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SANS 10400:-XA 2001: APPLICATION OF THE NATIONAL BUILDING REGULATIONS PART XA: ENERGY EFFICIENCY IN BUILDINGS / RENEWABLE ENERGY

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The new SANS 10400 standards introduced requirements for the integration of non-electrical water heating in the building code. This chapter will look at the use of solar water heaters to produce (domestic) hot water.

The SANS 10400 standards stipulate that "at least 50 % (volume fraction) volume of the annual average hot water heating requirement shall be provided by means other than electrical resistance heating, including but not limited to solar heating, heat pumps, and heat recovery from other systems or processes". This requirement forces anyone erecting a new building to have a close look at the hot water requirements of the building.

HOT WATER HEATING REQUIREMENTS

SANS 10400 does refer to tables 2 and 5 of SANS 10252-1:2004 to determine the total hot water requirements of a building. The first table does give an overview of the average water consumption (hot and cold) of appliances, while the second does focus on hot water requirements only. In combination with the usage pattern of the building a total hot water requirement can be determined. The tables are reproduced here as Table 10.1 and Table 10.2 respectively.

For households the guidance given by Tudor Jones in the SA Plumbers' Handbook (Tudor Jones, 2004) can be used. He comes to an average household consumption of approximately 300 litres / day for a four persons' household.

BASIC PRINCIPLES OF SOLAR WATER HEATING

Solar water heaters do come in wide variety of types and models. The most basic solar water heater is a piece of black plastic pipe or black plastic bag, filled with water, and laid in the sun for the water to heat up.

In general a solar water heater will consist of the two following components:

1. An absorber, or collector that is an energy conversion device that absorbs the solar radiation and transfers it to the fluid that passes through it. In the example of the black plastic bag, the bag is the collector and the water in the bag is the working fluid.
2. A storage tank to store the heated water, commonly made of steel with a protective inner layer, stainless steel or a polymer. Like with standard electrical geysers these storage tanks come in standard sizes and are sized in relation to the hot water demand, storage required and size of collectors used.

The working fluid used can be cycled through the tank several times to raise the heat of the fluid to the required temperature.

There are two common simple configurations for such a system:

1. The thermosyphon system makes use of the natural tendency of hot water to rise above cold

water The tank in such a system is always placed above the top of the collector and as water is heated in the collector it rises and is replaced by cold water from the bottom of the tank. This cycle will continue until the temperature of the water in the tank is equal to that of the collector. A one-way valve is usually fitted in the system to prevent the reverse occurring at night when the temperature drops. As hot water is drawn off for use, fresh cold water is fed into the system from the main water supply.

2. Pumped solar water heaters use a pumping device to drive the water through the collector. The advantage of this system is that the storage tank can be sited below the collector. The disadvantage of course is that electricity is required to drive the pump.

Typically, solar water heaters in South Africa are equipped with a back-up electrical element that is controlled through a timer[1] and thermostat to provide auxiliary heating during days with limited solar radiation or when all hot water has been consumed. Due to the inclusion of the heating element, electricity savings for hot water production will not be 100% of electricity consumption, but depending on the usage pattern between 50 – 90%.

NORMS AND STANDARDS

The use of solar water heaters and their testing is governed through a number of SANS standards, which look into the solar water heater as a system and how they should be integrated into a building. Table 10.3 given an overview of the applicable standards.

Herewith it should be noted that in South Africa solar water heaters are tested and certified on a systems level, i.e. a SABS mark does apply to a combination of collector(s) and storage tank.

TYPES OF SOLAR WATER HEATERS

From the basic black pipe or bag, solar water heaters have developed into a number of distinct different types related to the way water is being heated and the type of collector being used.

DIRECT VERSUS INDIRECT SYSTEMS

Direct solar water heaters circulate the water directly from the storage tank through the collector. As water is being used in the collector, direct systems are very vulnerable to overnight frost conditions that can freeze the collector and associated pipes, resulting in bursts. Although limited frost protection can be achieved through drain back valves that drain the system in case of frost, direct systems should only be used in frost-free areas. Also the quality of the water being used in the system should be monitored closely as scaling by hard water can clog the system.

Indirect, or closed systems, utilise a heat transfer fluid in the primary circuit of the collectors and a heat exchanger to transfer heat from the collector circuit to water in the storage tank. Indirect systems can be used under all circumstances as they only use the heat transfer fluid in the collector and not the potable water. Flat plate collectors are therefore popular in areas subject to extended freezing temperatures and in areas with hard water.

FLAT PLATE VERSUS VACUUM TUBE COLLECTORS

The collector used to convert the solar radiation into heated water can be grouped in two distinctive categories:

1. Flat plate collectors consisting of a dark flat absorber of solar energy covered by a transparent cover that allows solar energy to pass through but reduces heat losses. The absorber consists of a thin absorber sheet often backed by a grid or coil of fluid tubing placed in an insulated casing with a glass or polycarbonate cover. See Figure 10.2.

1 A timer is mandatory when the solar water heater is installed under the DSM programme of ESKOM to avoid electricity usage during peak times

1. Vacuum tube collectors use heat pipes for their core instead of passing liquid directly through them. Evacuated heat pipe tubes are composed of multiple evacuated glass tubes each containing an absorber plate fused to a heat pipe. The heat from the hot end of the heat pipes is transferred to the transfer fluid. See Figure 10.3.

The debate on whether vacuum tubes or flat plat collectors are the preferred option is an ongoing debate in the industry, without a very clear answer as local circumstances can influence the comparison considerably. The flat plate has the advantage of having stood the test of time – it is a mature technology and has benefitted from years of improvements. On the other hand, evacuated tubes perform better when the ambient temperature is low (e.g. during winter) or when the sky is overcast for long periods.

In general it can be said that performance of collectors decrease as the temperature differential increases (difference between ambient and collector inlet temperatures). Flat plate collectors start out with a higher efficiency, but once ambient temperatures drop to close to freezing point a cross over takes place and vacuum tubes become more efficient due to the reduced radiation losses, which is important in cold temperatures, but is not a factor in a South African climate. Several research studies have been done on this topic and the cross over point on efficiency gain of the one type over the other is depending on solar radiation, type of collectors used, etc.
It is important to note that flat plate collectors will raise water temperature to 60°C at a faster rate than vacuum tubes, after this point flat plates will slow as their efficiency drops. This in and of itself is an advantage as it limits the system's ability to overheat, which will lead to water wastage and system damage.

Flat Plates	Vacuum Tubes
Advantages • Long life expectancy • High efficiency in sunny to moderate climates • Suitable for domestic and industrial applications • Freeze protection is available • Long and proven track record in SA conditions • Robust / hard wearing • Less strain on the primary circuit pipe field • Glycol in the collector loop has a longer service life • More resistant to hail than vacuum tubes **Disadvantages** • Performance reduced in freezing conditions and at low light levels • Larger roof area required in large scale systems • Greater single lifting weight during installation	**Advantages** • Useful where orientation to north is a problem • Perform efficiently in very cold climates • Suitable for high heat and steam generation in industrial applications **Disadvantages** • Limited local track record • Less robust and susceptible to hail damage • Good quality tubes are more expensive / longer pay backs • Greater overheating potential in warm climates • High stagnation temperatures with corresponding demands on all the materials within the collector field including the solar fluid • Safety valves and expansion vessels are required to deal with overheating more frequently • Risk of reduced efficiency over time as vacuum could disappear

HEAT PUMPS AS AN ALTERNATIVE

SANS 10400 offers the option to use any other technology than electrical resistance heaters. Besides solar water heaters, heat pumps are becoming a viable alternative for hot water requirements.

Heat pumps use the reverse cycle of a refrigeration plant to heat water. In effect, it transfers heat from a source such as air or water to the water which is to be heated. As in other refrigeration equipment, the heat pump system employs an evaporator, a compressor, a condenser, refrigerant gas, and an expansion valve within a closed circuit. Latent heat is given off when the refrigerant gas is liquefied through the condenser and transferred to the surrounding water together with further "sensible" heat loss, effectively raising the temperature of water to a higher temperature.

Heat pumps can operate independently from the ambient circumstances, but do require electricity to operate. They are able to reduce electricity consumption for hot water production, but cannot, contrary to solar water heaters, eliminate the use of electricity., like solar water heaters can.

CONCLUSIONS

Solar water heaters are a viable alternative to electric resistance water heating, with different technical options. Systems can be installed on north facing roofs with the storage vessel either above the collectors (thermosyphon systems), or hidden inside the roof when a pumped system is used.

If placing solar collectors on the roof is not feasible or not desired, heat pumps can be used instead.

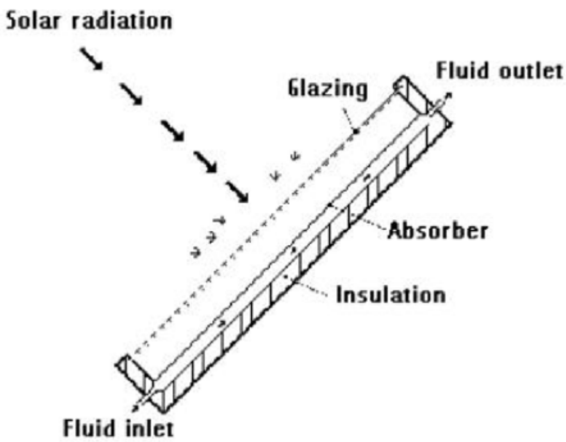

Figure 10.1 Representation of the thermosyphon principle. Water can be taken out of the system at 1, while 2 represents the hot water storage tank which is filled with hot water from the collector (4) at inlet 3, while new, cold water is introduced at 5.

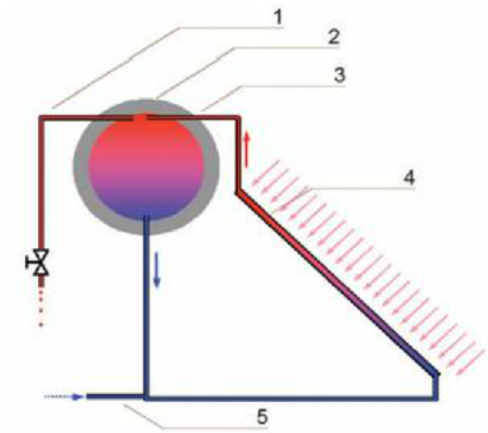

Figure 10.2 Schematic view of a flat plate collector

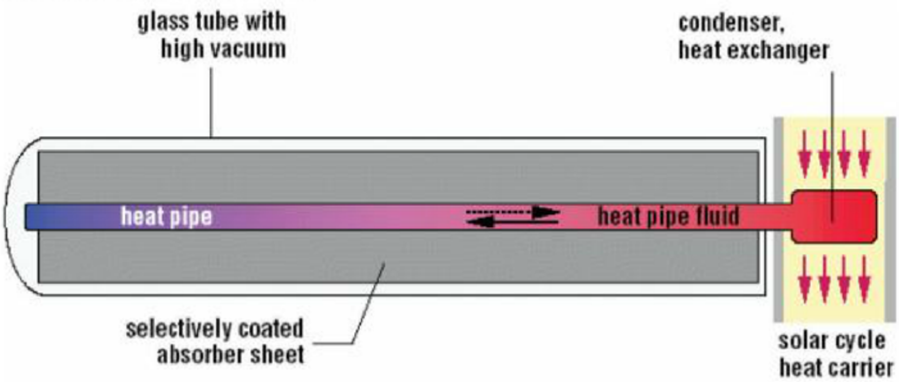

Figure 10.3 Schematic view of evacuated tubes

Table 10.1 Average water consumption (hot and cold) of appliances (table 2 of SANS 10252-1:2004)

Domestic and commercial appliances L/operation	
Bath	80 – 90
Bidet	6 – 8
Clothes washing machine	60 – 180
Dishwashing machine	3 – 70
Domestic waste disposal unit	10 – 15 (per minute)
Shower	3 – 6 (per minute)
Wash-hand basin	4 – 8
WC flushing valve (normal flush)	8 – 10
Domestic appliances L/day/person served	
Car washing and garden use	3 – 6
Drinking, food preparation and cooking	18 – 22
Laundry	10 – 15
Personal washing and bathing	20 – 30
Washing dishes	8 – 12
WC flushing	32 – 40
Office installation appliances L/day/person served	
Hand washing: normal taps	8 – 15
Hand washing: spray taps	3 – 7
Urinal flushing - 24 h day	10 – 18
Urinal flushing - 8 h day	4 – 6
WC flushing - no urinals provided	12 – 18
WC flushing - urinals provided	4 – 6

Table 10.2 Hot water demand, storage and heater power requirements (table 5 of SANS 10252-1:2004)

Premises	Total hot water demand	Storage volume at 60 °C	Heater powera
Colleges and schools			
Day school	(10-12) L/capita/d	(5-6) L/capita	0,1 kW/capita
Boarding schoolb	(50-115) L/capita/d	(25-50) L/capita	0,5-0,8 kW/capita
Dwelling housesc			
Low rental	(80-115) L/capita/d	(100-150) L/unit	2-3 kW/unit
Medium to high rental	(115-140) L/capita/d	(40-50) L/capita	2-5 kW/unit
Factories			
Staff	(10-20) L/capita/d	(5-7) L/capita/d	0,1 kW/capita
Ablutions	(30-60) L/capita/d	(30-60) L/capita/d	1,5-2 kW/capita
Flats (blocks)			
Low rental	(65-75) L/capita/d	(20-25) L/capita	2-3 kW/unit
Medium to high rental	(115-140) L/capita/d	(25-35) L/capita	2-5 kW/unit
Hospitals			
General	(130-140) L/bed/d	(25-30) L/bed/d	1-1,5 kW/bed
Clinics	(120-150) L/bed/d	(30-35) L/bed/d	1,5 kW/bed/d
Infectious	(220-230) L/bed/d	(40-50) L/bed/d	1,5-2 kW/capita
Infirmaries	(65-75) L/capita/d	(20-25) L/capita/d	0,9-1,2 kW/capita/d
Infirmaries with laundry	(85-95) L/capita/d	(25-30) L/capita/d	1-1,4 kW/capita/d
Maternity	(220-230) L/bed/d	(30-35) L/bed/d	1,5-2 kW/bed
Mental	(85-95) L/capita/d	(20-25) L/capita/d	1-1,4 kW/capita/d
Nurses' homes	(120-130) L/capita/d	(40-50) L/capita/d	1-1,5 kW/bed
Hostels	(80-120) L/capita/d	(30-35) L/capita/d	0,8-1,1 kW/capita/d
Hotels			
Hotels (with resident staff)	(120-140) L/bed/d	(50-70) L/bed/d	0,9-1,2 kW/bed
Hotels (without resident staff)	(100-120) L/bed/d	(40-60) L/bed/d	0,8-1,1 kW/bed
Kitchens			
Full meal preparation	(5-7) L/meal	(5-6) L/meal	0,1 kW/meal
Offices			
Offices with canteens	(25-28) L/capita/d	(20-25) L/capita/d	0,5 kW/capita
Offices without canteens	(10-12) L/capita/d	(5-7) L/capita/d	0,1 kW/capita
Shops (staff only)	(10-12) L/capita/d	(5-6) L/capita	0,1 kW/capita
Sports pavilions(participants only)	(30-40) L/capita/d	(30-40) L/capita/d	1,5-2 kW/capita

a Refers to direct electrical heating elements only.
b Excluding kitchen but including laundry.
c Storage normally a minimum of 115 L with a 4 h heat-up period.

Table 10.3 SANS standards applicable to solar water heaters

SANS standard	Area of coverage
SANS 10106	Covers requirements for the installation, maintenance and repair of solar water heating systems for domestic use. Excludes the installation of solar water heaters for swimming pools and commercial buildings.
SANS 1307	Specifies the requirements of domestic solar water heating systems. Does not apply to solar water heaters for swimming pools or to industrial and commercial solar water heaters, or to push-through type domestic solar water heaters.
SANS 6210	Specifies test methods for the mechanical qualification of domestic solar water heaters.
SANS 6211-1	Describes an outdoor test method for the determination of the thermal performance of domestic solar water heaters.

REFERENCES

Tudor Jones, D. (2004). Solar water heating. SA plumbers' handbook (2004th ed., pp. 106). Edenvale: Pipe Trades Media Group.