NUCLEAR WASTE MANAGEMENT AT THE PSI HOT LABORATORY FACILITIES

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The PSI hot laboratory facilities are utilised for materials research and service work on a large variety of nuclear and radioactive components and samples. These installations are unique in Switzerland, because at the same place, scientists and co-workers operate with radioactive matter ranging from only few Bequerel up to some hundreds of Terrabequerel. Naturally, such a laboratory produces radioactive waste from the research programmes carried out there. The collection, treatment and conditioning of this waste for safe disposal in a future repository is a very important task with high responsibilities and will be presented in this contribution.

1 INTRODUCTION

At the PSI hot laboratory, radioactive waste is produced during post-irradiation studies carried out in the hot cells as well as from actinide ceramics research in the plutonium laboratories. Additional radioactive waste is produced in other PSI facilities such as the school of radiation protection and the accelerators. Based on Swiss Radiation Protection Regulations [1], PSI is also responsible for collecting radioactive waste from medical, industrial, and research facilities in Switzerland. Some of this additional waste is also treated in the hot laboratory.

According to the regulations, the waste must be treated in such a way that there is no radiation risk for the working staff members. In addition, all waste must be conditioned appropriately and sealed in safe containers for final disposal in a future repository. Since 1990, the Swiss Federal Nuclear Safety Inspectorate (HSK) has required a certificate of acceptability for final storage from the National Cooperative for the Disposal of Radioactive Waste (Nagra) before issuing permission for waste conditioning [2]. In order to meet all official requirements, a good and efficient waste management programme is essential.

2 CHARACTERISTICS OF WASTE

Radioactive wastes from the hot laboratory are characterised mainly by their inventory of irradiated and non-irradiated nuclear fuel. From the actinide ceramics laboratories, non-irradiated fissile material, i.e. plutonium and uranium, goes into the waste. This waste includes mostly α-emitters. These are not a problem from the radiation field protection point of view, but if ingested, these nuclides are highly toxic and their alpha radiation is a serious radiological problem.

Structural components and fuel rods from nuclear power plants are examined after having been irradiated for several years. The radioactive waste from this material consists not only of high α-activities from plutonium and uranium isotopes present in the nuclear fuel, but also of high β and γ-activities due to nuclear fission and neutron activation. Most of these isotopes have half-lives between a few months and some years.

Radioactive waste from other PSI installations and from medical applications consists mostly of experimental and medical radiation sources made of γ-emitters like ^{60}Co or ^{137}Cs which are transported to the hot laboratory in order to dismantle them. The origin of accelerator waste is irradiated target materials which are replaced in a hot cell. Their isotopic composition results from activation and spallation processes during the irradiation. Their radioactivity also includes γ-emitters with half-lives of less than a hundred years.

3 DEFINITION OF WASTE STREAMS

In the hot laboratory, the waste is collected separately and packed, according to physical and radiological criteria. It is then divided into waste streams and must be treated according to the waste management regulations [3] that are part of the laboratory regulations [4]. These regulations define the waste streams on the basis of physical parameters (e.g. kind of material, size, and weight) and radiological parameters (e.g. kind of radioactivity and dose rate). The waste is temporarily stored in special storage rooms in lead boxes or in one of the hot cells. Once a year, the waste is transferred to the radioactive waste treatment facilities of PSI, where it is combusted, compacted or cut into pieces and sealed in a concrete matrix. The final waste package is usually a 200 l drum which can be stored in the Swiss Federal Interim Storage for radioactive waste (BZL). In some cases, special waste packages, e.g. MOSAIK or large concrete containers are used.

Fig. 1 shows an overview of the waste streams that are presently defined. The first division is between inactive and active waste. Active waste is then separated into combustible, compactable or bulky solid waste, and aqueous waste solutions.

4 WASTE TREATMENT

One of the major rules concerning waste management at the hot laboratory is that the waste producer is responsible for the correct separation, packing and declaration (written description) of his waste. Special packaging exists for each waste stream including plastic bags and foils, 20 l, 100 l, and 200 l steel barrels, tin cans and other types of containers and boxes. The waste treatment steps in the hot laboratory are

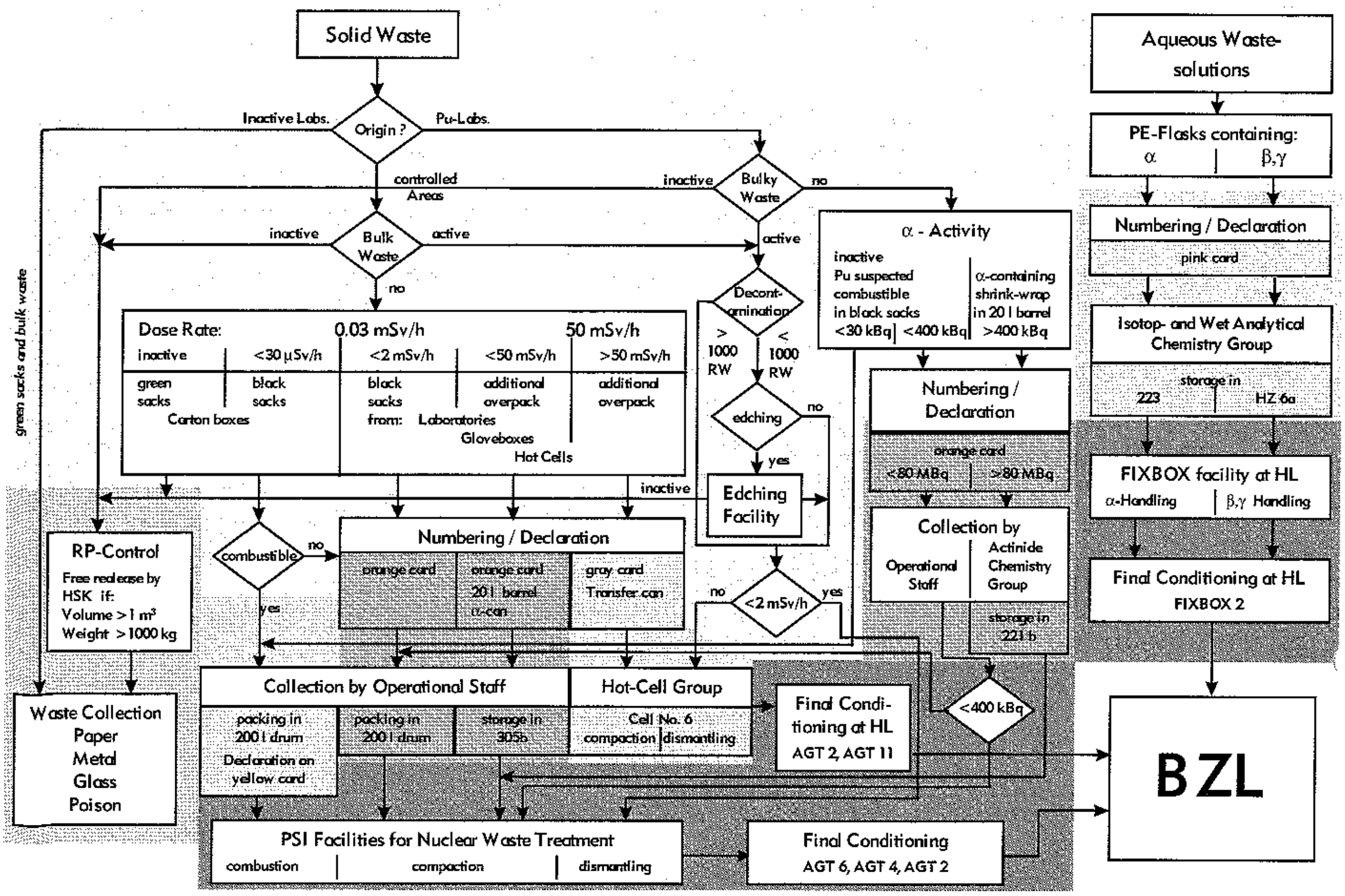

Fig. 1: Waste streams in the hot laboratory

defined in the waste management regulations of the facility [3].

4.1 Inactive waste

Inactive waste is defined by Swiss radiation protection regulations [1] as having a surface dose rate of less than 100 nSv/h, and surface contamination of less than 0.3 Bq of α-activity and less than 3 Bq of β,γ-activity.

At PSI, inactive waste from both controlled and non-controlled areas of the hot laboratory is packed in green bags. Waste from non-controlled areas is inactive by definition, whereas inactive waste from controlled areas must be checked by the radiation protection group before it can be freely released. Inactive waste can then be managed through the normal public waste refuse system.

4.2 Active waste

4.2.1 Combustible waste

Combustible waste consists mainly of paper, cellulose, gloves and plastic. It can be incinerated in the combustion facility of PSI if neither the allowed surface gamma dose rate of 30 µSv/h nor the maximum α-activity of 30 kBq is exceeded. This waste is collected separately, packed in black plastic bags, and marked as combustible waste. The bags are packed in 200 l drums for transportation to the combustion facility of PSI, where it is incinerated once a year. The ashes from this waste are directly mixed with concrete and filled into 200 l drums. In such a concrete matrix, the activity is sealed for a future repository. Finally, the waste packages are brought to the BZL for interim storage. Approximately three tons of raw waste per year pass through this waste stream.

4.2.2 Compactable waste

Radioactive waste which can be compacted in one of the compaction facilities at PSI is called compactable waste. It contains non-irradiated fuel from the plutonium laboratories and irradiated material from post-irradiation experiments or other radioactive sources. The radioactive inventory of the non-irradiated fuel consists of plutonium and uranium isotopes and their decay daughters. It arises only in the plutonium laboratories and is collected separately. Because the inventory of fissile material in the hot facilities is regularly checked by the International Atomic Energy Agency (IAEA), the amount of plutonium and uranium in the waste is measured using a Segmented Gamma Scanner (SGS) analysis system.

Irradiated material contains principally ^{60}Co or ^{137}Cs as key nuclides. Its source is activated core structural material and destructive fuel rod investigations for the Swiss nuclear power plants. Because of the wide variety of sources of radioactivity, the surface dose rate of this waste can amount to several Sievert per hour.

Compactable waste with a total surface dose rate below 50 mSv/h and non-irradiated fuel waste from the plutonium laboratories are packed separately into 20 l drums and stored in special storage areas at the hotlaboratory. Once a year, the 20 l drums are transferred to a waste treatment facility at PSI, called the waste laboratory, where the drums are compacted directly into 200 l drums using a remote-controlled system. In these 200 l drums, the waste pellets are completely surrounded by a layer of concrete.

This waste stream amounts annually to about 800 kg from the plutonium laboratories and 600 kg from other installations in the hot laboratory.

Compactable waste with higher dose rates must stay in the hot cells. It is packed in cans or tightly sealed containers of 20 l volume and stored in a specially designed storage and conditioning hot cell which has been in operation since 1997. The dose rate for the individual waste cans must be less than 2 Sv/h in order to meet the dose rate limits for the final waste package. In the storage and conditioning hot cell, the waste is sorted and can be compacted by means of two different compaction units. The waste pellets from this compaction are placed in steel cylinders and finally put into a special waste package, i.e. a MOSAIK container. In the first campaign, approximately 1.5 tons of high level radioactive waste collected during the previous seven years was compacted.

4.2.3 Bulky waste

Bulky waste, e.g. glove boxes, sawing or drilling machines or pieces from the former nuclear research reactors of PSI, can either be treated manually in the waste treatment facilities of PSI or in one of the hot cells of the hot laboratory. The limitations on where such waste is handled is given either by the degree of surface contamination or by the surface dose rate of the waste pieces.

If the waste consists of contaminated metal, e.g. steel, aluminium or copper, it is expected that it will be decontaminated in an etching facility where the material will be treated chemically by means of pickling solutions. In this way, it is possible to dispose of part of the material as inactive waste. After etching, radiation safety must be ensured by testing the waste before it can be freely released. Annually, two tons of waste are foreseen in this waste stream.

If no decontamination is possible, waste with a surface dose rate below 2 mSv/h is usually wrapped into plastic foil and stored in the hot laboratory. Once a year, it is transferred to the waste laboratory, where it is first cut into smaller pieces and then sealed directly with concrete into a 200 l drum (see Fig. 2). For radiation protection reasons, waste with a surface dose rate above 2 mSv/h is handled in a hot cell in the same way by first cutting the larger pieces and then sealing it with cement into a 200 l drum. Finally, the 200 l drums are transferred to the BZL for interim storage.

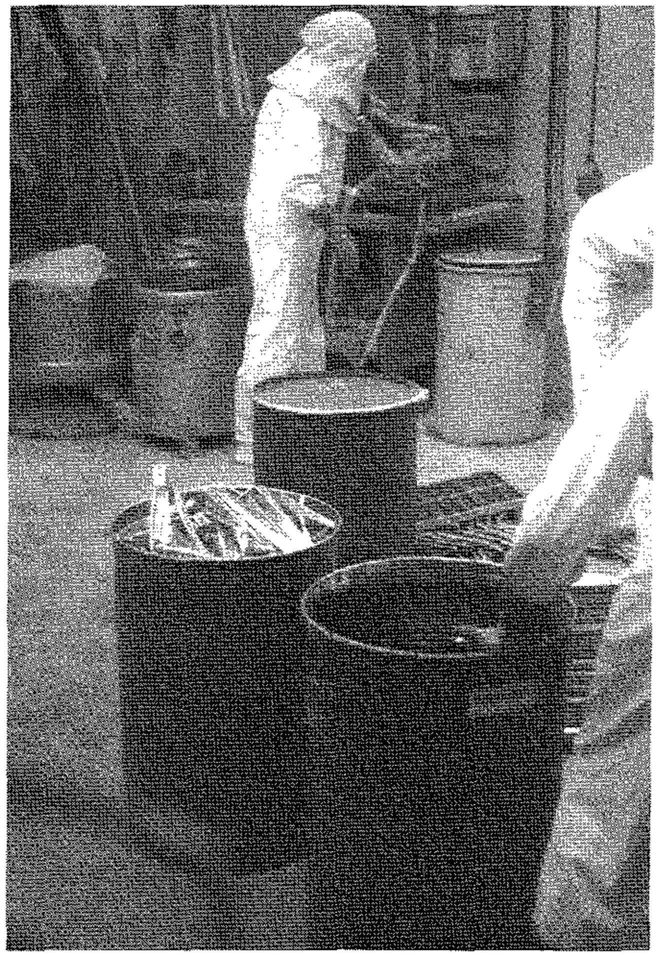

Fig. 2: Waste treatment in the waste laboratory

Approximately one ton of waste per year passes through this channel, but fortunately most of it can be treated in the waste laboratory.

4.2.4 Aqueous waste solutions

Aqueous waste solutions arise either from the preparation of actinide ceramics or from post-irradiation investigations. Depending on the specific activity level, the waste is usually packed in glass or polyethylene flasks and stored in one of the hot cells. A special treatment facility was designed for these solutions in the hot laboratory. The facility, called FIXBOX [5], consists of two combined glove-boxes as shown schematically in Fig. 3. In box No. 1, there are two storage vessels in which the solutions are mixed, and from which the mixture is pumped to the filling station placed in box No. 2. Aliquots of the mixture are injected into evacuated polyethylene flasks containing a dry concrete mixture. The mixtures of concrete and waste solution are homogenised, and the flasks are left in the second box while the concrete hardens. Finally, the concrete-filled flasks are placed in a 200 l drum, sealed with cement, and stored in the BZL.

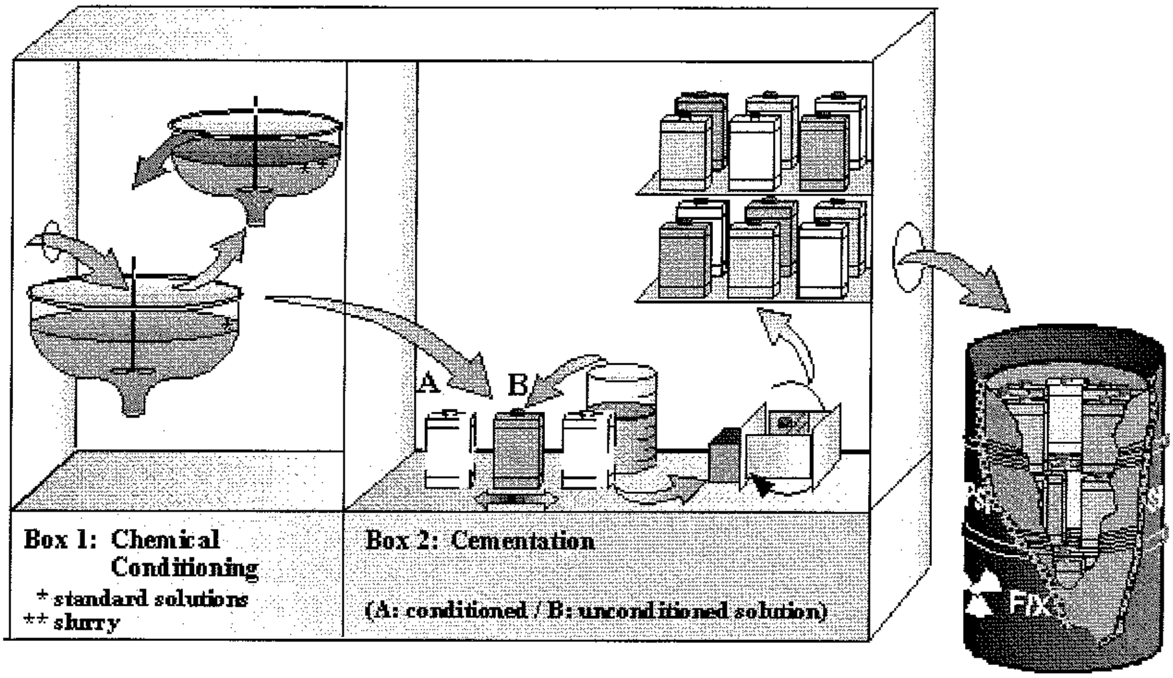

Fig. 3: Scheme of the FIXBOX facility

4.2.5 Additional waste streams

Additional waste streams arise from the dismantling of large medical radiation sources and from nuclear fuel either from the former nuclear research reactors of PSI or from the post-irradiation research programmes for the Swiss nuclear power plants. These waste streams are not included in Fig. 1 because today's policy is to recover as much still-useful material as possible for recycling or return to the owner.

Large medical radiation sources with ^{60}Co or ^{137}Cs are sometimes shipped to PSI for dismantling of the inactive part and disposal of the pure source activity. In the past, such sources had to be stored for decades to reduce the activity by natural radioactive decay before they could be added to the compactable high level waste stream. Today, these recovered sources are shipped to Amersham-Buchler company (Braunschweig, Germany), where they are recycled and prepared for further usage.

A second waste source is fuel from the PSI research reactors. After their shut down, the fuel in casks was transported to the hot laboratory and packed into special transport containers in which they were shipped to a reprocessing plant in the USA.

Finally, irradiated fuel from the destructive inspection of fuel rods from the Swiss nuclear power plants is recovered very carefully, in order to return it to the owner and to reduce the high level waste at the hot laboratory. The fuel segments are inserted in new zircaloy cladding tubes (overcanning), pressurised with helium gas and sealed by TIG welding of new end caps.

5 QUALITY ASSURANCE

For quality assurance, the production of each type of waste package must be described from the starting waste collection to its state after final conditioning [2]. Every step during this procedure needs to be completely documented, in order to describe the quality of the final waste package before it is allowed to enter the Swiss Federal Interim Storage (BZL). Thus, for each waste stream, a specific type of waste package exists [6-10].

The basic document in this series is the waste declaration card, which has to be filled out by the waste producer for each particular waste component, e.g. bag, barrel, flask or piece of bulky waste. This card summarises relevant data on the waste, e.g. producer, origin, waste description, waste constituents, radioactive inventory, and surface dose rate. The declaration cards are colour-coded according to waste stream and the card must stay with the waste package until the waste is conditioned.

When the waste is conditioned, a second document is opened for each final waste package, collecting the data from all the waste that was put into the package and about the package itself.

Finally, when the waste package is transferred to the BZL, a computer based document, called ISRA (Information System of Radioactive Waste Packages) documentation, is opened according to the specification of the waste package type. For quality assurance, this documentation contains values for all parameters required and the data collected from the previous documentation for each particular waste package. This information is also made available to Nagra.

The most important information in the ISRA documentation is the inventory of radioactive nuclides in the waste. This inventory defines the kind of final repository in which the waste will be disposed. In most cases surface-dose-rate-to-activity tables are used for the declaration. The values based on the tables are checked for each waste drum after conditioning using a gamma scanning facility at the waste laboratory. Here, each drum is rotated at a constant rate on a turntable and γ-ray spectra are taken in horizontal segments, in order to measure the complete inventory of the detectable radioactive nuclides. However, this method is only useful when the γ-rays emitted from the nuclides in the waste have energies above 500 keV and strong intensities, e.g. ^{60}Co or ^{137}Cs, because in most cases the waste is already surrounded by a layer of concrete which serves as shielding against γ-radiation.

As mentioned above, fissile material including the unconditioned waste from the plutonium laboratories is controlled by the IAEA. Therefore, the amount of Pu and U in the waste must be quantified, in order to balance the total inventory of fissile material in the plutonium laboratories. This measurement cannot be executed on the scanner unit at the waste laboratory, because Pu gamma radiation is too weak to penetrate the concrete shielding of the final waste package.

The determination of plutonium and uranium can be done usefully only in small waste packages, i.e. the 20 l drums, with low density waste matrices, and the waste density has to be determined in order to correct for the energy dependent photon absorption. Since 1997, the rebuilt Segmented Gamma Scanner (SGS) facility at the hot laboratory (see Fig. 4) has been used to measure the plutonium and uranium isotopic composition in this waste stream [11,12].

The system consists of a moveable turntable on which the waste package can be positioned. A high purity germanium (HPGe) detector registers the γ-radiation emitted from the waste. The measurements are usually performed in ten horizontal segments. During the measurements, the drum is rotated at a constant rate in front of the detector. A transmission source of ^{75}Se placed on the opposite side of the detector serves as a calibration standard and for the determination of the waste density. Standard NIM electronics is used for signal processing, and PC-based software is responsible for controlling the movement of the turntable, data acquisition and final spectrum analysis.

The system was carefully calibrated for energy linearity, detector efficiency and photon absorption as a function of the γ-ray energy emitted. The influence of geometric effects was also studied [12].

The results from an initial measuring campaign show good agreement between the isotopic compositions determined and the isotopic composition known from the plutonium mixtures used. Also, the measured amounts of plutonium and uranium were in good agreement with estimates made from surface dose rate measurements.

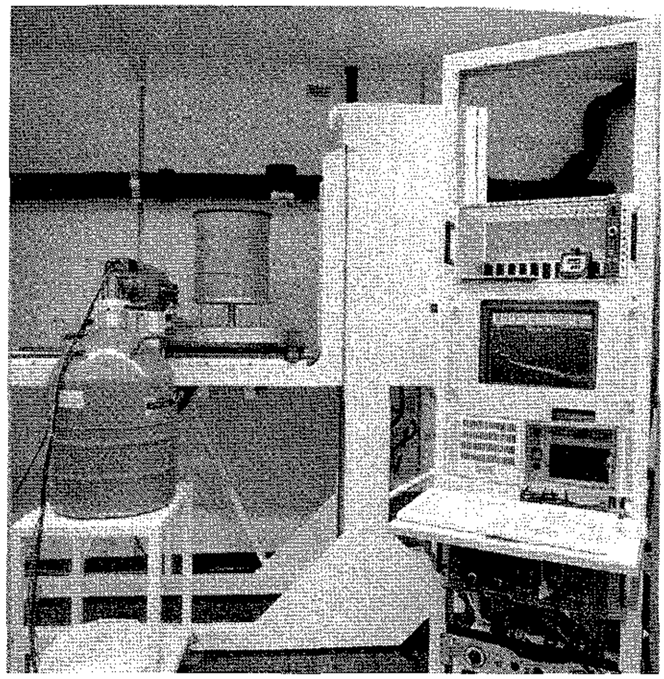

Fig. 4: The Segmented Gamma Scanner build up at the hot laboratory.

With only few modifications, the system can also be used for the investigation of other nuclides and of waste matrices of higher density.

6 CONCLUSIONS

The waste management system in operation at the facilities of the Laboratory for Materials Behaviour is oriented to safe handling and sealing of radioactive waste in compliance with official and internal regulations. Standard and newly developed facilities are used to minimise the waste volume by combustion, compaction or dismantling. Major efforts are made to recover radioactive material for recycling. The main activities are driven not only by the need for safe disposal, but even more by a desire to reduce and avoid radioactive waste.

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