Energy Consumption for the Echo Station (DSS 12)

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This article presents an analysis of the energy consumption for the Echo Station (DSS 12). HVAC equipment is shown to be the largest consumer of electrical energy. The energy consumption for the buildings at this station is itemized and compared to the electrical meter data. The figures for energy consumption as predicted by the ECP computer program are found to agree well with the meter data.

I. Introduction

At the end of 1973, the Goldstone Deep Space Communication Complex (GDSCC) initiated an energy management program, following NASA guidelines, towards energy consumption reduction and self-sufficiency. The program objectives, formally started in 1975, were to reduce the consumption of purchased energy by 50% by the end of 1985, using the consumption level in 1973 as a base. In 1977, a similar program was formally started for the overseas Deep Space Stations.

A reliable model for the simulation of energy consumption in buildings is necessary in order to implement this reduction of purchased energy. A computerized model for energy consumption in buildings is developed for this purpose, the ECP Program (described in Refs. 1, 2, and 3), using the description of building construction, weather data, and mechanical and electrical systems. The ECP calculation of energy requirements for heating or cooling in any building involves three major consecutive steps. First, the heat loss or heat gain to the space that is heated or cooled is computed. Second, the heating or cooling loads imposed on the heating or cooling coils inside 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, and engines is calculated. Given these calculations, ECP can then provide an economic analysis to evaluate the payback period of money spent on a specific modification.

Initial verification of the computer model is done by comparing the results of the computer simulation to the measured meter data. The verification yields data pertaining to the two types of energy consumption: electrical and thermal, as well as daily, monthly, and yearly total building or site consumption.

The GDSCC is divided into a number of sites. In this article we present the verification analysis for the Deep Space Station Echo (DSS 12). This is the largest site and includes a 26-m antenna and 22 support, storage, and control buildings as listed in Table 1.

II. Energy Consumption

The ECP Program output provides a detailed simulation of the total energy consumption, dividing the energy consumers into the following groups: HVAC equipment, accessories, electronics, and lights. The HVAC equipment group includes vapor compression refrigeration units, absorption chillers, and heating units such as boilers and heat pumps. The accessories include the equipment that is necessary for building operation but does not affect heating and cooling load calculations. The accessories are subdivided into thermal and electrical. Included in the electric accessories are air-handler fans, condenser fans (air-cooled), condenser pumps (water-cooled), and boiler pumps. Thermal accessories equipment includes fuel consuming devices that are not located within any air-conditioned zones such as domestic hot-water boilers. The electrical and electronic equipment includes computers, electronic racks, and electronic equipment not related to air-conditioning and/or accessories. The lighting equipment is classified into incandescent and fluorescent types. Table 2 summarizes the simulated energy consumption for the entire Echo Station on a monthly basis.

A. Electrical Consumption Analysis

The distribution of energy between HVAC equipment, accessories, electronics, and lights is illustrated in Fig. 1. From Fig. 1, it can be seen that the largest consumers of electrical energy are the HVAC equipment (29.1%), electrical and electronics equipment (29.0%), and accessories (27.6%). The smallest consumers are the lights (10.1%) and machinery (4.3%). Figure 2 gives a graphical representation of the electric consumption for the entire Echo Station on a monthly basis. The pattern of the consumption shown in this figure is due mainly to the heating and cooling loads of the station. These loads are shown on a monthly basis in Figs. 3 and 4. The data on which these two figures are based is given in Tables 3 and 4.

In Table 5 the yearly electric consumption for each building in the station is summarized. Six buildings, G-29, G-36, G-39, G-40, G-43, and G-44, are not included in Table 5 because they are extremely small consumers of energy. For example, building G-29 has only two light bulbs and G-43 has been shut down. Figures 5, 6, 7, and 8 indicate which buildings are the largest consumers in each electrical category. G-26 is the largest consumer for electric accessories, electronics, and lights. G-38 is the largest consumer for electric equipment. Other large consumers in various categories are buildings G-33, G-23, and G-34/35. The relative distribution of building electrical consumption at the Echo Station is shown in Fig. 9.

B. Thermal Consumption Analysis

Table 6 shows the thermal consumption for the buildings forming the Echo Station. Thermal energy is obtained from the burning of LPG. As can be seen from Table 6 and Fig. 10, the largest thermal accessories consumer is building G-23. The largest equipment consumers are buildings G-33 and G-38, constituting over one-half the total consumption.

C. Verification of Results

A number of watt-hour meters monitor the electrical consumption at the Echo Station. A diagram of the metering system is shown in Fig. 11. There are two types of meters on the site: those for Southern California Edison (SCE) generated power and those for station generated power. The latter are meters 04 and 61; all others are SCE meters. Meters 04 and 60 are connected to the major tracking buildings. Meter 59 is connected to the smaller "housekeeping" buildings. All meters are read once a month. The meter readings are averaged for the years 1977 to 1979. This averaging process is necessary because of variations in tracking hours and, therefore, consumption. These readings are compared with ECP values and the results are given in Table 5 where individual and site comparisons between meter data and ECP values are made. Note that the largest difference between the two is about 10%, and for the complete site the discrepancy is less than 5%.

One meter monitors LPG consumption for the Echo Station (meter 19, shown on Fig. 11). Comparing the ECP thermal consumption of these buildings with the meter readings, averaged for the years 1977 to 1979, we observe that they agree within 6.64%.

III. Summary

It is important to realize that the GDSCC is a dynamic system with programmatic and nonprogrammatic equipment constantly being added, improved, and eliminated. Changes in building functions occur periodically; therefore, the present verification report represents only a basis for future analysis of the energy consumption of the Echo Station.

Comparison of the simulated consumption values with actual measured values shows ECP to be an accurate program when applied to energy consumption of the Echo Station. The program has identified the largest electrical consumers to be G-26 and G-38 and the largest thermal consumers to be G-23, G-33, and G-38. The verification analysis for the other Deep Space Stations at Goldstone will be presented in another TDA progress report.

References

1. Stoller, F. W., et al., "Energy Consumption Program," in *The Deep Space Network Progress Report 42-45*, pp. 288-293, Jet Propulsion Laboratory, Pasadena, Calif., 1978.

2. Lansing, F. L., et al., "The Updated Algorithm of the Energy Consumption Program (ECP)," *The Deep Space Network Progress Report 42-49*, pp. 107-115, Jet Propulsion Laboratory, Pasadena, Calif., 1979.

3. Plankey, B., "Computer Simulated Building Energy Consumption for Verification of Energy Conservation Measures in Network Facilities," *TDA Progress Report 42-62*, Jet Propulsion Laboratory, Pasadena, Calif., April 1981, pp. 142-146.

Table 1. Echo site buildings

Building No.	Building description
G-21	Administration and Cafeteria
G-22	Pump House
G-23	Dorm
G-24	New Power Plant
G-25	Transportation and Shop
G-26	Control Building
G-27	Generator Building
G-28	Machine Shop
G-29	Storage Building
G-30	HVAC
G-33	Engineering and Communications
G-34	Hydromec
G-35	26-m Antennae
G-36	Collimation Tower
G-37	Seismic Lab
G-38	Lab and Maintenance
G-39	Paint Shop
G-40	Flammable Storage Building
G-41	Shipping, Receiving, and Warehouse
G-42	Maintenance Office
G-43	Security
G-44	Drum Storage Building
G-45	Carpenter Shop
G-46	Antennae Repair
G-47	Supply Warehouse

Table 2. Simulated energy consumption for Echo site using ECP Program[a]

Month	Accessories		Lights		Electrical and electronic equipment, kWhe	Machinery, kWhe	HVAC Equipment	
	Thermal, kWht	Electric, kWhe	Incandescent, kWhe	Fluorescent, kWhe			Thermal, kWht	Electric, kWhe
January	70	99,291	9,334	28,757	109,852	12,969	169,206	57,937
February	66	90,351	8,450	26,346	99,512	11,854	124,696	69,690
March	70	98,166	9,334	28,757	109,852	12,969	128,868	81,887
April	70	95,715	9,059	28,100	106,529	12,644	113,722	91,888
May	70	100,797	9,334	28,757	109,852	12,969	114,302	103,457
June	70	109,899	9,059	28,100	106,529	12,644	82,557	142,108
July	70	115,513	9,284	28,626	109,632	12,963	86,602	152,822
August	70	116,563	9,383	28,887	109,971	12,750	88,230	150,510
September	70	107,988	8,960	27,839	106,199	12,632	88,375	134,940
October	70	101,655	9,334	28,757	109,852	12,969	103,494	116,227
November	70	99,044	9,059	23,100	106,529	12,644	111,181	71,620
December	70	102,268	9,087	28,103	108,992	12,939	165,769	53,594
Year Total	836	1,237,250	109,677	339,129	1,293,301	152,870	1,411,390	1,226,680

[a]Numbers rounded to the nearest integer.

Table 3. Heating load in MWh(e) for the Echo site

Building No./Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Building total
G-21	13.4	10.0	9.8	9.0	13.0	9.7	8.4	8.7	10.4	7.4	10.7	14.1	124.6
G-23	8.5	6.5	6.4	5.5	5.4	4.0	3.2	3.4	4.5	4.6	7.0	8.8	67.8
G-24	1.3	0.3	0.2	–	–	–	–	–	–	–	0.2	1.6	3.5
G-25	0.7	0.2	0.1	–[a]	0.2	–[a]	–	–[a]	–[a]	–[a]	0.2	0.9	2.4
G-26	22.6	16.0	16.5	13.9	9.9	5.4	4.1	4.3	6.8	12.4	17.6	23.8	153.3
G-27	4.9	2.8	2.8	2.2	1.6	1.0	0.5	0.5	1.2	1.5	3.2	5.3	27.6
G-28	0.4	0.2	0.2	0.1	0.3	0.1	–	–	0.1	–	0.2	0.4	2.1
G-30	0.1	–	–	–	–	–	–	–	–	–	–	0.1	0.1
G-33	36.9	28.7	30.4	27.3	29.2	22.8	20.8	21.2	24.2	25.3	31.0	38.1	335.8
G-34/35	0.1	–	–	–	–	–	–	–	–	–	–	0.2	0.2
G-37	1.5	0.6	0.5	0.3	0.1	–	–	–	–	–	0.6	1.7	5.3
G-38	55.4	47.4	51.9	50.5	56.1	44.9	53.9	54.2	45.9	56.1	50.6	55.2	622.3
G-41	0.4	0.1	–[a]	–	0.2	–	–	–	–[a]	–	0.1	0.5	1.3
G-42	0.1	–[a]	–[a]	–	–[a]	–	–	–	–	–	–[a]	0.1	0.3
G-45	0.6	0.5	0.4	0.3	0.2	–	–	–	–[a]	0.1	0.5	0.6	3.1
G-46	0.2	–[a]	–	–	–[a]	–	–	–	–	–	–[a]	0.3	0.6
G-47	0.5	0.3	0.2	0.1	0.2	–	–[a]	–	–[a]	–[a]	0.4	0.7	2.6
Monthly Total	171.1	103.6	119.3	109.3	116.5	88.0	91.0	92.3	93.2	107.6	122.4	152.1	

[a]A value less than 0.1 MWhe

Table 4. Cooling load in MWh(e) for the Echo site

Building No./Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Building total
G-21	6.4	8.4	9.5	10.5	11.7	15.3	17.0	16.6	14.4	12.2	8.6	5.8	136.3
G-23	0.8	1.5	1.8	2.3	0.9	2.8	3.9	3.6	2.0	2.8	1.5	0.6	24.5
G-24	15.8	14.6	16.2	17.9	30.3	33.2	36.5	36.2	32.0	19.8	15.6	15.7	283.9
G-25	–[a]	0.5	0.6	0.7	0.8	1.2	1.2	1.2	1.0	0.8	0.5	–[a]	8.6
G-26	76.8	72.7	81.4	80.5	87.5	89.7	95.4	94.9	88.1	85.3	77.5	76.0	1006.0
G-27	–	0.7	1.0	1.2	1.8	2.7	3.3	3.3	2.3	1.4	0.6	–	18.3
G-28	2.3	2.4	2.8	2.8	2.8	3.1	3.4	3.4	3.0	3.1	2.5	2.2	33.9
G-30	–[a]	0.3	0.4	0.5	0.6	0.9	1.1	1.0	0.8	0.6	0.3	–	6.6
G-33	36.2	37.5	43.3	44.4	48.0	54.5	60.6	60.5	51.4	49.4	39.9	34.1	559.7
G-34/35	2.7	4.0	5.1	7.4	15.3	24.6	30.4	29.9	22.2	10.8	3.9	2.5	158.9
G-37	–	0.2	0.3	0.5	0.8	2.0	2.7	2.6	1.6	0.9	0.1	–	11.8
G-38	52.3	53.3	60.0	62.7	76.7	75.4	91.1	90.6	73.5	74.2	55.9	50.1	815.6
G-41	–	1.3	1.9	2.8	1.3	3.7	4.6	4.3	2.7	3.5	1.0	–	27.1
G-42	0.1	0.2	0.2	0.3	0.2	0.4	0.5	0.5	0.3	0.4	0.2	–[a]	3.3
G-45	–	–	–	–	–[a]	0.5	0.7	0.7	0.4	0.1	–	–	2.4
G-46	–	0.1	0.3	0.4	0.3	0.6	0.8	0.7	0.5	0.4	0.1	–	4.2
G-47	–	–	–	0.2	0.2	0.8	1.0	1.0	0.6	0.5	–[a]	–	4.3
Monthly Total	193.5	197.7	224.9	235.2	279.1	311.2	354.3	351.0	296.9	266.3	208.2	187.1	

[a]A value less than 0.1 MWhe

Table 5. Total yearly electric consumption for Echo site buildings

Building no.	Electrical consumption, kWhe
G-21	224,673
G-23	30,860
G-24	628,664
G-25	48,388
G-26	1,109,720
G-27	38,870
G-28	93,899
G-30	8,694
G-33	705,700
G-34	473,659
G-37	15,571
G-38	941,875
G-41	53,453
G-42	27,917
G-45	23,528
G-46	11,363
G-47	30,796

Table 6. Thermal consumption for buildings at Echo site

	Accessories		HVAC equipment	
Building	kWht	Percent of site total	kWht	Percent of site total
G-21			155,758	11.0
G-22			15,245	1.1
G-23	836	100	84,879	6.0
G-24				
G-25			3,805	0.3
G-26			195,454	13.8
G-27				
G-28			2,807	0.2
G-30			350	0.025
G-33			419,786	29.7
G-34/35				
G-37				
G-38			527,750	37.4
G-41			1,594	0.1
G-42				
G-45			3,961	0.3
G-46				
G-47				
Total	836	100	1,411,390	100.0

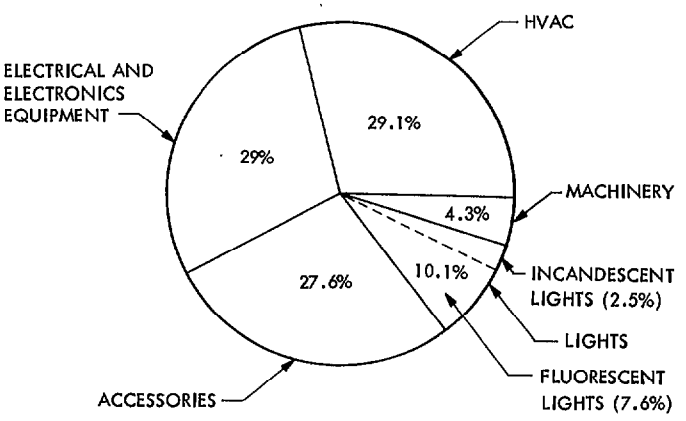

Fig. 1. Itemization of annual electrical consumption at Echo Station

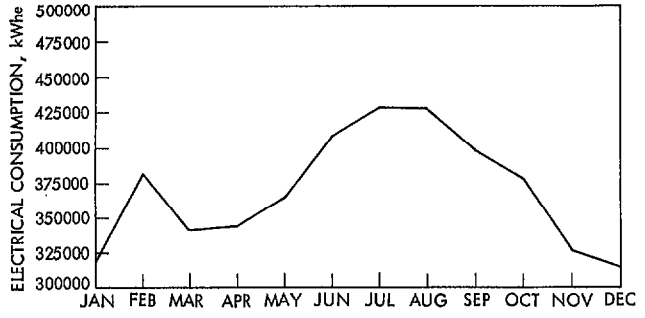

Fig. 2. Electric consumption on a monthly basis

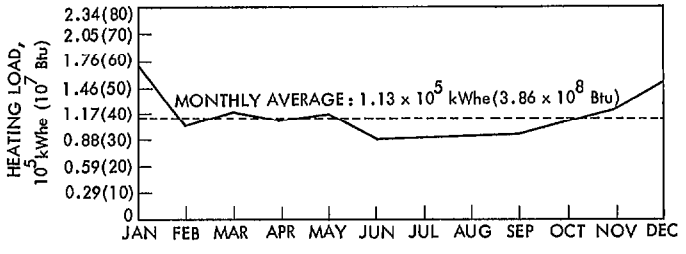

Fig. 3. Monthly variations in the heating load of Echo Station

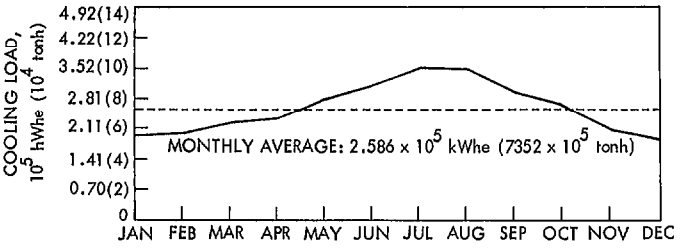

Fig. 4. Monthly variations in the cooling load of Echo Station

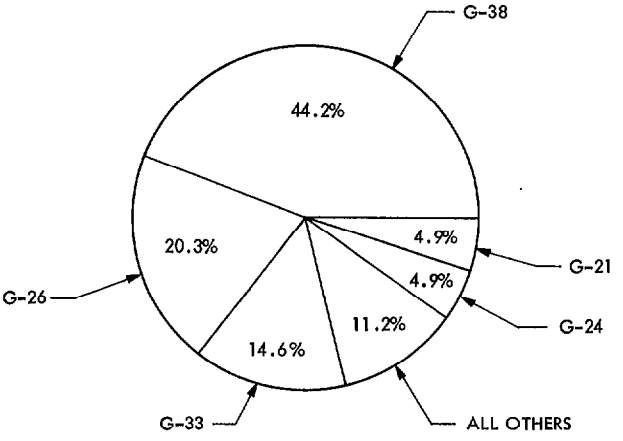

Fig. 5. HVAC electrical consumption for buildings at Echo Station

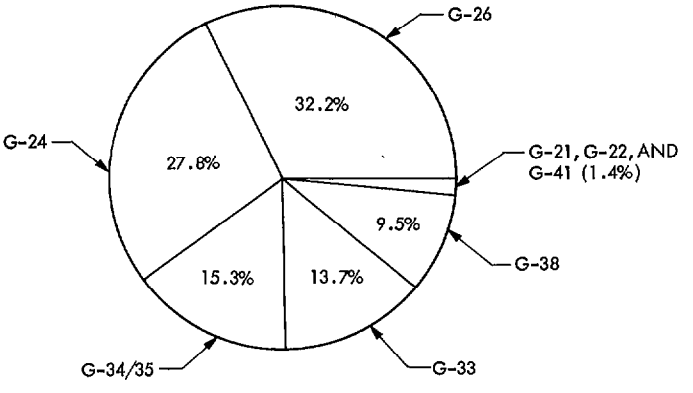

Fig. 6. Electrical and electronics equipment consumption for buildings at Echo Station

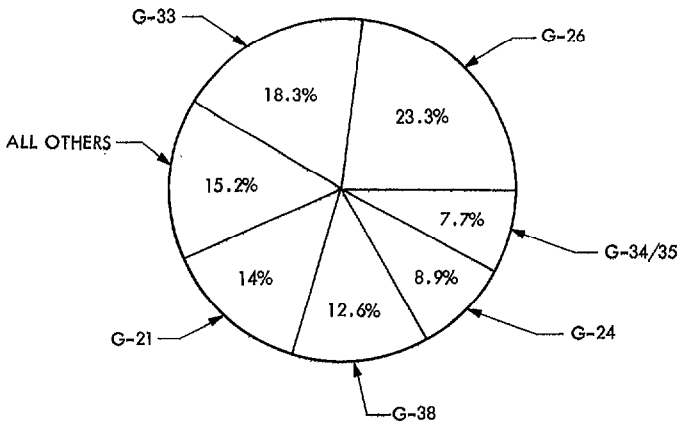

Fig. 7. Electric accessories consumption for buildings at Echo Station

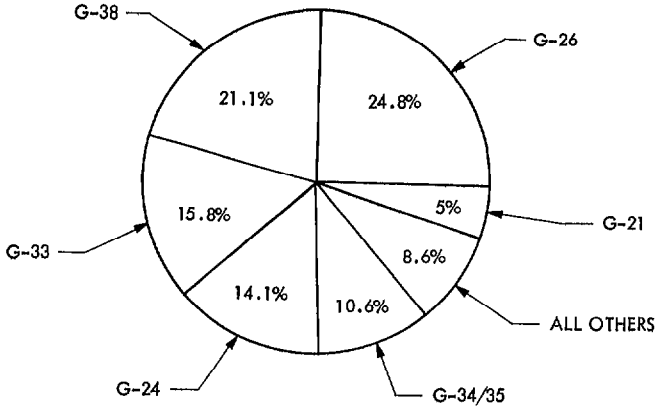

Fig. 9. Total electrical consumption for buildings at Echo Station

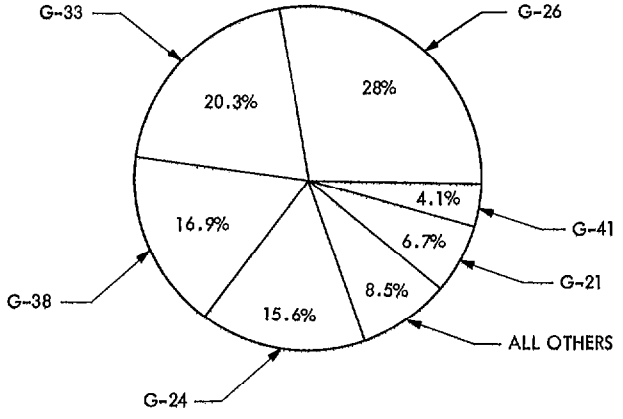

Fig. 8. Light consumption for buildings at Echo Station

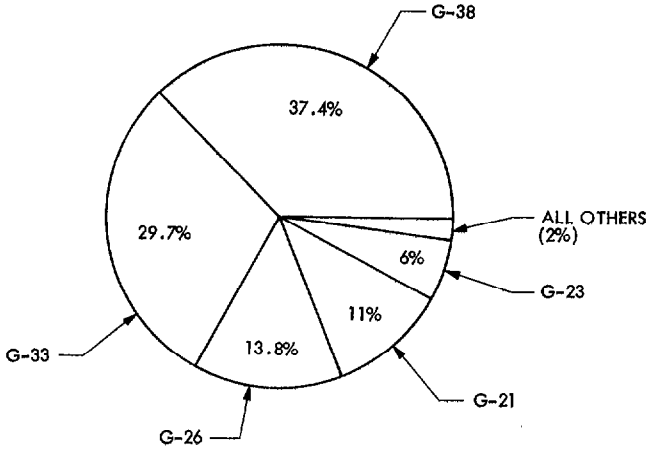

Fig. 10. Thermal equipment consumption for buildings at Echo Station

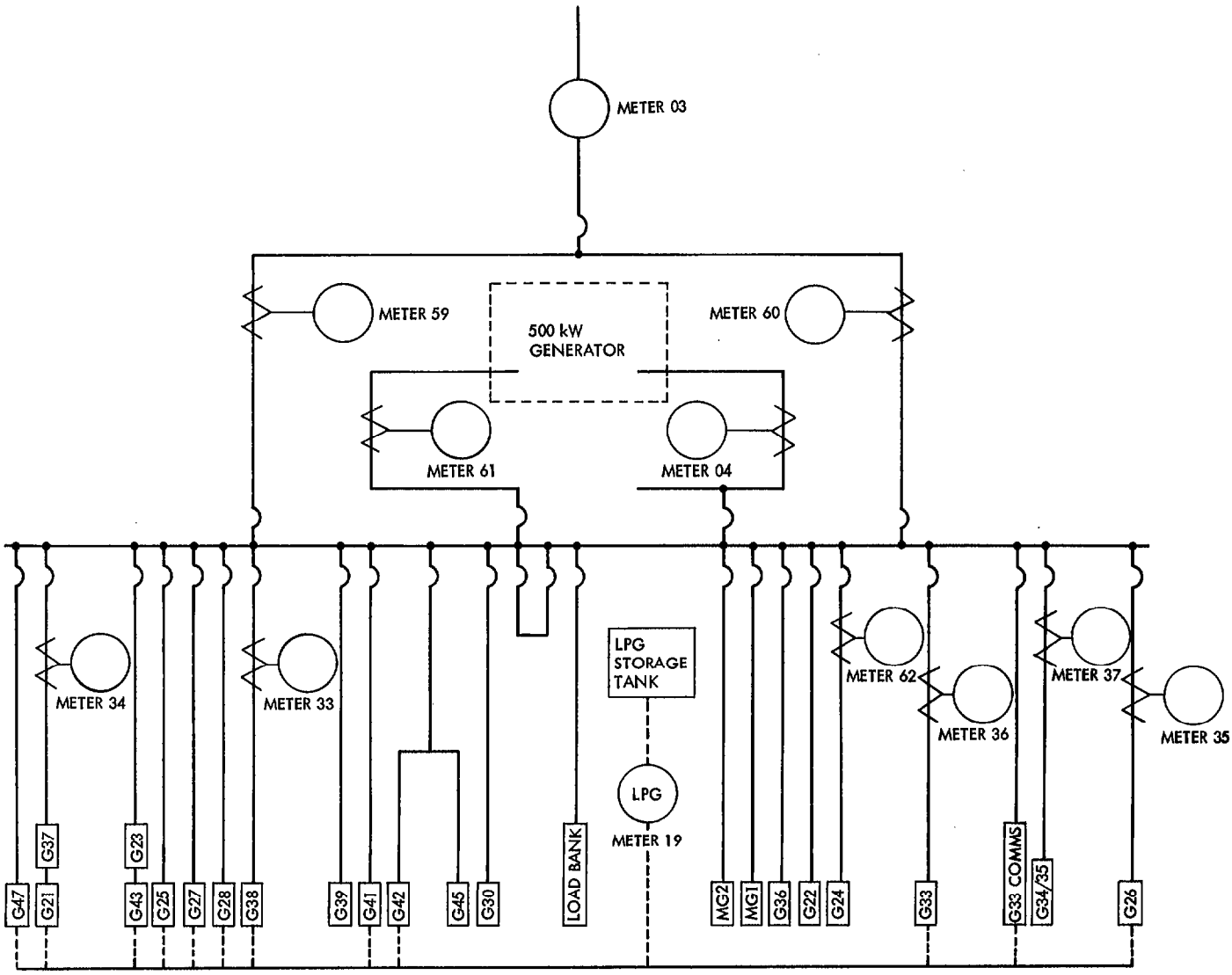

Fig. 11. Metering system for Echo Station