TERMALINE®

Hi-Power RF Calorimeter

Model 6030

SPECIFICATIONS

Calorimeter Model 6030

(Using R.F. Coaxial Loads Models 8732, 8733, 8736)

Minimum measurable power — — — — — — — — — — — — — — 2,000 Watts
Maximum measurable power — — — — — — — — — — — — — — 10,000 Watts
The accuracy — ±3.0%
Frequency — DC to 1400 MHz
VSWR — DC to 1,000 MHz, 1.1 to 1.0
1,000 to 1,400 MHz, 1.15 to 1.0

Minimum input-output Δ t — — — — — — — — — — — — — — 5°C
Minimum water input temp. * — — — — — — — — — — — — — — +5°C
Maximum water input temp. ** — — — — — — — — — — — — — — +60°C
Minimum water flow *** — — — — — — — — — — — — — — — — 1.5 gpm
Maximum water flow — — — — — — — — — — — — — — — — — 5.2 gpm
Reading waiting period (stabilization time) — — — — — — — app. 5 min.
Water purity — Any potable

*   For 2,000 Watts. The input water temp. is lower for higher power.

**   Maximum water input temp. depends on range of thermometers.

The standard package includes:

1 Thermometer	0 to 10°C
2 Thermometers	10 to 20°C
1 Thermometer	20 to 30°C

***   See the curves of min. flow vs. max. power.

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Model 6030 TERMALINE Hi-Power RF Calorimeter

SECTION I - GENERAL DESCRIPTION

The Model 6030 Series Hi-Power RF Calorimeter (RF Load Resistor not supplied) is designed to make calorimetric measurements of RF power under non-radiating conditions, with an accuracy of ± 3 percent or better. With this high degree of accuracy, it may be used as a comparison standard for high power wattmeters. Other uses include measurement of total RF power under AM conditions or transfer type measuring of direct power. The entire Calorimeter assembly consists of a Bird TERMALINE RF Dummy load, a flowmeter, flow rate control valve, four mercury partial-immersion type stem thermometers, and complete piping. It is fully housed in a 29-3/8 by 29-3/8 by 6-1/2 inch corner-framed aluminum cabinet.

The mercury thermometers are used for measuring temperature differential. These thermometers are calibrated in degree centigrade, with calibration markings of .05 of a degree, making it possible for the average observer to properly differentiate .025 degree centigrade.

A Rotameter is employed as the flowmeter, and calibrated in gallons per minute, with a range of approximately 0.4 to 5.2 gallons per minute. The calibration accuracy is $\pm$ one percent in region of 30 to 100 percent of the scale length at a temperature of $70^\circ F$ ($21.1^\circ C$).

A Bird 8700 Series Coaxial Load Resistor is used for the RF line termination. This load provides a very low-reflection non-radiating termination which assures exceptionally high absorption of the applied RF power, and virtually complete transfer of the energy to the flowing coolant water.

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SECTION II - THEORY OF OPERATION

1.   Basic Calorimetry

The term calorimetry refers to the measurement of quantities of heat. Heat

is energy in transition resulting from a temperature differential. This energy in

transition may be expressed in ft-lb/hr, BTU/min, or cal/sec.

The "First Law" of thermodynamics states that energy can neither be created

nor destroyed, but only converted from one form to another. This then, is the basic

concept behind the calorimetric method of measurement. A basic definition should

be noted: If a quantity of heat is transferred into one gram of water until the temper-

ature of the water is increased one Centigrade degree, it would be called one gram-

calorie, or more commonly referred to as one calorie. In the English system, if

one pound of water will increase its temperature one Fahrenheit degree, one BTU of

heat has been transferred into it.

$$\text{Hence:} \quad \begin{aligned} 1 \text{ BTU} &= \text{lb} \times F^o \\ 1 \text{ calorie} &= \text{gram} \times C^o \end{aligned} \qquad (1)$$

The relationship of grams to pounds and C^o to F^o is such that it makes one BTU

equal to 251.996 calories.

Another factor in calorimetric measurement should also be taken into consideration;

the specific heat of a substance. It has been proven that different substances having a

weight of one pound would require less or more energy to increase their temperature

one Fahrenheit degree. To compensate for this behavior of different materials, in-

cluding water, a correction factor was assigned called specific heat. The units for

specific heat are BTU/lbF^o. By employing this correction factor to equation (1), the

calorimetric formula for heat thus becomes:

$$1 \text{ BTU} = 1 \text{ lb} \times 1 \text{ F}^O \times 1 \text{ BTU/lbF}^O \qquad (2)$$
$$\text{or,} \quad \text{heat} = \text{mass} \times \triangle T \times C_p$$

Since 1 BTU of heat is equal to 778.16 ft-lb of work, and the time rate of doing work

is power, ft-lb/hr or BTU/hr could be a description of electrical watts of mechanical

ft-lb power.

Thus, when the time element is introduced into equation (2), it simply becomes:

$$\text{BTU/hr} = \text{mass (lb/hr)} \times \triangle T \text{ (F}^O) \times C_p \text{ (BTU/lbF}^O) \qquad (3)$$

This is the equation of calorimetry. Knowledge of $\triangle T$, rate of mass flow, and speci-

fic heat would produce BTU/hr equal to power.

2.   6030 Series Calorimetry

Calorimetry as applied to the Model 6030 Series Calorimeter is essentially the

same as described in the preceding paragraphs.

The availability of RF loads, such as the TERMALINE 8700 Series, with almost

100% transfer of RF power into a cooling liquid (in this case water), has made possible

such an arrangement that the elementary calorimetric form could be utilized:

$$\text{RF Power} = \text{flow} \times \triangle T \times \text{constant} \times C_p$$

The constant is used to present the power relation in direct form, converting F^O to

C^O, and rendering easier and possible direct reading of the calorimeter.

The $\triangle T$ is most accurately indicated by thermometers which utilize the thermal

expansion of a liquid isolated from the environment. For this measurement, mercury

stem thermometers are used. In order for the thermometers to have a high accuracy

and not be affected by outside temperature, the ratio of the mercury chamber volume

to the volume of the total indicating column must be as high as possible. The thermo-

meters are calibrated in ^OC.

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The water flow is measured by a Rotameter which is calibrated in gallons per minute. The scale calibration is $\pm$ one percent from 30 to 100 percent of the scale length. This calibration is made for a water temperature of 70°F (21.1°C). The flowmeter is not sensitive to change in viscosity; it is a Viscosity Compensated Rotameter. However, the density error is still present, and the graph of Figure C should be used as a multiplier to correct power measurements.

3. Coaxial Load Termination

The termination resistor used to dissipate the RF energy in the 6030 Series Calorimeter is a Bird 8700 Series Coaxial Load Resistor. The load itself is a carbon film-on-ceramic resistor, with a protective plastic coating covering the outer surface. The RF energy is converted into heat and transferred directly to the cooling agent (water) without the use of an intermediate transfer fluid. Organic hydrocarbon coolants are not required as the dielectric media, because the generated heat is conducted to the inside of the resistor. Air will suffice as the coaxial dielectric. The resistor is enclosed in an exponentially tapered housing which provides a linear reduction in surge impedance directly proportional to the distance along the resistor.

With this configuration, the characteristic impedance is therefore 50 ohms at the RF input (connector end), 25 ohms at the mid-point to compensate for the resistance already passed over, and zero ohms where the resistor joins the housing, forming the return conductor of the coaxial circuit. This produces the uniform, practically reflectionless line termination over the stated frequencies of the load resistor.

When cool water enters the load, it is led by a center pipe down to the RF input end of the inside of the load resistor and released through peripheral holes in its wall.

The water flows out of the unit by first passing over the inside surface of the ceramic resistor tube. This pipe, which is supported at both ends, is constructed of a dielectric material to prevent interaction with the electrical properties of the device.

The heat carried off by water as a result of the dissipation of energy in the load produces an increase in water temperature flowing out of the unit. This difference in water temperature from input to output is the basis for the 6030 Series calorimetric type of measurement.

SECTION III - INSTALLATION

The Model 6030 is not regularly portable in this series. It is designed for vertical fixed mounting only. When mounted, the instrument should be located convenient to both a supply of running water (with drain facilities), and feasible connection to the RF transmission line. For best accuracy, calorimeter should be installed with shortest feasible transmission line length. The unit should be affixed for easy reading at eye level, otherwise misreading of the rotameter and thermometers could occur.

Before mounting, lay the Calorimeter on its back and insert the float into the rotameter by removing the 1-7/8 inch drain cock at the bottom of the rotameter. The float must be inserted with the spoked wheel facing the bottom of the rotameter. DO NOT DROP THE FLOAT. DAMAGE TO THE FLOAT WILL CAUSE INACCURATE READINGS. Refer to Figure 4-1 for an illustration of the float.

After the float has been installed, mount the Calorimeter on a solid surface vertically with fasteners of a suitable style. The type of fastener will depend on the surface which the unit is mounted on.

After the Calorimeter has been mounted, unscrew the thermometer guards from the thermometer wells and fill the wells with water. Remove the thermometers from their cylindrical containers (noting input and output) which are attached next to the rotameter. Carefully slide the thermometers into the guards. Slide the thermometer and guard into the well through the two 1" diameter holes in the cabinet. Do not subject the thermometers to any binding. Screw the thermometer guard down snugly into the well, making sure the opening of the guard is facing outward. The thermometers should be resting on the bottom of the test wells.

Connect the water input and output with hose having std. 1/2" (or 3/4") female hose connectors. Ordinary garden hose may be used. Burnout possibilities are just as much a hazard with this instrument as in any 8700 Series installation. Therefore, it is important that the flow of water is not interrupted even for a fraction of a second. The power should be applied only when necessary flow is established.

Attach the RF generator to the load. The Calorimeter is now ready for operation.

SECTION IV - OPERATION

After the Calorimeter has been properly installed, follow the procedure below to operate. At the end of the operating procedure, an illustrative example is given to show clearly the steps described.

1. Turn on the water and adjust the flow rate for the maximum power of the load being used. These are minimum values. Flow rate must be regulated at the water flow valve with the source valve turned on full. See Fig. 4-1 below to determine the reading edge of the float.
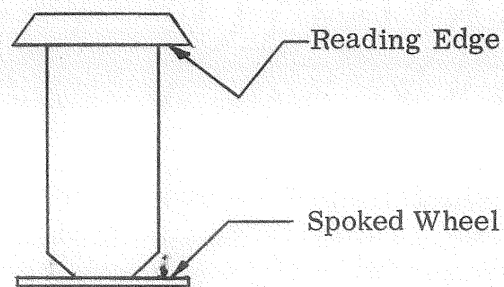

Figure 4-1. Rotameter Float

2. Adjust the input thermometer for easy reading. The thermometer should be resting on the bottom of the test well.

3. Read the input water temperature and obtain the correction factor from the graph of Figure B.

4. Apply RF power to the load. Make sure not to exceed the load rating.

5. Adjust the output thermometer for easy reading. Follow the same procedure as in Step 2.

6. Read the output water temperature after the mercury column has stabilized. Make sure constant RF power and water flow is maintained when taking this reading.

7. Obtain ΔT by subtracting the input temperature from the output.

8. Find the RF power, P_x, from the graph of Figure A, using flow rate vs ΔT.

9. Find the specific heat of water, C_p, using the graph of Figure C. This is the average C_p of the input and output water temperature.

10.   To find the actual power, P_a, apply the information obtained in the above steps to the following equation:

$$P_a = P_x \text{ x Correction Factor x } C_p$$

EXAMPLE

1.   Flow rate set at 5 gallons per minute.

2.   Input temperature read at 10^oC. Correction Factor read from graph of Figure B - at 10^oC = .9985

3.   Output water temperature read at 17.225^oC

4. $\triangle$ T obtained; 17.225 minus $+10^oC$ = 7.225

5.   RF power P_x, found on graph of Figure A. With 5 gpm and $\triangle$ T 7.225^oC P_x = 9,494 watts

6.   Average Specific Heat found from graph C by:
        a) C_p of input water temperature (10^oC) = 1.0013
        b) C_p of output water temperature 17.225 = .9994
        c) Average C_p would be 1.00035

7.   Find the actual power, P_a, by multiplying P_x x Correction Factor x C_p.

$$P_a = 9,494 \text{ x } .9985 \text{ x } 1.000$$
$$P_a = 9,480 \text{ watts}$$

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SECTION V - MAINTENANCE

1.   General

The 6030 Calorimeter is generally maintenance free. Handle the instrument with care; this equipment contains delicate precision components. Store the 6030 in a clean location when not in use, and do not subject it to shock or vibration.

Care and cleanliness are the main factors. Keep the equipment free of visible accumulation. Clean the thermometers and wells with water. Use a dry solvent such as trichlorethylene on a cotton swab stick to clean the RF line input connector. This also applies to the 3-1/8" Anchor Bullet (#4600-021) used to make the line connection. Carefully clean all metallic contact areas and also the exposed faces of the teflon insulators.

If the unit has not been used for a long time, flush it out thoroughly before placing it into operation. This equipment should only be used with clean fresh water. Do not use hard or salt water.

2.   Inlet Valve and Plumbing

No special maintenance is required for the Inlet Valve or Plumbing. A defective component should be returned to the factory for repair.

3.   Rotameter

If leakage should occur at either end of the glass tube, tighten the gland cap screws with a 3/4" flat wrench. There are four cap screws at both the top and bottom ends of the Rotameter. Care should be taken to pull down these glands evenly on both ends.

To clean the inside surface of the metering tube, unscrew the inlet plug and remove the float and float stop. Carefully insert a brush or soft swab on a wooden dowel

and wipe the tube free of accumulation. When replacing the float, make certain it is inserted with the spoke wheel facing the bottom of the Rotameter.

A defective Rotameter must be returned in its entirety to Bird Electronic Corporation for recalibration or repair.

4.   Thermometers   ·

No special maintenance is required. Wipe clean with a soft cloth and water. Handle the thermometers with care, and do not expose them to temperatures above scale markings.
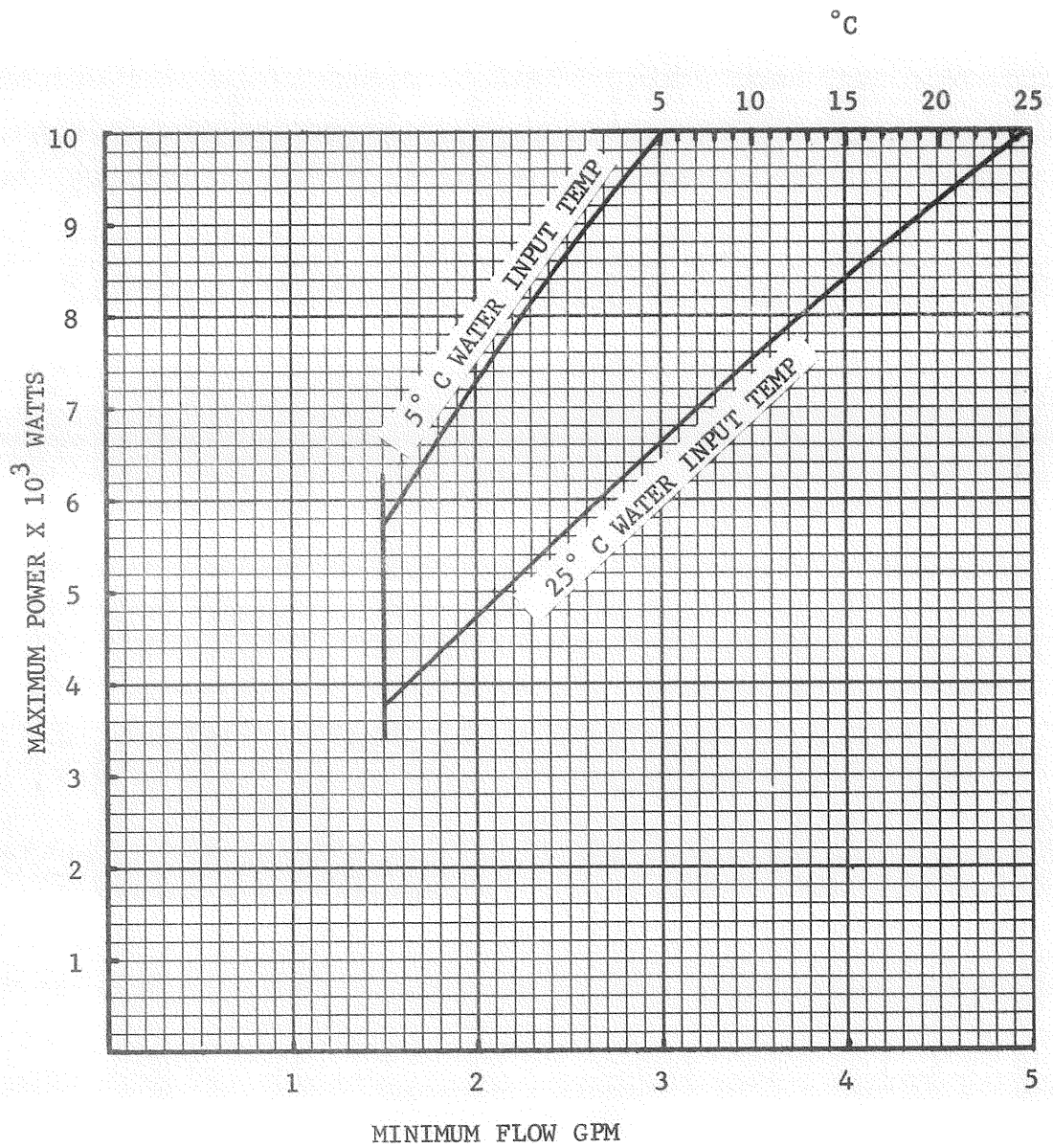
5.   RF Load Resistor

As different Coaxial Resistors of the 8700 Series are supplied with the various Calorimeter Models, refer to the individual Load Resistor instruction manual for information covering them.

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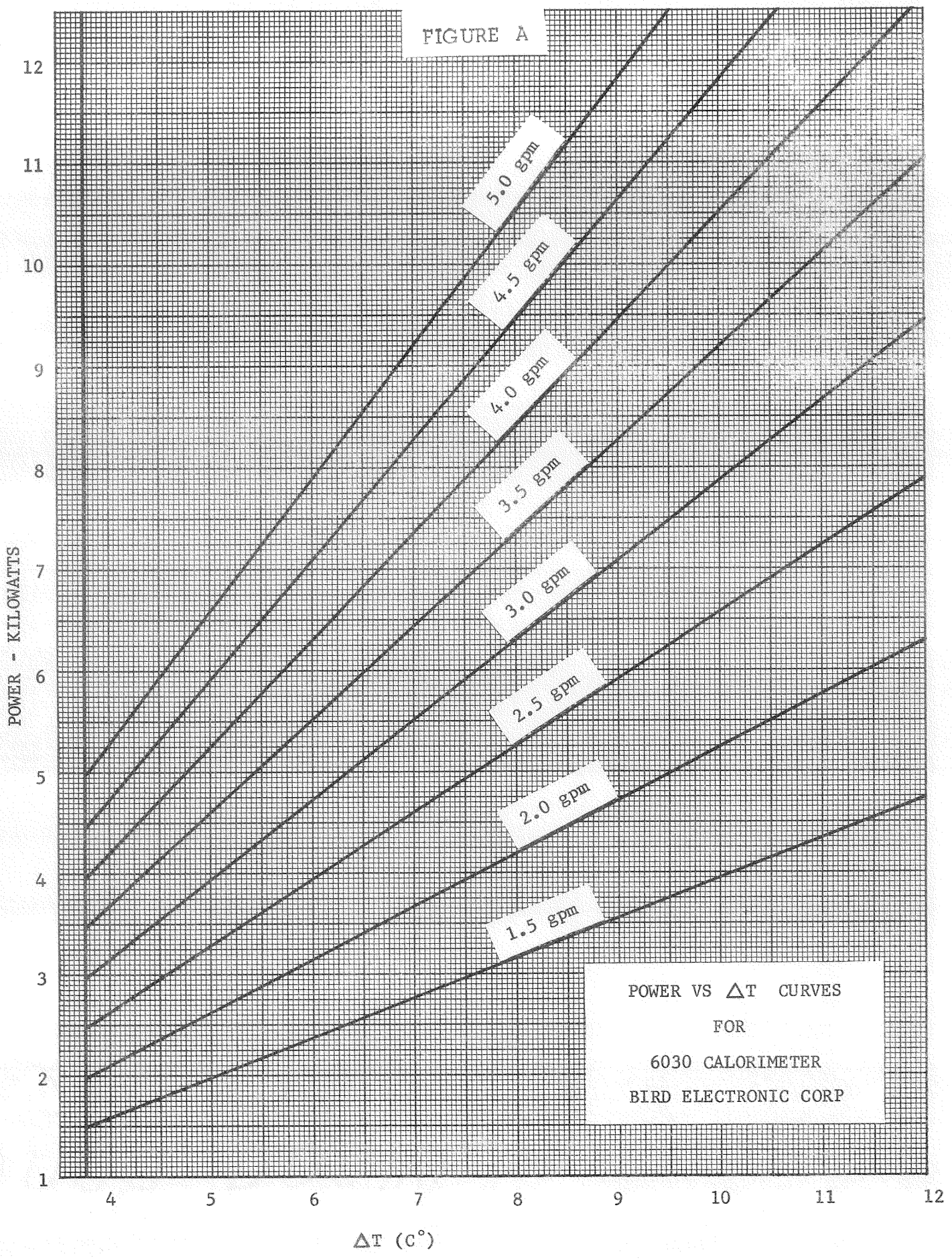
FIGURE A

POWER VS △T CURVES

FOR

6030 CALORIMETER

BIRD ELECTRONIC CORP

MINIMUM FLOW VS MAXIMUM POWER

FOR

6030 CALORIMETER

BIRD ELECTRONIC CORP

-B-

TEMPERATURE VS CORRECTION FACTOR

for

Model 6030 Calorimeter

BIRD ELECTRONIC CORP.

Figure B

SPECIFIC HEAT, C_p of WATER

vs

TEMPERATURE

Model 6030 Calorimeter

BIRD ELECTRONIC CORP.

Figure C