Säteilyturvakeskus
Finnish Centre for Radiation
and Nuclear Safety

YVL-ohje
YVL Guide
27 May 1986

YVL 5.7
1 (23)

Second, revised edition
Translation

PUMPS AT NUCLEAR FACILITIES

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Helsinki 1987
Government Printing Centre

ISBN 951-47-0537-8
ISSN 0783-2400

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STUK 41.01 1985 – 05

8085035600 – 12/6345/PTP

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1 GENERAL

The Finnish Centre for Radiation and Nuclear Safety (STUK) follows this guide in regulating and controlling pumps in Safety Classes 1, 2 and 3 at nuclear facilities. The criteria for safety classification are presented in Guide YVL 2.1 /1/. STUK does not conduct separate inspections on pumps of Class EYT (non-nuclear) at nuclear facilities, but they are inspected in connection with the commissioning inspections of systems or their parts.

2 CONSTRUCTION PLAN

The construction plan shall be submitted to STUK in accordance with Guide YVL 1.2 /2/. If a document or its part has been delivered to STUK earlier, reference to this document is sufficient.

The construction plan shall comprise information on following items:

1. manufacturer
2. design bases
3. materials
4. fabrication methods
5. quality control program
6. basic dimensioning and stress analysis
7. drawings
8. coupling pump to motor and joining pump to piping
9. motor
10. auxiliary systems of the pump and its motor
11. measuring and control devices of the pump and its motor
12. installation plan of the pump and its motor
13. type tests and operating experience.

The scope of the construction plan shall be determined

taking into account the safety significance of the pump and the structural and operational requirements placed on it.

The data relating to installation and maintenance of the pump, as well as the data on the motor, auxiliary systems and accessories (sections 2.9...2.12), may also be submitted later, but well before the installation is initiated.

2.1 Manufacturer

The manufacturer of the pump shall give an account of his technical and administrative qualifications for fabricating pumps described in the construction plan. The pump manufacturer's experience should be demonstrated, for example, with reference lists of the places where pumps of the same type have been installed, including the commissioning dates

The manufacturer of pumps in Safety Classes 1 and 2 shall present an account of his quality assurance procedures, for instance, a quality assurance manual used in the company. The account shall include data on the procedures adopted by the manufacturer for supervising the subcontractors who take part in the fabrication, installation or quality control of the load-bearing and/or hydraulic parts of the pump.

Persons responsible for design and fabrication shall be designated for the projects defined in the construction plans of pumps in Safety Classes 1 and 2.

The inspection agencies and inspectors conducting the quality control shall be approved by STUK in accordance with Guide YVL 1.3 /3/.

As deemed necessary, STUK performs audits at the factory so as to assess the competence of the manufacturer.

2.2 Design bases

The design data shall provide information required for inspection of the pump type and its structural solutions, material selections, strength claculations, quality control program and operational test schemes.

The design data shall include all operational circumstances that affect the operation of the pump at the nuclear facility (normal operation, transients and accidents), including at least following information:

- the intended use of the pump (identification symbol)
- safety class
- tightness requirements
- mode of operation (continuous or intermittent operation, parallel operation, etc.)
- the dimensioning data used as a basis of strength calculations and eventual stress analysis, such as pressures and temperatures and their variation ranges, and permissible forces and torques from piping to the pump
- the medium to be pumped, its temperature and temperature variations
- inlet pressure variations
- required operating points and/or ranges (volume flow, head).

At least the following characteristics shall be presented of the selected pump:

- characteristic curves showing also the required NPSH value
- need for cooling, sealing and flushing water and

their design data, like pressure, flow, temperature and purity of the medium
- required shaft output within the operating range, during start-up, and with the highest possible loading
- counter-torque curve
- required minimum flow
- selection criteria for bearings
- permissible vibrations and bearing temperatures
- construction data on shaft sealings
- maintenance intervals recommended by the pump manufacturer for continuous and/or intermittent operation during normal plant operation
- eventual special requirements concerning the start of the pump (e.g. start-up against a closed valve, need for lubrication in start-up, and waiting time before re-start)
- protection of the pump against hydraulic shocks or back flow
- special requirements for the support and installation of the structures in the pump unit (pump, motor, gearing and clutch)
- tests and inspections required for control of the pump condition
- list of the measurements needed for control of the pump operation and operating condition.

The design data shall primarily be presented as a summary filled in a form. When necessary, the summary shall be supplemented with a more extensive account.

2.3 Materials

In the material data it shall be described the applicability of the materials to their intended use and presented the criteria and requirement levels for the approval of their properties.

The material data shall include a list of base materials and weld filler materials with part numbers and standard markings of the materials.

In the material data or the quality control program it shall be described the delivery condition, testing requirements and type of material certificate (e.g. SFS3/4) for all pressure loaded structures. If the material is subjected to heat treatment, hot forming, cold forming or some other treatment affecting its properties during the fabrication, the material properties of the completed product shall be demonstrated. The same data shall also be given on the shaft, impellers and stator blades, as well as on other comparable parts affecting the operation of the pump. The materials of non-loaded parts welded to the pressure frame shall be chemically analyzed and the materials of seals and seal supports shall be given a quality certificate.

The base materials shall conform to the requirements of the standards the base materials are designated to comply with. In the material report it shall be given eventual additional requirements that may be placed on the materials. Welds and heat-affected zones shall conform to the requirements on strength and toughness set for the base material of the finished product.

The testing methods and the scope of sampling shall be defined on the basis of the safety class, type of material, service conditions and dimensioning.

The fabrication and repair welding methods of pumps in Safety Classes 1 and 2 shall be qualified with procedure tests. The base materials and welding filler materials that are used in the procedure tests shall also be described. The procedure test plans of exacting welds and the results of completed procedure tests shall be included in the material data or in the quality control

program. If the procedure is standardized, a reference to the standard is sufficient.

When necessary, additional information shall be provided on each material, including e.g.

- bases for the selection of a material, if there is not enough experience of the use and properties of the material in the structures in question, or if the selection deviates from the recommendations set forth in the material standard
- fabrication methods of the parts (forging, casting, coating, heat treatment etc.) if the method to be used is not conventional or if the completion of the work with this method requires special care
- specified requirements for the material characteristics, if they are not unequivocally defined by a standard or deviate from standards
- testing methods and scope of sampling, if they are not defined in the material standard in question or if a deviation is made from the requirements in the standard
- supervision of sampling and testing.

2.4 Fabrication methods (only in Safety Classes 1 and 2)

In the description of fabrication methods it shall be given a general account of the fabrication methods and quality control procedures at the various manufacturing stages. The description of fabrication methods shall include the instructions given for heat treatment, casting, forming, welding and coating.

The description of fabrication is required only for pressure loaded parts and, as regards to coating, also for other hydraulic parts and the shaft.

2.5 Quality control program

The quality control program shall include information on the quality control measures applied to the design, fabrication, installation and functional tests of the pump, including inspection procedures.

The quality control of construction materials, welds, coatings, installation and completed structure of the pump shall be given part-specific.

The program shall be include:

- identification of each part and welded joint in accordance with the drawings
- name and quantity of the part
- standard markings of construction materials and welding filler materials
- procedure tests that qualify fabrication welds and eventual repair welds
- inspections required for each item and the inspection procedures to be applied
- inspector and supervisor of the inspection (e.g. manufacturer, contractor, approved inspection agency, utility, authority).

The inspection procedures shall cover the inspection and supervisory measures that relate to the design, fabrication, installation and functional tests of the pump. The inspections procedures shall define the object, method, scope, acceptance limits and reporting procedure concerning the inspection/supervision.

The most general quality control measures given in the inspection procedures may be grouped as follows:

- review of the construction plans and drawings
- identification, marking and certificates of materials

- sampling and supervision concerning materials and procedure tests
- destructive testing
- non-destructive testing
- inspection of the competence of welders (the competence of welders shall be verified according to standard SFS 2218/5/ or in some other way, which shall be submitted to approval separately)
- supervision of welding
- supervision of heat treatment
- supervision of coating or surface finishing
- inspections of the dimensions of the structures
- balancing of rotating parts
- leak and pressure tests
- functional tests and supervision of them at the factory
- inspections of the pump that has been disassembled after the functional tests
- supervision and inspections of installations.

The dimensions of the pump hydraulic parts, their clearances, fits and passes shall be checked with special care. The same applies to the way the checkings are performed, to the accepted accuracy limits of the dimensions and reporting of the inspections.

The pressure test of the pump shall be conducted according to the standard used in the dimensioning. If no such standard exists, the requirements in Standard SFS 3321 /6/ shall be complied with. It is recommended that the functional tests be carried out in accordance with Standards ISO 3555 /7/, ISO 2548 (SFS 4448) /8/, BS 599 /9/, DIN 1944 /10/.

2.6 Basic dimensioning and stress analysis

The purpose of the basic dimensioning is to demonstrate that the dimensions and shaping of the pump meet the

pertinent requirements in all design conditions.

The pumps in Safety Classes 1 and 2 shall be dimensioned to meet the requirement level presented in ASME Code Section III, NB-3400 /11/ and NC-3400 /12/. In individual cases, STUK may also allow the use of some other comparable dimensioning standard. As to pumps in Safety Class 3, it is possible to use a standard generally used in the country of fabrication and is applicable to nuclear facility pumps.

Besides pressure loaded parts, also the shaft and other parts bearing considerable loads shall be subject to dimensioning calculations.

In addition to the basic dimensioning, pumps in Safety Class 1 shall be subjected to a separate stress analysis in order to show that the pressure loaded parts of the pump maintain their integrity in all supposed loading conditions. The stress analysis shall have the approval of STUK before the pump is placed in operation. The requirements concerning the stress analysis are set forth in Guide YVL 3.5 /13/.

2.7 Drawings

The pump, the motor, their coupling and installation, as well as the parts of the auxiliary systems associated with the structures of the pump shall be described in drawings. The drawings shall contain data needed for the assessment of the acceptability of the dimensioning, fabrication, installation and operation of the pump structures.

If the pump must undergo inservice inspections with non-destructive methods, as stipulated in Guide YVL 3.8 /14/, the information given in the drawings shall make it possible to assess whether the inspections of the pump

housing and its welds, as well as the welds between the pump and piping, can be conducted in a reliable way.

The drawings shall be unequivocal and clear. The drawings of the pump itself shall contain at least following information:

- the assembly with lists of parts and materials
- the dimensions and shapes used in the dimensioning or defined by means of the dimensioning, with permissible tolerances, and the finishing of surfaces
- the types, locations and dimensions of joints and fixtures
- welds and coatings
- the clearances, fits and passes essential to operation (these data can be given in connection with the construction inspection)
- groundwork and installation in sufficient detail.

2.8 Coupling pump to motor and connecting pump to piping

Design bases and drawings shall be provided of the coupling of the pump to the motor. As for pumps in Safety Class 3, a reference to a standard is sufficient.

If some special requirements are placed on the dimensions, materials and installation of the piping to be connected to the pump, they shall be specified. As to pumps connected to piping by welding, a description of the welding is required.

2.9 Motor

If the motor is of the so-called wet motor type, the same data is provided on the pressure loaded parts of the motor as on the pump itself (sections 2.1 - 2.7 above).

As stipulated in Guide YVL 5.5 /15/, the following information shall be given on the motors of all pumps in Safety Classes 1 and 2 and on those pump motors in Safety Class 3 that are safety related on the basis of operational requirements placed on the pump.

- safety class of the motor
- motor manufacturer
- quality control program
- design data, which include
  - operating voltage, control voltage and the symbols of the distribution boards supplying them (the auxiliary voltages and the symbols of the distribution boards can be given in a separate topical report)
  - permissible operating times within abnormal voltage and frequency range
  - start current and rated power
  - load capacity at the long-term undervoltage used as design basis
  - power factor in the load range at rated voltage and long-term undervoltage used as design basis (calculated values)
  - normal environmental conditions and those used as design basis (pressure, temperature, humidity, chemicals, radiation level)
  - efficiency in the load range at rated voltage and long-term undervoltage used as design basis (calculated values)
  - cooling system and the highest permissible temperature of the coolant
  - starting and maximum torques as a function of the speed of rotation
  - methods of electrical protection (can be described in a separate topical report)
  - insulation and enclosure class
  - selection criteria of the bearings
  - permissible vibration on bearing supports
  - permissible bearing temperatures.

The above data can be left out from the construction plans of pump motors in Safety Class 3 only for well-founded reasons.

2.10 Auxiliary systems of the pump and its motor

Design data shall be provided on the auxiliary systems required by the operation of the pump and its motor.

Such auxiliary systems are, for example:

- sealing systems
- cooling systems
- lubrication systems
- minimum flow piping
- testing systems
- flywheel
- eventual missile shields
- electromagnetic bearings.

The document shall define the maximum times that each auxiliary system can be out of operation during pump operation.

2.11 Measuring and control equipment of pump and its motor

The data required in Guide YVL 5.5 shall be provided on the measuring and control equipment of the pump and its motor. If the data have been submitted to STUK earlier, a reference to the document in question is sufficient.

The data shall be given on the measuring and control equipment of the pump and the motor. The equipment may include, e. g. following devices:

- flow meters
- pressure meters, alarms and switches
- temperature meters, alarms and switches

- vibration meters
- devices for measuring the displacement and/or bending of the shaft
- measuring devices controlling the lubrication of bearings.

The data shall show, among other things,

- the type of the measuring instrument
- measuring range
- accurary of measurement.

The assembly, installation and system drawings shall show the locations of the transducers and detectors and/or metering and control devices.

2.12 Installation plan

The installation plan shall show the dimensioning, structural solutions and inspections of the groundwork fixtures and supports. The groundwork of pumps in Safety Classes 1 and 2 shall be planned in such a way that the significant characteristic vibration frequencies of the pump unit and the groundwork are not the same.

The plan shall describe the installation divided into working phases. In addition, the plan shall show the limits set for the precision of the installation and the tightness of the screw joints.

The installation plan of pumps in Safety Class 3 can be given in connection with the construction inspection of the installation.

An account shall be given of the procedure applied to the qualification of the subcontractors taking part in the installation.

2.13 Type tests and operating experience

The purpose of type tests and operating experience data is to show that the pump and its motor work reliably in long-term operation and are not subject to external disturbances.

A detailed type test program shall be submitted to STUK as part of the construction plan. If the results of some type tests conducted earlier are to be submitted for approval, the applicant shall annex the result material of the tests to the type test program.

The operating experience encompasses the number of similar pumps fabricated earlier, the inservice times of the pumps and other eventual operating experience. Sufficient operating experience can be used to substitute for some of the above-mentioned type tests.

STUK presupposes that the motors of those pumps needed in case of accidents is experimentally demonstrated to perform as designed in the supposed accident conditions. More detailed requirements are given in Guide YVL 5.5.

3 SUPERVISION OF FABRICATION AND CONSTRUCTION INSPECTION

STUK supervises the fabrication of pumps and motors in Safety Classes 1 and 2 by conducting audits at the factory. STUK shall be given an opportunity to view the organization and quality assurance procedures at the factory and to follow the fabrication and testing. For the audits, STUK shall in good time be informed of the dates of the inspections specified in the approved inspection plans of the pump and its motor. STUK follows the fabrication, as deemed necessary.

If STUK finds it necessary to supervise the fabrication of a pump or a motor in Safety Class 3, the concerned parties will be notified thereof.

The construction inspection of pumps in Safety Classes 1, 2 and 3 is generally conducted at the factory. A request for a construction inspection shall be made well in advance of the time of inspection. If the whole construction inspection is to be carried out in the course of one audit, STUK recommends that the inspection be arranged at a time when an inspector employed or approved by STUK can supervise the operational tests and the subsequent physical examination.

The construction inspection of pumps in Safety Classes 1 and 2 is conducted by an inspector employed by STUK the pump being dissambled and assembled. The fabrication documents of pumps in Safety Class 3 are reviewed in whole, and the rest of the construction inspection is carried out to the extent agreed upon separately. A complete construction inspection is usually conducted on only one Safety Class 3 pump in the series of similar pumps included in one consignment.

If STUK requires that an electric motor be subjected to a construction inspection, the decision on the approval of the construction plan will contain an additional requirement to this effect.

The Finnish Centre for Radiation and Nuclear Safety supervises the installation to the extent deemed appropriate. STUK shall be informed of the beginning of the installation of pumps in Safety Classes 1 and 2 in good time. The construction inspection of installation is conducted on all pumps in Safety Classes 1, 2 and 3 after the installation has been completed.

The general requirements for a construction inspection are given in more detail in Guide YVL 1.15 /16/.

4 COMMISSIONING INSPECTION

Pumps will undergo a commissioning inspection after installation. The request for a commissioning inspection is made in writing in good time before the planned date of inspection. An inspector employed by STUK conducts the commissioning inspection on all pumps in Safety Classes 1, 2 and 3 and on the motors of pumps in Safety Classes 1 and 2, as well as on those pump motors in Safety Class 3 that are specified in section 2.9. The commissioning inspection of the motor is carried out in accordance with Guide YVL 5.5. The commissioning inspection of pumps in Class EYT is performed in connection with the commissioning inspection of a system or its part. An inspector employed by STUK does not conduct commissioning inspections on pumps which have been installed in piping of Group EYT/B. The licensee shall see to it that also these pumps are properly controlled and inspected.

The commissioning inspection is divided into two parts: the verification of installation and inspection status and the supervision of operational tests.

4.1 Verification of installation and inspection status

In the verification of installation and inspection status, the safety of the pump is evaluated for the issuance of the operational test permit.

The documents concerning pumps in Safety Classes 1, 2 and 3 shall be compiled and filed separately for each pump. The acceptance status of the documents is checked in the verification, and the document material shall include at least:

- document list
- covering letters and front leaves of the documents

- decisions and letters sent by STUK
- inspection protocols of STUK
- written accounts on the notes made during inspections
- design data of the pump
- results of the functional tests conducted at the factory
- assembly and installation drawings
- results of the preservice examinations included in the inservice inspections.

During the verification the representative of STUK shall be provided with the approved construction plan and a written account verifying that the notes and the additional requirements set forth in the decision has been complied with.

4.2 Supervision of functional tests

The functional tests relating to the commissioning inspection may be carried out as part of the preoperational and start-up testing of the system, as described in Guide YVL 2.5 /17/. STUK supervises the start-up testing by reviewing system-specific start-up testing programs and result reports and by following system tests. The preoperational testing shall demonstrate the applicability of the pump to the various operational situations in the system.

Pumps in Safety Classes 1 and 2 shall be subjected to a test run of at least 50 hours in conditions comparable to normal operation without interim maintenance or repair measures. The scope of testing of pumps in Safety Class 3 can be agreed on a case-by-case basis.

During the testing, the pumps and motors shall be determined with basic parameters characteristic of each pump and motor so that it will later be possible to compare

the results of inservice tests with these parameters and to detect any hydraulic or mechanical changes that may have occurred in the function of the pump.

Written instructions shall be prepared for the determination of the basic parameters. These instructions and the results of the start-up testing shall then form the basis for the preparation of procedures for the inservice tests. The procedures specify the pumps involved, the guidelines followed in each measurement, the measuring equipment with calibration requirements, and the method for recording the results. The procedures shall also show the acceptance limits of the results. The limits shall be based on accident analyses and requirements for control of the pump condition. It is recommended that the preparation of the procedures be carried out using ASME Code Section XI, Subsection IWP /18/ as a basis.

5 CONTROL OF PUMPS DURING OPERATION

5.1 Inservice tests

The Finnish Centre for Radiation and Nuclear Safety supervises the inservice tests of pumps in Safety Classes 1, 2 and 3. For the tests, the operator of the plant shall have a testing schedule for each pump and the rules and instructions to be applied in the tests. The results of the tests shall be filed in the way that subsequent results can be compared with them, as deemed necessary.

STUK need not to be specifically notified of the inservice tests, but STUK supervises them by reviewing test results and by following the tests at random.

5.2 Inservice inspections

The inservice inspections of pumps shall be conducted in accordance with requirements set forth in Guide YVL 3.8.

5.3 Preventive maintenance

For the preventive maintenance of pumps in Safety Classes 1, 2 and 3, the operator of the nuclear facility shall prepare programs, which show the preventive maintenance measures the pump and the motor (pump unit) is subjected to. Typical such measures are, for example, oil changing, follow-up of the operating condition of the pump and replacement of worn parts.

At the nuclear facility, a database shall be kept of pumps in Safety Classes 1, 2 and 3 and their motors. The data to be entered in the database comprise accomplished maintenance and repair measures, etc.

STUK supervises preventive maintenance by following the equipment database and the result material of the condition control of the pump and by conducting random inspections at the various phases of preventive maintenance.

5.4 Repairs and modifications

The design and implementation of repairs and modifications shall be carried out according to the requirements set forth in Guide YVL 1.8 /19/.

Pump motors are subjected to a commissioning inspection after a repair, if the construction plan of the repair or modification shall be approved by STUK.

An approved spare pump shall be installed and commissioned following the requirements set forth for repairs and modifications in Guide YVL 1.8 /19/.

5.5 Spare parts

For each pump type, the operator of the nuclear facility shall have a practice for follow-up of the sufficiency of spare parts.

The construction plan of the pump and its motor is also valid for spare parts. All changes shall be submitted to STUK for approval. The construction inspection of spare parts is carried out to the same extent as the inspection of the original parts.

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20 ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, Article NB-6000 Testing

In the event of any differences in interpretation of this guide, the Finnish version shall take precedence over this translation.