Radiation and Nuclear Safety Authority 126/0002/2016
20.1.2020

Guide YVL E.9, Pumps of a nuclear facility

1 Scope of application

Guide YVL E.9 applies to nuclear facilities' pumps belonging to safety classes 1, 2 and 3 throughout their service lifetime. The Guide's requirements apply to licensees as well as those in the pump supply chain.

2 Justifications of the requirements

The justifications of the requirements presented in the Guide are presented for each chapter and in so far as licensees have requested justifications when commenting the Guide or the requirements are otherwise presumed to need a more detailed examination.

2.1 Chapter 1 Introduction

The chapter presents the grounds for Guide YVL E.9 "Pumps of a nuclear facility". The introduction makes references to the Nuclear Energy Act and STUK regulations on the safety of nuclear facilities and final disposal of nuclear waste and justifies the significance of pumps in the safe operation of nuclear facilities.

The Guide allows for serially manufactured pumps procedures deviating from those of built-to-order pumps to demonstrate their acceptability for nuclear facility use. For this reason, the requirements pertaining to procurement of a serially manufactured pump are presented separately in a dedicated chapter.

The Guide has adopted the concept of "low-energy pumps". When the criteria of the definition[1] are met, the pumps belong to the scope of inspection of the authorised inspection organisation (AIO) and the technical requirements of Safety Class 3 may be applied to them, even though the pumps would belong to Safety Class 2. Over-dimensioning of a low-energy pump at the service place in view of the load or stress targeting the component can be proven so great that relieving the requirements regarding design, dimensioning and quality control of manufacturing will not cause an additional risk of losing pump operability during operation. In addition, due to the low process parameters, consequences to the environment in a potential loss of component integrity are smaller than those of a high-energy component. On these grounds, there is room for flexibility in the requirements of low-energy pumps according to the Graded Approach principle (consideration of the safety significance).

2.2 Chapter 2 Scope of application

The chapter presents the scope of the Guide and its interfaces with other guides. The Guide applies to safety-classified pumps throughout their service lifetime. This shall refer to the pump design, manufacture, installation, commissioning and operation.

[1] Low-energy equipment shall refer to Safety Class 2 equipment with a design pressure of up to 20 bar(g) and a design temperature of up to 120 °C and to which the design, dimensioning and quality-control requirements of a corresponding equipment from Safety Class 3 can be applied with technical justifications without having a risk to lose the operability of the equipment.

Where applicable, the requirements apply to the licensee and operators in the pump supply chain.

2.3 Chapter 3 Licensee's general equipment requirement specification

The chapter presents a requirement to the licensee on the pumps' general equipment requirement specification[2]. The requirement does not take a stand on who prepares the general equipment requirement specification. Key factors in a general equipment requirement specification are the "general" data sheet and quality control plan. The data sheet presents the design bases and values that are typically specified in pump procurements. The data sheet also includes the requirements that the drive sets for the pump and the pump for the drive. Correspondingly, the general quality control plan (general inspection plan) specifies at a principle level the inspections and tests to take place from the material procurement to the test run of the pump. The general requirements are supplemented in connection with procurement with requirements specific to the service place both in normal operation and possibly in transient and accident conditions. If a pump has, e.g., operational requirements for dirty water, the data sheet template presents the water particle sizes and concentrations and, if there are not any, the field is marked with N/A or in a similar manner. The principle is that similar specifications are prepared for all mechanical components that are procured to the nuclear facility in large volumes during the construction process or operation for repairs and modifications. These components typically include tanks, piping, valves and lifting equipment in addition to pumps. In the case of components to be procured once-only or very rarely, such as the diesel generator serving as the emergency power supply, the general equipment requirement specification serves no actual purpose and STUK does not require one for approval.

The requirement is justified as follows:

- the licensee's "component standard" harmonises the requirements to a level that is more detailed than the YVL guides and, thereby, reduces the interpretation needs of the requirements
- the part-specific classification of the requirements is possible according to the "Graded Approach" (requirements are set in proportion based on the significance of the component in fulfilling the design bases and implementing the safety function required of the component)
- it serves as a clear requirement basis for the AIO inspections
- the construction plan can be approved also after starting manufacture (for now, only in Safety Class 3), because the equipment requirement specification serves already as the component's partial advance approval, while the location-specific suitability shall be assessed later, however, before the construction inspection.

2.4 Chapter 4 Manufacturer

This chapter presents requirements for the pump manufacturer. The general aim of the requirements is to make the manufacturer understand the safety significance of

[2] The general equipment requirement specification shall refer to a document that includes the component group-specific general design and quality control requirements for safety classes 1, 2 and 3 set by the licensee. In component procurement, the requirements set out in this document shall be supplemented by requirements specific to the service place.

the delivery. Another justification is to reduce the risk of the pump containing manufacturing defects that weaken operability and are not necessarily detected in inspections.

The management system of the pump manufacturer shall be appropriately certified and in Safety Classes 1 and 2 successfully certified for the nuclear industry. Appropriate certification shall refer to a situation where the certification body has been accredited against the requirements of standard EN ISO/IEC 17021 and the accreditation is covered by the Multilateral Agreements (MLA) entered into by FINAS. It is possible to deviate from the particular requirement regarding nuclear industry certification in a case where the management system is supplemented with a delivery-specific quality plan describing the procedures ensuring quality control.

If the pump manufacturer is not appropriately certified in Safety Class 3, the licensee may apply for approval for other management system assessment performed by an independent third party. The third party shall be an organisation independent of the pump delivery, design, manufacture and inspections. The preconditions and qualifications of the third party to assess the manufacturer's management system against the applied standard shall be assessed separately in connection with the processing of the construction plan.

2.5 Chapter 5 Design

The chapter presents the design requirements of pumps. The shared justification for all requirements presented in this chapter is the objective of ensuring that pumps operate in the required manner in situations where they are expected to operate. The design bases shall be specified to match the pump's performance requirements with the loads, stresses and conditions of the service place during normal operation and transient and accident conditions. Pumps still need to be designed and dimensioned so that the requirements set forth as design bases are met. Nuclear design standards take priority, but also other standards may be accepted, if it can be justified that their design yields corresponding operational certainty. Already in the design phase, investments shall be made also to the inspectability and maintainability of pumps.

As one design requirement it is mentioned that the pump's $NPSH_a$ (available net positive suction head) shall be at least equal to $NPSH_r$ (required net positive suction head) increased with a margin of 0.5 m. Such pumps that are meant to be operated in accident conditions for long periods of time still need to apply a value as the pump's required net positive suction head where incipient cavitation is caused by the intake flange but where it does not yet affect the head. This requirement to apply an acceptance criterion, which is stricter than the generally applied so-called 3% criterion, to $NPSH_r$ of pumps meant for managing long-term accident situations, is based on the fact that long-term incipient cavitation may significantly weaken the performance of the pump. If the 3%-cavitation criterion were to be applied, the pump would already cavitate, which is clearly demonstrated by the 3% decrease in the head.

With regard to condition monitoring, requirement 509 requires that *condition monitoring of a pump in Safety Class 1 and 2 shall be fixed and produce online data when the pump operates in cases where such condition monitoring substantially*

enhances the effectiveness of the pump's condition monitoring as compared to condition monitoring conducted periodically. The pump may be monitored by measuring a parameter yielding information on the performance (or change thereof) either in real time when the pump operates or with periodic inspections. The requirement primarily applies to new facilities and cases where online condition monitoring is considered to improve nuclear safety. In case "online testing" does not substantially improve the situation in comparison to periodic testing of the pump, the requirement does not need to be applied. This requirement does not apply retroactively to condition monitoring of pumps at operating facilities either, for example, in the case of replacement projects. The grounds for the requirement is to promote commissioning of new condition monitoring methods in order to reduce the risk related to technological ageing of nuclear facilities.

2.6 Chapter 6 Construction plan

The pump shall be designed and manufactured so that the design basis requirements are met, the demonstration of which is the ultimate purpose of the construction plan. By virtue of the Nuclear Energy Act (990/1987), the licensee is obliged to assure the safe use of nuclear energy and this obligation cannot be delegated or transferred to another party. In order to fulfil this obligation, a statement by the licensee on the acceptability of the pump (summary of justifications) shall always be appended to the construction plan. Based on the data of the construction plan, the licensee shall justify the abilities of the delivery chain and correspondence of the design input data to the service place as well as the conformity of the design and sufficiency of quality control.

In this Guide, a pump refers to a mechanical component (hydraulic machine transferring liquid), which transfers liquid and produces head for it. The pump is considered to also include the pump's auxiliary devices, such as couplings and coolers and other integral parts of the pump structure and operations, e.g., supports. The electrical and I&C equipment, such as the pump drive's preliminary suitability assessment comparable to the construction plan, is processed separately according to the requirements of Guide YVL E.7 "Electrical and I&C equipment of a nuclear facility". The preliminary suitability assessment is not included in the pump's construction plan but it shall have been processed according to the delivery method and schedule presented in Guide YVL E.7.

Instead, the mutual compatibility of the pump and its drive shall be demonstrated with a operability analysis[3] to be appended to the construction plan. It shall be demonstrated, among other things, that vibrations do not weaken the performance of the pump. Vibration-causing internal excitation may be caused by the rotation speed and external excitation may be caused by a design basis earthquake. If necessary,

[3] The operability analysis includes the vibration and play analysis of the pump unit (pump, coupling, gear, drive, supports, foundations) and a possible strength analysis in an exceptional connection situation of its drive's supply voltage. The analyses shall demonstrate that the vibrations and changes caused by thermal expansion on the operational clearances do not weaken the performance of the pump unit in design basis operational conditions (required in Safety Class 3 only if the pump unit is intended for severe accident management). If the design bases of the pump unit include an exceptional connection situation of the supply voltage, a strength analysis shall also be presented to demonstrate the maintenance of the pump unit operability in such a situation.

the operability analysis can be submitted separately, in which case approval shall be sought before installing the pump.

In Safety Classes 1 and 2, approval for the construction plan shall be sought before the manufacture is started, i.e., before the manufacture of the pump begins from the raw materials (casting, forging or some other structural material) by machining, welding or some other manufacturing method. The grounds for the requirement is to maintain the possibility to impact design solutions in case there are remarks to the conformity of the pump. Modifications are difficult to implement on a finished pump. Here, however, the Graded Approach principle is applied and in Safety Class 3 the construction plan can be approved, if necessary, after the start of manufacturing. This requires that the pump has been designed and manufactured in accordance with the approved general equipment requirement specification of pumps. The general equipment requirement specification can be interpreted as the component's "general" advance approval before the start of manufacture, when the complementary location-specific acceptability can be assessed later in Safety Class 3 (before the construction inspection).

In Safety Class 1, an approval for the pump's pressure-retaining frame structures (material manufacturing) shall be applied for before material procurement starts. This requirement is justified by the fact that the frame structure forging (or casting) specifies the pump's structural and, in some cases, functional dimensioning; the acceptability of dimensioning of pumps especially significant to safety should be established as early as possible. In this way, further clarifications and possible rejection of the part can be avoided, if the dimensioning is proven insufficient afterwards.

Requirement 604 allows the submittal of minor revisions to the construction plan for information. In this context, minor revisions refer to revisions that do not have immediate significance to the pump's design basis operability, e.g., replacing one sealing material to another. In any case, STUK and an AIO can take a stand on a revision submitted for information, if necessary.

According to requirement 612 the pump's design bases shall be determined in the scope of the requirements that have been set for the pump's operability in normal operation, during anticipated operational occurrences, postulated accidents, design extension conditions and severe reactor accidents. Regarding pump's aforementioned service beyond normal operation (and conditions), the possible integrity and functionality requirements are determined both during and after such events.

If requirement 616 *in addition to the pump's main dimensions, the construction plans shall show the dimensions used as input data for calculations and the dimensions, part markings, part materials, hard-facings, surface treatments and welded joints essential for operation* cannot be observed, e.g., due to a business secret, alternative methods for indicating the said structural dimensions can be presented. In such a case, a procedure shall be described that allows the verification of the dimension data indicated in other ways as the actual dimensions of the structure.

The inspection plan to be appended to the construction plan shall define the scope of pump disassembly after functional testing. The requirement aims to exclude possible manufacture and assembly errors from the manufactured pump individuals that could surface only when the pump is already in use. It should be noted that, due to the different structures of pumps, the disassembly need is case-specific and that the disassembly is always implemented in the scope accordant with the approved construction plan. Typically, the clearance and guiding surfaces shall be visible to the inspector.

2.7 Chapter 7 Type test

The conformity of the pump's design solutions shall be ensured by a once-only type test or other similar functional test. The requirement is based on the fact that a type test is considered to be the most reliable method of demonstrating performance of a functional component (such as a pump) according to its design requirements. The type test is needed because normal factory inspections, which mostly focus on inspecting the acceptability of the manufacture and assembly of an individual pump, do not in every case have the chance or intention of ensuring functional properties required of the pump in all respects. For example, the performance of the pump in accident conditions (if it is a design basis) is not normally tested as part of the factory inspections constituting a part of the construction inspection.

A new type test is not required, if the type test has been previously performed and it is sufficient for demonstrating the conformity of the pump in question.

The scope of type testing is restricted to such properties required of the pump that cannot be verified reliably with any other means. A separate type test is not necessary, if the pump's design basis performance can be ensured with the help of operating experience or factory tests.

2.8 Chapter 8 Manufacturing

Requirements regarding manufacturing of the pump are presented in this chapter. In practice, it is not possible for STUK or an AIO to monitor the manufacturing of the pumps' structural materials or parts excluding exceptions. The requirements of the chapter are justified generally with the aim of ensuring manufacturing quality, which meets the requirements set for the pump and which simultaneously excludes at least such quality non-conformances that cannot be detected in the final inspections carried out by STUK or an AIO.

2.9 Chapter 9 Construction inspection

The construction inspection serves as the pump's final inspection and this chapter presents the requirements pertaining to it. The construction inspection is an established practice for mechanical components with the aim of getting proof that the materials, manufacture, structures and operation conform to the approved construction plan (manufactured according to its design). In the inspection, the acceptability of the manufacturing result documentation is determined, inspections are carried out and tests are monitored in the scope of the inspection plan submitted together with the construction plan.

STUK and an AIO may use their discretion on whether to monitor a specific inspection or test at the site or to assess the acceptability of the results based on the inspection report appended to the result documentation.

If the pump is repaired or parts (other than single-use wearing parts) are replaced due to faults or some other non-conformances detected during the factory tests, the factory tests shall be repeated. The requirement is justified with the fact that only final and fully successful factory tests provide the most reliable confirmation of the pump's conformity. In the same connection, it becomes clear whether the repaired or replaced part is responsible for the detected issue or is the repair or replacement need a result of some other issue.

2.10 Chapter 10 Installation

The pump installation is comparable to pump manufacturing from the monitoring perspective. A plan (installation construction plan) and final inspection on the finished installation (installation construction inspection) are needed. Necessary instructions, drawings and inspection plan for quality control are appended to the installation construction plan in order to enable the acceptability assessment of the installation work in advance. The installation construction inspection makes sure that the installation work and its quality control have been conducted according to the construction plan.

2.11 Chapter 11 Commissioning

Requirements regarding the two-phase commissioning inspection of the pump are presented in this chapter. In the first phase of the commissioning inspection, the test run preconditions are confirmed by verifying that all the previous pump inspection phases have been successfully completed, the suitability assessments of the actuator have been processed as specified in Guide YVL E.7, the licensee has carried out its own inspections, etc. In this phase, the aim is no longer in performing inspections but only on becoming convinced that the pump is ready, short of a test run.

In the second phase of the commissioning inspection, the operability of the pump and drive combination is verified with a test run. The test run is carried out according to a plan, the sufficiency of which has been confirmed in the first phase of the commissioning inspection. At its simplest, the test run procedure may be the licensee's procedure, as long as it fulfils the test procedure criteria, i.e. it includes the test and measurement arrangements, test phases and result acceptance criteria. At the end of a successful test run, the pump is granted either a permanent or fixed-period operating licence. It is granted for a fixed period if, e.g., a test run phase cannot be completed until later and the pump is safe to operate despite this phase preventing the granting of a permanent operating licence.

2.12 Chapter 12 Operation, condition monitoring and maintenance

This chapter presents the general requirements that apply to the operation, condition monitoring and maintenance of pumps. The aim is that the pumps are not subjected to unnecessary loading or unfavourable operating conditions during operation. Moreover, the pump is serviced and its condition is monitored to a scope that the loss

of the pump or weakening of its operability cannot cause a safety risk at the nuclear facility.

During operation and outages, the pumps shall undergo inspections and tests especially in view of the targets and parameters that allow the confirmation of design basis operability.

A maintenance task not forming a part of the pump's maintenance programme is considered repair work for which approval shall be sought with a repair plan and an inspection following its implementation. The repair plan shall include a procedure description, illustrative drawings and an inspection plan covering manufacturing, installation and commissioning. The repair plan and construction inspection are not required, if the repair work only involves the replacement of parts to approved spare parts without any special processes or if the repair work is minor and targets pump parts insignificant for the pump's operability.

2.13 Chapter 13 Modifications

Requirements regarding possible modifications of the pump are presented in this chapter. Typically, modifications impact the pump performance or operability or the safety of the nuclear facility.

Modifying the structure or operation of a safety-classified pump requires a systematic approach and comprehensive assessment of the impact of the modification. For this reason, a modification with its design bases shall be approved in advance with a construction plan and the implementation of the modification with a construction inspection.

2.14 Chapter 14 Serially manufactured pumps

Requirements regarding procurement of a serially manufactured pump[4] are presented in this chapter. It is possible to have a serially manufactured pump approved for nuclear facility use following a procedure deviating from that of a built-to-order pump in Safety Classes 2 and 3. In such a case, it is assumed that a serially manufactured pump can be just as good in terms of quality and suitability or, in some cases, even better due to its manufacture in large series of uniform quality than a built-to-order pump.

The difference to having a built-to-order pump approved is more flexible procedures for demonstrating conformity. A serially manufactured pump can also be approved against design values only without knowing the final service place and have it approved for the service place later before its installation. It is essential that the validity of the design values and acceptability of manufacturing quality can be reliably and unambiguously confirmed. The correctness of the design values can be demonstrated with one or more of the following methods: granted type approval,

[4] A serially manufactured pump has not been designed to meet the requirements of the purchaser, instead, it is procured based on the manufacturer's product description. Typically, the pump is manufactured in large batches and it is also suited to other purposes of use. The structure, dimensions and materials of the pump, and the methods and quality of manufacture, do not essentially differ within or across manufacturing batches.

qualification reports, the manufacturer's dimensioning table or similar, computational analyses, clarifications on the fulfilment of the requirements of the applied dimensioning standard and operating experiences. At the factory, manufacturing quality is monitored at least in the form of random inspections and the licensee is expected to supplement, where necessary, the manufacturer's quality control with its own acceptance inspections. Demonstrating the correctness of the pump's design values is not solely sufficient, the suitability of the pump for its intended service place shall also be confirmed before installing the pump. The service place-specific suitability shall be justified in the construction plan of either manufacture or installation.

2.15 Chapter 15 Regulatory oversight by the Radiation and Nuclear Safety Authority

This chapter presents STUK and an AIO's regulatory activities concerning the pumps of a nuclear facility (documents to be submitted and inspections to be carried out in the different phases of the pumps' service lifetime).

3 International provisions concerning the scope of the Guide

- IAEA Safety Standards No. SSR-2/1, Safety of Nuclear Power Plants: Design (Vienna 2012).
- IAEA Safety Standards No. SSR-2/2, Safety of Nuclear Power Plants: Commissioning and Operation (Vienna 2011).

4 Impacts of the Tepco Fukushima Dai-ichi accident

The Fukushima accident has no impact on the requirements of the Guide.

5 Needs for changes taken into account in the update

The needs for changes due to changes made to international and national laws/regulations and the change proposals made in connection with the preparation of the YVL Guide implementation decisions (SYLVI) together with others recorded in STUK's change proposal database have been considered when updating the requirements. In addition, the possibilities to reduce the so-called administrative burden have been considered.

An example of reducing the administrative burden is allowing the use of serially manufactured pumps under certain conditions. Another example worth mentioning, which is believed to further clarify the licensing of pumps, is having electrical and I&C equipment now approved solely against the requirements of Guide YVL E.7, i.e., against the preliminary and final suitability assessments. However, the compatibility of the pump and drive shall be demonstrated with the so-called operability analysis to be appended to the pump's construction plan.