Bendix

Aerospace Systems Division

| NO. | REV. NO. |
|---|---|
| ATM-675 | |

The Effect of Changes in Reserve Power on Central Station Thermal Control



DATE 6/22/67

This memorandum presents a discussion of the interdependence of ALSEP system electrical operation and the thermal balance of the electronics bay in the central station. The sensitivity of variations in electrical dissipation in the central station to RTC output and load variations is indicated.

Re P.9 -
I see it but don't exactly believe it - couldn't we just as well come up with a little nomogram or something? Ideas? BCS

Return to Miley
Sharpe BCS
James
McDonald
Gauthier

H. W. Wilson

xdydxy

## 1.0 PRESENT ALSEP SYSTEM DESIGN

The ALSEP system is designed to perform all the functions associated with the normal operation of the two arrays of equipment specified in the present contractual Exhibit B when supplied by 56 watts of power at 16 volts from a SNAP 27 power source. This normal operation includes certain scheduled overloads which require "power-sharing", if necessary, such as dust cover removal, LSM flip/calibrate, etc. To accomplish this, much attention has been given to maintaining the total system power requirements well below the 56 watt level to ensure satisfactory operation -

—of these intermittent modes without interrupting normal data flow

—of the system during anticipated power demand increases due to normal degradation of electronics and insulation

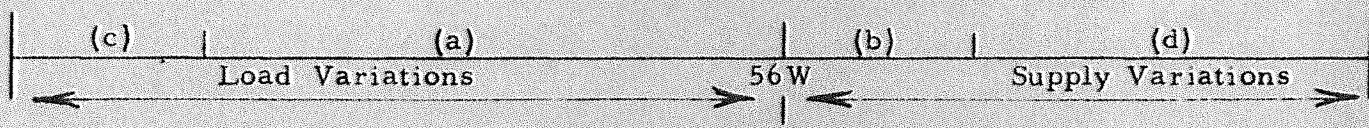
—of the system (or portions thereof) in the event the RTG did not give the anticipated output due to unforeseen assembly, deployment and/or environmental problems.

Since it was reported that the RTG power output might be significantly higher during initial operation than it was expected to be at the end of one year of operation, the power control circuit was designed to cope with a differential between power input and power demand of up to 35 watts. It must be remembered that, with an RTG power source, system operation is jeopardized as much by inadequate power consumption as by power demands in excess of supply. Hence, the total capability of the present ALSEP design to cope with variations in power (either supply power or consumed power) is 35 watts.

This 35 watts of power variation is presently budgeted as follows:

| | | |
|---|---|---|
| (a) | normal operational load variations (mode switching, thermal control, etc.) | 15 watts |
| (b) | intermittent and transient loads | 5 watts |
| (c) | contingencies (circuit breaker blow, standby mode, etc.) | 5 watts |
| (d) | RTG output uncertainty and operational decay | 10 watts |

This budget can be represented in analog form as:




It is recognized that not all of these conditions exist simultaneously. The budgeted items indicate the power changes which must be dealt with during relatively routine operation. There are similarly-recognized situations (for example, initial turn-on of the system, multiple experiment failures, etc.) during which more stringent demands are made on the regulator range.

To cover the contingencies when insufficient ALSEP functional load was available to ensure proper operation of the regulator, two commandable power dump loads have been provided which are not included in the above discussion. These make it possible (provided the command link is serviceable) to increase the load on the power supply by 7, 13 or 20 watts. These can be considered either to be a commandable extension of (c) above, if the supply power is 56 watts, or as an extension of (3) above if the RTG power output exceeds 66 watts.

These load and supply power variations, both scheduled and unscheduled, impose certain constraints on the design of the thermally-controlled bay in the central station. In the initial design of ALSEP the unused power was to be dissipated in the RTG. The selection of central station thermal control technique was predicated on a constant amount of power being used in the electronic units being thermally protected. With the advent of the proportional-shunt regulator came the dilema of locating in this electronics bay a unit requiring thermal protection but whose power dissipation is related to such independent variables as the lunar surface temperature, the power profile of the RTG and the number of operational experiments. To reduce the magnitude of power variations in the thermally-controlled bay, a part of the regulator which could supposedly endure the raw lunar environment was mounted on the central station structure. This has imposed two important constraints on the system which restrict the freedom to change the electrical characteristics of ALSEP without detailed evaluation. These constraints are:

- Components critical to ALSEP operation (parts of the voltage regulator) are operating in the raw lunar environment. Hence, for reliability considerations, their operational derating must not be significantly changed.

- The temperature of the central station electronics bay is a non-linear function of both input and output power. Hence, a change in the system electrical design (RTG power output or experiment power profiles) directly affects the operation and reliability of the central station electronics.

## 2.0 THE POWER DISSIPATED IN ALSEP CENTRAL STATION

The electrically-powered units of ALSEP Flight Systems 1 and 2 that are mounted in the central station are the elements of the Data Subsystem, the power conversion unit (PCU) and the electronics package of the Passive Seismic Experiment. The power consumed by the Data Subsystem and the PSE electronics does not vary with time or functional mode to any extent significant to the present discussion. When the Array A system is fully operational these latter components consume 19 watts of DC power and supposedly dissipate the majority of this into the thermal plate in the quantities and at the locations on this plate relevant to each of the individually packaged elements.

On the other hand, the power conditioning unit in its dual role of voltage converter and voltage regulator has a power consumption (by definition of function) which is intimately (but non-linearly) related to such diverse activities as the lunar surface temperature, the current flow out of the RTG necessary to maintain its voltage output at 16 volts, the number of experiments operational and the power demand of each experiment millisecond by millisecond.

When considering the effect of this PCU operation on the operating temperature of the thermally-controlled portion of the central station it is necessary to differentiate between power consumption and power dissipation. The power consumption of the PCU is related to its electrical performance and has a characteristic time constant less than a millisecond. The power dissipation of the PCU is related to its mass, material and mounting. The equivalent thermal resistance associated with the PCU is estimated to be 0.17 $\frac{\text{hours } ^{o}\text{R}}{\text{BTU}}$ and the equivalent thermal capacitance is estimated to be 0.95 BTU per $^{o}$R. These yield an estimated thermal time constant of 10 minutes. Hence, when discussing power consumption it is in terms of watts averaged over a time less than 1 millisecond (i.e., high frequency noise is averaged out). And when discussing power dissipation it must be done in terms of watts averaged over 10 minutes (i.e., the experiment cyclic variations are averaged out.)

Functionally, the power consumed by the PCU is best considered in two parts:

a. that power required for the function of voltage conversion (the ALSEP load uses six different voltages.)

b. a portion of that power received from the RTG at 16 volts which is not required for the functional electrical load or for (a) above.

All the power received at the central station from the RTG that is not consumed functionally is consumed either in the PCU or in the power dissipation resistors mounted outside the thermally-controlled portion of the central station.

The power dissipated within the central station thermally-controlled volume consists of:

-the steady-state power dissipation of the data subsystem and the PSE electronics - (19 watts)

-the power dissipation of the PCU - (non-linearly dependent on the RTG output power and the average reserve power.)

Figure 1 demonstrates the effect on the total dissipation within the central station of variations of PCU output for three different designs of voltage regulator and five different values of RTG power output. These curves were generated during an earlier study of this problem conducted on an analog computer. The present regulator has a range of approximately 37 watts.

The major causes of change in PCU power dissipation are:

a. variations in RTG output due to fuel degradation and ambient temperature change (2 to 10 watts)

b. variations in experiment thermal control electrical load (7 watt change twice a month)

c. such contingencies as failure of one or more experiments, degradation of insulation, etc. (variable).

Variations in power consumption are caused by all of the above plus all the cyclic operational power variations of each item and the intermittent and transient variations associated with various commanded operations. None of these latter variations has any significant effect on the thermal balance of the central station.

Figure 1

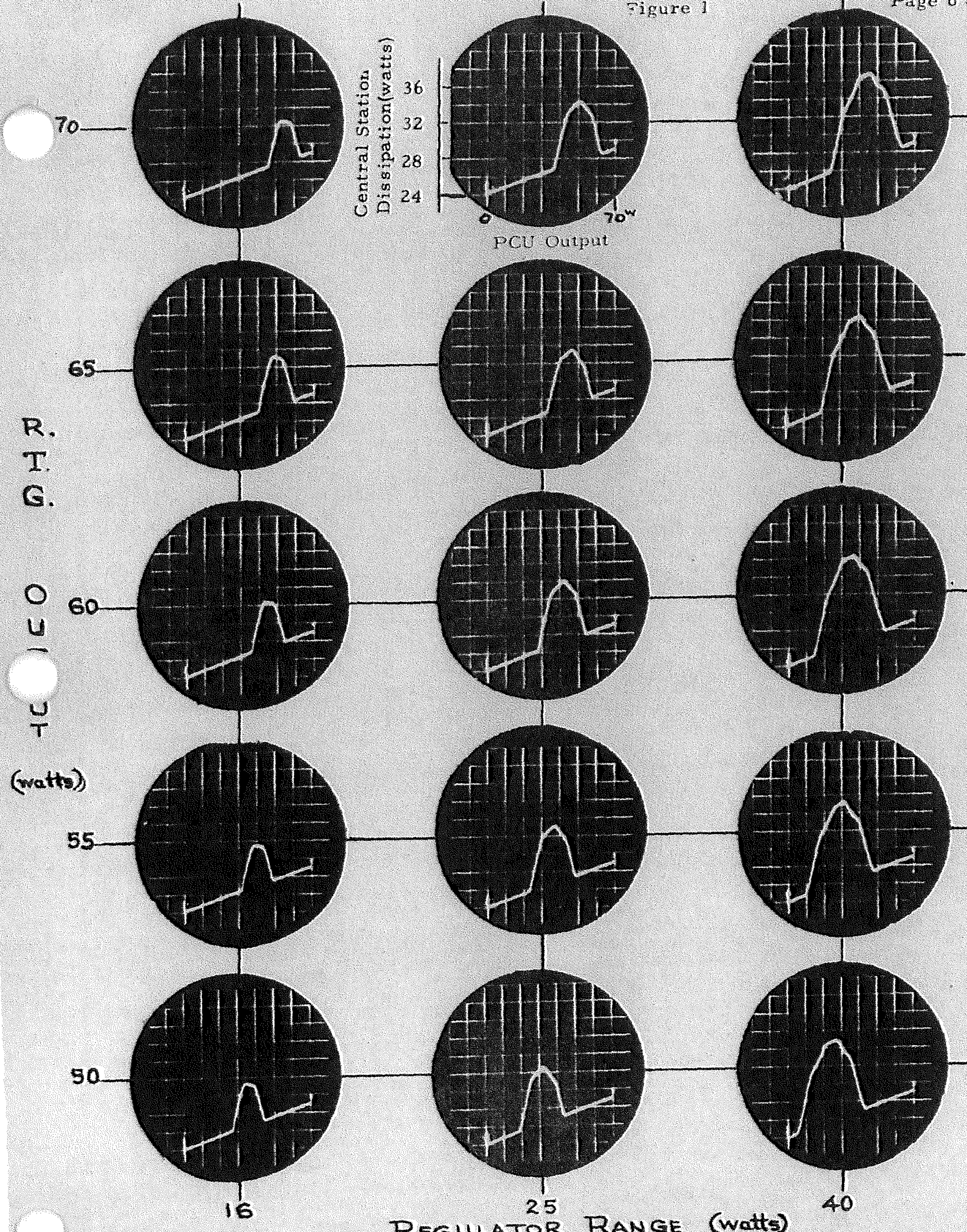

Central Station Dissipation (watts)
36
32
28
24
0
70W
PCU Output
70
65
60
55
50
R.T.G. OUTPUT (watts)
16
25
40
REGULATOR RANGE (watts)

Table I gives some specific examples of typical power dissipations during normal operation of the present Flight Systems 1 and 2 to show the effects of variations (a) and (b) listed above. Since several experiment designers are considering applying for extra electrical power for use in thermal control of their equipment, Table I also shows the effect of increasing experiment thermal control power by 5 watts ---that is, operating with a lunar day/night load variation of 12 watts rather than 7 watts.

TABLE I

| RTG Output (watts) | POWER DISSIPATION WITHIN CENTRAL STATION (WATTS) | | | | | |
|---|---|---|---|---|---|---|
| | Present Array A Design | | | Array A + $5^W$ Thermal Control | | |
| | Day | Night | Diff. | Day | Night | Diff. |
| 56 | 35.6 | 32.2 | -3.4 | 35.6 | --- | --- |
| 60 | 36.6 | 34.7 | -1.9 | 36.6 | 31.5 | -5.1 |
| 65 | 36.7 | 36.7 | 0.0 | 36.7 | 34.9 | -1.8 |
| 70 | 35.5 | 37.4 | 1.9 | 35.5 | 36.9 | 1.4 |
| 75 | 33.1 | 36.8 | 3.7 | 33.1 | 37.7 | 4.6 |
| 80 | 29.4 | 35.0 | 5.6 | 29.4 | 37.3 | 7.9 |

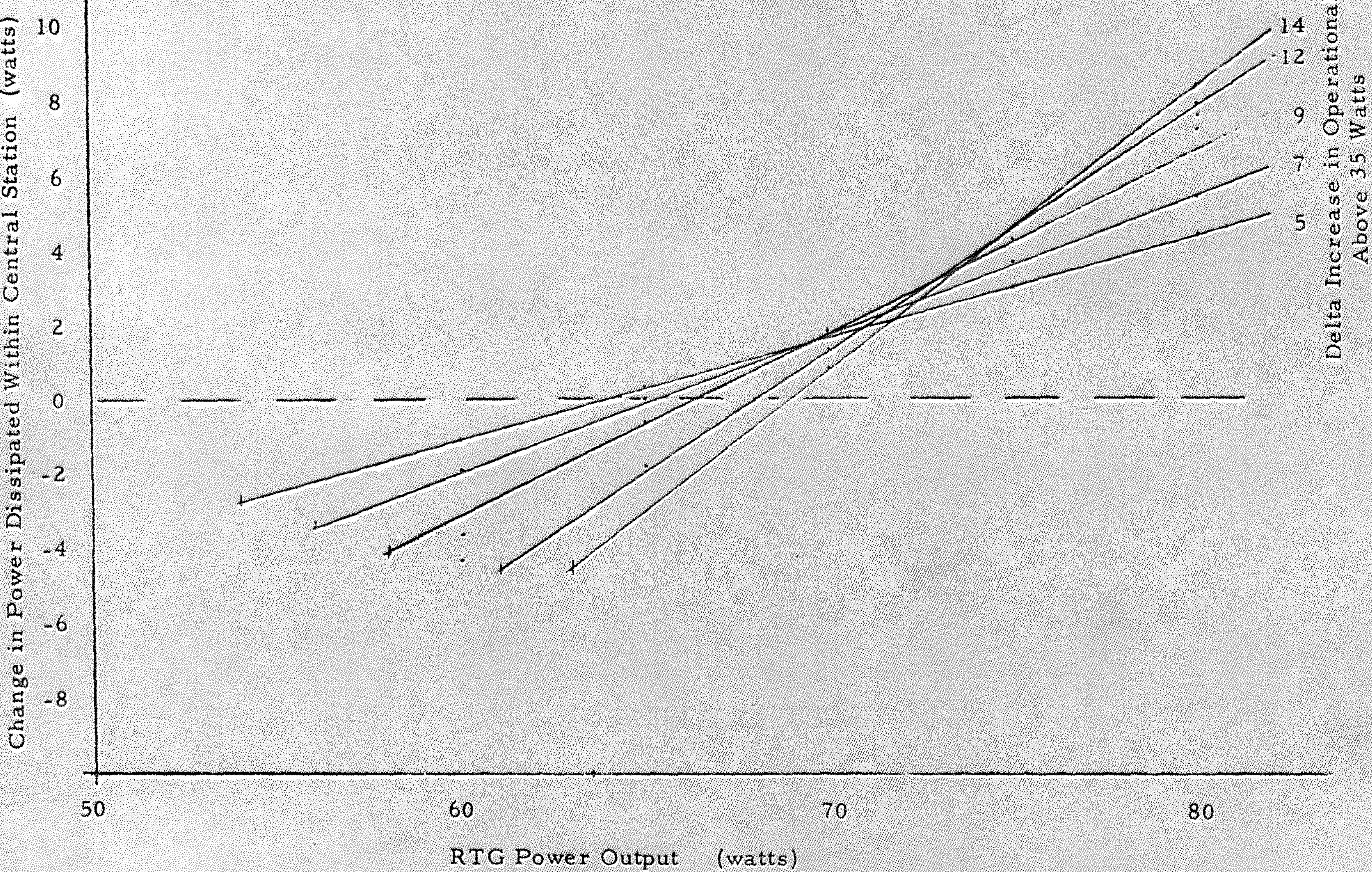
Any decrease in central station power dissipation (a negative differential in Table I) during lunar night aggravates an already critical problem of thermal balance. Figure 2 shows the sensitivity of central station power dissipation to operational load changes. The data in this figure is based on the functional power requirements of ALSEP Array A and the curve labeled "7" in Figure 2 can be used to evaluate the effect of the present day/night load change on central station dissipation.

The effect of contingency variations in power dissipation ('c' above) has not been considered in any of the above analysis. It is considered that each set of contingent circumstances will require separate analysis considering:

Figure 2

SENSITIVITY OF CENTRAL STATION POWER DISSIPATION TO OPERATIONAL LOAD CHANGES

For ALSEP Array A (Present Design) Only




H.W.W. 15 JUNE 1967

- whether the problem occurs at lunar day or lunar night.

- whether the problem causes an increase or decrease in the operational load on the PCU.

- the RTG output power.

- the sensitivity of the central station power dissipation to load increases and load decreases.

A relatively simple computer program can be compiled to provide rapid analysis of all the dependent factors. In fact, part of this program exists now. It is highly recommended that such a mathematical model be thoroughly developed to assist the MCC-H flight control operators to make fast, accurate decisions as to how best to use the commandable load relief or external dump loads to deal with such contingencies as may arise during lunar operation.