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Self Heating Effects of the IOSDL Temperature Transfer Standards

T J P Gwilliam

1990

Natural Environment Research Council

INSTITUTE OF OCEANOGRAPHIC SCIENCES
DEACON LABORATORY

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ABSTRACT

Measurements have been carried out to determine the errors included by self heating with the temperature transfer standards used at IOSDL.

Plots have been produced showing the relationship between the power dissipated in the thermometers and flow and no flow conditions.

KEYWORDS

ASL F17 BRIDGE
GALLIUM STANDARDS
PLATINUM RESISTANCE THERMOMETERS
TRONAC

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SELF HEATING EFFECTS OF THE IOSDL TEMPERATURE TRANSFER STANDARDS.

1. INTRODUCTION.

This report contains the results of an investigation into the self heating effects of the IOSDL transfer standard platinium resistance thermometers (prts) and the possible errors introduced when comparing stirred and unstirred temperature readings.

The measurements were all taken at or very close to the IOSDL gallium temperature standard of 29.7639 degs.C. rather than the ice point temperature at which self heating effects are usually specified. A major advantage of using the elevated temperature of the gallium cell for the experiment was the ease in which the absolute temperature could be maintained for long periods. To realise the same temperature stability at the ice point over the same length of time would have been far more labour intensive and very difficult to achieve.

The stirred measurement tests were carried out in the Tronac temperature controlled bath, the controller maintaining the water temperature at 29.7667 degs.C. +/- 0.2mK over the measuring period.

2. THERMOMETERS UNDER TEST.

Below is a list of the prts tested together with details of the equipment with which they are normally associated. Specifications of the prt transfer standards, the gallium standard and the ASL F17 bridge have been included in the report. Although not as detailed as one would wish, because of the limited data published by the manufacturers, they still contain valuable information.

1. CTD TRANSFER PRT.

This probe is a high precision,very expensive prt used to calibrate the Neil Brown MK3 conductivity, temperature and depth underwater units. It is a 4 lead device and is normally coupled with the Neil Brown conductivity-temperature transfer bridge for calibration measurements. At 29degs.C., drive current is nominally 2.3ma producing a power dissipation of 144micro watts.

2. TINSLEY '706 PRT.

The platinium resistance element in this device is housed in a 480 mm long fused silica tube and as a result great care is needed in its handling. It is used in the standards room with the Automatic Systems Laboratories (ASL) F17 bridge for calibrating other thermometers. At 29 degs.C., drive current is 1ma and power developed in the prt is approximately 28micro watts.

3. TINSLEY ,707 PRT.

This transfer standard is very similar to the ,706 PRT. It has an identical prt element housed in a fused silica tube but this is also enclosed in a stainless steel sheath for added protection. A penalty for this added protection is a longer time constant of 20 seconds. However, this probe, together with the MK1 ASL bridge is only used to determine the standard sea-water Autosal operating temperature so the longer time constant is not a problem. Power dissipation at 29degs.C is similar to the 706 device, 28microwatts.

4. SDL PRT.

This probe is also mounted in a stainless steel sheath for added protection and is used where less stringent accuracies are required. It is a 25 ohm prt manufactured by Sensing Devices Ltd (SDL) and is used with the ASL F17 bridges. This prt is also normally operated with a 1ma drive, so power levels close to 28 microwatts would be developed at 29 degs.C.

5. ASL F25 PRT.

This probe has a lower specification than those previously mentioned. It is a 100 ohm unit, the others are all 25 ohm devices, and the purity of the platinium is not as good. Used with the ASL F25 bridges and the manufacturers calibrations, accuracies of +/- 25mK can be achieved. However we have found that it has a very good long term stability and coupled with our restricted range calibrations, accuracies better than 5mK can be achieved. With its higher resistance, power dissipation in the prt is approximately 110 microwatts at 29 degs.C.

3. METHOD.

To minimise experimental errors, measurements for each prt was made using the same F17 ASL bridge. A 25 ohm resistance standard type 5685A was used as the reference for the 25 ohm prts, while the F17 bridge internal 100 ohm reference was used for the 100 ohm prts.

Using a 1ma drive current, each prt was calibrated at three temperatures, to (ITS 90,) using the temperature standard cells that covered the range of the experiment. These were:

1. The phenoxybenzene triple point cell (tpc) at 26.8625 degs.C.

2. The gallium cell at 29.7639 degs.C.

3. The ethylene carbonate tpc at 36.3135 degs.C.

From the calibration data, the prt resistance was evaluated for each temperature. A best fit second order polynomial was then derived from this resistance/temperature information.

For the unstirred measurements the prt under test was placed in the gallium cell and the F17 bridge balanced for nine values of drive current over the range 0.1 to 7.07 ma. The F17 bridge has a very convenient press button switch system on the front panel for reproducible changes in the current drive.

Similar measurements were taken for each prt when placed in the well stirred temperature controlled bath which was stabilised at 29.7666 degs.C.

4. RESULTS.

From the stirred and unstirred data collected the value of resistance and heat developed (I^2R) was calculated for each prt. Using the calibration data and the change in drive current, the absolute and change in temperature was then deduced from this calculated resistance. Because the prts were placed in a medium maintained at constant temperature, these observed temperature changes must be due to the self heating effect (SHE) produced by the changing current through the platinium resistance.

It was not intended that this report should contain a vast amount of numerical information to convey the results of the data collected. It was felt that a visual interpretation using graphical results would increase the understanding of self heating with flow and no flow conditions. Therefore two graphs for each prt were produced, each illustrating the relationship between the dissipated power in the prt and the resulting change in temperature. The first graph is an overall picture over the range zero to 1000 microwatts. The second, having a more restricted power range, highlights the temperature errors about the normal working power levels. It should be noted that for the purposes of clarification these latter plots have been drawn from the condition of zero power and hence zero SHE by extrapolating the data.

5. CONCLUSIONS.

Inspection of the SHE plots show that for a given power, the CTD PRT produces the lowest SHE errors while the Tinsley ,706 and '707 the highest. These variations can be explained by the difference in construction. The CTD prt element is mounted in very close proximity to the sheath, allowing for little or no temperature differentials to be set up and the temperature measured would be that of the liquid in which it is immersed. However self heating effects can be seen from the unstirred curve where there is a build up of heated water surrounding the probe. In the stirred condition, this insulating layer of water is dispersed and the SHE errors considerably reduced. Normally the probe is operated with power levels of approximately 140 microwatt so differences of 0.6 millideg.C. could be experienced when making measurements in stirred and unstirred water at the same temperature.

With the '707 PRT having a stainless steel sheath and the '706 in a fused quartz tube it would be expected that the Tinsley probes have a very different SHE characteristic, but the curves are very similar. This however can be explained by the large insulating layer of low pressure air between the element and the fused quartz sheath which overrides any difference the metal sheath may make. At 28 microwatts, the normal operating power, the SHE error is near 3 millideg.C. but the flow no flow error is only 0.3 millideg.C.

Inspection of the ASL F25 PRT plots show that this relatively inexpensive probe is still a useful instrument with SHE errors of 3 millidegs and differential flow errors of 0.6 millidegs.C.at the working power levels of 100 microwatts.

6. ACKNOWLEDGMENTS.

Thanks are due to Steve Wright for his asssistance in the laboratory.

SPECIFICATION.

CTD TRANSFER PRT.

MANUFACTURER : ROSEMOUNT ENGINEERING Co. LTD.

MODEL NUMBER : 162D.

O Deg.C RESISTANCE : 25.55 OHMS

STABILITY : 0.010 Degs.C/year.

TIME CONSTANT. : 5.0 Seconds in water flowing at 1m/s.

ELEMENT LENGTH : 47mm

ELEMENT DIAMETER : 5.56mm

TOTAL PROBE LENGTH : 246mm

SPECIFICATION.

TINSLEY '706 PRT.

MANUFACTURER : H TINSLEY & Co.Ltd.

MODEL NUMBER : 5187SA

O Deg.C RESISTANCE : 25 ohms +/- 0.5 ohm

REPRODUCIBILITY : +/- 0.001 Deg.C

TIME CONSTANT. : 5-10 Seconds.

ALPHA : 0.003926 to 0.003928

SHEATH MATERIAL : Fused silica tube.

SHEATH LENGTH : 480mm

SHEATH DIAMETER : 6.5 to 7.5mm

IMMERSION DEPTH : 300mm

SPECIFICATION.

TINSLEY '707 PRT.

MANUFACTURER : H TINSLEY & Co.Ltd.

MODEL NUMBER : 5187SA

O Deg.C RESISTANCE : 25 ohms +/- 0.5 ohm

REPRODUCIBILITY : +/- 0.001 Deg.C

TIME CONSTANT. : 20 Seconds.

ALPHA : 0.003926 to 0.003928

SHEATH MATERIAL : Fused silica tube inside stainless steel sheath.

SHEATH LENGTH : 480mm

SHEATH DIAMETER : 8-9mm

IMMERSION DEPTH : 300mm

SPECIFICATION.

SDL PRT.

MANUFACTURER : SENSING DEVICES LTD.

MODEL NUMBER : S511 TYPE 1.

SERIAL NUMBER : R25/013.

O Deg.C RESISTANCE : 25.55 OHMS

ALPHA (min.) : 0.0039265

ELEMENT LENGTH. : 50mm

SHEATH LENGTH. : 450mm

SHEATH MATERIAL. : STAINLESS STEEL.

SHEATH DIAMETER. : 60mm

SPECIFICATION.

F25 PRT

MANUFACTURER : AUTOMATIC SYSTEMS LABORATORIES

MODEL NUMBER : T25/02

O Deg.C RESISTANCE : 99.997 ohms

TIME CONSTANT. : 10 Seconds.

ALPHA : 0.0038526

SHEATH MATERIAL : Stainless steel.

SHEATH LENGTH : 358mm

SHEATH DIAMETER : 6mm

High Precision Resistance Thermometry Bridge Model F17 and F17A

Automatic or Manual Operation

Specification

Range	0 to 3.999999 ratio of R thermometer to R standard. With a:– 5 ohm standard 5×10^{-6} to 20 ohms. 100 ohm standard 10^{-4} to 400 ohms. 1000 ohm standard 10^{-3} to 4000 ohms.
Accuracy	Better than 0.0001% at unity ratio. The measured ratio of reference resistor to sensor resistance will be correct within 1 part per million of full scale.
Internal Standard	100 ohm ± 50 ppm temperature controlled. A trim control allows exact adjustment to agree with an external standard.
External Standard	Any available reference resistor up to 1000 ohm.
Sensor Current	0.1; 0.2; 0.5; 1; 2; 5 mA and $\sqrt{2}$ multiplier. Stabilised to 0.1% of nominal value. Constant Current over measuring range. Maximum Permitted voltage across R_{STD} = 0.7 V rms.
Operating Frequency	75 Hz.
Effect of Connecting leads to sensor and reference resistors	Resistance of 50 ohms in series with all or any of the sensor leads will produce a maximum charge in reading of less than 1 ppm.
Self checking and self calibrating facilities	Unity – Confirms accuracy of 1:1.000 000 ratio. Zero – Confirms accuracy of 0.000 000 setting. Residual Noise – Displays total environmental noise. Quadrature – Displays value of reactance which has been automatically balanced out.
Quatrature Balance	Fully automatic balance of reactance of sensor, standard and leads. Range 20 nF parallel or 0.4 mH Series with 100 ohms.
Dimensions	525 x 158 x 480 mm. Rack mount option.
Weight	17 kgs (37.5 lbs).
Operating Temperature	0 to 40°C with external reference resistor. The internal reference resistor is stabilised in an oven at 35°C. This requires ambient temperature less than 30°C.
Supply	115 or 230 volts ± 10% 50 to 60 Hz.
Manual Operation	The automatic instrument (F17A) can also be used with manual balance.
Resolution	The peak to peak noise is 6×10^{-9} volts with 0.1 Hz bandwidth at a ratio of 1. This is 3×10^{-6} ohms with 2 mA current in 100 ohm sensor or less than 0.1 mK with 1 mA in a 25 ohm Platinum Resistance Thermometer at 0°C.
Output	Analogue out-of-balance signal 10 – 0 – 10 vDC equivalent to meter f.s.d.
Automatic Operation	F17A only.
Resolution	1 least significant digit. This is 10^{-5} ohms with 10 ohms reference. 10^{-4} ohms with 100 ohms reference. 10^{-3} ohms with 1000 ohms reference. With low energising current the resolution will be restricted due to the inherent noise.

ISOTECH

ITL Gallium Cell & Temperature Standard

Pure gallium melts at 29.7715°C[1], a temperature known with an uncertainty of less than 0.0005°C[2,3,4], and is an accepted reference point of the IPTS. The location of this fixed point in the near-ambient provides an important calibration temperature in biological, ecological, energy research and similar disciplines. It can also be used as a ready reference against which to reset the calibrations of thermometers (such as quartz thermometers) that are subject to calibration drift.

The ITL-M-17402 Gallium Temperature Standard requires an ITL-M-17401 Gallium Cell. The standard provides a semi-automatic melt environment for the gallium cell in a convenient benchtop unit. You may also use the gallium cell without the melt module in a 30.1°C ± 0.05°C water bath.

Each gallium cell is furnished with a certificate listing the mean and standard deviation of a number of measurements of its melt temperature and its traceability to the National Standards.

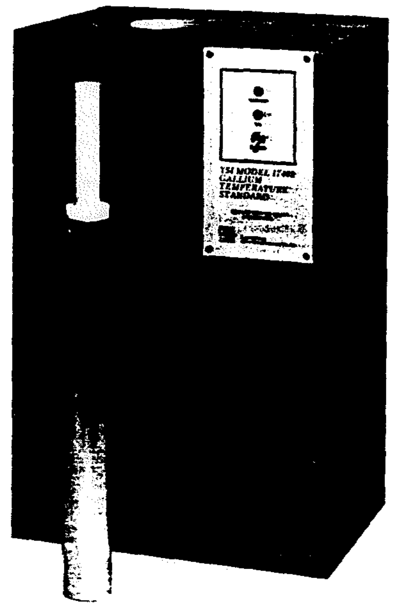
[1]Temperature as given on the International Practical Temperature Scale.

[2]Sostman, H.E., *Melting Point of Gallium as a Temperature Calibration Standard.* Rev. Sci. Instr. 48:127 (1977).

[3]Bedford, R.E., G. Bonnier, H. Maas, F. Pavese, *Recommended Values of Temperature for a Selected Set of Secondary Reference Points.* Metrologia 20:145 (1984).

[4]Borovicka, M., H.E. Sostman, *Melting and Triple Point Temperatures of Gallium as Fixed Points of the International Temperature Scale.* Rev. Sci. Instr. 55:1639 (1984).

Net Weight : **7Kgs. (15½ lbs) approx**
Gross Weight : **9Kgs. (20 lbs) approx**



SPECIFICATIONS

Equilibrium Temperature: 29.7715°C on the International Practical Temperature Scale (IPTS) of 1968.

Uncertainty: ± 0.001°C.

Certification: Each cell is supplied with a certificate of traceability to the National Standards and a statement of the equilibriumn plateau temperature and standard deviation. Since the equilibrium temperature is a constant of nature, recertification is normally not required.

Repeatability: ± 0.001 or better.

Gallium Purity: 99.99999%.

Plateau Duration: Not less than 12 hours under specified ambient conditions; 20 hours typical. Plateau duration is different when the 17401 Gallium Cell is used independently; consult Industrial Customer Service for further information.

Cycle Time: With cell at 0°C, time to plateau is 1 hour maximum, 45 minutes typical. Recycling time, including freezing the cell, is typically 3 to 4 hours.

Thermometer Well: Accommodates thermometers 11.4mm (0.45") or less in diameter with total stem length not less than 37 cm (14.5"), such as Hewlett-Packard 18111A and 18112A, Leeds & Northrup 8163 and 8167, and ITL 8163 and 8167.

Gallium Temp. Standard Size: 18.1 x 25.9 x 42.9 cm (7.12 x 10.2 x 16.9 inches).

Power: 115/230 VAC, 50/60 Hz, 75 W maximum.

Ambient Temperature: - 20 to + 55°C storage; 15 to 30°C operating.

Ambient Humidity: 70% RH maximum.

HOW TO ORDER

Order using the numbers below; also specify power.
ITL-M-17401 Gallium Cell.
ITL-M-17402 Gallium Temperature Standard (without cell).

ISOTHERMAL TECHNOLOGY LIMITED
Pine Grove Southport Merseyside PR9 9AG England
☎ 0704 43830 Fax 0704 44799 Telex 67179 ISOTEC G

PTC-41

SPECIFICATIONS

BATH TEMPERATURE CONTROL

Typical one sigma bath temperature control using a Tronac 408R bath is better than ±0.0001 C°. Similar performance can be expected with other baths.

GENERAL CONTROL SPECIFICATION

The PTC-41 can be used in a variety of control applications. The controller will handle power loads from a few milliwatts to 1000 watts. A stable operating system can be estalished with most power level/heat capacity combinations through the use of gain and response adjustments.

RESETABILITY

Coarse Control .... ±0.25 C°
Fine Control .... ±0.001 C°

USABLE HEATER SIZE COMPARED TO BATH HEAT CAPACITY

From 0.25 to 12.6m C° / sec.

TYPE OF HEATER CONTROL

Time proportioning zero-crossing solid-state relay control of main power line voltage: zero voltage turn-on, zero current turn-off.

MAXIMUM HEATER POWER

1000 Watts

HEATER OUTPUT

A 3-wire AC receptacle allows controller to be used with any heating or cooling device employing an AC power cord.

POWER REQUIREMENTS

25 watts plus heater power at either 105-125 VAC or 210-250 VAC, 50-60 Hz

DIMENSIONS

10x27x22 cm (4x10.5x8.5 in)

WEIGHT

1.3 kg (3 lbs)

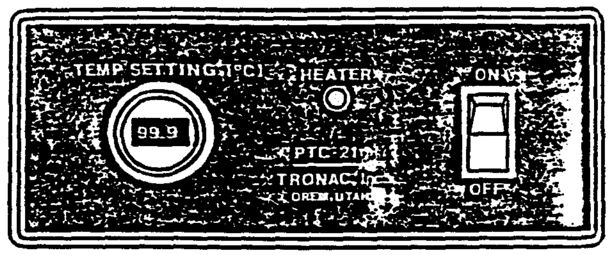
DROOP OR SAG

Tronac's unique design entirely eliminates droop or sag commonly found in proportional controllers (even those with reset).

RANGE

Depends upon the probe used. A standard 25°C probe is supplied with the PTC-41. Other standard probes are listed below. These thermistor probes are available in stainless steel with a cable length of 6 feet. Spetial probes and other cable lengths are available on request. Useful range: -20°C to 250°C.

Standard Probes	Design Center Temperature	Guaranteed Range	Useful Range
TCP-10-S	10° C	-5° to 25° C	-20° to 50° C
TCP-25-S	25° C	15° to 40° C	0° to 60° C
TCP-40-S	40° C	25° to 60° C	15° to 80° C
TCP-60-S	60° C	45° to 80° C	35° to 80° C
TCP-80-S	80° C	55° to 100° C	55° to 160° C
TCP-100-S	100°C	75° to 150° C	75° to 180° C



PTC-21

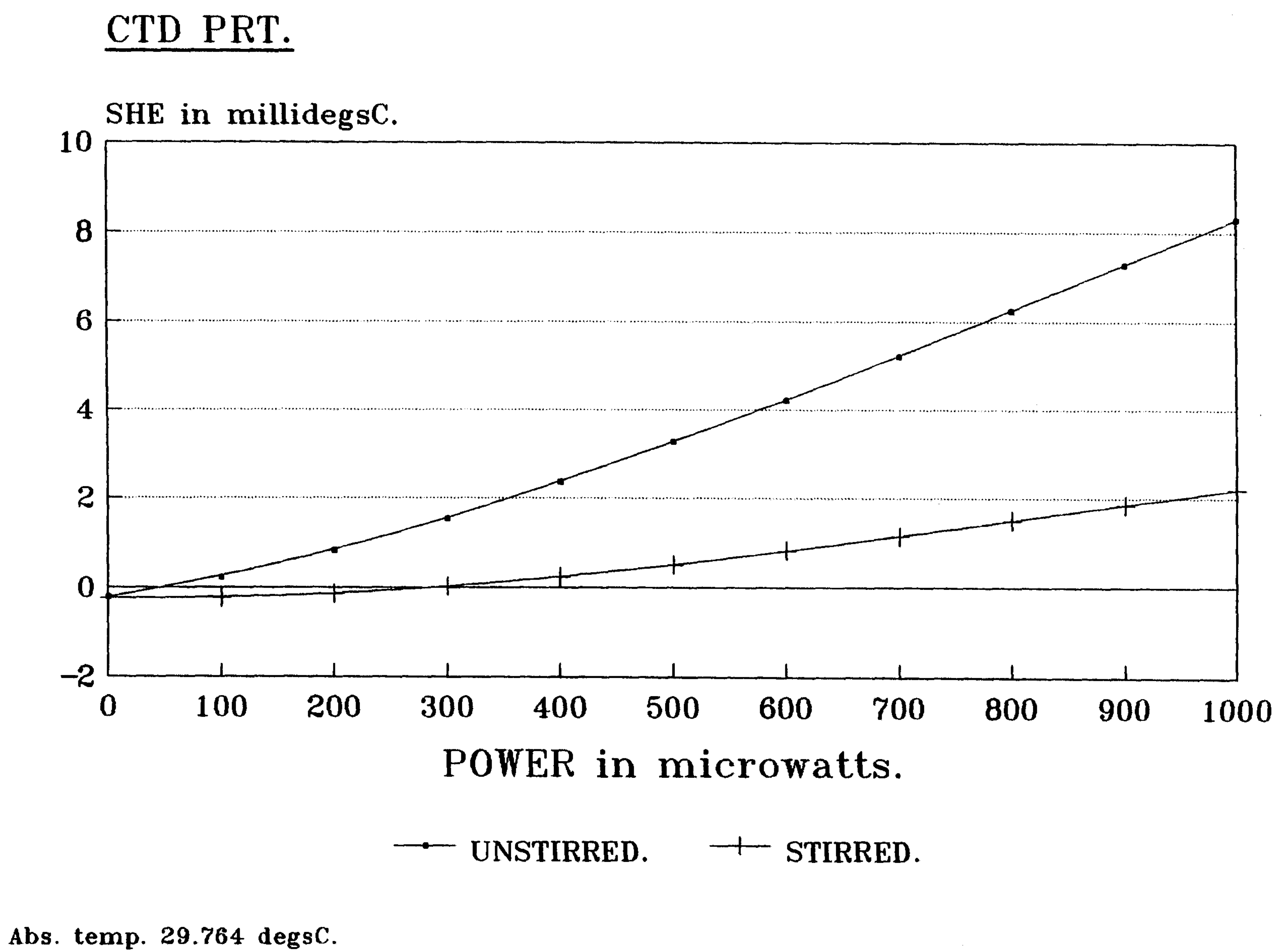
DESCRIPTION

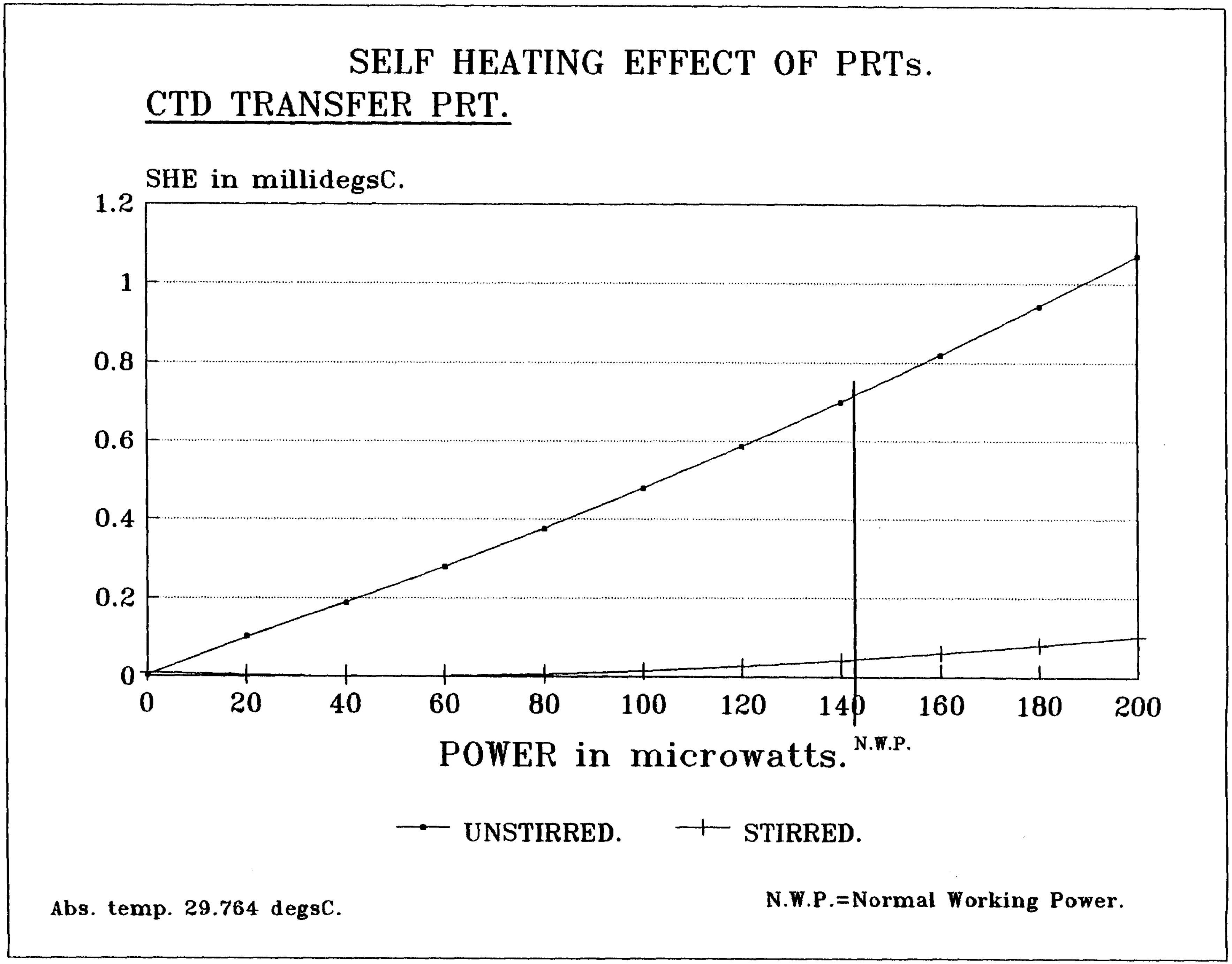
For those applications where the extreme stability of the PTC-41 is not required, **Tronac** offers the economical Model PTC-21. This instrument offers a temperature stability of ±0.01°C. The set point may be selected by means of a digital dial located on the front panel. This controller may be used in many applications in industry and research where price as well as high stability are important. The PTC-21 can control gas or air temperatures as well as liquid temperatures. The PTC-21 is designed to be used with **Tronac** bath systems, but other air and liquid bath designs can also be controlled.

TRONAC, Inc.

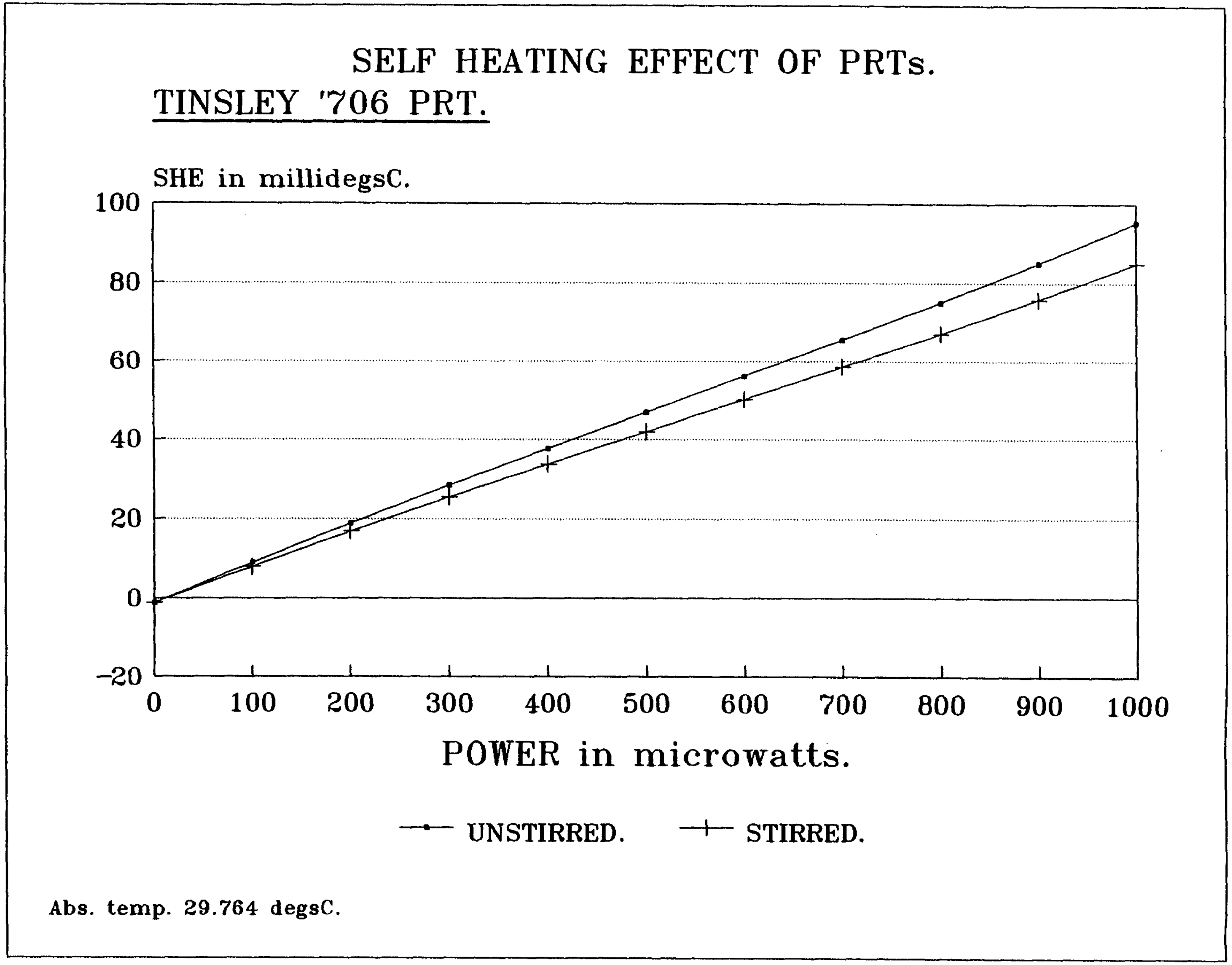
1804 South Columbia Lane Orem, Utah 84057 (801) 224-1131 Telex 910-971-4003

SELF HEATING EFFECT OF PRTs.



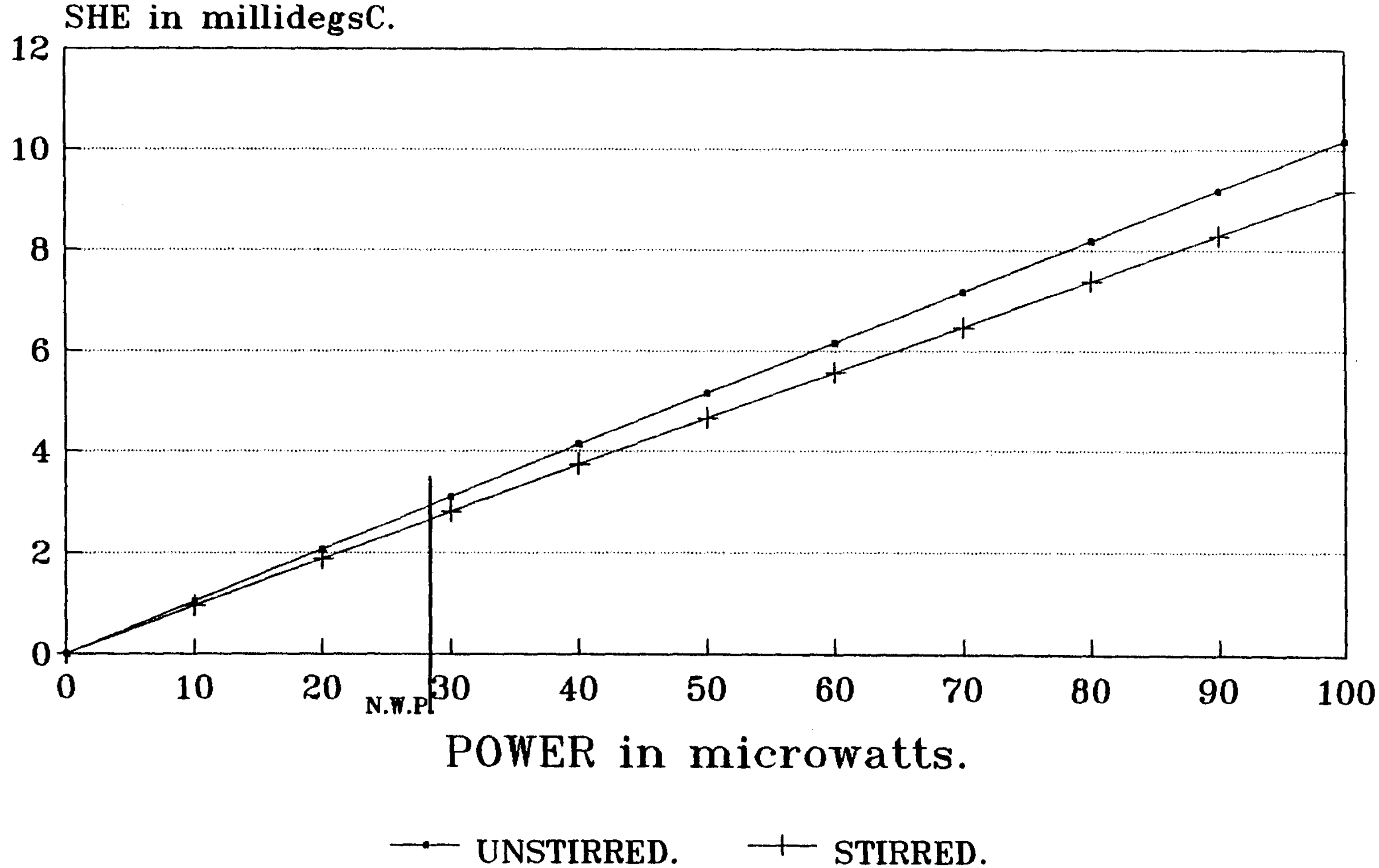


SELF HEATING EFFECT OF PRTs.
CTD TRANSFER PRT.
SHE in millidegsC.
1.2
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
140
160
180
200
N.W.P.
POWER in microwatts.
UNSTIRRED.
STIRRED.
Abs. temp. 29.764 degsC.
N.W.P.=Normal Working Power.


SELF HEATING EFFECT OF PRTs.
TINSLEY '706 PRT.
SHE in millidegsC.
100
80
60
40
20
0
-20
0
100
200
300
400
500
600
700
800
900
1000
POWER in microwatts.
UNSTIRRED.
STIRRED.
Abs. temp. 29.764 degsC.

SELF HEATING EFFECT OF PRTs.

TINSLEY '706 PRT.

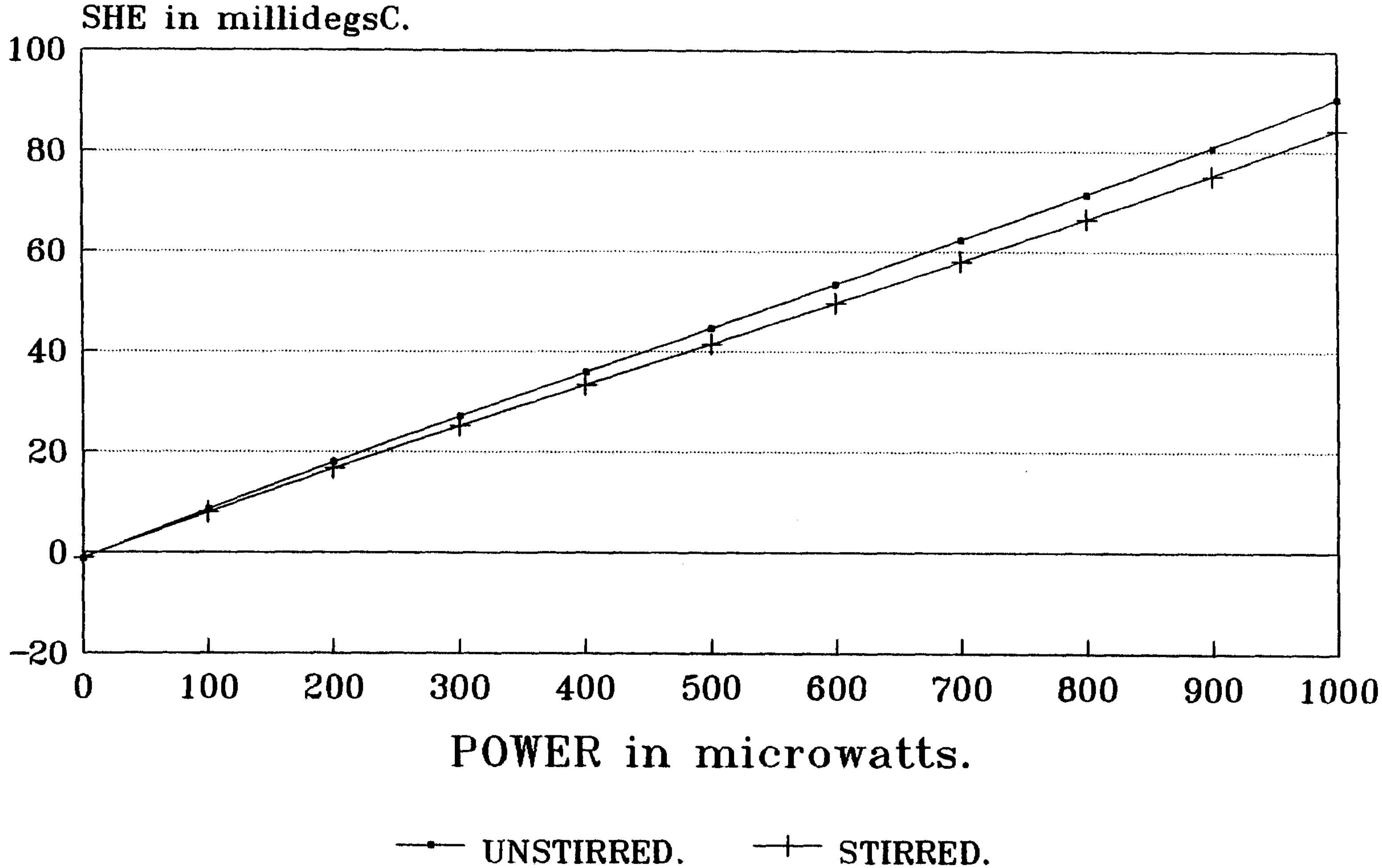


Abs. temp. 29.764 degsC.

N.W.P.=Normal Working Power.

SELF HEATING EFFECT OF PRTs.

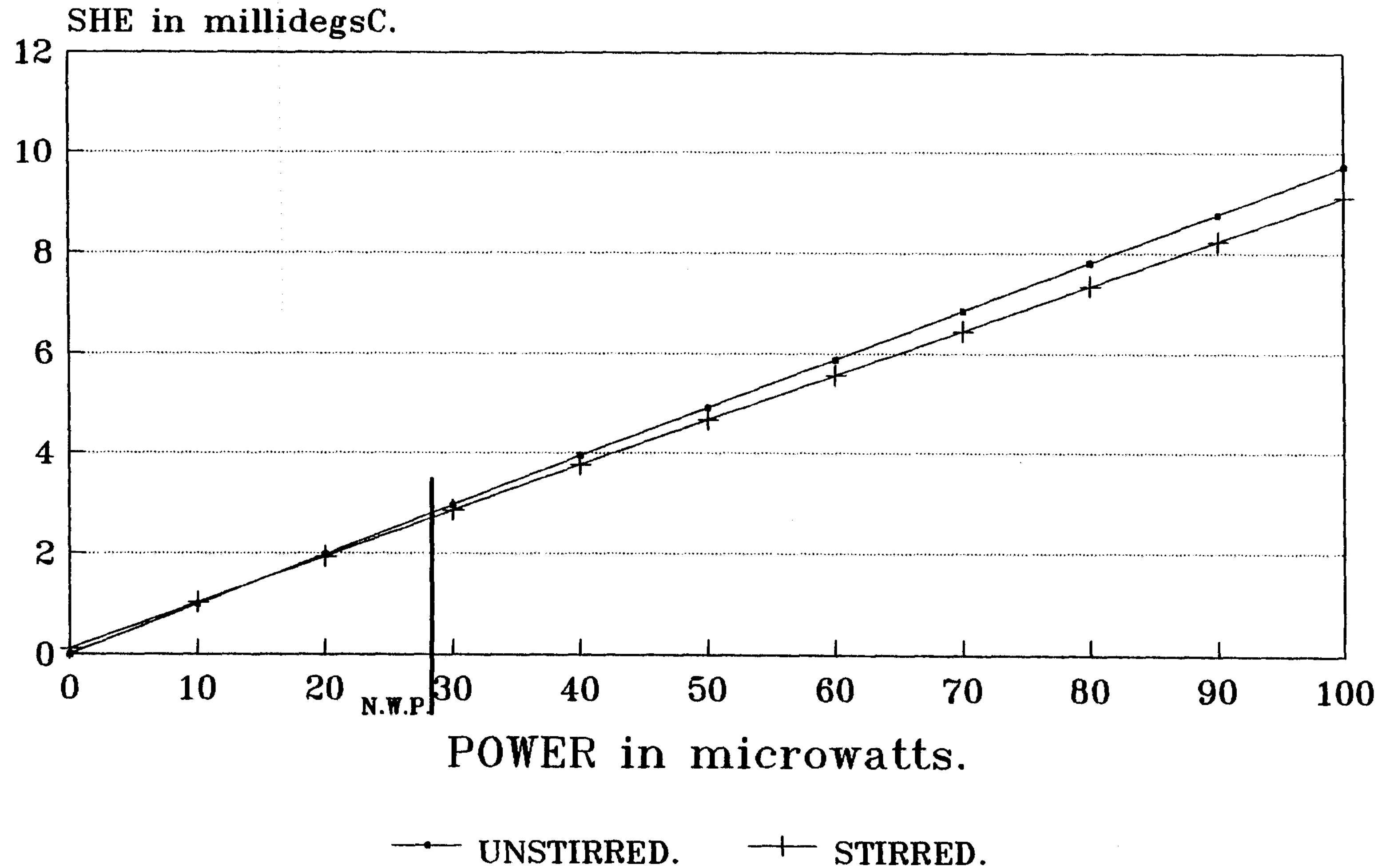
TINSLEY '707 PRT.



Abs. temp. 29.764 degsC.

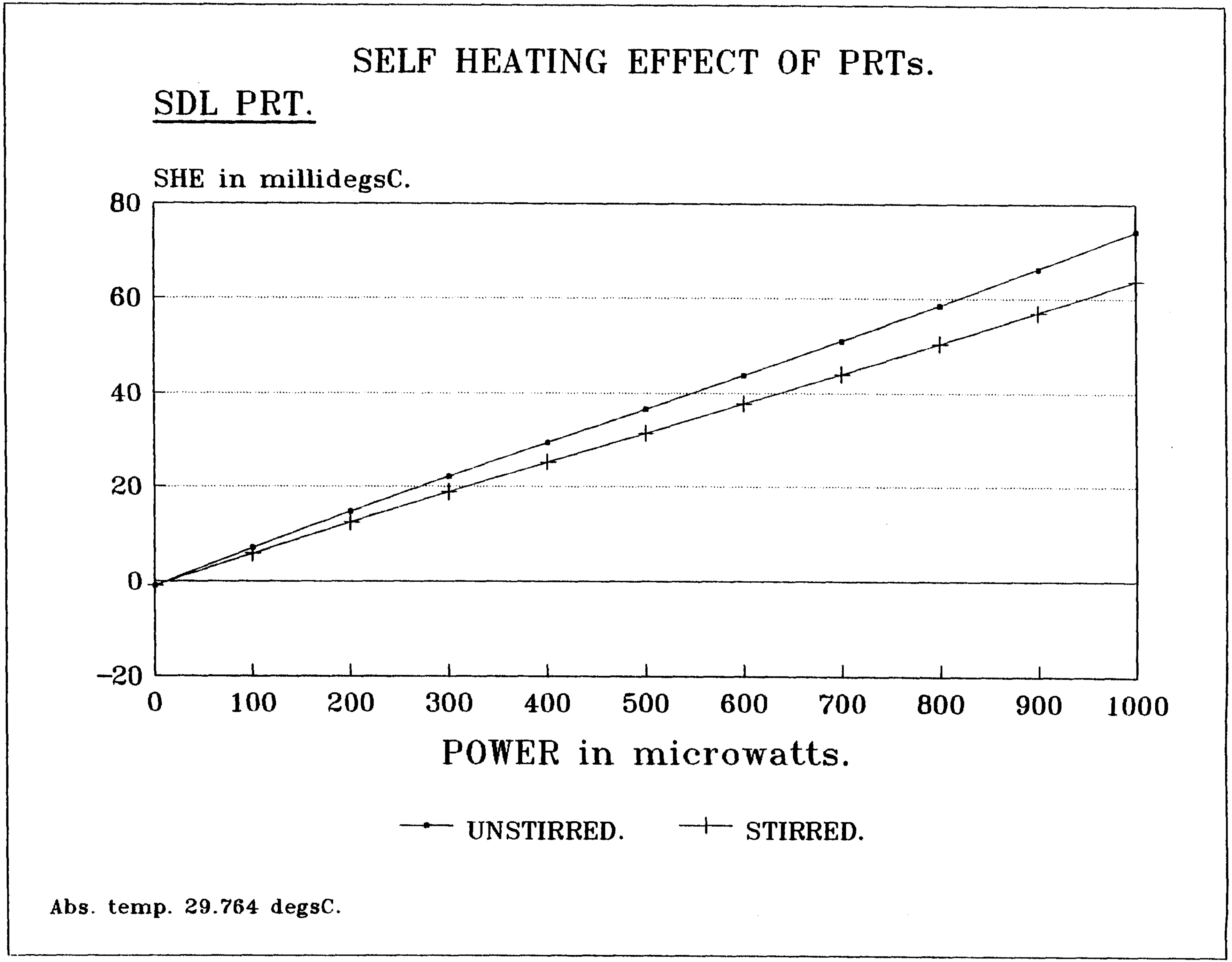
SELF HEATING EFFECT OF PRTs.

TINSLEY '707 PRT.

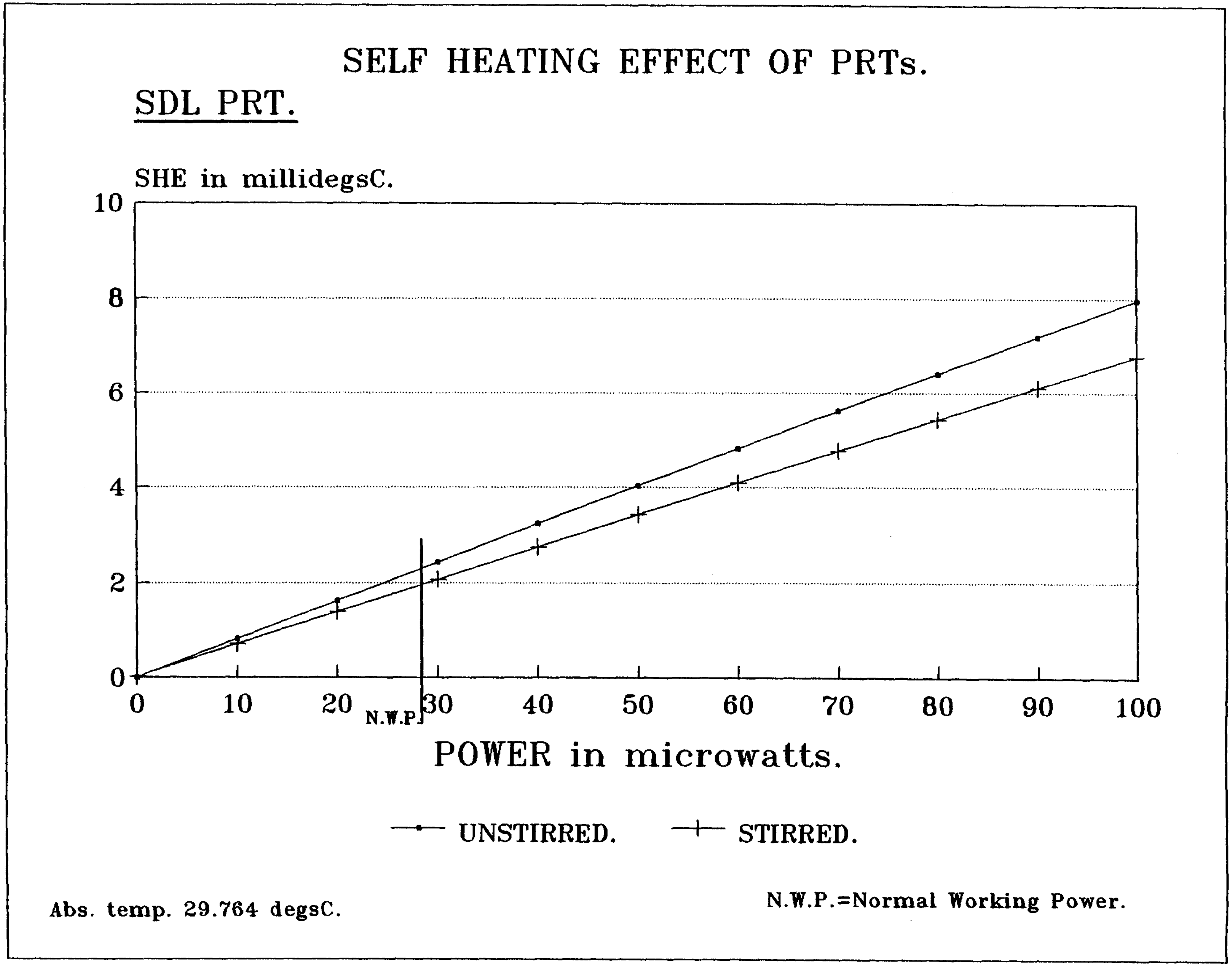


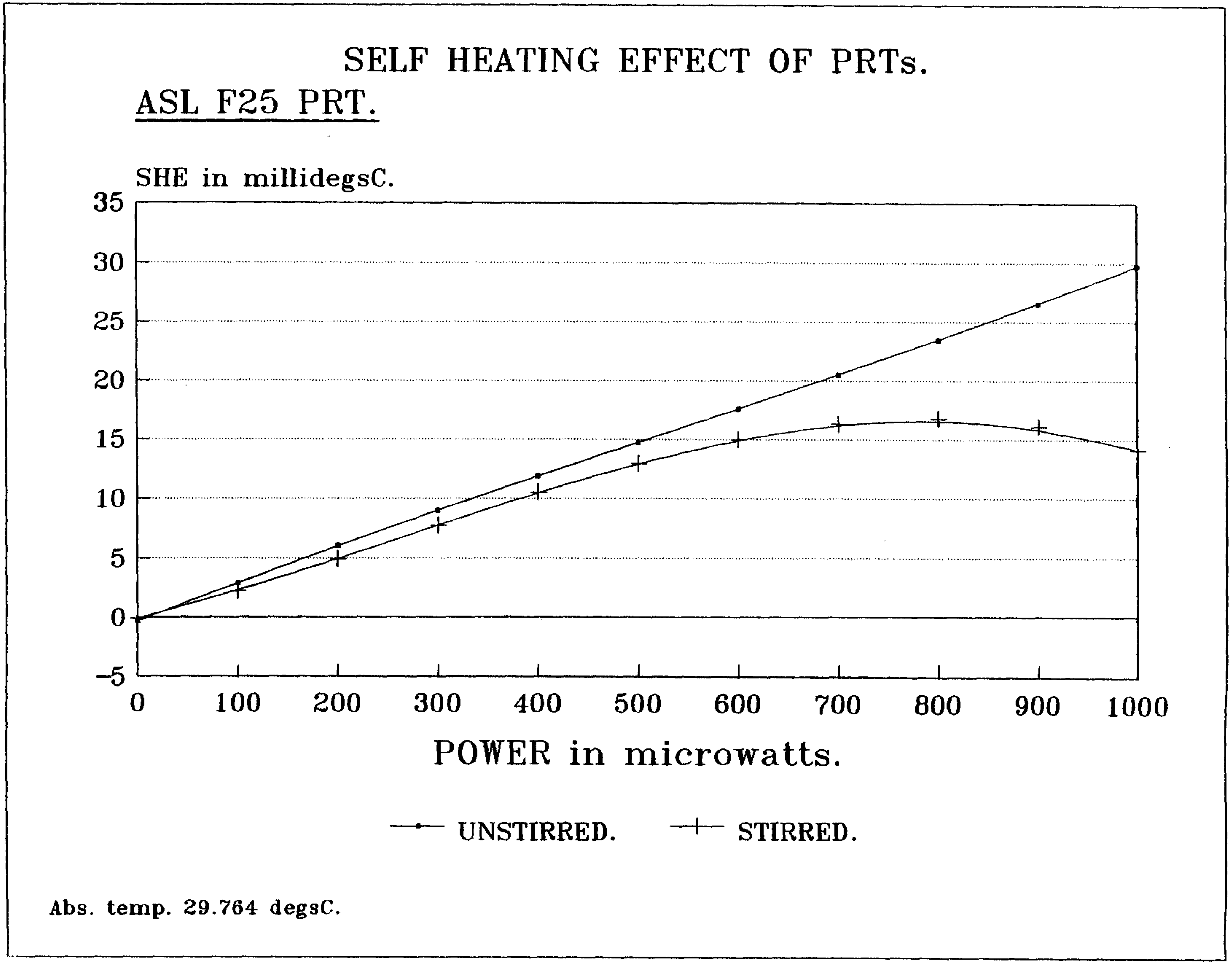
Abs. temp. 29.764 degsC.

N.W.P.=Normal Working Power.



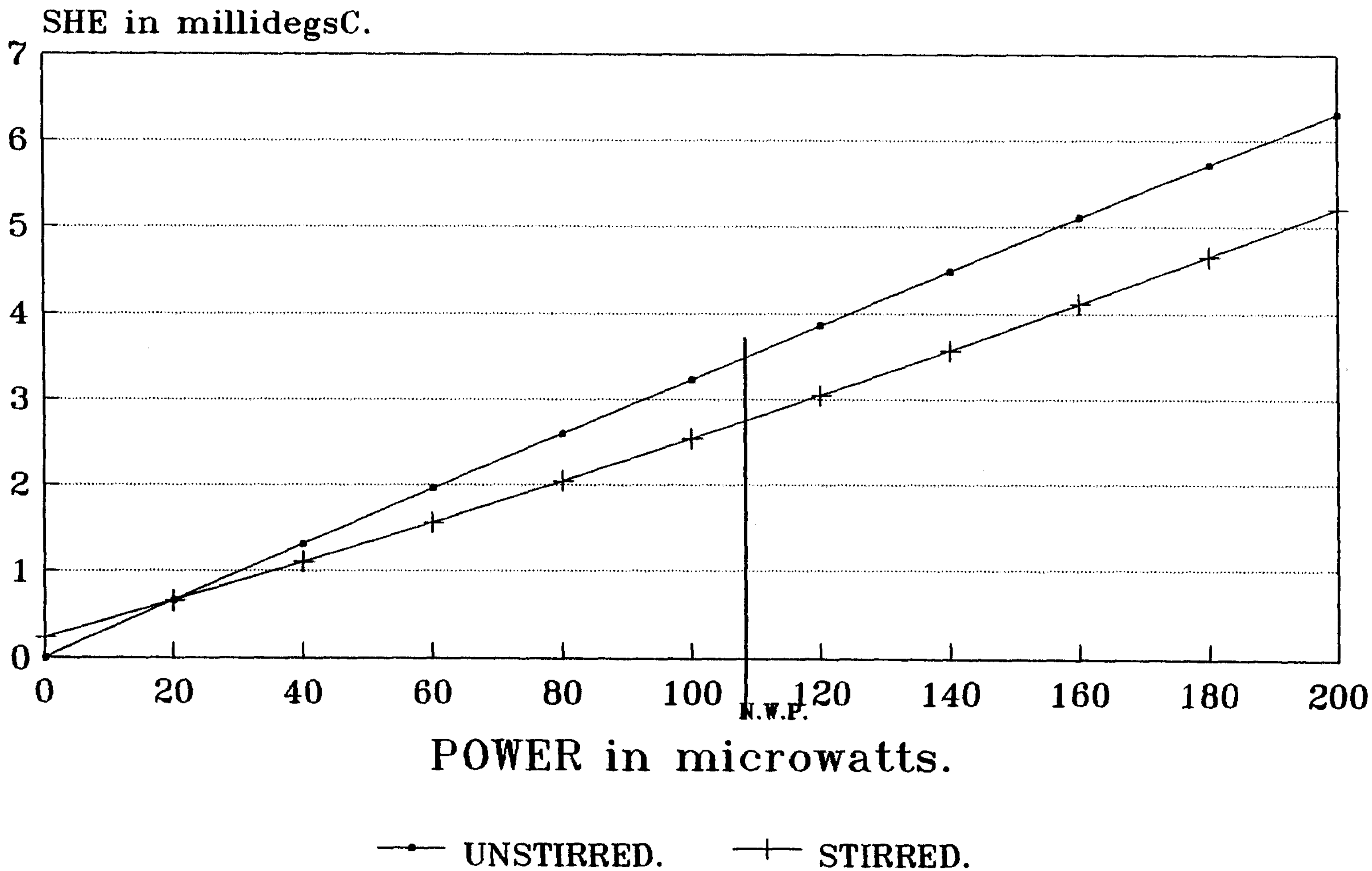
SELF HEATING EFFECT OF PRTs.
SDL PRT.
SHE in millidegsC.
80
60
40
20
0
-20
0
100
200
300
400
500
600
700
800
900
1000
POWER in microwatts.
UNSTIRRED.
STIRRED.
Abs. temp. 29.764 degsC.


SELF HEATING EFFECT OF PRTs.
SDL PRT.
SHE in millidegsC.
10
8
6
4
2
0
0
10
20
N.W.P.
30
40
50
60
70
80
90
100
POWER in microwatts.
UNSTIRRED.
STIRRED.
Abs. temp. 29.764 degsC.
N.W.P.=Normal Working Power.


SELF HEATING EFFECT OF PRTs.
ASL F25 PRT.
SHE in millidegsC.
35
30
25
20
15
10
5
0
-5
0
100
200
300
400
500
600
700
800
900
1000
POWER in microwatts.
UNSTIRRED.
STIRRED.
Abs. temp. 29.764 degsC.

SELF HEATING EFFECT OF PRTs.

<u>ASL F25 PRT.</u>



Abs. temp. 29.764 degsC.

N.W.P.=Normal Working Power.