Energy Consumption Analysis for the Mars Deep Space Station

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This article is the second in a series of energy consumption analysis and verification reports for the Goldstone Deep Space Communications Complex. Results for the energy consumption analysis at the Mars Deep Space Station are presented. It is shown that the major energy consumers are the 64-Meter Antenna Building and the Operations Support Building. Verification of the antenna's energy consumption is highly dependent on an accurate knowledge of the tracking operations. The report also indicates the importance of a regular maintenance schedule for the watt-hour meters installed at the station.

I. Introduction

In 1973, the Goldstone Deep Space Communications Complex (GDSCC) initiated an energy management program in order to reduce energy consumption. The specific objective was to reduce the consumption of purchased energy by 50% by the end of 1985, using the consumption level of 1973 as a base.

A computer model was developed which simulates energy loads in buildings. This model, the Energy Consumption Program (ECP, described in Refs. 1 and 2) uses parameters of building construction, weather conditions, and mechanical/electrical components usage to calculate the energy consumption requirements of the building and the cost of the energy and to suggest which configurations and procedures would expend less energy upon modification.

The ECP model simulates the energy requirements for a building in four major steps. First, the heat loss or heat gain to the space under observation is computed. Second, the heating or cooling loads imposed on the air handlers are determined. Third, the energy input to all of the primary equipment or components constituting the air-conditioning system, such as compressors, heat pumps, boilers, etc., is calculated. Fourth, the model provides an economic analysis of existing configurations through which the cost-effectiveness of a specific modification may be obtained. The simulation yields data that describes daily, monthly, and yearly total consumption for one or more buildings. The computer model is later verified by comparing its predictions to the actual watt-hour meter data.

The GDSCC is composed of a number of Deep Space Stations. A verification analysis of the Echo Station (DSS 12) was presented earlier (Ref. 3). This report analyzes the energy consumption at the Mars Station (DSS 14).

II. Energy Consumption Analysis

The Mars Station is composed of eleven support, storage and control buildings dominated by the 64-Meter Antenna Building. The buildings are listed by their function in Table 1. The ECP divides the energy consumers for each building interior into the five following groups: (1) electrical equipment, (2) mechanical equipment, (3) heating, ventilation, air-conditioning (HVAC) equipment, (4) accessories, and (5) lights. The interior electrical equipment includes computers, electronic racks, and other electronics not related to HVAC. Mechanical equipment includes those heat generating machines inside the space such as machine shop equipment, air compressors and oil pumps. Other mechanical and electrical equipments associated with the HVAC operation are listed separately under accessories. The accessories include equipment necessary for building operation but which do not affect interior heating and cooling load calculations. The accessories are divided into thermal-powered and electrical-powered types. Air handler fans, condenser fans (for air-cooled type), boiler pumps, and building external lights are classified as electrical-powered accessories. Thermal-powered accessories include fuel-consuming equipment not located within air-conditioned zones, such as domestic hot water boilers. The lighting equipment is classified into incandescent and fluorescent types. A month-by-month listing of energy consumption by each of the above five groups is given in Table 2. Monthly heating and cooling loads for all the buildings are presented in Tables 3 and 4, and depicted in Figs. 1 and 2. A discussion of these simulated results is given below.

A. Electrical Consumption Analysis via the ECP Program

Figure 3 illustrates the distribution of electrical energy consumption between electrical equipment, mechanical equipment, HVAC, accessories, and lights. The largest consumers of energy are the accessories. Figure 4 gives a graphical representation of the electrical energy consumption for the entire Mars Site on a monthly basis.

Table 5 presents the yearly electrical consumption for site buildings as calculated by the ECP. Buildings G-85, G-87, G-89, and G-90 are not included in this listing because they are small consumers of energy. Figures 5, 6, 7, and 8 indicate which buildings are the major consumers in four categories. G-80, the 64-m antenna, is the largest consumer for HVAC and accessories. The Operations Support Building, G-86, houses data acquisition/processing equipment for the station (computers, printers, etc.) and is the primary consumer in the electrical equipment category (70.7%). It accounts for 23% of the HVAC consumption, because such equipment is necessary to the operation of computing devices. The relative distribution of building electrical consumption at Mars Station is shown in Fig. 9.

B. The ECP vs Watt-Hour Meter Verification

Electrical consumption at GDSCC is monitored by watt-hour meters. The stations are supplied with commercial (Southern California Edison) and site-generated power. All meters are read once a month. A review of the meter readings was done for the years 1978-1980. The ECP vs building meter readings have generally been accurate to within 10%.

The 64-meter antenna consumes power in accordance with the nature of the tracking assignment. For example, the antenna uses a 20-kW transmitter for routine signals to spacecraft, and a 100-kW transmitter when more power is necessary. For research and development assignments such as radar mapping and planetary radio astronomy, the antenna uses a 400-kW transmitter. The other buildings at the site perform support functions to the radio antenna; their energy consumption reflects the antenna's schedule. The tracking schedule at Mars Station has been erratic in recent years: the 64-meter antenna was down 15 March – 19 May 1980 for alignment. For this reason, the 1980 data had to be excluded from the ECP-hour meter verification.

During the course of this study, it was discovered that a number of the meters monitoring the two generators (500 and 750 kW) at the site were either out of service or malfunctioning. It can be deduced, however, from a comparison of the SCE meter (number 15) and the total reading of the meters monitoring individual buildings (see Fig. 10) that the generators provided DSS 14 with 31% of its energy in 1978, 41% of its energy in 1979, and 30% of its energy in 1980. The total ECP vs individual meter readings agree to 1.2% in 1978 and 3.5% in 1979. The only thermal consumer at DSS 14 is G-82/83, the Pump House/Cooling Tower System. There is no LPG consumption at the site.

At the beginning of 1980 it was discovered that the G-82/83 Pump House/Cooling Tower System would operate adequately with only one of its two cooled water loops in operation. This modification resulted in a 45% reduction in energy consumption by that building.

III. Summary

The ECP program allows a detailed analysis of energy consumption for a complex of buildings that includes a categorization of energy consumption. The present verification study disclosed that G-86, the Operations Support Building, is the largest consumer in the electrical equipment category. This study also showed the irregular tracking schedule during the years 1978–1980, a schedule that necessitated the taking of averages and the exclusion of some data. The irregular tracking schedule during 1978–1980 precludes a close year by year agreement between the ECP results and the meter data. For this reason the electrical consumption data was averaged over this period and then compared with the meter readings.

It was found during the course of this study that several of the meters monitoring the two generators supplying the site were malfunctioning. It is suggested that the meters be inspected regularly and that meter systems be regularly checked for consistency (the sum of the readings of generator meters numbers 44 and 46, for example, should equal the reading of meter number 70).

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References

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Table 1. Mars Station buildings

Building no.	Building description
G-80	Large radio antenna, 64-m (210-ft) diameter
G-81	Generator building
G-82	Pump house
G-83	Cooling tower
G-84	Training and office building
G-85	Flammable storage building
G-86	Operation support building
G-87	Security building
G-88	Transmitter-rectifier building
G-89	Reverse osmosis building
G-90	Storage building
G-91	Switch gear building

Table 2. Simulated energy consumption for Mars Station using ECP program

Month	Accessories, electric, MWhe	Lights		Electronic equipment, MWhe	Mechanical equipment MWhe	HVAC equipment		Monthly Total, MWhe
		Incandescent, MWhe	Flourescent, MWhe			Thermal, MWht	Electric, MWhe	
January	485	1.1	23.3	89.9	22.6	0.67	141	762.9
February	437	1.0	21.1	81.2	20.4	0	132	692.7
March	500	1.1	23.3	89.9	22.6	0	230	866.9
April	483	1.0	22.5	87.0	22.0	0	148	763.5
May	499	1.1	23.3	89.9	22.6	0	177	812.9
June	500	1.0	22.5	87.0	22.0	0	192	824.5
July	517	1.1	23.3	89.9	22.6	0	409	1062.9
August	517	1.1	23.3	89.9	22.6	0	214	867.9
September	484	1.0	22.5	87.0	22.0	0	185	801.5
October	500	1.1	23.3	89.9	22.6	0	161	797.9
November	484	1.0	22.5	87.0	22.0	0	142	758.5
December	485	1.1	23.1	89.9	22.6	0.97	139	760.0
Year total	5891	12.7	274.0	1058.5	266.6	1.64	2270	

Table 3. Heating load (in MWh) for the Mars Station

	January	February	March	April	May	June	July	August	September	October	November	December	Total (year)
G-80	63.6	54.6	60.0	57.0	49.4	45.9	46.7	46.8	46.3	57.4	58.8	64.3	650.8
G-81	8.6	6.2	6.3	4.7	11.5	9.1	9.6	10.0	9.8	4.9	6.6	8.4	95.7
G-82/83	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
G-84	3.1	1.3	1.2	0.7	0.6	0.1	0.0	0.0	0.14	0.14	1.4	3.6	12.3
G-86	1.0	0.4	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.2	3.5

1 Btu = 0.293×10^{-6} MWh

Table 4. Cooling load (in MHh) for the Mars Station

	January	February	March	April	May	June	July	August	September	October	November	December	Total (year)
G-80	83.4	78.7	88.1	87.1	125.7	127.9	136.1	135.4	126.0	93.0	84.1	82.5	124.8
G-81	5.8	5.7	6.3	5.6	11.9	12.3	14.4	14.6	12.3	7.4	6.0	5.2	107.5
G-82/83	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
G-84	0.04	0.75	1.25	1.9	1.6	3.6	5.2	4.9	2.7	2.6	0.6	0.003	25
G-86	128.2	120.0	134.1	131.8	142.5	146.8	157.3	156.4	144.0	140.0	128.4	126.8	165.6

1 ton-hr = 3.516×10^{-3} MWh

Table 5. Simulated yearly electrical consumption for major Mars Station buildings

Building no.	Electrical consumption, MWhe
G-80	5913.621
G-81	777.619
G-82/83	885.210
G-84	64.928
G-86	1856.944

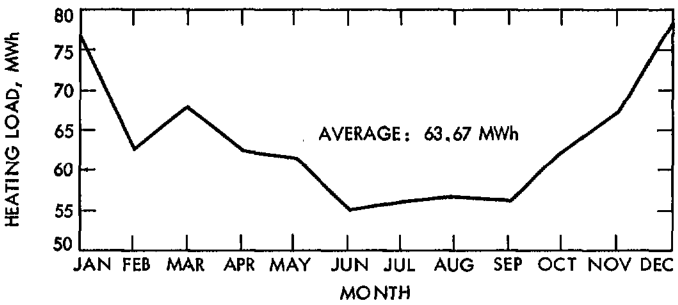

Fig. 1. Monthly variations in the heating load of the Mars Station

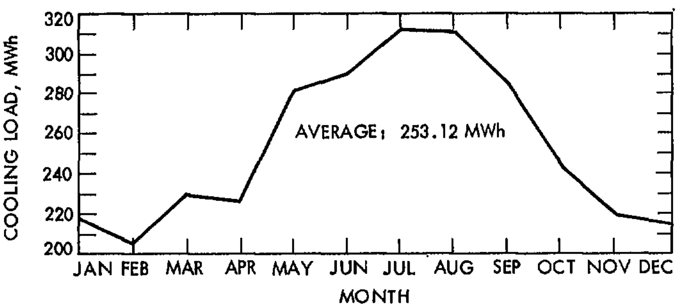

Fig. 2. Monthly variations in the cooling load of the Mars Station

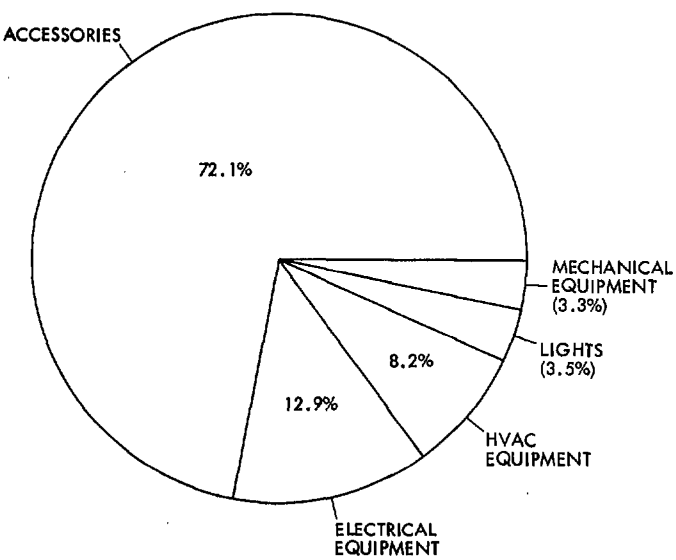

Fig. 3. Itemization of annual electrical consumption at the Mars Station

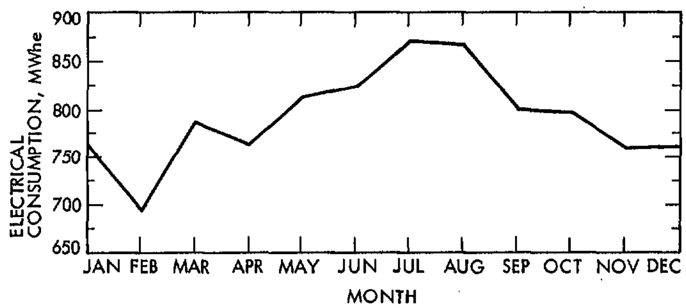

Fig. 4. Electrical consumption on a monthly basis, Mars Station

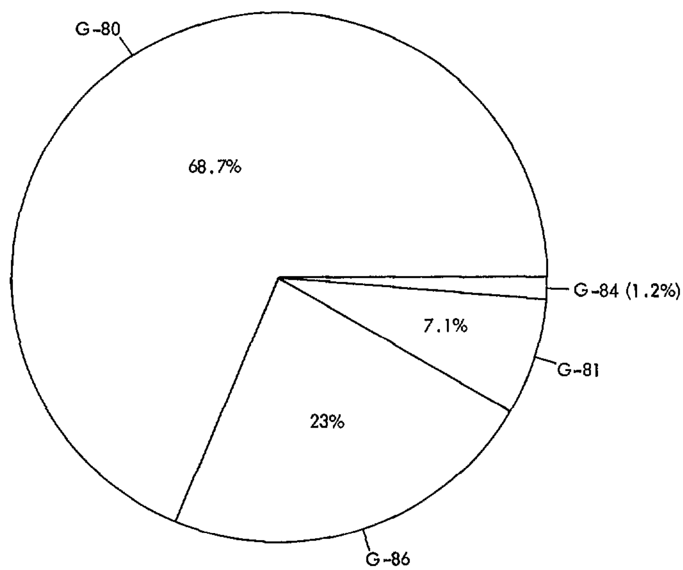

Fig. 5. Electrical consumption of HVAC equipment for buildings at the Mars Station

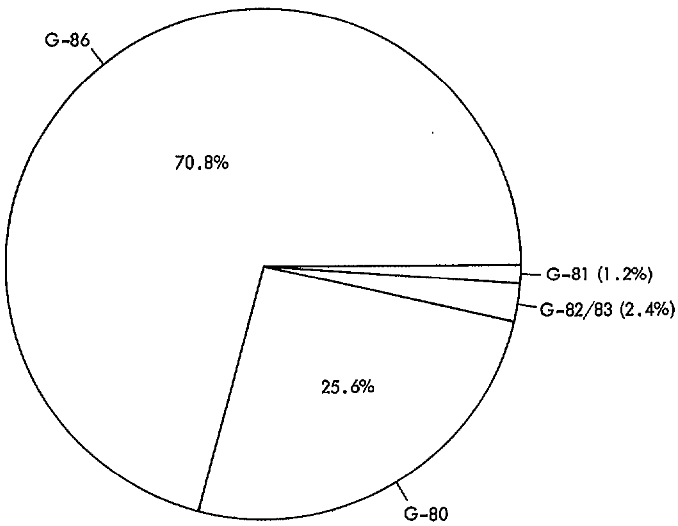

Fig. 6. Electrical equipment consumption for major buildings at the Mars Station

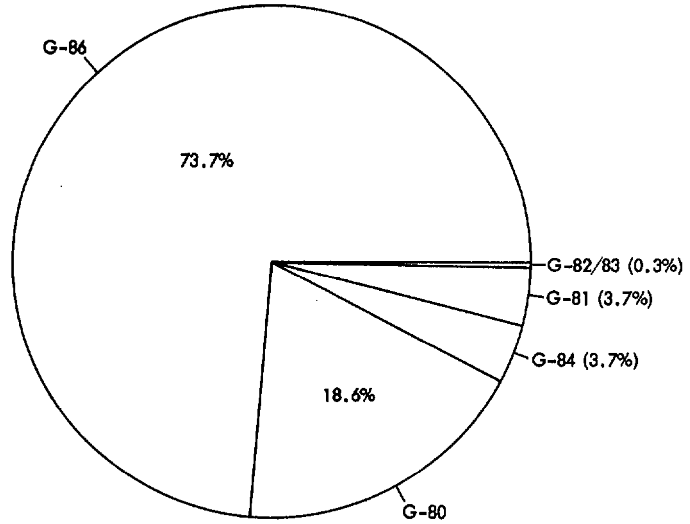

Fig. 8. Light consumption for major buildings at the Mars Station

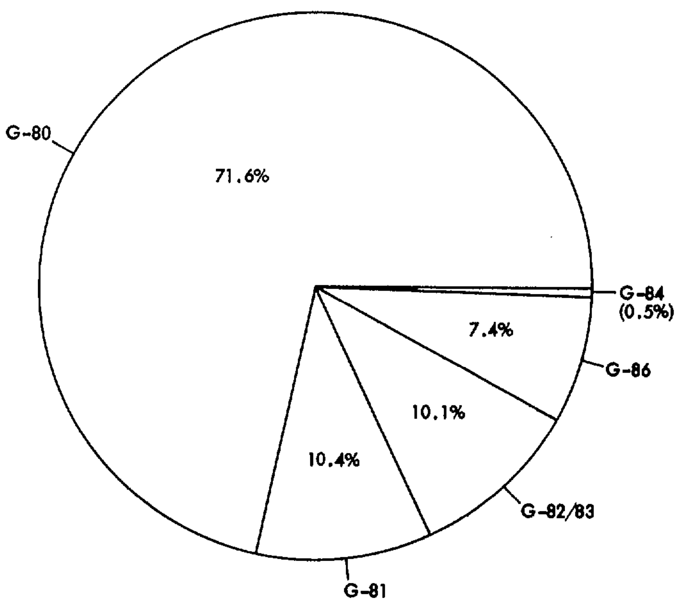

Fig. 7. Accessories electrical consumption of major buildings at the Mars Station

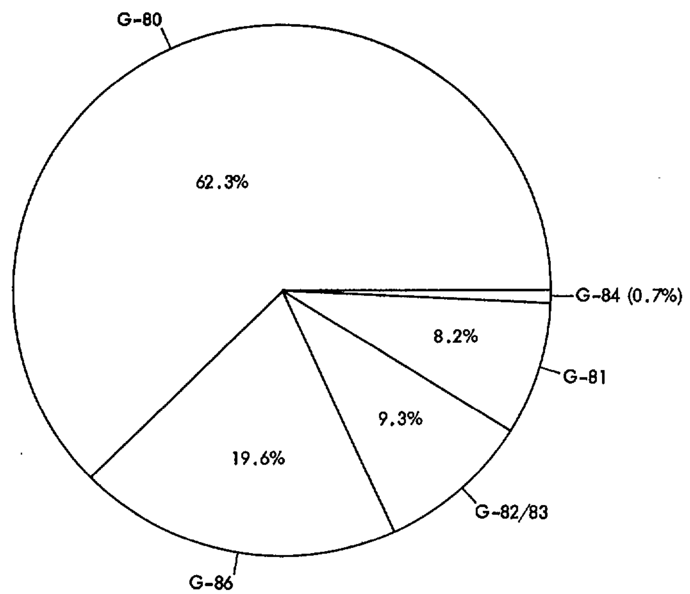

Fig. 9. Yearly electrical consumption for major buildings at the Mars Station

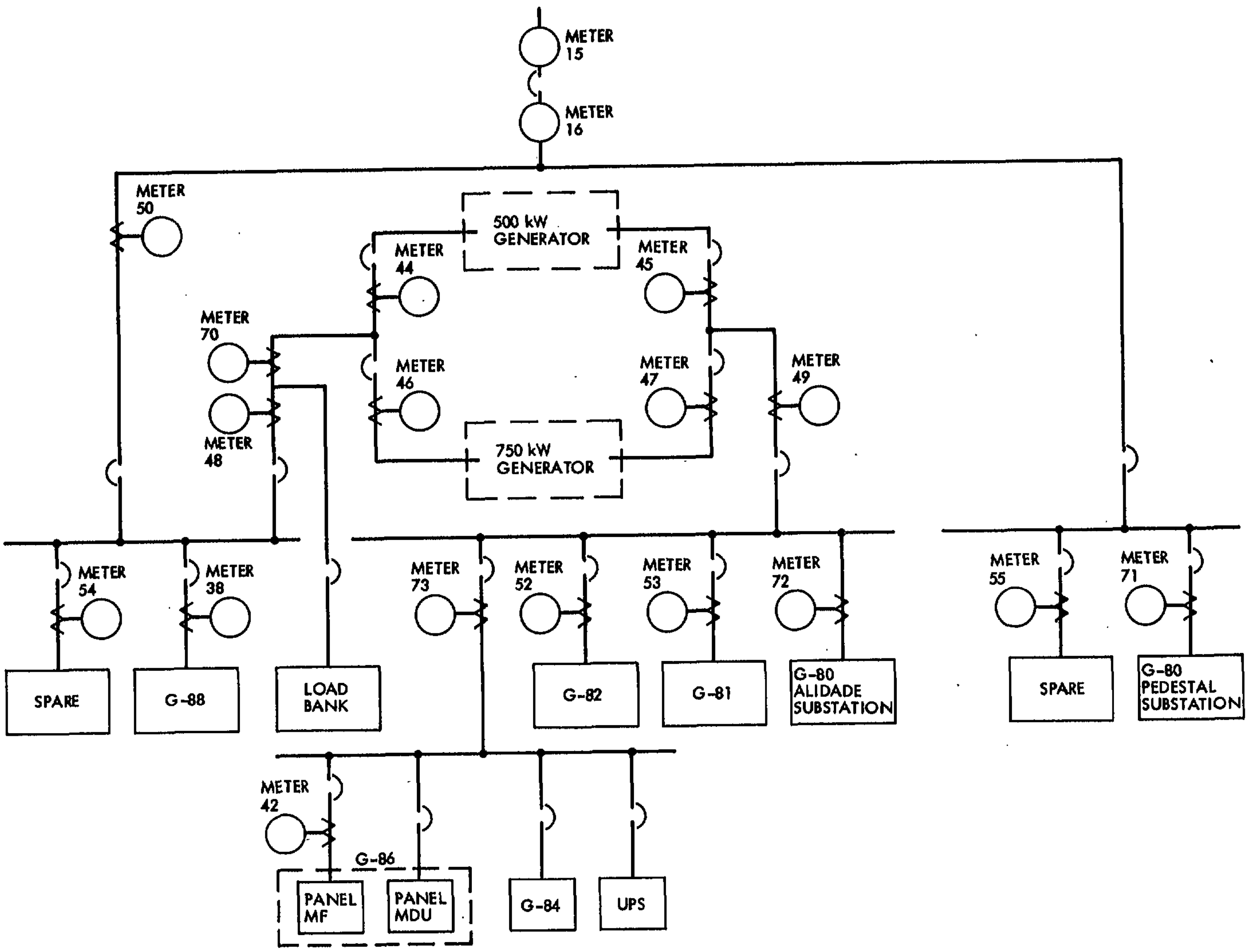

Fig. 10. Layout of watt-hour meters for the Mars Station