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This booklet describes a dynamic radioisotope thermoelectric system studied by the Martin Company for the Advanced Sr-90 Space Power Supply. It is applicable to vehicles having large skin areas available in space. For vehicles having insufficient skin area, a static system has been studied. It is described in a companion booklet (MND-3393-4).
A DYNAMIC RADIOISOTOPE THERMOELECTRIC SYSTEM uses the spacecraft skin as a large, low temperature radiator. Waste heat is transferred to the skin by means of a dynamic coolant loop.

Application is restricted to missions where the payload has a skin or where the last booster stage or transition section is orbited with the payload. To such missions the dynamic system offers significant advantages in weight, size and potential--while retaining the safety and reliability features essential to AEC SNAP programs.

**Installation.** Because generator thermal radiative surfaces are eliminated, the generator can be located anywhere within the vehicle. Coolant line routing is simple and light in weight. As shown opposite, boom deployment of the generator and radiator skin section from the payload reduces or eliminates both the thermal input to the vehicle payload and the amount of nuclear radiation shielding required.

**Re-entry burn-up.** The dynamic generator system is a rigid assembly during all ground, launch and orbiting conditions; but upon re-entry it will break up into sections, allowing the fuel capsules to fall free. The capsules are thus exposed as soon as possible to assure complete capsule burn-up and fuel particle dispersion.

The release is initiated by aerodynamic heating of V-band clamps which will burn through rapidly in the thin band sections between supports during the very high local heating. The cold junction plates are then free to fall apart along with the thermoelectric modules and hot plates.

Each hot plate is tied to one of the cold junction plates with a thermoelectric module sandwiched between them. Once the hot plates separate, the fuel capsule assembly will fall apart since the hot plates supply the only fuel assembly retention. The generator and fuel assembly separation forces are supplied by aerodynamic pressure.
GENERATOR DESIGN

Heat source
Thermoelectric module
Cold junction heat exchanger
Converter
Check valves
Coolant pumps
Radiation to outer space
Radiator
Accumulator
Heat is produced by decay of the radioisotope Strontium-90 in the fluoride form, encapsulated into hemispherical ended cylinders. The capsules are placed in pairs forming a rectangular parallelepiped heat source. By placing two thermoelectric modules adjacent to the two major surface areas of the heat source, the heat is converted directly to electricity by solid-state thermoelectric elements.

Each module contains thermoelectric couples paired in parallel, which, in turn, form series connections. The parallel pairs provide redundancy required for high reliability. The series connections enable a single module to produce 7 volts dc. The two modules are then connected in series with a converter-regulator to produce 250 watts(e) net at 28 volts dc.

Sealed thermoelectric modules are used with segmented telluride thermoelements operating between 1000° and 240° F, and a coolant chamber at the cold end. Water, propelled by redundant pumps, transfers the unconverted heat from the module to the remote radiator. The radiator consists of tubes brazed to the vehicle skin, protected from meteoroid damage both by the skin and by shields sandwiched between the skin and tubes. The optimum radiator skin area is approximately 45 square feet.
GENERATOR FUELING aboard Atlas-Agena space vehicle is accomplished by ground support equipment. The GSE consists basically of a semi-automatic remote controlled fueling machine, a storage rack for the fuel shipping cask, a closed circuit television system and a control system. Provisions are made for fuel assembly storage at the payload elevation. Transport and installation of the fuel assembly into the generator is expeditious yet highly reliable.
PERFORMANCE

(all values for 5-year design point except as noted)

Net power, watts(e) 250
Pump power, watts(e) (ac) 7
Control system power, watts(e) (ac) 10
dc-to-dc inverter efficiency, % 90
dc-to-dc converter efficiency, % 90
Gross power, watt(e) 297
Hot junction temperature, °F 925
Cold junction temperature, °F 240
Thermoelectric efficiency, % 8.9
Total heat input watts(t) 3980
System net efficiency, % 6.28
Fuel loading (beginning of life), watts(t) 4505
Total generator weight, lb 145.6
Typical converter and inverter weight, lb 12.0
Total unshielded system weight, lb 157.6

DESIGN FLEXIBILITY

This dynamic system design gives the spacecraft designer ample flexibility. Almost any voltage is available to the payload by simple taps placed on the dc converter output.

If the only voltage requirement is 28 volts ± 10%, system weight can be reduced 10%. Here the inefficient converter is replaced by a simple 100% efficient overvoltage limiter and by designing the thermoelectric system to produce 28 volts.

In this way, 10% of the fuel (approximately 1 capsule) can be eliminated, and the generator and regulator are reduced in size accordingly. A generator so designed will weigh approximately 141 pounds. There will be no converter—only a dc-ac inverter for the canned pumps.
While a major advance in itself, the dynamic system will not require major development expenditure. All development objectives are clearly attainable at a modest cost within a suggested 30-month span. Each technological advance is a logical progression in isotopic power system design and has, as a solid base, the knowledge gained from prior SNAP programs of the AEC.