EXAMPLES OF IN-SERVICE INSPECTIONS AND A TYPICAL MAINTENANCE SCHEDULE FOR A LOW-POWER RESEARCH REACTOR

Learning Objectives

1. Understand the concept of failure rate and the postive effects a routine preventative maintenace and inspection program has on the failure rate or lifetime of facility equipment

2. Become familiar wtih various non-standard inspection or maintenance tools not considered in the original facility design that may be required as the facility ages.

3. Develop a facility maintenance program using the example maintenace documentation as guidance.

Objectives of Training Module

At the end of 2003 there were 273 research reactors in operation worldwide, about 87% of them are more than 20 years old and 66% are more than 30 years old. Of these 273 research reactors, 205 have a power level below 5 MW and are considered as low power research reactors. This limit is, however, arbitrary and other classifications according to reactor power do exist (i.e. < 2 MW is Low Power in the USA). As these facilities age, equipment or components may begin to fail more frequently as they reach or exceed their original, expected lifetime. Many facility Safety Analysis Reports and procedures as originally written do not cover aspects of plant age. Hence, unanticipated problems caused by historically poor maintenance or slow corrosion rate processes can cause rapid and catastrophic failure modes. A good example of this occurred in 2004 at a nuclear power plant in Japan. This particular nuclear facility had a non-nuclear system steam pipe that had not been on a preventative maintenance and inspection program. The steam pipe unexpectedly ruptured, killing four people. This particular pipe had not been inspected for 28 years and failed due to corrosion.

It is obvious that careful maintenance and periodic in-service inspections of the research reactor components have a positive influence on the technical state of the reactor and may extend its lifetime considerably. Reactor facility life extension is best accomplished by establishing and complete maintenance program at an early stage in the facility's operation. However, high quality routine maintenance of reactor safety systems and operation within the established technical specifications is also essential to ensure the safety of the reactor and the public.

All operating reactor facilities are expected, by technical specifications, to have some form of preventative or corrective maintenance schedule. This training module may be used to extend the existing maintenance program to other, essential or non-essential facility systems. It may also provide guidance to those facilities that require an improved maintenance program.

Without question, all facilities must establish and follow some level of quality assurance and quality control with regard to facility maintenance. These maintenance programs may consist of

- following written, established and approved procedures
- establishing and following a periodic preventative maintenance program
- establishing and following procedures for upgrades or repairs of the facility equipment that include a review of the repair to insure the facility remains as described in the final safety analysis report or the changes do not constitute a reduction in the original safety analysis or margins
- an audit or review system to routinely evaluate if the above items are being performed

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1. Introduction

In-service inspection methods for low-power research reactors are described in this module. Two practical examples of an in-service inspection and maintenance task at a TRIGA reactor and at a MTR reactor are given, and a typical maintenance schedule is presented in Annex 1. The inspection methods and the maintenance schedule are based on 42 years of operation and maintenance experience of a typical 250 kW TRIGA Mark-II reactor. Although this experience is related to a TRIGA reactor, most of the ISI methods and a large part of the maintenance schedule can be applied with minor changes to other types of low power research reactors such as ARGONAUT, SLOWPOKE, and MNSR type reactors.

The useful lifetime and the safe operation of a research reactor depends on two main criteria which are

1. Regular maintenance of all reactor components and systems,
2. Periodic in-service inspection (ISI) using various non destructive testing (NDT) methods.

For the maintenance program of a research reactor, a maintenance schedule has to be established which lists all systems and components necessary for a safe reactor operation. These are, however, not only the direct related safety related systems and components but also auxiliary systems and components which may have an indirect effect on the safety systems or the safety of the facility. The frequency of maintenance depends on the importance of the components and also on operational experience but it will usually be at least once a year. More frequent inspections should be considered for components that show an increasing deterioration rate, require frequent corrective maintenance or are operating significantly pass their original expected lifetime.

In-service inspection (ISI) will be carried out with more sophisticated equipment using various methods described in chapter 3. During this ISI, one component is investigated in detail; usually an inspection report is prepared both for the operation license holder and, in many cases, also for the regulatory body. The ISI methods may vary from simple visual inspections and measurements to very sophisticated and expensive NDT inspections. The reactor type and its power level should be taken into consideration when selecting the appropriate inspection method. Typical examples of instances requiring more sophisticated inspections are the visual inspection of the reactor tank, reflector or the inspection of welds in the primary piping system by NDT methods.

The responsibility for in-service inspections is, in many cases, with the staff of the reactor operation group. Experiences with a 250 kW TRIGA reactor has shown that the manpower involved for a simple monthly ISI is about 2 man-days but a complete yearly ISI may be in the range of 14 man-days [1-6]. The number of safety systems and fuel elements requiring inspection at facilities up to 1 MW are only marginally larger so the maintenance periods are similar to the 250 kW facilities. Larger, high power reactor facilities may have more systems requiring routine maintenance but often their larger staff sizes will compensate.

2. Reliability and Maintainability of Research Reactors

2.1 General Considerations

The development of a maintenance and in-service inspection schedule for a complex technical system must be based both upon certain theoretical considerations such as reliability of components, failure rates and upon practical past experience with components to be maintained. The evaluation of the facility needs may be quite complicated with several computerized databases generated. However, a facility may adequately evaluate the system components by maintaining a good written record of repairs and modification to all equipment in the facility. The procedures given below may be used by the facility over the lifetime of a component

2.1.1 Theoretical Considerations

Ideally, failure data used for reliability analyses should be based on facility specific data. However, the availability of accurate facility specific data requires the expenditure of considerable resources to develop and maintain an extensive database. The collection of database source information from the field, i.e. from reactor maintenance and/or operation reports, requires a systematic approach and ongoing commitment, if the information is to be processed efficiently and if it is to be kept up to date. In addition to the need for operational and maintenance staff to provide the raw data input, a software system and analytical personnel to process the raw data are also required. Data processing primarily produces component reliability parameter statistics and trend analysis data. The reliability parameter data is often formatted so that information can interface directly with Probabilistic Safety Analysis (PSA) studies. For example, component failure rate data may be linked to a PSA specific basic event labelling format. The use of generic data by themselves will not provide an adequate data source to aid in a trend analysis of facility specific system equipment. However, generic data can still indicate whether there may be facility specific features or facility specific equipment problems that may be considerably different from that which might be predicted from international generic sources of other research reactors.

Component reliability is a function of its design, use and maintenance. Components designed for specific research reactor application (especially safety related) are usually highly reliable and should be maintained as such during their lifetime. The reliability data, however, often show variations which are related to operating conditions and practices, component application maintenance and testing practices. A brief discussion of the influence of each of these is given below.

Operating conditions and practices

A facility's operating conditions and practices may greatly influence component reliability. Some of the factors are:

- operating mode,
- operating time and demands,
- operating environment.

The operating mode has been recognized as influencing equipment reliability, especially on active components (such as pumps). Some data sources provide separate data for running, alternating and standby categories. In an IAEA survey [7] variations of more than two orders of magnitude have been documented for failure to run of motor operated pumps, in comparing between alternating pumps, running pumps and pumps where no mode has been specified. This finding supports the view that failure data for similar equipment having differing operating modes should be kept separate.

A component's failure to start may be caused by a demand related stress (e.g. vibration), or stress in standby (e.g. corrosion) or a combination of both. Most data sources disregard these differences and provide data on failure to start either as demand related or time related. When time related data are provided, the failure rate denomination is usually calendar time, or sometimes plant operating time. Since similar components at a different location may have a substantially different test interval, the actual number of demands in a period may vary, which in turn may greatly influence the failure rate. Some data collection systems also systematically collect information on the number of demands; in others the number of demands is estimated on the basis of testing demands owing to the costs of collecting the information.

Operating conditions may also influence component reliability. Examples of this would be ambient temperature, humidity, chemical control, radiation fields and vibration.

Design and application

Design and application of a component will have an important influence on reliability. The application of the component will determine the operating mode and environment. Variation due to these causes has been discussed in previous sections.

Environmental conditions

In general, the failure rate of equipment depends on the environmental conditions. Therefore, these circumstances should ideally be taken into consideration in all data acquisition activities. However, few data bases provide the environmental application factors needed to do this and they are generally only available for electrical and electronic components [8].

The environmental application factor is a multiplicative constant used to modify a failure rate to incorporate the effects of other normal and abnormal environmental operating conditions.

Generic abnormal environmental conditions are:

(mechanical):	impact, vibration, high pressure, stress, grit, moisture, ...
(thermal):	over temperature, freezing, humidity, ...
(electrical):	electromagnetic interference, contact with conducting medium, power surge voltage or current, short circuit, ...
(radiation):	radiation damage, insulation failures, gamma heating, neutron activation, ...
(chemical):	acidic corrosion, oxidation, chemical reactions, poisonous gases, ...
(human interaction):	students in the control room, ...
(others):	missile hazards, explosion, ...

Maintenance and testing practices

Significant plant to plant variations for otherwise identical components can be identified. These variations are most probably caused by facility specific maintenance and testing differences. The influence of the testing interval and practice has been extensively investigated. The testing interval has an influence on the failure rate, but it is strongly related to the component type. The testing interval has greater influence on components where standby stresses dominate failure probability (usually motor operated valves) and lower on components with higher demand stresses (such as diesel generators or compressors).

In order to compare reliability data from different facilities for similar components it is very important that all data are based on common definitions. A set of definitions also used within IAEA documents (i.e. [7,8]) is given below.

Definitions related to the calculation of reliability parameters

Failure rate

The failure rate is a numerical value which represents the probability of specified failures of a component per time unit. The all modes failure rate of a component is an aggregate of failure rates summed over relevant failure modes.
The failure rate λ(t) of a system, subsystem or component is defined as

□

$$\lambda(t) = \frac{f(t)}{1 - F(t)},$$

where

f(t) ...... probability density for a failure of the device
1-F(t)... probability that the device did not fail up to the time t.

For many devices, the behaviour of λ(t) follows the classic bathtub curve (Figure 1):

1. Early in life, the failure rate for most devices is high because of "break-in failures" or failures arising due to poor quality assurance during manufacturing or installation.
2. During the middle of lifetime, failures occur at a rather uniform rate corresponding to random failures.
3. Late in life, λ(t) begins to increase because of "wear-out failures" caused by equipment aging.

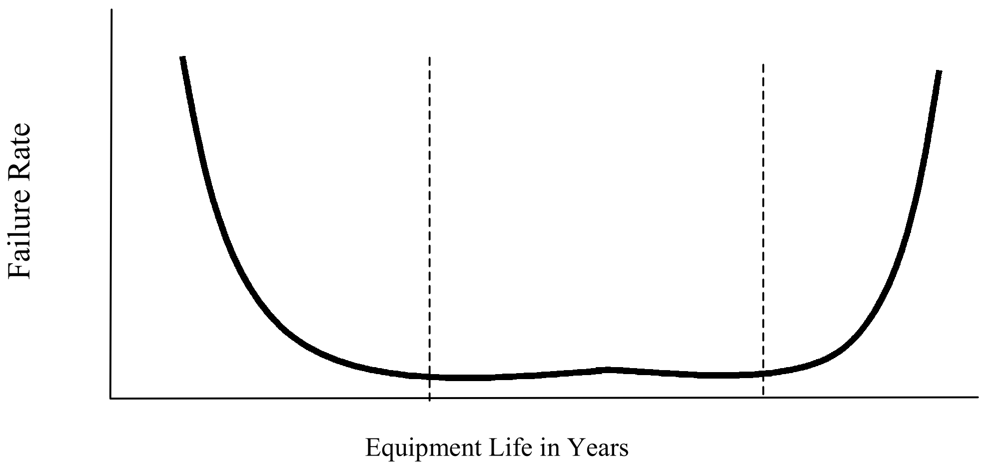

Figure 1. Classic “Bathtub” Reliability Curve

Time related failure rates

Two time related failure rates are defined:

- operating failure rate,
- standby failure rate.

The failure rate for continuously operated equipment (operating failure rate) is the expected number of failures of a given type in a given time interval (failures per hour, per year) - while the equipment is continuously in use.

Examples of failure rates of continuously operated components:

(electronic):	capacitor short circuit failures per million operating hours while under nominal voltage,
(sensors):	self-powered neutron detector degraded current output failure per thousand full power days.

The standby failure rate is the expected number of failures per time unit for those components which are normally dormant or in a standby state until tested or required to operate. Data representing standby failure rates is often not available in practice.

Failure on demand

Failures on demand is relevant to failures occurring on periodically or cyclically operated equipment. Failure on demand is the expected number of failures of a given type during a given number of operating cycles on demand when required to start, change state, or function.

Example of failure rates of demand operated components:

(electromechanical): relay contact failure per million switching cycles.

Operating time

The operating time is the accumulated time period during which an item, component or a system performs its intended function within specified limits.

Standby time

The standby time is the accumulated time period during which an item, a component or a system performs its intended function as standby equipment.

Outage time

The outage time is the time when equipment is not available for its specified service due to failure or maintenance. Outage times can be divided into three categories: out of service, restoration and repair.

Out of service time

The out of service time is the time required to identify the failure, analyze it, obtain spare parts, repair, and return the equipment to service, including planned delays.

Restoration time

The restoration time is the time period from the moment the failure is revealed to full restoration to operable state. It is the same as out of service time except that planned delays are excluded.

Repair time

The repair time is the time from when the failure is revealed, and includes the time to analyze the failure, prepare for repair, repair, test, qualify, and return the equipment to service. The repair time is, therefore, the time necessary to repair the equipment and restore it to operation or standby (this excludes all planned delays and waiting for spare parts and tools). The repair time is the same as the out of service time except for spare part waiting.

Active repair time

The active repair time is the time which is actually spent for the repair of an equipment.

Maintenance time

The maintenance time is defined as the time required to plan, administrate, and prepare for test or inspection, test or inspect, and return the component back to service.

Active maintenance time

The active maintenance time is the time spent for the maintenance (test, inspection, ...) itself.

2.1.2 Practical Experience

First hand practical experience with the reliability of a given component originates from one's own facility and observant operators. Therefore, it is very important to maintain an accurate documentation on all experience gained during the history of a given component. A standardized format is highly recommended, i.e. Event Record (Annex 1) where all necessary data of a component failure are concentrated. If other facilities use the same component, an exchange of information between the operators is relatively easy. Due to the relatively few research reactors in the world, compilation of failure data is slow and the data is often limited or sparse. This makes is more difficult to calculate meaningful average failure rates or mean time between failures (MTBF). Another source of failure rate information are data banks which are established by various groups [9,10] but which might be difficult to access in many cases due to costs and restriction. Failure rates for various components have been calculated based on the component failure data collection system used at the Atominstitut der Österreichischen Universitäten since 1988 [11], and are listed in Annex 2. The inspection and maintenance frequencies for particular components are reflected in these failure rate values.

To establish a maintenance schedule for a low power research reactor it is necessary to define all systems which are necessary for a safe reactor operation following the license of the regulatory body. Typical systems to be maintained regularly are, i.e. the

- reactor tank and shielding structure
- reactor safety system
- reactor cooling system.

Once the systems have been defined each system has to be broken down into sub-systems or components, such as

- reactor core
- nuclear channels
- primary pump.

Each of these sub-systems or individual components have to be maintained, inspected or recalibrated in different time intervals which may be

- once a month (1xm)
- four times a year (4xy)
- two times a year (2xy)

Other intervals, ranging from daily checks to once a year, are possible. After having defined the frequency of maintenance, it is necessary to define the type of maintenance work to be carried out. In many cases this would be just a visual check, it could be a test run (i.e. for a pump), it could be readings of a scale (i.e. differential pressure across filters) or it could be a complete recalibration using signal generators (i.e. for the nuclear safety channels).

Finally, for each maintenance task to be carried out it has to be defined who will carry out this task. Usually it is the reactor staff who has the best operating experience of all the systems and components. However, in some cases the reactor staff is either not qualified to carry out maintenance (i.e. reactor crane, emergency diesel generators) or is not authorized to do the work without supervision or control of an independent expert. In some cases the independent expert is appointed by and acts on behalf of the regulatory body.

It is now possible to establish a maintenance schedule for a low power research reactor. As an example, such a schedule is given in Annex 3 for a typical 250 kW TRIGA Mark-II reactor. Twelve systems, each one with several sub-systems or components have been identified. These sub-systems are maintained in periodic intervals by different personnel according to their qualifications. For each sub-system a maintenance check list has been developed which is the basis for the maintenance work and which has to be completed. Long term experience has shown that a typical monthly maintenance period following the schedule requires about 2 man-days while an annual maintenance requires about 14 man-days of labour.

3. In-Service Inspection Equipment for a Low Power Research Reactor

At low power research reactors, in-service inspection (ISI) is usually carried out on components which are not directly accessible due to a high radiation level; such as the reactor tank, the core structure, fuel elements, etc. For these ISI inspections tools and methods have been developed based on experience in non-nuclear applications and modified or adapted to the nuclear environment. Some ISI methods that are used at some facilities are:

- visual inspections using
  - underwater telescope
  - endoscopes
  - underwater cameras using radiation hardened systems
- replica method

Other non-radioactive components may be inspected with methods used in conventional industries. The following methods and tools are typically used in a TRIGA Mark-II reactor but may easily be adapted for any other low or even high-power research reactor.

3.1 Nuclear Underwater Telescope

Nuclear underwater telescopes are high resolution devices (resolution 0.1 mm) with continuously variable magnification which allow remote underwater viewing of the reactor tank and core components such as fuel elements, core support structures, etc. both vertically and also horizontally. Such a telescope penetrates the water level while the water fills up the periscope tube, providing complete radiation shielding for the viewer. Since no radiation-sensitive optical element is built in at the lower end of the unit, diminishing of optical image quality due to radiation induced decolourization, reflection losses and distortions are eliminated. In order to facilitate acquisition of the object and detail observation, the magnification can be continuously controlled. Photo and video recording is also possible for some equipment types.

3.2 Endoscope (Fig. 2)

For the inspection of the inner surface of neutron beam tubes or internal core structures, a modular endoscope has found to give excellent results. A typical system consists of a set of ocular and rigid optical extension pieces of 1 meter (diameter 18 mm) length each. These modules can be coupled together to the desired length up to several meters. The front end of the endoscope houses the objective together with an integrated 100 W/12 V lamp powered by a transformer. Various objectives with forward-, 45°-forward-, 90° and 45°-backward viewing angles are available. Photos or videotapes can also be taken through the endoscope for permanent record. In case of gamma radiation streaming out of the beam tube, the ocular can also be mounted at an angle of 90 and viewing can be performed from outside the radiation field. Some systems have flexible sections that may turn as needed to reach tight areas.

3.3 Underwater Camera

Some facilities may use specially designed underwater video cameras or place a video camera inside a water-tight housing to perform routine or non-routine ISI. Often, a set of underwater lamps is necessary to illuminate the object deep inside the reactor pool. The output from the camera may be sent to a recorder or video monitor for the inspection.

3.4 Replica Material (Fig. 3)

To determine the dimension of a corrosion spot (or i.e. the surface structure of small activated items in the core region) a two component silicon-based material (similar to that used by dentists) has been found very useful. In the present case, a plastic cap of a powder bottle was mounted at the end of an aluminium rod and filled with the mixed silicon paste. This material remains soft or pliable for about 3 minutes in ambient air. Then the rod was lowered into the reactor tank (water temperature about 30 °C) and immediately pressed on the corrosion crater for 4 to 5 minutes. Within this period, the silicon paste hardens completely and the system can be removed from the reactor tank. The hardened material gives an exact replica of the corrosion crater for further investigation.

Operators must control the type of materials that enter the reactor tank and not all "impression clay" are chemically compatible with materials in the reactor tank or could increase the pool water conductivity. Some materials may have a high neutron absorption cross section and become radiation hazards when the reactor is restarted. The chemicals in dental plaster or similar molding materials are likely acceptable because they are used in people's mouths. However, materials coming in contact with fuel cladding (especially aluminium) must be careful evaluated to prevent the inspection from causing actually causing a failure.

3.5 Tank Cleaning Pump with Integrated Filters (Fig. 4)

Dirt or debris in the reactor tank may cause cloudiness or potentially cause thermal and hydraulic problems within the reactor fuel. The most effective manner of keeping the reactor tank clean is to eliminate the source by covering the pool with a transparent cover and remaining diligent when working above the pool to not drop materials into the water. Most research reactors have some system of purifying the primary coolant. These systems are generally not designed to remove relatively large debris that sinks quickly to the pool bottom. A conventional, plastic pump used for cleaning swimming-pools has been found useful to clean the tank bottom from small debris. This system is equipped with a coarse filter to collect larger objects (such as screws) and twelve units of candle-type fine filters for collecting small particles. One advantage is that these fine filters are reusable, they may be washed and reinstalled into the pump. Some reactor facilities will perform a pool cleaning annually if the equipment is routinely available.

3.6 Underwater Jet to Remove Deposits (Fig. 5)

One tool that has been found very useful to clean remote areas in reactor tanks from debris is a strong water jet (160 bars) produced by a portable compressor together with different types of jet nozzles. The material stirred up from the tank bottom or any deposits removed from the tank wall will ultimately by collected in the filters of the water purification system but it would be preferred to remove the material quickly with a local vacuuming system as described in section 3.4. Some of these jet nozzles are small enough that they can be inserted through a hole of the top grid plate right into the core volume and can be used to clean the core of debris or corrosion deposits. Operators must be cautioned that high pressure water jets can cause damage of sensitive reactor components and should not direct the jet directly at fuel elements.

3.7 High Intensity Underwater Lights

Miniature, strong underwater lamps are necessary to inspect remote areas in reactor tanks. Generally, this is done in conjunction with the use of an underwater camera or a pair of binoculars used at the pool surface. This 24 V DC lamp (13 cm length, 6 cm diameter) has a power of 250 Watts and can only be operated under water. The lamp, mounted on modular 1 m aluminium tubes that are coupled together to the desired length, can be directed to any desired position in the reactor tank for optimal viewing. Another useful system for illuminating objects underwater has been the high intensity directional lamp used from the pool surface. These 12 VDC lamps are usually extremely bright (1,000,000 candle-power) and focused in a very tight beam of perhaps 6-10 cm in diameter.

3.8 Rotating Underwater Brush

In many areas of a reactor tank, small surface spots of corrosion may be seen during inspections. If desired, these spots can be brushed away using an underwater rotating brush connected to a standard drilling machine by an extension shaft. Practically all areas inside the reactor tank can be cleaned using various types of brushes (radial, pot-type). As with in cleaning equipment around the reactor, operators must be extremely cautious to prevent damaging the object they are attempting to clean.

4. Practical Example of an In-Service Inspection Carried Out at a TRIGA Reactor and at a MTR Reactor

The TRIGA facility at the Atominstitut Wien (in Vienna, Austria) was requested to provide equipment for detailed inspection of core internals and remote cleaning of the pools of several research reactor facilities. The following equipment was provided:

- an underwater endoscope with 6.5 m length and three viewing angles (0°, 45° forward, 90°)
- a high pressure water jet to stir up debris from tank internals
- a circulation pump with coarse and fine filters
- a pick-up tool for small pieces
- photo and video equipment

4.1 Typical Inspection Program at Small Reactor Facility

After setting up all equipment, the tank inspection usually starts in one sector of the tank and continues clockwise through the other sectors. The tank bottom, the reflector, the respective beam tubes and their connection to the tank are optically inspected by the endoscope in each sector. Usually, many particles of different sizes are found with the larger particles or objects (e.g. bolts and screws) are removed with the pick-up tool developed at the Atominstitut. The optical inspection usually lasts for two days followed by cleaning of the tank bottom with the circulation pump.

After another visual check, the high pressure water jet is used to stir up all deposits and flush the tank surfaces. This task takes about half a day and this causes the tank water to become very cloudy and semi-transparent due to suspended particles. At the same time, the circulation pump filters out these particles. The primary and purification loop are kept operating overnight to filter the water and to remove the suspended particles. Normally, by the following day, all tank surfaces and the tank water are clean and no deposits are found at the tank bottom (Figs. 6 to 8).

4.2 Inspection of a 250 kW TRIGA type reactor

In one particular case it was found that the central thimble (CT) showed a deformation below the top grid plate and could not be moved vertically more than 10 cm. This was clearly seen in a video inspection using an underwater endoscope. The Reactor Safety Committee convened and reviewed and approved the removal of the top grid plate. All three rod drive mechanisms had to be disconnected and removed from the reactor bridge and the reactor core unloaded before removing the top grid plat. When the top grid plate was unbolted and removed the operators were able to cut the CT about 30 cm above the grid plate. The CT was then removed downwards through the center hole. The dose rate from the grid plate when pulled up within 30 cm below pool water level and measured at bridge level was about 0.5 mSv/h.

During reinstallation of the grid plate, it was obvious that the guide tube for the regulating rod was not firmly fixed into the lower grid plate. Optical viewing with the endoscope showed a 5 mm gap between the bottom of the guide tube and the lower grid plate. With the 90° endoscope, the bottom area of the lower grid plate was inspected and the locking device was found not fixed in place and probably damaged. Therefore, the whole regulating rod guide tube was removed from the tank and inspected behind an appropriate shielding.The dose rate from the guide tube was about 0.1 Sv/h . It was found by direct inspection, that the guide tube locking wire did not penetrate the full length into its position resulting in a very loose and unstable connection between guide tube and lower grid plate. The guide tube was returned into its position and the locking screw was tightened remotely from the tank top. The guide tube connection was inspected optically with the endoscope and documented by video to verify the position. The full task required approximately 30 Man-hrs to complete. After this task, the reactor tank and all the tank internals were inspected and found to be excellent condition, no major corrosion spots were found.

4.3 Inspection and repair at a 4 MW MTR reactor

A small crack in the primary circuit tubing of a 4 MW MTR reactor made an optical inspection and repair necessary. Using an endoscope mounted on a platform with reduced pool water level, the position of the crack was identified and a stainless steel sleeve was inserted to plug the crack. The correct positioning of the sleeve was inspected and verified and a pressure test was successfully carried out following the equipment repairs.

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FIGURES AND TABLES

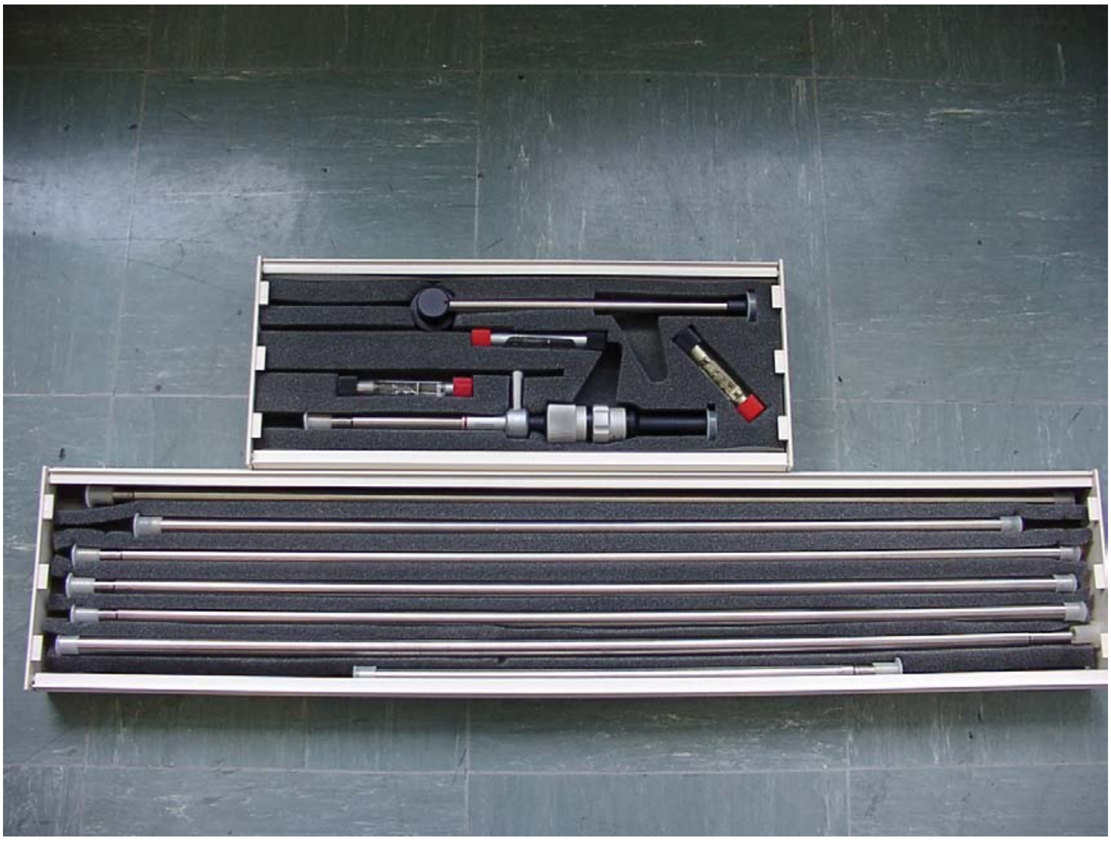

Figure 2: Underwater endosope

Figure 3: Replica material to determine the dimension of a corrosion spot

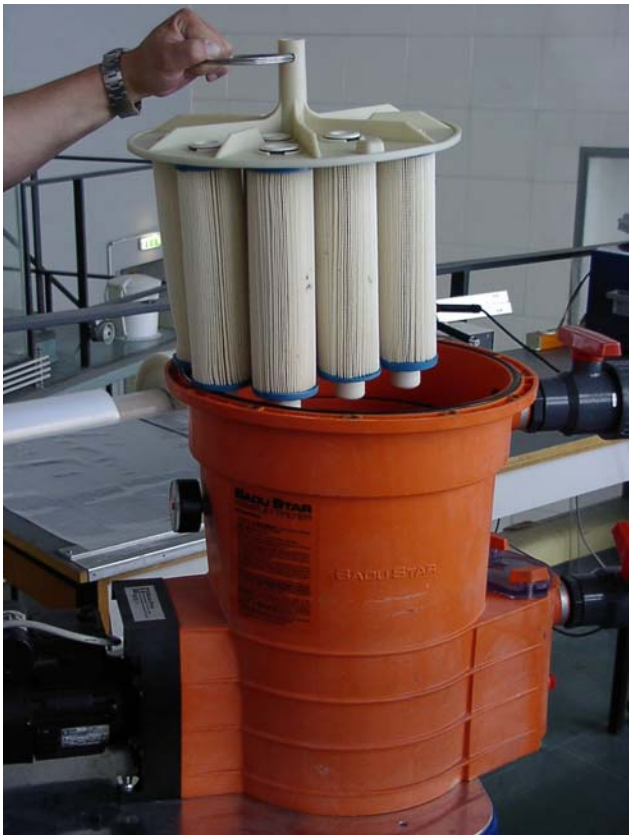

Fig. 4: Tank cleaning pump with integrated filters

Fig.5: Underwater jet to remove deposits

Fig. 6: Pick-up tool

Fig. 7: Collected pieces with the pick-up tool

Fig. 8: Collected pieces in the coarse filter

ANNEX 1

Event Record to be Used for Data Collection at the TRIGA Wien

EVENT RECORD

Event Code(s) Date:
Time:

Facility: TRIGA Mark II Vienna

Reactor power level at event:

System: Reactor safety & control system
Reactor core & fuel
Confinement & ventilation system
Electrical & emergency supply system
Radiation protection system
Primary coolant circuit
Secondary coolant circuit
Purification circuit
Radioactive waste treatment system
Experimental facilities
Others

Main component:

Sub-component:
Model type:
Manufacturer:
Date of first installation:
Frequency of inspection:
Last inspection date:
Average # of demands per year:

Failure mode:
Stand-by systems: - fails to start on demand
- false start (e.g. spurious trip)
Continuously operating system:
- fails to run (pump, circulate ...)
- fails to stop (trip, close ...)
Both system types: - fails to operate as specified
(e.g. shift in calibration, leakage ...)

Type of failure:	Mechanical
	Electrical or electronically
	Chemical
	Human error
	Calibration failure
	Common mode
	Others (like maintenance, wear)

Failure reason:

Failure detection during

	routine operation on demand
	routine operation self-annunciating
	shut down
	inspection & service
	others:

Any present alarm level triggered:

yes	no

alarm level setting:
maximum alarm
level reached:

Consequences:	Reactor shut down
	Activity release
	Radiation exposure
	Contamination
	Chemical hazard
	Fire
	Others:
	like temporary loss of redundancy)

Environmental conditions at failed component:

	Normal value	Event value
Temperature	ºC	ºC
Rel. humidity	%	%
Radiation	Gy	Gy
Others		

Suggestion for improvement:

ANNEX 2

Component failure rates evaluated at the TRIGA Mark-II reactor Wien

Reactor	Components	Cumulative calendar time	Cumulative operating time	Demands	Failure modes		Failures	Failure rate	Failure probability	90% Confidence bounds	
code	#	Mill. hours	Mill. hours	#	crit	degr	#	1E-6/h	1/demand	0,05	0,95
AT	3	0,297			F		2	6,73	-	1,20	15,97
AT	1	0,099			F		2	20,20	-	3,59	47,92
AT	12	1,190			F		2	1,68	-	0,30	3,99
AT	1	0,031			I		1	31,93	-	1,64	95,65
AT	1	0,027			F		1	36,49	-	1,87	109,30
AT	1	0,009			F		1	115,42	-	5,92	345,77
AT	1	0,009				B	1	115,10	-	5,90	344,81
AT	25	2,677			F		3	1,12	-	0,31	2,35
AT	4	0,397			F		3	7,56	-	2,06	15,86
AT	3	0,096				B	2	20,78	-	3,69	49,29
AT	16	0,491			F		14	28,52	-	17,24	42,11
AT	4	0,104			I		3	28,89	-	7,87	60,63
AT	1	0,140			F		1	7,13	-	0,37	21,36
AT	2	0,198			F		1	5,05	-	0,26	15,13
AT	6	0,063			F		1	15,84	-	0,81	47,44
AT	3	0,297			F		3	10,10	-	2,75	21,20
AT	3	0,297			Y		1	3,37	-	0,17	10,09
AT	10	0,992			F		2	2,02	-	0,36	4,78
AT	15	1,487			F		40	26,90	-	20,31	34,26
AT	1	0,069			F		1	14,52	-	0,74	43,51
AT	20	1,983			F		10	5,04	-	2,74	7,92
AT	1	0,062			F		1	16,23	-	0,83	48,61
AT	2	0,198				B	2	10,10	-	1,79	23,96
AT	33	1,654			F		22	13,30	-	9,01	18,28

Reactor	Components	Cumulative calendar time	Cumulative operating time	Demands	Failure modes	Failures	Failure rate	Failure probability	90% Confidence bounds	Reactor	Components
code	#	Mill. hours	Mill. hours	#	crit	degr	#	1E-6/h	1/demand	0,05	0,95
AT	5	0,060			K		5	83,70	-	32,98	153,23
AT	1	0,021			F		1	48,51	-	2,49	145,31
AT	1	0,009			K		1	106,29	-	5,45	318,42
AT	2	0,061				B	2	32,91	-	5,85	78,07
AT	2	0,025			F		2	78,76	-	14,00	186,83
AT	3	0,032			K		3	94,84	-	25,85	199,03
AT	3	0,297			M		2	6,73	-	1,20	15,97
AT	2	0,034			M		2	58,89	-	10,46	139,69
AT	3	0,297			M		2	6,73	-	1,20	15,97
AT	1	0,126			F		1	7,94	-	0,41	23,78
AT	1	0,072			R		1	13,87	-	0,71	41,54
AT	1	0,099			F		1	10,10	-	0,52	30,26
AT	1	0,099			R		1	10,10	-	0,52	30,26
AT	1	0,099			F		1	10,10	-	0,52	30,26
AT	1	0,025			F		1	39,31	-	2,02	117,76
AT	7	0,433			F		2	4,61	-	0,82	10,94
AT	1	0,064			F		1	15,74	-	0,81	47,14
AT	1	0,099			E		2	20,20	-	3,59	47,92
AT	30	2,975			F		1	0,34	-	0,02	1,01
AT	1	0,099			X		2	20,20	-	3,59	47,92
AT	9	0,892			Y		1	1,12	-	0,06	3,36
AT	85	8,429			Y		4	0,47	-	0,16	0,92
AT	1	0,087				Y	1	11,55	-	0,59	34,61

ANNEX 3

Maintenance Schedule for a Low Power Research Reactor

CONTENT Page

1. EXPLANATION OF ABBREVIATIONS

1.1 Period of maintenance

m	once a month
4xy	four times a year
2xy	two times a year
y	once a year

1.2 Type of maintenance work

V	Visual inspection of the component
CL	Cleaning of the component either manually or by flushing with water
TR	Test run of the component (i.e. pump, ventilator) and acoustical control
Δp	Verifying the pressure difference (i.e. across water filter, air filter, ion exchange resin)
ON/OFF	On/off switch (i.e. of indicator lamps, control room light)
Ca	Calibration: Using a certified instrument (i.e. signal generator) to recalibrate a complete measuring channel (i.e. neutron channel)
S	Sample test: Using, i.e., a radiation source to test the performance of an area monitor
R	Records: Recording a value (i.e. consumption of cooling water, electricity)
St	Maintenance according to available national standards (i.e. crane, lifting device, emergency power supply)
T	Test: Activating a component and control of its function (i.e. movement of a control rod)
M	Measurement: For example, control of excess reactivity, dimensions of fuel elements, etc.

1.3 Responsibility of maintenance

IP Internal personnel of operating license holder (i.e. reactor staff, technicians employed with the license holder).

EP External personnel: Persons not employed by the license holder (i.e. outside companies hired and paid by the license holder).

- BM Building management: In some cases maintenance of buildings is carried out by a governmental building management division, it could also be IP or EP.
- IAEA International Atomic Energy Agency or any other international group carrying out safeguards inspection (i.e. EURATOM).
- EX Expert nominated by the national regulatory body to participate in selected maintenance work (i.e. recalibration of nuclear channels).

2. SYSTEMS TO BE INSPECTED

2.1 Reactor Building

	1	2a	2b	2c	3a	3b	3c
2.1.1	Roof	1xy	BM	V			
2.1.2	Windows	1xy	BM	V			
2.1.3	Foundations	1xy	BM	V			
2.1.4	Service door	1xm	IP	V			
2.1.5	empty						
2.1.6	Other doors to reactor	1xm	IP	V			
2.1.7	Lights in hall	2xy	IP	V			
2.1.8	Other lamps	1xm	IP	V			
2.1.9	Crane				2xy	EP	St
2.1.10	Chains				1xy	EP	St
2.1.11	Fuel storage pits	2xy	IP	V	1xy	IAEA	V

2.2 Ventilation System

	1	2a	2b	2c	3a	3b	3c
2.2.1	Reactor Hall Ventilation System	1xy	IP	TR			
2.2.2	Beam Tube Ventilation System	1xy	IP	TR			
2.2.3	Control Room Ventilation System	1xy	IP	TR			
2.2.4	Central Heating of Air Condition	1xy	IP	TR			
2.2.5	Inlet-, outlet filter	1xy	IP	Dp			
2.2.6	Blower, Valves	1xy	IP	TR			
2.2.7	Under pressure Reactor Hall	1xm	IP	Dp			
2.2.8	Ventilation flow	1xm	IP	M			
2.2.9	Inlet electro filter	1xm	IP	Cl			

2.3 Reactor Tank and Shielding Structure

	1	2a	2b	2c	3a	3b	3c
2.3.1	Tank, beam tubes thermal column	1xy	IP	V			
2.3.2	Mechanical structure of core	1xy	IP	V			
2.3.3	Moisture control between tank and concrete	2xy	IP	V			
2.3.4	Under water lamps	4xy	IP	V			
2.3.5	Condition of shielding concrete (cracks, paint)	1xm	IP	V			
2.3.6	Distillation plant for tank water addition	4xy	IP	M			
2.3.7	Reinspection and cleaning of the reactor tank	4xy	IP	Cl			

2.4 Reactor Core

	1	2a	2b	2c	3a	3b	3c
2.4.1	Fuel element position	4xy	IP	V	1xy	IAEA	V
2.4.2	Fuel dimensions control	1xy	IP	M			
2.4.3	Control rods (motors, micro switch)	1xm	IP	V, M, TR			
2.4.4	Control of excess reactivity	2xy	IP	M			
2.4.5	Rod calibration	2xy	IP	M			
2.4.6	Compressor for transient control rod	4xy	IP	TR, V			

2.5 Reactor Safety System

	1	2a	2b	2c	3a	3b	3c
2.5.1	Nuclear channels (power calibration)	1xy	IP	Ca	1xy	Ex	Ca
2.5.2	High voltage supply	1xy	IP	M	1xy	Ex	Ca
2.5.3	Rod drop time	1xy	IP	Ca	1xy	Ex	Ca
2.5.4	Neutron source	4xy	IP	M	1xy	Ex	Ca
2.5.5	Fuel temperature channels	1xy	IP	M	1xy	Ex	Ca
2.5.6	Water temperature channel	1xy	IP	Ca	1xy	Ex	Ca
2.5.7	Water level channels	1xy	IP	T	1xy	Ex	Ca
2.5.8	Indicator lamps	1xy	IP	V	1xy	Ex	Ca

2.6 Primary and Purification System

	1	2a	2b	2c	3a	3b	3c
2.6.1	Primary pump	1xm	IP	TR			
2.6.2	Purification pump	1xm	IP	TR			
2.6.3	Primary filter	1xm	IP	Dp			
2.6.4	Valves and sensor (tightness)	4xy	IP	V			
2.6.5	Flow indicator (primary, (purification, filters)	1xm	IP	M			
2.6.6	Conductivity meter	1xy	IP	Ca			
2.6.7	Temperature meter	1xy	IP	Ca			
2.6.8	Differential pressure across heat exchanger	1xy	IP	V			
2.6.9	pH-value	4xy	IP	M			
2.6.10	Pipes and valves to empty the reactor tank	1xy	IP	V			
2.6.11	Sump pump near heat exchanger	1xm 1xy	IP IP	TR Cl			

2.7 Secondary Cooling System

	1	2a	2b	2c	3a	3b	3c
2.7.1	Ground water well	1xy	IP	V			
2.7.2	Secondary pumps	4xy	IP	TR			
2.7.3	Exchange switch pump 1 to pump 2	4xy	IP	on/off			
2.7.4	Compressor for pressure increase system	4xy	IP	TR	1xy	EP	Cl
2.7.5	Motor valve	1xm	IP	V	1xy	EP	TR
2.7.6	Sand filter	1xy	IP	Cl			
2.7.7	All valves (tightness)	4xy	IP	V			
2.7.8	Sump pump of pressure increase system	4xy	IP	TR	1xy	EP	Cl
2.7.9	Water meter	1xm	IP	R			
2.7.10	Sump pump at Institute exit	4xy	IP	TR	1xy	EP	TR

2.8 Area Monitors, Off-gas Monitors, Water Activity Monitors

	1	2a	2b	2c	3a	3b	3c
2.8.1	Set-points of alarm limits	1xm	IP	S			
2.8.2	Control of instrument function with radioactive sample	1xm	IP	S	1xy	Ex	S
2.8.3	Portable dose rate meters	1xm 1xy	IP IP	S Ca			
2.8.4	Primary water activity (γ-spectroscopy)	1xm	IP	M			
2.8.5	Contamination wipe test reactor platform	1xm	IP	M			
2.8.6	Contamination control of off-gas detectors	1xy	IP	M			
2.8.7	Aerosol monitor reactor top	1xm 1xy	IP IP	S Ca			
2.8.8	Water activity monitor (purification loop)	1xm 1xy	IP IP	S Ca			
2.8.9	Water activity monitor (institute discharge)	1xm 1xy	IP IP	S Ca			
2.8.10	Data logger	1xm	IP	S			

2.9 Fuel Element Handling

	1	2a	2b	2c	3a	3b	3c
2.9.1	Fuel element handling tool	1xm	A	V			
2.9.2	Fuel transfer container	1xm	A	V	1xy	EP	St

2.10 Experimental Facilities

	1	2a	2b	2c	3a	3b	3c
2.10.1	Irradiation tubes (or Lazy Susan) Control of position, humidity, loading	4xy	IP	V, TR			
2.10.2	Central thimble	4xy	IP	V			
2.10.3	Thermal column (motor and switches)	4xy	IP	V, TR			
2.10.4	Pneumatic transfer system	4xy	IP	V, TR			
2.10.5	Beam tubes	2xy	IP	V			
2.10.6	Beam tube parts (doors, loading machine)	2xy	IP	V			
2.10.7	Experimental tank	1xy	IP	V			
2.10.8	Vacuum cleaner (function, location, spare parts)	4xy	IP	V			

2.11 Electricity and Emergency Supply

	1	2a	2b	2c	3a	3b	3c
2.11.1	Emergency diesel	1xm	IP	TR	1xy	Ex	St
2.11.2	Emergency batteries	1xm	IP	TR			
2.11.3	Emergency lights	1xm	IP	TR			
2.11.4	Uninterrupted power supply	1xm	IP	TR			
2.11.5	Emergency hand lamps	4xy	IP	on/off			

2.12 Security System

	1	2a	2b	2c	3a	3b	3c
2.12.1	Door surveillance	1xm	IP	V			
2.12.2	Intercom system	4xy	IP	TR			
2.12.3	Alarm system	1xm	IP	TR			
2.12.4	Telephone system	1xy	BM				
2.12.5	Security system	2xy	IP	T			
2.12.6	Fire extinguisher Service	1xm	IP	V	1xy	EP	
2.12.7	Keys and locks	1xm	IP	on/off			
2.12.8	Gate to compound and TV-surveillance	1xm	IP	V, TR	1xy	EP	
2.12.9	Emergency equipment	1xm	IP	V			
2.12.10	Internal alarms	1xm	IP	TR			
2.12.11	Emergency drill exercise	1xy	IP	TR			
2.12.12	On-duty officer control	4xy	IP	V			
2.12.13	Meeting of emergency Group	2xy	IP		Discussion		
2.12.14	Retraining of reactor operators	1xy	IP		Lecture, technical excursion		

3. Some examples of inspection forms

Some examples of inspection forms are presented in #3. These sheets cannot be standardized as they depend strongly on local conditions and they have to be prepared for each facility individually. For more complex systems as the primary cooling system or the ventilation system it is advisable to add a schematic diagram of the system where all components to be checked are numbered one by one and these numbers are contained in the inspection form.

2.3.1 TANK, BEAM TUBES, THERMAL COLUMN

Sheet:

Responsibility: IP

Inspection period: 1xy

Date: ....
DD MM YY

Visual inspection of tank:

Beam tube A

B

C

D

Thermal column

Neutron radio-
graphy facility

Tank bottom cleaned by pump on:

Remarks

Unterschrift
(Signature)

2.4.3 CONTROL RODS

Sheet:

Responsibility: IP   Inspection period: 1xm   Date: ....
DD MM YY

Rod position indicators:

up: R (reg. rod)   (down): R
T (shim rod)   T
I (transient rod   I

Time interval in [s] from down to up

R =
T =
I =
shock absorber of transient rod

Failure of indicator lamps at push buttons

R	T	I
↓	↓	↓
↑	↑	↑
⊥	⊥	M
T	T	↓
		M
Scram	Scram	↑

Pressure of transient rod at different locations

Tightness of shock absorber
oil leakage

---

control of magnets:

R
T

Zero-point for position indicators

R
T
I

Optical inspection of rod guide tubes in the core

R
T
I

Remarks

Unterschrift (Signature)

2.5.1a NUCLEAR CHANNELS
LINEARITY CHECK NMP-Ch

Date: ....
DD MM YY

Current in [A]	Position of Range Switch in [kW/W]	Instrument	Display Grafik-monitor	Display Status Window	Display Bar Graph
1.10^{-3}	250				
4.10^{-4}	250				
1.10^{-4}	250				
1.10^{-4}	25				
4.10^{-5}	25				
1.10^{-5}	25				
1.10^{-5}	2,5				
4.10^{-6}	2,5				
1.10^{-6}	2,5				
1.10^{-6}	0,25				
4.10^{-7}	0,25				
1.10^{-7}	0,25				
1.10^{-7}	25 W				
4.10^{-8}	25 W				
1.10^{-8}	25 W				
1.10^{-8}	2,5 W				
4.10^{-9}	2,5 W				
1.10^{-9}	2,5 W				
1.10^{-9}	250 mW				
4.10^{-10}	250 mW				
1.10^{-10}	250 mW				
1.10^{-10}	25 mW				
4.10^{-11}	25 mW				
1.10^{-11}	25 mW				
1.10^{-11}	2,5 mW				

Attention: Check immediately the reactor scram at 250 kW+10% ________________________________

2.5.1b NUCLEAR CHANNELS
CHECK OF THE NM-1000

Date: ....
DD MM YY

---

1. NM-1000 in Calibration state # 4 :
Push F5, F8, 4, ENTER in Microprocessorbox ☐
2. The following values should be displayed:
a) Push F1 → 10% (Microprocessorbox) ☐
b) LOG Bar Graph → 10% ☐
c) % Power Bar Graph → 10% ☐
d) Recorder → 10% ..... kW
e) at Graficmonitor
Log Bar → 10% ☐
Lin Bar → 25 kW ☐
% PWR → 10% ☐
f) Rod Withdrawal Prohibit
Status Window ☐
Warning Window ☐
Graficmonitor ☐
3. NM-1000 in Calibration state #5 :
Push F5, F8, 5, ENTER in Microprocessorbox ☐
4. The following values should be displayed:
a) Push F1 → 110% (Microprocessorbox) ☐
b) LOG Bar Graph ~ 100% ☐
c) % Power Bar Graph → 110% ☐
d) Recorder → 110% ☐
e) at Graficmonitor
Log Bar ~ 100% ☐
Lin Bar → 275 kW ..... kW
% PWR → 110% ☐
f) Rod Withdrawal Prohibit
Status Window ☐
Warning Window ☐
Graficmonitor ☐
g) NM-1000 Power-HI Scram in Scram Window ☐
h) NM-1000 Period Scram in Scram Window ☐
5. NM-1000 in operation state:
Push F5, F8, 0, ENTER ☐
6. Push ACK-button
7. Remove source from core ☐
8. In Warning Window Rod Withdrawal Prohibit
Yes should be announced
Rod removal not possible (only T and R) ☐
9. Source into Core ☐
10. Press ACK-button, Rod Withdrawal possible
Prohibit erased

Signature

2.5.3 ROD DROP TIME

Date: ....
DD MM YY

In DAC Drawer AC/DC connection as follows:

•	•	•	•
Summary-Scram triggered	Scram Transient R. ☐	Scram Shim Rod ☐	Scram Reg.Rod ☐

Rod-drop time [ms]

Rod position	Transient rod		Safety rod		Regulating rod	
	last year	this year	last year	this year	last year	this year
500						
400						
300						
200						
100						

Remarks:

Signature:

2.5.5 FUEL TEMPERATURE CHANNELS

Date: ....
DD MM YY

Thermocouple Identification	Fuel element Number	TC Position	Core position
1	5284 TC	o	C6
2	5284 TC	m	C6
3	8257 TC	m	E13
4	5284 TC	u	C6
5	8257 TC	o	E13
6	8257 TC	u	E13

Used instrument GA CL-300-1000 C in DAC-drawer backside

Calibration:	Display at graphic monitor [°C]			Display at Status Window [°C]					
	1	2	3	1	2	3	4	5	6
0 °C									
50 °C									
100 °C									
150 °C									
200 °C									
250 °C									
300 °C									
350 °C									
400 °C									

Scram: should be at 360 °C, Transient rod

real scram temperature: °C ....

Voltage: mV ....

GA CL 305 Voltage Analyzer (0-100 mV, Source Position)

	1	2	3	4	5	6
Transient rod Scram at	☐	☐	☐	☐	☐	☐

Remarks

Ambient temperature: .... °C

Signature:

2.5.6 WATER TEMPERATURE CHANNELS

Date: ....
DD MM YY

Used Instrment: GA CL 301-250 C in DAC-drawer backside

Position [°C]	Display at Graficmonitor [°C]	Display at Status Window [°C]: Pool Temp Scram	Tank In Temp Alarm	Tank Out Temp Scram
0				
25				
50				
75				
100				

Used instrument: Heli-Pot, Resistance increased slowly until Scram is triggered

		Grafic-Window	Status Window
Announcement:	Rod up		
	Pool Temperature Scram triggered at	.....°C = ... Ω	.....°C = ... Ω
	Display at Graficmonitor	☐	
	Display at Scram Window	☐	
Announcement:			
	Tank In Temp Alarm triggerd at		.....°C = ... Ω
	Display at Graficmonitor		☐
	Display at Scram Window		☐
Announcement:	Rod up		
	Tank Out Temp Scram triggered at		.....°C = ... Ω
	Display at Graficmonitor		☐
	Display at Alarm Window		☐

Remarks:

Signature:

2.6.1 PRIMARY PUMP

Date: ....
DD MM YY

Visual examination for tightness

Acoustic test

Test rpm:		Board	Console
	Pot 4	Φ = ... m^3/h	Φ = ... m^3/h
	Pot 5	Φ = ... m^3/h	Φ = ... m^3/h

Pressure after heat exchanger

Secondary circuit

DP = ... bar   □p Siemens-Board = ... bar

Remarks

Signature

2.6.2 PURIFICATION PUMP

Date: ....
DD MM YY

Visual exermination for tightness

Acoustic test

Max. capacity
in (lt/h)

Remarks

Signature

2.6.3 PRIMARY FILTERS

Sheet:

Responsibility: IP

Inspection period: 1xm

Date: ....
DD MM YY

Visual inspection of housing tightness

Pressure drop across filters Dp

Filters to be replaced

Remarks

Signature

2.6.4a VALVES AND SENSOR
Primary circuit
(see scheme)

Date: ....
DD MM YY

Test of valves for movement	Test of valves for tightness (visual)
V1	V1
V2	V2
V3	V3
V4	V4
V5	V5
V6	V6
V7	V7
V8	V8

Check of sensor sockets

$\square_1$	T_E
$\square_1$	T_A
$\square_2$	ϕ
Reserve	

Remarks

Signature

2.6.4b VALVES AND SOCKETS
Purification circuit
(see scheme)

Date: ....
DD MM YY

Test of valves
For movement

V1	V9
V2	V10
V3	V11
V4	V12
V5	V13
V6	V14
V7	V15
V8	V16

Check of sockets for tightness

T_E	ϕ_5
$\square_E$	Scinti
$\square_A$	S_7
T_4	

Remarks

Signature

2.6.5a FLOW INDICATOR
Primary circuit

Date: ....
DD MM YY

Pressure drop
□□ (red area visible) yes □ no □

Primary pump On Pot = ...

V (drawer) = ... m^3/h

V (console) = ... m^3/h

Filter needs replacement yes □ no □

Remarks

Signature

2.6.5b FLOW INDICATOR
Purification circuit
(see scheme)

Date: ....
DD MM YY

Display basement [□/h]

Display drawer [mA]

Display console [m^3/h]

Filter need to be changed:

	1	2	3	4
yes				
no				

Remarks

Signature

2.6.6 CONDUCTIVITY MEASUREMENT
Purification circuit

Date: ....
DD MM YY

Display control room
Ionexchanger colum

before □S

after □S

Display board
Basement primary ircuit

before □S

after □S

Remarks

Signature

2.8.5 CONTAMINATION WIPE TESTS REACTOR PLATFORM Sheet:

Responsibility: IP Inspection period: 1xm Date: ....
DD MM YY

Control room

1

2

Reactor platform

1

2

3

4

5

6

7

8

Decontamination carried out on: by:

Remarks

The control room is checked on two spots, the platform at 8 spots, the position of the checked spots has to be marked at the drawing.

Signature

2.10.4 PNEUMATIC TRANSFER SYSTEM

Sheet:

Responsibility: IP

Inspection period: 1xm

Date: ....
DD MM YY

Check of support of tubings along its pathway

Tightness of tube fittings

Visual control in core

Filters to be replaced

Test run

sample in

sample out

Capsule wet

yes

no

Remarks

Repair work ordered

Signature

2.10.6 BEAM TUBE COMPONENTS

Sheet:

Responsibility: IP | Inspection period: 2xy | Date: ....
DD MM YY

Where are the beam tube doors stored:

beam tube A:

beam tube B:

beam tube C:

beam tube D:

Condition of door gaskets:

A:

B:

C:

D:

Condition of movable lead plugs:

A:

B:

C:

D:

Remarks

Repair work ordered

Signature