B. TECH. PROJECT REPORT

On

Measurement and Analysis of Effective Thermal Conductivity of Ammoniated Salts Packed Beds

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DISCIPLINE OF MECHANICAL ENGINEERING

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Measurement and Analysis of Effective Thermal Conductivity of Ammoniated Salts Packed Beds

A PROJECT REPORT

Submitted in partial fulfillment of the
requirements for the award of the degrees

of
BACHELOR OF TECHNOLOGY
in

MECHANICAL ENGINEERING

Submitted by:
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INDIAN INSTITUTE OF TECHNOLOGY INDORE
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CANDIDATE'S DECLARATION

We hereby declare that the project entitled **"Measurement and Analysis of Effective Thermal Conductivity of Ammoniated Salts Packed Beds"** submitted in partial fulfillment for the award of the degree of Bachelor of Technology in 'Mechanical Engineering' completed under the supervision of **Dr. E.Anil Kumar(Associate professor),** IIT Indore is an authentic work.

Further, I/we declare that I/we have not submitted this work for the award of any other degree elsewhere.

VidyaSagar Vemula

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Signature and name of the student(s) with date

CERTIFICATE by BTP Guide(s)

It is certified that the above statement made by the students is correct to the best of my knowledge and belief.

Signature of BTP Guide(s) with dates and their designation

Preface

This is the final report of the BTP project "**Measurement and Analysis of Effecive Thermal Conductivity of Ammoniated Salts Packed Beds**." prepared under the guidance of Dr. E.Anil Kumar

The following report inculcates within itself a detailed description of the actions undertaken that have led to the Design of the ETC Cell to measure the effective thermal conductivity and Simulation of Metal Chloride Packed Beds for Estimation of ETC and experiment setup.The report consists of an illustrated description of the entire BTP, starting from conception of the design and simulation of ETC.

The report throws light on all aspect of the design .It includes not only the final model but also its inception and how it can be made into reality.Cad models have been illustrated to do the same.

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Without their help and support,we wouldn’t have been able to complete the project.

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Abstract

The main objective of the project was to design the ETC Cell for measuring the ETC.This report presents the simulation of $CaCl_2.NH_3$ (n=4,8,) which was done by two mathematical models:Yagi-Kunii model & Zehner and Schlunder models which gave the approxmiate values close to the experimental values of Yuki Sakamoto. Keeping in view the salient differences between metal chloride beds in which chemisorption of ammonia takes place and conventional non-reactive packed beds. Variation in properties, such as, solid thermal conductivity and porosity, effect of temperature ,effect of pressure ,effect of ammonia concentartion during ammonia adsorption and desorption processes are disscused and the report focused on the experimental appartus and the steps to take while measuring the ETC.

ETC-Effective thermal conductivity.

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Nomenclature

d diameter; m

P pressure; Pa

d contact length of solid particles; m

k mean effective thermal conductivity of bed with stationary fluid in Yagi and Kunii model, in Eq. (1.3), W m-1 K -1

T temperature; K

X e effective pore length; m

φ porosity

ψ ξ , accommodation coefficient for gas, solid respectively

ϖ * * kg/ ks in Eq. (1.6)

Ke mean effective thermal conductivity of bed with stationary fluid in Yagi and Kunii model, in Eq. (1.1), W m-1 K -1

B shape factor, in Eq. (1.4)

Subscripts

b breakaway

a adsorption

d desorption

p probe

Superscripts

* in pores (for gas); dependent on ammonia concentration (for solid)

Abbreviations

ETC- Effective thermal conductivity.

Chapter-1 Introduction

Adsorption refrigerators and heat pumps have been thought to be environmentally benign and cost effective.when driven by recovered waste heat . Adsorption refrigerators and heat pumps have been thought to be environmentally benign and cost effective when driven by recovered waste heat . This, in turn, requires high rates of heat transfer in and out of the adsorbent. Most adsorbents exhibit poor heat transfer properties, mainly due to the high porosity of the material. To solve the problem mentioned above, expanded graphite was added as an additive to the composite adsorbent. Expanded graphite powders have been used as a heat transfer additive in adsorption refrigeration and heat pump systems . They have good heat transfer properties when fabricated by compression. Therefore, it is possible to enhance the heat transfer properties by mixing expanded graphite powders with the adsorbent.

The use of the expanded graphite led to enhancement of the Effective thermal conductivity and heat transfer coefficient. .Knowledge of the effective thermal conductivity is necessary for accurate heat transfer analysis and dynamic simulation of an adsorber. However, there have been few experimental studies on the effective thermal conductivityof expanded graphite–$CaCl_2$ nNH_3 (n = 4, 8) measured by the ‘‘hot-wire method’’ at a fixed pressure and temperature under an ammonia atmosphere.

In last four decades, huge number of metals/alloys have been discovered/developed, each one comparatively better than its predecessors. Ammonia adsorption and desorption by metal choride is exothermic and endothermic reaction respectively. The efficiency of any application of metal chloride depends mainly on the capacity and rate of ammonia adsorption/desorption. The ammonia adsorption capacity is a material dependent property but the kinetics of adsorption/desorption can very well be improved by material modification and better heat transfer characteristics of the Metal chloride bed. As the adsorption and desorption are exothermic and endothermic reactions, Generally metal chloride for any application is in the form of powder packed bed. The cyclic adsorption/desorption of material results in deterioration of particles and hence the usual size of particles of metal chloride beds is in the range of 15-35 microns. The minute size of powder results in poor heat transfer characteristics of metal chloride beds. The heat transfer in these beds is mainly through conduction in solid and ammonia gas as convection due to the fluid motion is generally negligible. Owing to these facts Effective Thermal Conductivity (ETC) becomes a crucial parameter governing the heat and mass transfer processes of these beds .

ETC of reactive packed beds of chloride materials mainly depends on the thermal conductivity of solid and gas, gas pressure, bed temperature, void fraction and ammonia concentration .

In general the value of ETC for these beds is low and needs to be enhanced. the following characteristics make the estimation of ETC relatively difficult: (a) Continuous variation in concentration and particle size due to adsorption and desorption of chloride, (b) High reaction pressures, and; (c) Continuously varying reaction temperature and reaction rates.

Adsorption beds need to be protected from high temperatures and pressure because each working pair has its working temperature and pressure Metal chloride packing bed has a working temperature of (290-350k) and pressure of (2-10 bar).

1.1 Measurement of ETC Metal Chloride Beds:

Steady state-

In steady state method, the test material is filled in to a simple geometry, either cylindrical or rectangular enclosure. The boundary conditions are maintained constant to achieve one dimensional heat flux and the bed is allowed to reach steady state and the temperature profile is measured. Thermal conductivity can be calculated by comparing the experimental results with Fourier or Laplace equation .The steady state methods are time consuming. Also some loss in accuracy is seen due to non-fulfillment of assumption of homogeneous beds caused by the presence of thermocouples within the bed.

Transient state-

In transient method of measurement thermal response due to a sudden heat pulse is recorded. The ETC of the bed is then obtained by fitting the solution of the Fourier equation to the measured temperaturetime curve. Most commonly used transient techniques are hot wire method, thermal probe method and transient plane source method.Under trasient method we adopted **hot wire method.**

Hot wire method-

In this method, an infinitely long wire (length/radius ratio $\gg$200) dissipating constant electrical power with uniform initial temperature is used as heat source. It is encased in the material to be tested and its temperature change with time as a result of step change in voltage applied is measured.

Chapter 2 – ETC Cell Design

Fig. 1 shows the schematic diagram of ETC cell. The ETC cell was a cylinder made up of SS 316 and was designed and fabricated to attain the required conditions of one dimensional, Transient state, radial heat transfer. For achieving unidirectional radial heat transfer the aspect ratio (L/D) of the reactor was kept as 4.33:1. The Metal Chloride bed in powder form (4) assumed a hollow cylindrical shape with a Nichrome Wire (5) of 0.3mm diameter located centrally with a height of 195mm, at the inner radius and enveloped by the inner surface of high pressure cylinder (10) of 30 mm inner diameter, 34 mm outer diameter and 170 mm height, at the outer radius. Coolant jacket(11) has an annular volume between the outer surface of high pressure cylinder and inner wall of another cylinder of 45 mm inner diameter, 47 mm outer diameter and 170 mm length. Suitable fittings were provided to this cylinder for coolant inlet (7) and

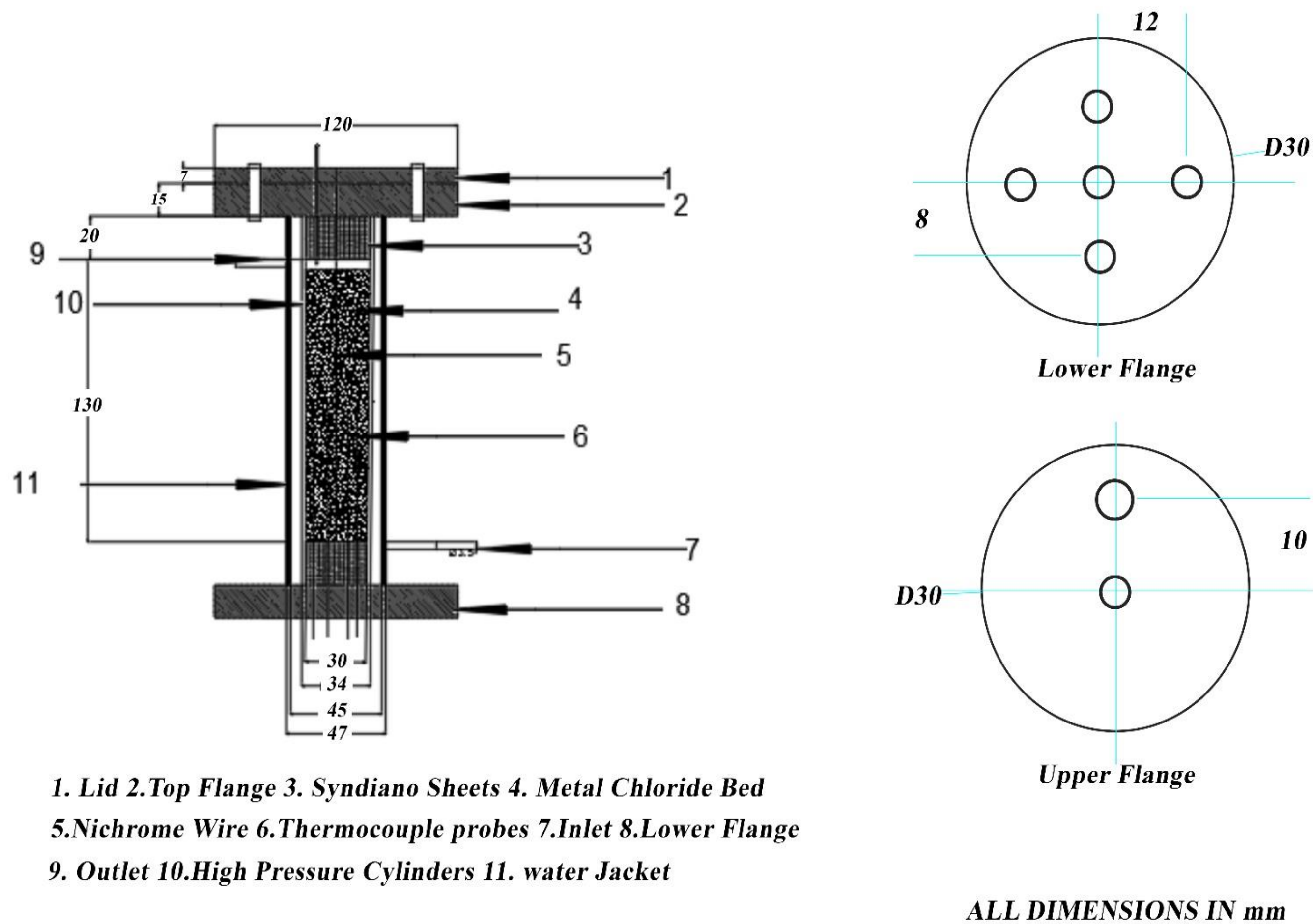


Fig.1.Schematic Diagram Of ETC Cell.

outlet (9). Two flanges, one at each end of the cylinders were welded to make this a single assembly. The top flange (2) was made as a hollow disc of 30 mm inner diameter, 120 mm outer diameter and 15 mm thickness. The 30 mm bore was intended to facilitate the filling of material from this end of the cell. A lid (1) of 120 mm diameter and 7 mm thickness was used as the top cover for the ETC cell. It had a hole of quarter inch at its center with a quarter inch tube, fitted to it for gas passage to / from the Metal Chloride bed. PTFE gasket was fitted into the grooves made in the top flange and lid to assure leak proof sealing of the ETC cell. Six holes of 10 mm diameter were drilled along an appropriate pitch circle diameter on the lid as well as on top flange to fit the lid to the top flange using threaded joint. The lower flange (8) was equipped with a Nichrome Wire (5) and arrangements for leak proof fitting of four probe type thermocouples (6) and connections for one thermocouple junction each brazed on heater surface and inner surface of high pressure cylinder (10). Thus temperatures at five points at different radii and same axial height and at two points at same radius and different axial heights were monitored for measurement of ETC. The temperatures at same radius and different axial heights were monitored to assure that temperature variation in lateral direction was negligible.

Chapter 3 - Effect of Operating Parameters on ETC of Metal Chloride Beds

Effect of gas pressure, temperature, Ammonia concentration, packing density adsoption/desorption on ETC of the Metal chloride beds is discussed in this section.

3.1 Effect of Pressure :

With the increase in gas pressure the mean free path decreases which results in collision of gas molecules which results in higher gas conductivity, consequently resulting in increase in ETC.This trend continues till the pressure value reaches break away pressure,When the pressure reaches break away pressure of corresponding gas, the mean free path of the gas molecules becomes much lower than the effective size of the voids.The value of Ammonia pressure up to which its effect is not significant on ETC, varies for different metal Chloride beds as the characteristic features like particle size, solid thermal conductivity, packing density (or porosity) of metal choride bed etc. are the deciding factors for the value of ETC in this region. The heat transfer in this region is derived from conduction between solid particles only as the usual range of temperature and very low surface area of particles generally nullify the chances of thermal radiation. As the interaction of Ammonia with different metal chloride will be at different pressure and temperature conditions and will lead to different changes in parameters like bed porosity, contact between solid particles etc., the ETC variation for different metal chloride beds with pressure are different. The ETC can be increased by 0.2-0.3 W m-1 K -1 for the pressure between 2-6 bar for $CaCl_2.4NH_3$ bed whereas for a $CaCl_2.8NH_3$ bed an increase of 7-9 bar resulted in the increase of ETC by 0.3-0.4 W m-1 K -1.

3.2 Effect of temperature:

The thermal conductivity of gas is a stronger function of temperature as compared to thermal conductivity of solid.The thermal conductivity of solids decrease with increase in temperature, the thermal conductivity of gases increase due to the increase in molecular kinetic energy. The effect of temperature variation on ETC of Metalchloride beds is defined by the relative weightage of variation of thermal conductivity of gas or that of solid particles.The variation of ETC with bed temperature is depended on bed parameters like bedgeometry etc. and no fixed trend for this can be suggested.

3.3 Effect of ammonia concentration:

The ETC of reactive packed beds of Metal chloride beds increases with increase in Ammonia concentration.As the ammonia concentration increases, the bed contact area increases porosity decreses effective thermal conductivity increases.

3.4 Effect of particle size:

The particle size ultimately defines the surface area of particle available for heat transfer. With the decrease in particle size the heat transfer through particles by conduction as well as by radiation gets reduced significantly. As a consequence the contribution of solid particles towards ETC of Metal chloride bed decreases thus decreasing the ETC value. With decrease in particle size, the ETC decreases**.** The particle size also affects the range of pressure dependency of ETC. This is obvious due to the change in void volume and Ammonia-Metal choride interaction caused due to variation in particle size of the Metal chloride.

3.5 Effect of bed porosity:

With the increase in bed porosity the ETC of Metal chloride bed decreases as the contact between solid particles decreases with increase in porosity. The repeated adsorption/desorption of Metal chloride bed causes particle size reduction. A consequence of this is increase in packing density or decrease in bed porosity . The increase in ETC of Metal chloride bed due to reduction in bed porosity is at the cost of amount of ammonia adsorbed / desorbed by the Metal chloride bed.

3.6 Effect of adsorption and desorption:

The Ammonia adsorption by the Metal chloride particles in the bed results in swelling or expansion of the particles thus improving the contact between solid particles and increase in surface area of Metal chloride particles. Both of these phenomena have positive effect on ETC of Metal chloride bed. These Metal chloride particles contract during desorption of the Metal chloride bed . This frequent adsorption and desorption act as cyclic loading on the solid particles and stresses caused due to such cyclic loading leads to deterioration of solid particles hence bringing about changes in packing density and bed porosity.

Chapter-4 Simulation of Effective Thermal Conductivity of Metal Chloride Packed Beds

Different mathematical models have been developed for estimation of ETC of porous beds providing an insight on the dependencies of ETC on various operating parameters . These models acted as base for the development of models to simulate the ETC of Metal chloride beds. The significant differences between non reactive bed and chloride beds in modeling ETC are the solid conductivity is constant in non reactive packed beds. Due to the expansion and contraction of particle the contact resistance between the particles varies and also the porosity of the bed varies. The set of mathematical expressions formed from the modeling of Metal chloride bed can be solved either analytically or by applying suitable approximation technique. The primary parameters influencing ETC (ke) of Metal chloride packed beds are: ¬ Thermal conductivity of the solid (ks) ¬ Thermal conductivity of the gas (kg) and ¬ The relative proportion of these phases in the bed . Generally structure of the metal chloride bed is described by the term porosity φ. The porosity is equal to the volume of gas phase per unit volume of the system. The additional factors affecting effective thermal conductivity are solid to solid heat transfer at the contact, gas pressure and heat transfer by radiation.

Several mathematical models are available for estimation of effective thermal conductivity (ETC) of non-reactive packed beds. Keeping in view the salient differences between metal chloride beds in which chemisorption of ammonia takes place and conventional non-reactive packed beds, modified models are proposed here to predict the ETC. Some well-known models developed by Yagi and Kunii , Zehner and Schlunder , have been extended to incorporate the consequences of ammonia adsorption and desorption. The extended models are then used for simulation of ETC of $CaCl_2(4,8)NH_3$ packed bed. The experimental data was taken from Yuki Sakamoto Applicability of the extended models for estimation of the ETC at different operating conditions such as pressure, temperature and ammonia concentration is discussed.

4.1 Variation in porosity of bed:

Variation in Porosity of bed Due to ammonia adsorption, the porosity continuously decreases due to swelling of the Metal chloride bed which is confined within a given volume.

4.2 Effect on Heat Conduction through Solid Particles and Gas in Voids:

Unlike non-reactive packed beds where the contact area between particles remains unchanged, in case of Metal chloride beds, contact area between the particles increases with ammonia adsorption, thus decreasing the contact thermal resistance between solid particles. On the other hand, the thermal conductivity of individual solid particles decreases due to ammonia adsorption. The accommodation coefficient for solid ξ is a parameter dependent on solid-gas combination of the Metal chloride bed. In the present case, it is assumed as 0.48.This variation in voids configuration results in appreciable variation in thermal conductivity of the gas present in the voids. Hence the variation in thermal conductivity of gas in voids needs to be taken into consideration.The mean size of void in the present analysis is assumed to be equivalent to mean diameter of particles . To obtain the value of can be used, where breakaway pressure is dependent on solid-gas combination of the bed and in the present case it is taken as 10 bar . The accommodation coefficient for gas (ψ) is empirically assumed to be 0.15.

4.3 Extended Mathematical Models:

For the sake of accounting the effects of adsorption and desorption on the bed porosity, solid thermal conductivity and thermal conductivity of gas in voids. The models obtained after these implementations are presented below which are applicable for Metal chloride beds.

4.3.1 Yagi and Kunii Model:

Considering a randomly packed bed of spherical particles with seven heat transfer mechanisms broadly classified on the basis of their dependence on fluid flow, Yagi and Kunii[2] found that for small Reynolds number which generally is the case for Metal chloride packed beds, only four heat transfer mechanisms were predominant.That are thermal conduction through solid particles, thermal conduction through the contact surfaces of two particles, radiation heat transfer between particles and conduction heat transfer through the fluid film in the voids. Their assumptions stipulated that the convection heat transfer in packed beds is not considerable and the conduction heat transfer through the fluid film in the voids is unaffected by the fluid flow. They obtained good agreement of the calculated values of ETC for different types of particles and different fluids with the experimental data reported by several investigators. Yagi and Kunii model[2] results in the expression given by equation (1.1),(1.2),(1.3) for ETC of Metal chloride packed beds. The value of ε for the present case is taken as 0.078, and β is taken as unity as discussed by Yagi and Kunii.

$$k_e = \frac{k_g \beta}{1+\frac{7.4412\times10^{-15}T}{PX_e}\left(\frac{2}{\psi}-1\right)} \left\{ \frac{\frac{1-\varphi_0+(1-\varphi_0)\times1.7321\times10^{-3}\rho_s X}{k_g}}{k_s^{*}\left\{1+\frac{7.4412\times10^{-15}T}{PX_e}\left(\frac{2}{\psi}-1\right)\right\}}+\varepsilon \right\}$$

(1.1)

$$P_b = 1770\times10^{-24}\frac{(T+491.67)}{d^2 d_z}$$

(1.2)

$$k_s^{*} = k_s + \xi X$$

(1.3)

Equation (1.1),(1.2),(1.3) illustrate the value of ETC of $CaCl_2$.(n=4,8)NH_3

4.3.2 Zehner and Schlunder model:

The unit cell considered by Zehner and Schlunder[3] was basically an eighth part of a cylinder. Thus they assumed the bed to be made up of cylindrical cells filled with solid spherical particles. The remaining part of the cylinder was considered to be filled by a low conductivity fluid ammnia in present case. As, is clear Zehner and Schlunder model[3] does not consider the effect of contact areas between the particles of the packed bed and thus the model under predicts the values of ETC for packed beds in many cases. On substitution of value of B obtained from the ETC of non-reactive packed beds can be obtained.

$$k_e = \left(1-\sqrt{1-\varphi_0+(1-\varphi_0)1.7321\times10^{-3}\rho_s X}\right)k_g + \frac{\sqrt{4-4\varphi_0+(1-\varphi_0)6.9284\times10^{-3}\rho_s X}}{E}\left\{\frac{(1-\varpi)B}{E^2}\ln\frac{1}{\varpi B}-\frac{B+1}{2}-\frac{B-1}{E}\right\}$$

(1.4)

$$\varphi = \varphi_0 - 1.7321\times10^{-3}\left(1-\varepsilon_0\right)\rho_s X \tag{1.5}$$

where:

$$\varpi = \frac{k_s^{*}\left(P\times10^{5}\times X_e + \left(1-\varphi_0\right)1.135\times10^{-8}T\left(\frac{2}{\psi}-1\right)\right)}{k_g P\times10^{5}\times X_e}$$

$$B = -6.49\varphi + 3.35 \qquad E = \left(1-\varpi B\right) \tag{1.6}$$

Equation (1.4),(1.5),(1.6) illustrate the value of ETC of $CaCl_2.(n=4,8)NH_3$

4.3.3 Simulation results:

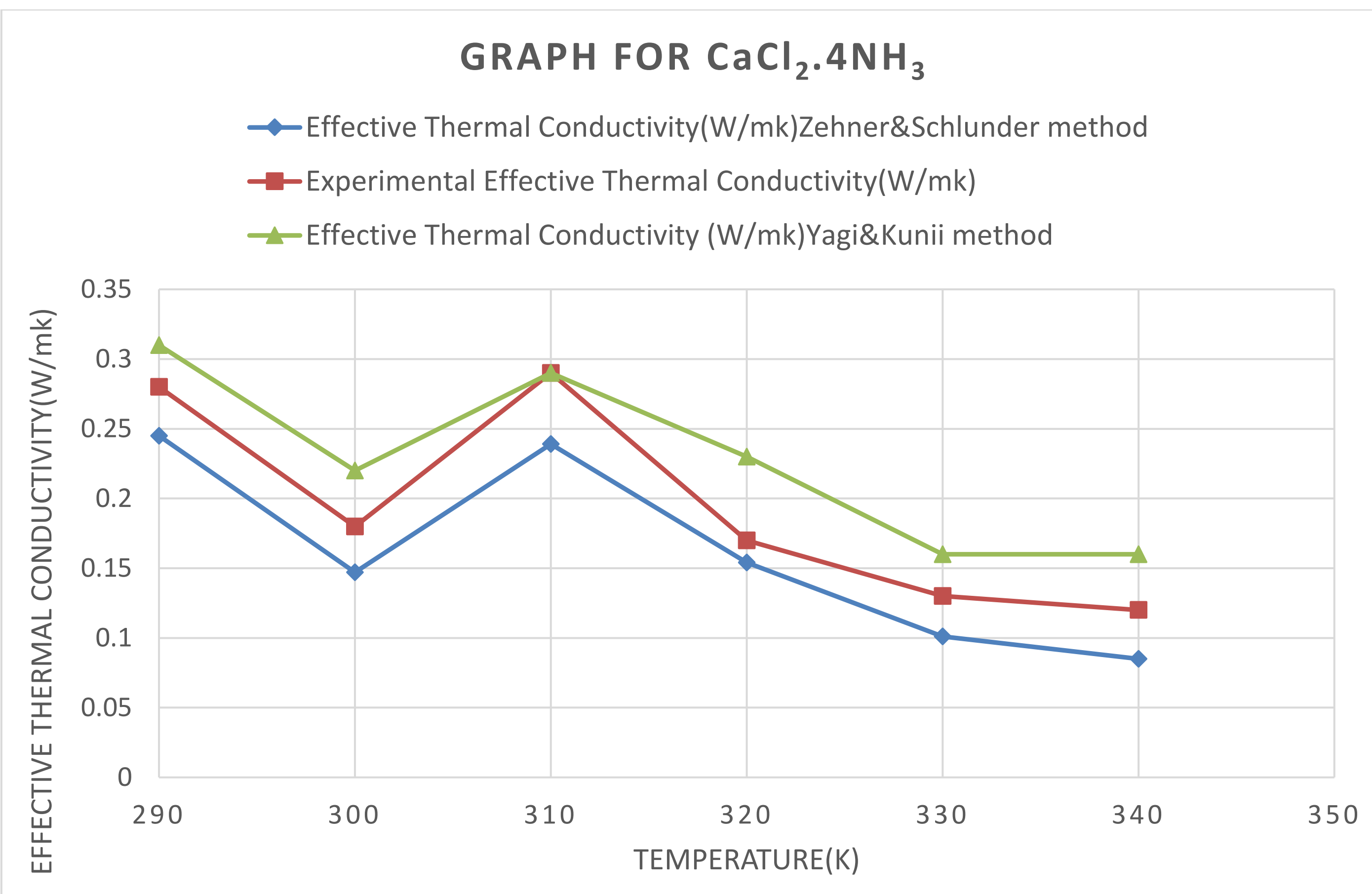


Table 1 Results for yagii&Kunii,Zehner&Schlunder& Experimental.

Temperature (K)	**Effective Thermal Conductivity(W/mk)Zehner&Schlunder method**	**Experimental Effective Thermal Conductivity(W/mk)**	**Effective Thermal Conductivity (W/mk)Yagi&Kunii method**
290	0.245	0.28	0.31
300	0.147	0.18	0.22
310	0.239	0.29	0.29
320	0.154	0.17	0.23
330	0.101	0.13	0.16
340	0.085	0.12	0.16

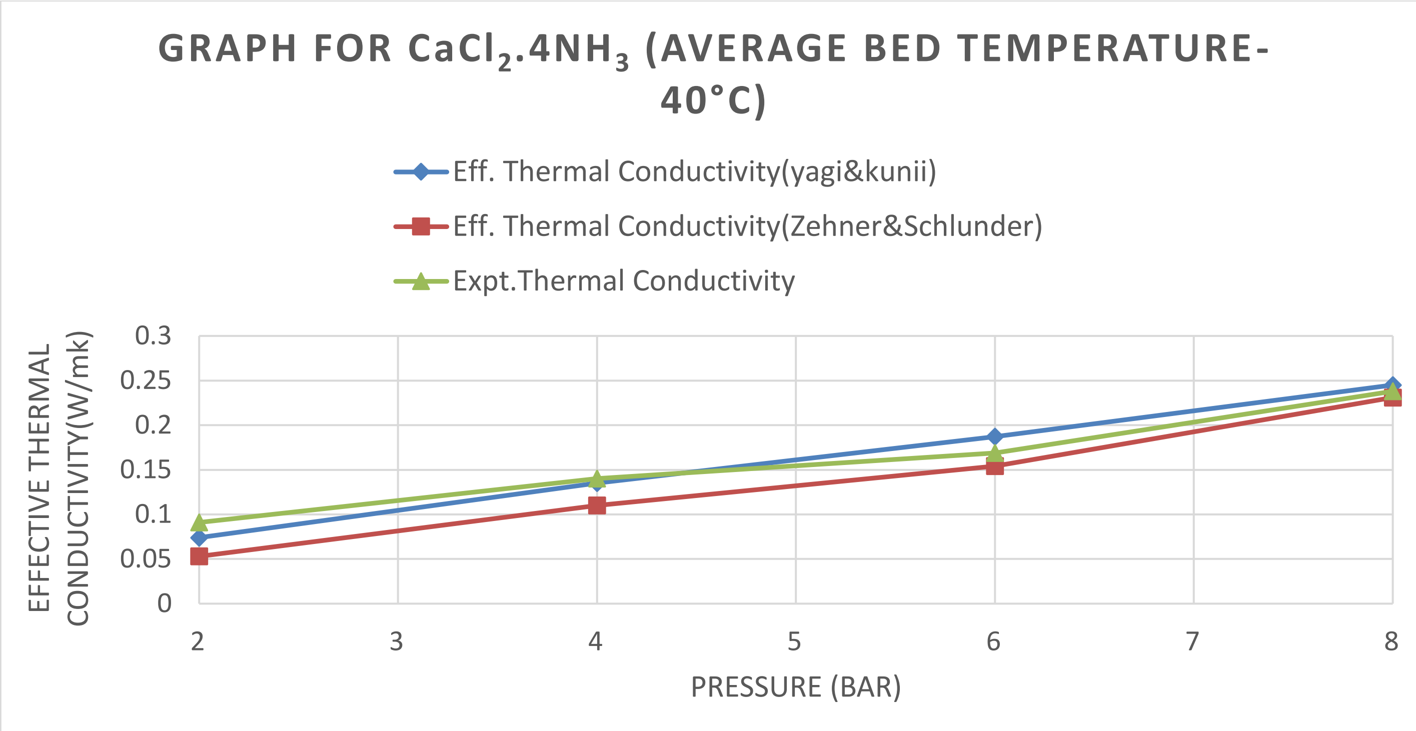


Table 2 Results for yagii&Kunii,Zehner&Schlunder& Experimental at Average bed temperature.

Pressure(bar)	**Eff. Thermal Conductivity(yagi&kunii)**	**Eff. Thermal Conductivity(Zehner&Schlunder)**	**Expt.Thermal Conductivity**
2	0.074	0.053	0.091
4	0.135	0.11	0.14
6	0.187	0.154	0.169
8	0.245	0.231	0.238

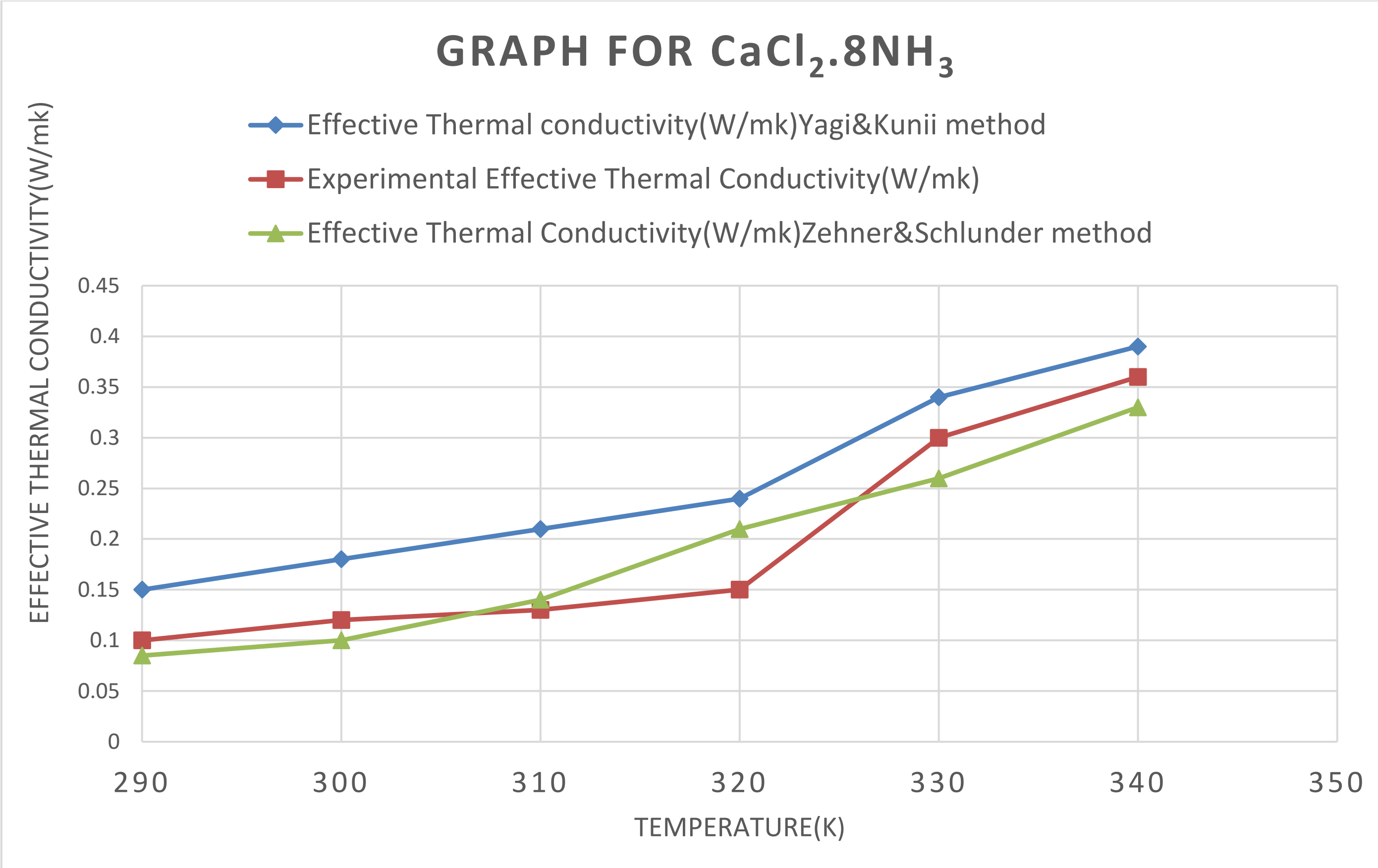


Table 3 Results for yagii&Kunii,Zehner&Schlunder& Experimental at 8 bar pressure:

Temperature (K)	**Effective Thermal conductivity(W/mk)Yagi&Kunii method**	**Experimental Effective Thermal Conductivity(W/mk)**	**Effective Thermal Conductivity(W/mk)Zehner&Schlunder method**
290	0.15	0.1	0.085
300	0.18	0.12	0.1
310	0.21	0.13	0.14
320	0.24	0.15	0.21
330	0.34	0.3	0.26
340	0.39	0.36	0.33

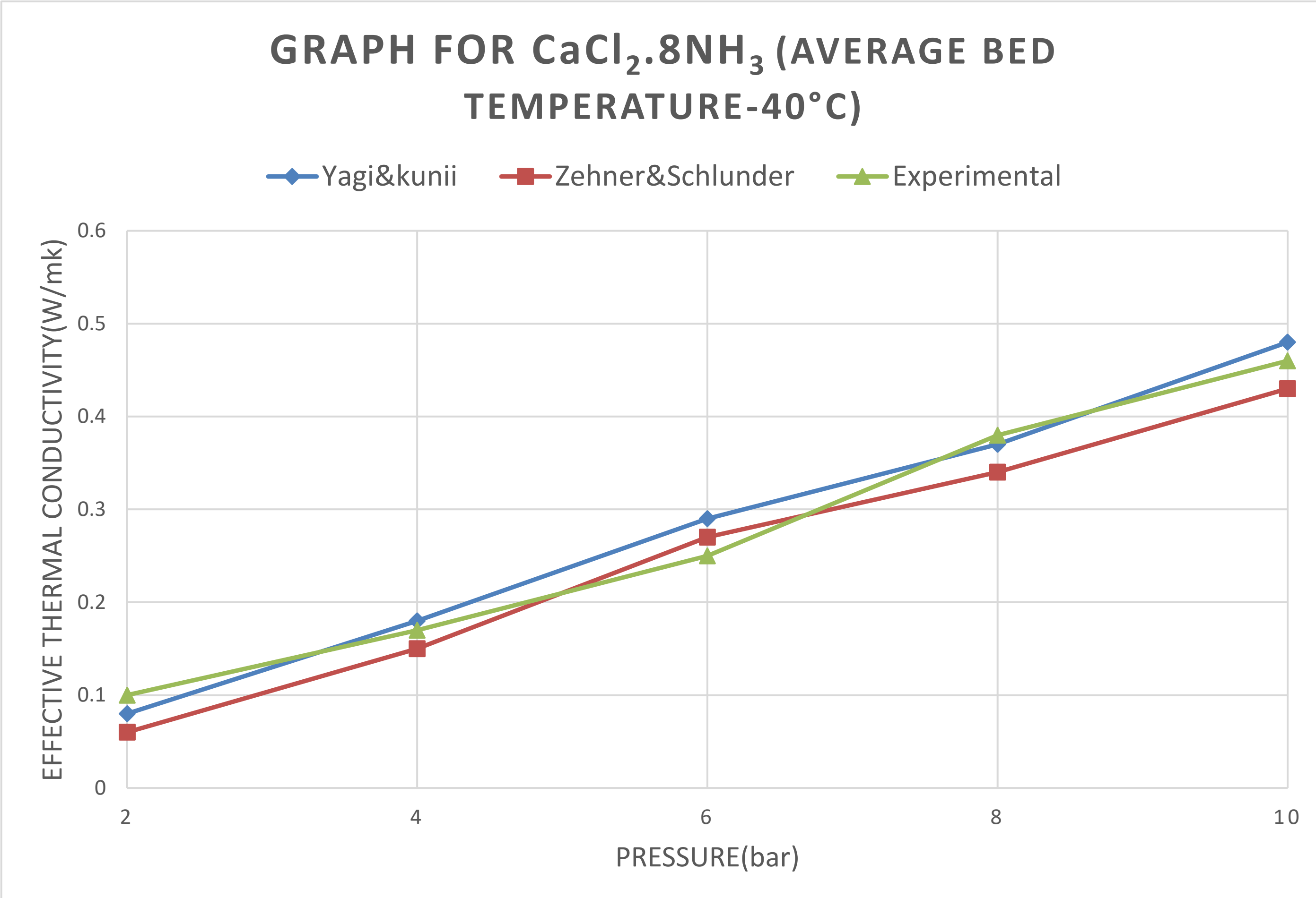


Table 4 Results for yagii&Kunii,Zehner&Schlunder& Experimental at average temperature.

Pressure(bar)	**Yagi&kunii**	**Zehner&Schlunder**	**Experimental**
2	**0.08**	**0.06**	**0.1**
4	**0.18**	**0.15**	**0.17**
6	**0.29**	**0.27**	**0.25**
8	**0.37**	**0.34**	**0.38**
10	**0.48**	**0.43**	**0.46**

Chapter-5 Experimental apparatus

In the present work as the intention was not only to evalute the ETC augmentations achieved through different augmentation techniques but also to evalute the relative effect of the augmentation technique on the amount of ammonia adsorbed by the metal chloride. To full fill these intentions the experimental set-up was desined for activation of metal chloride quantification of Ammmonia adsorption and ETC measurment (Fig 1.3) shows the schematic diagram of Experimental set up used in the present work.Quater inch seamless SS 316 tubes were used for building the gas flow circuit. These tubes could sustain pressure upto 500bar The gas flow in this circuit was controlled through high pressure bellow sealed valves(working presuure up to 172 bar, in the temperature range of -28˚C to 343˚C) .Calibirated SS 316 cylinders (2250 ml-1No., 1000 ml-2 no.s) were utilized for supply of Ammonia gas to the ETC cell in metered quantites.For monitoring Ammonia pressure, piezoresistive type pressure transducers were installed at different locations in the set up.

P_1 and P_2 were installed for monitoring the supply pressure and transcuder P_3 is used for monitoring the pressure in the Etc cell.The working pressure range for all the pressure transducer was 0 to 100 bar with 0.1% accuracy on full scale. K type thermocouples with an accuracy of $\pm$ 0. 5˚C and time constant of 0.2s were used at different locations in the Ammonia supply circuit and in the ETC cell to monitor the Ammonia gas temperature .Pirani gauge attached to the vaccum line was utilized for monitor the vacuum level in the circuit. Computerized data logger system was used for monitoring and recording all the temperatures and pressure data during the experiments. Heat transfer rate (Q) was calculated from the electric power suppiled to the heaing element.

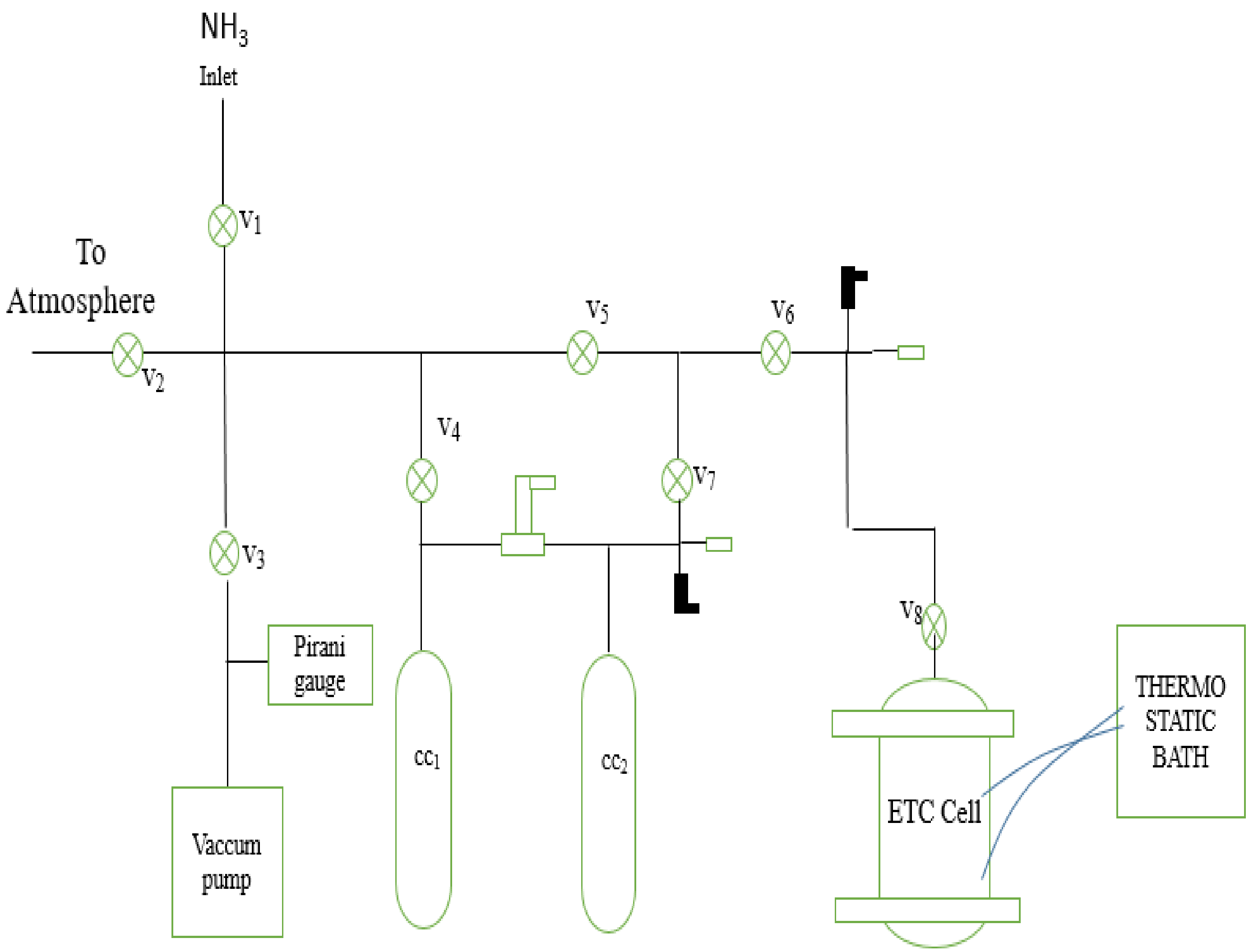


Fig.(2) Schematic arrangement for experimental measurement of ETC.

1)Calibrated cylinders 2)Cold /Hot Fluid Circulator 3)Data logger 4)pirani gauge

Fig. (3) Experimental set up for ETC measurement

5.1 ETC measurement of metal chloride beds:

The ETC estimation comprised following steps(Refer Fig. 3)Evacuation of entire setp to 10^{-3} mbar pressure by opening all valves except v_1,v_2,v_3.The temperature of coolant was set to a fixed value and coolant circulation is started.Power was supplied to the Nichrome wire through a DC power supply unit.All the thermocouples readings were monitored in the ETC cell in intervals of 15 minutes till the transient state

The ETC value for the Metal chloride bed at vacuum was estimated using equation:

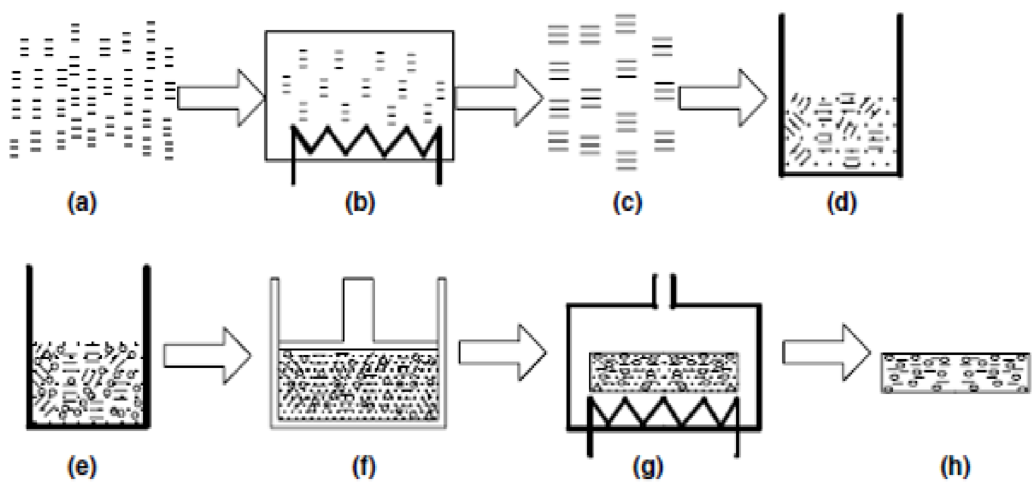
$$\mathbf{ETC}= \frac{\boldsymbol{Q}}{\boldsymbol{2\pi L}(\boldsymbol{dt/dlnr})}$$

Valves v_4 and v_{11} were closed and Ammonia was supplied to volumes V_2,V_3,V_4,V_5, and V_6 and V_7 to a predetermined incremental pressure by opening valve v_1.

During the experiment after sometime valve v_1 was closd and intial pressure in the volumes V_2,V_3,V_4,V_5,V_6 and V_7 were recorded.

Valve v_{11} was opened to allow ammonia to the etc cell. All the steps are repeated to estimate the value of ETC corresponding to different ammonia concentaration,pressure and average bed temperatures.The same procedure was adopted for measurment of ETC in case of pellets also.

5.2 Procedure for making a composite:



Manufacturing procedure of consolidated composite adsorbent. (a)Expandable graphite powders.(b)heat treatment for expansion(c)expanded graphite powders,(d)slurry of expanded graphite and water;(e)mixture of the slurry and cacl2;(f)pressing;(g)vaccum drying;(h)consolidated composite adsorbent.

Ref :: Wang RZ, Wu JY, Wang W, Jangzhou S. Adsorption refrigeration. Beijing: China Machine Press; 2002.

Fig.(4).Procedure for making composite.

Chapter-6 Conclusions

The final model was able to perform the desired tasks and was designed to the requirement set of the project.It is a ETC Cell made up of SS316 which can be use to measure the Effective thermal conductivity.

This report focuses on the design of the model and the mathematical model for simulation to estimate the ETC of $CaCl_2.nNH_3$ (n=4,8) using the experimental results Yuki Sakamoto.It is also undertakes the comparision of the proposed model to its alternative models.

The scope of this report is focused at,however not limited to,the design of the ETC Cell to calculate the Effective thermal conductivity can be use for energy storage which reqiures some fabrication.However,for futher research,designing for the proposed design can be considered.

It should also be noted that the final design made requires nesessary modifications needed to be made before it is implemented for futher usage.

Although this design primarily for measuring the ETC purposes,the model has a wide field of uses such as energy storage.

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