IS 13129-2 (1991): Solar heating - Domestic water heating systems, Part 2: Procedure for system performance characterization and yearly performance predication [MED 4: Non-Conventional Energy Sources]

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सौर-तापन – पानी गरम करने की घरेलू प्रणाली

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Indian Standard

SOLAR HEATING — DOMESTIC WATER HEATING SYSTEMS

PART 2 PROCEDURE FOR SYSTEM PERFORMANCE CHARACTERIZATION AND YEARLY PERFORMANCE PREDICATION

UDC 683-97 : 697·329 : 620·16

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Price Group 5

Non-Conventional Energy Sources Sectional Committee, HMD 4

FOREWORD

This Indian Standard (Part 2) was adopted by the Bureau of Indian Standards, after the draft finalized by the Non-Conventional Energy Sources Sectional Committee, had been approved by the Heavy Mechanical Engineering Division Council.

A wide variety of solar domestic hot water (SDHW) systems are marketed throughout the world. A natural consequence of this highly dispersed activity is the need to understand, predict and compare the performance of these systems. Standardized test methods are essential for assessing the performance potential. This standard has been developed to help facilitate comparision of these systems.

Because various testing methodologies for determining thermal performance are at different stages of development and acceptance, it has been decided to concurrently prepare separate parts of this standard each covering a separate methodology. The advantage of this format is that each part can proceed on its own and not be delayed until all methodologies are at the same point of development.

This standard is, therefore, being published in following parts:

Part 1 — Performance rating procedure using indoor test methods

Part 2 — Procedure for system performance characterization and yearly performance predication

Part 3 — Procedures for system component characterization and predication for yearly performance using component performance data

Part 4 — Test methods to determine durability and reliability

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

SOLAR HEATING — DOMESTIC WATER HEATING SYSTEMS

PART 2 PROCEDURE FOR SYSTEM PERFORMANCE CHARACTERIZATION AND YEARLY PERFORMANCE PREDICATION

1 SCOPE

1.1 This standard sets out a method of determining the performance of a solar water heating system under natural outdoor conditions and prescribes a method of transforming the test results from the particular climate conditions of the test to long-term average conditions for the test location or for other location with similar solar irradiation conditions.

2 REFERENCES

The following Indian Standards are the necessary adjuncts to this standard:

IS No.	*Title*
12933 (Part 1) : 1991	Solar flat plate collector : Part 1 General requirements
12933 (Part 2) : 1991	Solar flat plate collector : Part 2 Components
12933 (Part 3) : 1991	Solar flat plate collector : Part 3 Measuring instruments
12933 (Part 4) : 1991	Solar flat plate collector : Part 4 Performance requirements and accepted criteria
12933 (Part 5) : 1991	Solar flat plate collector : Part 5 Test methods

3 FIELD OF APPLICATION

The tests are carried out in typical operational conditions, the only restriction on the nature of systems that can be tested is that there can be no long-term energy storage. The total energy storage capacity in the solar pre-heat section of the system must be less than twice the nominal system capacity.

The standard applies only to systems with an auxiliary heating system that can satisfy the load under no-solar input conditions.

Types of solar water heating systems that can be tested include:

a) Solar collector with remote hot water container system – both components supplied as a complementary and rated system with the primary circuit piping arranged to suit site conditions when installed.

b) Close coupled or integral unit system – which may be tested as a complete unit.

The primary energy transfer circuit between the collector and container may be either thermosiphon or forced circulation for the type described in (a) above. Supplementary water heating incorporated in the solar water heating system may be either integral with the solar water heater or remote from it.

4 DEFINITIONS, SYMBOLS AND ABBREVIATIONS

4.1 For the purpose of this standard, the following definitions shall apply.

4.1.1 *Absorber*

Device within a collector for absorbing radiant energy and transferring this energy as heat into a fluid.

4.1.2 *Angle of Incidence (of direct solar radiation)*

The angle between the solar radiation beam and the outward drawn normal from the plane considered.

4.1.3 *Angle of Inclination*

Angle between the absorbing surface of the collector and the horizontal.

4.1.4 *Aperture Area*

Of a solar thermal collector, the maximum projected area through which the unconcentrated solar radiation is admitted.

4.1.5 *Close-Coupled – Solar Water Heater*

Unit where the collector abuts the container on a common chassis or cradle.

4.1.6 *Collector*

Device containing an absorber.

4.1.7 *Container*

Vessel (including fittings) in which the heated water is stored; sometimes referred to as a storage container, cylinder or tank.

4.1.8 *Electricity Tariffs*

4.1.8.1 *Continuous tariff*

Tariff for continuously available electricity supply.

4.1.9 *Irradiance*

Power density of radiation incident on a surface, that is the quotient of the radiant flux incident on the surface and the area of that surface, or the rate at which radiant energy is incident on a surface, per unit area of that surface.

NOTE – Solar irradiance is often termed "incident solar radiation intensity", "instantaneous insolation", or "incident radiant flux density" – the use of these terms is deprecated.

4.1.10 *Irradiation*

Integrated total irradiance normal to the plane of the collector aperture whose effect on the thermal output of the collector would be the same as that of the integrated total solar radiation. Irradiation is normally expressed in megajoules per square metre (MJ/m^2).

4.1.11 *Solar Water Heater*

System normally consisting of a collector and a container which may be integral, close coupled or remote, and which heats water by means of radiant energy from the sun. It is normal for solar water heaters to be either fitted with or connected to a supplementary heating source.

4.1.12 *Load*

The daily system hot water load defined as the product of the mass, specific heat and temperature increase of the water as it passes through the solar hot water system.

4.2 Symbols and Abbreviations

The following quantity symbols used in this standard:

Symbol	*Meaning*
A	collector aperture area (m^2)
a	correlation coefficient
B	daily supplementary energy used by solar water heater (MJ/d)
B_c	supplementary energy used by a conventional (non-solar) water heater (MJ)
B_g	daily gas energy consumption for a gas water heater (MJ)
B_n	supplementary energy used on last day of test period (MJ)
B_o	supplementary energy used on day before test period (MJ)
B_s	annual supplementary energy used (MJ)
b	correlation coefficient
c	correlation coefficient
E_1	energy delivered at water temperature of 55°C and above (MJ)
E_2	energy delivered at water temperature below 55°C (MJ)
f	solar fraction = $(L - B)/L$
f_c	supplementary energy fraction (B/L)
f_R	energy savings relative to a conventional water heater $(B_c - B_s)/B_c$
G	daily solar radiation on the total aperture of the collector (MJ/d). (Beam radiation for concentrating collectors, global radiation for all other types)
g	daily solar radiation on unit area of collector aperture (MJ/d)
L	daily load demand (MJ/d)
L_a	annual load demand (MJ/year)
L_o	load demand on day before test period (MJ)
L_n	load demand on last day of test period (MJ)
N	number of test periods
n	number of days in test period (5 to 15)
q_b	burner heat input on a gas water heater (MJ/h)
q_e	heat loss from container of gas water heater (MJ/h)
T_a	ambient temperature over 24 h (°C)
T_c	bulk mean cold water supply temperature (°C)
T_e	effective ambient temperature (°C) $T_a + (T_a - T_c)/2$
T_d	bulk mean hot water delivery temperature over 24 h (°C)
Z_d	firing efficiency of gas water heater
V_T	total volume of potable water contained by the system (L)
V_B	total volume of potable water heated by the supplementary energy supply (L)

NOTE – The subscript indicates an individual test value of the quantity concerned.

5 TEST EQUIPMENT AND INSTRUMENTATION

5.1 General Description

The solar system shall be mounted in the manner prescribed by the manufacturer. The collectors shall be mounted on a roof facing the equator, within 20 degrees, and any separate auxiliary tank may be mounted indoors or outdoors to simulate the installation requirement of the manufacturer.

The roof on which the collectors are mounted may be specified by the manufacturer to suit the design of the collector system. Roof integrated systems may be installed in a typical roof attic installation. The collector shall be mounted at an angle specified by the manufacturer.

NOTE – Radiation must be monitored in the plane of the collector aperture .

The location of the collectors and storage tank and all plumbing arrangements shall be as specified by the manufacturer. The size and location of plumbing components considered to be part of the internal structure of the complete system shall not be restricted in any way. External plumbing connections for the cold water inlet and hot water delivery shall satisfy local water supply authority regulations.

5.2 Instrumentation

5.2.1 *General*

The following quantities are required to be controlled or measured to determine the performance of solar water heating systems:

a) Delivered hot water flow rate.

b) Supplementary energy used.

c) Event timing to a standard pattern of hot water energy delivery.

d) Thermal demand, embodying heat metering (in megajoules) which is automatically segregated into two bins E_1 and E_2 (*see* **5.2.7**).

e) Supply and delivery temperatures of the water flow through the storage container.

f) Irradiation, ambient temperature and wind speed.

5.2.2 *Data Recording*

The data acquisition system shall record the following information:

a) Daily total load energy.

b) Load energy in bins E_1 and E_2 (*see* **5.2.7**).

c) Daily total load volume.

d) Bulk mean delivery temperature.

e) Bulk mean cold water temperature.

f) Daily supplementary energy consumption.

g) Daily irradiation on the plane of the collector aperture.

h) Daily average ambient temperature.

j) Daily average wind speed at a height equal to the mid point of the collector. (Not used in the data analysis, but recorded for reference.)

5.2.3 *Flow Rate Control*

For storage heaters, the water flow rate during all draw-off episodes shall be maintained at 12.5 to ±0.5 L/min via a suitable means. For example a needle valve and solenoid on/off control valve.

For instantaneous supplementary heaters, the flow rate is set at the rate specified by the manufacturer. The flow rate shall be maintained at the specified rate ±0.5 L/min via a suitable means.

5.2.4 *Supplementary Energy Meters*

a) Electric: Watt-hour meter with an accuracy of ±0.1 percent.

b) Gas : Suitable meter with an accuracy of ±1.0 percent.

5.2.5 *Control of Supplementary Energy*

Supplementary energy may be supplied on a continuously available basis or restricted by a time clock to simulate any required off peak supply system. Thermostat settings shall be as recommended by the manufacturer.

5.2.6 *Draw-off Control*

The draw-off of hot water energy during testing shall be as specified in Table 1.

Table 1 Load Draw-off Sequence
(*Clauses* 5.2.6, 6.4.2 *and* 6.4.5)

Time (h)	Load (litres)
0700 — 0800	0.20 V
0800 — 0900	0.20 V
0900 — 1000	
1000 — 1100	
1100 — 1200	0.20 V
1200 — 1300	
1300 — 1400	
1400 — 1500	
1500 — 1600	
1600 — 1700	0.20 V
1700 — 1800	
1800 — 1900	
1900 — 2000	0.20 V

The loads may be applied within 30 min of the times specified in Table 1. The times given are for the 24-hour clock.

The draw-off shall be under the control of a time switch, capable of initiating draw-off episodes at specified intervals. Each hot water energy draw-off episode, shall be initiated by the time switch but will be terminated by the heat metering apparatus when the total amount of energy for that episode has been delivered or when the volume of water has reached the volume that would have been withdrawn if all the water was delivered at 55°C.

5.2.7 *Thermal Demand (Heat Metering)*

The heat metering equipment used to control and monitor the hot water draw-off shall, in addition to measuring the total hot water energy delivered at any stage during a draw-off episode, indicate the quantity of energy (in megajoules) delivered as hot water:

a) at a temperature below 55°C (designated E_2); and

b) at a temperature of 55°C and above (designated E_1).

The hot water energy shall be measured by water mass flow and temperature rise from inlet to outlet, integrated to give a continuous reading of energy delivered in each of the energy bins (E_1 and E_2) and the total energy delivered. A control facility shall be provided so that the draw-off will be terminated when the appropriate energy has been delivered in any particular draw-off episode (*see* **5.2.6**, **6.4.1** and **6.4.2**)

5.2.8 *Location of Transducers*

The cold water temperature probe should be located on the supply side of the non-return and/or cold pressure relief valves. For low pressure systems the cold temperature probe may be located in the outlet of the feed tank provided the pipe to the main tank is shielded from direct sun and contains less than 0.5 l of water.

The hot outlet temperature probe should be located within 100 mm of the tank outlet and insulated to minimize temperature transients at the start of a load draw-off. Temperature transducers should have a time constant of less than 5 s in mixed water.

The flow meter should be located in the cold inlet line for a pressurized system. In a falling level low pressure system the flow meter must be located in the hot delivery line.

Flow meter accuracy of ±0.5 percent and temperature measurement accuracy of ±0.15°C are required.

6 TEST METHOD

6.1 The tests set out in this section are designated the no-solar test and the solar test.

If the specifications of the system under the no-solar test are met then the system is subjected to the solar test until the range of operating conditions defined in **6.5** have been observed.

6.2 Preliminary Evaluation

The system shall be inspected to determine its basic construction details as per IS 12933 (Parts 1 to 5) and the written specification supplied by the manufacturer shall be examined. The following details shall be verified as being in accordance with the manufacturer's description:

a) *Collector*

   i) Collector type.

   ii) Absorber material and surface treatment.

   iii) Total aperture area (A).

b) *Storage Tank(s)*

   i) Number of tanks.

   ii) Total volume of potable water contained by the system (V_T).

   iii) Total volume of potable water heated by the supplementary energy supply (V_B).

c) *Supplementary Heating*

   i) Source.

   ii) Rating.

6.3 System Load Capacity

The manufacturer shall nominate a daily total load that the particular system is designed to deliver.

6.4 No-Solar Test

6.4.1 *General*

The purpose of the no-solar test is to determine the ability of the system to meet the load specified by the manufacturer, when the solar input is zero (to ensure that the auxiliary heating system is adequate).

6.4.2 *System Load*

While applying the load draw-off sequence specified in Table 1, the ability of the system under test to meet the nominated load, while maintaining delivery temperatures in excess of 55°C, shall be assessed.

If the system under test fails to meet the requirement, then the manufacturer may opt to de-rate to the next lowest load, or increase the thermostat setting (where possible) to retain that nominal load capacity.

Whenever a manufacturer changes the thermostat setting, electricity tariff, load or classification ratings because of failure to meet the original specifications, the no-solar test must be repeated in accordance with the new specifications. The new specifications must also be applied in the solar test.

6.4.3 *System Configuration During No-Solar Test*

For the no-solar test all plumbing connections shall be as for a normal operating installation. The collector shall be shaded by an insulated cover supported 150 mm above the collector surface to leave a clear path for air movement over the collector the cover being sufficiently large to ensure that the collector is shielded from irradiation at all times.

The thermostat setting, supplementary energy supply type and load draw-off profile selected for the no-solar tests must be retained for the solar tests.

6.4.4 *Correction for Test Conditions*

The measured system capacity shall be corrected to correspond to an ambient temperature of 20°C by the following equation:

Nominal system capacity = measured system capacity + tank heat loss correction

where

$$\text{Tank heat loss correction} = (B - L)\left[1 - \frac{T_d - 20}{T_d - T_a}\right]$$

If the tank heat-loss correction is negative, the load used for the no-solar test must be higher than the nominal system capacity that the test is intended to check.

To minimize testing time the last draw-off each day may be increased if necessary to account for tank-loss correction. This would only be necessary in situations where the tank-loss correction may result in a system just failing to meet one of the nominal system capacities specified in **6.4.2**.

6.4.5 *Test Method*

The system under test is connected to the cold water supply and filled. The supplementary energy source is switched on and the system left until the first thermostat cut-out occurs following which the manufacturer's specified load is applied using the draw-off sequence in Table 1.

The system shall be operated with constant (within 2 percent) daily energy draw-off for 5 days after the first thermostat cut-out. The delivered temperature for the purpose of assessing energy draw-off shall be not less than 55°C.

If the variation of daily supplementary energy consumption between Days 3, 4 and 5 is less than 2 percent of the daily load, the performance shall be averaged over Days 3, 4 and 5. If the variation of daily supplementary energy consumption is greater than or equal to 2 percent the test period shall be extended to 8 days and the performance shall be averaged over Days 3 to 8. Four no-solar test periods (each of 3 days or 6 days duration) should be evaluated.

6.5 Solar Test

6.5.1 *General*

For the solar test the performance of the system shall be evaluated for three different daily loads. The difference between the maximum and minimum loads shall be at least 0.5 times the nominal system capacity. To minimize transient effects associated with outdoor operation the performance is averaged over test periods of 5 or more days (*see* **6.5.2**).

6.5.2 *Test Period*

The system should be operated until 7 stable test periods of 5 more days consecutive operation are recorded for each load.

The test periods may be based on a sliding 5-day to 15-day period. Thus, the first 7 points could be completed in a minimum of 11 days (plus 2 days initial stabilizing operation); however, the stability requirement of the test point period (*see* **6.5.3**) may result in the rejection of some data.

6.5.3 *Selection of Test Period Data*

To avoid selecting data from periods when there is a significant change of internal energy in the tank, the performance data is averaged over any consecutive sequence of 5 days to 15 days operation that satisfies the following conditions:

a) System must be operated for 2 days before the test period.

b) The net change in daily supplementary energy from the day before the test period to the last day of the test period must be less than 3 percent of the daily load.

c) The change of solar irradiation from the day before the test period to the last day of the test period must be less than 5 $MJ/m^2.d$.

d) Daily loads must be within ±10 percent of the average load over the period.

e) The daily solar fraction (f) during the test period must be less than 0.90.

NOTE – This is to avoid selecting test data from periods when over-temperature safety devices have operated.

f) The daily solar fraction (f) during the test period must be greater than — 0.1.

NOTE – This requirement is to avoid selecting test data from periods of heavy rain or high winds when little solar energy is collected and the system operation may deviate from normal.

6.5.4 *Test Loads*

Test loads may be selected in the range from approximately 0.5 times the system capacity to a maximum consistant with the required delivery temperature (55°C minimum). The first load should be the system capacity. The other two loads should be selected so that the system operation is consistent with **6.5.3** (d). The middle load shall be approximately halfway between the maximum and minimum loads. The exact relationship of the loads to the system capacity is not critical provided the specified range of loads is used.

6.5.5 *Range of Test Conditions*

The performance of a solar water heater is a function of the parameters G/L and $(T_d - T_c)/L$. To correlate outdoor test data measurements must cover a range of these two parameters. The specification of tests for 3 daily loads ensures a satisfactory range of the parameter $(T_d - T_c)/L$. To ensure that a range of values of the parameter G/L are also included the test periods must satisfy the distribution specification in Table 2. A minimum of four test points must also be obtained from periods of medium to high solar contribution, that is four test points with $f > 0.4$.

Table 2 Required Distribution of Test Point Data

(*Clause* 6.5.5)

$\frac{G/L}{(G/L)_{max}}$*	Minimum Number of Test Points		$\frac{G/L}{(G/L)_{max}}$	Minimum Number of Test Points
1 to 0.7	5	OR	1 to 0.6	5
0.7 to 0.4	5		0.6 to 0.3	5

*$(G/L)_{max}$ = maximum value of G/L observed in the valid test periods.

If the initial 21 solar test points fail to satisfy these conditions the tests should be continued with appropriate loads until the required distribution is obtained.

6.6 Analysis of Test Results

The 25 (or more) solar and no-solar test points are to be correlated as follows:

$$f = [a + b\,(T_d - T_e/L]\,(G/L) + c(T_d - T_e)/L$$

The coefficients '*a*', '*b*', and '*c*', are evaluated using the least squares curve fitting technique.

6.7 The system performance shall be reported in the following manner:

a) No solar capacity

System capacity MJ/d	______
E_1 delivery MJ/d	______
E_2 delivery MJ/d	______
Supplementary energy MJ/d	______
continuous supply	
off peak supply	______
Average daily temperature *C*	______

Type of Supplementary Energy : [that is gas, continuous electric, off peak electric (hours ...... to ....)].

b) Solar performance:
i) System characteristics

$$f = [a + b\,(T_d - T_e)\,/L]\,(G/L) + c(T_d - T_e)/L$$

where

$a =$ $b =$ $c =$

ii) Long-term average energy savings relative to a conventional water heater (f_R), and supplementary energy fraction (f_c), for the relevant climate and load conditions selected from Tables 3 and 4. (The energy savings should be evaluated for the system capacity and for loads of 20 and 40 MJ/d. The water delivery temperature should be taken as the delivery temperature recorded during the no solar tests.)

Table 3 Solar Performance (Annual)

(*Clause* 6.7)

Climate Number	Daily Load Demand (Winter Peak Months) MJ/d	Supplementary Energy Fraction	Energy Savings Relation to Conventional Water Heater	
			Electric	Gas

Table 4 Standardised Conditions for Analysis of Long Term Energy Savings

(*Clause* 6.7)

Month	Climate 1		Climate 2		Fraction of Nominal Load
	g (MJ/m².d)	T_e(°C)	g (MJ/m².d)	T_e(°C)	
Jan	24	22	22	20	0.7
Feb	23	22	20	20	0.8
Mar	21	21	18	18	0.85
Apr	18	18	14	15	0.9
May	16	15	11	12	0.95
June	14	12	9	10	1.0
July	16	11	10	9	1.0
Aug	18	12	13	11	1.0
Sep	20	14	16	12	1.0
Oct	22	17	18	15	0.95
Nov	23	19	19	16	0.9
Dec	24	21	20	18	0.8

The irradiation for each climate type is typical of a surface facing the equator and inclined at the local latitude angle. The system characteristic equation can also be used to evaluate the performance for other orientations provided the inclination change does not affect the operation of the system – other than due to changes of incident irradiation.

c) Evaluate the solar contribution relative to a conventional water heating system, and the supplementary energy fraction, as follows:

$$f_R = \frac{B_c - B_s}{B_c}$$

$$f_c = \frac{B_s}{L_a}$$

where

f_R = energy savings relative to a conventional water heater,

f_c = supplementary energy fraction,

B_c = supplementary energy used by a conventional water heater (electric or gas) = load + losses,

B_s = annual supplementary energy used by the solar water heater (MJ/year), and

L_a = annual load demand (MJ/year).

6.8 Sample calculations of **6.6** and **6.7** are illustrated in Annex A.

ANNEX A

(Informative)

(*Clause* 6.8)

EXAMPLE CALCULATION

A-1 TEST DATA

a) No-solar load cycle performance (3-day average)

1	2	3	4	5	6	7	8	9
T_{ei} °C	G_i MJ/d	L_i MJ/d	B_i MJ/d	T_{di} °C	T_{ci} °C	f_i	$\frac{G_i}{L_i}$	$\frac{T_{di} - T_{ei}}{L_i}$
19.7	0	60.4	66.5	59.2	19.2	–0.10	0	0.65
20.1	0	60.5	67.1	59.5	19.3	–0.11	0	0.65
19.6	0	60.2	66.2	59.0	19.5	–0.10	0	0.65
19.8	0	60.3	65.7	59.1	19.3	–0.10	0	0.65

Container heat loss correction positive or approximately zero, hence the system operates satisfactorily (that is delivery temperature is 55°C or more) for a nominal system capacity of 60 MJ/d.

b) Solar test results (5-day to 15-day average)

1	2	3	4	5	6	7	8	9
Test point (i)	T_{ei} °C	G_i MJ/d	L_i MJ/d	T_{di} °C	T_{ci} °C	f_i	$\frac{G_i}{L_i}$	$\frac{T_{di} - T_{ei}}{L_i}$
1	23.6	60.0	46.5	57.7	22.0	0.38	1.29	0.73
2	23.0	59.8	46.4	57.7	22.2	0.37	1.29	0.74
3	22.0	61.3	46.4	57.6	22.1	0.38	1.32	0.77
4	22.3	73.4	46.4	57.9	22.4	0.52	1.58	0.77
5	22.2	76.3	46.4	59.0	22.5	0.55	1.65	0.79
6	22.3	84.7	46.4	59.9	23.0	0.58	1.83	0.81
7	22.4	80.2	46.3	59.3	22.5	0.64	1.73	0.80
8	23.2	81.6	60.5	57.3	22.5	0.53	1.35	0.56
9	23.0	81.4	60.7	57.8	22.5	0.55	1.34	0.57
10	23.2	75.9	60.5	57.6	22.3	0.51	1.25	0.57
11	23.1	89.9	60.5	57.0	23.0	0.61	1.49	0.55
12	23.9	88.2	60.5	57.2	23.1	0.64	1.46	0.55
13	22.5	61.5	60.6	57.7	22.2	0.40	1.02	0.58
14	22.5	58.2	60.6	57.7	22.1	0.37	0.96	0.58
15	16.4	50.7	35.2	57.4	15.2	0.43	1.44	1.16
16	14.3	61.0	35.2	58.0	15.0	0.54	1.73	1.24
17	14.0	65.5	35.2	58.2	15.3	0.61	1.86	1.25
18	14.4	58.5	35.5	57.9	15.5	0.52	1.65	1.22
19	14.5	56.7	35.6	57.7	15.2	0.50	1.59	1.21
20	15.0	55.1	36.2	57.0	15.6	0.48	1.52	1.16
21	14.9	54.1	36.9	57.2	15.2	0.47	1.47	1.15

$$f = \left[0.461\,6 - 0.036\,1 \left(\frac{T_d - T_e}{L} \right) \right] \frac{G}{L} - 0.151\,9 \left(\frac{T_d - T_e}{L} \right)$$

A-2 PERFORMANCE

The performance of this system operating in an installation with Climate 1 conditions is as shown in the table below.

NOTE – Peak monthly load equal to system capacity.

1	2	3	4	5	6	7
Month	G MJ/d	T_e °C	T_d °C	L MJ/d	f	B MJ/d
Jan	91.2	22.0	59.0	42.0	0.80	8.4
Feb	87.4	22.0	59.0	48.0	0.67	15.7
Mar	79.8	21.0	59.0	51.0	0.57	22.1
Apr	68.4	18.0	59.0	54.0	0.43	30.5
May	60.8	15.0	59.0	57.0	0.35	37.3
June	53.2	12.0	59.0	60.0	0.27	44.1
July	60.8	11.0	59.0	60.0	0.32	41.0
Aug	68.4	12.0	59.0	60.0	0.37	37.5
Sep	76.0	14.0	59.0	60.0	0.44	33.8
Oct	83.6	17.0	59.0	57.0	0.53	27.0
Nov	87.4	19.0	59.0	54.0	0.59	22.1
Dec	91.2	21.0	59.0	48.0	0.70	14.3

A-3 CALCULATIONS

Supplementary Energy Fraction

$$f_c = \frac{\text{Supplementary energy used } (B_S)}{\text{Annual load } (L_a)}$$

$$= \frac{10\ 170}{19\ 809}$$

$$= 0.51$$

Energy Saving Relative to a Typical Electric Water Heater

Based on a storage tank with a heat loss of 2.56 kW.h/day (9.22 MJ/day), the energy consumption of a conventional electric water heater supplying the above loads in Climate 1 would be:

$$B_c = 19\ 809 + 3\ 400 = 23\ 209 \text{ MJ/year}$$

Energy saving relative to a conventional electric water heater:

$$f_R = (B_c - B_s)/B_c = (23\ 209 - 10\ 170)/23\ 209$$

$$= 0.56$$

Energy Saving Relative to a Gas Water Heater

The efficiency of a conventional gas water heater is a function of the heat loss (q_e) from the container (and through the flue) when the burner is off, and the energy input efficiency (Z_b) when the burner is operating (firing efficiency).

The daily gas energy consumption is:

$$B_g = \left(\frac{L + 24\, q_e}{Z_b\, q_b + q_e}\right) q_b$$

For a new 100 litre gas water heater typical performance factors are:

q_b = 40 MJ/h (burner heat output)
q_e = 0.73 MJ/h
Z_b = 0.83

For a load of 54.3 MJ/day

B_g = 84.7 MJ/day = 30 900 MJ/year

Energy saving relative to a conventional gas water heater is

$$f_R = (B_g - B_s)/B_g$$

$$= \frac{30\,900 - 10\,170}{30\,900}$$

$$= 0.67$$

Annual Load L_a = 19 809 MJ/year = 54.3 MJ/d
Supplementary Heat B_S = 10 170 MJ/year = 27.9 MJ/d

A-4 RELATIVE ENERGY SAVING RESULTS

Climate Type	Load	f_R Electric	f_R Gas
1	60	0.56	0.67
1	30	0.86	0.91
2	60	0.45	0.59
2	30	0.72	0.81

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The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act, 1986* and the Rules and Regulations made thereunder. The Standard Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard under a well defined system of inspection, testing and quality control which is devised and supervised by BIS and operated by the producer. Standard marked products are also continuously checked by BIS for conformity to that standard as a further safeguard. Details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

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