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RECENT DEVELOPMENTS IN TOPAZ II REACTOR SAFETY ASSESSMENTS*

Albert C. Marshall
Sandia National Laboratories
Albuquerque, NM

Introduction

In December 1991, the Strategic Defense Initiative Organization (SDIO) decided to investigate the possibility of a United States (US) launch of a Russian Topaz II space nuclear power system. The primary mission goal would be to demonstrate and evaluate Nuclear Electric Propulsion technology to establish a capability for future civilian and military missions. A preliminary nuclear safety assessment, involving selected safety analyses, was initiated to determine whether or not a space mission could be conducted safely and within budget constraints. This paper describes our preliminary safety assessment results and the nuclear safety program now being established for the Nuclear Electric Propulsion Space Test Program (NEPSTP).

Description of Reactor System

The Topaz II space reactor power system uses an in-core thermionic reactor, a radiation shield, a pumped NaK coolant, and a radiator to dissipate waste heat into space. The overall system mass is 1061kg and the system length is 3.9m. The reactor is moderated by zirconium hydride and has an epithermal neutron spectrum. The core contains 37 thermionic fuel elements within the zirconium hydride moderator. 96%-

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enriched UO_2 fuel is used with a loading of about 27kg of uranium-235. Payload radiation shielding is provided by a LiH/steel shield. The design electrical power output and lifetime are 6kWe for one year or 4-1/2 kWe for three years, and the net efficiency is about 5%. Reactor control is provided by Be control drums, each with a borated poison segment; these are located in the radial reflector.

Safety Assessment Process

The first step in the preliminary nuclear safety assessment was to establish a safety approach, a nuclear safety policy, and top level safety functional requirements. Some important safety functional requirements include:

- No startup of the reactor until established in a sufficiently high orbit (a sufficiently high orbit is one in which the orbital lifetime is adequate to allow radioactive decay to the level of the actinides. Zero-power testing prior to launch is excluded from this requirement provided that the radioactive inventory is not significant.).
- Inadvertent criticality must be precluded for all credible accident conditions
- Radiological release to the space environment will have no significant effect on other space assets
- On-orbit disposal is limited to sufficiently high orbit
- The tentative requirement for inadvertent reentry of the nuclear system is either essentially intact reentry or fully dispersed reentry. (This requirement is now being investigated to determine whether partially dispersed, radiologically cold inadvertent reentry is an acceptable option.).

Using the policy and safety functional requirements as a guide, selected safety analyses were carried out to examine:

- Reactor water flooding, water immersion, and sand impaction with respect to system criticality/subcriticality,

- Reconfiguration of the reactor core by high speed impact, propellant fires and propellant explosions,
- The effects of aerothermal heating as a result of an inadvertent reentry accident,
- The behavior of the reactor following an inadvertent reactor startup and an assessment of the Topaz II temperature coefficients of reactivity,
- The induced and residual radioactivity of the reactor system as a function of operational time, time in a disposal orbit, and
- The Russian nuclear analysis and testing program for Topaz II.

Results

Our neutronics analysis using the Monte Carlo Neutron Photon (MCNP) code indicates that for the original design of Topaz II, the reactor will achieve supercriticality during a postulated water flooding accident scenario. This scenario requires the following series of events to occur: a launch abort, impact, breach of the reactor barriers, water flooding and immersion in either wet sand or water. Several reasonable design modifications are being pursued to prevent water flooding criticality. These modifications include removable neutron poisons or loading some of the fuel after the system achieves a sufficiently high orbit. Both of these options are made feasible by the unique design of Topaz II, which allows fuel loading after complete assembly of the reactor power system.

Our reentry analysis indicates that a reentry shield will probably be needed if intact reentry is the preferred reentry response of the system. Without reentry protection, partial dispersal of the core and its radioactively "cold" fuel is predicted during a postulated inadvertent reentry. Two reentry shield options are being investigated. The safety requirement for accidental reentry reactor configuration (i.e. intact for all conditions vs intact only for radiologically hot conditions) is now being reviewed.

Calculations have been performed for a Reactivity Initiating Accident (RIA) during ground testing. Our preliminary analysis for this accident case suggests that the temperature coefficients of reactivity for Topaz II provide controllable operation with important safety advantages. The prompt negative temperature coefficient for Topaz II helps mitigate postulated RIAs and promote stable control. The very delayed positive temperature coefficient for Topaz II allows an initial cold excess reactivity of less than $1.00 which insures sufficient time prior to full heatup for operator intervention, thus virtually precluding a prompt disassembly accident during the pre-orbital phase.

Our preliminary impact, fire, and explosion analyses suggest that a reconfiguration criticality accident is highly improbable for these accident scenarios. An analysis of the reactor induced and residual radioactivity following operations in space has shown that the reactor will be radiologically cold for any orbital decay reentry that might be postulated.

A formal safety program has now been established for the NEPST mission. The formal safety program activities include preparation of a detailed Probabilistic Risk Assessment, detailed deterministic safety analyses, safety testing, production of preliminary, updated, and final safety analysis reports and formal independent safety review by the Interagency Nuclear Safety Review Panel (INSRP) to permit an informed Presidential decision to launch based on risk-benefit considerations.

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