a specific tank can not be opened in automatic or manual mode.
- A low-low level on a tank must close the outlet valve on that tank (automatic mode).
- A high-high level on a tank must close the inlet valve on that tank.
- When the theoretical maximum level of uranium in a tank is reached the inlet valve must be closed. After testing for uranium levels the actual level must be entered into the system. This level will be the new starting point for calculating the theoretical level of uranium.
- When the actual uranium content in the tank is at the maximum permitted level the inlet valve must close and the tank marked as full.
- The total uranium content of each tank must be stored on the system.
- The starting uranium content level of an empty tank is zero.
- At no stage shall it be possible to open the inlet and outlet valves simultaneously on a tank.
- No valve shall be able to open automatically if not instructed by the responsible person.

7. Records:

Records of the Uranium tests must be kept.

7.2.2 Process Description for the VRF PLC system (NLM-PD-002):

1. Purpose:

The purpose of this Process Description is to describe the logic that governs the PLC system to assist the designers of the PLC. This document may be used to train personnel working at the VRF.

2. Scope:

This document describes the logic that governs the PLC system at the VRF.

3. References:

1. NLM – TECH – 08/001: Basis of design for Volume Reduction Facility.

4. Definitions and Abbreviations:

4.1 Definitions:

4.2 Abbreviations

VRF: Volume Reduction Facility.

PLC: Programmable Logic Controller.

NLM: Nuclear Liabilities Management Department.

QMS: Quality Management System.

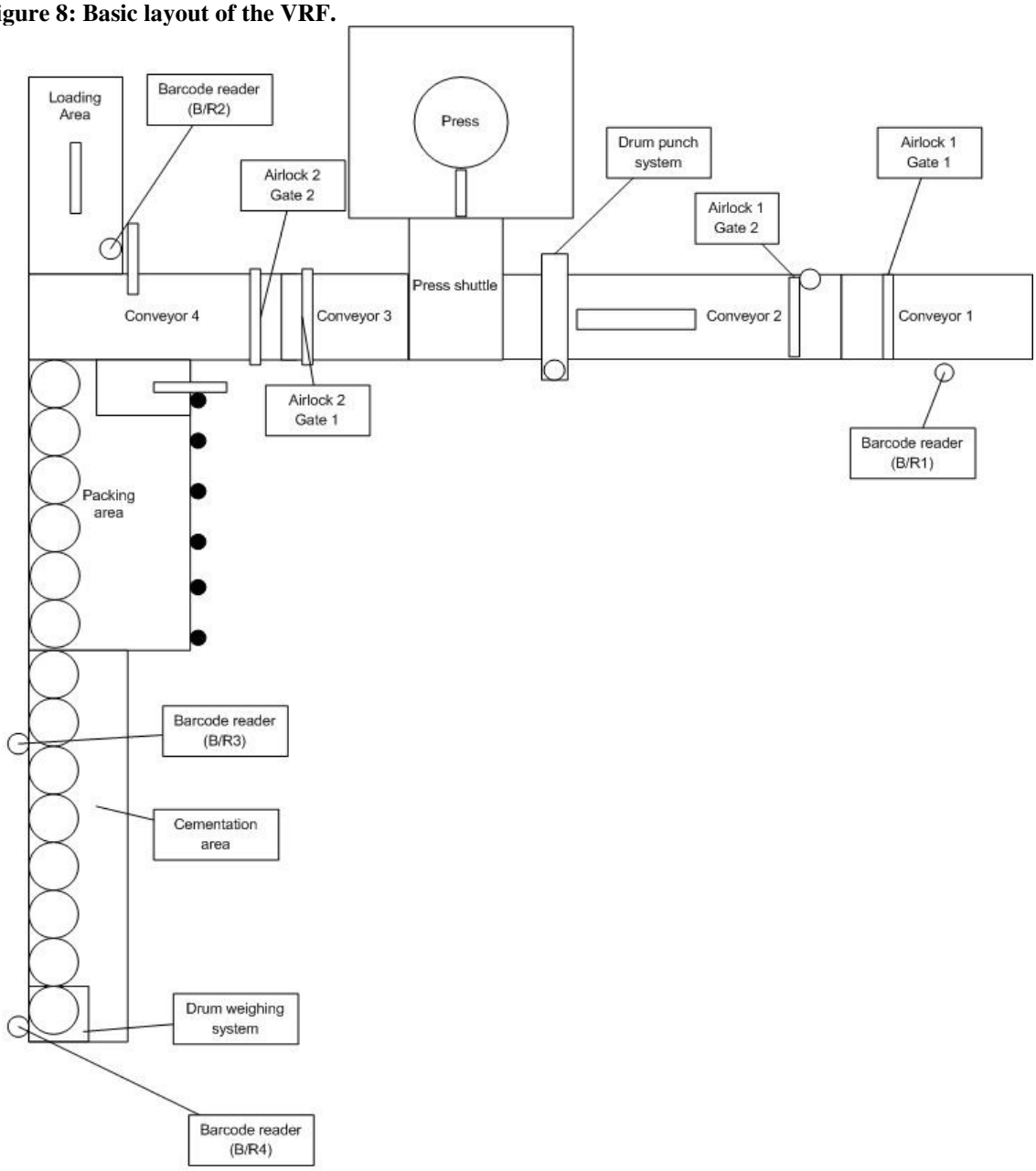
Bq: Becquerel

5. Responsibilities:

The programmers of the PLC and all employees working on the PLC system must be aware of the working of the PLC.

6. Process description:

Figure 8: Basic layout of the VRF.



The following detailed process description is based on the general description given in NLM – TECH – 08/001: Basis of design for Volume Reduction Facility. A drum containing radioactive waste is placed on conveyor 1. The worker then scans the barcode with a hand held barcode scanner when the yellow light indicates that the system is ready to accept a new drum. (If a

fixed position barcode scanner is used the drum must be positioned in the right orientation to ensure that it will be scanned when the conveyor moves it past the scanner). The data obtained from scanning the drum must be stored in the data string. This data together with the height of the puck will later on be used to determine the packing configuration of the pucks into the 210L drums.

After scanning the drum's barcode the system will either accept or reject it. If it is rejected a red light must shine for five seconds to indicate that the drum must be removed from the conveyor and the data must be stored in the "rejected drums" data string.

If the drum is accepted a green light must indicate that it is accepted. It will then move through airlock one. When moving through the air lock it must be ensured that gate 1 and 2 is not open simultaneously. This means that gate 1 must be closed when gate 2 is open and vice versa. This is to prevent any contamination of the 100L/ 160L drum loading area.

After moving through air lock 1 it will advance to the drum punching system. When the drum is inside the drum punching system the conveyor must stop. After stopping the conveyor the drum punching system must be activated. The drum punching system must then go through its cycle automatically.

After the drum punching cycle is completed and the shuttle has returned to its normal position, a pusher arm must push the drum that is in the drum punching system onto the shuttle. If there is a puck on the shuttle as the next drum is moved onto the shuttle it will be pushed from the shuttle onto the next conveyor.

The shuttle then moves the drum into the press and the pressing cycle follows. It is very important that the ventilation system is working while pressing the drum. This is to prevent the spreading of radioactive contamination.

After pressing the drum the piston and the sleeve must return to its normal position. The operator must then look at the condition of the puck. If it has exploded or ruptured it must be rejected. It will then be pushed of at the back of the press by a pusher arm; it will then fall into a

funnel. The puck will then be pressed into another drum that will be sealed to stop any contamination from spreading. The system must keep track of the drum's location in the system. When it is rejected the system must mark it as rejected and keep the sequence of the accepted drums in the system. This data will be vital for the packing cycle.

If it is accepted the shuttle returns to its original position, exiting the puck from the press. The puck is pushed onto conveyor 3 by the next drum moving onto the shuttle. The height of the puck is then measured and the data is stored in the data string. The puck will then move through airlock 2 onto conveyor 4. The same rules apply to airlock 2 and airlock 1.

There must at least be five pucks on conveyor 4. This is to ensure that there are enough pucks to choose from to fill the 210L drums optimally. It must be ensured that there is no more that six pucks on conveyor 4. When there are six pucks on conveyor 4, the puck on conveyor 3 must wait before moving through airlock 2. The loading of the shuttle must wait until there are no puck on conveyor 3.

The pucks on conveyor 4 will be packed into the 210L drums by the packing system making use of an automated grab. The automated packing system will determine the optimal packing configuration of the pucks into the 210L drums. This will be done by considering the data acquired by scanning the drum and the height of the puck. The objective is to maximize the volume utilized by the pucks in the 210L drums. This must be done according to the following constraints:

1. The Alpha radiation activity per gram of the total weight of the cemented drum may not exceed 400 Bq.
2. The Uranium-235 level may not exceed 250 grams per 210L drum.
3. Packed pucks may not exceed a certain height.

The grab will take the pucks at the end of conveyor 4 and move it to one of the six 210L drums in the packing area. The puck will be packed onto a steel frame inside the drum that can be lifted or lowered into the drum. When a puck is put onto the steel frame it must be lowered by the height of the puck into the drum. To ensure that the steel frame is lowered far enough,

sensors will be used to fine tune the lowering of the steel frame. This is to ensure that the next puck can be stacked on top of the previous one without any obstruction.

After the six 210L drums have been filled they are moved to the cementation area where the excess space in the drum will be filled with cement. This will help to contain the contamination and block off radiation. The drums will then move to the post cementation area where they will be sealed after the cement has set. The drums are moved in a “train”, this is because the drums are attached with external frames to each other. This is done to keep the spacing between the drums correct and to keep the contamination from spreading. The plates will help to seal off the holes in order to maintain the negative pressure inside the contaminated area.

The drums moved from the packing area are directly replaced by new empty drums. This is done to minimize the chance of contamination due to the drop in air pressure.

7.3 Specifications:

It was deemed necessary to create the following Specifications to ensure that the specific requirements of the VRF are adhered to according to the generic Procedures. The Specifications were created according to the Procedure for creating a document (NLM-PROC-009) as far as possible. This means that the structure of the document was followed but without the document number, revision number, logos, Necsa copyright statement or classification. This will be done by Necsa on the appropriate template designed for creating new documents.

According to the Procedure for the Control of Documents (NLM-PROC-001) Specifications are of level 3 of controlled QMS documents. Specifications shall be identified with the following number: NLM-SPEC-XXX where the XXX represent the unique number. For the purpose of this document the unique numbering starts at 001. The numbering should thus be changed when implementing the Specifications at the VRF. The following table shows the 3rd tier documents developed for use at the VRF.

Table 9: 3rd Tier Specifications at the VRF

Quality Management System	NLM-
3rd Tier	
The SCADA system	SPEC-001
The alarm system	SPEC-002
The PLC control system	SPEC-003
The Waste Water Traceability	SPEC-004

7.3.1 Specification for the SCADA system (NLM-SPEC-001):

1. Purpose:

The purpose of this document is to specify the display requirements of the iFIX viewing.

2. Scope:

This document specifies the information to be displayed on the iFIX viewing of the SCADA system at the VRF. This includes the display of the:

1. Water effluent tanks.
2. Press.
3. Airlocks and conveyors.
4. Pakking area.
5. Ventilation system.

3. References:

1. NLM-PD-001: Process Description for Waste Water Handling System.

4. Definitions and Abbreviations:

4.1 Definitions:

See NLM-PD-001: Process Description for Waste Water Handling System for the definitions of the water levels.

4.2 Abbreviations:

VRF:	Volume Reduction Facility.
PLC:	Programmable Logic Controller.
NLM:	Nuclear Liabilities Management Department.
QMS:	Quality Management System.
SCADA:	Supervisory Control And Data Acquisition.
Bq:	Becquerel.

5. Responsibilities:

The programmers of the PLC and SCADA system must ensure that the specifications are adhered to when programming. The management of the VRF must ensure that the specifications are adhered to and that any non-conformances are corrected.

6. Specifications:

iFIX viewing must be possible for the following areas:

1. The water effluent tanks.
2. The press.
3. The air locks and the conveyors.
4. The packing area.
5. The ventilation system.

More than one area may be displayed on the same PC screen but not at the same time, the alarm that is initiated in any of these areas must be brought forward for direct viewing.

6.1 Information to be displayed on the iFIX viewing for the water effluent tanks:

- The open/ close status of all of the inlet/ outlet valves.
- The water level in each tank (see NLM-PD-001: Process Description for Waste Water Handling System for a description of the water levels).
- The amount of uranium in each tank (see NLM-PD-001: Process Description for Waste Water Handling System for a description of the uranium calculations).
- Show when the maximum uranium has been reached.
- The running/ stop status of the circulation pumps.
- Readiness of tank to be sampled.
- Readiness of tank to be released. Auto and manual mode.

6.2 Information to be displayed on the iFIX viewing for the press:

- The pressure gage setting in kN.
- The stage in the pressing cycle it is currently performing.
- The position of the shuttle.
- The oil pressure and oil level of the press.
- Isolation mode when applicable.

- All alarms initiated must be displayed in such a way that it is clearly visible (as big as possible) with a clear indication to the operator what originated the error/ alarm. All alarms must be displayed separately.

6.3 Information to be displayed on the iFIX viewing for the airlocks and conveyors:

- Airlock open/ close status.
- Conveyor running/ stop status.

6.4 Information to be displayed on the iFIX viewing for the packing area:

- Number of pucks waiting at the puck transfer area.
- The volume percentage of each 210L drum used.
- When a 210L drum is filled it must be displayed as “full”.
- The status of the grab.
- Estimated time left to fill the six 210L drums.
- The number of pucks in each drum and the sum of the pucks in the six drums.
- The total amount of uranium-235 in each drum.
- The total alpha activity as a percentage of the total weight after cementation.

6.5 Information to be displayed on the iFIX viewing for the ventilation system:

- The running/ stop status for all of the extraction fans.
- The airflow status for all of the air flow meters.
- Show when air filters needs to be replaced.
- The duct air velocity.
- Open/ close status of the ducts.
- Level of monitored radioactivity in the gaseous discharge.
- The differential pressure over the filter banks.

7. Records:

7.3.2 Specification for the Alarm System (NLM-SPEC-002):

1. Purpose:

The purpose of this specification is to specify the working of the alarm system at the VRF.

2. Scope:

This document specifies the conditions that will trigger the alarm, the indication of an alarm and the actions that must be taken to cancel the alarm.

3. References:

No references applicable.

4. Definitions and Abbreviations:

4.1 Definitions:

1. Visible alarm: An alarm visible on the SCADA system that shows a text message, specifying clearly where and what condition triggered the alarm.

2. Audible alarm: Sounds at the loading, cementation and the control room when a predetermined condition it triggered. To silence the audible alarm the visible alarm (alarm flicker) must be accepted in control room (flickering will stop).

4.2 Abbreviations:

VRF:	Volume Reduction Facility.
PLC:	Programmable Logic Controller.
NLM:	Nuclear Liabilities Management Department.
QMS:	Quality Management System.
SCADA:	Supervisory Control And Data Acquisition.
Bq:	Becquerel.

5. Responsibilities:

The programmers of the PLC system are responsible for programming the alarm system according to the specifications. The control room operator and the VRF manager must be aware of the working of the alarm system.

6. Specifications:

Alarms that are triggered by a predetermined condition are categorised in two different categories to differentiate between different actions to be followed before the cancellation of the alarms. They are categorised as follows:

Table 10: Alarms

Alarms			
Condition	Indication	Action	
		Audible alarm	Visible alarm
Either Air lock 1 or air lock 2 not in the closed position.	Audible alarm sound at conveyor 1 and in control room.	To silence audible alarm, visible alarm must be accepted in control room by operator.	Alarm can be accepted by operator. Operator can cancel alarm after non conforming condition is corrected.
Negative pressure less than 20 Pa between zones.	Audible alarm sound at conveyor, loading area and in the control room. A visible alarm must also be activated in the control room. Visible alarm on SCADA system.	Alarm can not be accepted or cancelled by operator until condition is corrected. Special authorisation needed to accept or cancel alarm before non conforming	Alarm can not be accepted or cancelled by operator until condition is corrected. Special authorisation needed to accept or cancel alarm before non conforming

		condition is corrected	condition is corrected
Differential pressure over filter bank too low.	Audible alarm sound in the control room. Visible alarm on SCADA system.	To silence audible alarm, visible alarm must be accepted in control room by operator.	Alarm can be accepted by operator. Operator can cancel alarm after non conforming condition is corrected.
Press oil low level	Audible alarm in the control room Visible alarm on SCADA system.	To silence audible alarm, visible alarm must be accepted in control room by operator.	Alarm can be accepted by operator. Operator can cancel alarm after non conforming condition is corrected.

7. Records:

Records of any alarms must be kept for identification of reoccurring problems. A summary of the alarms must be available in report format.

7.3.3 Specification for the PLC Control System (NLM-SPEC-003):

1. Purpose:

The purpose of this document is to specify the design specifications of the PLC system.

2. Scope:

This document specifies the rules that the PLC system must adhered to in Manual and Automatic mode.

3. References:

No references applicable.

4. Definitions and Abbreviations:

4.1 Definitions:

1. Manual mode:
   - All alarms are still valid.
   - Clear indication on SCADA system indicating “Manual Mode”.
   - Section head password needed to change over from and to manual mode.

2. Automatic mode: All actions are controlled by the PLC system.

4.2 Abbreviations:

VRF:	Volume Reduction Facility.
PLC:	Programmable Logic Controller.
NLM:	Nuclear Liabilities Management Department.
QMS:	Quality Management System.
SCADA:	Supervisory Control And Data Acquisition.

5. Responsibilities:

The PLC programmers must ensure that the rules of operation and the different modes are programmed into the PLC system. Management of the VRF must ensure that the system is functioning properly.

6. Specifications:

The layout of the VRF and the components used are shown in the attached diagram.

6.1 Automatic mode:

Before the system can start and accept a drum the following conditions must be met:

- Airlock 1 gate 1 must be in the open position.
- Airlock 1 gate 2 must be in the closed position.
- The ventilation system must be functional (the correct negative pressure must be maintained).
- An effluent tank must be open and available to receive the effluent.
- A drum in position at the back of the press to receive a rejected puck.
- There must be six drums in position at the packing area.
- There may be no more than six pucks on conveyor 4.
- Press oil levels must be normal.
- All alarms must be off.
- The press must be in its normal position (normal when the container and piston has returned to its upper position).
- No emergency stop activated.
- The press oil levels must be correct.

When these conditions have been met a yellow light must indicate that the system is ready.

The following conditions must also be satisfied while the system is running:

- If at any time an emergency stop is activated all activities must be stopped.
- Before airlock 1 gate 1 may open airlock 1 gate 2 must be closed and vice versa.
- Before conveyor 1 may start, proximity switch 1 and 2 may not be activated and airlock 1 gate 1 must be open. The drum's barcode must be scanned and accepted as compressible.
- Conveyor 1 must stop when proximity switch 1 is activated.
- Before conveyor 2 may be activated airlock 1 gate 2 must be in the open position and proximity switch 1 must be activated but proximity switch 2 may not be activated.
- Never may any of the airlock 1 gates be activated while conveyor 1 or 2 is activated.

- Never may airlock 1 gate 1 and 2 be activated or opened simultaneously.
- Conveyor 1 and 2 may not be activated simultaneously.
- Conveyor 2 must stop when proximity switch 2 is activated.
- Airlock 1 gate 2 must close when proximity switch 2 is activated.
- The drum punching system may only be activated after conveyor 2 has stopped and proximity switch 2 has been activated.
- Pusher 1 may only be activated after the shuttle has returned to its normal position and the drum punching system has finished its cycle and proximity switch 2 is activated. There may also be no puck on conveyor 3 this means that while sensor 1 is activated pusher arm 1 may not be activated.
- The shuttle may only be activated when the press is in its normal position.
- The shuttle may not be activated while pusher arm 1 is activated and when there is no drum at the back of the press.
- The press may not be activated when there is no drum at the back of the press.
- The press may not be activated when the negative pressure at the press is too low or when there is no tank open to receive the effluent.
- The press may be activated when the shuttle is completely inside the press; it may not be activated when the shuttle is moving or while it is at its normal position.
- After pressing the press must return to its normal position and a buzzer must sound in the control room. The operator must inspect the puck to decide to keep or reject it.
- Pusher arm 2 may only be activated when the reject button is pressed after the operator is prompted to reject or accept the puck and the press has returned to its normal position. There must also be a drum in position at the back of the press. After pusher arm 2 has returned the shuttle may return.
- When the accept button is pressed after the operator is prompted to accept or reject the puck and the press has returned to its normal position the shuttle may return.
- The Accept and Reject buttons should only work when the operator is prompted to make a decision.
- The height of the puck will be measured when sensor 1 is activated.
- The two gates of airlock 2 may not be open simultaneously. Before either one of them may be opened they must both be in the closed position.

- Conveyor 3 may be activated when there is a puck at sensor 1 and no puck at proximity switch 3 and airlock 2 gate 1 is open and the height has been measured and stored in the data base.
- Conveyor 3 must stop when proximity switch 3 is activated and airlock 2 gate 1 must close.
- Conveyor 4 may not be activated while airlock 2 gate 2 is closed.
- Conveyor 4 must stop when sensor 6 is activated and may only be reactivated after sensor 6 is deactivated and proximity switch 3 has been activated and airlock 2 gate 2 is open.
- Pusher arm 3 may only be activated when sensor 6 is activated and when the grab has returned to its normal position.
- Pusher arm 3 may not be activated while conveyor 4 is activated.
- The grab may only be activated when there are drums ready to be filled in the packing area this means that they are in position and that the frames have been raised to the correct height. This means that the grab may not move while the 210L drums are moved. The grab must move to the drum where the puck needs to be packed; only then may the grab plate and pusher arm 4 be activated.
- The grab plate and pusher arm 4 may not be activated while the grab is moving and if the sensor at the designated drum is activated, indicating an obstruction at the drum.
- The grab may not return to its normal position while the grab plate and/ or pusher arm 4 has not returned to its normal position.
- A drum may only be scanned out as “finished” after the height sensor - at the position where it was filled with cement - confirmed that it is filled and then sealed with a lid.
- Pusher arm 5 may only be activated when:
  1. All of the internal frames have been lowered and released into the drums; this must be confirmed by sensor 8.
  2. Sensor 7 shows that an empty drum and frame is in place and the empty drum has been scanned by barcode reader 2 and the “ready” button at the loading area was pressed indicating that the operator is finished loading the empty drum and external frame.
  3. Before the drum can be scanned out as finished it needs to be cemented. A premix of cement will be poured into the drum to fill the cavities. The amount of cement will be

predetermined by the PLC according to the height of the pucks packed into the drum. A height sensor will stop the filling when the desired level has been reached.

4. The finished drum must be scanned out at barcode reader 4 and the external frame removed; this will be confirmed by sensor 9.
5. The drum must be weighed and the data stored in the data base.
6. Barcode reader 3 can only be operated in manual mode.
7. The system must keep track of the content data and the position of the drum in the system

In automatic mode it is very important to ensure that negative pressure is maintained inside the VRF. When the ventilation fails all operations should be stopped and the system be placed on hold until the problem has been fixed.

6.2 Manual mode:

The manual mode will be used when maintenance is done. The following logic applies to the system. This is to prevent any damage to the components used in the system and to prevent any contamination from spilling. It is therefore important to ensure that the conditions are adhered to before an element can be operated manually. Before any manual operations can be performed the ventilation system must be fully functional and no alarms may be triggered.

- Airlock 1's gates may be opened and closed manually according to the following rules:

1. The doors may not be opened simultaneously.
2. The doors may not be closed while their respective conveyors are activated.

- Conveyor 1 and 2 may be activated manually according to the following rules:

1. Airlock 1 gate 1 must be open before conveyor 1 can be activated.
2. Airlock 1 gate 2 must be open before conveyor 2 can be activated.
3. Conveyor 1 may not be activated when proximity switch 1 indicates that there is something in airlock 1.
4. Conveyor 1 must stop when proximity switch 1 is activated.
5. Conveyor 2 may not be activated when proximity switch 2 is activated.
6. Conveyor 2 must stop when proximity switch 2 is activated.

7. Conveyor 2 may not be activated while pusher arm 1 is activated.

- Pusher arm 1 may be operated manually according to the following rules.

1. Pusher arm 1 may not be activated while the drum punching system is activated.
2. Pusher arm 1 may not be activated when the shuttle is not at its normal position and proximity switch 2 is activated.
3. When proximity switch 2 is not activated pusher arm 1 may be activated whether the shuttle is at it normal position or not.
4. Pusher arm 1 may not be activated while conveyor 2 is activated.

- The shuttle may be operated manually according to the following rules:

1. The shuttle may not be activated while pusher arm 1 is activated.
2. The shuttle may not be activated while the press's piston and container is not at its normal position.
3. It may not be activated while pusher arm 2 is activated.

- Pusher arm 2 may be operated manually according to the following rules:

1. Pusher arm 2 may not be activated when the shuttle is moving. It may be activated when the shuttle is at its normal position.
2. Pusher arm 2 may not be activated when the press's piston and container is not at its normal position.
3. Pusher arm 2 may not be activated when there is no drum in position at the back of the press.

- The press may be operated manually according to the following rules:

1. The press's piston and container may not be activated while the shuttle is moving or when it is not at its normal position or fully inside the press.
2. It may not be activated when there is no tank open to receive the effluent when the shuttle is inside the press. When the shuttle is at its normal position the press may be activated even when no tank is open to receive the effluent and no drum at the back of the press is needed.

3. The press may not be activated when the shuttle is inside the press and there is no drum at the back of the press to receive a rejected puck.

- Conveyor 3 and 4 may be operated manually according to the following rules:

1. Conveyor 3 may not be activated when airlock 2 gate 1 is closed while proximity switch 3 or sensor 1 is activated.
2. Conveyor 3 may be activated while sensor 1 is activated while airlock 2 gate 1 is open.
3. When proximity switch 3 is activated, conveyor 3 must be stopped.
4. When sensor 6 is activated conveyor 4 must stop and may also not be re-activated.
5. When airlock 2 gate 2 is closed and proximity switch 3 is activated, conveyor 4 may not be activated
6. Conveyor 4 may not be activated when pusher arm 3 is activated.

- Airlock 2 gates 1 and 2 may be operated manually according to the following rules:

1. Airlock 2 gate 1 may not be activated to close while conveyor 3 is activated.
2. Airlock 2 gate 2 may not be activated to close while conveyor 4 is activated.
3. Airlock gates 1 and 2 may not be opened simultaneously. Both of them must be closed before one of them may be opened.

- Pusher arm 3 may be operated manually according to the following rules:

1. Pusher arm 3 may not be activated while conveyor 4 is activated.
2. Pusher arm 3 may not be activated when sensor 6 is activated and the grab is not in its normal position. When sensor 6 is not activated; pusher arm 3 may be activated independently from the position of the grab.
3. Pusher arm 3 may not be activated while the grab plate and pusher arm 4 is not in its normal position.

- The grab may be operated manually according to the following rules:

1. All of the 210L drums must be in place.
2. All of the internal frames must be in position; the height sensor at each drum must indicate that the stack of pucks on the frame is below the top level of the 210L drum.
3. The grab plate and pusher arm 4 must be at their normal position.

4. The grab may not be activated simultaneously with the grab plate and pusher arm 4.

- The grab plate and pusher arm 4 may be operated manually according to the following rules:

1. The grab plate and pusher arm 4 may not be activated when the 210L drums are not in place or when the internal frames with the puck stacks are not in place or level to the top of the drum.
2. Pusher arm 4 may not be activated when the grab plate is not activated or at its normal position.
3. The grab plate may be activated independently from pusher arm 4 while pusher arm 4 is at the normal position.
4. Pusher arm 4 may be activated independently from the grab plate while the grab plate is not in its normal position.

- Pusher arm 5 may only be activated when:

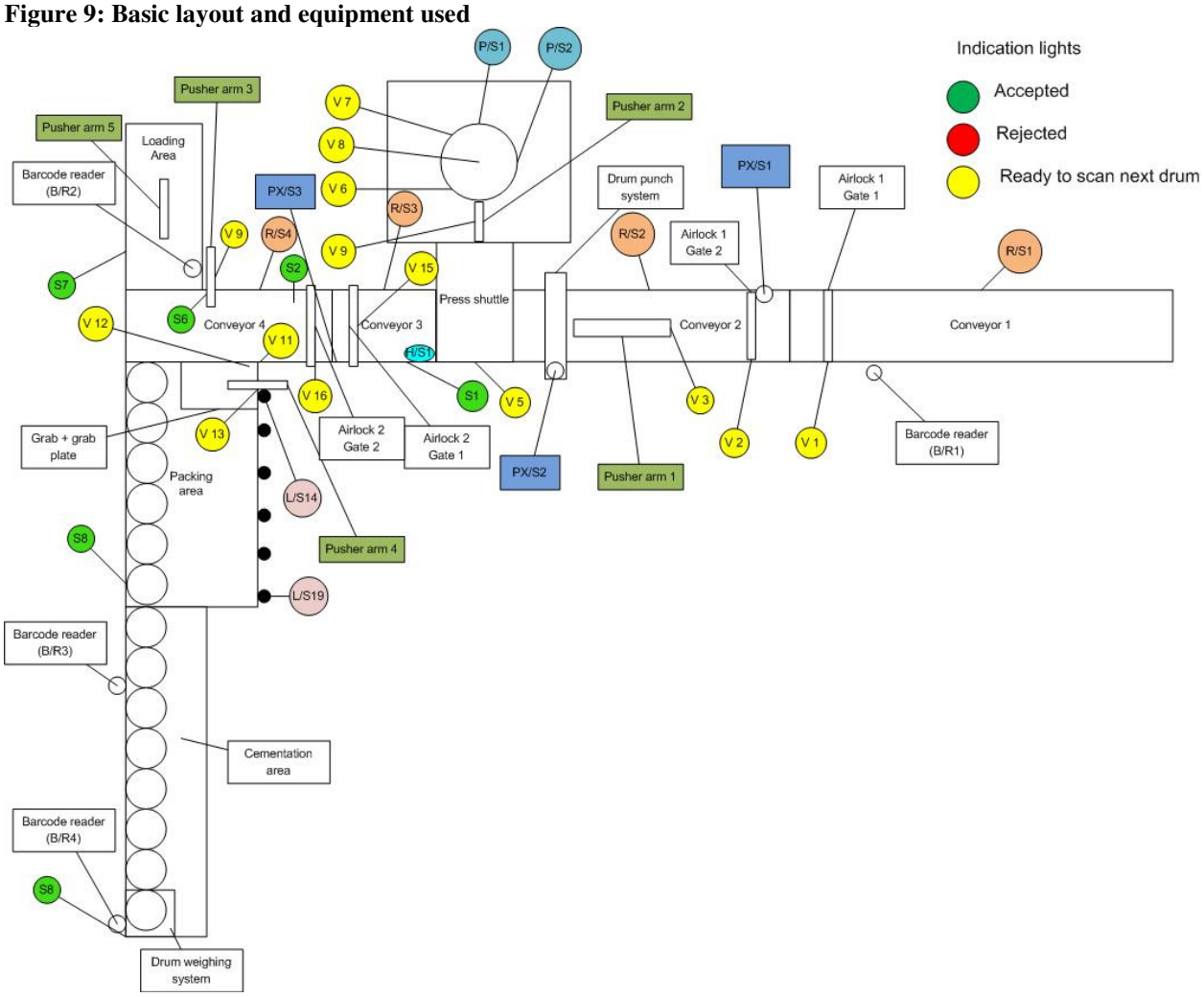
1. All of the frames have been lowered and released into the drums; this must be confirmed by sensor 8.
2. Sensor 7 shows that an empty drum and frame is in place and the empty drum has been scanned by barcode reader 2 and the “ready” button at the loading area was pressed indicating that the operator is finished loading the empty drum and external frame.
3. The finished drum must be scanned out at barcode reader 4 and the external frame removed; this will be confirmed by sensor 9. Half filled un-cemented drums must be scanned out with bar code reader 3 and the external frame removed.
4. It should not be possible to scan a drum with the wrong barcode reader; the system must keep track of the drums and activate the right barcode reader to scan the drums.
5. The half filled drums scanned by barcode reader 3 must be marked as “unfilled” and must be re-entered into the system by loading then the same way as the empty drums at the loading area and scanning then with barcode reader 2. After scanning it for the second time at barcode reader 2 the drum must be put into sequence with all of its data on the data base.
6. The system must keep track of the content and the position of the drum in the system

In manual mode it is important that the airflow is sufficient. When the airflow is insufficient or the ventilation system fails the entire system must be put on hold.

7. Attachment

The following diagram shows the layout and components of the VRF.

Figure 9: Basic layout and equipment used



The following symbols are used in the diagram:

V*x*: Solenoid valve no. *x*	B/R*x*: Barcode reader no. *x*
R/S*x*: Relay switch no. *x*	PX/S*x*: Proximity switch no. *x*
P/S*x*: Pressure switch no. *x*	S*x*: Sensor no. *x*
L/S*x*: Limit switch no. *x*	H/S*x*: Height sensor no. *x*

7.3.4 Specification for Waste Water Traceability (NLM-SPEC-004):

1. Purpose:

The purpose of this Specification is to specify the programming requirements for the waste water data tracking and storage system at the VRF. The main purpose is to aid the programmers of the data base and the PLC to comply with the requirements.

2. Scope

This document specifies the format and type of data that must be stored in the data base of the VRF in order to comply with the Procedure for Identification and Traceability (NLM-PROC-022). Data relating to the material flow through the VRF and the final product leaving it must be stored.

3. References:

1. NLM-PROC-022: Procedure for Identification and Traceability.
2. NLM-PROC-002: Procedure for the Control of Records.
3. NLM-PD-001: Process Description for Waste Water Handling System.

4. Definitions and abbreviations:

4.1 Definitions:

Waste Water: The water escaping from the drum being pressed, this water may be contaminated with oil and uranium-235.

4.2 Abbreviations:

VRF: Volume Reduction Facility.
PLC: Programmable Logic Controller.
NLM: Nuclear Liabilities Management Department.
QMS: Quality Management System.
Bq: Becquerel.

5. Responsibilities:

The programmers of the PLC are responsible for the programming of the PLC and data base to comply with this Specification. Management and the data base users must ensure that it functions correctly.

6. Work Instruction:

According to the Procedure for Identification and Traceability (NLM-PROC-022) it is important that all waste should be traceable. For more information on the logic governing the Waste Water System see the following: Process Description for Waste Water Handling System (NLM-PD-001). The following data should be stored in the data base and made available in report format.

Tank number: e.g. 1, 2,…,5
Volume (Litres):
Percentage volume usage:
Total Uranium-235 content (grams):
Total Theoretical Uranium-235 content (grams):
Number of uranium-235 tests performed:

Test number	Test unique ID number	Total Uraium-235 (g)	Difference between tests
1		X	0
2		Y	= Y-X

Percentage Uranium-235 usage: (Based on theoretical value).
Inlet valve status: “open” or “closed”.
Outlet valve status: “open” or “closed”.
Tank “full” confirmation: “Volume” or “Uranium”.
Time and date of Report generation: yyyy/mm/dd hh/mm

7. Records

See NLM-PROC-022: Procedure for Identification and Traceability, section 6 or NLM-PROC-002: Procedure for the Control of Records, section 7.