Safety Standards

of the
Nuclear Safety Standards Commission (KTA)

KTA 3504 (2015-11)

Electrical Drive Mechanisms of the Safety System in Nuclear Power Plants

(Elektrische Antriebe des Sicherheitssystems in Kernkraftwerken)

The previous version of this safety standard was issued in 1988-09 and 2006-11

If there is any doubt regarding the information contained in this translation, the German wording shall apply.

Editor:

KTA-Geschaeftsstelle
c/o Bundesamt fuer kerntechnische Entsorgungssicherheit (BfE)

Willy-Brandt-Str. 5 • 38226 Salzgitter • Germany

Telephone +49(0)1888-333-(0) • Telefax +49(0)1888-333-1625

KTA SAFETY STANDARD

November 2015	**Electrical Drive Mechanisms of the Safety System in Nuclear Power Plants**	KTA 3504

Previous versions of the present safety standard: 1988-09 (BAnz No. 37a of February 22, 1989)
2006-11 (BAnz No. 245b of December 30, 2006)

Contents

Comments by the Editor:

Taking into account the meaning and usage of auxiliary verbs in the German language, in this translation the following agreements are effective:

shall	indicates a mandatory requirement,
shall basically	is used in the case of mandatory requirements to which specific exceptions (and only those!) are permitted. It is a requirement of the KTA that these exceptions - other than those in the case of shall normally - are specified in the text of the safety standard,
shall normally	indicates a requirement to which exceptions are allowed. However, exceptions used shall be substantiated during the licensing procedure,
should	indicates a recommendation or an example of good practice,
may	indicates an acceptable or permissible method within the scope of this safety standard.

Basic Principles

(1) The safety standards of the Nuclear Safety Standards Commission (KTA) have the objective to specify safety-related requirements, compliance of which provides the necessary precautions in accordance with the state of the art in science and technology against damage arising from the construction and operation of the facility (Sec. 7 para. 2 subpara. 3 Atomic Energy Act - AtG) in order to achieve the fundamental safety functions specified in the Atomic Energy Act and the Radiological Protection Ordinance (StrlSchV) and further detailed in the Safety Requirements for Nuclear Power Plants as well as in the Interpretations of the Safety Requirements for Nuclear Power Plants.

(2) Based on the Safety Requirements for Nuclear Power Plants and their Interpretations, the present safety standard specifies the requirements for the electrical drive mechanisms of the safety system and for their assignment to the process-engineering systems of the safety system.

(3) In the present safety standard, it is presumed that conventional requirements and technical standards (e.g., Accident Protection Requirements, DIN-Standards, VDE Regulations) are adhered to under consideration of the safety-related requirements specific to nuclear power plants.

(4) The present safety standard specifies those requirements for the electrical drive mechanisms of the safety system that cover the generally accepted design loads derived from the analyses of design basis accidents.

(5) This safety standard supplements the safety standards KTA 3701 through KTA 3705 dealing with the supply of power and operating media and KTA 3501, Reactor Protection System and Monitoring Equipment of the Safety System. Furthermore, regarding the valves and machines driven by the electrical drive mechanisms of the safety system, there is a connection in particular to safety standard KTA 3404, Isolation of Operating System Pipes Penetrating the Containment Vessel in the Case of a Release of Radioactive Substances into the Containment Vessel, and to safety standard KTA 3301, Residual Heat Removal Systems of Light Water Reactors.

(6) Safety standard KTA 1401 specifies the “General Requirements Regarding Quality Assurance”.

1 Scope

(1) This safety standard applies to electrical drive mechanisms of the safety system in nuclear power plants. With respect to this safety standard, these include actuators, actuating magnets of valves, drive mechanisms of driven machines, and the control rod drive mechanisms.

(2) However, with respect to control rod drive mechanisms, only Section 8 of the present safety standard applies.

Note:
Further requirements for the control rod drive mechanisms are specified in safety standard KTA 3103, Shutdown Systems of Light Water Reactors.

(3) The present safety standard, furthermore, specifies requirements for the devices of the mechanical-equipment protection for those electrical drive mechanisms of the safety system whose signals do not have priority over reactor protection signals.

(4) The scope of this safety standard does not apply to:

a) the mechanical-equipment protection whose signals do have priority over the signals of the reactor protection system,

   Note:
   Requirements for this kind of mechanical-equipment protection are specified in safety standard KTA 3501.

b) the electric protective features,

   Note:
   The requirements for these devices are specified in safety standard KTA 3705, Switchgear, Transformers and Distribution Networks for the Electrical Power Supply of the Safety System in Nuclear Power Plants.

c) the design, analysis, fabrication, assembly, tests and operation of actuator modules, control modules and priority-control modules.

   Note:
   The respective requirements are specified in safety standard KTA 3501 and in safety standard KTA 3503, Type Testing of Electrical Modules for the Safety Related Instrumentation and Control System.

2 Definitions

(1) Controlled shut-down of an electric actuator

The controlled shut-down of an electric actuator is the disconnection or shut-down of the drive motor by the associated controlling devices.

Note:
The controlled shut-down of an electric actuator may be effected as a function, e.g., of a specified position (path-dependent controlled shut-down) or of a specified torque (torque-dependent controlled shut-down).

(2) Shut-down failure

A shut-down failure exists whenever the motor of an actuator is not disconnected or shut-down even though the specified end position has been reached.

(3) Mechanical-equipment protection

The mechanical-equipment protection is a device that is assigned to a certain piece of equipment in order to protect this equipment against operating conditions for which the equipment is not designed or not planned.

Note:
The controlled shut-down of actuators is not a part of the mechanical-equipment protection.

(4) Closed-loop actuator

The closed-loop actuator is the actuator of a control equipment.

(5) Authorized expert

An authorized expert is a qualified person or organization consulted by the nuclear licensing or supervisory authority based on Sec. 20 AtG.

(6) Safety system

The safety system comprises the entirety of those devices within a reactor plant that have the task of protecting the plant against impermissible loadings and, in case of the occurrence of a design basis accident, to prevent that the effects of this occurrence on the operating personnel, the plant and the environment exceed specified limits.

(7) Spindle force

The spindle force is the longitudinally directed force as a result of the torque introduced to the spindle by the spindle nut.

(8) Actuator

The actuator is a drive unit that positions a final control element.

Note:
Actuators may be open-loop or closed-loop actuators. The various types of actuators comprise, e.g., rotary actuators, linear actuators, pivoting actuators. Final control elements comprise, e.g., valves, butterfly valves, gate valves.

(9) Open-loop actuator

The open-loop actuator is the actuator of a controlling device.

(10) Design basis accident

A design basis accident is a sequence of events upon the occurrence of which peration of the plant or the activity cannot be continued for reasons of safety, and which sequence was considered in the plant design or for which activities protective measures were provided.

Note:
With respect to the plants under Sec. 7 Atomic Energy Act, a “design basis accident” is defined as being a sequence of events upon the occurrence of which operation of the plant cannot be continued for reasons of safety, and which sequence of events was considered in the plant design.

3 Superordinate Requirements for the Interaction of Electrical Drive Mechanisms and Engineered Safety Features

3.1 Basic Requirements

It shall be verified that the electrical drive mechanisms, in their interaction with other active and passive engineered safety features, are designed, manufactured and operated such that intolerable effects from design basis accidents and internal and external hazardous events are prevented.

Note:
It is permissible to perform this verification mutually for the entirety of all components of the safety system.

3.2 Failure-Initiating Events

3.2.1 Failure-initiating events in the electrical drive mechanisms of the safety system

(1) The electrical drive mechanisms shall be planned and arranged in conjunction with the process-technological systems such that a failure-initiating event in the electrical drive mechanisms will not prevent the protective actions necessary in case of a design basis accident.

Note:
This can be achieved, e.g., by arranging the process-technological systems in separate trains.

(2) The failure-initiating events in the electrical drive mechanisms of the safety system that shall be taken into consideration are, among others:

a) failures resulting from short circuits, power interruptions, shorts-to-ground, voltage or frequency changes, mechanical failures, fires,
b) several of the failures specified under item a) occurring simultaneously or in short succession of each other because of their having a common cause (fabrication faults, design faults, drift), and
c) human errors during operation or maintenance of the electrical drive mechanisms.

3.2.2 Failure-initiating events inside the reactor plant

Failure-initiating events inside the reactor plant shall be taken into consideration.

Note:
See also: Annex 4 of the “Safety Requirements for Nuclear Power Plants”: Principles for applying the single failure criterion and the maintenance.
Examples of failure-initiating events inside the reactor plant include: electromagnetic interferences line-conducted and field-bound, fire, water ingress, pipe whip, debris from a failed component, mechanical impingement of fluid jets, e.g., from steam, water, gas and oil.

3.2.3 Failure-initiating events outside the reactor plant

The electrical drive mechanisms of the safety system shall be protected against the same external events as the process-engineering system to which they are assigned.

Note:
Failure-initiating events are, e.g., earthquake, plane crash, blast wave from an explosion, flooding.

3.3 Failure Assumptions

(1) It shall be verified that the electrical drive mechanisms in their interaction with active and passive engineered safety features will, in addition to a design basis accident, be able to deal with

a) one random failure (single failure),
b) one maintenance case, and
c) consequential failures,

provided, this is also required for the associated process-engineering systems.

(2) The random failure and maintenance case shall only be assumed once for the entirety of those components of the safety system that are required in dealing with a specific design basis accident.

(3) Common mode failures do not need to be assumed, provided, the probability of common mode failures is sufficiently reduced by taking the following measures:

a) selecting suitable types of electrical drive mechanisms,
b) design of the electrical drive mechanisms taking all possible ambient conditions, including those caused by design basis accidents, and also any possible impairments of the power and media supply into account,
c) physical separation or other precautions against consequential damage, and
d) quality assurance (type approval tests, suitability tests, factory tests, commissioning tests, inservice inspections).

3.4 Process-Engineering Design

(1) The electrical drive mechanisms of valves and driven machines for a process-engineering system shall normally be physically arranged according to the train of the associated process-engineering system.

(2) If a secure closing and opening of a media supply system is required, the circuitry of the valves shall be such that a high level of reliability is achieved for each of these actions.

Note:
This can be achieved, e.g., by connecting two sets of series-connected valves parallel to each other.

(3) Process-engineering systems shall normally be designed such that valves and driven machines of the safety system, including the associated electrical drive mechanisms, can be can be operated for the purpose of testing during specified normal operation of the reactor plant without any impermissible reduction of the safety of the plant, and under load, e.g., in the case of pumps at their minimum delivery rates.

(4) With regard to monitoring the process-engineering-related function of a subsystem of the safety system (safety subsystem), feedback signals shall normally be derived from process-engineering parameters. If position checkback signals from electrical drive mechanisms are used to monitor the process-engineering-related function of a safety subsystem, a reliable coupling between position-signal generator and final control element shall be ensured.

3.5 Testability and Monitoring of Electrical Drive Mechanisms of the Safety System

(1) It shall normally be possible to test the electrical drive mechanisms of the safety system such that, even during the test, all protective features are functional when triggered by operational signals.

(2) If the electrical drive mechanisms of the safety system are connected by means of plug-in connections (i.e., power cables and cables for the instrumentation and controls), any disconnection of such plug-in connections shall normally be detectable from the main control room either directly, e.g., by wire-break monitoring, or indirectly, e.g., by a functional check of the drive mechanism.

(3) It shall be possible to test the actuators of the safety system such that, even during the test, the controlled shut-down of the electric actuators is possible [when triggered by operational signals].

3.6 Loadings from Leak Rate Tests of the Containment Vessel

Electrical drive mechanisms inside the containment vessel shall be designed such that their functional capability will not be impaired by the overpressure during inservice inspections of the containment vessel.

3.7 Redundancy and Independence

(1) The redundancy and independence existing as a result of the construction of the process-engineering equipment shall be maintained in the design and physical arrangement of the electrical drive mechanisms of the safety system.

(2) As protection against the failure-initiating events specified in Section 3.2, the electrical drive mechanisms of redundant process-engineering trains of the safety system shall normally be physically separated from each other or arranged such that they are protected from each other. A physical separation is not required if the failure-initiating events cannot prevent the protective actions.

4 Suitability Certification

(1) The suitability of the electrical drive mechanisms that will be used in the safety system shall be verified.

Note:
The suitability test includes the suitability certification as specified in Section 4 and the suitability review as specified in Section 13.

(2) It is permissible to submit the suitability certification for an entire production series of electrical drive mechanisms of the safety system. In this context, those individual drive mechanisms of the production series which would be subjected to the most severe assumed loads shall normally be subjected to the type approval test.

Note:
Electrical drive mechanisms of the safety system are considered as belonging to an individual production series if they are designed and fabricated according to the same mechanical and electro-technical design principles.

(3) The suitability of an electrical drive mechanism of the safety system or of an individual production series of electrical drive mechanisms shall be considered as certified, if

a) the type of drive mechanism has been successfully subjected to a type approval test as specified in Section 9 and furthermore, depending on the individual type of drive, as specified in Section 10, 11 or 12, or

b) the selected drive mechanisms of an individual production series have been subjected to type approval tests as specified in Section 9 and furthermore, depending on the individual type of drive, as specified in Section 10, 11 or 12 and if a satisfactory service experience under comparable operating conditions has been certified on ten drive mechanisms of the production series for at least five years of service in the case of actuators and actuating magnets of valves, or for at least three years of service in the case of drive mechanisms of driven machines. In the case of indications of overloaded components, of a wrong selection of materials or of other common mode failures, a proof that the cause of failure has been removed shall be presented.

(4) If an electrical drive used in the safety system has individual components which differ from those of the type-tested production series, a separate suitability test on those components is permissible.

(5) If modifications are made to a type-tested series with a certified satisfactory service life of electrical drives of the safety system which have functionally important characteristics, the suitability of the modified series for use in the safety system shall be demonstrated by supplementary or renewed type tests in accordance with paragraph 3 (see KTA 1401 Section 3 (9) and Section 6.2 (2)).

(6) If a new production series of electrical drive mechanisms is to be used for which a satisfactory service experience has not yet been certified, however, the important functional properties are comparable to those of a prior production series for which proof of successful operating experience is available, then it is permissible to perform supplementary tests only with respect to the new properties.

(7) If the deployment in nuclear power plants requires additional safety-related properties not covered by the certified satisfactory service experience and by the type approval tests as specified in Section 9 and furthermore, depending on the individual type of drive, as specified in Section 10, 11 or 12, then additional suitability tests shall be performed.

(8) Kind and scope of the suitability tests specified in paras. 4, 5, 6 and 7 shall be specified in agreement with the authorized expert.

5 Design of the Actuators

5.1 General

With respect to linear actuators, the term “torque” used in the following requirements shall be replaced by the term “thrust force”.

5.2 Basic Requirements

The actuator (open-loop actuator or closed-loop actuator) shall be designed such that it will meet the requirements of the actuated valve and process-engineering system under the ambient conditions of specified normal operation and of the design basis accidents to be considered.

Note:
Requirements for the valve design are specified only insofar as they concern the mutual interdependency of valve and actuator.

5.3 Required Valve Torque

(1) The actuators shall be designed for the largest torque required for the valve which shall be determined under consideration of both task-related and design-related influences (e.g., ageing, wear).

(2) In the case of open-loop actuators, the torque characteristic shall be specified and tuned to the mode of operation of the drive motor and, for the case that the regular torque characteristic is exceeded, to the strength of the actuator.

Note:
Regarding the regular torque characteristic for open-loop actuators, it shall be assumed that the highest torque will not be sustained longer than 2 seconds, that the torque during actuation (operating

torque) will not exceed 50 % of the highest torque and the travel time will not exceed 60 seconds.

(3) In the case of closed-loop actuators, the torque characteristic shall be specified and tuned to the mode of operation of the drive motor.

5.4 Torque Delivered by the Actuator

(1) The torque to be delivered by the actuator shall be determined based on the required valve torque as specified in Section 5.3, and under consideration of the transmission ratio and efficiency of any intermediate transmissions and remote-control components.

(2) The actuator shall be designed for a higher torque than the torque required for the valve. In the case of actuators with a torque trip device, the maximum permissible adjustable cut-out torque shall be larger than the highest required torque by an amount equal to the adjustment tolerance specified in Section 5.8 para. 6.

5.5 Torque Magnification Factors

(1) Regarding the actuator and valve design, all possible torque magnification factors shall be determined which occur during operational travel at the end positions against a mechanical stop (in case of a valve, e.g., the valve seat or a mechanical path limiter). In this context, the tripping delay of Section 5.12 and the stiffness of the valve shall be specified. The torque magnification factors shall not cause the permissible torques for the valve and the actuator to be exceeded.

(2) Regarding the actuator and valve design, those torques and torque magnification factors shall be determined which may be applied to the actuator upon a shut-down failure or in the course of manual operation (by means of a hand wheel).

5.6 Design of the Drive Motor

(1) The drive motor shall be designed such that the actuator can deliver a torque that is at least equal to the maximum torque specified in Section 5.4 even when the motor is started with the operationally lowest possible voltage at the motor connecting terminals. In this context, the following conditional requirements shall be taken into account:

a) The limit values of the motor torque deviations (i.e., of the startup, saddle and pull-out torques) relative to the design-basis values shall be taken into account. In this context, limit values may be specified that will restrict the deviations otherwise permissible in accordance with Table 20 of DIN EN 60034-1.

b) The reduction of motor torques due to the voltage drop during motor startup shall be taken into account. The lowest voltage at the motor connecting terminals during startup shall normally be assumed at 80 % of the design-basis motor voltage. In the case of a connection to a voltage-controlled busbar with a high voltage stability, e.g., to a converter unit with limit values in accordance with Table 4-1 of safety standard KTA 3704, it is permissible to assume that the lowest voltage will not be lower than 90 % of the design-basis motor voltage.

c) If a functional capability is required under design basis accident conditions, e.g., a loss-of-coolant accident in the case of light water reactors, the reduction of the motor torque due to the increased ambient temperature on account of the design basis accident conditions shall be taken into account.

(2) Both the heat rating and the type of insulation material of the motor coil shall be selected with regard to the most unfavorable ambient conditions and the largest loading.

5.7 Electric Power Supply

(1) The actuator shall be connected to an electric power supply such that, taking the voltage drop during motor startup into account, the connecting terminal voltage is never lower than the lowest design-basis connecting terminal voltage taken into account in the design under Section 5.6 para. 1 item b).

(2) The voltage drop shall be determined based on the lowest specified static busbar voltage as follows:

a) In the case of a connection to an emergency diesel switchgear, the basis shall be that limit value of the design-basis busbar voltage specified as startup criterion in accordance with Sec. 3.12.2 of safety standard KTA 3702.

Note:
In order to be able to maintain a minimum connecting terminal voltage of 80 % of the design-basis motor voltage as specified in Section 5.6 para. 1, it may be necessary to install a voltage stabilizer.

b) In the case of a connection to a voltage-controlled busbar with a high voltage stability, e.g., to a converter unit with the limit values in accordance with Table 4-1 of safety standard KTA 3704, the basis shall be the lower limit value of the static voltage deviation.

(3) If a functional capability is required under design basis accident conditions, e.g., a loss-of-coolant accident in the case of light water reactors, the increase in ohmic resistance of the supply cables due to the increased ambient temperature on account of the design basis accident conditions shall be taken into account.

5.8 Controlled Shut-down, Torque Limitation and Position Checkback Signals

(1) The devices involved in the controlled shut-down and the torque limitation, including the existing bypass circuits, shall be designed to such a degree of reliability that they are not the determining factor of the non-availability of the actuator with its associated valve.

Note:
Devices that are involved in the controlled shut-down may depend on, e.g., path, time, flow or torque.

(2) During startup and change-over procedures, the torque limitation may not cause any disconnection or shut-down of the actuator on account of the accelerated mass.

(3) In the case of actuators with a torque-dependent controlled shut-down, if, in a certain control range, the breakaway torque can be greater than the preset cut-out torque, then the torque-dependent controlled shut-down shall be bypassed in this control range. In this context, after the bypass is removed, it shall be ensured that the differential of the by-passed torque switch does not lead to any unintentional disconnection or shut-down of the actuator.

(4) During bridged-mode operation, the stress calculation specified in Section 5.9 shall normally be based on the maximum torque achievable by the actuator. The calculation may be based on a torque smaller than the maximum achievable torque, provided, preventive measure ensure that this smaller torque is not exceeded during the by-pass mode of operation.

Note:
This may be achieved, e.g., by activating an overriding second torque switch that is adjusted to a higher torque limit value or by a slip clutch, provided, either one of these methods remains active whenever the torque-dependent disconnection or shut-down is bypassed.

(5) The position checkback signal of the actuator may be used as position checkback for the valve, provided, a reliable relationship exists between the position checkback signal transmitter and the position of the valve.

(6) Any torque limiting device shall be designed such that the cut-out torque cannot deviate from the required value by more than 10 % of the maximum permissible adjustable cut-out torque.

5.9 Stress Calculation

The component parts subjected to mechanical loads shall be designed such that they can absorb any of the loads to be considered without the permissible stresses being exceeded and their functional capability being reduced.

5.10 Design for Design Basis Accident Conditions

Any actuator required to perform its function under design basis accident conditions, e.g., a loss-of-coolant accident in the case of light water reactors, shall, including its cable connecting terminals, be designed taking the design-basis-accident-related influences into account, e.g., temperature, pressure, humidity, radiation, corrosive media. The influence of any prior operational loadings shall be taken into account.

5.11 Manual Operation, Monitoring and Mechanical Safety Features

(1) Motorized operation shall always have priority over manual operation (by means of a hand wheel).

(2) Electro-technical plug-in devices and plug connectors shall be secured such that no self-unplugging is possible. The unplugged condition shall be detectable as specified in Section 3.5 para. 2.

5.12 Controlled Shut-Down Time

(1) The actuator controls and the utilization of the limit switches shall be coordinated with each other.

(2) The maximum time required for a controlled shut-down, i.e., the time period between the triggering of the controlled shut-down devices of the actuator and the separation from the power grid (shut-down delay), shall be specified. This shut-down delay shall be taken into account when determining the torque magnification factor as specified in Section 5.5.

5.13 Technical Documents

(1) The technical documents specified in paras. 2 and 3 shall indicate how the actuators are designed, fabricated, assembled and tested in accordance with the safety requirements.

(2) The following superordinate technical documents shall be prepared:

a) list of the actuators of the safety system, including a specification of the type of required resistance to design basis accident conditions and including their assignment to the respective valves and final locations,

b) list of the technical requirements.

(3) The following technical documents shall be prepared for the actuators to be used:

a) specification of the technical data of the actuators (without the drive motor):
   - aa) manufacturer,
   - ab) designation of the type,
   - ac) design-basis output speed,
   - ad) maximum adjustable cut-out torque, or design-basis torque,
   - ae) maximum permissible torque during operation and in the case of a cut-out failure,
   - af) torque magnification factors as a function of the valve stiffness during operation and in the case of a cut-out failure,
   - ag) transmission ratio and efficiency of the transmission, and
   - ah) total mass, and the location of the center of gravity.

b) specification of the technical data of the drive motor:
   - ba) manufacturer,
   - bb) designation of the type,
   - bc) design-basis power,
   - bd) mode of operation,
   - be) design-basis voltage, design-basis frequency and permissible deviations,
   - bf) design-basis current and startup current,
   - bg) design-basis speed,
   - bh) maximum torque,
   - bi) minimum startup torque at the lowest specified connecting terminal voltage and at the maximum ambient temperature and, if required, at the design basis accident temperature,
   - bk) heat rating,
   - bl) type of protective enclosure, and
   - bm) type of construction.

c) indications and certifications that the design requirements specified in Section 5 are fulfilled,

d) certification regarding the suitability of the actuator for its deployment in nuclear power plants and that the requirements specified in Section 4 are fulfilled,

e) schedule of the planned commissioning tests,

f) schedule of the planned inservice inspections.

6 Design of the Valve-Actuating Magnets

6.1 Basic Requirements

The actuating magnet of a valve (individual valve, pilot valve or supplementary magnetic load) shall be designed such that it meets the requirements of the actuated valve and of the associated process-engineering system under the ambient conditions prevailing during specified normal operation and during the design basis accidents to be considered.

Note:
Requirements regarding valve design will be specified only as far as they relate to the mutual dependencies of actuating magnet and valve, or if tests can only be performed on the entire solenoid-operated valve. Actuating magnets may actuate, e.g., independent solenoid-operated valves or the pilot valves of hydraulic or pneumatic valves.

6.2 Determining the Magnetic Counterforce and the Biasing Force

The stroke-length dependent forces shall be determined that are required for actuating and repositioning the valve and which, considering the given actuation times and operational influences (e.g., ageing, wear), result from overcoming the system-related differential pressure across the valve; the actuating magnet and the biasing-force elements shall be designed accordingly (magnetic-counterforce versus stroke-length characteristic). The largest and the smallest magnetic forces shall be specified with regard to the strength calculation of the valve and other components, e.g., biasing spring.

6.3 Electro-technical Design

(1) The actuating magnet shall be designed to deliver a magnetic force over the entire travel distance and within the

required travel time (dynamic magnetic-force versus stroke-length characteristic) with said magnetic force, even under the most unfavorable operating conditions, remaining above the magnetic-counterforce versus stroke-length characteristic as specified in Section 6.2.

Note:
To characterize the work capacity of an actuating magnet, the manufacturer specifies the static magnetic-force versus stroke-length characteristic. The actual forces supplied over the travel distance are a function of the load and the linear velocity and are represented by dynamic magnetic-force versus stroke-length characteristics. These latter characteristics, in the case of direct-current actuating magnets, can be lower than the static magnetic-force versus stroke-length characteristic by a factor of between 1.5 and 2. A reliable switching operation of the actuating magnet is, therefore, only ensured if the static magnetic-force versus stroke-length characteristic is larger than the magnetic-counterforce versus stroke-length characteristic by a corresponding factor.

In this context, the following conditional requirements shall be taken into account:

a) The limit values of the deviations of the magnetic force.

b) The most unfavorable of the anticipated operating modes (short-term operation, intermittent operation or continuous operation) as well as the most unfavorable kind of duty cycle (relative duty cycle, transition duty cycle, maximum duty cycle).

c) The temperature-rise limit of the magnet system at maximum voltage on account of the maximum self-heating of the magnet coil during the specified mode of operation and, if applicable, on account of the influence of the temperature of the medium.

d) The maximum ripple of the planned direct-current power supply.

   Note:
   In the case of small actuating magnets, the ripple may influence the magnetic force.

e) The range of the permissible voltage change shall be specified between an upper limit value of the connecting terminal voltage where operation of the actuating magnet shall be possible under conditions as specified in item b) or c), and a lower limit value (response value of the voltage) where the maximum required forces of the actuating magnet are still ensured over the travel distance as specified in Section 6.2. The specified values shall be based on the voltage range of the planned electric power supply and shall take the maximum voltage drop of the feeder cable into account. Examples for the ranges of the permissible voltage changes at the connecting terminals of the actuating magnets are presented in **Table 6-1**.

f) A distance of at least 5 % of the response value of the voltage shall be maintained between the response value of the voltage specified under item e) and the voltage value when leaving the functional position of the valve (repositioning value of the voltage). The repositioning value of the voltage at warm operating condition shall not be smaller than 15 % of the lower limit value of the connecting terminal voltage.

g) If functional capability is required under design basis accident conditions, e.g., a loss-of-coolant accident in the case of light water reactors, the reduction of the magnetic force due to the increased ambient temperature on account of the design basis accident conditions shall be taken into account.

(2) Both the heat rating and the type of insulation material of the excitation coil of the actuating magnet shall be selected in accordance with the most unfavorable ambient conditions and with the most unfavorable mode of operation as specified in para. 1 item b).

(3) Impermissible switching overvoltages shall be limited by corresponding circuitry measures. Circuitry devices for this purpose shall normally, under consideration of the ambient conditions, be installed as close to the actuating magnet as possible.

6.4 Electric Power Supply

(1) The actuating magnet shall be connected to an electric power supply such that, taking the voltage drop at maximum current through the actuating magnet into account, the connecting terminal voltage is never lower than the lowest design-basis connecting terminal voltage accounted for in the design as specified in Section 6.3 para. 1.

(2) When determining the voltage drop, the specified static range of the corresponding busbar voltage shall be taken into account.

Note:
Examples are presented in **Table 6-1**.

6.5 Design for Design Basis Accident Conditions

An actuating magnet required to perform its function even under design basis accident conditions, e.g., a loss-of-coolant accident in the case of light water reactors, shall, including its cable connecting terminals, be designed taking the design basis accident-related influences into account, e.g., temperature, pressure, humidity, radiation, corrosive media. The influence of any prior operational loadings shall be taken into account.

6.6 Monitoring and Mechanical Safety Features

(1) In the case of valves actuated by one or more pilot valves equipped with actuating magnets, the function of the pilot valves shall be detectable in the main control room, e.g., by position signal displays, provided, this is necessary with regard to testability or to the assessment of the condition of the system.

(2) Electro-technical plug-in devices and plug connectors shall be secured such that no self-unplugging is possible. The unplugged condition shall be detectable as specified under Section 3.5 para. 2.

6.7 Technical Documents

(1) The technical documents specified in paras. 2 and 3 shall indicate how the actuating magnets for the valves are designed, fabricated, assembled and tested in accordance with the safety requirements.

(2) The following superordinate technical documents shall be prepared

a) list of the actuating magnets of the safety system, including a specification of the type of required resistance to design basis accident conditions and including their assignment to the respective valves and final locations,

b) list of technical requirements.

(3) The following technical documents shall be prepared for the planned actuating magnets and valves:

a) specification of the technical data of the actuating magnets:

   aa) manufacturer,

   ab) designation of the type,

   ac) maximum excitation current,

   ad) smallest and largest magnetic force in the initial and end positions of the travel path,

   ae) mode of operation,

Running No.	Range of Voltage Change	Upper Limit Value	Lower Limit Value
1	Direct current actuating magnets connected to 48 V dc-current switchgear (battery facility with lead battery, 2 × 13 cells)		
1.1	at the busbar	58.5 V [1]	47.0 V [2]
1.2	at the connecting terminals of a magnet, e.g.,		
1.2.1	in case of a low loop resistance and low voltage drop (e.g., 1 V) in the feeder cable, or	57.5 V [4]	46.0 V [4]
1.2.2	in case of a high loop resistance and high voltage drop (e.g., 4 V) in the feeder cable	54.5 V [4]	43.0 V [4]
2	Direct current actuating magnets connected to 220/380 V diesel emergency switchgear (with rectifier)		
2.1	at the busbar	242 V [3]	176 V [3]
2.2	in the branch-off at the output of a rectifier 220 V /198 V	218 V	158 V
2.3	at the connecting terminals of a magnet, e.g.,		
2.3.1	in case of a low loop resistance and low voltage drop (e.g., 2 V) in the feeder cable, or	216 V [4]	156 V [4]
2.3.2	in case of a high loop resistance and high voltage drop (e.g., 8 V) in the feeder cable	210 V [4]	150 V [4]
3	Direct current actuating magnets connected to 220 V dc-current switchgear (battery facility with lead battery, 108 cells)		
3.1	at the busbar	243 V [5]	193 V [6]
3.2	at the connecting terminals of a magnet, e.g.,		
3.2.1	in case of a low loop resistance and low voltage drop (e.g., 2 V) in the supply cable, or	241 V [4]	191 V [4]
3.2.2	in case of a high loop resistance and high voltage drop (e.g., 8 V) in the supply cable	235 V [4]	185 V [4]

1) Maximum output voltage of the rectifier unit during trickle charge of 2 x 13 cells with 2.23 V + 1 % each (cf. Table 3-3 of safety standard KTA 3705).

2) Minimum battery voltage during discharge of 2 × 13 cells down to 1.85 V each (cf. Table 3-3 of safety standard KTA 3705) minus a voltage drop of 1 V downstream to the busbar.

3) 1.1 U_N to 0.8 U_N for U_N = 220 V (cf. Table 3-1of safety standard KTA 3705).

4) Based on the given voltage range at the busbar or at the outlet of the branch rectifiers, the voltage drop in the feeder cable shall be included in the calculation with respect to both the upper and the lower limit value of the connecting terminal voltage. In order to comply with a given maximum voltage drop between switchgear branch and magnet terminals, a sufficiently dimensioned cable diameter shall be chosen corresponding to the respective magnet rating. In this context, the loop resistance shall be based of the maximum ambient temperature or on the expected ambient temperature during a design basis accident. In addition, the change of the coil resistance as a result of self-heating may be included when determining the voltage change.

5) Maximum output voltage of the rectifier unit during trickle charge of 108 cells with 2.23 V + 1 % each (cf. Table 3-4 of safety standard KTA 3705).

6) Minimum battery voltage during discharge of 108 cells down to 1.80 V each (cf. Table 3-4 of safety standard KTA 3705) minus a voltage drop of 1 V downstream to the busbar.

Table 6-1: Examples for ranges of the permissible voltage changes at the connecting terminals of actuating magnets

af) voltage limit values and permissible ripple in the case of a direct-current power supply,

ag) course of the minimum magnetic force at the lowest specified connecting terminal voltage and at the maximum ambient temperature and, if required, at the design basis accident temperature,

ah) heat rating,

ai) type of protective enclosure, and

ak) protective circuitry for the limitation of overvoltages.

b) indications regarding the force required for operation of the valve as specified in Section 6.2 and regarding the required shortest and longest actuation time for the valve,

c) indications and certifications that the design requirements specified in Section 6 are fulfilled,

d) certification regarding the suitability of the actuating magnet for its deployment in nuclear power plants and that the requirements specified in Section 4 are fulfilled,

e) schedule of the planned commissioning tests,

f) schedule of the planned inservice inspections.

7 Design of the Electrical Drive Mechanisms of Driven Machines

7.1 Basic Requirements

The electrical drive mechanism of a driven machine (e.g., pumps, fans, compressors) shall be designed such that it meets the requirements of the driven machine and of the associated process-engineering system under the ambient conditions prevailing during specified normal operation and during the design basis accidents to be considered.

7.2 Power Rating and Torque Curve

(1) The loading torque characteristic of the electrical drive mechanism of a driven machine shall be determined as a function of rotational speed and mode of operation, e.g., startup against an open or closed gate valve, and shall be taken into account in the design of the drive motor. In this context, manufacture-related permissible deviations and operational influences (e.g., ageing, wear) shall be taken into account.

(2) The power rating and torque class of the drive motor shall be chosen such that, in the range between standstill and design-basis rotational speed, the motor torque is sufficiently higher than the load torque such that a startup and stable continuous operation are ensured. In this context, the following conditional requirements shall be taken into account:

a) The most unfavorable limit values of the permissible motor torque deviations (i.e., of the startup, saddle and pull-out torques) relative to the design-basis values shall be taken into account. In this context, limit values may be specified that will restrict the deviations otherwise permissible in accordance with Table 20 of DIN EN 60034-1.

b) The reduction of the motor torques due to the voltage drop during motor startup shall be taken into account.

   Note:
   The lowest voltage at the motor connecting terminals during startup amounts to, e.g., in accordance with Table 3-1 of safety standard KTA 3705, in the case of high-voltage motors 75 % and in the case of low-voltage motors 70 % of the design-basis motor voltage.

c) If functional capability is required under design basis accident conditions, e.g., a loss-of-coolant accident in the case of light water reactors, the reduction of the motor torque due to the increased ambient temperature on account of the design basis accident conditions shall be taken into account.

(3) The thermal design shall normally be based on three successive startups from the cold state or on two startups from the warm operating condition.

7.3 Electric Power Supply

(1) The drive mechanism shall be connected to an electric power supply such that, taking the voltage drop during motor startup into account, the connecting terminal voltage is never lower than the lowest design-basis connecting terminal voltage accounted for in the design as specified in Section 7.2 para. 2.

(2) When determining the voltage drop, the lowest specified static busbar voltage shall be taken into account. In the case of a connection to a diesel emergency power switchgear, the limit value of the design-basis busbar voltage shall be as specified for the startup criterion in accordance with Sec. 3.12.2 of safety standard KTA 3702.

(3) If functional capability is required under design basis accident conditions, e.g., a loss-of-coolant accident in the case of light water reactors, the increase in ohmic resistance of the low-voltage supply cables due to the increased ambient temperature on account of the design basis accident conditions shall be taken into account.

7.4 Design of the Drive Motor

(1) The drive mechanisms of driven machines shall normally be three-phase current asynchronous squirrel-cage induction motors allowing an immediate startup switching.

Note:
Other types of motors may be necessary, e.g., if control of the rotational speed is required.

(2) Both heat rating and type of the insulation material of the motor coil shall be selected with regard to the most unfavorable ambient conditions and the largest loading.

7.5 Design for Design Basis Accident Conditions

A drive motor of a driven machine where the motor is required to perform its function even under design basis accident conditions, e.g., a loss-of-coolant accident in the case of light water reactors, shall, including its cable connecting terminals, be designed taking the design-basis-accident-related influences into account, e.g., temperature, pressure, humidity, radiation, corrosive media. The influence of any prior operational loadings shall be taken into account.

7.6 Monitoring

Pressure-lubricated friction bearings shall be designed such that both the oil pressure and the bearing temperature can be measured. High-voltage motors shall normally be provided with coil temperature sensors.

7.7 Mechanical-Equipment Protection

Notes:
(1) This section addresses only those mechanical-equipment protection devices whose signals do not have priority over the signals of the reactor protection system.

(2) Mechanical-equipment protection devices whose signals do have priority over the signals of the reactor protection system are designed in accordance with Sec. 6 of safety standard KTA 3501 (cf. Section 1 para. 4 item a)).

(1) Mechanical-equipment protection devices whose signals do not have priority over the signals of the reactor protection system shall be designed to be highly reliable. Components with a proof of successful operating experience shall normally be used. Their static and dynamic characteristics shall meet the requirements of the mechanical equipment. They shall also meet the requirements of the prevailing ambient and operating conditions at their final location. In particular, their functional capability shall not be impermissibly impaired by

a) mechanical loadings, e.g., vibrations,

b) influences from the measurement medium,

c) temperature, pressure, humidity, radiation, and

d) chemical influences.

(2) Monitors shall normally themselves be monitored by control circuits (non-equivalence monitoring, wire break monitoring).

(3) The mechanical-equipment protection devices shall normally be supplied from a non-interruptible emergency power supply system with the energy storage in the form of parallel operated batteries with rectifier units.

(4) The mechanical-equipment protection devices shall normally be testable without manipulations of the circuitry. It shall be possible to perform any partial tests such that they overlap each other.

(5) The mechanical-equipment protection devices of those electrical drives of the safety system that are required for the mitigation of design basis accidents and that are not triggered by the reactor protection system shall meet the requirements of paras. 1 through 4 and shall, additionally, be able to withstand the ambient conditions due to a design basis accident.

7.8 Technical Documents

(1) The technical documents specified in paras. 2 and 3 shall indicate how the electrical drive mechanisms of driven machines are designed, fabricated, assembled and tested in accordance with the safety requirements.

(2) The following superordinate technical documents shall be prepared:

a) list of the electrical drive mechanisms of the safety system, including an indication of the kind of the required resistance to design basis accident conditions and their assignment to the respective driven machines and final locations,

b) list of the technical requirements.

(3) The following technical documents shall be prepared for the planned electrical drive mechanisms of driven machines:

a) specification of the technical data of the electrical drive mechanisms:

   aa) manufacturer,

   ab) designation of the type,

   ac) design-basis power,

   ad) mode of operation,

   ae) design-basis voltage and design-basis frequency,

   af) design-basis current and startup current,

   ag) design-basis speed,

   ah) minimum startup torque at the lowest specified connecting terminal voltage and at the maximum ambient temperature and, if required, at the design basis accident temperature,

   ai) heat rating,

   ak) type of protective enclosure, and

   al) type of construction.

b) indications regarding the power required as specified in Section 7.2 for the drive mechanism of the driven machine,

c) indications and certifications that the design requirements specified in Section 7 are fulfilled,

d) certification regarding the suitability of the electrical drive mechanism for its deployment in nuclear power plants and that the requirements specified in Section 4 are fulfilled,

e) schedule of the planned commissioning tests,

f) schedule of the planned inservice inspections.

8 Electro-Technical Design of the Control Rod Drive Mechanisms

(1) The electro-technical design of the control rod drive mechanisms of the reactor trip system shall fulfill the following requirements:

a) The control rod drive mechanisms shall be designed to withstand the ambient conditions prevailing during specified normal operation and during the design basis accidents to be taken into account.

b) The control rod drive mechanisms and their control interface shall be designed such that the limit values for the rod velocities on which the design basis accident analysis is based are maintained.

c) In the case of cooled drive mechanisms, the driving coil shall basically be designed such that failure of any active components of the cooling system is permissible for a duration of 30 minutes. This requirement may be waived if the active components of the cooling system meet the single failure criterion. A failure of the cooling system shall cause a class I hazard alarm.

d) If the design basis accident analysis is based on the assumption that the shut-down position is secured by an electric backup device (e.g., a following counter-nut), then the drive mechanism shall be capable of performing this backup operation even upon occurrence of a design basis accident.

(2) With respect to the trigger circuit of the reactor trip system, the requirements in accordance with Sec. 4.1.3.1 of safety standard KTA 3501 shall be met with respect to failure combinations; in this context, common mode failures shall be prevented by applying the design principle of diversity.

Note:
In the case of PWR plants (control rod drop by gravitational force), this requirement may be met, e.g., by shutting down the power supply to the control rod drive mechanisms with different switching devices than the ones used for shutting down the associated busbar voltage.

(3) Technical documents shall be prepared that prove that the requirements of paras. 1 and 2 are fulfilled.

9 Basic Requirements for Type Approval Tests of Electrical Drive Mechanisms of the Safety System

(1) Type approval tests shall be performed to certify the specified properties of electrical drive mechanisms of the safety system. If a production series is subjected to a type approval test, it shall be verified that the individual types of drive mechanisms are associated with this batch.

(2) It is permissible to use the results of type approval tests performed in accordance with DIN IEC 60780.

(3) Type approval tests shall normally be performed on three units of the respective drive mechanism type or on selected drive mechanisms of a production series.

(4) Available operating experience and the results of prior tests may be considered in the type approval test, provided, the safety-related requirements of the present safety standard are fulfilled.

(5) In the case of electrical components, e.g., electrical motors, actuating magnets, plug-and-socket devices, or switches, it is permissible to perform type approval tests in accordance with VDE regulations to certify the properties specified in these VDE regulations.

(6) Whenever the application in a safety system requires safety-related properties which are not covered by the type approval tests specified in para. 2, additional type approval tests shall be performed. This requirement applies, in particular, to the following cases:

a) The resistance to radiation shall be verified for those electrical drive mechanisms of the safety system which are planned for use under operational conditions involving radiation exposure. In this context, either an irradiation test or an analytical verification shall be performed. The source of the data used in the analytical verification shall be specified. In case of an experimental verification, the conditional requirements specified, e.g., for actuators in Section 10.3.4 paras. 4 and 5, shall be fulfilled.

b) If required in the particular case, it shall be verified, within the frame of specified requirements, that the electrical drive mechanisms will withstand the induced vibrations to be expected. Vibration tests performed on other electrical drive mechanisms which are comparable with regard to their vibrational behavior may be used for this certification.

   Note:
   Detailed requirements are specified in safety standard KTA 2201.4, Design of Nuclear Power Plants against Seismic Events, Part 4: Requirements for the Procedures for Verifying the Safety of Mechanical and Electrical Components against Earthquakes. Regarding the experimental verification, the conditional requirements specified, e.g., for actuators in Section 10.3.6 of the present safety standard shall be fulfilled.

c) For those electrical drive mechanisms of the safety system required to perform their function even under design basis accident conditions, e.g., a loss-of-coolant accident in the case of light water reactors, the resistance to the design basis accident conditions shall be verified by a type approval test.

Note:
In this context, see the conditional requirements specified in Section 10.3.7 e.g. for actuators.

(7) A test schedule shall be prepared which shall contain at least the following data:

a) description of the drive mechanism or of the production series, including technical drawings, parts lists and data on materials, as well as a description of the planned factory tests,
b) criteria for selecting the test objects,
c) technical data identifying the test objects,
d) dimension sheets for the test object,
e) description of the testing device,
f) extent of the test steps,
g) sequence of the test steps, and
h) the method and boundary conditions, the intermediate tests and the test criteria for each test step.

(8) The test objects shall be taken directly from factory production. The planned factory tests shall have been performed and documented. The results of the factory tests on the complete drive mechanism shall be recorded for use as baseline data and as data for later reference.

(9) If a failure occurs during the type approval test, an investigative report shall be prepared that shall contain information on the investigation performed and a statement on the determined cause of failure. If the investigation shows evidence of a common mode failure, corresponding corrective measures shall be taken. The extent of the type approval test to be repeated shall be specified in agreement with the authorized expert. If no common mode failure was identified, the test object shall be repaired and the interrupted test step repeated before the remaining test steps of the type approval test are continued.

(10) The type approval test is considered as successfully passed if the inspection of the submitted technical documents gave no cause for complaints and the physical tests were able to demonstrate the functional capability.

10 Type Approval Tests of Actuators

10.1 Verification of the Torque-Related Design

The [torque-related] design of the actuators in accordance with the requirements specified in Sections 5.5, 5.6 and 5.8 para. 6 shall be verified within the framework of the type approval test.

10.2 Stress Analysis

10.2.1 General requirements

(1) A stress calculation shall be performed for all those parts of the actuators, interposed transmissions and components of the remote controls that are within the load path.

(2) The stress calculation may be replaced or supplemented by experimental verifications. The experimental verifications shall be based on the same conditional requirements as the analytical verification. In case of experimental verifications, a test schedule shall be prepared and agreed upon with the authorized expert.

(3) The analytical strength verification shall be performed as specified in Sections 10.2.2 through 10.2.5. The resistance to the external forces shall be verified by the physical part of the type approval test specified in Section 10.3 or by analysis. Dynamic loads may be accounted for by introducing equivalent static loads.

(3) In case of an analytical strength verification, the applied characteristic values of the materials and the applied German quality standards shall be specified. If there are no applicable quality standards, the strength characteristics and the test requirements shall be specified. In this case, a verification is required that the strength characteristics of the chosen materials of the parts in the load path are maintained, and this verification shall either be in the form of an acceptance test certificate 3.1 in accordance with Sec. 4.1 of DIN EN 10204 or in the form of a mechanical test, e.g., of one finished product from each production series, to be performed in accordance with test requirements that are to be specified.

10.2.2 Analytical strength verification in the case of repeated loadings

The strength in the case of repeated loadings shall be verified analytically as specified under item a) or b). The bearing strength of the tooth dedendum and the tooth flank shall be verified as specified under item c).

Note:
The loading combinations may be determined, e.g., in accordance with safety standard KTA 3902, Lifting Equipment in Nuclear Power Plants.

a) In the case of actuators with a torque tripping device, the fatigue strength shall be verified for the maximum permissible adjustable cut-out torque at the actuator, and, in the case of actuators without a torque tripping device, for the design-basis torque of the actuator. In this context, a safety factor greater than or equal to 2 shall normally be maintained with respect to the characteristic values of the materials.

b) The creep limit shall be verified with respect to the loadings specified in Section 5.4 including the torque magnification factor specified in Section 5.5 para. 1. In this context, the number of load collectives applied to open-loop actuators shall basically be 5000; any deviation from this requirement shall be documented in the test records. Within a single load collective, the maximum permissible adjustable cut-out torque shall normally be assumed to be

   ba) for a duration of 2 seconds, at 100 %,

   bb) for a duration of 0.1 seconds and

      bb1) actuators with worm-gear technology, at 200 %,

      bb2) actuators with a mechanical torque limiter (controlled friction coupling) and with an ensured torque magnification factor, as specified by the manufacturer.

   and

   bc) for a duration of 57.9 seconds, at 50 %.

   In the case of closed-loop actuators, the number of loadings in the end positions and the load collective shall be specified depending on the planned mode of operation; the verification of the creep limit shall be based on these values. In this context, a safety factor greater than or equal to 2 shall normally be maintained with respect to the characteristic values of the materials.

c) In the case of gears, worms and worm gears, the bearing strength of the tooth dedendum and the tooth flank shall be verified. In this context, a safety factor shall be applied relative to the calculated characteristic values that is greater than or equal to 1.1 for the tooth flank bearing strength and greater than or equal to 1.5 for the tooth dedendum bearing strength.

10.2.3 Analytical strength verification in the case of static loadings to be assumed

(1) Component parts which are loaded only once during a load cycle shall be analyzed with respect to static loadings.

Actuators with a torque-dependent controlled shut-down shall be analyzed with respect to static loadings

a) at twice the maximum permissible adjustable cut-out torque, and

b) at the torque on account of failure of the torque limiter and on account of manual operation.

(2) In the case of standardized component parts with specified load limit values (e.g., coiled spring pins or retaining rings), it shall be verified for each kind of stress (e.g., shear, bending, tension, compression) that the loading limits will not be exceeded.

(3) The stress design shall be verified for the loadings that can occur in case of a failure of the torque limiter of the actuator, e.g., in case of a failure of the torque limiter or of a blocking whenever the torque-dependent disconnection or shut-down is bypassed. The loading to be assumed for these kind of functional failures shall be the maximum torque of the drive motor at 110 % of the design-basis voltage at the motor connecting terminals. The stress analysis shall be based on a total of ten of these functional failures; a safety factor greater than or equal to 1.25 shall normally be maintained relative to the yield strength.

(4) Splines, spline shafts and parallel keys shall be analyzed with regard to bearing stress; in the case of a parallel-key connection, a safety factor shall be maintained relative to the yield strength that shall normally be greater than or equal to 2.5 for the loading condition specified under para. 1 item a) and greater than or equal to 1.6 for the loading condition specified under para. 1 item b).

10.2.4 Analytical strength verification in the case of threaded connections

(1) In the case of threaded connections that are stressed within the load path, the minimum prestress force shall be verified in accordance with Part 1 and 2 of VDI 2230 taking the startup torque, coefficients of friction and materials into account. The minimum prestress force shall be sufficiently large such that the possible torques and forces can be transmitted. In the case of a positive (frictionally tight) transmission of forces, the calculation shall be based on a coefficient of friction for (non-greased) steel on steel of $\mu = 0.15$.

(2) In case of the flange connection between actuator and valve, the maximum permissible prestress force of the bolt and its minimum required depth of engagement shall be specified and verified.

Note:
The dimensions of the flange connection are verified together with the verifications of the valve.

10.2.5 Analytical strength verification in the case of roller bearings

(1) The fatigue life of roller bearings shall be verified for the load collectives specified in Section 10.2.2. The roller bearing design shall be based on the calculation data supplied by the bearing manufacturer. In this context, the nominal fatigue life to be assumed shall be that for a survival probability of 97 %.

Note:
In this context, the nominal fatigue life (L 10) from the calculation data of the bearing manufacturers shall be multiplied by a factor of 0.44.

(2) The dynamic loading of the roller bearings may be determined based on the analytic method of cubic averaging. The static loading of the roller bearings to be assumed shall be the maximum load during functional failure of the actuator.

10.3 Physical Test

10.3.1 General requirements

(1) The basic requirements for the type approval tests of electrical drive mechanisms of the safety system as specified in Section 9 shall be fulfilled.

(2) In the case of the drive motors for actuators, the temperature-rise test in accordance with Sec. 8 of DIN EN 60034-1 and the coil test in accordance with Sec. 9.2 of DIN EN 60034-1 shall be certified. In addition, the following tests of the drive motors shall be certified:

a) the test of the minimum startup torque at the lowest specified connecting terminal voltage and at the maximum permissible coil temperature, and

b) the test of the maximum torque at the highest specified connecting terminal voltage and a coil temperature of 25 °C.

(3) In the case of actuators from a production series, type approval tests as specified in the flow chart shown in **Figure 10-1** shall be performed; the extent of these tests shall be as follows:

a) To verify the mechanical fatigue life, a type approval test shall basically be performed that comprises the pre-loading specified in Section 10.3.4 and the test of mechanical fatigue life specified in Section 10.3.5. This type approval test may be waived if the mechanical fatigue life is verified by a certification of satisfactory service experience.

b) If vibration resistance is required for the actuators of a production series and an experimental verification is required, the vibration resistance shall be certified by a type approval test that comprises the pre-loading specified in Section 10.3.4 and the vibrational fatigue resistance test specified in Section 10.3.6.

c) In as far as the requirement to resist design basis accident conditions applies to a production series of actuators, a type approval test shall be performed to verify the resistance to design basis accident conditions that comprises the pre-loading as specified in Section 10.3.4 and the test of the resistance to the design basis accident conditions as specified in Section 10.3.7.

(4) The type approval tests shall be performed in accordance with the sequence of the test steps shown in **Figure 10-1**, however, each test object is required to be subjected to only one of the tests specified in para. 3 item a), b) or c). If more than one of the tests specified in para. 3) item a), b) or c) are performed on one and the same test object, the pre-loading specified in Section 10.3.4 need only be applied once in the course of the first test performed.

(5) Before and after each test step, an intermediate test shall be performed [as shown in **Figure 10-1**]. In these intermediate tests, the test objects shall be subjected to a visual examination and the functional capability shall normally be verified by a load cycle shown in **Figure 10-4**, however, without simulating any torque magnification factors. This load cycle shall normally be performed at 100 % of the design-basis voltage. Prior to each test step, a check of the testing device shall be performed.

10.3.2 Selection of the test objects

(1) The test objects shall normally be selected from a production series according to their major design characteristics. These include:

a) physical dimensions,

b) torques,

c) design-basis speeds,

d) dimensions of the drive motors,

e) type of switching and signaling device,

f) type of transmission, and

g) materials within the load path.

(2) The test objects shall be selected such that, with respect to their major design characteristics, there is comparability to those types of the production series which have not been tested; one of the test objects shall be that actuator most severely loaded by the individual type approval test specified in Section 10.3.1 para. 3 item a), b) or c).

10.3.3 Fabrication of the test objects and determination of the baseline data

The test objects selected as specified in Section 10.3.2 shall be taken as random samples from the production line. The factory tests specified in Section 14 shall have been performed and documented. The results of the final tests performed in the course of the factory test as specified in **Table 14-1** column 6 shall be recorded for use as baseline data and as data for later reference.

10.3.4 Pre-loading

(1) The functionally relevant, non-metallic materials used shall be thermally pre-loaded by subjecting the test objects to elevated temperatures taking the specified service life and the specified mean ambient temperature into account. In the case of wearable parts which will be replaced within the framework of operational maintenance (e.g., seals or lubricants), a correspondingly shorter service life may be used as basis than that which is used for the entire electrical drive mechanism. The pre-loading shall normally be calculated according to the Arrhenius equation. The n-degree rule shall basically be used if the activation energy of the functionally relevant components is unknown, but the material-dependent temperature constant is known.

Note:

n-degree-rule: $t_1 = t_2 \times 2^{\frac{T_2 - T_1}{n}}$

Arrhenius equation: $t_1 = t_2 \times e^{\frac{\Phi(T_2 - T_1)}{k \times T_2 \times T_1}}$

where

t_1 = specified service life

t_2 = testing time, pre-loading time

T_1 = specified mean ambient temperature taking the influence of radiation heat and heat conduction into account

T_2 = testing temperature

Φ = activation energy of the material

n = material-dependent temperature constant

k = Boltzmann constant

(2) With respect to its mechanical pre-loading, the test object shall be subjected to load cycles at the design-basis voltage, the normal ambient temperature and under the following conditions:

a) Open-loop actuators shall be subjected to 2000 load cycles (open-close cycle) with torque-dependent tripping in both end positions at the maximum permissible adjustable cut-out torque and an operating torque larger than or equal to 50 % of the maximum permissible adjustable cut-out torque, as well as with an operating time in each direction larger than or equal to 30 seconds. In this context, a torque magnification factor between 120 % and 200 % of the maximum permissible adjustable torque shall normally be achieved (see **Figure 10-2**).

b) Closed-loop actuators shall, for a specific operating time, be subjected to a specific number of loadings in the end positions and, additionally, to a specific mode of operation without torque loading in the end positions; the values for operating time, number of loadings and the operating mode shall be specified.

For one load cycle each at the beginning, in the middle and at the end of the mechanical pre-loading, the torque loading and motor power shall be recorded as a function of time.

(3) To simulate the loading from external overpressure, one load cycle at an increased ambient air pressure of 5 bar shall be performed as follows:

increase of pressure:	between 5 and 30 minutes,
holding time of pressure:	between 3 and 10 minutes,
decrease of pressure:	between 5 and 30 minutes.

(4) In the case of actuators which are planned for operation under radiation exposure where, therefore, test objects have to be subjected to an irradiation test as specified in Section 9 para. 6 item a), the test values for the absorbed dose and for the absorbed dose rate shall be specified as a function of the prevailing deployment conditions. In the case of actuators which are to be used inside the containment vessel of nuclear power plants with light water reactors, the test object shall normally be subjected to pre-loading by radiation at an absorbed dose rate smaller than or equal to 5×10^2 Gy/h until the test object has accumulated an absorbed dose larger than or equal to 5×10^4 Gy. The values for energy dose and dose rate are specified with respect to air and to a photon energy in the range between 0.8 MeV and 2 MeV.

(5) The following requirements shall be fulfilled when performing the irradiation test:

a) The test object may be irradiated with gamma rays under atmospheric conditions (oxygen content of the air).

b) The measurement uncertainty of the dosimetric procedures used shall be calculated into the measurement result such that the test dose required as specified in para. 4 is achieved. The choice of the measurement procedure may be left to the discretion of the testing division.

c) The test object shall normally be exposed to an ambient climate of a temperature between 18 °C and 28 °C (margin of fluctuation ± 5 K) and a relative humidity less than 75 %. If the required constancy of the temperature cannot be ensured, the ambient temperature shall be recorded during irradiation.

(6) For the simulation of the loading resulting from operational vibrations, e.g. vibration of pipes, the test object shall be subjected to a vibrational loading occurring sequentially in all three axes using a sine-sweep excitation with the following values:

a) 10 cycles from 5 Hz to 200 Hz to 5 Hz at 2 octaves per minute,

b) in the range of 5 Hz to 18 Hz, a constant amplitude of oscillation of ± 0.6 mm, and

c) in the range of 18 Hz to 200 Hz, a constant amplitude of acceleration of 0.75×9.81 m/s².

Note:
A vibrational loading simultaneously in all three axes is also permissible.

It is permissible to combine the vibrational fatigue resistance test specified in Section 10.3.6 with this test step.

(7) To determine intermediate test data, the measurements specified in **Table 14-1** column 6 – with the exception of the electric coil test – shall normally be performed at the end of the pre-loading phase.

10.3.5 Test of mechanical fatigue life

(1) In order to verify their mechanical fatigue life, the test objects pre-loaded as specified in Section 10.3.4 shall be subjected to the following loading:

a) In the case of open-loop actuators, the test objects shall be subjected to 3000 load cycles as specified in **Figure 10-2**,

b) In the case of closed-loop actuators, the test objects shall be subjected to 1.5 times the number of load cycles specified in Section 10.3.4 para. 2 item b).

(2) For one load cycle each at the start, in the middle and at the end of the test of mechanical fatigue life, the loading torque and motor power shall be recorded as a function of time.

(3) The measurements specified in **Table 14-1** column 6 shall be performed to determine the final data. Subsequently, the test object shall be dismantled and its component parts examined for wear.

(4) The test of mechanical fatigue life is considered as successfully passed if there are no indications of any

overstressing of component parts, of a wrong selection of materials or of other common mode failures.

10.3.6 Vibrational fatigue resistance test

(1) In the case of actuators for which an experimental verification of vibrational fatigue resistance is required as specified in Section 9 para. 6 item b) this vibration test shall be performed on test objects which were preloaded as specified in Section 10.3.4. In this context, it shall be verified that induced vibrations will have no detrimental effects on the physical integrity nor on the functional capability of the actuator. If, in special cases, the actuator is required to stay functional during vibrational impacts, the corresponding test procedures shall be specified.

Note:
If, e.g., switching functions have to be tested, the length of time that these switches are inadvertently open or closed shall be measured during the vibration test. Within the scope of the suitability review, it shall be determined whether these times are permissible with respect to their interaction with the control system.

(2) In case of the test for resistance against induced vibrations in the frequency range between 1 Hz and 35 Hz, e.g., due to earthquakes, the frequency range may be reduced to between 5 Hz and 35 Hz, provided, the test object does not show any resonance (magnification factor not larger than 2) below 10 Hz. The test may be performed either with a sine-sweep or a sine-beat excitation under the following conditions:

a) In the case of sine-sweep excitation:
   - aa) in the frequency range from approximately 5 Hz to 35 Hz – a constant amplitude of acceleration of 4.5×9.81 m/s²; in the frequency range below approximately 5 Hz – a constant amplitude of deflection of ± 50 mm,
   - ab) sweep rate: 1 octave/min, and
   - ac) test along each axis with one cycle.

b) In the case of sine-beat excitation:
   - ba) test amplitude: 4.5×9.81 m/s²,
   - bb) five sine-beat packages for each test frequency and along each axis,
   - bc) five sinusoidal oscillations per sine-beat package, and
   - bd) distance between test frequencies: ⅓ octave.

(3) The test for resistance to induced vibrations in the frequency range between 5 Hz and 100 Hz, e.g., due to an aircraft crash, may be performed either with a sine-sweep or a sine-beat excitation under the following conditions:

a) In the case of sine-sweep excitation:
   - aa) amplitude of acceleration shall be constant at 5×9.81 m/s²,
   - ab) sweep rate shall be less than of equal to 10 octaves/min, and
   - ac) test shall be performed with one cycle along each axis.

b) In the case of sine-beat excitation:
   - ba) test amplitude: 5×9.81 m/s²,
   - bb) one sine beat package for each test frequency and axis,
   - bc) four sinusoidal oscillations per sine beat package, and
   - bd) distance between test frequencies: ⅓ octave.

(4) The measurements specified in **Table 14-1** column 6 shall be performed to determine the final data.

(5) The test for resistance to vibrational fatigue is considered as successfully passed if there are no indications of overstressed parts, of a wrong selection of materials or of other common mode failures.

(6) The test for resistance to vibrational fatigue specified in Section 10.3.6 may be combined with the pre-loading in order to simulate the operational vibrations specified in Section 10.3.4 para. 6.

Note:
A vibrational loading simultaneously in all three axes is also permissible.

10.3.7 Test of resistance to design basis accident conditions

(1) If, as specified in Section 5.10, the design must accommodate design basis accident conditions, the loading sequence during the test shall be specified in form of a diagram plot (test curve). In this diagram plot, the values for pressure, temperature and humidity, the rise, fall and dwell times as well as the permissible deviations shall normally be specified. If the design basis accident is accompanied by radiation exposure, the test values for the absorbed dose and the absorbed dose rate shall be specified as a function of the prevailing deployment conditions. The test object shall be subjected to these loadings.

(2) If, as specified in Section 5.10, the design must accommodate conditions of a loss-of-coolant accident inside the containment vessels of a nuclear power plant with light water reactor, those actuators that were subjected to pre-loading as specified in Section 10.3.4 shall be subjected to the tests of the following paragraphs. These tests shall also include the interfaces to other components, e.g., to cables and cable connecting terminals.

(3) The test object shall be exposed to a steam admission at a pressure, temperature and humidity as specified in the conditions plotted in **Figure 10-3**. In the case of open-loop actuators, the functional tests and measurements shall be performed as specified in **Table 10-1**. For the closed-loop actuators, the functional tests and measurements shall be specified. For the case of a loss of coolant accident occurring outside of the pressure vessel (annulus, main steam valve compartment) and in other plants than the PWR 1300, the corresponding requirements shall be specified.

(4) For loss-of-coolant accident outside of the containment (main steam valve compartment, annulus) and other equipment than the PWR 1300, corresponding requirements apply which shall be specified in each case. The respective underlying test curves are shown in Figures 5-3, 5-4 and 5-5 of KTA 3505.

(5) If the functional operating time is specified at more than two hours after the onset of a design basis accident, the test object shall be subjected to an irradiation test in which it shall be irradiated with an absorbed dose rate smaller than or equal to 5×10^2 Gy/h until the test object, in addition to its pre-loading as specified in Section 10.3.4 para. 4, will have accumulated an additional absorbed dose larger than or equal to 2×10^5 Gy/h. The values for energy dose and dose rate are specified with respect to air and to a photon energy in the range between 0.8 MeV and 2 MeV. The irradiation test shall be performed under the conditions specified in Section 10.3.4 para. 5.

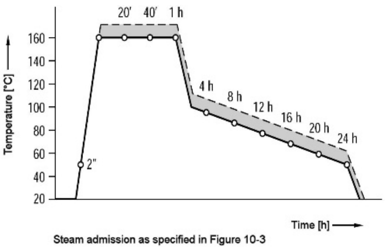
(6) If the functional operating time is specified at more than 24 hours after the onset of a design basis accident, the test objects shall normally be subjected to a long-term test during which the effects of temperature, humidity and corrosive media are simulated by performing a climate test lasting for 56 days at 75 °C and a relative humidity higher than or equal to 95 %. The corrosive effects from the boron content in the ambient air during a design basis accident in a power plant with a pressurized water reactor shall normally be simulated by spraying the test objects with borated water (boron concentration higher than or equal to 20 mg/kg). The measurements specified in **Table 10-1** shall be performed during this climate test.

(7) The measurements specified in **Table 10-1** column “Final Test” shall be performed, in case of a specified functional operating time of up to 2 hours following the steam admission specified in para. 3, in case of a specified functional operating time of up to 24 hours following the irradiation specified in para. 5, and in case

of a specified functional operating time of more than 24 hours following the long-term test specified in para. 6.

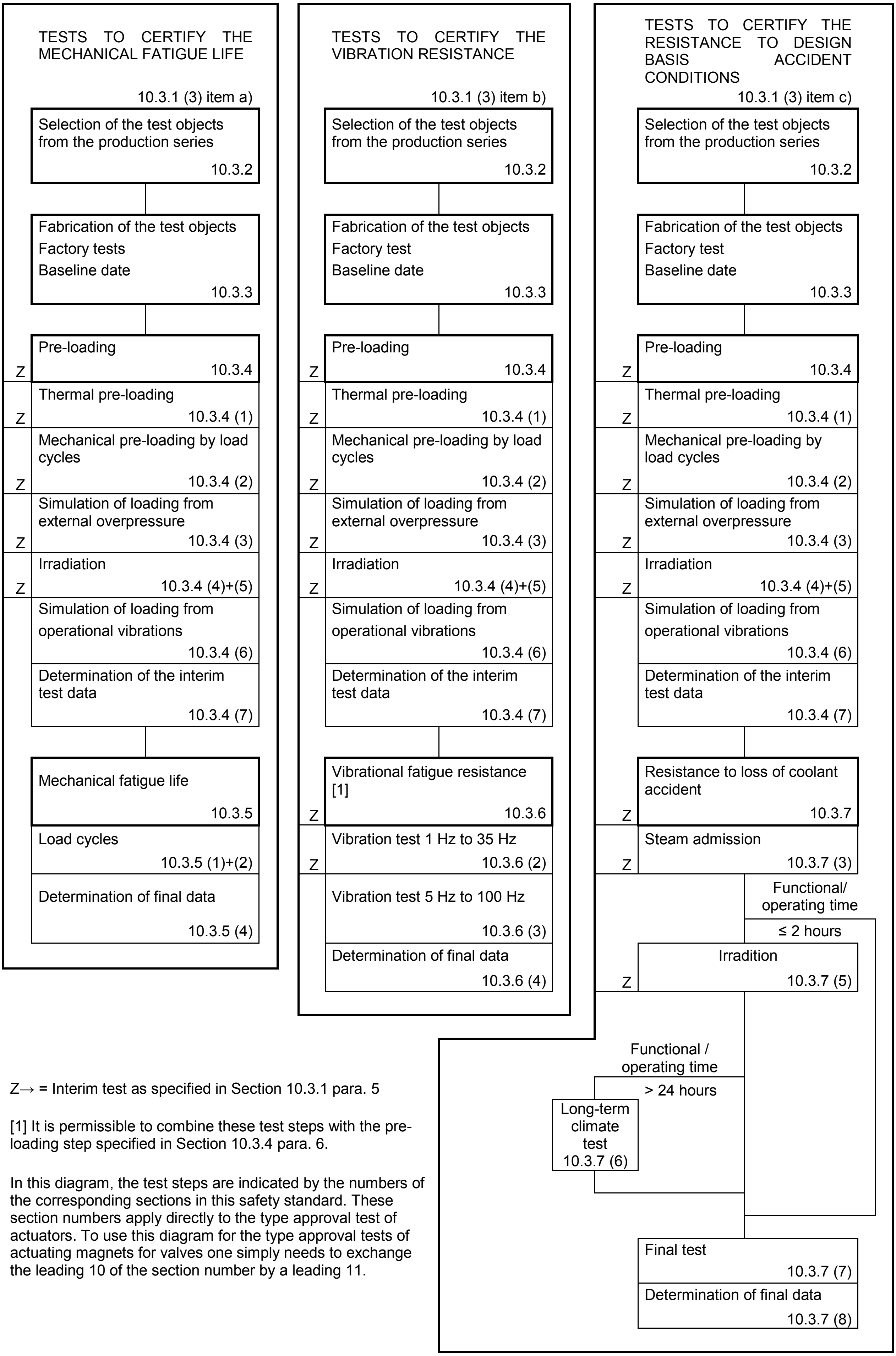
(8) In order to determine the final data, the measurements specified in **Table 14-1** column 6 shall be performed on the dry test object at room temperature, whereby it is sufficient to perform the coil test at twice the design-basis voltage.

(9) The test for resistance to design basis accident conditions is considered as successfully passed if the specified required values were maintained and the final load cycle was properly carried out.

Testing Steps as specified in Section 10.3.7			**para. 3**														**para. 4**		**para. 5**														**para. 6**	**para. 7**
Type of Test	Testing Conditions Testing Instructions	Interim Test specified in Section 10.3.1 para. 5														Interim Test specified in Section 10.3.1 para. 5	2nd Irradiation	Interim Test specified in Section 10.3.1 para. 5	Long-Term Climate Test in days														Final Test	Determination of Final Data
Point in time of test				2''	20'	40'	1h	2h	4h	8h	12h	16h	20h	24h					4th	8th	12th	16th	20th	24th	28th	32th	36th	40th	44th	48th	52th	56th		
Functional test at an operating voltage in % U_N	1 load cycle as specified in Section 10.3.1 para. 5	100	80 110	80	100	110	80	100	100	100	100	100	100	100	80 110	100		100															100	100
Coil test at the testing voltage level	in accordance with Sec. 17 VDE 0530 Part 1																																2 x U_N	2 x U_N
Check of the testing equipment		•	•													•	•	•	•														•	•
Visual examination		•	•												•	•	•	•															•	•
Switching voltage pulse	3 pulses 250/2500 in accordance with Sec. 13 VDE 0432 Part 2 Motor: 1900 V Controls: 300 V		•	•		•								•	•																			
Insulation resistance in the control circuit *)			•	•	•	•	•	•	•	•	•	•	•	•	•				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Loading torque			•	•	•	•	•	•	•	•	•	•	•	•	•																		•	•
Active power of motor			•	•	•	•	•	•	•	•	•	•	•	•	•																		•	•
Phase current of motor			•	•	•	•	•	•	•	•	•	•	•	•	•																			
Operating voltage			•	•	•	•	•	•	•	•	•	•	•	•	•																			
Function of the switches			•	•	•	•	•	•	•	•	•	•	•	•	•																		•	•
Elapsed run-time OPEN / SHUT			•	•	•	•	•	•	•	•	•	•	•	•	•																			
Pressure				•	•	•	•	•	•	•	•	•	•	•																				
Temperature				•	•	•	•	•	•	•	•	•	•	•					•→	→	→	→	→	→	→	→	→	→	→	→				
Humidity																			•→	→	→	→	→	→	→	→	→	→	→	→				
Radiation dose																	•																	
Boron admixture																			•→	→	→	→	→	→	→	→	→	→	→	→				
Visual examination, disassembled																																		•
Testing extent at the specified functional operating time:		A_{2h}														B			C														D	
		A_{24h}																																
≤ 2 hours (short-term)	A_{2h} + D																																	
≤ 24 hours (medium-term)	A_{24h} + B + D																																	
> 24 hours (long-term)	A_{24h} + B + C + D																																	

*) The insulation resistance in the control circuit is a result of combining the individual resistances of the actuator limit switches and those of the cable and cable penetrations used in the test setup. The insulation resistance shall not be lower than 1 kΩ per Volt of the specified rated voltage of the control circuit. The direct current measurement voltage shall be at least 100 V.

Table 10-1: Tests and measurements during the test of the open-loop actuators for their resistance to loss-of-coolant accidents (PWR, 1300 MW (electric))

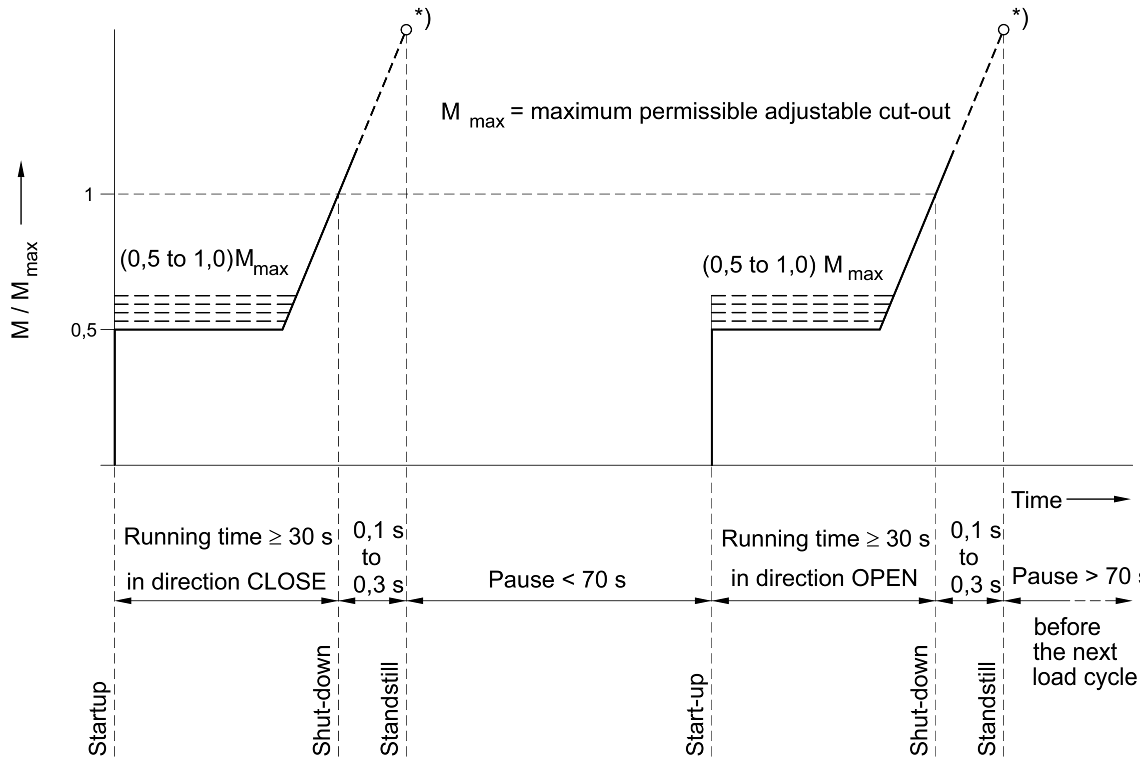


Z→ = Interim test as specified in Section 10.3.1 para. 5

[1] It is permissible to combine these test steps with the pre-loading step specified in Section 10.3.4 para. 6.

In this diagram, the test steps are indicated by the numbers of the corresponding sections in this safety standard. These section numbers apply directly to the type approval test of actuators. To use this diagram for the type approval tests of actuating magnets for valves one simply needs to exchange the leading 10 of the section number by a leading 11.

Figure 10-1 Test steps of the physical test for the type approval of a production series of actuators specified in Section 10 or for a production series of actuating magnets for valves specified in Section 11



*) torque magnification factor (1,2 to 2) M_{max}

Figure 10-2: Schedule for the load cycle of an open-loop actuator during pre-loading and the test of mechanical fatigue life

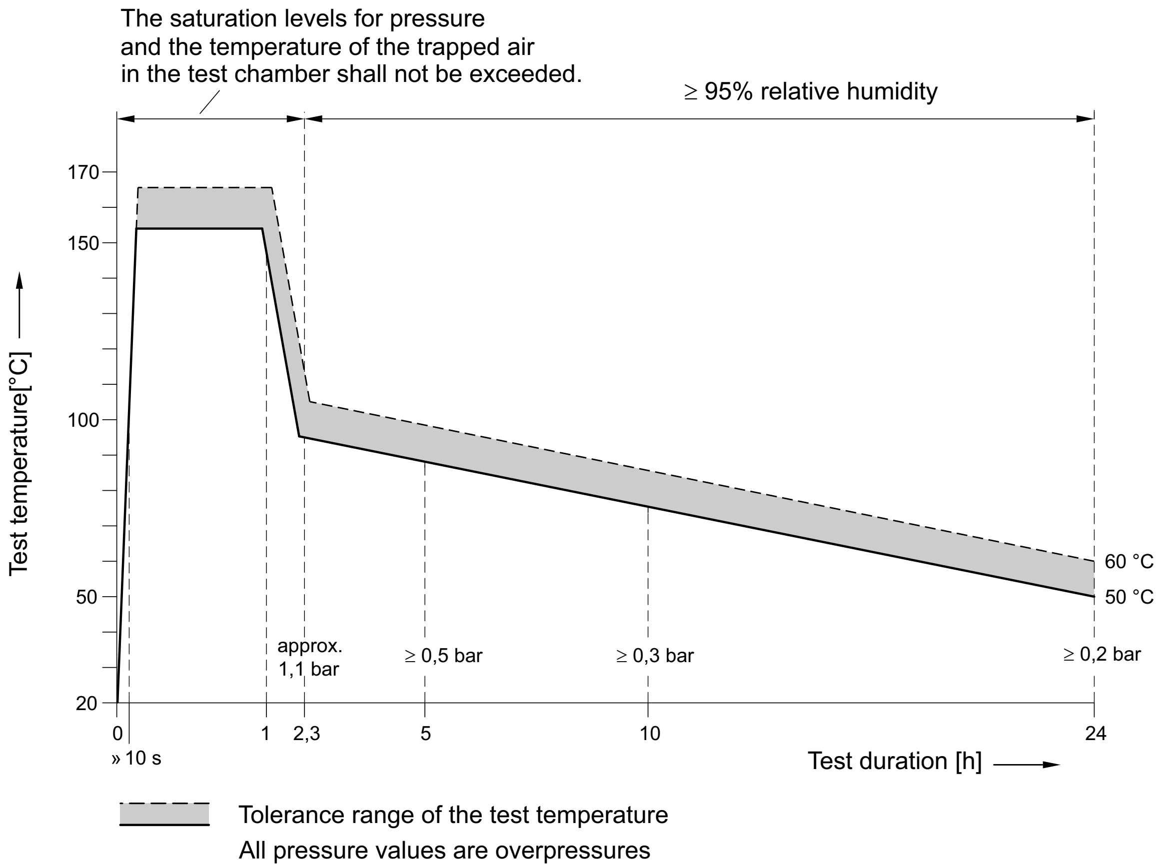
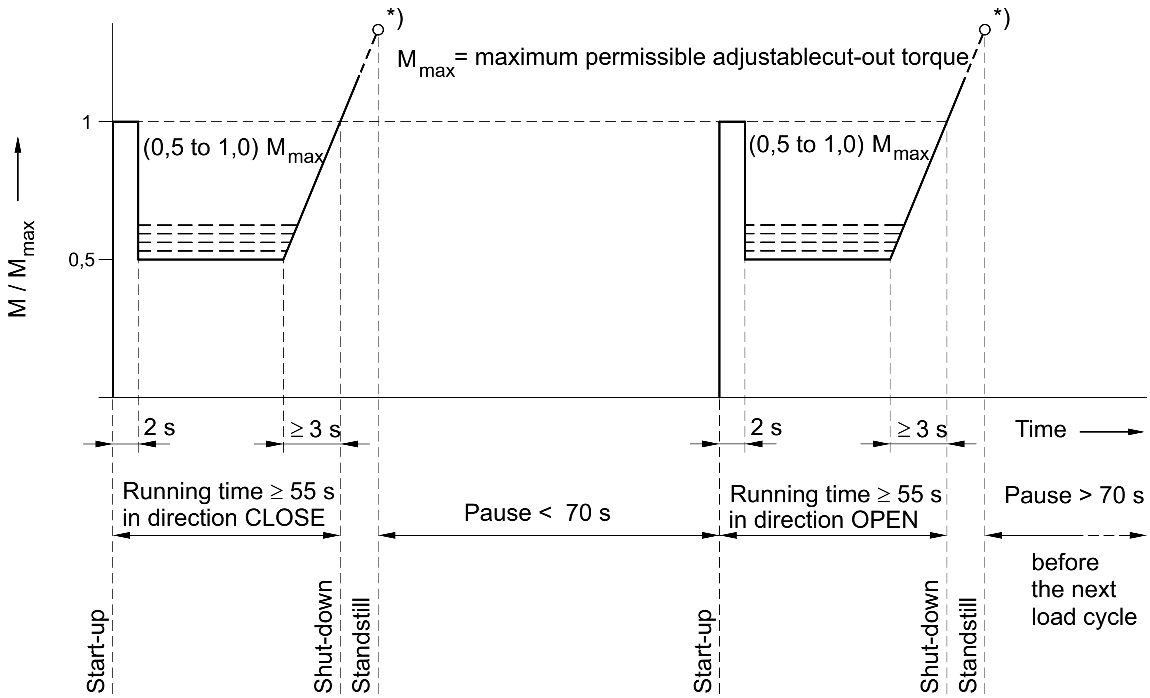


Figure 10-3: Conditions of the steam admission during the test of the resistance to a loss of coolant accident (PWR, 1300 MW(electric))



*) Run down only, no torque magnification factor

Figure 10-4: Schedule for the load cycle of an open-loop actuator during the interim functional test as specified in Section 10.3.1 para. 5

11 Type Approval Tests of the Actuating Magnets for Valves

11.1 Verification of Magnetic-Force Design

Within the framework of the type approval tests, the magnetic-force design of the actuating magnets for valves shall be verified as being in accordance with the requirements specified in Section 6.3.

11.2 Stress Analysis

An analytical stress analysis shall normally be performed for those component parts of the actuating magnets in the direct load path.

11.3 Physical Test

11.3.1 General requirements

(1) The basic requirements for the type approval tests of electrical drive mechanisms of the safety system as specified in Section 9 shall be applied. These tests shall normally be performed on the entire solenoid-operated valve (actuating magnet and valve). If the valve is replaced by a pre-loading device, this shall be described in the type approval test schedule.

(2) In the case of the actuating magnets of valves, the type approval tests shall be certified in accordance with Sec. 5.1 as well as Secs. 5.3 through 5.9 of DIN VDE 0580. These tests shall be performed at the lowest connecting terminal voltage as specified in Section 6.3 para. 1.

(3) In the case of actuating magnets for valves from a production series, type approval tests as specified in the flowchart of **Figure 10-1** shall be performed; the extent of these tests shall be as follows:

a) To verify the mechanical fatigue life, a type approval test shall basically be performed that comprises the pre-loading specified in Section 11.3.4 and the test of mechanical fatigue life specified in Section 11.3.5. This type approval test may be waived if the mechanical fatigue life is verified by a certification of satisfactory service experience.

b) If vibration resistance is required for the [actuating magnets for valves of a] production series and an experimental verification is required, the vibration resistance shall be certified by a type approval test that comprises the pre-loading as specified in Section 11.3.4 and the test of vibration resistance specified in Section 11.3.6.

c) If it is required that the [actuating magnets for valves of a] production series must resist design basis accident conditions, the resistance to design basis accident conditions shall be certified by a type approval test that comprises the pre-loading as specified in Section 11.3.4 and the test of the resistance to the design basis accident as specified in Section 11.3.7.

(4) The type approval tests shall be performed in accordance with the sequence of the test steps shown in **Figure 10-1**, however, each of the test objects is required to be subjected to only one of the tests specified in para. 3 item a), b) or c). If more than one of the tests specified in para. 3 item a), b) or c) are performed on one and the same test object, the pre-loading specified in Section 11.3.4 need only be applied once in the course of the first test performed.

(5) Before and after each test step, an intermediate test is shall be performed [as shown in **Figure 10-1**]. In these intermediate tests, the test objects shall be subjected to a visual examination and the functional capability shall normally be verified by one load cycle (ON-OFF cycle). This load cycle shall normally be performed at 90 % of the upper limit of the connecting terminal voltage range specified in **Table 6-1**. Prior to each test step, a check of the testing device shall be performed.

11.3.2 Selection of test objects

(1) The test objects of the actuating magnets for valves shall normally be selected from a production series according to the major design characteristics. These include:

a) physical dimensions,

b) exerted forces, biasing forces,

c) type of construction of the actuating magnets,

d) voltage range at the connecting terminals,

e) type of signaling device, and

f) materials within the load path.

(2) The test objects shall be selected such that, with respect to the major design characteristics, there is comparability to the types of the production series which have not been tested; one of the test objects shall be that solenoid-operated valve most severely loaded by the individual type approval test as specified in Section 11.3.1 para. 3 item a), b) or c).

11.3.3 Fabrication of the test objects and determination of the baseline data

The test objects selected as specified in Section 11.3.2 shall be taken as random samples from the production line. The factory tests specified in Section 14 shall have been performed and documented. The results of the final tests performed in the course of the factory tests as specified in **Table 14-2** column 2 shall be recorded for use as baseline data and as data for later reference.

11.3.4 Pre-loading

(1) The functionally relevant, non-metallic materials used shall be thermally pre-loaded by subjecting the test objects to elevated temperatures taking the specified service life and the specified mean ambient temperature into account. In this context, the requirements of Section 10.3.4 para. 1 shall be applied. In the case of actuating magnets planned for continuous operation during their service life, the influence of self-heating of the magnet coil at the specified [mean] ambient temperature T_1 on the accumulated in-operation period shall, additionally, be taken into account. In this context, the determined testing temperature T_2 of the magnet coil shall normally be achieved by applying a current such that hot spots are simulated inside the coil.

(2) With respect to its mechanical pre-loading, the test object shall be subjected to load cycles at the upper limit value of the connecting terminal voltage range, the normal ambient temperature and under the following conditions:

a) In the case of solenoid-operated valves required for open-loop control tasks, the test objects shall be subjected to 2000 load cycles (ON-OFF cycles) with a mean duty factor of 50 % (i.e., duty factor equals 50 % of the load cycle duration). In this context, the actuating magnet shall normally be subjected to a counterforce whose characteristic, in case of direct-current magnets, shall be lie at about 50 % of the static magnetic-force versus lifting-force characteristic.

b) In the case of solenoid-operated valves required for closed-loop control tasks, the test objects shall be subjected to a specific number of load cycles, a specific stroke amplitude, a specific mean duty factor and a specific operating time; the values for number of load cycles, stroke amplitude, mean duty factor and operating time shall be specified.

For one load cycle each at the beginning and at the end of the mechanical pre-loading, the load force of the testing device and the magnetic force shall be recorded as a function of the stroke amplitude at the design-basis current.

(3) To simulate loading from external overpressure, one load cycle at an increased ambient air pressure of 5 bar shall be performed as follows:

increase of pressure:	between 5 and 30 minutes,
holding time of pressure:	between 3 and 10 minutes and
decrease of pressure:	between 5 and 30 minutes .

This test may be waived if it is verified that these overpressure loads cannot have any influence on the functional capability.

(4) In the case of solenoid-operated valves which are planned for operation under radiation exposure where, therefore, test objects have to be subjected to an irradiation test as specified in Section 9 para. 6 item a), the test values for the absorbed dose and the absorbed dose rate shall be specified as a function of the prevailing deployment conditions. The further conditions of Section 10.3.4 para. 4 shall be applied.

(5) The irradiation test shall be performed under fulfillment of the requirements of Section 10.3.4 para. 5.

(6) For the simulation of the loading resulting from operational vibrations, e.g. vibration of pipes, the test object shall be subjected to a vibrational loading occurring sequentially in all three axes using a sine-sweep excitation and the values specified in Section 10.3.4 para. 6. It is permissible to combine the vibrational fatigue resistance test specified in Section 11.3.6 with this test step. A vibrational loading simultaneously in all three axes is also permissible.

(7) To determine intermediate test data, the measurements specified in **Table 14-2** column 2 – with the exception of the voltage test – shall normally be performed at the end of the pre-loading phase.

11.3.5 Test of mechanical fatigue life

(1) In order to verify their mechanical fatigue life, the test objects pre-loaded as specified in Section 11.3.4 shall be subjected to the following loading:

a) In the case of solenoid-operated valves required for open-loop control tasks, the test objects shall be subjected to 3000 load cycles at the loads specified in Section 11.3.4 para. 2 item a).

b) In the case of solenoid-operated valves required for closed-loop control tasks, the test objects shall be subjected to 1.5 times the number of load cycles as specified in Section 11.3.4 para. 2 item b).

(2) For one load cycle each at the start and at the end of the test of the mechanical fatigue life, the load force of the testing device and the magnetic force shall be recorded as a function of the stroke amplitude at the design-basis current.

(3) The measurements specified in **Table 14-2** column 2 shall be performed to determine the final data. Subsequently, the test object shall be dismantled and its component parts examined for wear.

(4) The test of mechanical fatigue life is considered as successfully passed if there are no indications of any overstressing of component parts, of a wrong selection of materials or of other common mode failures.

11.3.6 Vibrational fatigue resistance test

(1) In the case of solenoid-operated valves for which an experimental verification of vibrational fatigue resistance is required as specified in Section 9 para. 6 item b), this vibration test shall be performed on test objects, the actuating magnets of which were preloaded as specified in Section 11.3.4. In this context, it shall be verified that induced vibrations will have no detrimental effects on the physical integrity nor on the functional capability of the test object. If it is impermissible that the valve opens or closes inadvertently during the vibration impact, a test procedure shall be specified to verify these properties.

Note:

If, e.g., switching functions have to be tested, the length of time these switches are inadvertently open or closed shall be measured during the vibration test. Within the scope of the suitability review, it shall be determined whether these times are permissible with respect to their interaction with the control system.

(2) In case of the test for resistance against induced vibrations in the frequency range between 1 Hz and 35 Hz, e.g., due to earthquakes, the conditions specified in Section 10.3.6 para. 2 shall be fulfilled.

(3) The test for resistance to induced vibrations in the frequency range between 5 Hz and 100 Hz, e.g., due to an aircraft crash, the conditions specified in Section 10.3.6 para. 3 shall be fulfilled.

(4) The measurements specified in **Table 14-2** column 2 shall be performed to determine the final data.

(5) The test for resistance to vibrational fatigue is considered as successfully passed if there are no indications of overstressed parts, of a wrong selection of materials or of other common mode failures.

(6) The test for resistance to vibrational fatigue specified in Section 11.3.6 may be combined with the pre-loading in order to simulate the operational vibrations specified in Section 11.3.4 para. 6.

11.3.7 Test of resistance to design basis accident conditions

(1) If, as specified in Section 6.5, the design must accommodate design basis accident conditions, the loading sequence during the test shall be specified in form of a diagram plot (test curve). In this diagram plot, the values for pressure, temperature and humidity, the rise, fall and dwell times as well as the permissible deviations shall normally be specified. If the design basis accident is accompanied by radiation exposure, the test values for the absorbed dose and absorbed dose rate shall be specified as a function of the prevailing deployment conditions. The test object shall be subjected to these loadings.

(2) If, as specified in Section 6.5, the design must accommodate conditions of a loss-of-coolant accident inside the containment vessels of a nuclear power plant with light water reactor, those test objects that were subjected to pre-loading as specified in Section 11.3.4 shall be subjected to the tests of the following paragraphs. These tests shall also include the interfaces to other components, e.g., to cables and cable connecting terminals.

(3) The test object shall be subjected to a steam admission at a pressure, temperature and humidity specified in the conditions plotted in **Figure 10-3** where the upper temperature peak duration shall be extended to three hours in order to verify the loading of the actuating magnet during continuous operation. In the case of solenoid-operated valves required for open-loop control tasks, functional tests and measurements shall be performed as specified in **Table 11-1**. For the solenoid-operated valves required for closed-loop control tasks, the functional tests and measurements shall be specified. For the case of a loss of coolant accident occurring outside of the pressure vessel (annulus, main steam valve compartment) and in other plants than the PWR 1300, the corresponding requirements shall be specified.

(4) For loss-of-coolant accident outside of the containment (main steam valve compartment, annulus) and other equipment than the PWR 1300, corresponding requirements apply which shall be specified in each case. The respective underlying test curves are shown in Figures 5-3, 5-4 and 5-5 of KTA 3505.

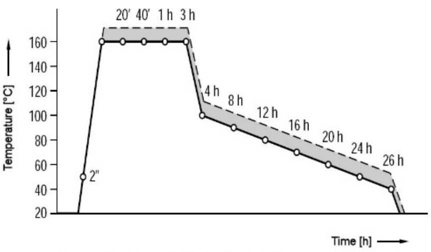
(5) If the functional operating time is specified at more than two hours after the onset of a design basis accident, the test object shall be subjected to an irradiation test under the conditions specified in Section 10.3.7 para. 5.

(6) If the functional operating time is specified at more than 24 hours after the onset of a design basis accident, the test objects shall normally be subjected to a long-term climate test under the conditions specified in Section 10.3.7 para. 6; in this context, the measurements specified in **Table 11-1** shall be performed.

(7) The measurements specified in **Table 11-1** column “Final Test” shall be performed, in case of a specified functional operating time of up to 2 hours, following the steam admission specified in para. 3, in case of a specified functional operating time of up to 24 hours, following the irradiation specified in para. 5, and in case of a specified functional operating time of more than 24 hours, following the long-term test specified in para. 6.

(8) In order to determine the final data, the measurements specified in **Table 14-2** column 2 shall be performed on the dry test object at room temperature, whereby it is sufficient to perform a voltage test at twice the upper limit of the connecting terminal voltage range specified in **Table 6-1**.

(9) The test for resistance to design basis accident conditions is considered as successfully passed if the specified required values were maintained and the final load cycle was properly carried out.

Testing Steps as specified in Section 11.3.7			para. 3																para. 4		para. 5														para. 6	para. 7
Type of Test	Testing Conditions Testing Instructions	Interim Test specified in Section 11.3.1 para. 5	 Steam admission as specified in Figure 10-3, however, with three hours at maximum temperature															Interim Test specified in Section 11.3.1 para. 5	2nd Irradiation	Interim Test specified in Section 11.3.1 para. 5	Long-Term Climate Test in days														Final Test	Determination of Final Data
Point in time of test				2''	20'	40'	1h	2h	3h	4h	8h	12h	16h	20h	24h	26h					4th	8th	12th	16th	20th	24th	28th	32th	36th	40th	44th	48th	52th	56th		
Functional test at an operating voltage U 1)	1 load cycle as specified in Section 11.3.1 para. 5	U_B	$\overline{U}$ U	U	U_B	$\overline{U}$	U_B	U_B	2)	U_B	U_B	U_B	U_B	U_B	U_B	U_B	$\overline{U}$ U	U_B	U_B	U_B															U_B	U_B
Voltage test at the testing voltage level	in accordance with Secs. 37 to 40 VDE 0580																																		2 x $\overline{U}$	2 x $\overline{U}$
Check of the testing equipment		•	•															•	•	•	•														•	•
Visual examination		•	•														•	•	•	•															•	•
Insulation resistance in the control circuit 3)			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•				•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Loading force			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•																		•	•
Coil current			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•																		•	•
Operating voltage			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•																			
Function of the switches			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•																		•	•
Start-up time / close-down time			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•																			
Pressure				•	•	•	•	•	•	•	•	•	•	•	•	•																				
Temperature				•	•	•	•	•	•	•	•	•	•	•	•	•					• →															
Humidity																					• →															
Radiation dose																			•																	
Boron admixture																					• →															
Visual examination, disassembled																																				•
Testing extent at specified functional operating time: ≤ 2 hours (short-term) A_{2h} + D ≤ 24 hours (medium-term) A_{24h} + B + D > 24 hours (long-term) A_{24h} + B + C + D			A_{2h} A_{24h}															B			C														D	

1) Operating voltages:
$\overline{U}$: upper limit value as specified in Table 6-1
U : lower limit value as specified in Table 6-1
U_B : operating value = 0.9 x $\overline{U}$

2) Continuously ON

3) The insulation resistance in the control circuit is a result of combining the individual resistances of the actuator limit switches and those of the cable and cable penetrations used in the test setup.
The insulation resistance shall not be lower than 1 kΩ per Volt of the specified rated voltage of the control circuit. The direct current measurement voltage shall be at least 100 V.

Table 11-1: Tests and measurements during the test of the operating magnets of valves with controlling functions for their resistance to loss-of-coolant accidents (PWR, 1300 MW (electric))

12 Type Approval Tests of the Electrical Drive Mechanisms of Machines

(1) The type approval tests of electrical drive mechanisms of the safety system shall be performed according to the basic requirements specified in Section 9.

(2) In the case of drive motors of driven machines, a temperature-rise test in accordance with Sec. 8 and a coil test in accordance with Sec. 9.2 of DIN EN 60034-1 shall be certified. In addition, the test of the minimum startup torque shall be certified. If the test of the startup torque was not performed

at the lowest connecting terminal voltage as indicated in Section 7.2 para. 2 item b), the corresponding change of the startup torque shall be determined.

(3) Whenever the application in a safety system requires safety-related properties which are not covered by the type approval tests specified in paras. 1 and 2, additional type approval tests shall be performed. In this context, the requirements specified in Section 9 para. 6 shall be fulfilled.

13 Suitability Review of Electrical Drive Mechanisms of the Safety System

(1) A suitability review of the technical documents specified in Sections 5.13, 6.7, 7.8 and 8 para. 3 shall be performed to verify the extent to which the ambient conditions to be assumed for the planned operation in the actual plant are covered by the plant-independent test conditions of the type approval tests as specified in Section 9.

(2) If the type approval tests were performed at lower test data than those to be assumed for the actual plant, the electrical drive mechanisms of the safety system shall be subjected to a supplementary verification of suitability with respect to the thus far not covered range of ambient conditions.

(3) With regard to the suitability review, informational data shall be made available that permit making the following comparisons:

a) Determination of the identity between the electrical drive mechanisms of the safety system to be deployed in the actual plant and the drive mechanisms or production series subjected to the type approval test.

b) Comparison of the requirements from plant operation and the pre-loading conditions with regard to the simulation of operational loadings in the course of the type approval tests.

c) Comparison of the plant-specific requirements with regard to seismic vibrations at the final location of the electrical drive mechanisms of the safety system and the conditions of the type approval test with regard to the vibrational fatigue resistance in the range between 1 Hz and 35 Hz. In this context, a plant-specific review shall be performed to check whether a functional capability is required during the impact and whether this requires any particular verifications.

d) Comparison of the plant-specific requirements with regard to induced vibrations at the final location of the electrical drive mechanisms of the safety system due to an aircraft crash or a blast wave and the conditions of the type approval test with regard to the vibrational fatigue resistance in the range between 5 Hz and 100 Hz. In this context, a plant-specific review shall be performed to check whether a functional capability is required during the impact and whether this requires any particular verifications.

e) Comparison of the plant-specific requirements with regard to the design basis accidents and the conditions of the type approval test regarding the resistance to design basis accident conditions.

14 Factory Tests

The factory tests of the electrical drive mechanisms of the safety system shall be performed as routine tests in accordance with Sec. 5.16.3 of safety standard KTA 3701. In the case of actuators, the extent of the factory tests shall be at least that of **Table 14-1**, and in the case of actuating magnets for valves, at least that of **Table 14-2**.

15 Commissioning Tests

(1) The commissioning tests of the electrical drive mechanisms of the safety system shall be performed as specified in the commissioning schedule. The requirements in accordance with Sec. 4 of safety standard KTA 3506 shall be fulfilled.

(2) The electrical drive mechanisms of the safety system shall be subjected, essentially, to the following tests:

a) Check for compliance with the manufacturer specifications.

b) The ohmic resistance of the insulation shall be tested.

c) The protective measures to be provided in accordance with DIN VDE 0100-410 shall be tested.

d) The ohmic loop resistance of the power cable shall be measured. In this context, it shall be checked that the specified voltage drop is not exceeded.

e) A rotational direction check shall be performed.

f) The functional capability of the path and torque dependent controlled shut-down, of the bypasses and of the signaling and alarms shall be tested.

During these tests, operation of the process-engineering systems is not required.

(3) During the commissioning of the process-engineering systems, the electrical drive mechanisms shall be operated together with the driven components. The boundary conditions for this test shall be chosen such that it will be possible to compare the results obtained by the inservice inspections with those obtained by the commissioning tests as specified in para. 4.

> Note:
> These boundary conditions include:
> a) loadings due to the defined operating or testing mode of the process-engineering system, and
> b) the specified operating voltage at the busbar.

(4) During the tests specified in para. 3, the following measurements shall be taken:

a) In the case of actuators, the active power or the torque shall be measured as a function of time during one load cycle and the results shall be compared with the specified design data. These measurements shall be documented as reference data for the inservice inspections.

   > Note:
   > The spindle force may be measured to supplement the active power measurements.

b) In the case of actuating magnets for valves, the exciter current shall be measured as a function of time during one load cycle. The startup time (response delay and lifting time) and the close-down time (close-down delay and return time) shall normally be determined and compared with the specified design data. These measurements shall be documented as reference data for the inservice inspections.

c) In the case of electrical drive mechanisms of driven machines with a power rating larger than 300 kW, the current, the active power and startup time shall be measured and compared with the specified design data.

1	2	3	4	5	6
ests and Examinations	**Component in the load path**	**Surfaces with sealing function**	**Transmission housing**	**Drive motor**	**Entire actuator**
Hardness test	X				
Roughness test		X			
Leak tightness test			X		
Electrical coil test				X	Y
Torque test					Y
Torque adjustment					Y
Position transducer and travel limit switches					Y
Cf. the text indicated by the alphabetic letters	a g			b	c d e f

The tests for dimensional accuracy and cleanness are mandatory and, therefore, not specifically mentioned.

X: Factory certificate in accordance with Sec. 3.1 DIN EN 10204 in the form of a collective certificate for the entire actuator; this includes verification of identity between test object and type tested drive or type tested production series.

Y: Certification by acceptance test certificate in accordance with Sec. 4.1 DIN EN 10204

a: Hardness test of at least 10 % of the surface-hardened parts from each hardening lot and material.

b: Coil test in accordance with Sec. 9.2 DIN EN 60034-1 at the manufacturing plant of the drive motor.

c: Repeat of the coil test at 80 % of the value of the initial test of the motor or of the equipment.

d: Torque in the case of shut-down failure at maximum connecting terminal voltage (110 % U_N). Maximum adjustable torque with the starting torque of the motor at the specified minimum connecting terminal voltage (80 % U_N unless otherwise specified); torque magnification in the case of torque-dependent tripping with basis conditions as specified under Section 5.5 para. 1. It is admissible to perform the test at a voltage in the range between 110 % and 80 % U_N and to convert the measured torques for the specified voltage limit values on the basis of the square of the voltage ratio.

e: Adjustment of the specified torque tripping points.

f: Functional test.

g: As far as required in accordance with Section 10.2.1 para. 4, the strength characteristics of the materials shall be certified by acceptance test certificate 3.1 B in accordance with Sec. 4.1 of DIN EN 10204.

Table 14-1: Extent of the factory tests of actuators

1	2	3
Tests and Examinations	**Actuating Magnet**	**Entire Solenoid Valve**
Electric resistance of magnet coil	X	
Voltage test	X	X
Functional test	X	X
Position transducer and travel limit switches		X
Cf. the text indicated by the letters	a b c	d e f

The tests for dimensional accuracy and cleanness are mandatory and, therefore, not specifically mentioned.

X: Factory certificate in accordance with Sec. 3.1 of DIN EN 10204 in the form of a collective certificate for the entire solenoid valve; this includes verification of identity between test object and type tested drive or type tested production series.

a: Ohmic resistance at 20 °C.

b: Voltage test in accordance with Secs. 5.3 of DIN VDE 0580 at the manufacturing plant of the actuating magnet.

c: Verification of the specified forces for opening and resetting for the minimum voltage and operating temperature of the coil.

d: Repeat of the voltage test at 80 % of the value of the initial test of the actuating magnet.

e: Determination of the response level and the repositioning value of the current.

f: Functional test.

Table 14-2: Extent of the factory tests of the actuating magnets for valves

16 Inservice Inspections

Note:
Additional requirements are specified in safety standard KTA 3706, Ensuring the Loss-of-Coolant-Accident Resistance of Electro-Technical Components and of Components in the Instrumentation and Controls of Operating Nuclear Power Plants.

(1) The tests shall be performed in coordination with the inservice inspections of the associated process-engineering system such that the necessary protective actions are not prevented.

(2) Inservice inspections shall be performed such that they can verify that the functional capability of the electrical drive mechanisms of the safety system is maintained.

(3) A regularly performed function in the course of operation may be rated as the inservice inspection with respect to functional capability as specified in para. 6 item a) or para. 7 item a) or para. 8 item a).

(4) In case the connection with the process-engineering system precludes performing the tests during power operation of the plant, the inservice inspections shall be performed during plant outages.

(5) The test intervals shall be specified on the basis of operating experience or of reliability analyses.

(6) The following functional capability tests shall be performed as inservice inspections of the actuators:

a) One load cycle shall be executed in test intervals as required for the inservice inspection of the process-engineering system and the valve. In this context, it is sufficient to verify proper functioning of the actuator and the associated valve.

b) One load cycle shall be executed under the same conditions on which the measurements during the commissioning test as specified in Section 15 paras. 3 and 4 item a) were based. These tests shall be performed on a random sample of the actuators with the associated valves no later than 4 years after the commissioning test and under comparable operating conditions and shall be continued in this manner such that all actuator types shall have been tested within a period of 8 years. The test shall normally be repeated in 8 year intervals. In this context, the controlled shut-down and limiting devices shall be checked for impermissible deviations by comparing the results with the reference data from commissioning as specified in Section 15 para. 4 item a).

   Note:
   The spindle force may be measured to supplement the active power measurements.

c) The setting of the torque limiting equipment of the actuators shall be checked in test intervals shorter than the maintenance cycle on which the type approval test was based. However, the test cycle shall be no longer than eight years.

   Note:
   This check may be combined with other maintenance activities.

(7) The following functional capability tests shall be performed as inservice inspections of the actuating magnets of valves:

a) The solenoid-operated valve shall be activated in test intervals as required for the inservice inspection of the process-engineering system and the valve. In this context, it is sufficient to verify proper functioning of the solenoid-operated valve.

b) One load cycle shall be executed under the same conditions on which the measurements during the commissioning test as specified in Section 15 paras. 3 and 4 item b) were based. These tests shall be performed on random samples of solenoid-operated valves no later than 2 years after the commissioning test and under comparable operating conditions and shall be continued in this manner such that all solenoid-operated valve types shall have been tested within 6 years after commissioning. Each one of the solenoid-operated valves shall normally have been tested within 12 years. The test shall normally be continued in 8 year intervals. In this context, a check for impermissible deviations shall be performed by comparing the results with the reference data from commissioning [as specified in Section 15 para. 4 item b)].

(8) The following functional capability tests shall be performed as inservice inspections of the electrical drive mechanisms of machines:

a) The electrical drive shall be activated in test intervals as required for the inservice inspection of the process-engineering system and the associated driven machine. In this context, it is sufficient to verify proper functioning of the electrical drive and of the driven machine.

b) Those drive mechanisms of driven machines with a power rating larger than 300 kW where no process-engineering technological test of the pump characteristic or of the rate of air flow is performed, shall be subjected to inservice inspections with those measurements on which the commissioning test specified in Section 15 para. 4 item c) was based. These tests shall be performed on a random sample of the electrical drive mechanisms with the associated driven machines no later than 4 years after the commissioning test and under comparable operating conditions and shall be continued in this manner such that all of the drive mechanisms of driven machines required to be tested shall have been tested within a period of 8 years.

17 Tests during Servicing or after Repairs

(1) Following the completion of any servicing or repair task that has led to an interruption of operational availability, a test as specified in Section 15 para. 2 item f) and para. 4 shall be performed to verify that operational availability is restored. Depending on the kind and extent of the component parts or functions concerned, a functional trial run shall be performed.

(2) If the maintenance or repair tasks leads to a replacement with parts of a changed design with respect to the original design, the suitability of these parts shall have been verified.

18 Test Certification

(1) Test certificates shall be prepared as proof that the tests have been performed, these test certificates containing all important data in connection with the test. These data include in particular:

a) identification number of the certificate,

b) type and designation of equipment as well as its state of revision,

c) list of the test documents as well as the list of technical documents,

d) manufacturer of the equipment tested,

e) testing program, including test steps,

f) test results,

g) place and date, and

h) organization, names and signatures of the tester and the authorized experts.

(2) It is permissible to combine several test certificates to form a single comprehensive test certificate.

(3) With regard to the tests during servicing or after repairs as specified in Section 17, technical documents shall be prepared and agreed upon with the authorized expert which specify the kind and sequence of the individual test.

(4) The tests shall be documented.

19 Testers

(1) The technical documents for the type approval tests specified in Sections 10.1, 10.2, 11.1 and 11.2 shall normally be prepared by the manufacturer. These documents shall normally be reviewed by an authorized expert. The testing program for the physical part of the type approval tests shall normally be prepared by the manufacturer and agreed upon with the authorized expert. The physical tests shall normally be performed by a plant expert of the manufacturer.

(2) The suitability reviews specified in Section 13 shall be performed by authorized experts.

(3) The factory tests specified in Section 14 shall normally be performed by plant experts of the manufacturer or under their responsibility. In justified cases, authorized experts shall be consulted.

(4) The commissioning tests specified in Section 15 and the inservice inspections specified in Section 16 shall be performed by expert personnel designated by the licensee. To the extent this is provided for in the testing schedule, authorized experts shall be consulted.

20 Documentation

20.1 Documentation of the Review of Technical Documents

The following technical documents shall be included in the documentation:

a) technical documents as specified in Section 9 para. 6,

b) calculations and certifications of the electrical drives (technical documents as specified in Sections 5.13 or 6.7 or 7.8),

c) testing instructions for the physical tests, and

d) test certificates.

20.2 Documentation of the Physical Tests

(1) Each test step shall be documented by an examination record that shall contain the following data:

a) identification number of the examination record,

b) type and description of the subassembly including its state of revision,

c) identity of the test object,

d) manufacturer of the test object,

e) test step,

f) test setup, testing equipment, testing device,

g) number of measurement value tables,

h) test results,

i) place and date, and

k) organization, name and signature of the tester.

(2) Any failures, visible flaws and defects shall be documented in the examination record.

(3) The results of the tests shall be summarized in test certificates.

20.3 Test Reports

(1) The examination of the technical documents and the conducting of the physical tests shall be summarized in test reports.

(2) Possible application restrictions and special application instructions shall be included in the test reports.

20.4 Validity of the Test Certificates

A test certificate shall keep its validity for newly fabricated component parts, provided, it is confirmed in intervals of 3 years, e.g., by quality audits in accordance with safety standard KTA 3507, that no changes with respect to the test certificate (including the test report) were introduced that would impair the tested properties.

20.5 Storage and Archiving

Requirements regarding storage and archiving of the test documentation are specified in safety standard KTA 1404.

Appendix A
Regulations Referred to in this Safety Standard

Regulations referred to in this safety standard are valid only in the versions cited below. Regulations which are referred to within these regulations are valid only in the version that was valid when the latter regulations were established or issued.

AtG		Act on the peaceful utilization of atomic energy and the protection against its hazards (Atomic Energy Act – AtG) of December 23, 1959, revised version of July 15, 1985 (BGBl. I, p. 1565), most recently changed by Article 307 of the Act of August 31, 2015 (BGBl. I, No. 35 p. 1474)
StrlSchV		Ordinance on the protection from damage by ionizing radiation (Radiological Protection Ordinance – StrlSchV) of July 20, 2001 (BGBl. I, p. 1714; 2002 I, p. 1459), most recently changed by Article 5 of the Act of December 27, 2014 (BGBl. I, p. 2010)
SiAnf	(2015-03)	Safety Requirements for Nuclear Power Plants (SiAnf) of 22 November 2012 (BAnz AT 24.01.2013 B3), revised version of 3 March 2015 (BAnz AT 30.03.2015 B2).
Interpretations of SiAnf	(2015-03)	Interpretations of the "Safety Requirements for Nuclear Power Plants of 22 November 2012" (BAnz AT 24.01.2013 B3), revised version of 3 March 2015 (BAnz AT 30.03.2015 B2)
KTA 1404	(2013-11)	Documentation during the construction and operation of nuclear power plants
KTA 3501	(2015-11)	Reactor protection system and monitoring equipment of the safety system
KTA 3505	(2015-11)	Type testing of measuring sensors and transducers of the instrumentation and control system important to safety
KTA 3506	(2012-11)	System testing of the instrumentation and control equipment important to safety of nuclear power plants
KTA 3507	(2014-11)	Factory tests, post-repair tests and certification of satisfactory performance in service of modules and devices of the instrumentation and control system important to safety
KTA 3701	(2014-11)	General requirements for the electrical power supply in nuclear power plants
KTA 3702	(2014-11)	Emergency power generating facilities with diesel-generator units in nuclear power plants
KTA 3704	(2013-11)	Emergency power facilities with static and rotating AC/DC converters in nuclear power plants
KTA 3705	(2013-11)	Switchgear facilities, transformers and distribution networks for the electrical power supply of the safety system in nuclear power plants
KTA 3902	(2012-11)	Design of lifting equipment in nuclear power plants
DIN VDE 0100-410 VDE 0100-410	(2007-06)	Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock (IEC 60364-4-41:2005, modified); German implementation HD 60364-4-41:2007
DIN VDE 0580 VDE 0580	(2011-11)	Electromagnetic devices and components - General specifications
DIN EN 10204	(2005-01)	Metallic products - Types of inspection documents; German version EN 10204:2004
DIN EN 60034-1 VDE 0530-1	(2011-02)	Rotating electrical machines - Part 1: Rating and performance (IEC 60034-1:2010, modified); German version EN 60034-1:2010 + Cor.:2010
DIN EN 60060-2 VDE 0432-2	(2011-10)	High-voltage test techniques - Part 2: Measuring systems (IEC 60060-2:2010); German version EN 60060-2:2011
DIN IEC 60780	(2000-12)	Nuclear power plants - Electrical equipment of the safety system - Qualification (IEC 60780:1998)
VDI 2230, Part 1	(2014-12)	Systematic calculation of highly stressed bolted joints - Multi bolted joints
VDI 2230, Part 2	(2014-12)	Systematische Berechnung hochbeanspruchter Schraubenverbindungen - Mehrschraubenverbindungen