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of Researches in Engineering: A

Mechanical & Mechanics Engineering

Echo the Caves

Waste Water with Garbage

Highlights

Pressure and Temperature

Distillate Yield Improvement

Discovering Thoughts, Inventing Future

VOLUME 15 ISSUE 4 VERSION 1.0

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Mechanical and Mechanics Engineering

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Distillate Yield Improvement using a Parabolic Dish Reflector Coupled Single Slope Basin Solar Still with Thermal Energy Storage using Beeswax

By Aondoyila Kuhe & Alex Okibe Edeoja
University of Agriculture, Nigeria

Abstract- A single slope solar still, integrated with latent heat thermal energy storage system coupled to a parabolic concentrator was designed with the aim of improving productivity. 14 kg of beeswax was used as phase change material (PCM) beneath the absorber plate to keep the operating temperature of the still high enough to produce distilled water even during the sunset hours. The underside of the still is covered by 0.2 m aluminum sheet painted black on the side facing the parabolic concentrator to help in absorbing solar radiation reflected from the parabolic concentrator and conducting same to the PCM. To determine the performance of single slope solar still, it was tested without the PCM effect and then with the PCM effect. The temperature of water, température of PCM, air température, inner surface glass temperature and outer surface glass temperature were measured. Experimental results show that the effect of thermal storage in the parabolic concentrator-coupled single slope solar still increased the productivity by 62%.

Keywords: *solar still; beeswax; parabolic dish reflector; distillate yield; phase change material.*

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Aondoyila Kuhe [α] & Alex Okibe Edeoja [σ]

Abstract- A single slope solar still, integrated with latent heat thermal energy storage system coupled to a parabolic concentrator was designed with the aim of improving productivity. 14 kg of beeswax was used as phase change material (PCM) beneath the absorber plate to keep the operating temperature of the still high enough to produce distilled water even during the sunset hours. The underside of the still is covered by 0.2 m aluminum sheet painted black on the side facing the parabolic concentrator to help in absorbing solar radiation reflected from the parabolic concentrator and conducting same to the PCM. To determine the performance of single slope solar still, it was tested without the PCM effect and then with the PCM effect. The temperature of water, température of PCM, air température, inner surface glass temperature and outer surface glass temperature were measured. Experimental results show that the effect of thermal storage in the parabolic concentrator-coupled single slope solar still increased the productivity by 62%.

Keywords: solar still; beeswax; parabolic dish reflector; distillate yield; phase change material.

I. Introduction

Portable drinking water is a core component of daily human existence. Though three quarter of the earth's surface is covered by water, 97% of available water sources are brackish and microbiologically unsafe. Only 1% of earth's water is safe for drinking [1].Access to safe water and sanitation is a major challenge in Nigeria. Water and Sanitation coverage rates in Nigeria are amongst the lowest in the world. Nigeria is currently not on track to reach the MDG targets of 75% coverage for safe drinking water and 63% coverage for basic sanitation by the year 2015 [2].

A good method of obtaining portable drinking water is by distillation. Most conventional distillation methods such as reverse osmosis, membrane distillation, multistage and multiple effect distillation are energy intensive, expensive and require a high level of technical skill to operate. Therefore, solar distillation is an ideal solution and the simplest technique among other treatment processes suitable for supplying small Communities in rural and remote areas with portable drinking water [3,4].

The basic principles of solar water distillation are simple yet effective, as operation of solar still is similar to the way nature makes rain that includes two processes, namely evaporation and condensation [5]. The sun's energy heats brackish water in a basin to the point of evaporation in an air tight environment. As the water evaporates, water vapor rises, condensing on the cooler surface of a transparent cover for collection. This process removes impurities such as salts and heavy metals as well as eliminates microbiological organisms. The end result is water cleaner than the purest rainwater [1].

Solar stills are generally classified into two types: active and passive. In active solar still the water coming into the basin is preheated externally in order to increase the water temperature in the basin, which will inevitably increase the evaporation rates. Passive solar still are the conventional solar stills (CSS).Direct solar energy falling on the basin effective area is the only source of thermal energy. The heat collection, evaporation and condensation all occur within one system. Simple modifications within the basin are used to enhance the productivity [6].

Solar still are the ideal solution for standalone water distillation systems in rural and isolated areas. Although solar stills havelow productivities, they are the most sustainable water productionmethod in these areas. The current research focus is how to improve the poor productivity of these systems.

The performance of solar still is generally expressed as the quantity of water produced by basin area in a day. The quantity of water produced by the solar still is affected by design, operational and ambient conditions. The ambient conditions cannot be controlledby humans as they are dependent on meteorological parameters. The design conditions which include assembly materials can be easily manipulated by humans to affect the production rate.

Phase change materials (PCM) can improve the productivity of solar stills, when applied in latent heat systems. This method relies on heat being release from

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the bottom of stills [7]. The solar radiation is transmitted through the transparent cover and isabsorbed by the basin and PCM thereby increasing their temperatures. Part of the energy absorbed by the basin is transferred by convectionto the basinwater and the other transferred by conduction to the coolerPCM under the basin. As the PCM is heated, heat is first stored as asensible heat until the PCM reaches its melting point. At this time, thePCM starts to melt and after complete melting of the PCM, the heatwill be stored in the melted PCM as a sensible heat. Improving the performance of CSS using phase change material (PCM) as heat storage media in solar still have been previously studied. [8] studied two cascade solar stills constructed with and without latent heat thermal energy storage system (LHTESS). Paraffin wax was selected as the phase change material (PCM) which acts as a LHTESS. Thermal performances of the stills were compared in typical sunny and partially cloudy days. Results showed that the total productivity is nearly the same for both stills in a typical sunny day. However, for a partially cloudy day, the still with LHTESS has a significantly higher productivity. [4] developed a theoretical model for a still with and without phase change material (PCM). They concluded that the daily productivity of the still with and without the PCM was 6.7 and 5.1 kg/m^2/day respectively. The results showed that the productivity of the still with PCM was theoretically 31% higher than that of without PCM. [9] studied the effect of minimum depth of water with different storage materials in the basin. The performance of the solar still was compared with different types of energy storing materials like quartzite rock, washed stone, cement block pieces, red brick pieces and iron scraps. It was observed that, the still with 3/4 in. sized quartzite rock is the effective basin material. The transient performance of a stepped solar still with built-in latent heat thermal energy storage was studied by [10]. He concluded that the still has an efficiency of 57% and the total yield is about 4.6 L/day/m^2. A mathematical model for a single basin-single slope solar still with and without PCM under the basin liner of the still was presented [7]; numerical calculations were carried out using stearic acid as a PCM, on typical summer and winter days. The results of the study showed a productivity of 9.005 (kg/m^2 day) with a daily efficiency of 85.3% has been obtained compared to 4.998 (kg/m^2 day) when the still was used without the PCM. A concentrator-coupled hemispherical single-slope solar still solar still with and without phase change material (PCM) were studied experimentally by [11]. Results indicate that the effect of thermal storage in the concentrator-coupled hemispherical basin solar still increases the productivity by 26%.

In this paper, a parabolic reflector-coupled single slope basin solar still is integrated with beeswax as a PCM beneath the basin liner of the still. Because of the high melting point of beeswax, heat from the parabolic dish reflector apart from direct solar radiation was used. The distillate yields, with and without PCM effect are reported.

II. Material and Method

A schematic and pictorial diagram of the parabolic reflector dish solar still with phase change material (PCM) as a heat storage medium is shown in Fig. 1-2. The basin area of the still is 0.3 m^2, fabricated from a black painted aluminum sheet of thickness 0.2 cm leaving a3 cm gap under the horizontal portion of the basin liner. This gap is loaded with the 14 kg of PCM. Waste beeswax which is a by-product of the local honey processing industry is used as the PCM because of its low cost, wide availability and stability in the working range. The under of the solar still is covered with another aluminum sheet of thickness 0.2 cm painted black on the side facing the parabolic concentrator. Table 1 summarizes the thermo-physical properties of beeswax (Ravi Ramnanan-Sing, 2012). The sides of the basin are insulated by 3 cm layer of rockwool contained in a wooden frame of 1 cm thickness to prevent heat losses. Rookwool which have a thermal conductivity of 0.038 W/m^2 K is used as an insulator on the still sides.The cover of the still is made up of 0.3 cm thick simple window glass, making an angle of 27.9^0. Optimum slope of collector for Makurdi city was calculated using angle of solar declination (δ), number of days, latitude at test site, and angle of incidence from the following equation [12]:

Slope of collector (β) is calculated by using the following formula:

$$\beta = (\phi - \delta) \quad (1)$$

Where, ϕ = Latitude at test site, = 7.7^0 N

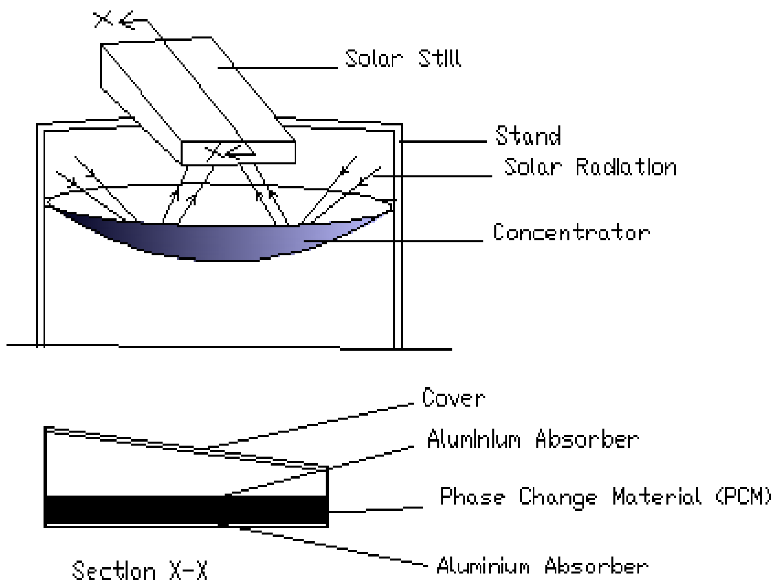

Figure 1 : Schematic diagram of parabolic reflector dish coupled single slope basin solar still

Figure 2 : Pictorial view of the parabolic reflector dish coupled single slope basin solar still

Table 1 : Thermo-chemical properties of beeswax [13]

Material properties	Beeswax
Melting Temperature, ^{0}C	61-8
Latent heat of fusion, kJ/kg	1.7×10^5
Solid density, kg/m^3	970
Thermal conductivity, W/m ^{0}C	2.5×10^{-3}
Specific heat capacity, kJ/kg ^{0}C	3.4

Experimental parameters used in the experimental work are shown in Table 2. This optimum angle is about 27.9° for Makurdi which is located in the middle belt region of Nigeria. The fresh water is collected in an aluminum channel fixed at the lower end of the glass cover. Various temperatures like ambient (T_{amb}), water (T_w), air (T_a), and condensing glass cover inner–outer surfaces (Tig and Tog) were recorded hourly between the hours of 9:00 am-5:00 pm using K-type thermocouples.

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Table 2 : Experimental parameters

Parameters	Symbol	Value
Transmittance of cover	τ_c	88%
Emissivity of cover	ε_c	0.98
Wind velocity	V	0.8 m/s
Density of water	ρ	989 kg/m^3
Latent heat of vaporization	h_{fg}	2,463 kJ/kg
Declination angle	δ	20.2^0
Latitude	φ	7.7^0

Table 3 summarizes accuracies and error percentage of variousmeasuring instruments used inthe experiment.The solar radiation transmitted through the glass cover and basin water is absorbed by the basin liner; hence, its temperature increases. Part of thermal energy is transferred by convection to the basin water and the other will be transferred by conduction to the PCM beneath the basin liner. A 0.2 cm aluminum sheet painted black on the parabolic collector facing side is used as cover under the solar still. The solar parabolic concentrator focuses solar radiation under the solar still, which is transmitted by conduction to the PCM, heat from the parabolic solar concentrator is first stored as a sensible heat till the PCM reaches its melting point irrespective of the liner temperature.

Table 3 : Accuracies, range and errors of measuring instruments used

S/No.	Instrument	Accuracy	Range	% Error
1	Solarimeter	$\pm 1W/m^2$	0-2500W/m^2	2.5
2	Digital thermometer	$\pm 1^0$C	0-250 ^{0}C	0.5
3	K-type thermocouples	$\pm 0.1^0$C	0-300 ^{0}C	0.5
4	Anemometer	$\pm 0.1 m/s$	0-20 m/s	5
5	Measuring jar	$\pm 10\ ml$	0-1000 ml	10

The PCM melts before the temperature of the liner rises to the melting temperature of the PCM. By the time, the PCM starts to melt and after complete melting of the PCM, the heat will be stored in the melted PCM as a sensible heat. The combined effect of the sun's radiation and concentrated flux from the parabolic dish reflector speeds up the melting of the PCM. Afternoon, when the solar radiation decreases, the PCM is kept molten by the heat from the parabolic concentrator and will continue to transfer heat to the basin liner and from the latter to the basin water until the PCM completely solidified. In other words, the PCM will act as a heat source for the basin water during low intensity solar radiation periods.

III. Results

It has been proven that the productivity of a solar still is dependent on meteorological conditions of a place like solar radiation, ambient temperature etc. Fig. 3 depicts the variation of solar radiation and ambient temperature with time on 26/1/2015. Insolation is measured in the range of 580 W/m^2 to 899 W/m^2, insolation gradually increases from early morning to 1 pm as the sun rises and then reduced towards evening due as the sun begins to set. The ambient temperature is in the range of 37.3 °C to 39.3 °C.

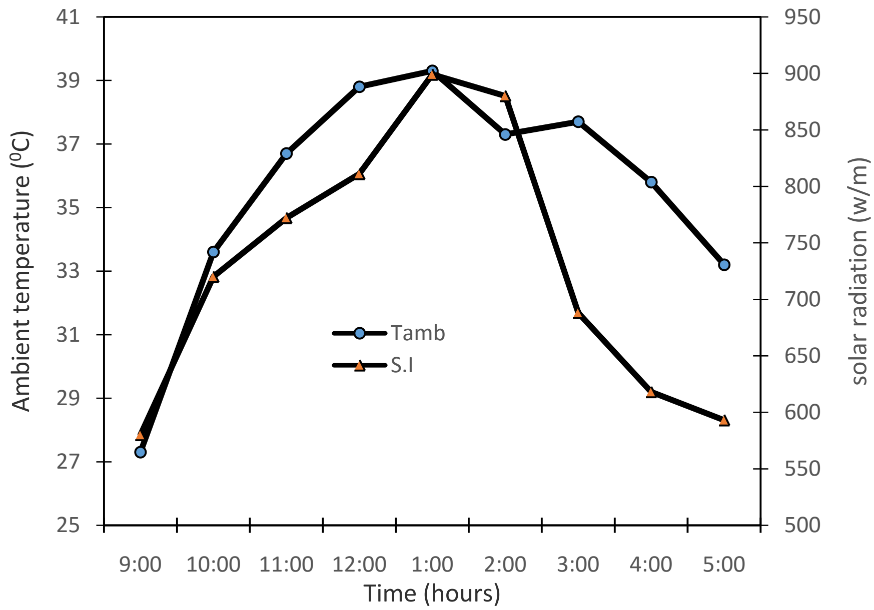

Figure 3 : Hourly variation of solar radiation and ambient temperature with respect to time.

The variation of water temperature, air temperature, inner cover temperature and outer cover temperature with time for parabolic concentrator-coupled single slope basin solar still with PCM is shown in Fig. 4.

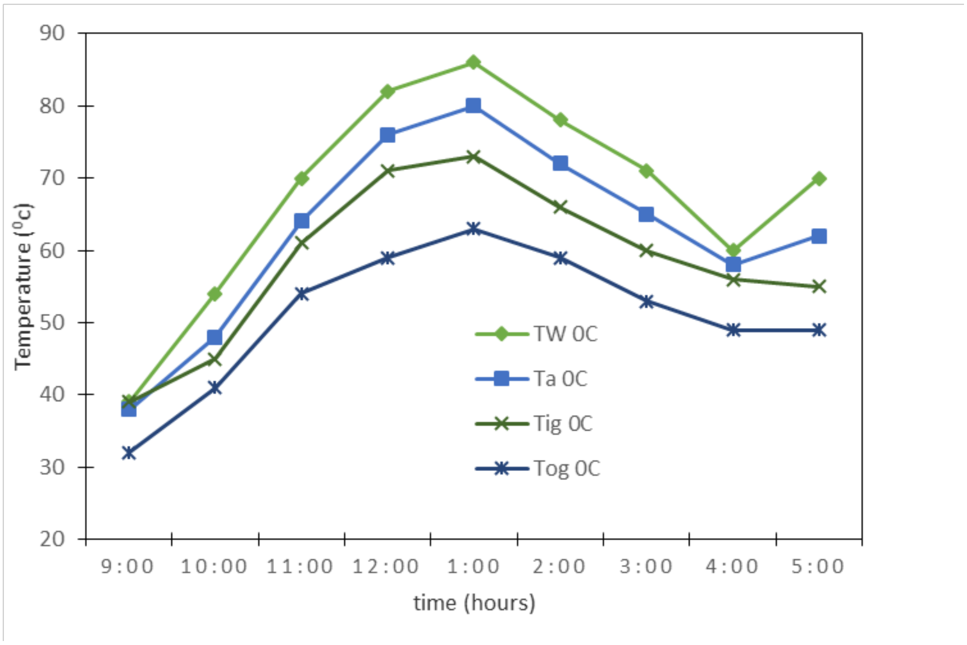

Figure 4 : Hourly variation of solar radiation and ambient temperature with respect to time.

The maximum water temperature observed was 86 °C at 1 pm. Similarly the maximum air temperature of 80 °C was measured, while the inner and outer cover temperatures were in the range of 39–73 °C and 32–63 °C, respectively. Fig. 5 shows the variation of water temperature, air temperature, inner glass temperature, and outer glass temperature with respect to time for concentrator-coupled single slope basin solar still without PCM. The maximum water temperature observed was 76 °C. Similarly the maximum air temperature of 79 °C was measured, while the inner and outer glass temperatures were in the range of 32–67 °C and 30–60 °C, respectively.

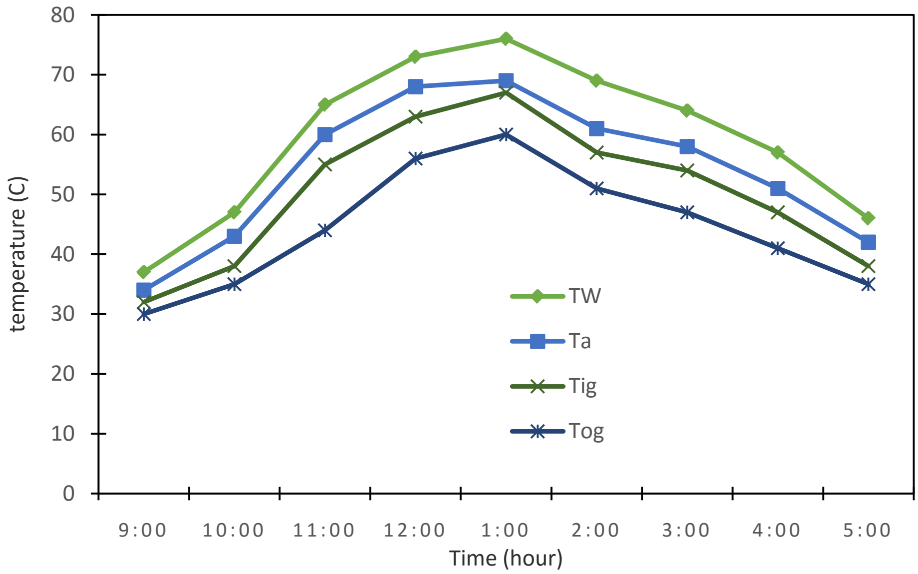

Figure 5 : Hourly variation of temperature in concentrator coupled hemispherical basin solar still without PCM.

Fig. 6 shows the distillate yield with respect to time. The maximum output collected for concentrator-coupled hemispherical basin solar still with PCM was 5243 ml/m^2/day, and 3240 ml/m^2/day for the solar still without PCM.

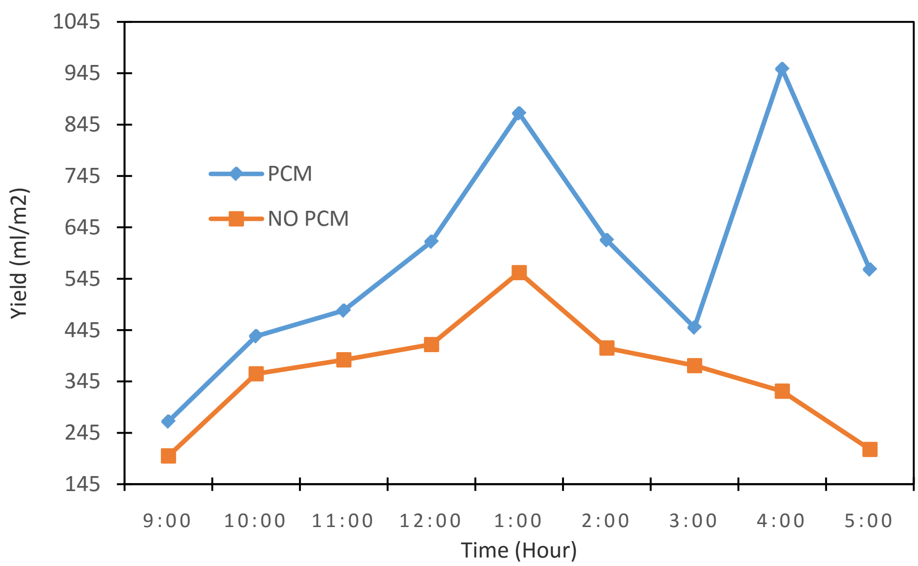

Figure 6 : Distillate yield with respect to time

IV. Discussion

The hourly productivity with the PCM is much higher than that without the PCM during sunrise which is characterized by increasing solar intensities. This behavior is unexpected because the PCM under the basin liner absorb heat from the liner. But in the current configuration, the parabolic dish provides concentrated heat flux to the PCM via the basin linerthereby increasing the basin water temperature as well as the productivity throughout the day and into the evening. The beeswax is melted in the morning hours due to the high intensity of solar radiation from the parabolic concentrator. It melts entirely during the charging phase from 10:00 to 11:00 h. The beeswax is kept molten by the intensity of the radiation from the parabolic concentrator even with a decrease in the ambient temperature and solar intensity. Subsequently, with a further decrease in solar intensity towards sunset, it becomes solid again releasing sensible heat into water. The still with PCM yields larger amounts of distilled water than the still without PCM because of the higher operating temperature. This high operating temperature is obtained because the stored heat from the PCM is transferred by conduction through the basin liner to evaporate the water at enough high temperature.

Furthermore, the increase in temperature noticed in the still at 16:00 to 17:00 h is due to the effect of heat released by the PCM during the discharge phase. The productivity of the concentrator coupled single slope single basin solar still with PCM was approximately 62% higher than the concentrator coupled single slope single basin solar still without PCM.

V. Conclusion

In this present work, parabolic concentrator coupled single slope single basin solar still was fabricated and tested in Makurdi climate conditions. Many experiments have been conducted to enhance distillate output of solar still. The performance of parabolic concentrator coupled single slope single basin solar still without PCM under the basin liner was compared with that parabolic dish reflector coupled single slope single basin solar still with PCM under the basin liner. It was observed that, on a good sunny day, the daily productivity of the parabolic concentrator coupled single slope single basin solar still with increased to 62% with PCM under basin liner of solar still. The higher temperature difference observed between the basin water and inner glass temperature is due to the absorbed energy of PCM. It is recommended to integrate latent heat energy storage system in solar stills to further enhance their productivity.

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Echo the Caves

By F.F. Mende & A. S. Dubrovin

Abstract- The conducted experimental investigations showed that mechanical stresses or destruction of conductors and dielectrics lead to the appearance of unitary charge in such models. Friction between the separate threads or the dielectric layers they lead to the same effect. With the earthquakes, which are the consequence of the accumulation of stresses in the layers of species and their subsequent break or relative shift, also must appear the electric potentials, which present the unitary of charge, whose fields can without difficulty penetrate through the rocks, falling into the atmosphere and into the ionosphere. The shift processes, which associate earthquakes, which lead to the friction between the shifting layers, also can lead to the appearance of electrical pour on. These fields can ionize the atmosphere and the ionosphere, causing its glow. If tension pour on, that appear with such processes, exceeds breakdown stress for the atmosphere, then lightning can appear. The seismic waves, which are extended during the earthquakes, also lead to the periodic mechanical deformations of the layers of species. These deformations also can cause the appearance of electrical pour on out of the zone of the propagation of such waves. In the article the physical substantiation of the obtained experimental results is given. Conducted investigations give the physical and theoretical substantiation of the electrical phenomena, which associate earthquakes.

Keywords: thunderstorms, caves, electrical phenomena, seismic waves, mechanical stresses.

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Keywords: thunderstorms, caves, electrical phenomena, seismic waves, mechanical stresses.

I. Introduction

Earthquakes are accompanied by the appearance of electrical phenomena which they did not up to now find its explanation. In 1847 before the earthquake into Sinsyu (Japan) against the background of dark sky arose the revolving fiery cloud. It moved to the side of mountain it was ide and, its reach, it disappeared. In 1911 on the eve of the earthquake in Germany in the cloudless sky appeared the fireball, and 26 November 1930 before the earthquake in before the earthquake in peninsula Idzu (Japan) of the aurora borealis. Survived Ashkhabad tragedy 1948 they say, that on the eve of the earthquake they saw the arc from the electrical discharges flying on the sky, then, immediately after wind gust, it was heard the first underground push. During the Tashkent earthquake 1966 from under the earth was pulled out the gigantic luminous torch, it swiftly rose upward and it was dissolved in air. In 1976 occurred super-power Tien-Shan earthquake, during which light flashes they were controlled hundreds of kilometers from the epicentre of earthquake.

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Earthquake begins from break and displacement of the rocks in the depth of the Earth [1-4]. This place is called seismic center or hypocenter. Its depth usually is not more than 100km, but sometimes it reaches also 700 km. In some cases the layers of the earth, situated along the sides of breaking, are moved to each other. In others- the earth on one side of breaking descends, forming discharges. Underwater earthquakes are the reason for the tsunami. of the long waves, generated by powerful action on entire thickness of water in the ocean, during which occurs the sharp shift (raising or lowering) of the section of the sea bottom. Tsunami are formed with the earthquake of any force, but large forces those, which appear as a result of the strong earthquakes, reach. The sharp displacement of the large masses of the earth in the seismic center is accompanied by the mechanical impact of colossal force. The energy, isolated with such impacts, can repeatedly exceed energy of the nuclear explosions [5]. It is natural that such processes are accompanied by colossal mechanical stresses and powerful gaps of the layers of species. From the seismic center the seismic waves, which are also characterized by periodic mechanical compression and tension of layers and rocks, are propagated. Sometimes earthquakes are accompanied by the appearance of lightning.

From the aforesaid follows the consequence about the fact that the electrical phenomena, which accompany earthquakes, can be connected with the mechanical processes in the layers of species.

II. Experimental Study of the Appearance of Electric Potential During the Metallic Models and the Dielectrics with their Deformation and the Destruction

A study of the influence of mechanical stresses and kinetics of dislocations on the electrostatic potential of models was conducted employing the following procedure [6-8]. For this copper flask with the thickness of the walls ~ 3 mm and by volume near ~ 5 liters of it was placed into vacuum chamber, from which could be pumped out air. The end walls of flask were executed in the form hemispheres. The internal cavity of flask in conducting the experiments was found under the atmospheric pressure. Pumping out or filling into vacuum chamber air, it was possible to mechanically load its walls. Flask itself was isolated from vacuum chamber bushing from teflon resin and thus it had high resistance relative to the housing of unit. One of the typical dependences, obtained with such experiments, is represented in Fig. 1. It is evident that the amplitude of effect reaches 100 mV, dependence has strong hysteresis, moreover an increase in the negative potential corresponds to the tension of the walls of flask. In the figure the circuit on the hysteresis loop was accomplished clockwise. It follows from the obtained results that mechanical stresses of model lead to the appearance on it of electrostatic potential. The presence of hysteresis indicates that the formation of dislocations bears the irreversible nature. In this case the irreversibility of the influence of dislocations on the electrization is connected with the fact that dislocation they can, falling into potential wells, to be attached on the heterogeneities of crystal structure.

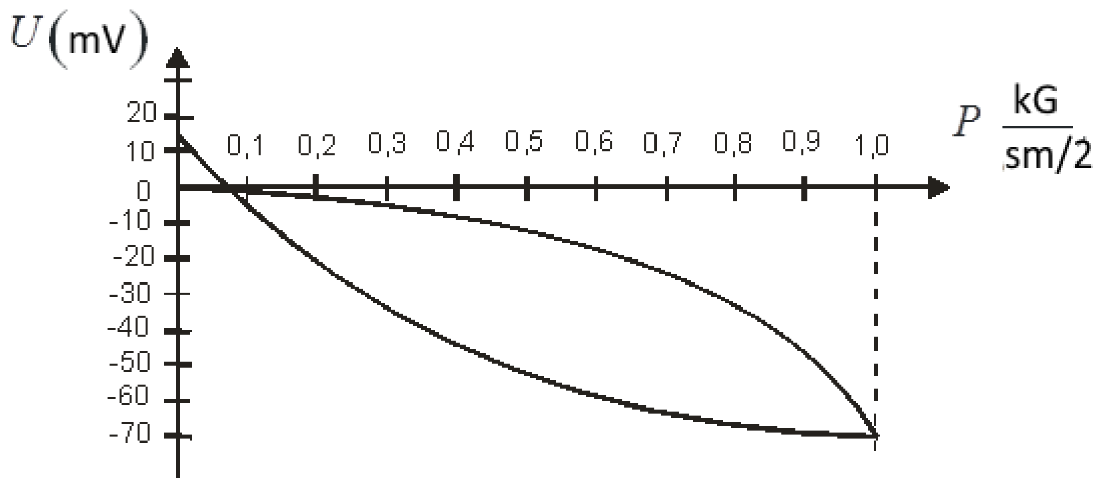

Fig. 1 : Dependence of the potential of copper flask on the external pressure

It follows from the carried out examination that also the appearance of rapid (impact) mechanical loads also must lead to the appearance in the isolated metallic model of pulse potential. This question was investigated on the installation, whose schematic was given in Fig. 2. [9]

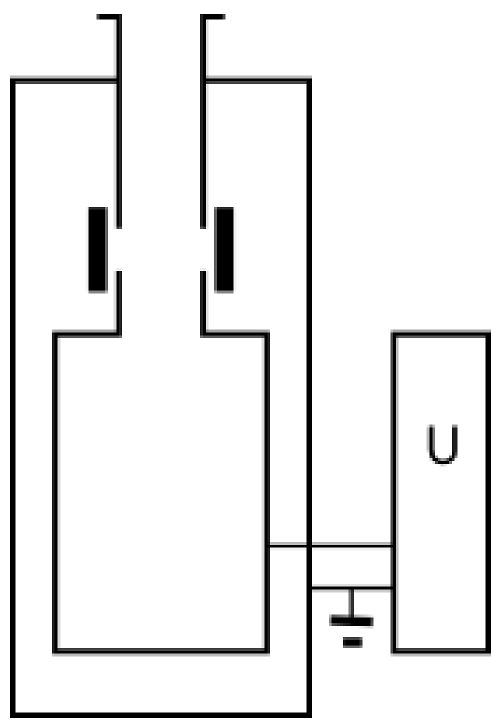

Fig. 2 : Installation diagram for investigating the appearance of the pulses of electric field with the impact loads.

Internal capacity is suspended to the external screen with the aid of wide neck. For eliminating the galvanic contact between the external screen and the internal capacity the neck has a section. Odd parts of the neck are connected by the insulating plates, which in the figure are designated by the short black sections of lines. Internal capacity is prepared from aluminum in the form of flask, its end walls are executed in the form hemispheres. This construction of end walls is necessary in order to avoid their severe strain with the realization of the explosions of explosive in the internal capacity. Common form installations for investigating the dynamic loads on the aluminum flask and the component parts of the installation are shown in Fig. 3 and Fig. 4.

Fig. 3 : The common form of installation for investigating the dynamic loads

Fig. 4 : Type of installation in the dismantled form.

During the inclusion into neck from a height 1 m of the bottom of the internal capacity of the rod with a weight 200 g between the external screen and the internal capacity is observed the voltage pulse, shown in Fig. 5. In order to avoid to the appearance of additional pulses with a lateral drop in the rod after the impact of its end about the bottom of flask, the side of rod is wound by soft tissue. Data of this experiment correspond to the experimental data, obtained with the copper flask, the code its tension led to the appearance on the flask of negative potential. With the impact of the end of the rod about the bottom of flask also occurs the local deformation of its bottom, with which in the point of impact occurs the tension.

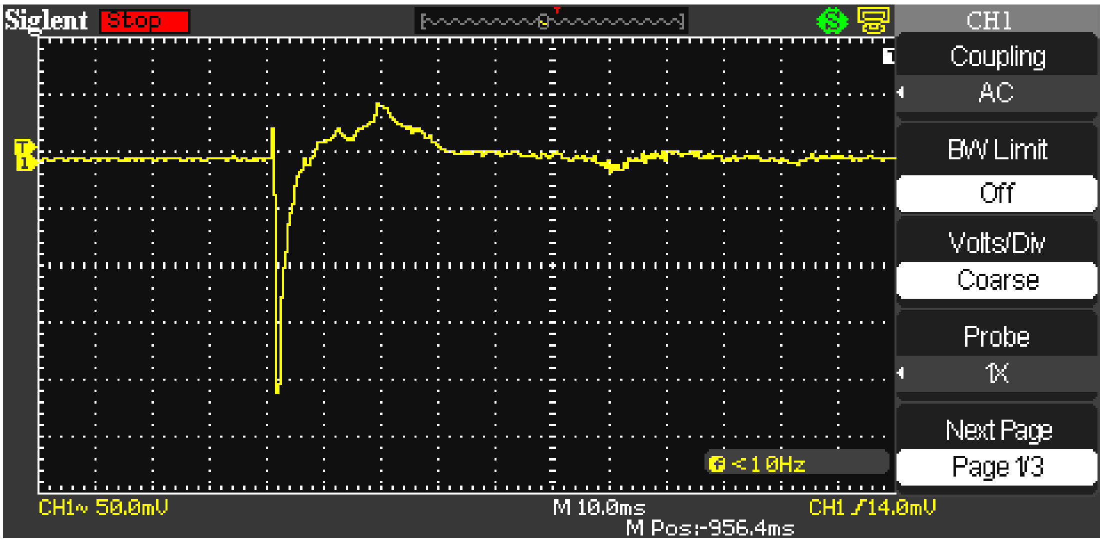

Fig. 5 : Shape of pulse after a drop in the rod on the bottom of internal capacity.

If we inside the aluminum flask explode the charge of small value, then is observed the voltage pulse, shown in Fig. 6.

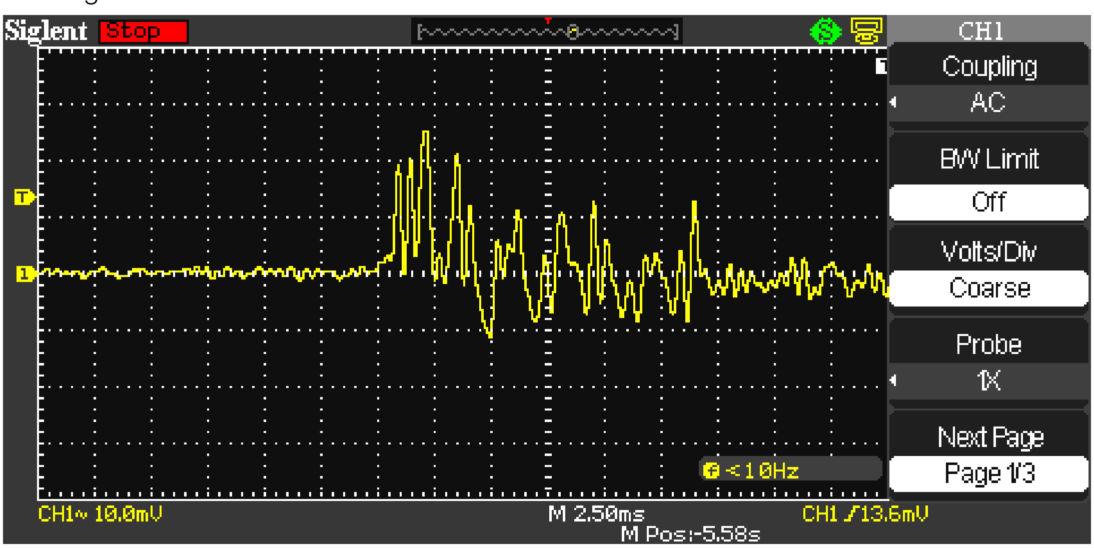

Fig. 6 : Form of the voltage pulses, obtained with the explosion of explosive in the aluminum flask.

The heteropolar repetitive pulses, which are been the consequence of the multiple reflection of shock wave from the walls of the flasks, which lead to its deformation, are observed in the oscillogram, in this case there are pulses corresponding to both the tension of the walls of flask and to their compression.

If we into the aluminum flask place the spring, isolated from the flask, and to force it periodically to be compressed, then potential on the flask also bears periodic nature. The experiment indicated was conducted according to the diagram, depicted in Fig. 7.

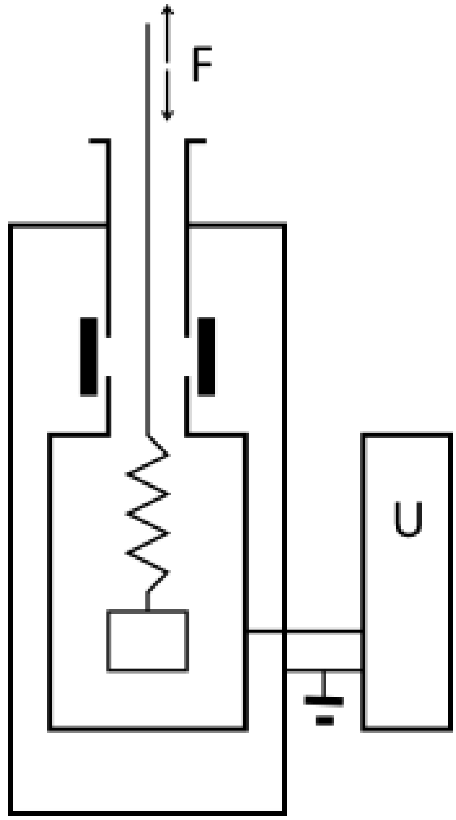

Fig. 7 : Diagram of experiment with the spring.

To the cotton cord, which emerges outside flask, is fastened the spring, from which is suspended the load. This system is had the mechanical resonance, whose resonance frequency, determined by spring constant and by cargo weight. If we toward the end thread exert periodic force at the frequency of resonance, then it is possible to attain the periodic deformation of spring at this frequency with in effect constant position of load.

The dependence of electric potential on the flask, obtained in this experiment, it is shown in Fig. 8.

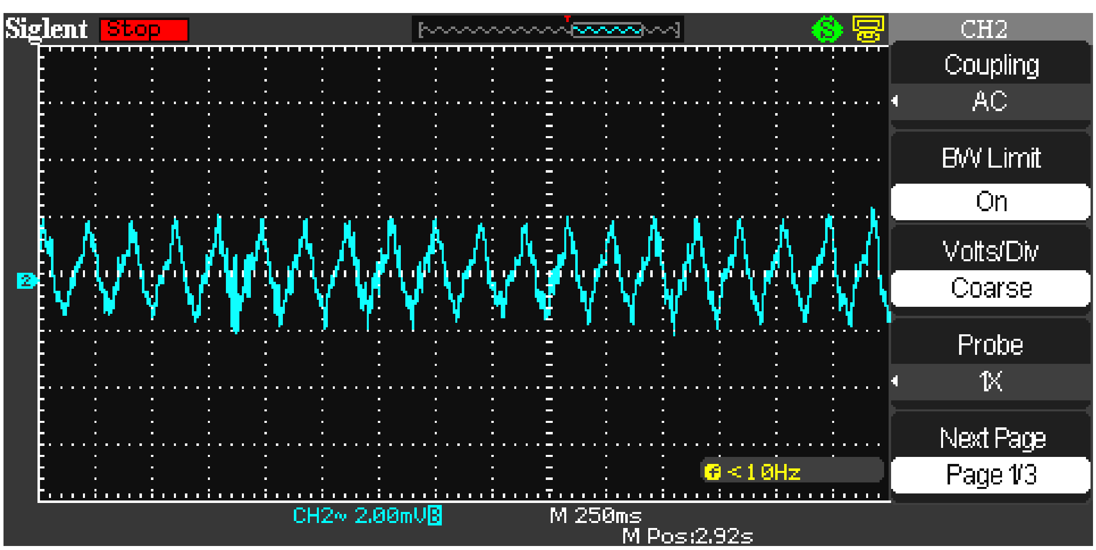

Fig. 8 : An alternation in the potential on the flask with the periodic compression of spring.

Obtained data attest to the fact that in the process of the deformation of spring, in the flask the alternating unitary charge is formed.

If we inside the flask tear thin copper wire, then the voltage pulse also is observed between the flask and the external screen. This experiment was conducted according to the diagram, shown in Fig. 9.

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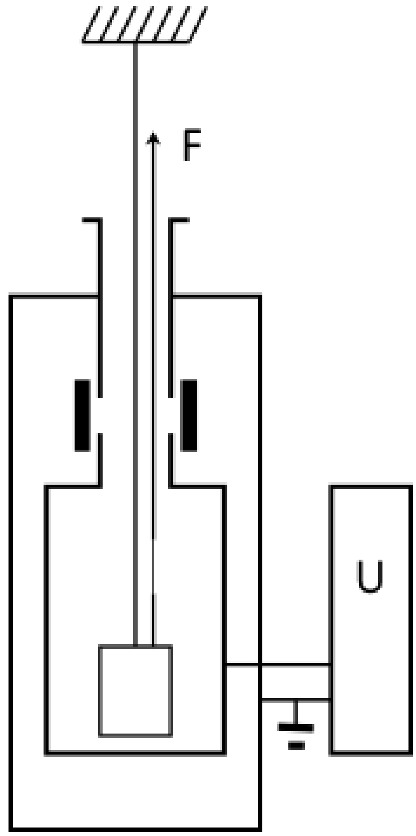

Fig. 9 : Experiment on the break inside the flask of copper wire.

The load is suspended inside the flask from the cotton cord. In parallel with the thread, from which is suspended the load, is located another kapron thread, in break of which is fixed the section of the copper wire with a diameter 0.3 of mm. At the moment of the break of the wire between the flask and the external screen is observed the pulse, depicted in Fig. 10.

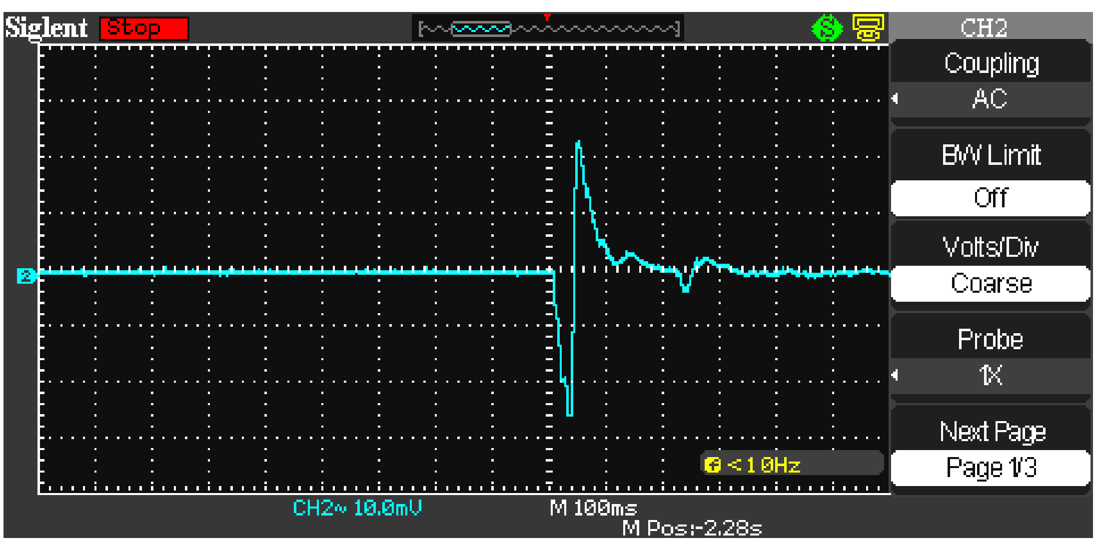

Fig. 10 : Pulse, obtained with the break of wire.

The negative part of the pulse corresponds to the tension of wire, which precedes its break. The positive part of the pulse corresponds to relaxation of deformation stress two parts of the torn wire.

In such a manner both the mechanical deformation of wire and its break it is accompanied by the appearance of unitary charge inside the flask.

Electrization appears also with the mechanical dielectric strains. If we conduct experiment with the dielectrics employing the procedure, depicted in Fig. 9, on it is possible to obtain the following results. With the break of silk thread is observed the oscillogram, given in Fig. 11.

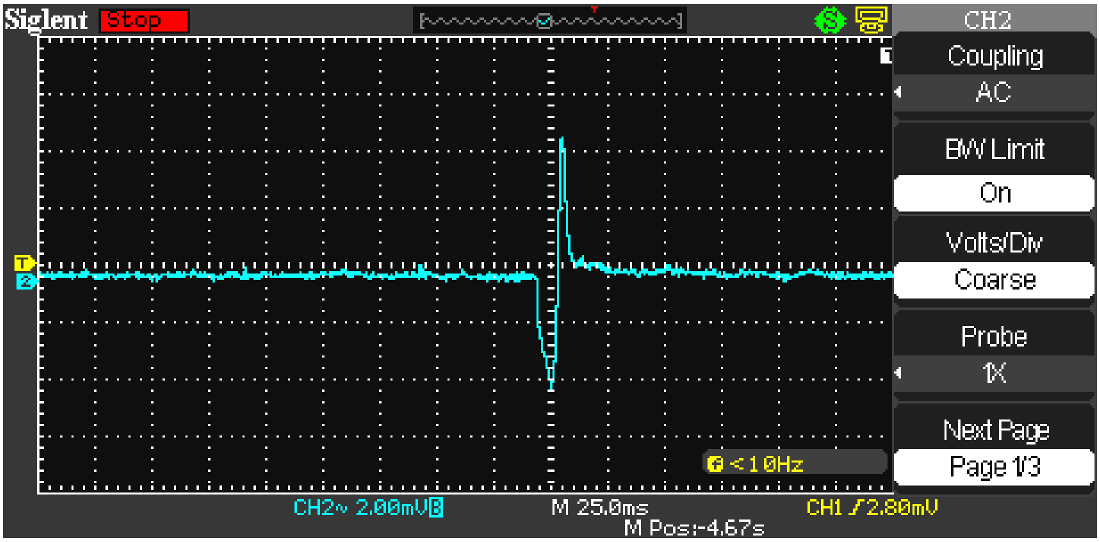

Fig. 11 : With the break of silk thread is observed the oscillogram.

In Fig. 15.is depicted the oscillogram, observed with the break of thread from vinyl chloride.

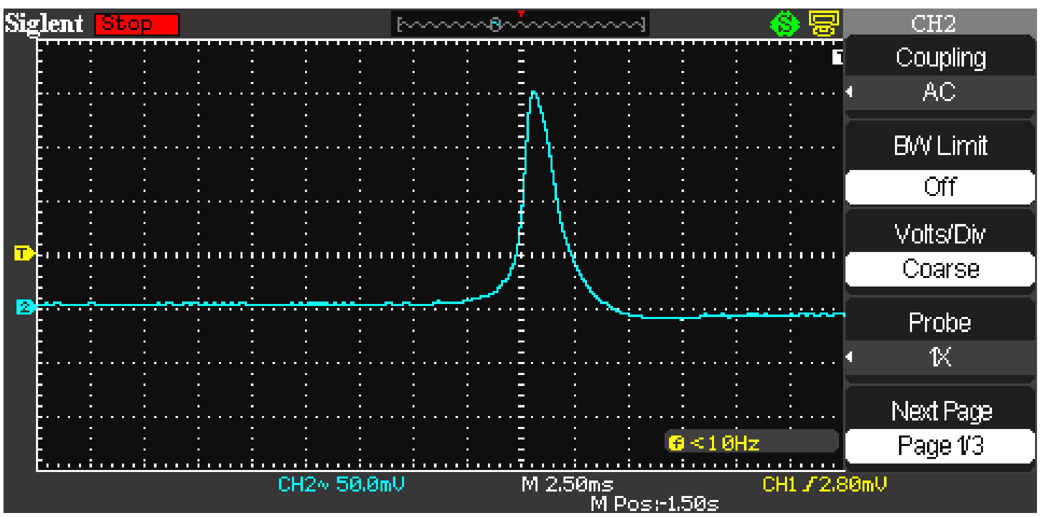

Fig. 12 : Is depicted the oscillogram, observed with the break of thread from vinyl chloride.

If we as the thread use the lace, interlaced from the synthetic fibers, and to subject to its periodic mechanical loads, then will be obtained the oscillogram, given in Fig. 13.

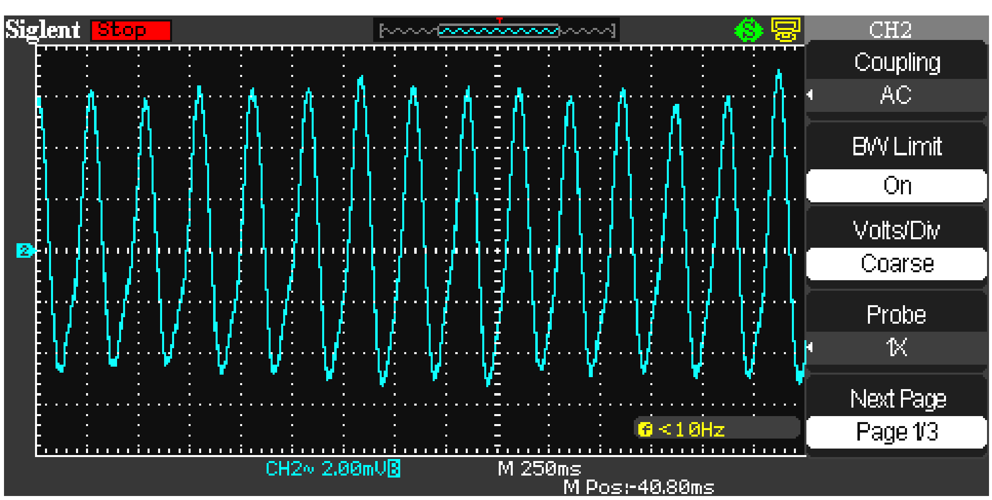

Fig. 13 : Oscillogram, observed during application to the lace of periodic mechanical loads.

Such properties of dielectrics earlier in the scientific publications are not described. Obtained experimental data speak, that by the way of compression, tension or destruction of conductors and dielectrics, placed in Faraday cage, it is possible to obtain in it the unitary charge of different signs, whose fields without difficulty penetrate through the metal screen of Faraday cage. Friction between the separate threads of dielectric generates the same effect, about than testify the experiments with the lace, made from such threads.

III. Physical Interpretation of the Experimental Results

If in any structure coexists several thermodynamic subsystems, then their chemical potential must be equal. In general form chemical potential for any subsystem can be found from the following expressions

$$\mu = \left(\frac{\partial U}{\partial N}\right)_{S,V} \overset{\Phi}{=} \left(\frac{\partial F}{\partial N}\right)_{T,V} = \left(\frac{\partial W}{\partial N}\right)_{S,P} = \left(\frac{\partial}{\partial N}\right)_{T,P}$$

Where N is number of particles, and the thermodynamic potentials of U, F, W, Φ represent internal energy, free energy, enthalpy and Gibbspotentialrespectively.

In the conductor there are two subsystems: lattice and electron gas, electron gas in the conductors at usual temperatures is degenerate and is subordinated the statistician Fermi-Dirac, his chemical potential is determined from the relationship of

$$\mu = W_F \left(1 - \frac{\pi^2 (kT)^2}{12 W_F{}^2}\right),$$

Where

$$W_F = \frac{h^2}{2m}\left(\frac{3n}{8\pi}\right)^{\frac{2}{3}}$$

is Fermi energy, h is Planck constant, and n, m are electron density and their mass.

Consequently, at an assigned temperature chemical potential of electron gas depends on its density.

Chemical potential of lattice depends on mechanical stresses and number of dislocations. And if lattice was subjected to mechanical stresses, then for retaining the electroneutrality of models should be changed the density of electron gas that it can be achieved by the way of addition or withdrawal of electrons from the model. If we this do not make, then model will acquire additional potential, that also is observed in the experiment.

IV. Conclusion

The conducted experimental investigations showed that mechanical stresses or destruction of conductors and dielectrics lead to the appearance of unitary charge in such models. Friction between the separate threads or the dielectric layers they lead to the same effect. With the earthquakes, which are the consequence of the accumulation of stresses in the layers of species and their subsequent break or relative shift, also must appear the electric potentials, which present the unitary of charge, whose fields can without difficulty penetrate through the rocks, falling into the atmosphere and into the ionosphere. The shift processes, which associate earthquakes, which lead to the friction between the shifting layers, also can lead to the appearance of electrical pour on. These fields can ionize the atmosphere and the ionosphere, causing its glow. If tension pour on, that appear with such processes, exceeds breakdown stress for the atmosphere, then lightning can appear. The seismic waves, which are extended during the earthquakes, also lead to the periodic mechanical deformations of the layers of species. These deformations also can cause the appearance of electrical pour on out of the zone of the propagation of such waves.

In the article the physical substantiation of the obtained experimental results is given. Conducted investigations give the physical and theoretical substantiation of the electrical phenomena, which associate earthquakes.

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Three Way Electricity from Waste Water with Garbage

By Giftson Felix D

Abstract- In today's world the increase in population leads to usage of more products and so waste [garbage] quantity is also increased. On the other hand the disposal of the same is still a question mark. Huge number of researches and inventions has been given to dispose the garbage in a good and useful way and in that way the very new technology is producing electricity from waste. So this paper gives a new efficient way to use the garbage as well as garbage water for producing electricity and even dispose it safely. This is done by a mechanism with a specially designed wheel which acts as a turbine as well as garbage transmitter and in turn it uses kinetic energy of water to operate.

Keywords: specially designed turbine wheel, belt conveyor, garbage water turbine, furnace, hot gas/smoke turbine.

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THREEWAYELECTRICITYFROMWASTEWATERWITHGARBAGE

Strictly as per the compliance and regulations of:

Three Way Electricity from Waste Water with Garbage

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Keywords: specially designed turbine wheel, belt conveyor, garbage water turbine, furnace, hot gas/smoke turbine.

I. Introduction

Today the dumping of large number of garbage is been done in the water bodies in most developing countries as seen in below image. This spoils the nature of water bodies. Avoiding this dumping is impossible.

So from this paper we can dispose that garbage to the maximum extent as well as generate electricity from that thing.

Previous improvements

- Domestic waste to Bio-Fuels

The garbage is dried and sent to the furnace where it is burnt and the gas or smoke from it is used to run a turbine and so electricity is generated

- Microbial Fuel Cell

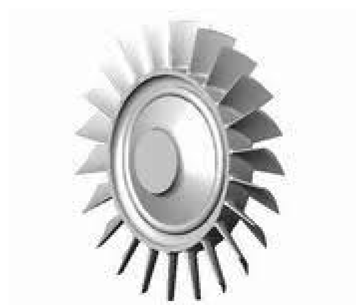
In this catalytic reaction of microorganisms and bacteria that are present in nature is used to produce electricity by converting chemical energy content of organic matter.

Author: e-mail: giftsonfelix191@gmail.com

Like this there are many processes but main problem or disadvantage is this is done in small amount or the amount of electricity produced is very less or more than 50% electricity produced is used by the same equipment.

II. Components Present

BELT / CHAIN CONVEYOR



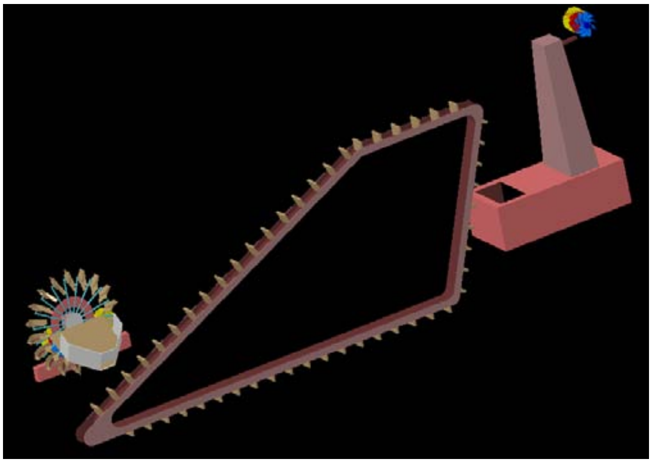
TURBINE WHEEL

GENERATOR

FURNACE

III. Principle Behind this Idea

The working principle of the idea presented in this paper is a specially designed turbine which operates by using the kinetic energy of the flowing waste water with garbage. During rotation the specially designed turbine wheel with buckets carry garbage along with waste water from here both garbage and waste water are diverted into separate passage and by means of turbine and furnace some process takes place and so at three different points electricity is generated.



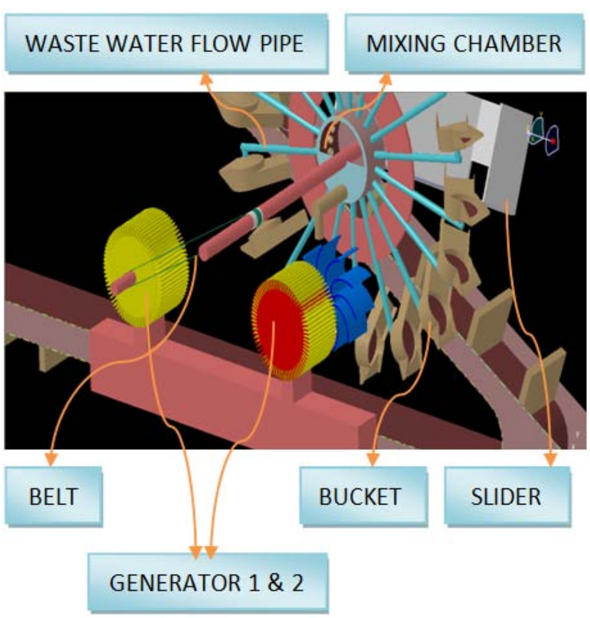
The above image depicts the complete working principle of this idea.

IV. Construction

The construction of this idea is very simple here it is divided into three separate units. They are

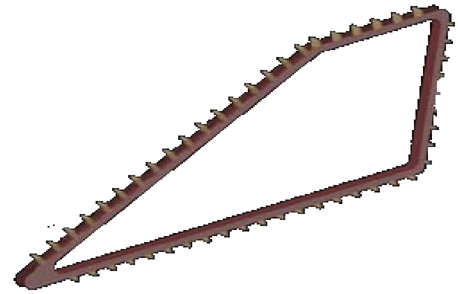
- Specially designed turbine setup
- Belt conveyor setup
- Furnace setup

Specially Designed Turbine Setup



In this setup the specially designed turbine with buckets is connected to mixing chamber by the waste water flow pipe. The mixing chamber outlet leads to the turbine wheel which is coupled to a generator at the same time the specially designed turbine wheel is also coupled to a generator by means of belt.

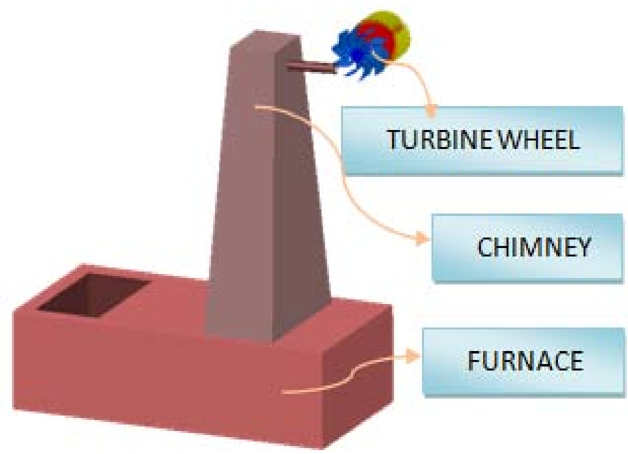
Belt conveyor Setup



This is the conveyor type used in this system this may be belt or chain. This conveyor has many separators attached to it.

This separator has two purposes one is during upward movement preventing the garbage from sliding down and on another side this separator moves due to the kinetic energy of water obstructed by the separator.

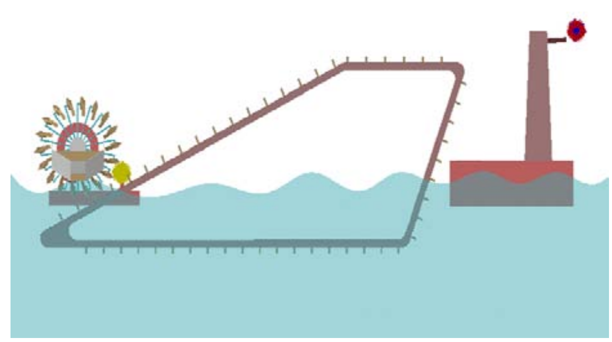
Furnace Setup



In this setup furnace, a chimney and an outlet are attached. The furnace has an opening which is used for getting the garbage from the belt conveyor. A turbine wheel is placed nearer to the outlet and so it is coupled to a generator.

V. Working

The working principle behind this idea is that a specially Designed turbine wheel which operates by using the kinetic energy of the flowing waste water with garbage this wheel carries the garbage along with waste water



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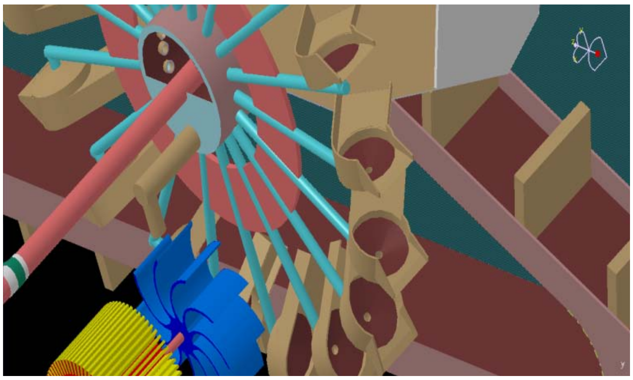
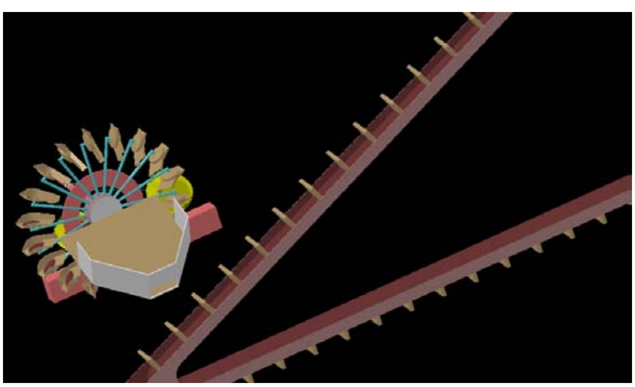
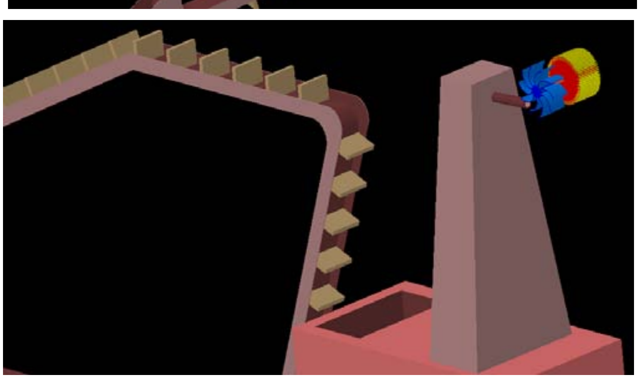
This specially designed turbine wheel has many buckets which has an opening at the centre which is connected to a waste water flow pipe as the wheel rotates with buckets carrying the garbage as well as waste water the waste water from the bucket is taken to the mixing chamber by the waste water flow pipe here cntinuously waste water is collected as shown in the below figure.



This collected waste water is taken out through the outlet this leads to a turbine wheel. Thus this wheel rotates and the same makes the generator coupled to that turbine rotates and so electricity is produces. This is the first electricity output point.

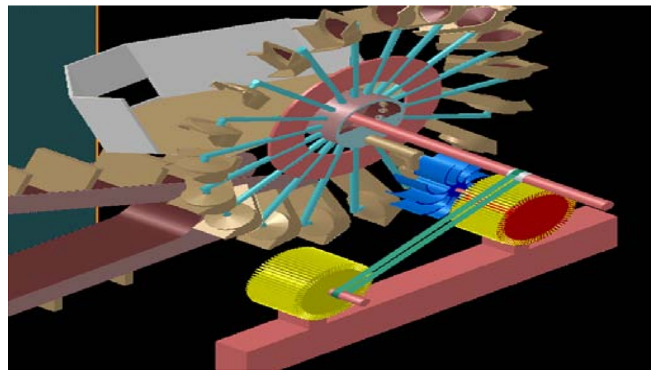
This turbine wheel has buckets which carries the garbage and throws it in the slider so that the garbage falls into the belt conveyor. This conveyor works by means of the same kinetic energy of water the separator in the conveyor is pushed by the water and so the conveyor rotates and thus it carries the garbage upward here it is taken to open air thus it is dried to remove the water content in it. Then it is dropped into the furnace





Inside the furnace there is a sliding plate which takes that garbage into the furnace and here it is dried by meanns of dry air. Then it is fired so that hot gases and smoke is left out this is taken out through the outlet pipe which leads to a turbine wheel. Due to the force of hot gases and smoke the turbine wheel rotates and so the generator coupled to it rotates and produce electricity as shown in the figure above. This is the second electricity output point.

The specially designed wheel which is operated by the kinetic energy of water.

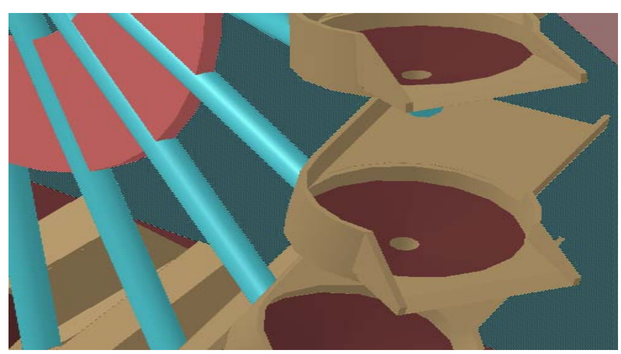


This operation also causes some rotational energy hence which in turn this is used by transferring the motion to the generator by means of a belt as shown in the above figure. So at this point also some small amount of electricity is produced this is the third electricity output point.

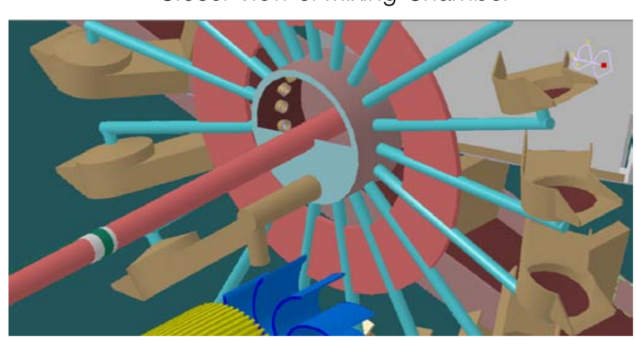
Thus at three points electricity is generated and at the same the garbage is also disposed safely without much harm.

VI. Other Images

Closer View of Bucket



Closer View of Mixing Chamber



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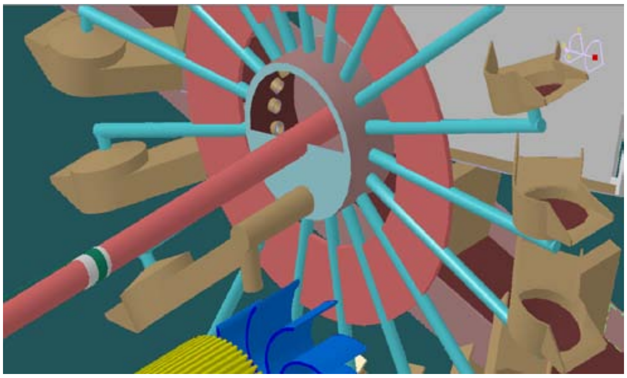
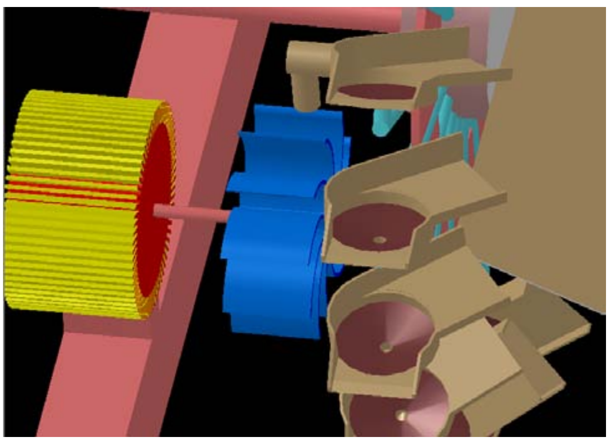
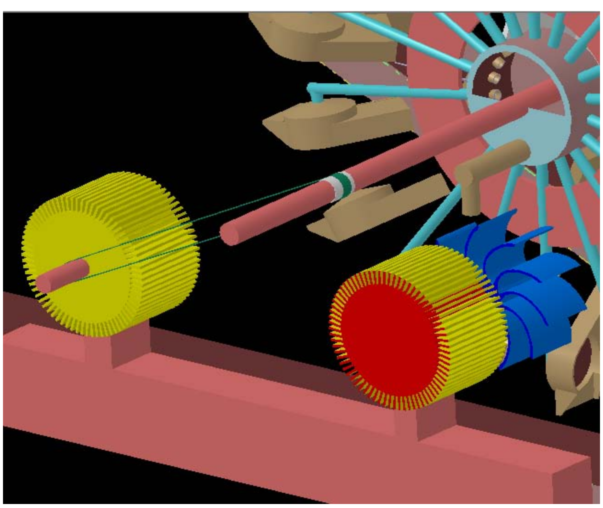


Closer View of First Electricity Generation Point



Closer View of Third Electricity Generation Point



VII. Advantages

- Electricity is generated at three points.
- Garbage is disposed safely.
- Waste Water and Garbage present in it separated to the extent.

VIII. Disadvantages

This purely depends on the flow of the water.

- Maintenance is a major problem

IX. Conclusion

On the way of many improvements to generate electricity from the waste water with the garbage this paper has added one more way which completely separates the waste water and garbage as well as generate electricity at three points.

X. Acknowledgement

I am using this oppurtunity to express my grattitude to my parents who supported me throughout the paper. I am thankful for their aspiring guidance and supervision during the process.

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Pressure and Temperature Response of Pneumatic System with Thermal Consideration

By Fazlar Rahman

Ahsanullah University of Science and Technology (AUST), Bangladesh

Abstract- The temperature and pressure response within control volume of a pneumatic system with thermal consideration is presented in this paper. The non-linear modeling equations of temperature and pressure are derived in a systematic way based on realistic estimation of heat transfer to the system, energy equation, ideal gas law and compressibility of fluid. The pressure and temperature response is compared analytically with the adiabatic condition and found that the system responds differently with thermal consideration.

Keywords: pneumatic system, thermal effect, temperature response, pressure response.

GJRE-A Classification: *FOR Code: 290501p*

PRESSUREANDTEMPERATURERESPONSEOFPNEUMATICSYSTEMWITHTHERMALCONSIDERATION

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Pressure and Temperature Response of Pneumatic System with Thermal Consideration

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Keywords: pneumatic system, thermal effect, temperature response, pressure response.

Nomenclature

ρ	Density of fluid
h	Specific enthalpy of fluid
h_c	Heat transfer coefficient or film coefficient
k	Ratio of specific heat
P_{cv}	Pressure inside control volume
R_{th}	Thermal resistance of system's wall
W	Work done at constant pressure
R	Gas constant
q	Rate of heat transfer
T_{cv}	Temperature inside control volume
V_{cv}	Control volume of the system
U	Internal energy
$\dot{}$	Rate of change with time
$\dot{m}_{in}$	Mass flow rate at inlet
$\dot{m}_{out}$	Mass flow rate at outlet
m_{net}	Mass inside the control volume
ρ_{cv}	Density of fluid
A_{th}	Area of thermal resistance
P_u	Pressure at upstream
P_d	Pressure at downstream

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I. Introduction

Pneumatic systems are an important part of the industrial world as compressed air can be easily and readily obtained. Pneumatic systems are widely used in industrial automation, such as drilling, gripping, spraying and other applications due to their special advantages, e.g. low cost, high power-to-weight ratio, cleanliness and ease of maintenance. It has long been promoted as low cost alternatives to hydraulic and electric servo motor in automated material handling tasks [1]. In spite of these advantages, Pneumatic systems are more complicated due to high compressibility and nonlinearities of the flow characteristics. In addition, when air is compressed, the density changes significantly which even further complicates the analytical considerations. Due to complexity of the models, which realistically describe the fluid power components and systems, the designers have elected to use only steady-state conditions in the process of developing of Pneumatic systems. However, in reality operation of Pneumatic systems are not steady-state condition [1-2]. The performance and reliability of the Pneumatic systems are depend on the pressure & temperature response within the control volume of the system. The mathematical models of pressure and temperature response are non-linear differential equations which are correlated to each other.

In general, the temperature variation within a control volume of a Pneumatic system is ignored in modeling and simultaneously declaring adiabatic condition in gas capacitance modeling. This approach disregard both temperature variations associated with gas compression as well as effect of heat transfer from the system's wall to the control volume or surrounding. It is observed that thermal consideration has significant effect on system response because of heat transfer takes place in between control volume and system's wall as well as effect of compressibility of pneumatic fluid [3].

The thermal effect of Pneumatic system, i.e. heat transfer in between control volume and the system's wall is not included in Fernandez and Woods [4]. They suggested that an accurate thermodynamic model will, furthermore, require inclusion of heat transfer effects and it is left for an expanded discussion [4]. To evaluate the thermal effect of Pneumatic system, the non-linear modeling equations of pressure and temperature response are developed (Appendix-A) and

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applied to a rigid pneumatic accumulator. Before modeling of non-linear differential equations, the theory of fluid power control, compressibility and technique of simulation have been studied well [3], [5-8].

The thermo-physical properties of fluid are considered homogenous within the control volume. Kinetic energy, potential energy and viscous friction of the fluid are neglected. Assuming, there is no frictional heating in the system and fluid follow the laws of perfect gases. The heat is transferred in between control volume and the system's wall by conduction only and other mechanisms of heat transfer are neglected.

The non-linear modeling equations are derived (Appendix-A) from the conservation of energy, first principles of pressure and temperature state equations for an ideal gas; which includes the rate of change of pressure, temperature and control volume. These equations are used to evaluate the temperature and pressure response within the control volume of a pneumatic accumulator.

II. Governing Equations

The governing equations are conservation of energy equation, ideal gas law, rate of change of internal energy, rate of work done, heat transfer rate, specific enthalpy, specific heat and mass flow rate; which are readily available in [3], [9].

The conservation of energy equation,

$$q_{in} - q_{out} + \dot{W} + h_{in}\,\dot{m}_{in} - h_{out}\,\dot{m}_{out} = \dot{U} \tag{1}$$

Ideal gas law, $P_{cv}\,V_{cv} = m_{cv}\,R\,T_{cv}$ (2)

Rate of change of internal energy,

$$\dot{U} = \frac{d}{dt}\left(C_v\,m_{cv}\,T_{cv}\right) \tag{3}$$

Rate of work done, $\dot{W} = -P_{cv}\dot{V}_{cv}$ (4)

Heat transfer rate,

$$q_{net} = q_{in} - q_{out} \tag{5.1}$$

$$q_{net} = \frac{T_w - T_{cv}}{R_{th}} \tag{5.2}$$

$$q_{net} = A_{th}\,h_c\left(T_w - T_{cv}\right) \tag{5.3}$$

Specific enthalpy,

$$h = C_p T \tag{6.1}$$

$$h_{in} = C_p T_{in} \tag{6.2}$$

$$h_{out} = C_p T_{out} \tag{6.3}$$

Specific heat,

$$k = \frac{C_p}{C_v} \tag{7.1}$$

$$C_v = \frac{R}{k-1} \tag{7.2}$$

Mass flow rate,

$$\dot{m}_{cv} = \dot{m}_{in} - \dot{m}_{out} \tag{8}$$

III. Modeling of Rate of Change of Pressure within Control Volume ($\dot{P}_{cv}$)

From governing equation (2), (3) and (7),

$$\dot{U} = \frac{d}{dt}\left(\frac{C_v}{R}\,P_{cv}\,V_{cv}\right) = \frac{C_v}{R}\left(P_{cv}\dot{V}_{cv} + V_{cv}\,\dot{P}_{cv}\right)$$

$$\dot{U} = \frac{1}{k-1}\left(P_{cv}\,\dot{V}_{cv} + V_{cv}\,\dot{P}_{cv}\right) \tag{9}$$

Substituting the value from equations (4) to (6) and (9) to the governing equation (1) and rearranging the variables yield,

$$\dot{P}_{cv} = \frac{kP_{cv}}{V_{cv}}\left(\frac{T_{in}\,\dot{m}_{in} - T_{out}\,\dot{m}_{out}}{\rho_{cv}\,T_{cv}} - \dot{V}_{cv}\right) + (k-1)h_c A_{th}\left(\frac{T_w - T_{cv}}{V_{cv}}\right) \tag{10}$$

The equation (10) is found consisted with [4] except thermal part or second right side part of the equation (10)

IV. Modeling of Rate of Change of Temperature within Control Volume ($\dot{T}_{cv}$)

From governing equation (3),

$$\dot{U} = C_v\left(m_{cv}\dot{T}_{cv} + T_{cv}\dot{m}_{cv}\right) \tag{11}$$

Substituting the value from equations (4) to (5), (8) and (11) to the governing equation (1) and rearranging the variables yield,

$$\dot{T}_{cv} = \frac{R}{V_{cv}}\left(\frac{T_{cv}}{P_{cv}}\right)\left[\dot{m}_{in}\left(k\,T_{in} - T_{cv}\right) - \dot{m}_{out}\,T_{cv}(k-1) - \frac{P_{cv}\,\dot{V}_{cv}}{C_v} + \frac{h_c\,A_{th}\,(T_w - T_{cv})}{C_v}\right] \tag{12}$$

The equation (12) is found consisted with [4] except thermal part or second right side part of the equation (12).

V. Modeling of Rate of Change of Control Volume ($\dot{V}_{cv}$)

The rate of change of control volume ($\dot{V}_{cv}$) depends on the system's physical characteristics, configuration and arrangement of the piston & cylinder of actuator. In case of rigid container, rate of change of control volume is equal to zero and other Pneumatic system like an actuator, rate of change of control volume can be determined from the physical characteristic of the actuator [3].

Consider a double acting pneumatic actuator (Fig. 1) with the following physical characteristics.

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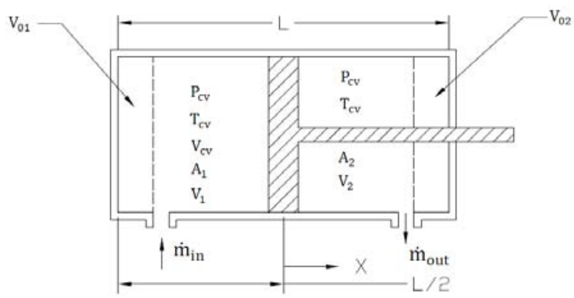

Fig.1. Configuration of double acting actuator.

Where,

V_1 = Volume of chamber[1] of the cylinder

V_2 = Volume of chamber[2] of the cylinder

A_1 = Area of chamber[1] of the cylinder

A_2 = Area of chamber[2] of the cylinder

V_{01} = Dead volume of chamber[1] of the cylinder

V_{02} = Dead volume of chamber[2] of the cylinder

L = Length of the cylinder

x = Position of the piston from neutral point

Assuming actuator's piston position at the middle point of the cylinder,

$$V_1 = V_{01} + A_1\left(\frac{L}{2} + x\right) \text{ and } V_2 = V_{02} + A_1\left(\frac{L}{2} - x\right)$$

Generalizing above equation,

$$V_i = V_{0i} + A_i\left(\frac{L}{2} + x\right) \text{ or } V_i = V_{0i} + A_i\left(\frac{L}{2} - x\right)$$

$$\frac{d}{dt}(V_i) = A_i\frac{d}{dt}(x) \quad \text{or} \quad \frac{d}{dt}(V_i) = A_i\frac{d}{dt}(-x)$$

$$\dot{V}_{cv} = A_i\dot{x} \text{ or } \dot{V}_{cv} = -A_i\dot{x} \tag{13}$$

VI. Modeling of Mass Flow Rate to Control Volume ($\dot{m}_{in}$ or $\dot{m}_{out}$)

The mass flow rate of compressible fluid flow through a restriction or through inlet and outlet valve port is given by [3],

$$\dot{m} = C_d\, A_s\, P_u \left(\frac{2}{R\,T_u}\right)^{\frac{1}{2}} \left(\frac{k}{k-1}\right)^{\frac{1}{2}} \left[\left(\frac{P_d}{P_u}\right)^{\frac{2}{k}} - \left(\frac{P_d}{P_u}\right)^{\frac{k+1}{k}}\right]^{\frac{1}{2}} \tag{14}$$

Where, C_d is the coefficient of discharge of Orifice meter. The mass flow rate depends on the ratio of downstream and upstream pressure. Equation (14) is subject to a phenomenon known as choking, which is unique to compressible flow. In choked flow, the mass flow rate will not increase with further decreasing in downstream pressure while upstream pressure is fixed, because sonic velocity is achieved at the throat at critical pressure ratio.

$$\left(\frac{P_d}{P_u}\right)_{critical} = \left[\frac{2}{k+1}\right]^{\frac{k}{k-1}} \tag{15}$$

The critical pressure ratio is limiting the mass flow rate through the orifice meter.

VII. Application of Modeling Equation to a Pneumatic System

The non-linear modeling equations can be applied to any Pneumatic system particularly in pneumatic actuator, accumulator and servo system to evaluate the system's pressure and temperature characteristics within control volume. All pneumatic power systems are synonymous with compressed air in the vicinity of 7 bar (100 psi). The four modeling equations [10], [12], [13] and [14] are non-linear differential equations and interrelated to each other. These non-linear modeling equations are applied to a pneumatic accumulator to evaluate the pressure and temperature response within the control volume. Working principles of most pneumatic systems are close to the vicinity of working principle of pneumatic accumulator since all of them work with high pressure compressed air [1], [8].

The characteristics of the pneumatic system is a rigid cylindrical accumulator of length 360 mm, outer diameter 22 mm and inner diameter 19 mm, which is charging from a static chamber of 0.70 MPa pressure and 15^{0}C air temperature through an Orifice meter (C_d = 0.65) of diameter 0.03 inch. The initial temperature at the wall of the accumulator is 20^{0}C and pressure one atmospheric pressure. Over all heat transfer coefficient or film coefficient at the wall of the accumulator is 50 Watt/m^2 K.

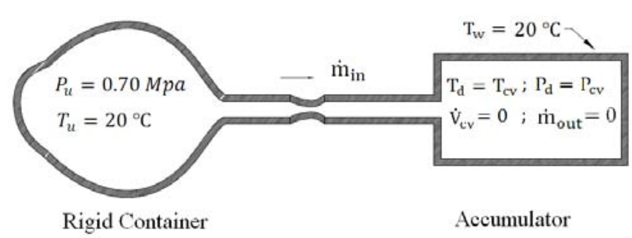

Fig.2. Charging of accumulator

The non-linear modeling equations are interrelated and solved with the following boundary conditions.

For rigid accumulator $\dot{V}_{cv} = 0$; $\dot{m}_{out} = 0$ and initial condition at time, t = 0, $\dot{m}_{in} = 0$; $P_{cv} = 1$ atmp and T_{cv} = 20^0 C = 293 K and T_u = 15^0 C = 288 K.

In adiabatic condition, $q_{net} = 0$ or no heat transfer in between control volume and the system's wall, which ultimately leads to $T_w = T_{cv}$ or isothermal condition.

VIII. Results and Discussion

The pressure and temperature increase significantly in thermal consideration than the adiabatic condition within control volume of the accumulator and it depends on initial temperature and pressure of the accumulator as well as of the charging system.

Temperature increases rapidly within short period of time than adiabatic condition because of instant compressibility, viscous friction, low heat capacitance or low specific heat of air. Usually, the polytropic equation $T_{cv} = T_{in}\left(\frac{P_{cv}}{P_{in}}\right)^{\frac{k-1}{k}}$ is used to predict the temperature but this equation is applied under closed or steady state condition. In Pneumatic system, mass added gradually and arbitrary to the system. So the thermal model of pressure and temperature response varies from the adiabatic model.

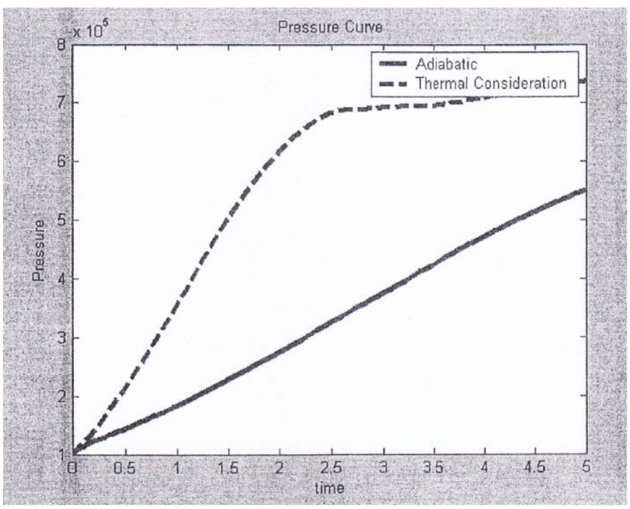

Fig.3. Pressure (N/m^2) response within accumulator (time in second).

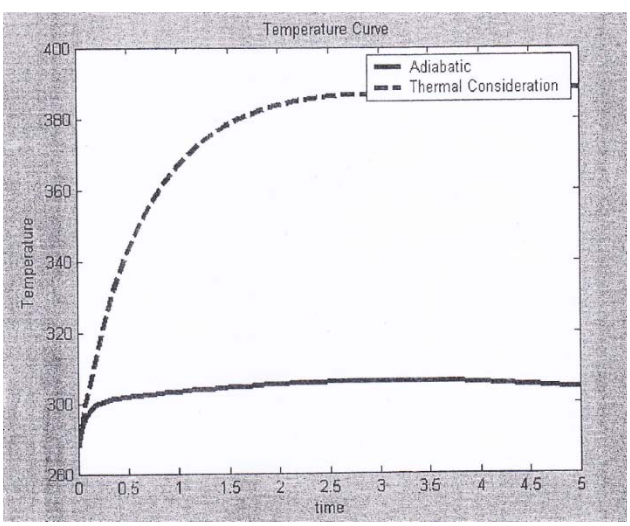

Fig.4. Temperature (K) response within accumulator (time in second).

IX. Conclusion

Thermal consideration in the modeling of pressure and temperature response of Pneumatic system has significant effect than adiabatic modeling especially to the system working in a high pressure and temperature environment. In thermal consideration, pressure and temperature increase exponentially within short period of time than adiabatic condition. Since performance of Pneumatic systems depend on the response of pressure, the thermal consideration in pneumatic system will improve the system's performance, accuracy, reliability as well as response time.

Acknowledgement

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Appendix-A

Modeling of Rate of Change of Pressure ($\dot{P}_{cv}$):

From governing equation (2), (3) and (7),

$$\dot{U} = \frac{d}{dt}\left(\frac{C_v}{R}P_{cv}V_{cv}\right) = \frac{C_v}{R}\left(P_{cv}\dot{V}_{cv} + V_{cv}\dot{P}_{cv}\right)$$

$$\dot{U} = \frac{1}{k-1}\left(P_{cv}\dot{V}_{cv} + V_{cv}\dot{P}_{cv}\right) \quad (9)$$

Substituting the value from equations (4) to (6) and (9) in the governing equation (1)

$$q_{net} - P_{cv}\dot{V}_{cv} + C_p\left(T_{in}\dot{m}_{in} - T_{out}\dot{m}_{out}\right) = \frac{1}{k-1}\left(P_{cv}\dot{V}_{cv} + V_{cv}\dot{P}_{cv}\right)$$

$$q_{net} - P_{cv}\dot{V}_{cv}\left(1 + \frac{1}{k-1}\right) + C_p\left(T_{in}\dot{m}_{in} - T_{out}\dot{m}_{out}\right) = \frac{V_{cv}\dot{P}_{cv}}{k-1}$$

Rearranging above equation,

$$\dot{P}_{cv} = \left(\frac{k-1}{V_{cv}}\right)q_{net} - \left(\frac{P_{cv}\dot{V}_{cv}}{V_{cv}}\right)k + \left(\frac{k-1}{V_{cv}}\right)C_p\left(T_{in}\dot{m}_{in} - T_{out}\dot{m}_{out}\right)$$

$$\dot{P}_{cv} = \frac{kR}{V_{cv}}\left(T_{in}\dot{m}_{in} - T_{out}\dot{m}_{out}\right) - \left(\frac{P_{cv}\dot{V}_{cv}}{V_{cv}}\right)k + \left(\frac{k-1}{V_{cv}}\right)q_{net}$$

Substituting value of q_{net} from equation (5),

$$\dot{P}_{cv} = \frac{kP_{cv}}{V_{cv}}\left(\frac{T_{in}\dot{m}_{in} - T_{out}\dot{m}_{out}}{\frac{P_{cv}}{R}} - \dot{V}_{cv}\right) + \left(\frac{k-1}{V_{cv}}\right)\left(\frac{T_w - T_{cv}}{R_{th}}\right)$$

$$\dot{P}_{cv} = \frac{kP_{cv}}{V_{cv}}\left(\frac{T_{in}\ \dot{m}_{in} - T_{out}\ \dot{m}_{out}}{\rho_{cv} T_{cv}} - \dot{V}_{cv}\right) + \frac{k-1}{V_{cv}}\left(\frac{T_w - T_{cv}}{R_{th}}\right)$$

$$\dot{P}_{cv} = \frac{kP_{cv}}{V_{cv}}\left(\frac{T_{in}\ \dot{m}_{in} - T_{out}\ \dot{m}_{out}}{\rho_{cv} T_{cv}} - \dot{V}_{cv}\right) + (k-1)h_c A_{th}\left(\frac{T_w - T_{cv}}{V_{cv}}\right) \quad (10)$$

For rigid accumulator, $\dot{V}_{cv} = 0$; $\dot{m}_{out} = 0$. Substituting in the value in equation (10)

$$\dot{P}_{cv} = \frac{k\,R}{V_{cv}}(T_{in}\dot{m}_{in}) + \frac{(k-1)h_c A_{th}}{V_{cv}}(T_w - T_{cv})$$

Modeling of Rate of Change of Temperature ($\dot{T}_{cv}$):

From governing equation (3),

$$\dot{U} = C_v\left(m_{cv}\dot{T}_{cv} + T_{cv}\dot{m}_{cv}\right) \quad (11)$$

Substituting the value from equation (4) to (5) and (11) to the equation (1),

$$q_{net} - P_{cv}\dot{V}_{cv} + C_p(T_{in}\dot{m}_{in} - T_{out}\ \dot{m}_{out}) = C_v\left(m_{cv}\dot{T}_{cv} + \dot{m}_{cv}\ T_{cv}\right)$$

Substituting $\dot{m}_{cv}$ from equation (8),

$$q_{net} - P_{cv}\dot{V}_{cv} + C_p(T_{in}\dot{m}_{in} - T_{out}\ \dot{m}_{out}) = C_v\left[m_{cv}\dot{T}_{cv} + T_{cv}\ (\dot{m}_{in} - \dot{m}_{out})\right]$$

$$C_v m_{cv}\dot{T}_{cv} = q_{net} - P_{cv}\ \dot{V}_{cv} + \dot{m}_{in}\left(C_p\ T_{in} - C_v\ T_{cv}\right) - \dot{m}_{out}\left(C_p\ T_{cv} - C_v\ T_{cv}\right)$$

$$\dot{T}_{cv} = \frac{q_{net}}{m_{cv}\ C_v} - \frac{P_{cv}\ \dot{V}_{cv}}{m_{cv}\ C_v} + \dot{m}_{in}\left(\frac{C_p\ T_{in} - C_v\ T_{cv}}{m_{cv}\ C_v}\right) - \dot{m}_{out}\left(\frac{C_p T_{cv} - C_v T_{cv}}{m_{cv}\ C_v}\right)$$

$$\dot{T}_{cv} = \frac{\dot{m}_{in}}{m_{cv}}(k\ T_{in} - T_{cv}) - \frac{\dot{m}_{out}}{m_{cv}}T_{cv}(k-1) + \frac{q_{net}}{m_{cv}\ C_v} - \frac{P_{cv}\ \dot{V}_{cv}}{m_{cv}\ C_v}$$

$$\dot{T}_{cv} = \frac{1}{m_{cv}}\left[\dot{m}_{in}(k\ T_{in} - T_{cv}) - \dot{m}_{out}\ T_{cv}(k-1) - \frac{P_{cv}\ \dot{V}_{cv}}{C_v} + \frac{h_c\ A_{th}\ (T_w\ - T_{cv})}{C_v}\right]$$

$$\dot{T}_{cv} = \frac{R}{V_{cv}}\left(\frac{T_{cv}}{P_{cv}}\right)\left[\dot{m}_{in}(k\ T_{in} - T_{cv}) - \dot{m}_{out}\ T_{cv}(k-1) - \frac{P_{cv}\ \dot{V}_{cv}}{C_v} + \frac{h_c\ A_{th}\ (T_w\ - T_{cv})}{C_v}\right] \quad (12)$$

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Optimization of Packed Concrete Bed Energy Storage System

By Adeyanju A. A. & Manohar K

Ekiti State University, Nigeria

Abstract- One of the major challenges with the use of solar thermal energy is the intermittent nature. As such, present day research is geared towards energy storage systems in which thermal energy is stored during the day for later use. However, in many engineering applications there is a continuous steady demand for energy. Hence, this study is focused on the optimization of a packed bed energy storage system to provide an uninterrupted continuous supply of energy in the absence of or availability of solar energy.

A mathematical model was developed from consideration of the basic phenomena of heat transfer to predict the thermal behavior of a simultaneous charging, storage and discharging system during a heating cycle.

Optimization of the entire storage system were carried out and it was discovered that the ratio of optimum volume to area at airflow rate of 0.0094, 0.012, 0.014, 0.017, 0.019, 0.021, 0.024, 0.026, 0.028, 0.031, 0.033, 0.035, 0.038, 0.040, 0.042 and 0.045m3/s were 0.123, 0.154, 0.185, 0.215, 0.247, 0.276, 0.308, 0.338, 0.369, 0.4, 0.43, 0.462, 0.491, 0.523, 0.554, and 0.584, respectively.

Keywords: packed concrete bed, optimization, energy storage system, mathematical model.

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OPTIMIZATIONOFPACKEDCONCRETEBEDENERGYSTORAGESYSTEM

Strictly as per the compliance and regulations of:

Optimization of Packed Concrete Bed Energy Storage System

Adeyanju A. A. [α] & Manohar K. [σ]

Abstract- One of the major challenges with the use of solar thermal energy is the intermittent nature. As such, present day research is geared towards energy storage systems in which thermal energy is stored during the day for later use. However, in many engineering applications there is a continuous steady demand for energy. Hence, this study is focused on the optimization of a packed bed energy storage system to provide an uninterrupted continuous supply of energy in the absence of or availability of solar energy.

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It was discovered that as a result of standard model, charged thermal energy increases generally with the increasing of the packed bed volume and that the intersection point of the two extreme models with flow rate shows the optimum volume of the packed bed.

Keywords: packed concrete bed, optimization, energy storage system, mathematical model.

Nomenclature

where,

G = Air mass velocity through the bed(kg/m^{2}s)

α = *Solar* absorptance

τ = *Solar* transmittance

t = time

m = mass (kg)

$\dot{m}$ = mass flow rate of air (kg/s)

T = *Temperature* (K)

h = heat transfer coefficient(W/m^2K)

W = Width of the solar collector(m)

subscript:

a = ambient

ab = absorber

p = plate

r = radiative

c/ct = concrete/copper tube

s = solar

conv = convective

g = glazing

fa = air above absorber

fb = air below absorber

I. Introduction

The design and optimization of Thermal Energy Storage systems has drawn specific attention, since it is the ecologic and economic benefits to this technology which make it an attractive alternative in the first place.

There are two main streams of research in this area; works which concentrate on the storage tank as a whole, and ones which concentrate on the thermal energy storage and retrieval process. For each, there are a number of techniques used, which can be broadly grouped as either analytical or numerical techniques. Experimental data in this field is also a common verification tool for many of the works studied here.

The thermal energy storage (TES) can be defined as the temporary storage of thermal energy at high or low temperatures. The TES is not a new concept, and at has been used for centuries. Energy storage can reduce the time or rate mismatch between energy supply and energy demand, and it plays an important role in energy conservation.

Energy storage improves performance of energy systems by smoothing supply and increasing reliability. For example, storage would improve the performance of a power generating plant by load leveling. The higher efficiency would lead to energy conservation and improve cost effectiveness. Some of the renewable energy sources can only provide energy intermittently.

Although the sun provides an abundant, clean and safe source of energy, the supply of this energy is periodic following yearly and diurnal cycles; it is

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intermittent, often unpredictable and diffused. Its density is low compared with the energy flux densities found in conventional fossil energy devices like coal or oil-fired furnaces.

The demand for energy, on the other hand, is also unsteady following yearly and diurnal cycles for both industrial and personal needs. Therefore the need for the storage of solar energy cannot be avoided. Otherwise, solar energy has to be used as soon as it is received. In comparison, the present yield in energy gained by fossil fuels and waterpower amounts to about 70×10^{12} kWh. But the technical use of solar energy presently poses problems primarily because of inefficient collection and storage.

One of the important characteristics of a storage system is the length of time during which energy can be kept stored with acceptable losses. If solar energy is converted into a fuel such as hydrogen, there will be no such a time limit. Storage in the form of thermal energy may last for very short times because of losses by radiation, convection and conduction. Another important characteristic of a storage system is its volumetric energy capacity, or the amount of energy stored per unit volume. The smaller the volume, the better is the storage system. Therefore, a good system should have a long storage time and a small volume per unit of stored energy.

If mass specific heat capacity is not small, denser materials have smaller volumes and correspondingly an advantage of larger energy capacity per unit volume. The space available is limited both in transport and in habitat applications. The volume occupied by the present available storage systems is considerable and may be an important factor in limiting the size of storage provided. The amount of energy storage provided is dictated by the cost. The cost of floor space or volumetric space should be one of the parameters in optimizing the size of storage.

The technology of thermal energy storage has been developed to a point where it can have a significant effect on modern life. The major nontechnical use of thermal storage was to maintain a constant temperature in dwelling, to keep it warm during cold winter nights. Large stones, blocks of cast iron, and ceramics were used to store heat from an evening fire for the entire night. With the advent of the industrial revolution, thermal energy storage introduced as a by-product of the energy production. A variety of new techniques of thermal energy storage have become possible in the past.

A major application for thermal storage today is in family dwellings. Heat storage at power plants typically is in the form of steam or hot water and is usually for a short time. Very recently other materials such as oils having very high boiling point, have been suggested as heat storage substances for the electric utilities. Other materials that have a high heat of fusion at high temperatures have also been suggested for this application. Another application of thermal energy storage on the electric utilities is to provide hot water. Perhaps the most promising application of thermal energy storage is for solar heated structures, and almost any material can be used for thermal energy storage.

A theoretical approach to the optimum volume of packed bed from a standpoint of capacity efficiency, charged thermal energy and the optimum air flow rate for an air-based solar heating storage system was considered in this study in order to optimize the system. The charged thermal energy in a packed bed for an air-based solar heating system depends on the following parameters; air flow rate, collector area, packed concrete bed volume, collector performance, intensity of solar radiation and ambient temperature (Duffie and Beckman 2006).

The parameters of a solar heating system specified by designers are basically collector area, air flow rate, packed bed volume, and other parameters are given as design conditions.

II. Thermal Energy Storage Systems

The review of works in sensible Thermal Energy Storage systems is interesting to note. Sensible thermal storage is possible in a wide number of mediums, both liquid and solid. Liquid media for thermal storage include oils, water, molten salts, etc. while solid media are usually in the form of rock, concrete or metals, and can include alloys such as zirconium oxide for extreme temperatures [Nsofor, 2005]. There are a number of works regarding both cases, though here we will consider two short examples; a solar pond and a rock bed, both designed for solar energy storage.

Karakilcik et al. (2006) perform an interesting performance investigation of a solar pond in Adana, Turkey. The pond was filled with salty water to form three zones of varying density which do not mix. The upper zone is the freshwater layer at the top of the pond, and is fed by rainwater and feed water to compensate for water lost by evaporation. The middle layer, called the insulation zone, is designed to keep the freshwater zone and the lower zone from mixing, while absorbing solar energy in the form of heat. The lower zone, which is the densest mixture, retains the most heat, and absorbs the most heat from the sun, contains the heat exchangers to the solar pond and exchanges heat with both the bottom of the solar tank as well as the insulation zone. As expected, the highest thermal efficiencies of the system came in mid-summer, when solar and ground radiation levels are at their highest and temperature gradients are quite low.

A performance investigation of a solar air heater connected to a rock bed thermal storage device is considered by Choudhury et al. (1995). A two-pass, single cover solar air heater is coupled to the rock bed, while operational parameters and geometric design are varied in order to study the effect on efficiency. Factors such as charging time, rock bed size, individual rock size, air velocity and void fraction are studied, as are the effects on thermal efficiency of the system. It was found that the charging time had the most significant effect on the overall efficiency, with the optimal charging time set at 8 hours for this particular location in New Delhi.

It has been conventional, as has been done in the above works, to use energy consumption, energy efficiency and cost minimization as the main benchmarks in determining optimal system configurations. However, in recent years, a new approach has been exercised which simultaneously reduces both energy and cost inputs.

These exergy analyses have been the preferred method of late to better analyze the performance of these systems, as well as the location and severity of energy losses. Dincer and Rosen (2002) discuss the usefulness of exergy analysis in the performance and optimization of various TES systems. During exergetic analyses of aquifer, stratified storage and cold TES systems, appropriate efficiency measures are introduced, is the increasing importance of temperature, especially during cold TES.

Rosen et al. (1999) provide detailed exergy analyses of many types of cold TES systems. They consider full cycles of charging, storage and discharging in both sensible and latent systems. The results indicate that exergy clearly provides a more realistic and accurate measure of the performance of a cold TES system, since it treats "cold" as a valuable commodity. This is in contrast to the energy analysis, which treats cold as an undesirable commodity. In addition, it was summarized that the exergy analysis is substantially more useful than the energy analysis. Furthering this study, Rosen et al. (2000) examine an industrial sized encapsulated ice TES unit during full charging, discharging and storage cycles. The results indicate that in addition to energy analyses being incomplete for cold TES, they also achieve misleadingly high efficiency values.

For the system in question, the overall energy efficiency was 99.5%, while the exergy efficiency was calculated to be 50.9%. This solidifies the fact that exergy analyses allow for a more complete diagnostic of cold TES systems and the locations of their shortfalls.

Henze (2005) investigate the relationships between cost savings and energy consumption associated with the conventional control of typical TES systems. Items accounted for in these optimizations include varying fan power consumption, as well as chiller and storage coefficient of performance. The results indicate that buildings can be operated in such a manner as to reduce overall costs, with only a small increase in total energy consumption.

III. Methodology

a) Environmental Conditions of the Optimized Systems

An outline of the system to be optimized was shown in Figure 1.0. The system includes flat-plate solar collectors connected in parallel, fans and a storage system which contain a packed spherical shaped concrete and some concretes imbedded with copper tube. Solar heating media air circulates through the collectors and the bed in charging mode and the discharging occur through the air flowing inside the copper tube. The air heated at the collector flows into the upper part of the packed concrete bed and collected heat transfers from air to concrete/copper tube due to temperature difference, and then air flows into the collectors through the lower part of the bed.

A steady state model for the solar collector and the heat transfer model in the packed bed are used for the system analysis and these are carried out under the typical conditions shown in Tables 1.0 and 2.0.

The incident solar radiation depends on latitude, solar constant, date, weather, orientation and slope of collector.

Table 1.0 : Mean Solar Insolation data for Trinidad

Time, t(hr)	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18
Solar Insolation (Langley/minute)	0.17	0.51	0.89	1.21	1.38	1.51	1.45	1.28	1.09	0.81	0.51	0.19
Solar Insolation (W/m^2)	119	353	620	844	960	1052	1012	893	761	565	353	134

Kochhar (1976)

Table 2.0 : Storage systems conditions

Parameters	Values
Solar collector	
Solar collector	Flat plate
Collector orientation	South
Collector tilt angle	10^0 (Kochhar 1976)
$F^{'}(\tau\alpha)_i$	0.76
$F^{'}U_L$	3.37
Environmental conditions	
Latitude	10^0N (Trinidad)
Permeability of atmosphere	0.8
Weather	Clear day
Ambient Temperature	24^OC
Packed Bed conditions	
Void fraction	0.4 m^3/m^2
C_p of air	1.005KJ/KgK
C_p of concrete	1130KJ/KgK
$\dot{V}$	20 – 95 cfm
Density of air	1.177Kg/m^3
Density of concrete	2400Kg/m^3

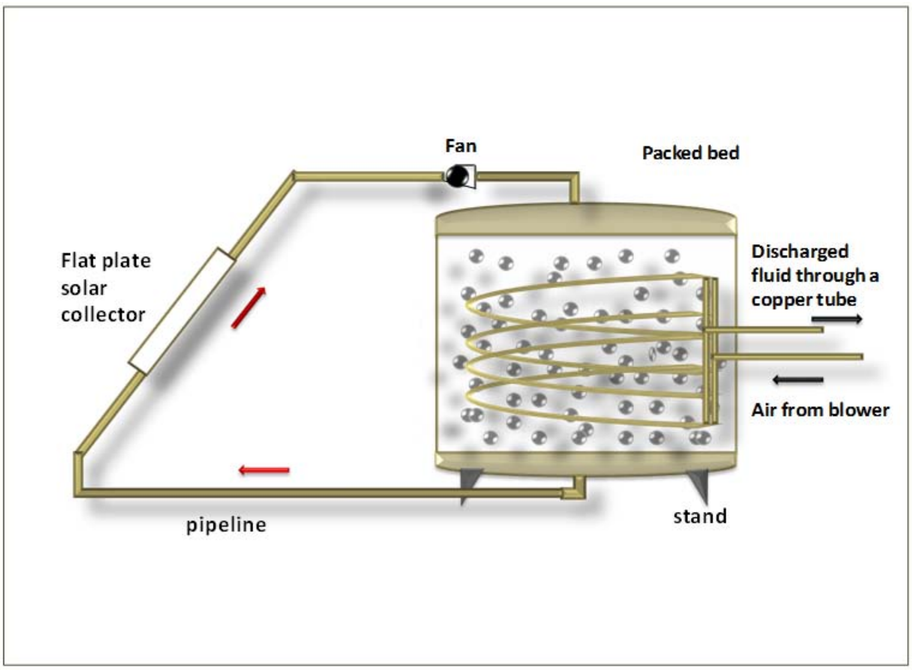

Figure 1.0 : Schematic of Storage systems for optimization

b) Collector Model

Thermal efficiency of solar collector is defined as the ratio of useful energy gain by the air to the solar radiation incident on the plate of the collector:

$$\eta = \frac{Q_u}{HA_p} \quad (1)$$

In terms of standard non-dimensional parameters for collectors, the thermal efficiency of a solar collector can be written as:

$$\eta = \left[F^{'}(\tau\alpha)_i - F^{'}U_L \frac{(T_{in,coll} - T_f)}{H} \right] \quad (2)$$

$$F^{'} = \left(\frac{\dot{m}_f C_f}{A_p U_L} \right) \left(1 - e^{\left[\frac{A_p U_L}{\dot{m}_f C_f} \right]} \right) \quad (3)$$

$Where, U_L$ = Collector loss coefficient (W/m^2K)

$F^{'}$ = Collector efficiency factor (dimensionless)

On the other hand, collector efficiency can also be described as follows (Duffie and Beckman 2006):

$$\eta = \left[\frac{C_f \rho_f \dot{V} \left(T_{out,coll} - T_{in,coll} \right)}{HA_{coll}} \right] \quad (4)$$

ρ_f = Density of air (Kg/m^3)

H = Solar radiation (W/m^2)

A_{coll} = Area of collector (m^2)

The collector model which gives the air temperature at the collector outlet was derived from equation (2) and (4) as follows

$$T_{out,coll} = \frac{\eta HA_{coll}}{C_f \rho_f \dot{V}} + T_{in,coll} \quad (5)$$

c) Packed Bed Standard Model

In this study, the Schumann model was used as the standard model of the packed bed and the basic assumptions leading to the Schumann model are one dimensional plug flow, no axial thermal conduction, constant properties, no heat loss to environment and no temperature gradients within solid particles. It was additionally assumed that specific heat of air is neglected. The differential equations for fluid and solid temperatures were written as:

$$C_f \rho_f \dot{V} \left(\frac{\partial T_{b,f}}{\partial x} \right) = h_V A_b \left(T_{b,s} - T_{b,f} \right) \quad (6)$$

and

$$C_{b,s} \rho_{b,s} A_b (1-\varepsilon) \left(\frac{\partial T_{b,s}}{\partial t} \right) = h_V A_b \left(T_{b,f} - T_{b,s} \right) \quad (7)$$

where, $T_{b,s}$ = *Temperature* of solid in bed (K)

$T_{b,f}$ = *Temperature* of air in the bed (K)

$C_{b,s}$ = *Specific* heat capacity of solid in bed (KJ/KgK)

$\rho_{b,s}$ = Density of solid in bed (Kg/m^3)

d_c = Diameter of concrete (m)

$$h_V = 1.4 \left(\frac{\dot{V} \rho_f}{d_c} \right)^{0.76} \quad (8)$$

The charged thermal energy per day was derived from the temperature distribution in the packed bed as follows:

$$Q_s = C_{b,s} \rho_{b,s} A_b (1-\varepsilon) \int_0^{l_b} \left(T_{b,s(t-end)} - T_a \right) dx \quad (9)$$

The dimensional proportion of the packed bed was fixed as 1:1:2 (length of the bed, l_b) for the standard model simulations.

IV. Results and Discussion

The results of the optimization of the standard model under the typical conditions (Table 1.0 and 2.0) and for air flow rates 0.0094, 0.012, 0.014, 0.017, 0.019, 0.021, 0.024, 0.026, 0.028, 0.031, 0.033, 0.035, 0.038, 0.040, 0.042 and 0.045m^3/s were shown in Table 3.0.

The effect of the charged thermal energy on the packed bed volume was illustrated in Figure 1.0. In this Figure, A_{coll} is the collector area, Q_s is the charged thermal energy in a day and V is the rock bed volume.

The charged thermal energy increases generally along with the increasing of the bed volume, but the charged thermal energy has an upper limit corresponding to each air flow rate. The minimum volume of packed bed in which it is charged almost upper limit is regarded as the optimum volume of the packed bed from a capacity efficiency standpoint.

Regardless of the air flow rate, the increasing curves of the charged thermal energy overlap each other in the range of smaller concrete volume than the optimum one.

Table 3.0 : Optimization of the Packed Bed Storage System

	Temp $T_{col,out}$ (^{O}C)	Volumetric Heat transfer coefficient (h_v)	Thermal energy charged (Q_S) KJ			Q_S/A_{coll} KJ/m^2			V_{opt}/A_{coll} m^3/m^2	$\dot{V}/A_{coll}$ $m^3/s/m^2$
Air flow rate/ m^3/s			D_C= 0.065m	D_C= 0.08m	D_C= 0.11m	D_C= 0.065 m	D_C= 0.08m	D_C= 0.11m		
0.0094	64.60	0.352	1.63	3.05	7.62	1.09	2.03	5.08	0.123	0.0063
0.012	57.11	0.419	2.86	5.52	13.77	1.91	3.68	9.18	0.154	0.008
0.014	52.10	0.488	3.56	6.67	16.63	2.37	4.45	11.09	0.185	0.0093
0.017	48.51	0.544	3.97	7.44	18.55	2.65	4.96	12.37	0.215	0.0113
0.019	45.82	0.604	4.26	7.96	19.87	2.84	5.31	13.25	0.247	0.0127
0.021	43.73	0.662	4.46	8.34	20.82	2.97	5.56	13.88	0.276	0.014
0.024	42.06	0.719	4.57	8.54	21.32	3.05	5.69	14.21	0.308	0.016
0.026	40.69	0.774	4.60	8.61	21.48	3.07	5.74	14.32	0.338	0.0173
0.028	39.55	0.829	4.60	8.62	21.49	3.07	5.75	14.33	0.369	0.0187
0.031	38.58	0.882	4.61	8.62	21.53	3.07	5.75	14.33	0.400	0.0207
0.033	37.76	0.935	4.61	8.63	21.54	3.07	5.75	14.36	0.430	0.022
0.035	37.04	0.986	4.62	8.64	21.55	3.08	5.76	14.37	0.462	0.0233
0.038	36.41	1.037	4.63	8.66	21.56	3.09	5.77	14.37	0.491	0.0253
0.040	35.86	1.088	4.64	8.67	21.57	3.09	5.78	14.38	0.523	0.0267
0.042	35.37	1.137	4.65	8.68	21.58	3.10	5.79	14.39	0.554	0.028
0.045	34.93	1.186	4.67	8.69	21.60	3.11	5.79	14.4	0.584	0.03

The outlet temperatures of the collector at air flow rates 0.0094, 0.012, 0.014, 0.017, 0.019, 0.021, 0.024, 0.026, 0.028, 0.031, 0.033, 0.035, 0.038, 0.040, 0.042 and 0.045m^3/s were shown in Figure 3.0.

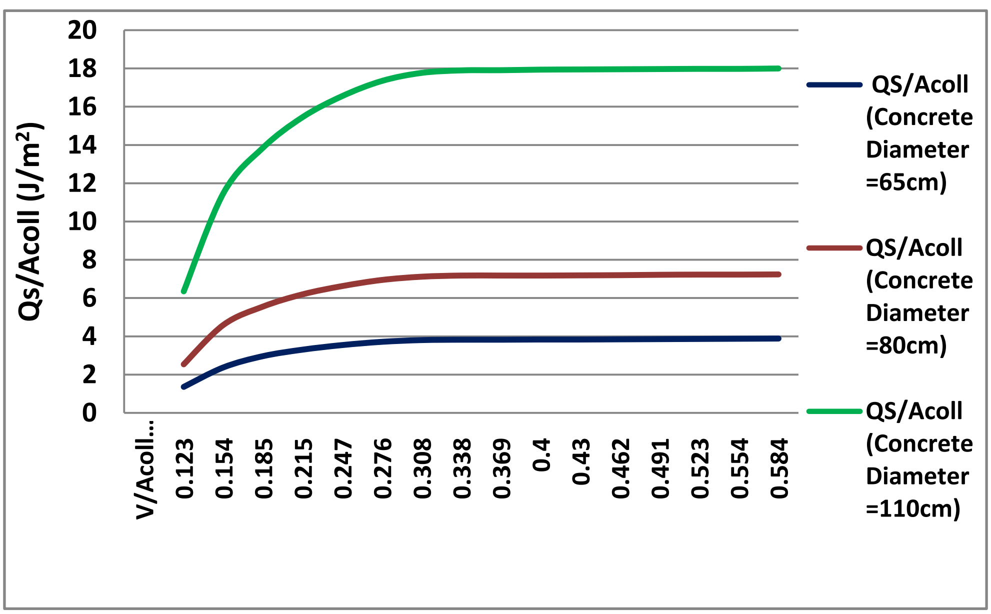

Figure 2.0 : Charged thermal energy in a day along with packed bed volume at the collector for spherical shaped concrete of diameter 0.065, 0.08 and 0.11m

a) *Packed Bed Storage System Optimum Volume Estimation*

The increasing curves of the charged thermal energy in bed as shown in Figure 2.0 were represented by a model on the assumption of infinite air flow rate. On the other hand, the relationship between the maximum charged thermal energy in bed and air flow rate was represented by a model on the assumption of infinite bed volume. The relationship between air flow rate and the optimum volume of the bed was approximately obtained as theoretical solution of simultaneous equations for two models on the assumption of extreme conditions.

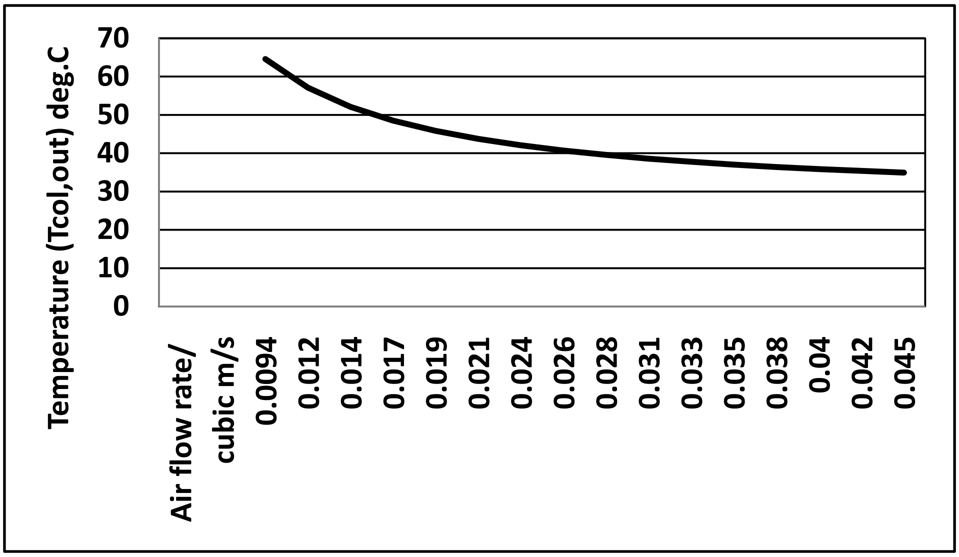

Figure 3.0 : Collector outlet temperatures at varying air flow rate

b) Two Models under Extreme Conditions

i. *The model of infinite packed bed volume*

This model was derived from Equations (8) and (9) under the following assumptions.

a. The outlet air temperature of the bed was identical to initial temperature of the bed at all time.
b. The heat loss was taken account of only at the collector.

Then, the outlet air temperature of the collector resulted to:

$$T_{out,coll} = \frac{\eta H A_{coll}}{C_f \rho_f \dot{V}} + T_o \tag{10}$$

The thermal energy charged in a day was represented as the following equation.

$$Q_s = C_f \rho_f \dot{V} \int_{t_{in}}^{t_{end}} \left(T_{out,coll} - T_o\right) dt \tag{11}$$

Combining equations (10) and (11) and solve for thermal energy charged per collector area produced the following equation.

$$\frac{Q_s}{A_{coll}} = \frac{\frac{\dot{V}}{A_{coll}}}{\frac{\dot{V}}{A_{coll}} + \frac{1}{2}\frac{F'U_L}{C_f \rho_f}} \times \left\{F'U_L\left(T_{in,coll} - T_f\right)\left(t_{end(\dot{V})} - t_{in(\dot{V})}\right) + F'(\tau\alpha)_o \int_{t_{in}(\dot{V})}^{t_{end}(\dot{V})} H dt\right\} \tag{12}$$

ii. *The model of infinite air flow rate*

This model was derived from equation (5) on the following assumptions.

a. The collected heat was entirely charged to spherical shaped concrete in the packed bed.
b. The temperature of air and the spherical shaped concrete in the bed was identical to the outlet air temperature of the collector.
c. The heat loss was taken account of only at the collector.
d. The heat capacity of air in the bed was neglected.

The heat balance equation for the packed bed was represented as follows:

$$C_b \rho_b V \frac{\partial T_{b,c/ct}}{\partial t} = \left\{F'(\tau\alpha)_o H - F'U_L\left(T_{b,c/ct} - T_a\right)\right\} H A_{coll} \tag{13}$$

The thermal energy charged in the bed per day resulted to:

$$Q_s = C_b \rho_b V \left(T_{b,c/ct} - T_o\right) \tag{14}$$

Combining equations (13) and (14) gives the charged thermal energy per unit collector area.

$$\frac{Q_s}{A_{coll}} = F^{'}\left(\tau\alpha\right)_o \exp\left[-\frac{F^{'}U_L\left(T_{in,coll}-T_f\right)\left(t_{end(\dot{V})}-t_{in(\dot{V})}\right)}{C_b\rho_b}\frac{A_{coll}}{V}\right]\times$$

$$\int_{t_{in}(\dot{V})}^{t_{end}(\dot{V})}\left(H\right)\exp\left[\frac{F^{'}U_L\left(T_{in,coll}-T_f\right)\left(t_{end(\dot{V})}-t_{in(\dot{V})}\right)}{C_b\rho_b}\frac{A_{coll}}{V}\right]dt+$$

$$C_b\rho_b\frac{V}{A_{coll}}\left\{1-\exp\left[\frac{F^{'}U_L\left(T_{in,coll}-T_f\right)\left(t_{end(\dot{V})}-t_{in(\dot{V})}\right)}{C_b\rho_b}\frac{A_{coll}}{V}\right]\right\}\times\left(T_a-T_o\right) \quad (15)$$

c) The Extreme Models Results

The result of the standard model and two extreme models at collector were shown in Figure 4.0. It was considered that the intersection point of two extreme models shows the optimum volume of packed bed storage system for an air flow rates 0.0094, 0.012, 0.014, 0.017, 0.019, 0.021, 0.024, 0.026, 0.028, 0.031, 0.033, 0.035, 0.038, 0.040, 0.042 and 0.045m^3/s.

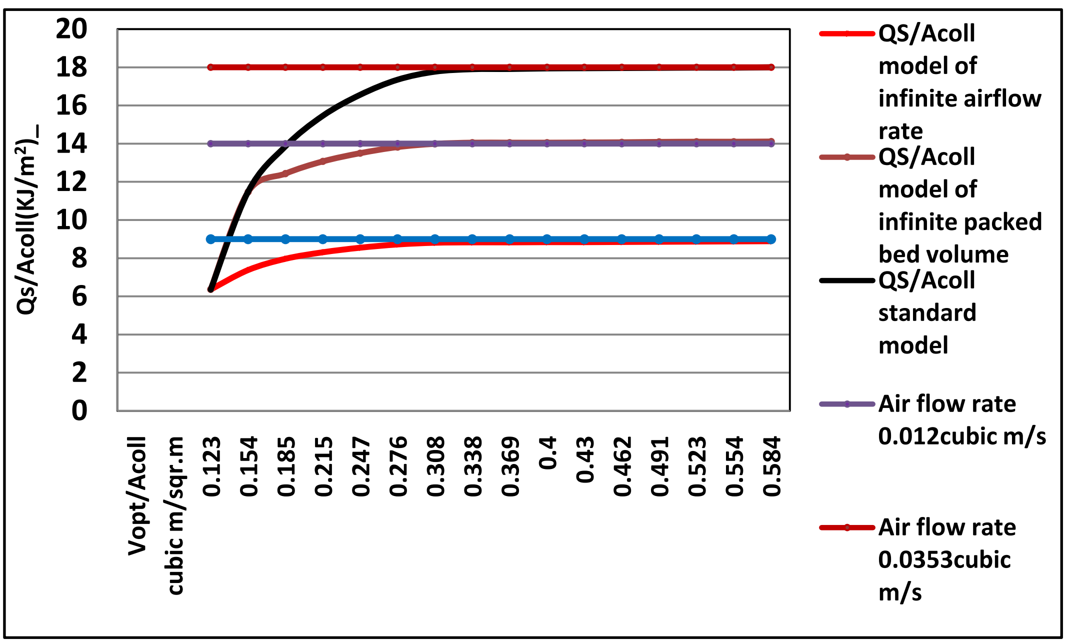

Figure 4.0 : Results of the standard model and two extreme models for the charged thermal energy along with the packed bed volume

d) Packed Bed Optimum Volume Linear Model

The previous results of extreme models shown in Figure 4.0 suggest that the relationship between the optimum volume from a capacity efficiency standpoint and the air flow rate was presented in a form of apparent linear equation.

The Combination of equations (12) and (15) produced the following linear equation.

$$\frac{V_{opt}}{A_{opt}} = Z\left(\frac{\dot{V}}{A_{coll}}\right) \quad (16)$$

$$\text{Where, } Z = \frac{2C_f\rho_f}{F^{'}U_L D_{V_{opt}}}\left\{F^{'}\left(\tau\alpha\right)_o\frac{V_{opt}}{A_{coll}}\int_{t_{in}(\dot{V})}^{t_{end}(\dot{V})}Hdt\right\}-$$

$$F^{'}U_L\frac{V_{opt}}{A_{coll}}\left(T_o-T_a\right)\left(t_{end(\dot{V})}-t_{in(\dot{V})}\right)-D_{V_{opt}}\frac{V_{opt}}{A_{coll}} \quad (17)$$

$$and, D_{V_{opt}} = F'(\tau\alpha)_o \int_{t_{in}(\dot{V})}^{t_{end}(\dot{V})} (H) \exp\left[\frac{F'U_L}{C_b\rho_b}\frac{A_{coll}}{V_{opt}}\left(t - t_{end(\dot{V})}\right)\right] dt -$$

$$C_b\rho_b \frac{V_{opt}}{A_{coll}}(T_o - T_a) \times \left(1 - \exp\left[-\frac{F'U_L}{C_b\rho_b}\frac{A_{coll}}{V_{opt}}\left(t_{end(\dot{V})} - t_{in(\dot{V})}\right)\right]\right) \quad (18)$$

Z is nearly constant for the optimum volume in equation (16). When exponential parts were expanded in a series, higher order was neglected, and $t_{in(\dot{V})}$ was identical to $t_{in(V)}$ and $t_{end(\dot{V})}$ is identical to $t_{end(V)}$. Equation (16) was written as:

$$Z = \frac{C_f\rho_f 2(\tau\alpha)_o \int\int_{t_{in}(V)}^{t_{end}(V)} (H)\, dt - U_L (T_o - T_a)\left(t_{end(V)} - t_{in(V)}\right)^2}{C_b\rho_b (\tau\alpha)_o \int_{t_{in}(V)}^{t_{end}(V)} (H)\, dt - U_L (T_o - T_a)\left(t_{end(V)} - t_{in(V)}\right)} \quad (19)$$

The flat plate solar collector orientation was set due south so that solar radiation was symmetrical with respect to true solar time at 12 noon; therefore the double integration of solar radiation (*H*) resulted to:

$$\int\int_{t_{in}(V)}^{t_{end}(V)} (H)\, dt = \frac{\left(t_{end(V)} - t_{in(V)}\right)}{2} \int_{t_{in}(\dot{V})}^{t_{end}(\dot{V})} (Hdt) \quad (20)$$

Optimum volume equation (16) can therefore be written as:

$$\frac{V_{opt}}{A_{opt}} = \frac{C_f\rho_f\left(t_{end(V)} - t_{in(V)}\right)}{C_b\rho_b} \frac{\dot{V}}{A_{coll}} \quad (21)$$

The optimum volume equation (21) shows that the optimum volume of a packed bed has heat capacity which is identical to the heat capacity of air which has passed through the bed during the charging period.

The relationship between the optimum volume of packed bed and the air flow rate obtained from two extreme models and the linear approximation model is shown in Figure 5.0. It can be seen from the graph that the linear approximation model agreed well with the extreme models.

Packed bed energy storage systems designers will easily obtain the packed bed volume from a linear approximation equation (21) and its charged thermal energy from equation (12) when air flow rate and collector operating time are given.

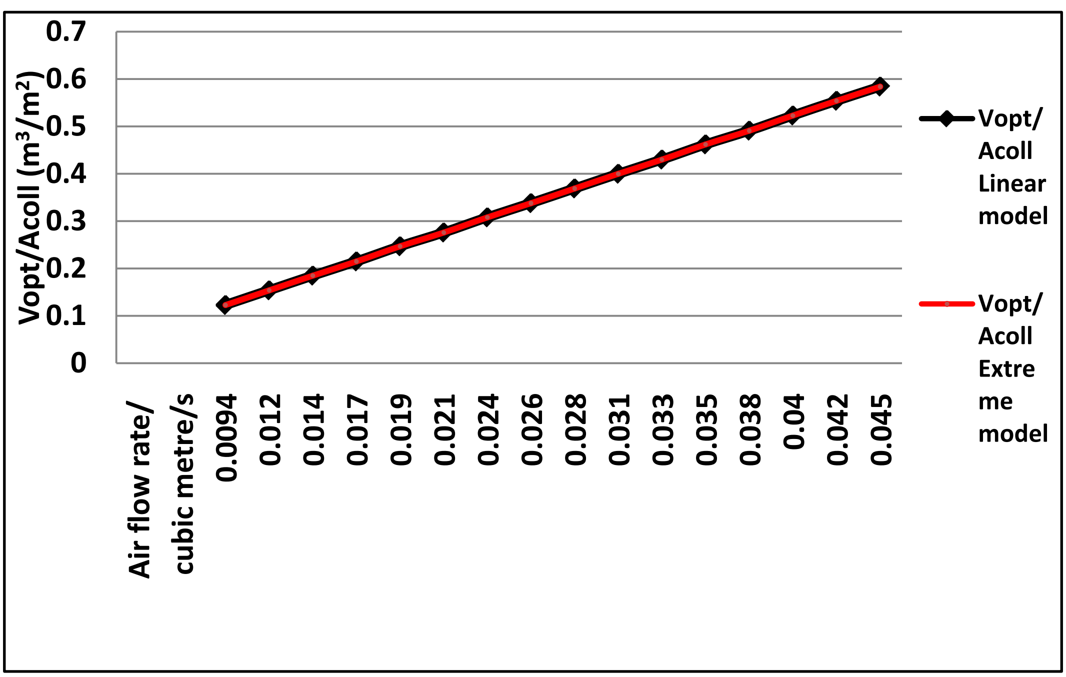

Figure 5.0 : Relationship between the optimum volume of packed bed storage system and the air flow rate obtained from the extreme and linear models

V. Conclusion

In this study, the Schumann model was used as the standard model of the packed bed and the basic assumptions leading to the Schumann model are one dimensional plug flow, no axial thermal conduction, constant properties, no heat loss to environment and no temperature gradients within solid particles. It was additionally assumed that specific heat of air is neglected.

Optimization and economic analysis of the entire packed bed energy storage system was carried out and the following were discovered:

1) As a result of standard model, charged thermal energy increases generally with the increasing of the packed bed volume.
2) The intersection point of the two extreme models with flow rate shows the optimum volume of the packed bed.

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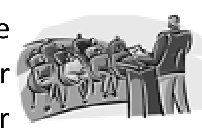

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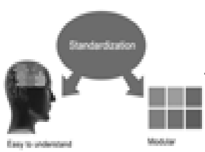

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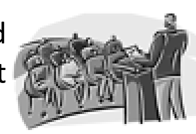

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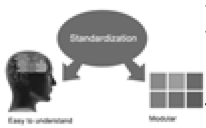

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3. Submission of Manuscripts,

4. Manuscript's Category,

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10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

Segment Draft and Final Research Paper: You have to strictly follow the template of research paper. If it is not done your paper may get rejected.

- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.
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- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

Criterion for Grading a Research Paper (Compilation) by Global Journals Inc. (US)

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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