For participants only
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Committee on the Peaceful Uses of Outer Space
Scientific and Technical Subcommittee
Forty-third session
Vienna, 20 February-3 March 2006
Item 9 of the provisional agenda*
Use of nuclear power sources in outer space

Joint United Nations/International Atomic Energy Agency technical workshop on the objectives, scope and general attributes of a potential technical safety standard for nuclear power sources in outer space (Vienna, 20-22 February 2006)

Unique design considerations for nuclear power source applications in outer space

Working paper submitted by the Russian Federation

Note by the Secretariat

1. In accordance with paragraph 16 of General Assembly resolution 60/99 of 8 December 2005, the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space will organize, jointly with the International Atomic Energy Agency, a technical workshop on the objectives, scope and general attributes of a potential technical safety standard for nuclear power sources in outer space, to be held in Vienna from 20 to 22 February 2006.

2. The working paper contained in the annex to the present document was prepared for the joint technical workshop in accordance with the indicative schedule of work for the workshop, as agreed by the Working Group on the Use of Nuclear Power Sources in Outer Space during the intersessional meeting held in Vienna from 13 to 15 June 2005 (A/AC.105/L.260).

* A/AC.105/C.1/L.283.

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Annex I

Unique design considerations for nuclear power source applications in outer space

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1. The unique design of space nuclear power sources derives from specific safety requirements for space nuclear power source applications and relevant general technical safety requirements.

2. The specific requirements for the safe use of space nuclear power sources at all stages of their design, manufacture, operation, withdrawal from operation and subsequent prolonged period in space, cover the following points:

a) The reasons for using of space nuclear power sources: the cutting-edge space research programme currently under way cannot be implemented using non-nuclear power sources and will be more comprehensive if nuclear power sources are used;

(b) The fact that the use of space nuclear power sources is subject to national legislation on space activities and on the use of nuclear power and to international principles governing nuclear power source use in outer space that have the status of recommendations. International principles governing the use of nuclear power sources in space that are based on the Charter of the United Nations and on international treaties and conventions may be supplemented by the future joint document of the United Nations and the International Atomic Energy Agency (IAEA) containing safety standards for reactor and radioisotope space nuclear power sources;

(c) Safety culture: the responsibilities of personnel of nuclear power source developers and manufacturers and of personnel of the operating organization; personnel qualifications and training; psychological training of personnel to ensure that they understand that the safety of nuclear power sources is a priority; and measures to ensure sufficient numbers of qualified personnel throughout the life cycle (development, manufacture, operation and withdrawal from operation) of a nuclear power source and any extended period during which the source remains in space after it has been withdrawn from operation;

(d) Quality assurance: development and implementation of a quality assurance programme with a view to building confidence that the safety requirements set out under various programmes will be met throughout the life cycle of the nuclear power source;

(e) The fact that the safety of space nuclear power sources is ensured through compliance with the principle of defence in depth, with emphasis on minimizing the impact of ionizing radiation and radioactive materials on the public and on the environment, including outer space;

(f) Safety systems and safety-related structural elements that ensure the safety of space nuclear power sources during normal operation and in the event of foreseeable and likely accidents, together with a set of organizational and technical measures for accident prevention and post-accident clean-up operations;

(g) The fact that levels of exposure of the public, the environment and outer space to ionizing radiation and radiation pollution caused by space nuclear power sources are established on the basis of the recommendations of the International Commission on Radiological Protection, the requirements set out under national standards and rules and possible future IAEA standards for space nuclear power sources;

(h) The fact that the safety of nuclear power source use and the risks associated with it are evaluated on a case-by-case basis, depending on the function and mission of the spacecraft and taking into account the reliability and efficacy of the equipment used to ensure the safety of the nuclear power source and the probability of accidents during the launch of the spacecraft with a nuclear power source on board, during operation or on withdrawal from operation of the nuclear power source or in the event that the source remains in space for a prolonged period, taking into account the probability of collision with space debris. The effects of such accidents on the safety systems and structural elements of the nuclear power source may lead to radiological impact that exceeds the acceptable levels set out in the relevant standards and rules—a situation that is classified as a radiation accident. A radiation accident may occur in the event of destruction of the nuclear power source, radionuclide emission in the case of radioisotope nuclear power sources or reactor supercriticality in the case of reactor nuclear power sources. The methodology for assessing the probability of radiation risk in the event of a radiation accident is based on analysis of the probability of final events, potential radiation doses received by the public in the event of a nuclear power source falling into an inhabited area, and the number of persons irradiated. In order to mitigate such consequences and reduce the risk of radiological impact, organizational and technical measures for clean-up operations and protection of the public are envisaged in the event of a radiation accident;

(i) Guarantees of the physical protection of nuclear materials in the event of a reactor nuclear power source being involved in one of the specific types of accident that occur during the insertion of a spacecraft with a nuclear power source on board into operational orbit or onto an interplanetary flight trajectory, including accidents on board spacecraft with nuclear power sources that lead to the orbital re-entry of the spacecraft or of an autonomous nuclear power source into the Earth's atmosphere and the fall of the nuclear power source to Earth. The guarantees do not apply in the event of complete aerodynamic destruction of the reactor and dispersion of nuclear fuel when it is broken down into fine particles;

(j) Publication of the results of work on the evaluation of nuclear power source safety; publication within the United Nations of a nuclear power source safety assessment; discussion of results of the work; furnishing of information to the United Nations and to IAEA in the event of an accident involving a nuclear power source; and the admissibility of keeping information confidential in the event of an accident involving the fall of a nuclear power source.

3. The general technical safety requirements for space nuclear power sources are in line with the specific safety requirements for the use of space nuclear power sources and contain the following provisions:

a) A requirement to ensure safety during the manufacture and testing of nuclear power sources in all normal operation regimes of the nuclear power source (storage and transportation; pre-launch preparations at the launch site; insertion into orbit on board the spacecraft and launch vehicle; operation on board the spacecraft; withdrawal from operation), during a prolonged period in space following withdrawal from operation and in the event of an accident at any stage of operation of the nuclear power source, spacecraft or launch vehicle;

(b) A requirement that the nuclear power source structure and the programme for insertion into orbit of the nuclear power source on board the spacecraft and launch vehicle are designed in such a way as to prevent the accumulation of space debris in near-Earth orbits;

(c) Requirements relating to materials, in particular that all materials used should be clean;

(d) Requirements relating to nuclear power source safety systems and safety-related structural elements;

(e) A requirement for the evaluation of nuclear power source safety.

4. The structure and content of the general safety requirements for space nuclear power sources are determined entirely by:

- The methodology for ensuring safety and the regulatory documents establishing safety standards and criteria;

- The structure of nuclear power sources, which is determined by scientific, technical and design considerations, depending on the function, type, characteristics and parameters of the nuclear power source.

5. In the case of reactor space nuclear power sources, i.e. nuclear power units with converter reactors (figure 1) and nuclear power propulsion units with reactors constructed on the basis of nuclear rocket propulsion technology (figure 2), the main nuclear and radiation safety principles to be applied during operation and in the event of accidents are as follows:

- In order to ensure nuclear safety: reactor subcriticality in all operation regimes, with the exception of the physical start-up of the reactor and normal operation on board a spacecraft in orbit or on an interplanetary flight trajectory;

- In order to ensure radiation safety: prevention of irradiation of personnel or the public above acceptable levels and prevention of uncontrolled dispersal of radioactive substances into the environment that affects the public.

6. Reactor subcriticality is maintained by the control cylinders of the reactor control and protection system, which are contained in the side reflector of the reactor, and by safety rods housed in the reactor core, which are made from materials with a high neutron absorption cross-section that contain burnable poisons (figures 1 and 2).

7. Ionizing radiation from the “cold” non-activated reactor is maintained at acceptable levels by limiting total power generation (neutron power and lifespan) during physical start-up of the reactor and by means of the time lag between start-up of the reactor and transport of the reactor nuclear power source in a transport container to the launch site.

8. Compliance with requirements for the nuclear and radiation safety of reactor nuclear power sources is determined entirely by the state of the reactor structure in the context of accident progression following the failure of insertion equipment (launch vehicle, upper stages and spacecraft propulsion units) resulting in partial or complete thermal, mechanical and aerodynamic destruction of the structure of both the nuclear power source and the reactor.

9. The following are regarded as foreseeable accidents: explosion of the launch vehicle and combustion of rocket propellant components in the event of a fire; ballistic descent and Earth impact of the launch vehicle; descent of an object into the Earth's atmosphere prior to or following ejection of the launch vehicle's nose cone; or orbital re-entry of a spacecraft with a nuclear power source on board into the atmosphere.

10. In the case of radioisotope space nuclear power sources, the main radiation safety principle is maintenance of the integrity and leak-tightness of the ampoules containing propellant based on a selected radionuclide in all nuclear power source operation regimes and in the event of foreseeable accidents. This is accomplished by cladding the radionuclide ampoule with multiple casings using high-temperature materials and alloys with corrosion-resistant coating, and by using an aerodynamic heat shield and thermal insulation made from carbon-based materials (figure 3).

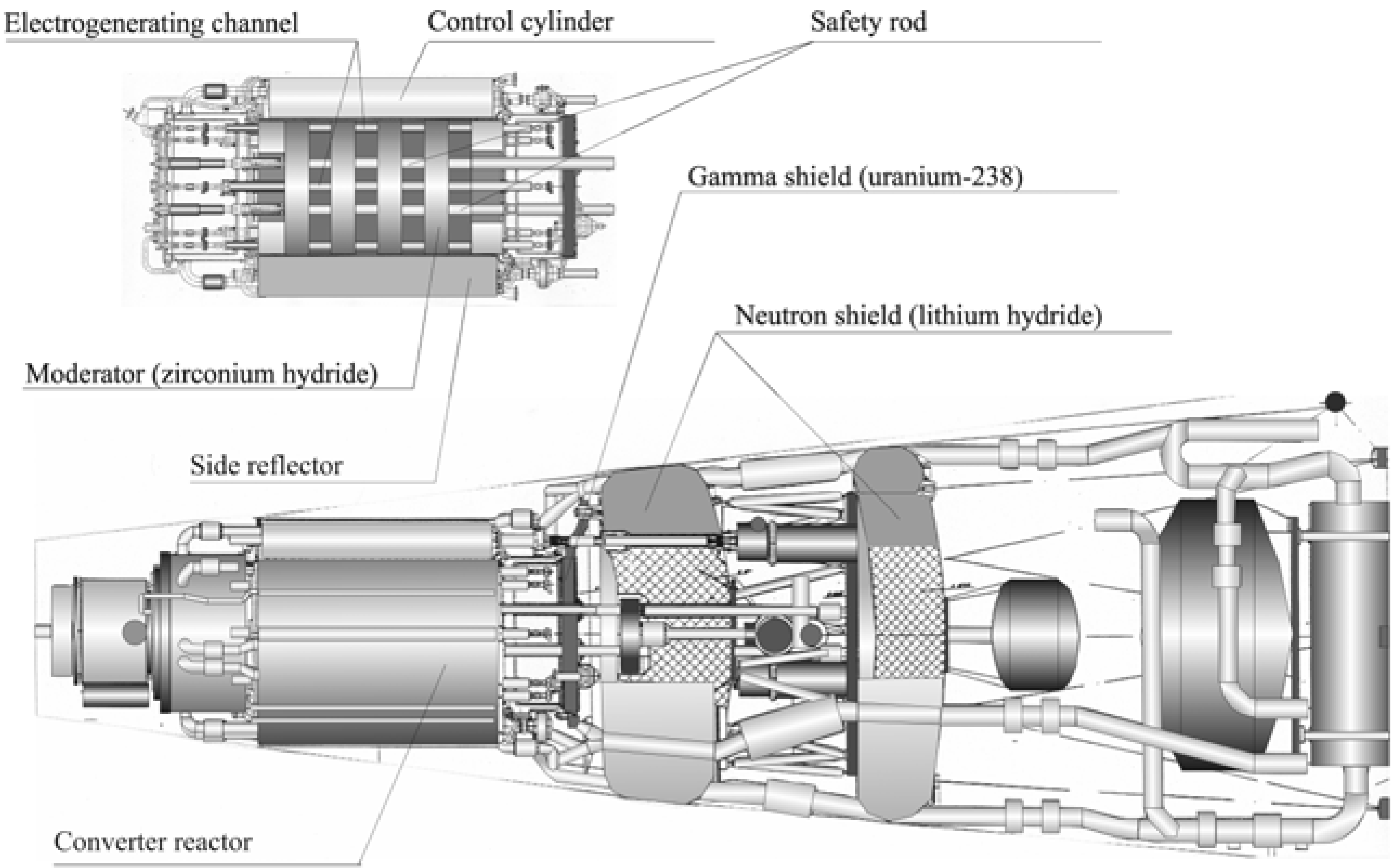

Figure 1 - Thermal-emission converter reactor and radiation shield of nuclear power unit

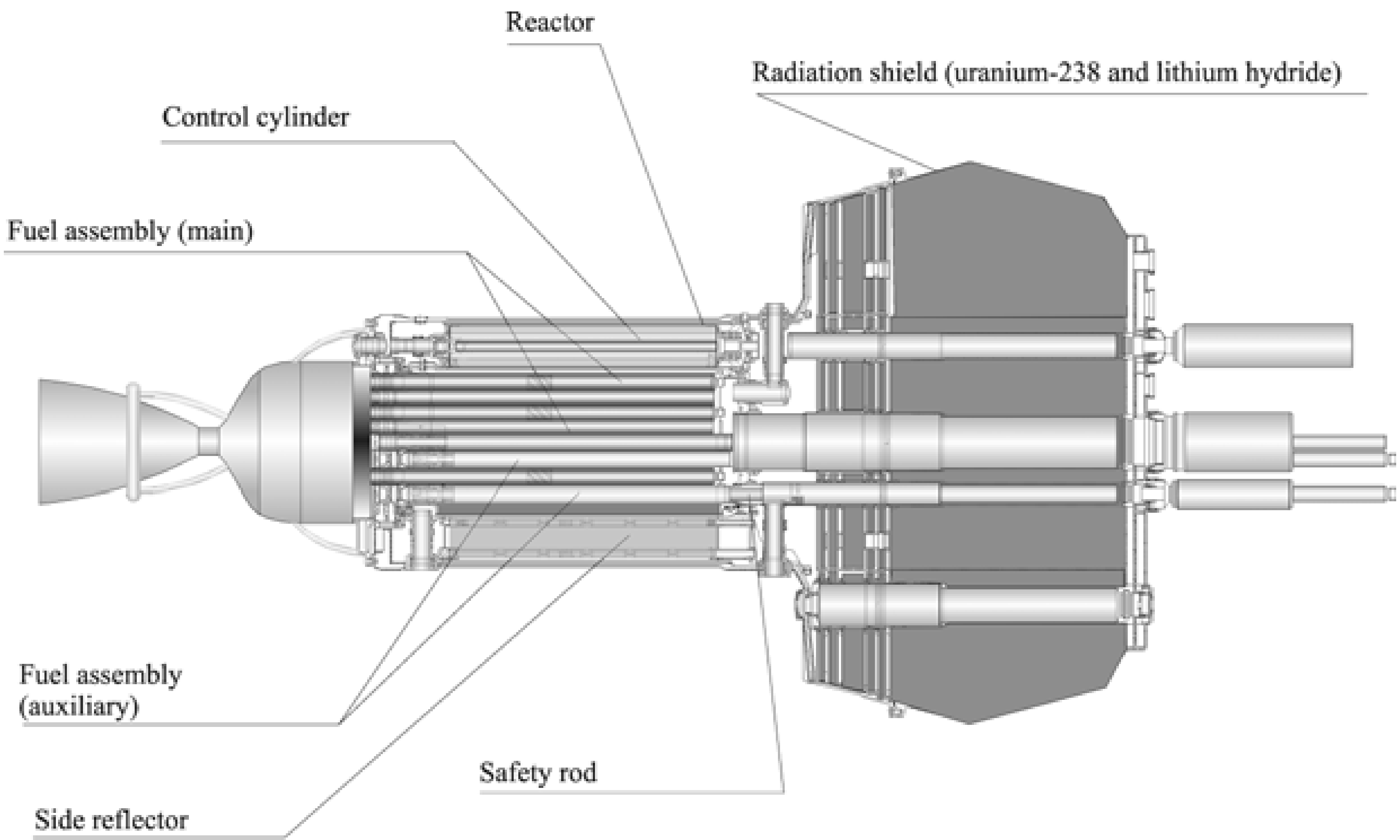

Figure 2 - Reactor and radiation shield of nuclear power propulsion unit

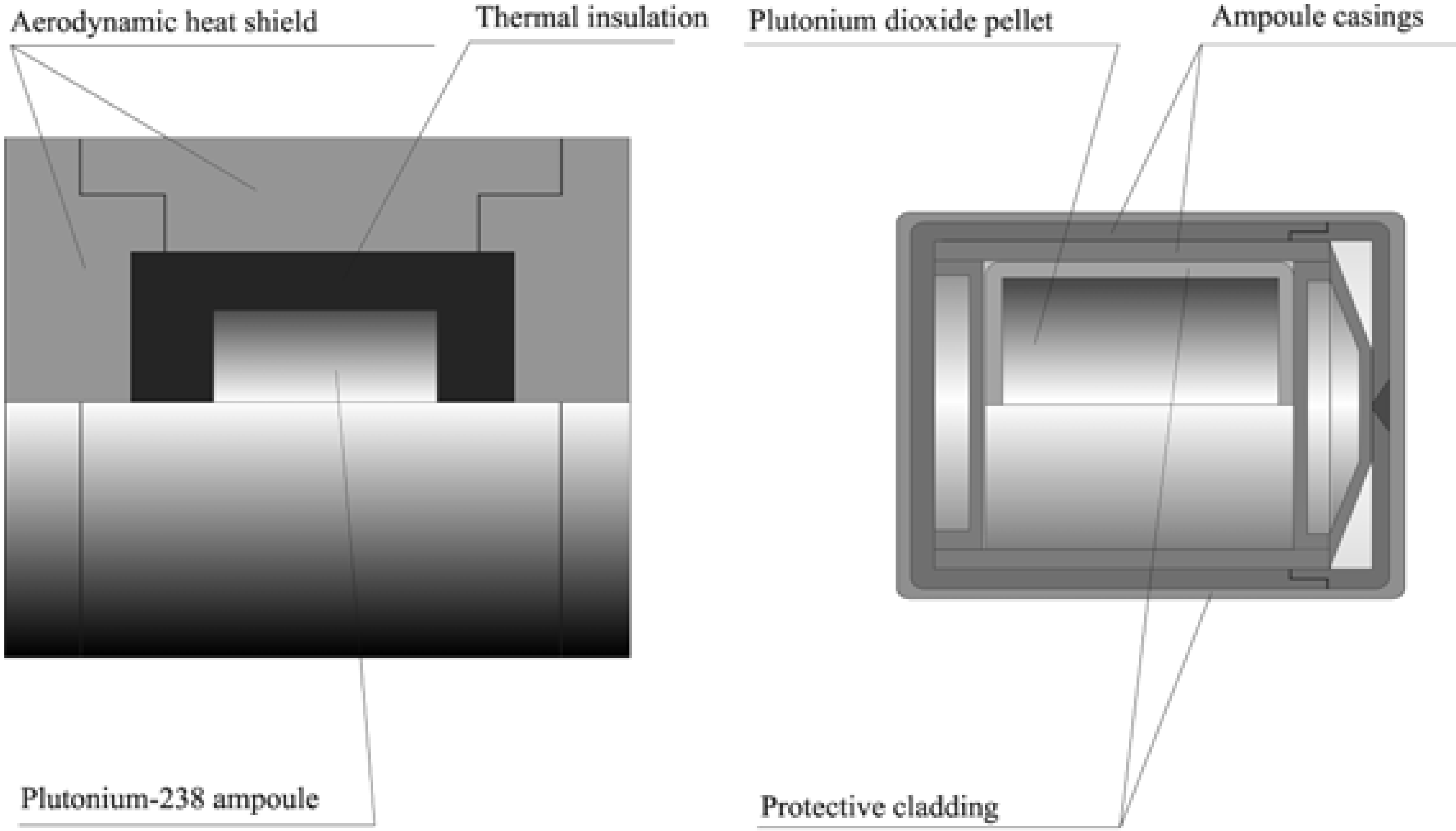

Figure 3 - Radioisotope heat source