STRONTIUM-90 FOR TERRESTRIAL

THERMOELECTRIC POWER GENERATION

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ABSTRACT

Radioisotope thermoelectric generators (RTGs) have established an outstanding record of reliability since the first unit was publicly demonstrated in January 1959. Such generators are now powering exploratory spacecraft and are used terrestrially wherever conventional electrical energy is unavailable and unattended, highly reliable operation is needed. Through the initiative of the U.S. Department of Energy (DOE), as part of a national plan for beneficial use of reactor byproducts, encapsulated heat sources containing strontium-90, with a half-life of 28.8 years, will be made available as energy sources, an alternative to long-term storage. DOE management is currently reactivating production facilities of the waste management program which will result in quantity production of byproduct heat sources. Additionally, DOE is currently designing a 500 Watt(e), strontium-90 fueled demonstration RTG which will be assembled, tested and prepared for fueling in 1984.

The radioisotope powered thermoelectric generator (RTG) was first demonstrated by the AEC in January 1959 with a public showing from President Eisenhower's office at the White House [1]. The fuel capsule was later modified to meet aerospace nuclear safety criteria and the device was launched into Earth orbit on June 29, 1961 aboard the Navy Transit IV-A satellite (Fig. 1) to provide the historical first application of nuclear electric power in space [2]. Designed to operate for five years or more, the unit continued for over twelve years before signals from the two nuclear powered navigational transmitters ceased. Since that time, RTGs have amassed an outstanding reliability record in space and terrestrial applications. That same year, on August 17, an RTG was placed into initial terrestrial service when the U.S. Atomic Energy Commission and the U.S. Weather Bureau activated a stronium-90 powered weather station on Axel Heiberg Island above the Arctic Circle [3]. Today, through continuing development, such fully shielded thermoelectric generators in unit sizes up to 500 electrical watts can power remotely located stations for 10 years or more, unattended and with no maintenance. Teledvne Energy Systems has designed and fabricated most of the RTG's and this experience through 1981 is shown in Table I. Updated power output prediction to 20 years, based on 11 year performance of four of the SENTINEL 25E generators, is given in Fig. 2.

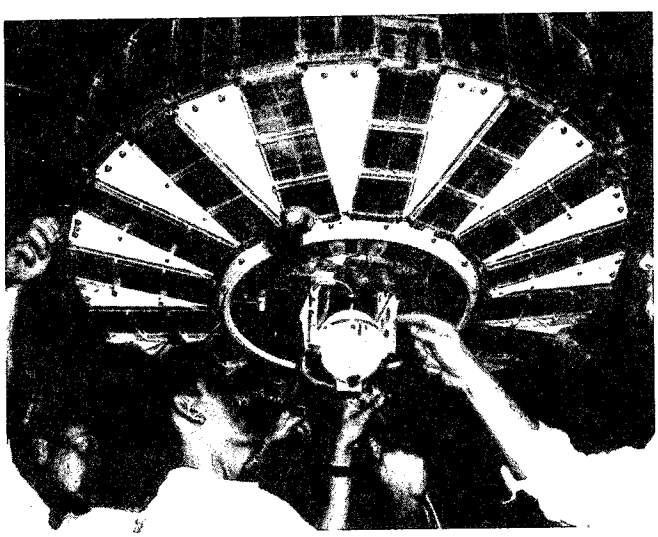
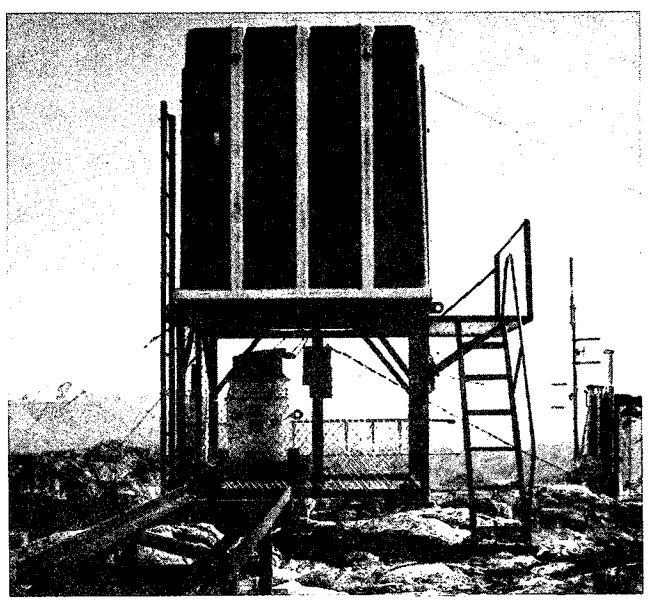


FIG. 1. NUCLEAR GENERATOR INSTALLATION-TRANSIT IV-A



FAA COMMUNICATIONS STATION-LAKE CLARK PASS, ALASKA

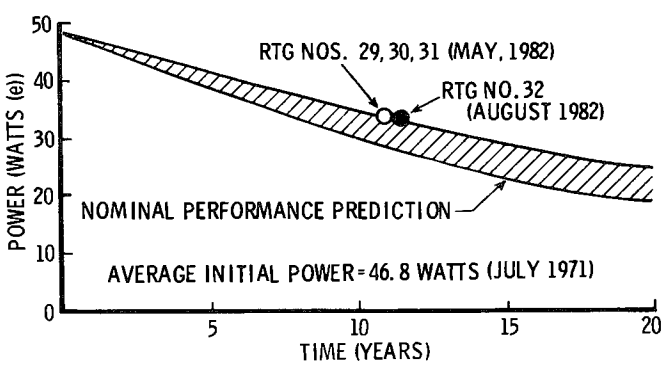


FIG. 2. POWER vs TIME-SENTINEL 25E

TABLE I. TERRESTRIAL APPLICATIONS OF ISOTOPE-FUELED GENERATORS

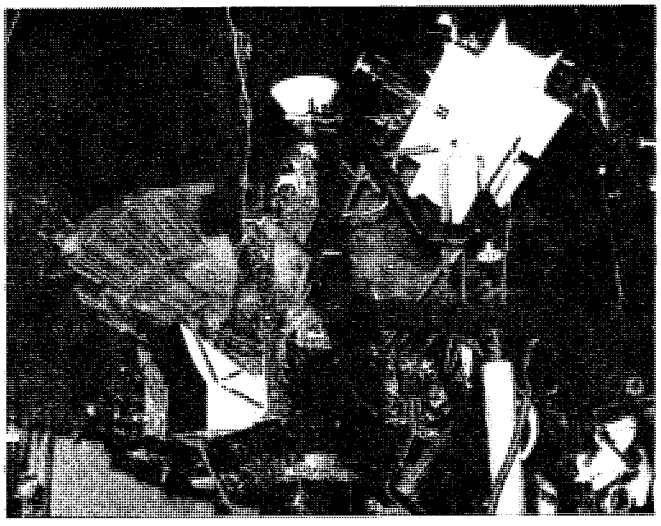
GENERATOR MODEL	NO. MFG.	YEAR	PRESENT OR FORMER APPLICATION	USER	STATUS (1981)
SENTRY	1	1961	ARCTIC WEATHER STATION	WEATHER BUREAU	4 YEARS SERVICE DECOMMISSIONED
SNAP-7 SERIES 7A-7E	6	1961-1965	BUOYS, OIL PLATFORM, WEATHER STATION, LIGHTHOUSE, ACOUSTIC BEACON	USCG USN PHILLIPS	IN STORAGE OR DEFUELED
SENTINEL 25A	1	1966	OCEANOGRAPHIC	USN	ON STANDBY-BERING STRAITS-OPERABLE
25B	1	1968	SUBSEA	EXXON	IN STORAGE-OPERABLE
3	4	1967	SUBSEA	ARCO	IN STORAGE-OPERABLE
25C-1	1	1967	SUBSEA	USN	OPERATING-SAN JUAN SEAMOUNT
25A	1	1967	COMMUNICATIONS RELAY	USAF	OPERATING-ALASKA
25D	3	1969	WEATHER STATION	USN	SCHEDULED ANTARCTIC WEATHER STATION DEPLOYMENT
25E	3	1968	SUBSEA, SEA SPIDER, MONITOR AMCHITKA	USN/ USAEC	SCHEDULED USAF ALASKA COMMUNICATIONS RELAY (3)
25F	5	1970	PAWS WEATHER STATION BUOY DATA DEMO	USN FAA FAA TELEDYNE	NAVY STORAGE (2) SCHEDULED ANTARCTIC (1) FAA STATION (1) TELEDYNE STORAGE (1)
8	1	1968	WEATHER STATION	USN	OPERATING-SAN MIGUEL ISLAND
25C-3	1	1969	ESSA EXPERIMENT	USN	OPERATING ANTARCTIC WEATHER STATION
25E	4	1971	SUBSEA	USN	SCHEDULED SUBSEA SEPLOYMENT (3) SCHEDULED USAF ALASKA (1)
100F	1	1972	COMPUTER POWER SOURCE	USN	SCHEDULED USAF ALASKA
25E	1	1971	DEMO	COMMERCIAL	OPERATING AS REMOTE COMMUNICATIONS POWER SOURCE
8S	22	1970-1982	COMMUNICATIONS RELAY	COMMERCIAL	OPERATING AS REMOTE COMMUNICATIONS POWER SOURCE
25F	3	1977	WEATHER STATION	COMMERCIAL	OPERATING AS REMOTE DATA COLLECTION POWER SOURCE
1S	4	1981	COMMUNICATIONS RELAY	COMMERCIAL	OPERATING AS REMOTE COMMUNICATIONS POWER SOURCE
TOTAL	63				

Through the cooperative efforts of our U.S. Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA), nuclear electric power has been used in all of our exploratory spacecraft to Jupiter, Saturn and the planets beyond where solar flux is insufficient for power generation. For example, Pioneers 10 and 11, which were launched in March 1972 and April 1973, respectively, have amassed an extraordinary number of scientific and technical achievements and after more than 10 years are in the process of providing heliospheric and cosmic-ray physics data from the outer reaches of the solar system. Each spacecraft is powered by four RTGs which use the same thermoelectric technology as that employed in Teledyne's SENTINEL line of generators. Updated RTG power output, as measured and transmitted back to earth by telemetry is shown in Fig. 3. The projected electrical output will be adequate to supply necessary electrical power for the spacecraft and most of the instruments beyond the year 1990[4]. At that time, Pioneer 10 will enter interstellar space. This will be a crowning achievement to obtain useful scientific data nearly 20 years after launch at 50 astronomic units (4.6 billion miles from the sun) on a hyperbolic escape trajectory from the solar system.

Some of the accomplishments for the NASA Ames Research Center/TRW Pioneer 10 and 11 spacecraft are the following:

- First spacecraft to fly through the asteroid belt establishing the feasibility of deep space missions.
- Greatly extended the distance over which radio telemetry has been conducted.
- First spacecraft to encounter the great outer planets of Jupiter and Saturn.
- Established the radiation environments of the two great outer planets.

Pioneer 10 will be the first man-made object to leave the solar system.



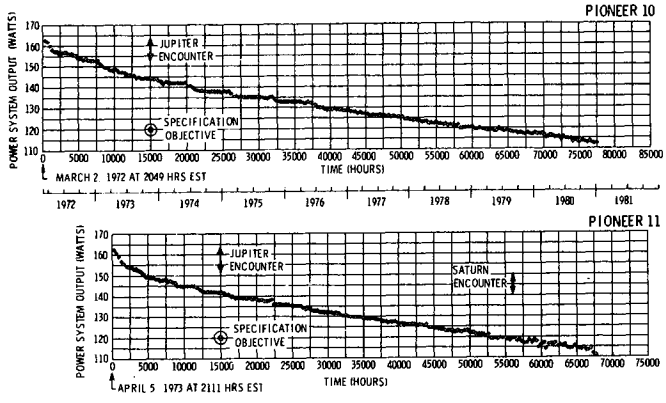


Fig. 3. PIONEER 10 and 11 RTG PERFORMANCE

Thermoelectric generators have demonstrated a service record of exceptional reliability. This reliability results directly from the design features incorporated in these devices. The major components are the heat source, a capsule containing strontium-90 fuel and its biological shield; thermal insulation to minimize parasitic heat loss; a sealed thermopile that converts heat to electricity; a structural housing to contain the device; and a radiator to reject heat. The radioisotope thermoelectric generator has no moving parts, therefore is not susceptible to the usual mechanisms of wear.

Strontium-90 for the fuel along with other reactor by-products are recovered during spent fuel reprocessing with subsequent strontium and cesium separation. The strontium is converted to strontium fluoride at the DOE Waste Encapsulation and Storage Facility (WESF). Fuel grade $Sr\text{-}90F_2$ currently available from WESF is of a purity and isotopic content that generates about 1.0 watt of decay heat per cubic centimeter. The strontium-90 fuel for RTG use is sealed into double-walled containers designed to withstand exposure to natural environments for a minimum of twenty half-lives, about six hundred years.

Initiatives are now being taken by DOE as part of a national plan for beneficial utilization of reactor byproducts, to provide encapsulated strontium-90 heat sources for electric power generators and other uses as an energy efficient alternative to long-term radioactive waste encapsulation and storage. A greater than two decade history of safe operations in the field with no incidents coupled with a thorough DOE sponsored strontium-90 heat source qualification program [5] makes this energy source technology an ideal candidate for long-term unattended operation where high reliability is the essential requirement.

Current plans are to assemble, test and fuel an RTG designed to produce 500 Watts(e) after 10 years of unattended operation, using modified WESF Sr-90 capsules as the basis for reestablishing the RTG system management and production process. This will be the largest RTG ever built and will meet all safety regulations. Planning is being implemented to design, build and test in 1983 and to fuel in 1984. This process will open the pipeline for delivery of similar production units, in the power output range of 50 to 500 Watts(e) as necessary to fulfill user requirements, starting in the mid-1980's.

The inherently reliable thermoelectric generator, in conjunction with strontium-90 which is available in megawatt quantities from spent fuel, is currently being evaluated for several terrestrial mission applications. Among these applications are the following:

- UNMANNED RADAR STATIONS
- TERRAIN AVOIDANCE RADAR
- SUBSEA CHANNEL TRANSPONDERS
- SUBSEA PETROLEUM PRODUCTION
- COMMUNICATIONS RELAY STATIONS
- UNMANNED MISSILE BASING

In summary, new initiatives by DOE will make relatively low cost and safe radioisotope thermal power available from the reactor spent fuel cycle. This valuable, energy efficient resource when coupled with the thermoelectric converter provides an ideal, long-lived electrical power source particularly suitable for unattended stations where infrequent maintenance is essential. The apparent benefits of primary importance are:

- HIGHEST RELIABILITY AND LOWEST MAINTENANCE
- CLEAN HEAT AVAILABLE FOR THERMAL CONDITIONING
- BENEFICIAL USE OF THE NUCLEAR POWER REACTOR BY-PRODUCT; STRONTIUM-90

References

1. Jerome G. Morse, "Remembering the First of Those Odd Snaps", Nuclear News, October 1982.

2. Paul J. Dick and Robert E. Davis, "Radioisotope Power System Operation in the Transit Satellite", AIEE Summer General Meeting, June 17-22, 1962.

3. James J. Keenan and Wilfred L. Kershaw, "Data Telemetry Package Powered by a Strontium-90 Fueled Generator Final Report, MND-SR-2615", September 1961.

4. James A. VanAllen, "Pioneer's Unfunded Reach for the Stars", Aviation Week and Space Technology, April 12, 1982.

5. H. T. Fullam, "Design and Qualification Testing of a Strontium-90 Fluoride Heat Source", PNL-3923, December 1981.