



DRAFT TANZANIA STANDARD

**Protection against ionizing radiation: Specification for industrial
radiographic installations**

for stakeholders' comments only

0. Foreword

The problem of ionizing radiation pollution is exacerbated by improper land use planning, failure to follow building permits in most of our cities, municipalities and towns. This Tanzania Standard is developed partly due to the requirements of the law (EMA, 2004) and partly because of the public outcry on randomly construction of ionizing radiation facilities without using standards. Therefore, the requirements values provided by this Tanzania Standard will provide the basis for authorities to assess and manage building enclosing ionizing radiation facilities.

In preparation of this Tanzania Standard, considerable assistance was derived from

Management of Radiation Protection in Defense Part 2: Leaflet 28- Industrial radiography including enclosures, site and underwater radiography. September 2013.

IAEA Safety Standard for protecting people and the environment; Radiation Safety in Industrial Radiography Specific Safety Guide No. SSG-11 International Atomic Energy Agency Vienna, 2011

Safety Report Series Radiation Protection and Safety in Industrial Radiography International Atomic Energy Agency Vienna, 1999

In reporting the result of a test or analysis made in accordance to this Tanzania Standard, if the final value, observed or calculated is to be rounded off, it shall be done in accordance with TZS 4 (see clause 2).

Introduction

The applications of ionizing radiation bring many benefits to humankind, ranging from power generation to uses in medical institutions, agriculture and industry. One of the lengthiest established industrial applications of radiation is the use of radiography for the non-destructive testing where by many types of manufactured components can be inspected to validate the internal structure and integrity of the sample. Industrial radiography provides a means of verifying the physical integrity of equipment and structures such as vessels, pipes, welded joints, castings and other devices. The integrity of this equipment affects not only the safety and quality of the products used by workers, but also the safety and quality of the environment for workers and the public at large. In particular, radiography can be performed so as to pose a negligible risk on the public and with sufficiently low occupational radiation exposure so as to pose no unnecessary radiological risk on the workers. However, experience has also shown that bad practice in industrial radiography resulted in high doses to a person accidentally exposed to the primary beam or in close contact with an unshielded source. The consequences of such practice might also results in injury to workers, causing severe health problems such as radiation burns and in other situation death might occurred.

Members of the public can also suffered radiation over exposures when radioactive sources used for industrial radiography were not properly controlled or regulated. Industrial radiographic work by its nature is often carried out under difficult working conditions in a variety of locations and under different environmental situations, such as in narrowed or restricted areas or in a place whereby extreme cold or heat exists. Working under such adverse conditions might result in operational situations in which the principle of keeping doses as low as reasonably achievable (ALARA) is challenged. All of these features demonstrated the necessity for governmental organizations to set the required standards and regulation in an environment that promotes a safety within the organizations, environment and general public at large. It is assumed that, this Safety standard will facilitate in the laying down of effective legal and regulatory steps that ensure effective measures are in place to limit the radiation exposure to any person as a result of radiographic operations wherever they are conducted.

1. Scope

This Tanzania standard provides requirement for design of industrial radiographic installations for the use of sealed nuclear substances, including fixed (permanent) and temporary structures. It is only concern with radiation protection and safety for occupational, general public and environment and does not deal with radiographic techniques for non-destructive testing.

2. Normative References

TZS942:2017/ISO 7212:1986 Enclosures for protection against ionizing radiation -- Lead shielding units for 50 mm and 100 mm thick walls

ISO 14152:2001 Neutron radiation protection shielding-Design parameters and considerations for the choice of appropriate materials

ISO 2919:20113 Sealed radioactive sources –General requirements and classification

ISO 12749-4:2015 Nuclear energy, nuclear technologies, and radiological protection -- Vocabulary -- Part 4: Dosimetry for radiation processing

ISO 3999:2004 Radiation protection-Apparatus for industrial radiography –Specifications for performance, design and tests

ISO 361:1975 Basic Ionizing Radiation Symbol.

3. Terms and definitions

For the purpose of this Tanzania standard, the following definition shall apply:

3.1 barrier

a physical obstruction that prevents or inhibits the movement of people, radionuclides or some other phenomenon (e.g. fire), or provides shielding against radiation.

3.2 controlled area

area set up before any radiographic exposure is undertaken outside an enclosure within an establishment where all areas outside it are to be at dose rates (over 1 minute) of less than 7.5 $\mu\text{Sv/hr}$.

3.3 industrial radiography

Method of non-destructive testing where many types of manufacturing components can be explained to verify the internal structure and integrity of the specimen using ionizing radiations.

3.4 ionizing radiation

electromagnetic radiation and subatomic particles with sufficient energy to overcome the binding energy of electron(s) in atom(s) or molecule(s) thus creating ion(s)

3.5 occupational exposure

contact with a potentially harmful physical, chemical, or biological agent as a result of one's work

3.6 permanent radiographic installations

an enclosed shielded room, cell, or vault, not located at a temporary radiographic installation, in which radiography is performed.

3.7 radiation source

material or apparatus emitting or capable of emitting ionizing radiation

3.8 radiographic installations

are an enclosed shielded rooms, cells, or vaults, located within establishment, in which radiography is performed.

3.9 sealed radioactive source

radioactive source sealed in a capsule or having a bonded cover, the capsule or cover being strong enough to prevent contact with and dispersion of the radioactive material under the conditions of use and wear for which it was designed

3.10 site radiography

method of non-destructive testing (NDT) where many types of the manufactured components can be examined to verify the internal structure and integrity of the specimen on site outside using either x-rays or gamma rays.

3.11 supervised area

area set up before any radiographic exposure is undertaken outside an enclosure within an establishment where all areas outside it to be set such that the expected annual biological full body dose to a person from normal operation and likely accident, during the time the area or room is accessible is between 1 mSv to 6 mSv.

3.12 survey meter

A portable instrument that measures radiation dose rate.

3.13 shielded enclosure:

an enclosed space engineered to provide adequate shielding from ionizing radiation for persons in the vicinity.

3.14 temporary radiographic installations

any location where industrial radiography is performed and where licensed material may be stored other than those locations of use authorized on the license or registration.

3.15 Warning sign

sign used as a warning to protect people from being exposed to radiation. The sign must be posted where radioactive materials are handled or radiation-producing equipment is used.

4. Requirements for design of industrial radiographic installations.

Design principles for industrial radiographic installations are based on the requirement that all operating organizations shall ensure that any radiation exposures as a result of radiographic operations remain within the national and international best practice requirements.

4.1 Requirements for shielded enclosure

- i. A shielded enclosure shall be designed to take account of the radiation sources that are to be used and the specific work that is to be carried out.
- ii. The enclosure shall be designed so that the exposure controls for the gamma source or radiation generator are located outside the shielded enclosure.
- iii. The design shall be planned for immediate and foreseeable future needs before the commencement of construction.
- iv. The design of the shielded enclosure shall include a drawing of the installation and its surroundings, including any adjacent offices or buildings.
- v. The drawing shall include dimensions, as well as the thicknesses, densities and types of shielding materials on all sides of, above and below the exposure area.
- vi. Entrances shall be marked and distances to potentially occupied areas adjacent to, above and below the exposure area shall be indicated, including information on the occupancy factor (i.e. the frequency of occupation and the average

4.1.1 Designation of shielded enclosures

- i. The designation of radiographic enclosures as controlled areas during the exposure of radiographic sources or the operation of an industrial X-ray set is to be undertaken in consultation with the Radiation Protection Authority (RPA).
- ii. Suitable controlled radiation areas signs detailing the nature of the radioactive source and the risks arising from the source, shall be displayed around the perimeter of the controlled area and at each entrance to the enclosure.
- iii. Suitably worded signs shall be posted on each outside wall of the radiation enclosure to warn, where appropriate, against access to the roof without the permission of the Radiation Protection Supervisor (RPS).
- iv. Where radiographic sources are used, the radioactive source store shall be a controlled radiation area. The store is to be appropriately marked and display a sign on the door listing the radioactive contents within the store and the risks arising from the sources held.
- v. All controlled and supervised areas are to be suitably described in local orders.

4.1.2 Access to shielded enclosures

Entry to the radiographic enclosure is prohibited during radiation exposure other than in special circumstances under a permit-to-work such as in returning a radiographic source to its container when it cannot be returned from outside the enclosure. All such special procedures shall be undertaken in consultation with the RPA.

4.1.3 Design of shielded enclosures

- i. Enclosures for industrial radiography using radioactive sealed sources or X-rays shall provide sufficient shielding to reduce the radiation dose rate to $7.5 \mu\text{Sv/hr}$ at any point on the surface of the outside wall of the enclosure. Additional shielding shall be provided for facilities in constant use. New facilities shall be designed, where reasonably practicable, to provide sufficient shielding such that the external dose rate will not exceed $1 \mu\text{Sv/hr}$.
- ii. Control panels for X-ray machines or radioactive sources shall be situated outside the walled enclosure.
- iii. Where an X-ray machine is used, interlocks shall be provided and maintained to ensure that should any door to the enclosure be opened while an X-ray machine within it is energized, the machine shall be automatically de-energized and cannot be operated so long as that door remains open.
- iv. Where a radioactive sealed source is used, where reasonably practicable, interlocks shall be provided and maintained at all entrances to an enclosure, such that while a sealed source is exposed no door to the enclosure can be opened, and that a sealed source cannot be exposed while any door is open.

- v. Where an interlock has been opened, a radiographic exposure is not to re-start simply by remarking the interlock. It shall be necessary to re-set the interlocks and the operator shall go through the re-start sequence at the control point before the X-ray machine or sealed source can be exposed.
- vi. All interlocks shall be designed and positioned so that they cannot easily be interfered with, and are to be of a fail-safe type.
- vii. Interlocks shall be regularly examined and tested at a frequency laid down in the local orders. Records of such tests shall be maintained, to identify the tests carried out, any actions required to maintain the interlocks and the date for next examination.
- viii. For the protection of persons accidentally locked inside an enclosure, an alarm shall to be provided to summon help from outside the enclosure. In addition, in all X-ray facilities and, where reasonably practicable, sealed source radiography, a means of controlling the radiation source from inside the room is to be provided. Such a control is to prevent exposure from taking place if activated outside the exposure phase, and terminate if operated during an exposure.
- ix. A sufficient number of prominently marked controls (stop buttons or pull cords) shall be provided such that they can be activated promptly and without crossing a main exposure beam. These controls are to be of a type that needs to be positively re-set from the location at which they were operated before further exposures may be initiated. Such devices are to be regularly tested and documented. If it is not reasonably practicable to control the sources from inside the room, a shielded refuge is to be provided inside the enclosure. The RPA shall be consulted about the design of this refuge.
- x. A prominent notice shall be displayed in the enclosure explaining the actions to be taken in the event of being accidentally locked inside the enclosure.
- xi. Where manually operated source wind out systems are used, or where the dose rate exceeds 50 mSv min⁻¹ at 1 m from the source, a search-and-lockup system shall be provided and operated before each exposure, to ensure that no-one may be accidentally locked inside at the beginning of an exposure.
- xii. Where an enclosure has been designed in a way that limits positioning of the radiographic source or the X-ray machine within the enclosure, the equipment operating area shall be clearly marked.

4.1.4 Radiation warning devices

- i. Adequate warning to all persons in the vicinity shall be given by appropriate visual or audible signals, or both:
 - a. When a sealed source is about to be exposed, or when an X-ray machine is about to be energized (pre-exposure warning alarm);
 - b. While a source is exposed or an X-ray machine is energized (continuous exposure warning alarm).
- ii. The duration of the pre-exposure warning alarm shall be sufficiently long for anyone accidentally locked inside the enclosure to take appropriate action.

- iii. The pre-exposure warning alarm shall be easily distinguishable from the continuous exposure warning alarm and both warnings shall be clearly explained on well sited signs. To achieve this, a warning signal may be combined with a sign in the form of an illuminated sign.
- iv. In the case of X-ray machines, and sealed sources capable of producing $>10 \text{ mSv min}^{-1}$ at a distance of 1 m, the warning signals and illuminated signs shall be arranged to operate automatically.
- v. Warning signals shall be installed inside the enclosure and outside each entrance to the enclosure.
- vi. A further exposure warning signal (such as a red light) shall be activated on the control panel and is to remain on long enough for the indication to be seen by the operator irrespective of the exposure duration.
- vii. Warning devices for X-ray enclosures shall be fail-safe, i.e. if the warning device fails the exposure will not proceed. If reasonably practicable, warning devices for sealed source enclosures are to be fail-safe.
- viii. All warning signals shall be regularly examined and tested to ensure their satisfactory operation. Records of such checks shall be maintained, to identify the tests carried out, any actions required to maintain the interlocks and the date the next examination is due.
- ix. Explanatory notices are to be provided to inform employees and other persons as to the purpose of the warning signal. The notice shall be in both Swahili and English.

4.1.5 Operating Procedures

- i. Work involving the exposure of sealed sources or operation of an X-ray set is only to be undertaken in accordance with practice related rules and written arrangements drawn up by the establishment in consultation with the RPA. Non-classified persons are only to enter a controlled area under written arrangements.
- ii. The movement or manipulation of sealed sources shall be undertaken by remote control. Radiographic sources shall never be handled with bare or gloved hands.
- iii. The radiographic set-up is to be completed before the X-ray machine is energized or the sealed source is exposed. No material is to be brought into the radiation beam except by the use of mechanisms operated from outside the enclosure.
- iv. Where there are limitations on the location of these equipment's inside the enclosure, the radiographic source or the X-ray machine shall only be operated in the demarcated area
- v. Before an X-ray machine is operated, or a sealed source is exposed, a search of the enclosure shall be made to ensure that no one has been accidentally locked inside.
- vi. After each exposure, personnel approaching the source shall do so with a dose rate monitoring instrument to verify that the X-ray machine has de-energized or that the source has retracted fully home into its container. Wherever possible practicable, suitable electronic alarming dosimetry should also be worn.

- vii. The dose rate outside an enclosure shall be checked regularly and particularly after any change of radiation source or methods of work. The results shall be recorded in a survey report which is to be retained for a period of at least 2 years from the date of completion.
- viii. All radiation protection and monitoring instruments used in radiographic work shall be calibrated and tested.

4.2 Requirements for site radiography

When objects to be radiographed cannot be physically moved into a shielded enclosure, the work shall be carried out under 'site radiography' conditions. This method of radiography is very common, but it is potentially hazardous because of the absence of engineered safety measures. Site radiographic work can be performed with gamma radiographic devices, X ray equipment or mobile accelerators.

4.2.1 Movement and transport of sources

When gamma exposure devices and sources are to be moved around a work site, they shall not to be removed from the storage facility until they are ready to be used. The sources are to be moved only in appropriate containers such as transport packages which are locked correctly and the keys of which are removed. The requirements for transportation of radioactive materials shall follow International Atomic Energy Agency (IAEA) Safety Standards Series No. ST-1.

4.2.2 Storage of Radiographic Sources

If it is necessary for a radiographic sealed source to be stored on site, it shall be stored in accordance with the general requirements. For short term exercises, where sources are used away from their base locations, it is acceptable for sources to be stored in their source container and transport packaging, in a locked and placarded vehicle in a secure area. For sources subject to Higher Activity Sealed Sources (HASS) regulatory control, the conditions on the notification certificate shall be applied.

4.2.3 Controlled Areas

- i) A controlled area shall be set up before any radiographic exposure is undertaken outside an enclosure. The extent of the controlled area shall fulfil the following, unless otherwise advised by the RPA:
 - a) Within an establishment, all areas outside the controlled area are to be at dose rates (averaged over one minute) of less than 7.5 $\mu\text{Sv/hr}$. Barriers and signs are to be set up where dose rates exceed 2.5 $\mu\text{Sv/hr}$.
 - b) The extent of controlled areas is to be determined in consultation with the RPA, initially by calculating the appropriate distance from the source to the 7.5 $\mu\text{Sv/hr}$ dose rate contour within

an establishment. On exposure of the sealed source or the X-ray machine, dose rate measurements are to be taken and the barrier moved until the dose rates do not exceed 7.5 $\mu\text{Sv/hr}$ or 2.5 $\mu\text{Sv/hr}$, as appropriate.

- c) It is to be set up so that access control can be effectively achieved. Access to controlled areas is to be restricted by the use of barriers, fixed structures, (such as the walls of buildings or bulkheads of ships).
 - d) It is to be minimized by utilizing local shielding such as walls, beam collimation etc.
- ii) Except where it is unavoidable for the purposes of initiating or terminating an exposure, where dose rates up to 2 mSv/hr would be permissible, no one shall work inside the controlled or supervised areas until the exposures are complete.
- iii) Where radiography is undertaken in a multi-storey building or on board ship, controlled and supervised areas are not only to include areas on the same level, but where appropriate, levels above and below the source of the radiation shall be designated.
- iv) Suitable warning signs shall be displayed at appropriate points around the perimeter of the controlled areas, such that a person approaching the controlled area from any direction would be made aware of the hazard. The signs shall state that the area is a controlled area and give details of the radiation hazard and the risks arising from the radiation source being used. An appropriate number of guards are to patrol the perimeter of the controlled area to prevent unauthorized entry.
- v) All controlled areas shall be suitably described in practice related roles. For site radiography, this can most easily be achieved by maintaining distances from the sealed source or X-ray machine.

4.2.4 Equipment Requirements

4.2.4.1 X-Ray Apparatus

Where X-ray machines are used, the following requirements are to be fulfilled:

- i. The beam filtration on the X-ray tube shall be equivalent to at least 2 mm of aluminium;
- ii. The leakage rate from the X-ray tube housing shall not exceed 2.5 mSv/hr at 1 m from the focal spot at the maximum rated voltage and current, and for pulsed X-ray tubes at the maximum pulse rate;
- iii. The lengths of cables from the X-ray machines shall be long enough to enable the control panel, whenever reasonably practicable, to be outside the controlled area;
- iv. For X-ray units operating up to 300 kV, cables of not less than 20 m in length shall be used. Longer cables are required for X-ray units operating at greater than 300 kV. Control cables to

warning signal devices shall be equal or greater in length than the tube head to control panel cables;

- v. The X-ray set shall be provided with a means of collimation to restrict the radiation beam to the minimum size necessary for the work;
- vi. The equipment shall be electrically safe;
- vii. The equipment shall be provided with a means of preventing unauthorized use (e.g. a key operated switch).

4.2.4.2 Sealed Sources

Sealed sources used in site radiography shall be provided with a suitable means of collimation to restrict the extent of the radiation beam to a minimum necessary to undertake the work and operated via a keyed switch to prevent unauthorized use.

4.2.5 Warning Signals

i. Adequate warning of the impending or actual presence of radiation shall be given to all persons within or approaching the marked off area during site radiography by appropriate visual or audible signals, or both. The two signals are as follows:

- a) When a source is about to be exposed or when an X-ray machine is about to be energized (pre-exposure warning alarm);
- b) While a source is exposed or an X-ray machine is energized (continuous exposure warning alarm).

ii. The duration of the pre-exposure warning alarm shall be sufficiently long for anyone within the controlled area to walk clear.

iii. The pre-exposure and the continuous exposure in progress warning signals shall be easily distinguishable from each other. Both signals shall be clearly explained on well sited notices at the boundary. The notice shall explain the significance of the barrier. Warning signals and notices may be combined in the form of illuminated notices.

iv. In the case of all X-ray apparatus, the warning signals shall operate at or near the X-ray tube head, at the control panel and be clearly recognizable at the boundary of the area. The pre-exposure and the continuous exposure signals shall operate automatically and the equipment is to be unable to function unless they are connected. Work is to cease if the warning signals are not operating correctly. Interlock defeat switches shall not be fitted. A device shall be provided to enable the warning signals to be tested while the X-ray head remains de-energized.

v. In the case of sealed sources, warning lamps are generally used which are switched on manually, and these are to be in good working order. They shall be positioned so that they are clearly visible to

all persons in the vicinity. The pre-warning alarm is usually an audible alarm, such as a manually operated air horn.

vi. All warning signals shall be examined and tested on a regular basis and records shall be kept of the tests undertaken.

4.2.6 Operating Procedures

- i. At least one designated RPS needs to be present on the site or establishment for the duration of any radiographic procedure. The RPS shall be easily contactable by the radiographers undertaking the task.
- ii. Written operating procedures shall be drawn up for all X-ray machines and sealed sources by the parent establishment of the radiographers, in consultation with their RPA. A copy of the operating procedure is to be displayed at the control point during each such exposure.
- iii. A controlled area shall be set up in accordance with the requirements above. It is important that control cables are laid out so as to maximize the distance of the operator from the X-ray tube head. The control point is to be, whenever possible, outside the controlled area, and where this is so it is to be continuously manned throughout the whole period of the exposure. At least two classified persons are to be employed on each radiographic exposure, one of these shall be an experienced radiographer and both shall have sufficient knowledge of the actions to be taken in the event of an emergency.
- iv. Where the control point is inside the controlled area, operators shall only enter the controlled area to start the exposure, terminate the exposure or in the event of an emergency. In exceptional circumstances where it is necessary for an operator to operate the control point inside the controlled area the dose rate at the control point is to not exceed 25 $\mu\text{Sv/hr}$.
- v. After setting up the controlled area and before exposure, all persons within the area not involved with the radiography shall leave. A thorough search of the area shall be conducted with special attention being paid to places where personnel may remain unobserved, such as remote compartments and the interior of empty tanks.
- vi. The radiographic set-up shall be completed before any sealed source is exposed or X-ray machine is energized. No changes to the exposure arrangements are to be made during an exposure.
- vii. Sufficient guards shall be posted around the perimeter of the area to prevent entry to the controlled area during radiography. Care shall be taken to ensure that there are no areas where personnel can enter unobserved. Where it is not practicable to provide line of sight communication between guards it may be necessary to provide a voice communication system.
- viii. To ensure that radiation exposure to personnel is kept as low as reasonably practicable the following conditions are to be satisfied:
 - a) The useful beam shall be directed away from the control point and all occupied areas, unless these areas are adequately protected by distance or shielding;

- b) The beam size and exposure duration shall be kept to the minimum compatible with obtaining a satisfactory radiograph;
- c) Only authorized persons (these shall be at least classified persons or people working in accordance with written procedures) may enter the controlled area.

ix. On completion of the radiation exposure, the X-ray set shall be switched off, or the radiation source retracted into its container. Where a sealed source is used, the radiographer shall approach the source container using an appropriate dose rate meter and confirm that the source is fully home in its container. Where an X-ray set is in use the radiographer may only enter the controlled area and using a suitable radiation monitoring instrument confirm that the exposure is terminated.

x. The movement or manipulation of sealed sources shall always to be undertaken by remote control. Care is to be taken to prevent any part of the body coming close to the exposed source. Radiographic sources shall never be handled with bare or gloved hands. All unnecessary movement of sources shall be avoided. Sources shall only be moved about a unit when they are locked in the shielded positions in their containers and the keys have been removed.

4.2.6 Monitoring Surveys

A radiation survey record shall be maintained, containing details of radiation dose rates at the barrier and within controlled areas where persons are exposed to levels of radiation in excess of 7.5 $\mu\text{Sv/hr}$. Radiation survey records shall be maintained for at least 2 years from the date of the survey, unless there is an incident in which case the records are to be kept indefinitely.

4.2.7 Emergency Procedures

i. Contingency plans shall be drawn up by the establishment in consultation with the RPA to cope with any foreseeable emergency. A copy of these plans and a set of emergency equipment described in these plans shall be carried to each radiographic site. Radiographic sources and containers shall be designed to withstand severe fires; if a fire occurs the sources are only to be removed from the area if this can be done without risk to life. If this cannot be done they shall be abandoned and the firefighting services informed of their presence as soon as possible.

ii. Special equipment shall be available to deal with emergencies such as detached sources, jammed sources and damaged containers. The equipment is listed as follows:

- a) Audible alarm monitor;
- b) Personal integrating dosimeter;
- c) Tongs or CeeVee reachers (1 metre and 2 metre);
- d) Pliers, screwdriver, long-handled wire and bolt cutters;
- e) Adjustable spanner or wrench, rope, hand lamp;

- f) Tripod (2 metres high - to hoist end of the projection tube to help gravity return of a detached source);
- g) Radiation barrier (quick erect type);
- h) Two bags of lead shot (2 kg each), for Iridium-192 source;
- i) Ten bags of lead or lead shielded semi-cylindrical tunnel for Cobalt-60 sources;
- j) Emergency storage container;
- k) Pouring funnel to suit emergency storage container, for speedy placing of the source.

iii. Each person involved in site radiography shall be familiar with the content of these contingency plans. Contingency plans shall be regularly practiced (and at least annually) using dummy sources etc., to ensure that all personnel are aware of the actions they are to undertake. Records of contingency plan exercises (including the names of personnel involved) shall be kept.

iv. Contingency plans for site radiography shall be submitted to the Health and Safety Executive if requested.

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