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Design and Simulation of a Solar Refrigerator on Adsorption Principle

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Abstract

In spite of the scarcity of references in the field of adsorption solar refrigeration, some hints were found in published papers, which enhanced the design of a small unit of solar freezer on adsorption principle. The unit has a product capacity of about 5kg of ice daily. A flat-plate collector of (1 m2) is used, and a water-cooled condenser of natural convection type is used, in diameter.

The evaporator was a flooded type evaporator, attached to the icebox to form a fully insulated unit. The machine was designed to work intermittently; the night period is the productive period; while day period is the generative period. This type of machines has a great need in the society, especially in the rural areas, for general cooling needs and in health centers for vaccines saving and others. It is our hope that this research has satisfied its objectives and that it shall continue to the stage of constructing this machine in commercial amounts for the benefit or need of our society.

NOMENCLATUR

A	Angstrom unit =10−10 m,3.973×10−11 in	n	Number of the day of the year
A.C,A/C	Activated carbon	NH3	Ammonia
ATT	Asian Institute of Technology ,Thailand	NPV	Net present value
a .m	Ante meridiem (before noon)	Nu	Nusselt Number
a t m	Atmosphere, atmospheric pressure1.0135	bar	papascal
Btu	British Thermal Unit	p.m	Post meridian (after noon)
C°	Degree Celsius (centigrade)	Pr.	Brandtl Number
Cal	Calories	Q	Heat
Cc, cm³	Cubic centimeters	R	Characteristic gas constant
Ch	Charcoal	Re	Reynolds Number
Cop	Coefficient of performance	$	U.S. dollar
Cos	Cosine of	s	Entropy,
Cp	Specific heat at constant pressure	sin	Sine of
C v	Specific heat at constant volume	T	Temperature
CH2OH	Methanol	t	Time
Deg	Degrees	tan	Tangent (trigonometry ratio
C	Base of Naperian logarithmic (=2.7182)	WHO	World Health Organization
E q	Equation	X	Concentration
Exp	Exponential function of	α	Absorptivity
G r	Grasso Number	∂	Partial Differentiation operator
G sc	Solar constant	δ	Solar direction
h	Enthalpy	ϵ	Emissivity
K	Degrees Kelvin	σ	Boltzmann Constant
K w	Kilowatts	Δ	Difference
M ,m	Mass	∑	Summation of
min	minutes	τ	Tramsmissivity
mm	millimeters	₦	Naira

1. INTRODUCTION

Adsorption refrigeration system is a technology which utilizes waste heat for cooling. This system also presents the benefits of being absolutely environment friendly and having zero Ozone Depletion Potential (ODP) as well as zero Global Warming Potential (GWP)[1]. Adsorption refrigeration is also attractive for the efficient use of solar energy and low-grade waste heat. In the last two decades, adsorption refrigeration has been gaining a lot of attention. Compared with the existing absorption systems and vapour compression refrigeration systems, the advantages of adsorption systems are less vibration, simple control, low initial investment, expenditure and less noise.

Among the thermal processes of solar energy, solar refrigeration is on of the most suitable processes for storage, transport and marketing of energy. Among its numerous applications, the adsorption refrigerating machine seems to be an interesting alternative to conventional refrigeration systems in isolated regions, where conventional electrical power is unavailable. However, these machines are not fully automatic because of manual interventions

Cooling operation is one of the important processes that mankind uses since early years of history. This process can take place naturally or artificially. It will be natural when it takes place due to the nature of heat of flowing from higher to lower temperature by conduction, convection or radiation. Any object that releases heat can simply be called “cooled”, whereas bodies receiving heat can relatively be called “heated”.

Many researches and academic papers were presented in the field of solar refrigeration, all trying to discover one or more of its various sides to make its design and hence construction easier and practicable. In this chapter, some of these trails are listed to show the possibility of the work based on previous experiments. Solar Refrigeration can be divided into two types:

1.1 Solar adsorption systems:

Absorption systems, which are similar to the ordinary absorption refrigerators, with solar energy used to operate the machine instead of generating heat from a conventional heating source. Solar powered refrigerators use solar power for regenerating the system during the day period; while the night ise productive period. The general theory is the same as the conventional absorption systems, the main difference is that conventional systems are continuously using heating sources, and solar powered are mostly intermittent ones using solar energy for regeneration except when some storage systems are incorporated.

System description:

Domestic charcoal, with its low price, when used as adsorbent realize good performance as compared with another types of activated carbon. This System consists of three main parts described as follows:

1. Generator/absorber:

This part is in a form of a flat-plate collector, its purpose is to absorb the solar thermal power from the sun to heat up charcoal particles packed in a box attached to the lower part of the collector-plate, this heat will generate refrigerant vapor (methanol) which will then be condensed to liquid in the condenser and collected for use in the productive time later.

2. Condenser:

It condenses the generated methanol vapor coming from the collector using immerged coil in an open container having water.

3. Receiver/evaporator unit:

This part works as a storage tank for the condensed methanol liquid during the day and as an evaporator during the night (productive time) where the flow of the refrigerant will reverse. There will be an ice mould box attached to this unit at the bottom, water filled in will act as the load, ice produced there is the product.

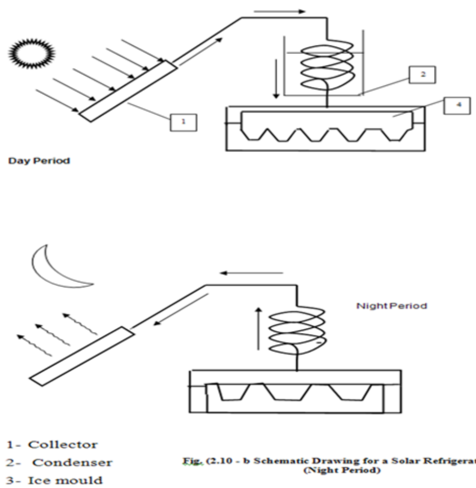

Fig. (2.10 - b Schematic Drawing for a Solar Refrigerator)
(Night Period)

Operation Principle:

The unit will work in an intermittent cycle of operation. During the day when the sun is shining, generation is taking place and the whole unit will be at condenser pressure and the direction of flow of methanol will be from collector to the receiver across the condenser. During the night, shutters are to be opened to cool down the collector, and methanol will flow back to collector at evaporation pressure, and this is the productive period till the sun rises again.

Research Contribution:

1.The research can offer a good contribution in the field of solar refrigeration in Sudan and enrich this type application especially for the use in rural areas for diverse kinds of need.

2. Design of a complete experimental testing apparatus to determine the hermodynamic and heat transfer rates within a solar absorption chiller;

3. Construction and instrumentation of the experimental apparatus within the Solar Energy Systems Laboratory;

4.Performance of calibration experiments on the thermocouples and thermopiles installed within the experimental apparatus;

5. Completion of an uncertainty analysis on the complete experimental system to determine the uncertainty on the heat transfer rates and coefficient of performance.

6. Determination of the experimental procedure for testing the absorption chiller through simulation.

Solar Cooling Technologies

From a sustainability perspective, directly using solar as a primary energy source is attractive because of its universal availability, low environmental impact, and low or no ongoing fuel cost. But there are many problems associated with its use. The main problem is that it is a dilute source of energy. Even in the hottest regions on earth, the solar radiation flux available rarely exceeds 1kW/m , which is a low value for technological utilization. Consequently, large collection areas are required in many applications and this results in excessive costs. A second problem associated with the use of solar energy is that its availability varies widely with time. The variation in availability occurs daily because of the day-night cycle and also seasonally because of the earth's orbit around he sun. In addition, variations occur at a specific location because of local eather conditions. Consequently, the energy collected when the sun is shining must be stored for use during periods when it is available. The need of storage also adds significantly to the cost of any system. Thus, the real challenge in utilizing solar energy as an energy alternative is of an economic nature. One has to strive for the development of cheaper methods of collection and storage so that the large initial investments required at present in most applications are reduced. In principle, there are many different ways to convert solar energy into cooling or air conditioning reversible thermo- chemical reactions with relatively low binding energies. There are two main concepts that can be combined with each other for cooling with solar energy:

(A) Solar collection technology

(B) Technologies for cold production

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(A) Solar collection technology

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Solar Collection Technologies:

Utilization of solar energy requires solar collectors. There are two general types:

1- Solar cells which can be used to produce electricity.

2- Solar thermal collector can be utilized to generate heat.

Solar (Photovoltaic) Cell:

A solar cell or photovoltaic cell is a device that converts solar radiation energy directly into electrical energy. The solar cell consists of a disc or surface with two thin layer of differently doped semiconductor material, often silicon.

ECONOMICS OF SOLAR SYSTEMS:

The basic pieces of hardware needed to build a solar house are readily available. But private builders have little incentive for putting them into practice. The solar home is initially more expensive to build than a conventional one, and consumers are largely ignorant of the potential savings on their energy bill. There is no incentive for the builders to innovate. On the contrary, the Federal Housing Administration and private lending institutions discourage solar homes because they base their loans solely on the initial cost of the house. Thus these institutions are an obstacle to innovation that costs more at the outset but that would save the homeowner money over the life of the house.

The potential market for rapid solar energy development is the residential sector. The technology is simple, and enough solar energy reaches the roof of an average house to meet heating and cooling needs. It would, of course, be difficult to fix existing homes with the system economically, but in many cases it could be done.

In any event it would be made. But even small percentages mean large savings in the U. S. energy market. By 1980 most new homes being built could well be solar heated and cooled, and the savings could at once be measured in millions of barrels of oil each year. [4]

SOLAR HEATING:

Solar energy may be our most neglected energy option. Yet despite our neglect we know enough to be certain that solar energy can be harvested economically to supply much of the space heating and cooling for new buildings. The opportunities of solar energy applications are well known, solar energy can no longer be laughed off. It is a source for immediate help in solving the problem of energy shortage.

The technology is available to use solar energy to supply a sizable fraction of the hot water, space heating and air conditioning requirements of homes in many parts of the world indeed. Experimental solar-heated homes are already in existence in Boston, Massachusetts, Washington D.C., Denver, Colorado and elsewhere, and they have a satisfactory record of performance. These techniques must be perfected for mass production, but no new inventions are needed. [4]

ELECTRIC SOLAR CELLS:

These solar energy cells have been handcrafted to meet stringent space requirements and are assembled much like Swiss watch. There has been no concentrated effort to supply mass production techniques to reduce the cost. Solar enthusiasts believe that a research and development effort to improve efficiencies and develop a continues silicon ribbon for mass production techniques to reduce the cost a thousand-fold, down $ 26 per watt. Cadmium cells also can be produced at about the same cost or possibly cheaper. This cost would be lower than the cost of a new nuclear power plant,which approaches $ 0.50 per waft. Fuel costs are much higher than solar energy equipment which is now being developed at a decreasing cost. But a solar cell would not produce power on steady bases. Even so, if cells would be produced for $ 0.26 per watt the supplemental power would be economical for many uses. [4]

SOLAR COOLING:

Solar heat can also be used to cool a building. There is nothing novel in the idea, the heat is used to power an absorption refrigerator, the type which is usually operated by fuel. Experiments show that the concept is tecimologically promising. The economics also seem attractive because there is a high degree of correlation between the availability of solar energy and the need for air-conditioning. The same basic collector system installed for solar heating can provide air-conditioning as well. In fact the cost of heating and cooling a house with solar energy as compared with conventional sowces may be extremely competitive.

A comprehensive economic analysis with electrically heated homes even before the latest escalation in fuel prices shows that the fuel savings from solar energy more than pay for the extra investment, in every section of U. S. expect the Pacific Northwest. [10]

SOLAR THERMAL CONVERSION

When a black body is exposed to solar radiation, it heats up, and as its temperature increases, the surface of that body loses heat to its surrounding at an increasing rate. At certain temperature, equilibrium condition will be reached where heat gain is equal to heat lost unless certain technologies are used to prevent heat loss or minimize its rate to allow continuity of heat gain, hence temperature increase.

Solar energy utilization can take place through either passive or active systems. Passive systems are where solar energy are used directly; where active systems are those where solar energy is extracted using energy collecting means. There are two types of solar radiation, direct radiation and diffused radiation. Direct radiation is the one intercepted by a collector surface at certain angle; diffused radiation is portion scattered by dust particles or water vapour in the outer space and does not have a specified angle. Total global radiation is the summation of diffused and direct radiation.

SOLAR ENERGY INCIDENT UPON A HORIZONTAL SURFACE:

The solar energy flux on a horizontal surface is given by the equation:

$$G_0 = G_{0,T} T \cos\theta_Z$$

$$= G_{0,T}\,(\mathrm{Sin}\,\varphi \sin\delta + \cos\varphi \cos\delta \cos\omega)$$

Where Solar heat flux incident on the surface directly facing the sun

θ_Z = solar zenith angle

δ = solar direction

φ = Latitude

ω = hour angle

The total solar energy incident on an extra terrestrial horizontal surface during the entire day is given by:

$$H_0 = \int_{tsr}^{tss} G_0\,dt \;\ldots\ldots\ldots\ldots\ldots\ldots$$

$$H_0 = \frac{24}{\pi} G_{sc}\left[1+0.033\cos\left(\frac{360n}{365}\right)\right] \times \left[\cos\varnothing \;\cos\delta \;\cos\omega + \frac{\pi}{180}\,\omega \sin\varnothing \sin\delta\right]$$

Where:

tsr = Sunrise time tss = Sunset time

G_{sc} = Solar constant = 1353 W/m2 ω = sunrise or sunset hour angle

s = Angle of tilt of the plate n = day number δ , φ = as mentioned before

Solar Refrigerators:

The concept of a solar home is really quite simple. A portion of the roof of the house is used as a “collector” made of a black surface to help absorb the heat and filled with water or air covered by sheets of glass to provide a “greenhouse” effect. The heat is then transferred for storage into a large water tank or gravel’s bin and circulated throughout the house in much the same way as a conventional hot water or air system. A supplemental heating system may be required for very cold days but the solar energy system supplies the greatest portion of the fuel supply, the portion varying, of course, with the region of the country.

In developing countries, there is an acute need for refrigerating foodstuffs and medicines. However, normal refrigerators familiar to us are luxury items for some areas in these countries. In order for them to work, they need electrical energy, often only available in large city centers, which are either difficult to access or simply impossible. However, the sun is shining everywhere and offers warmth in excess, especially in southern countries. With the assistance of a cooling aggregate and a parabolic solar collector, the warmth of the sun can be transformed into cold.

CHOICE OF SOLAR COOLING TECHNOLOGY:

Solar cooling methods are reviewed by the World Health Organization (WHO) as part of its Expanded Programme of Immunization in 1980. Five alternative approaches were identified:

(1) Photovoltaic/vapour compression
(2) Photovoltaic/thermoelectric
(3) Solar thermodynamic - solid adsorption (zeolite ! water)
(4) Solar thermodynamic - solid adsorption
(calcium chloride /ammonia)
(5) Solar thermodynamic - liquid absorption (water! ammonia)

THE SIMULATION ANALYSIS:

The various studies of charcoal/methanol system were focused on prototype testing and the performance analysis of the ideal cycles. The influences of component design parameters and climatic conditions were not considered. There was no effective performance simulation programmer that could be used for optimization purpose in practical design. The numerical simulation is to describe the behavior of a solar powered charcoal/methanol refrigerator and, with the help of simulation model, the sensitivity of the performance to certain component parameters is also to be determined. The system modeled on the prototype charcoal/methanol adsorption refrigerator developed in [3],where an intermittent adsorption cooling system composed of a container of adsorbent (charcoal), which serves as a solar heat collector, a condenser and a receiver/evaporator. Because the critical component of the system is the collector, the pressure modeling work focused on simulating the performance of the collector, which serves both as generator and a dsorber, in order to optimize its design.

Under the assumption of uniform pressure inside the system, the model developed is able to express the phenomena of heat and mass transfer inside the collector and to simulate dynamically the performance of the practical system under varying natural conditions. The model was validated by comparing the observed temperature and pressure histories of the solar powered charcoal methanol refrigerator at Asian Institute of Technology, Bangkok with the numerical curves obtained by the model.

Physical and Mathematical Model:

The system modeled is the collector contains 14 stainless steel tubes of diameter 60 mm and length 1.2 m arranged side by side oriented north south inside a casing. The casing has a single glass cover, well-insulated sides and back, and shutters at the top and bottom ends that can be opened to allow the tubes to be cooled by the natural convection of the ambient air. This configuration provided an effective collector area of 1.01. Within each collector tube there is anothei' concentric stainless steel tube of diameter 10 mm and perforated with small holes along its entire length. The annular space between the two tubes was filled with activated charcoal grains. The function of the small central tube is to ensure good distribution of the methanol on the charcoal, and eliminate pressure drops and temperature differences along the collector tube. The small tubes are connected to the rest of the system via a common header. The upper half of each collector tube receives heat from solar radiation and transfers it to the charcoal. The methanol adsorbed in the charcoal is then desorbed by the heat, and condensed in the condenser. Finally, the condensed methanol is collected in the receiver/evaporator. The collector tubes exchange heat with the glass cover, the casing, and the ambient air (when the shutters are opened).

Assumptions:

The model developed is based on the following assumptions:

1) There is no temperature gradient along the axis of the tube.

2) The charcoal and methanol are in local thermodynamic equilibrium.

3) The pressure is uniform in the system.

4) The heterogeneous charcoal is treated as a continuous medium.

5) The specific heat of adsorbed methanol is equal to that of the bulk liquid methanol.

6) Convective heat transfer and mass transfer resistance in the vapour-phase is neglected.

7) Side effects in the collector casing are neglected, and every collector tube is assumed to be in the same state.

DESIGN:

Energy Balance: Under the above assumptions, the energy balance equation is:

$$\frac{\partial^2 T}{\partial r^2} + (k/r)\left(\frac{\delta T}{\delta R}\right) + (k/r^2)\left(\partial^2/\delta\theta^2\right) + q_{hs} = \rho_c\left(\frac{\delta T}{\delta t}\right)$$

T = Temperature

r = radius

k = thermal conductivity

θ = angle coordinate (radians)

q = heat source /unit volume (W/m3)

ρ = mass per unit volume (kg/rn3)

C = specific heat capacity (J/kg K)

t = time (second, hour)

For the adsorption heat source term per unit volume:

q_{hs} = h_{ad} ρ^2 (dX/dt) ...

Subscript (2) = metal

For the metal tube; pC = 2C2 + X ρ 2C3

Subscript (3) = methanol

X = concentration (mass of methanol adsorbed on unit mass of chacoal) kg/kg % Dubinin -Astakhov (D-A) equation :-

The equation states saturation of methanol in charcoal is written as:
$X = \rho_3$ W0 exp [-D (T $\ln(\rho_s/p)^n$]

W0 = maximum volume available for adsorbate in adsorbent (1/kg)
D = parameter = K^n , K absorption coefficient
Subscript (s) = saturation
Clapeyron equation and pressure conditions:
When x remains constant, i.e. before macro desorption starts, and after adsorption finishes, the system pressure P can be determined by the Clapeyron equation: $(\delta \ln P/\delta T)_x\, h_{ad}/(RT^2)$
h = heat transfer coefficient (W/ m^2K)
subscript (ad) = adsorption
When the desorption starts, the system pressure is assumed to be equal to the saturation pressure of methanol at the condensing temperature

T cond :-

P = Ps (Tcond) ...
The condensing temperature Tcond used in the model calculations was computed from the observed temperatures Tcw (subscript (cw) is for condenser water temperature) of the static water tank surrounds the condenser, with the help of an empirical coefficient (CCE): [1]
Tcond = Tcw (H) + CCE [Tcw (H) - Tcw (l)]
H = Time interval
CCE = empirical condenser coefficient
Tcw (H) and Tcw (1) refer to the hour H and the initial hour (7:00 a.m.) respectively. During the adsorption period when the receiver/evaporator is the coldest part, the receiver/evaporator temperature Trec controls the system pressure: P = Ps (Trec) ...
c- Initial condition:
Initially, the temperature and concentration of methanol in the charcoal is assumed to be uniform. Thus we have;
i=2, ... ,M+1;j = 1 ... ,N ;t = 0
Tij = T0 and X ij= X0
And Po can be obtained from equation…
d- Equations for the Collector Casing and Receiver/Evaporator:

For the glass:

The whole glass cover is assumed to be at the same temperature Tg, whose change Tg in the small time interval is given by the equation:

(Tg -Ts) hga + (Tg - Tsky) Tg sky + (Tg - Tg Tmp) hgmp) + $\delta\rho_g$ CΔ Tg / Δt+ Qa = 0

Where,

Tgs ,Tsky are ambient temperature and sky temperature respectively.

T mp is the mean temperature of the upper half of the collector tube.

hga, hgsky, hgmp are for air, sky and the upper-half of the collector tube respectively, and Qa is the rate of absorption of solar radiation by the glass.

For the Casing:

e- The initial casing temperature assumed to be Tb, which satisfies:

(Tb- Tg)hba + (Tb Tmd)hbmd = 0.0 Where; Tmd is the mean temperature of the low half of the collector tubes. Because the insulation foam is a light material, its heat capacity is neglected. f- For the receiver/Evaporator:

During the evaporation\adsorption, it is assumed that receiver and the liquid methanol inside are at the same temperature Tev, whose change Δ Trec in the small time interval At is given by:

(m1C1 + mrcCrc) ΔTrec + hrea (Trc-Tg) Δt+ hrew (Trc-Tw) Δt=Lev$^{\Delta m1}$

Where, ml, mrc = mass of liquid methanol in receiver and mass of receiver/evaporator,

Ci, Crc = specific heat capacity of the liquid methanol and the receiver/evaporator,

V1 = volume of liquid methanol,

T = water temperature in ice tray,

Lev = latent heat of evaporation of methanol at temperature Trc.

Determination of Values for Parameters in the model Equation:

The solar heat absorbed per unit area per unit time (Qhgij) by the element (ij) on the upper-part of the collector tube is given by:

Qhgij = Id cos(θ_j) τ(θ_g) α +I_D α τ

Where θ_j = solar ray incidence angle to element (ij),

θ_g= solar ray incidence angle to glass cover, τ (θ_g) = ((1- τ)/(l+ τ)) exp(-KLg) $\approx$ (l- τ)/(l+ τ)

τ = 0.5 ($\sin^2$ ($\theta_g - \theta''$)/ $\sin^2$ ($\theta_g + \theta''$)/ $\tan^2$ ($\theta_g + \theta''$))

θ'' = $\sin^{-1}$l($\sin\theta_g$)/ n_2

n_2 = index of refraction of glass,

$\alpha\tau$ = mean transmittance and absorption coefficient for diffuse radiation. The solar heat absorbed by the glass cover per unit area per unit time is: Qg = Id cos θg a(es) + I_D α

Where the absorbtion is given by:

(θg) = (1- δ) (1- exp(-KLg))/(l - δexp(-KLg)

In the day time when the dampers are closed, the top heat loss coefficient ht,a (including convective and radaitive loss), is calculated with an empirical formula developed by Klein and discussed by Duffie [5]

$$h_{ta} = [\frac{1}{\frac{C}{T_{PM}}\left[\frac{T_{PM}-T_a}{1+f}\right]} + \frac{1}{h_w}]^{-1} + [\frac{\sigma(T_{PM}+T_a)(T^2{}_{PM}+T^2{}_{PM})}{(E_{p-0.00591hw})^{-1}+\frac{2+f-1+0.133\epsilon_p}{\epsilon_g}-1}]$$

Where:

Tp,m = tube temperature,

f =(1 + 0.089^{h_w}-0.116$^{h_w \epsilon_p}$)(1 + 0.07866N)

e = 0.043(1 - 100/Tp,m) C= 520(1 - 0.000051$^{\beta^2}$) β = tilt angle,

ϵ_p, ϵ_g = emittance of collector tube and glass cover,

h_w = wind heat transfer coefficient = 2.8 + W * WCED W = wind speed (m J/s)

WCEĐ = Wind correction Coefficient

The determination of the parameter WCED is discussed below

The back convective heat loss coefficient from the warmer lower half of the collector tubes to the cooler back casing a distance L below, is calculated by the formula given by Bejan: [9]

Nu (τ) = I + [Nu (90^0) sin (τ)

Where τ = 180 collector tilt angle, and

$h_{j-c:c}$= Nu (τ) Kair/L

The convective heat loss coefficient plus the radiative heat loss coefficient from the lower half of the tube to the casing (at temperature Tb) equals the total back loss coefficient. When the shutters are opened, wind correction factor (WCE) should be introduced to account for the total convective heat transfer coefficient h_{tc}in the evening, which is defined as:

h_{tc} = Natural convective coefficient + W * Al + WCE

Al = cross-section area of shutter channel in the collector (m^2)

Following Guilleminot and Meunier [6], a heat transfer coefficient Hl between charcoal and the metal tube, and an equivalent conductivity of charcoal k, were introduced in the model to account for heat diffusion inside the collector tube. The heat of adsorption is determined by the slope of the isosteric (lines of constant concentration) on the ln p versus (-l\T) diagram, for the charcoal pair used, which was determined experimentally The parameters . W0, D and n in (eq. 2.8) charcoal used in this refrigerator (AlT's design) are 0.365 I/kg, 14.96 x 10^5 and 1.34 respectively [2], which were also determined experimentally [8] Methanol properties used in the model are the values in the tables of Liley [7]

The parameters such as WCE, WCED, Hl, k, CCE, etc. are difficult to estimate theoretically. They were determined from experimental data by the tentative identification method of Grenier et al. in which actual temperature histories of the system under the sun are compared with temperature histories calculated by the model. The criterion of error chose in the method is the root mean square difference

F($\propto$, β) between the measured temperatures Ti and critical temperatures T,

where $\propto$, β are two of the parameters to identify are, thus:

F(($\propto$,β)=($\sum_{H=i}^{N}[TT_{chH}-T_{chH})^2+(TT_{upH}-T_{upH})^2+[TT_{loH}-T_{loH})^2]/3N)^{\frac{1}{2}}$..

Where the subscripts have the following meanings:

ch = charcoal average,

up = upper half part of the collector tube [1], lo = lower half part of the collector tube,

H = at the time step H, and

N = the number of time steps, which in this case is 48 per day for half-hour steps. The parameters are taken in pairs and are adjusted interactively until the values of F($\propto$, β) are minimized

CONCLUSION :

With the aid of some guides hints found in references , a design and construction of solar freezer unite on adsorption principle has become possible . The idea is a promising one for its simplicity and the availability of its materials in the local market and the simplicity of manufacturing technology and lab our skills needed . The research conducted enable me to arrive at a very simple design, which if it is applied perfectly can help in constructing a solar freezer of daily productivity of 5 kg of ice. The constructed unit did not work for which no further test results presented on it efficiency or performance, this fault is not for the mis-design, but for some constructional lapses, the major of it was the leakage problem which was difficult to find out.

The importance of the construction work is that: It brings out how the machine will look like also this makes it possible to detect any structural fault for another construction if needed next time. Observations recorded:

A lot of observations can be recorded concerning the structure of the machine for the benefit of readers and observers, some of them are:

1. Serious thermal stresses occurred during the welding process of joining the charcoal box to the collector plate.
2. Components should be tested for leakage before assembly.
3. Evacuating the system is so simple using a suitable evacuating machine.
4. The tightness of the system is a critical factor and without ensuring that the system will never run.
5. The system works under vacuum (below atmospheric, negative gauge pressure) in all its stages of evaporation and condensation.

The icebox is auto- gauging. Sufficient amount of water shall be put and allow overflow of the excess on joining it to the evaporator

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