Journal of Mechanics and Thermodynamics

Volume No. 12

Issue No. 1

January - April 2024

ENRICHED PUBLICATIONS PVT. LTD

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Journal of Mechanics and Thermodynamics

Aims and Scope

Journal of Mechanical Engineering and Thermodynamics publishes theoretical and practice oriented papers, dealing with problems of modern technology (power and process engineering, structural and machine design, production engineering mechanism and materials, etc.), Materials and Design Engineering, Vibration and Control, Thermal Engineering and Fluids Engineering.

Journal of Mechanics and Thermodynamics

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(Volume No. 12, Issue No. 1, Jan - Apr 2024)

Contents

CFD Analysis of Wavy Edge Rectangular Micro-Channel Heat Sink at Different Reynolds Number

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ABSTRACT

In this work fluid flow, pressure drop and characteristics of heat transfer in two types of micro channel heat sinks have been analyzed using computational fluid dynamics. One of them is a straight rectangular micro-channel heat sink on which validation is done by comparing experimental results with numerical results while the other is a wavy edge type rectangular micro-channel heat sink for which simulation results are obtained. Water is used as a coolant for the simulation. The material for heat sink is copper. Both the micro-channels have a width of 0.23 mm and height of 0.71 mm. The aspect ratio (ɣ) and the length of both the channels is kept same as 0.32 and 44.7mm respectively. The analysis for both the micro-channels is done for three sets of Reynolds number which are 400, 800 and 1200 respectively and the heat flux is 200W/cm^2. After constructing the geometry in Solid works the simulation is done on ANSYS CFX. For both the straight micro-channel and the wavy micro-channel investigated, it is found that the thermal performance of wavy edge micro-channels is better in comparison to that of straight micro-channels. The temperature rise of water is more in wavy edge type micro-channels in comparison to that of straight micro channels of the same hydraulic diameter for different sets of Reynolds number. Further the pressure drop is more in wavy type of channels which can be compensated due to the high heat transfer characteristics of wavy micro-channels.

Keywords: CFD; micro channel; heat sink; rectangular; wavy.

1. INTRODUCTION

Large amount of heat from small areas can easily remove by help of micro-channel. The heat sinks can be used for the next generation of cooling technology in various high performance supercomputer chips and diodes of laser. The construction of a typical micro-cooler comprise of very large number coolant channels. Heat sinks can be classified as single phase or two phase depending as to whether the fluid or liquid boils inside the micro–channels or not.

Various types of coolants can be employed in a micro-channel cooler for heat removal. A commonly used coolant in a heat sink is water. However, for better cooling performance of the micro-channel nano-fluids can be used. The material of the heat sink has high thermal conductivity such as silicon, copper and aluminum.

Peng and Peterson [1] practically analyses micro-channel and found that heat transfer is dependent upon the aspect ratio. Fedorov and Viskanta [2] analyze 3-D micro-channel and found that the mean channel wall temperature along the direction of flow was nearly same except in the region close to the micro-channel inlet portion. Kandlikar et al. [3] study heat transfer and fluid flow in mini-channel and micro-channel. This study analyzed micro channel heat sink by help of surrogate analysis and hybrid multi-objective evolutionary approach and found that design variables have significant effect on the thermal performance of microchannel heat sink [4]. A 3-D rectangular micro-channel heat sink has been geometrically optimized for minimum thermal resistance using surrogate models [5]. Weilin and Mudawar [6] practically and numerically studied fluid flow and heat transfer characteristics of a micro-channel heat sink and discussed detailed description of the local and mean heat transfer characteristics of the heat sink. The use of three-dimensional micro channels that incorporate either micro structures in the channel or grooves in the channel surfaces may lead to significant enhancements in single-phase cooling [7]. Yang et al. [8] say friction factor decreases slightly as the curvature radius of micro-channel increases.

2. PROBLEM DESCRIPTION

For creating geometry, first the heat sink was made in solid works as per the dimensions given in Table1. The wave dimensions were given according to the length of the channel which is 44.7 mm. A sinusoidal sine wave (Eq. 1) was constructed in the solid heat sink. The amplitude of the wave was taken as 0.15 mm while the wavelength was taken as 2 mm. However, fluid channel was created of the same dimensions as of the wavy rectangular slot along the length of heat sink.

$$y = A \sin(2\pi x / \lambda) \tag{1}$$

Here, 'A' is wave amplitude and 'λ' is wave length.

Both parts were created separately using Solid works and were later assembled by inserting fluid channel in solid heat sink using the insert components and mate option in solid works. Water is moving through a wavy edge rectangular smaller scale channel heat sink assembly. In this analysis a design for wavy edge type of micro-channel heat sink is constructed.

The mesh was generated in Ansys. Boundary conditions for the problem are: No slip on the surface, Uniform inlet temperature and static pressure were given at the entry of the channel, outlet of the channel is based on mass flow rate, a uniform heat flux of and 200 W/ cm^2 at the bottom wall of the heat sink was applied.

3. VALIDATION

In this computational analysis validation is done for straight rectangular micro-channel heat sink developed by Weilin and Mudawar [6] and the results given for pressure drop and heat transfer in straight rectangular micro-channel for 200W/cm^2 heat flux. Three values of Reynolds number are taken for the analysis which are 400, 800, 1200 respectively.

From Table 2 it clear that the values of computational pressure drop and temperature rise for heat flux value of 200W/cm^2 are found to be in close agreement with the experimental pressure drop and temperature rise. Hence the computational model is successfully validated on the basis of pressure drop and temperature rise along the channel length.

4. RESULTS

In the following computational fluid dynamics analysis, the results are plotted for pressure drop and heat transfer in wavy edge type rectangular micro-channel for two different values of heat fluxes applied at the bottom of the heat sink for varying set of values of Reynolds number. The value of heat flux used in The value of heat flux used in the analysis is 200 W / cm^2 Three values of Reynolds number are taken for the analyses which are 400, 800, and 1200 respectively. Results for heat flux 200 W/cm^2 and 400, 800 and 1200 Reynolds number are shown in Fig 3-11 and in Table 4.

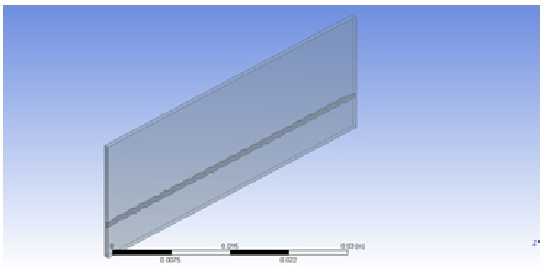

Figure 1. Geometry of wavy micro-cannel heat sink.

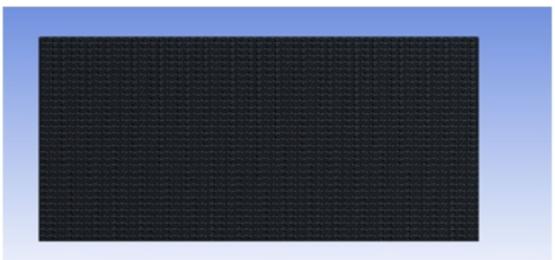

Figure 2. Meshing of geometry in ANSYS CFX

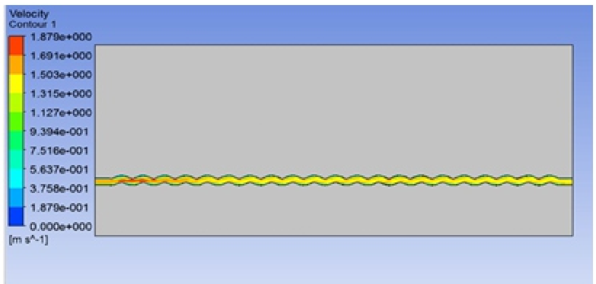

Figure 5. Velocity contour along wavy channel at Re=400.

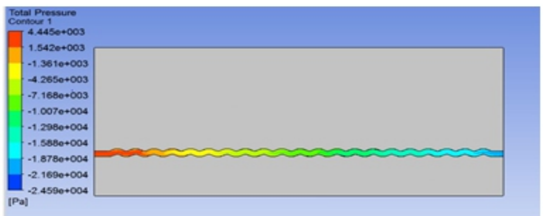

Figure 6. Pressure contour along wavy channel at Re=800.

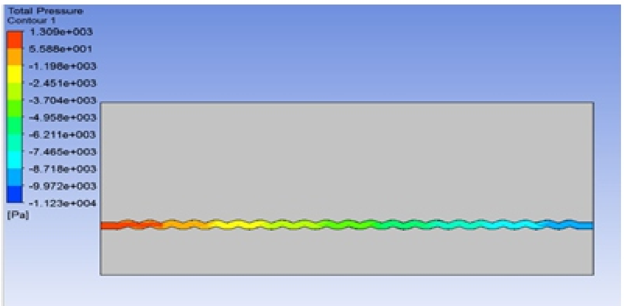

Figure 3. Pressure contour along wavy channel at Re=400.

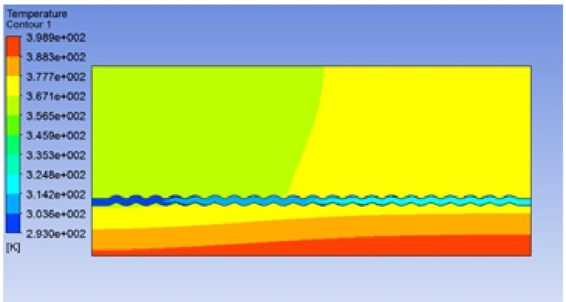

Figure 7. Temperature contour for heat sink and water at Re=800.

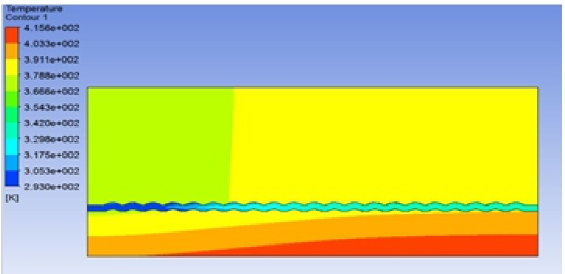

Figure 4. Temperature contour of water and heat Sink for wavy channel at Re=400.

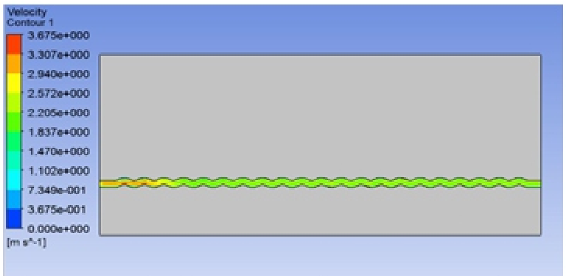

Figure 8. Velocity contour for wavy edge channel at Re=800.

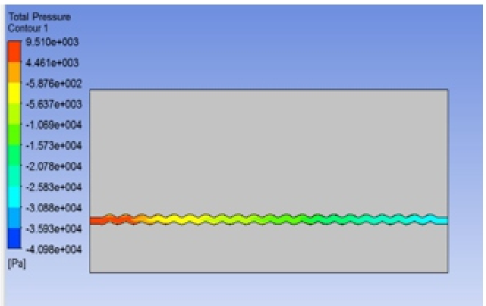

Figure 9. Pressure contour along wavy edge Channel at Re=1200.

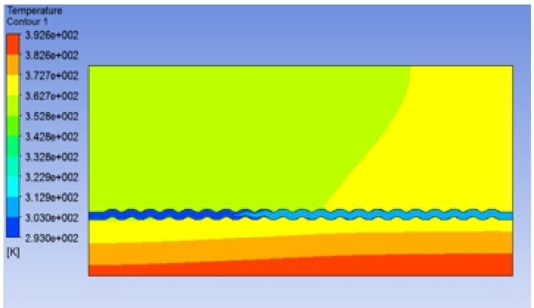

Figure 10. Temperature contour of heat sink And water channel at Re=1200.

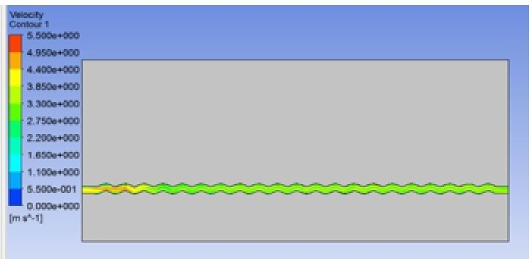

Figure 11. Velocity contour along wavy edge channel at Re=1200.

Reynolds number	Exp. pressure drop (bar)	Comp. pressure drop (bar)	Exp. temp. rise (°C)	Comp. temperature rise (°C)
400	0.08	0.10	44	43
800	0.21	0.22	22	22
1200	0.40	0.37	15	14

Table 1: Dimensions of the unit cell used for simulation

Table 2: Experimental and computational pressure drop and temperature rise for different Reynolds number for heat flux =200W/cm^2.

W_{wall} (μm)	W (μm)	H_{wall2} (μm)	H (μm)	H_{wall1} (μm)	L (mm)
118	231	12700	713	5637	44.7

Table 3: Computational temperature rise, pressure drop and maximum velocity for different Reynolds number for heat flux =200W/cm^2

Reynolds number	Comp. Temp. rise (°C)	Comp. pressure drop (bar)	Maximum comp. velocity (m/s)
400	49	0.124	1.870
800	31	0.286	3.672
1200	21	0.504	5.50

5. CONCLUSION

Based on the numerical study on both straight and wavy edge type micro-channel following conclusions can be made-

(i) Water temperature rise is more at the outlet of wavy edge type of micro-channels in comparison to straight micro-channels for same values of Reynolds number and heat flux.

(ii) From the above results both for straight rectangular micro-channel and wavy edge type micro-channel the thermal performance of wavy edge micro-channel is found to be better in comparison to that of straight micro-channel of same hydraulic diameter.

(iii) Pressure drop is found to be more in wavy edge micro-channels in comparison to that of straight micro-channels, however the loss in pressure is compensated by the better heat transfer characteristics of the wavy micro-channel.

(iv) Velocity of water is more in wavy type of micro-channels closer to inlet for different values of Reynolds number.

(v) Velocity of water decreases along the flow direction in wavy micro-channels due to loss in energy of fluid while travelling along wavy channel.

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Clean India Mission: Issues and Challenges

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ABSTRACT

To lead the mass movement for cleanliness, was one of the Mohandas Karamchand Gandhi's dream. However, we have named him as the father of the nation, but forgotten his dream. The year 2016 is completing but yet no concrete step is taken or large scale developments have been initiated to dispose off the wastes entirely from the country. In this work an attempt is made to discuss the challenges in clean India Mission and prioritized the probable directions and methods to achieve this goal. Some of the successful case studies across the world are also discussed.

***Keywords:* Clean India; Zero Waste Urbanization; Swachh Bharat Abhiyan; Garbage.**

1. INTRODUCTION

India is currently the world's third-largest garbage producer. The amount of waste generated is 3 million trucks of garbage and it remains untreated and disposed off by municipal authorities everyday in an unhygienic manner leading to health issues and environmental degradation.

Prime Minister Narendra Modi want a “Swachh Bharat” (clean India) by 2019, but sweeping the streets alone won't help India's to face real garbage challenge.

As our country is growing prosper, 62 million tonnes of garbage is generated everyday by the 377 million people living in urban India, now the world's third-largest garbage generator[1]. With rapid urbanisation, industrialisation and an explosion in population in India, solid waste management will be a key challenge for state governments and local municipal bodies in the 21st century.

The “Swachh Bharat Abhiyan” (Clean India Mission) was created to tackle the issues related to waste management, cleanliness and sanitation on a national level. Through this initiative the government of India aims at the complete collection and scientific processing, disposal, reuse/recycle of garbage, officially called municipal solid waste, for all 4041 statutory towns in the country.

The total cost of the mission is estimated at Rs. 62,009 crore out of which the central government will contribute Rs. 14,623 crore[1].

Everyone knows that dumping of waste can block drains which can cause floods, contamination of water and air pollution, leading to the spread of diseases around the area. The Government of Maharashtra even banned the production, sale and use of plastic bags in 2005, in response to annual flooding in Mumbai. A total of 1,33,760 tonnes per day (TPD) of garbage was generated in all states and union territories of India[1].

Only 68% of the garbage generated in the country is collected out of which 28% is treated by the municipal authorities. Thus, the poor collection and treatment of waste leads to dumped garbage on streets shows up the poor and inefficient system available to tackle waste management in our country. If this issue is not tackled efficiently, with better policies and practices, the total waste generation is projected to be 165 million tonnes by 2031 and 436 million tonnes by 2050.

"One should try to learn from various countries like Sweden, which is a zero waste country; Sri Lanka, which is segregating its waste, and from Bhutan too where everybody is conscious to not to pollute their land.

2. CONCEPT OF ZERO WASTE :-

Zero Waste means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them. It is a whole system approach that aims for a massive change in the way materials flow through society, resulting in no waste. Zero waste focuses more on eliminating waste through recycling and reuse, it also emphasize on restructuring production and distribution systems to reduce waste. Zero waste is a goal rather than a hard target. Zero Waste provides guiding principles for continually working towards eliminating wastes.

To achieve zero waste, waste management has to move from a linear system to being more cyclical so that materials, products and substances are used as efficiently as possible. Materials must be chosen so that it may either return safely to a cycle within the environment or remain viable in the industrial cycle.

Zero waste promotes not only reuse and recycling, but, more importantly, it promotes prevention and product designs that consider the entire product life cycle. Zero waste designs strive for reduced materials use, use of recycled materials, use of more benign materials, longer product lives, reparability, and ease of disassembly at end of life. Zero waste strongly supports sustainability by protecting the environment, reducing costs and producing additional jobs in the management and handling of wastes back into the industrial cycle. A Zero waste strategy may be applied to businesses, communities, industrial sectors, schools and homes.

Benefits include :-

- Saving money. Since waste is a sign of inefficiency, the reduction of waste can reduce costs.
- Faster Progress. A zero waste strategy improves upon production processes and improving environmental prevention strategies which can lead to take larger, more innovative steps.
- Supports sustainability. A zero waste strategy supports all three of the generally accepted goals of sustainability - economic well-being, environmental protection, and social well-being.
- Improved material flows. A zero waste strategy would use far fewer new raw materials and send no waste materials to landfills. Any material waste would either return as reusable or recycled materials or would be suitable for use as compost.
- There are a few cities around the world that have become leaders in the zero-waste movement. New York City has gotten a start—with a pilot composting program and a long-needed ban on styrofoam containers—it still has a long way to go.

3. CASE STUDIES OF ZERO WASTE

3.1 San Francisco's Composting Paradise

San Francisco became the largest U.S. city to commit to zero waste in 2002, promising to divert 100% of its waste from landfills by 2020. Working with restaurants, hotels, landlords, and the construction industry to get them to participate. Today, at more than 80% landfill diversion, San Francisco is well on its way to zero waste, but the last bit may be the hardest. The city can get to 90% landfill diversion by continuing its current activities. The last 10%, however, will require state or national laws that require or incentivize more product manufacturers to get on board with the program.

3.2 Sweden's Story

Sweden (and every city in it) has a slightly different approach to zero waste. It fuels itself off of trash, burning about 2 million tons of trash a year in waste-to-energy plants, is replacing a not-insignificant amount of the nation's fossil fuel use, and drastically reducing landfill waste. This, however, has a caused a problem: Sweden has become so efficient at recycling and reducing waste that it doesn't have enough trash to burn to power its facilities. It imports about 800,000 tons of trash annually from neighboring countries to feed its incineration plants.

Sweden's success was rooted in a cultural shift around attitudes towards trash that began in the 1970s and took decades to bear fruit.

3.3 Capannorı, Italy's Work

Capannori is a small town that is leading Europe towards its continent-wide zero-waste goal. It started in 1997 when local activists defeated a proposal for an incineration plant and developed an alternative instead: a waste tax that would reward residents for reducing non-recyclable waste. According to IPS News, the town gave residents garbage bags with codes on them to track each household's waste production. This was only the beginning of a long education effort that saw a nearly 40% reduction in the amount of waste generated per person between 2004 and 2012. Because of selling its recyclables, its zero-waste program is self sustainable and even makes money for the city.

4. ZERO WASTE CONCEPT FOR INDIA:-

Idea of Zero Solid Waste City for Delhi:-

In Delhi, 5 Municipal Authorities are responsible for Municipal solid Waste Generation and Management. Total 8360 TPD MSW generated daily in Delhi.

There are 3 landfill sites namely Bhalswa land fill site, Ghazipur sanitary land fill site, Okhla sanitary land fill site. Bhalswa These landfill site are not designed as per the schedule 3 of the MSW rules. In absence of availability of landfill sites, all the 5 Municipal Bodies are using these three sites for illegal disposal of MSW.

A Sustaınable Approach For Waste Management:-

- Now the time has come to reduce those piles of garbage which are lying over these areas & creating a boundary between Haryana & Delhi.
- Firstly, segregation of the biodegradable & non –biodegradable wastes is must.
- Secondly, make lots and send some of the biodegradable wastes for landfill composting, incineration process and rest other lots to waste to energy conversion plants.
- In this way we can sell fertilizers & manures formed as a result of composting to farmers at a cheaper price & electricity to small villages which are still living in dark. Also plant set-ups will lead to employment in that area.

Now the time has come we should start educating people to reduce the wastes at house levels.

Try to recycle, reuse as much as one can. For instance, use both sides of every page of a notebook before moving on to the next clean notebook. Use unneeded, printed on printer paper for a scratch pad.

Here are some useful steps that ensure to reduce the trips to the landfill each year:

1. Donate Clothes

Believe it or not, throwing away of clothes is one of the biggest contributions for landfills today. Open up our closets; pick clothes that are no longer needed like a sweater that was fashionable last year, a ripped shirt, or some clothes that one just don't want to keep any more. All these contribute to landfill. First, make sure that these are clothes that are not needed any more. Then, donate clothes to people in need or to Goodwill stores, or hold a sale in your garage (though assuming the clothes are still wearable, of course). You know what they say, another man's trash is another man's pleasure.

2. Reduce Food Waste

Food is another item that are often just carelessly toss away without thinking twice about it. Each year, a very large percentage of our purchased food is left uneaten. Instead of simply throwing away food, make good use out of it. Even keep just a small percentage of uneaten food and donate it, millions of needy people would be fed.

3. Eat Healthy

Also think about eating healthier. Buy healthier foods that don't require as much disposable waste in the form of packaging. Reuse old shopping bags and containers for maximum efficiency, and better yet, cloth bags. Don't buy fast food take out as often either.

4. Save Leftovers for Next Day

Don't forget about leftovers! Too many people are careless enough to throw away half of a good meal and not save it for later. Eating leftovers more often will save on money and result in less food waste. Try making it a habit to save the rest of tonight's food in the fridge for tomorrow's lunch or dinner.

5. Buy Things With Less Packaging

One can also stock up on food in the freezer. Buy a bunch o

f food at the same time and store it in the freezer, and don't buy any more food until the freezer is empty. In addition, buying food in bulk means less packaging and less waste.

6. Boycott Plastic Water Bottles

Millions of plastic water bottles are thrown away by people every day. Don't be one of those people. With this practice one can save boat load of money by switching to reusable glass bottles and produce less waste by dumping plastic water bottles into the trash, which in turn means no contribution to the mountains of bottles in landfills or (gulp) in the bottom of the ocean.

7. Just Don't Buy as Much Stuff….Really

Though it's quite tempting to buy as much things as money can buy, if one is serious about cutting down on the number of trips made to the landfill each year, simply buying less stuff will severely cut back on those number of trips all ready. Be mindful of what to throw and what to not.

8. Recycle

Don't just throw away old glass bottles or aluminium cans. Instead, recycle them. Keep a recycle bin at home, to place old soda cans, paper, metal and plastic cups. Most urban areas have a recycling station in town. Try making more trips to the recycling station than to the landfill.

9. Purchase Items Made From Recycled Products

Consider buying items made from recycled products so that one can help the environment in making it clean and green. Also, this will set as an example for one's friends, family and relatives and they will also start buying items made from recycled products.

10. Clean Smarter

Instead of buying cleaning solutions from market to unclog drains, use baking soda and vinegar for your cleaning projects. Baking soda has countless uses and neither vinegar nor baking soda will hurt the environment. This way one can avoid all the bottles of cleaners and cans used by us.

11. Composting

Composting is easy and natural process that takes remains of plants and kitchen waste and turns it into nutrient rich food which help your plants grow. Compost is organic materials that has been collected together and decomposed. Composting helps you recycle your kitchen waste and reduces the amount of that is sent to landfills that proves safe for the environment.

12. Reuse

Make habit of carrying old shopping bag with while going out for shopping. An old shopping bag can replace hundreds of plastic bags that will end up in landfills. Use empty wine or beer bottles into lamps, oil and vinegar dispensers or send them to recycling centers as few of them may be recycled.

13. Buy rechargeable batteries

Rechargeable batteries will help in saving money for the long run and keep disposable batteries out of landfills. Disposable batteries can prove very harmful for the environment as chemicals inside the batteries can leak.

14. Buy Items Packaged in Recycled Cartons

Buy products that are packaged in recycled cartons and reuse those cartons. Similarly, old newspapers make great packaging material. This helps to promote recycling.

5. CONCLUSION:

By studying the various methods of reducing waste worldwide, it may be understood that clean India is not an impossible task. However, a long way is to be covered. Many steps were proposed some of them have been initiated to dispose off the wastes entirely from the country. The concept of ZERO WASTE, if implemented by every individual, can reduce waste at root level and thus will be a great contribution towards clean India mission. It will be a great achievement for our country which is rich in culture & population and may became richer in cleanliness too.

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Comparison of Cooling Duty and Pressure Drop of Green Secondary Refrigerant (Ice Slurry) with Chilled Water in a Plate Heat Exchanger

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ABSTRACT

The present study reports the experimental comparison of cooling duty and pressure drop of ice slurry with chilled water. Experiments were performed on plate heat exchanger (PHE) using chilled water and ice slurry as secondary fluids. Propylene Glycol (PG) and Mono Ethylene Glycol (MEG) are used as depressants (10%, 20%, 30% and 40% concentration) in ice slurry formation. The results show that by using ice slurry in place of chilled water in plate heat exchanger, cooling duty found to be higher and pressure drop is slightly higher in case of ice slurry. Cooling duty of ice slurry increases with increase in antifreeze concentrations 10%, 20%, 30% and 40%. By using ice slurry in plate heat exchanger cooling duty was found to increased by 50% at 0.3m^3/h and increased by 37 % at 3.0 m^3/h of 10% ice crystal PG ice slurry and pressure drop increased by 10% at 0.3m^3/h and increased by 7 % at 3.0 m^3/h.

Keywords: : Ice slurry, depressants, scraped surface ice slurry generator, plate heat exchanger.

1. INTRODUCTION

Ice slurry has a great potential for the future due to industrial applications, ranging from commercial refrigeration and comfort cooling to industrial production processes and medicine. An important application of ice slurry system is in the milk production where high peak loads are to be adjusted. Ice slurry is a phase-changing secondary fluid consisting of both a liquid state and a solid–state fraction (composed of fine ice particles). The main purpose of using ice slurry is to take advantage of the stored cooling energy (in terms of latent heat) in the ice particles (0.1 to 1 mm size) during melting. Ethanol, ethylene glycol, Sodium chloride, and propylene glycol are the four most commonly used freezing point depressants by the refrigeration industry [1, 2]. The operating temperature [3] for ice slurry can be chosen between 0 to -35^{0}C depending on the type of additive and additive concentration.

Numerous experimental studies using PHEs have been performed in the recent past, to understand the flow behavior and heat transfer characteristics of ice slurry. Ma and Zhang [4] investigated pressure drop and heat transfer characteristics of 0-17.5 vol% tetrabutylammoniumbromide (TBAB) clathrate hydrate slurry (CHS) as a secondary refrigerant flowing through a PHE. It was observed that the pressure drop of TBAB CHS was about 3.0-50.0 kPa which was about 1.2-2 times that of the chilled water at the flow rate of 2.5-13.0 L/min. Further, the pressure drop increased with volume fraction. Heat transfer and pressure drop characteristics of an absorbent salt solution in a PHE serving as a solution sub-cooler in the high loop of triple-effect absorption refrigeration cycle was investigated by Warna kulasuriya and Worck et al. [5]. The main objectives of this research were to establish the empirical correlations to predict the heat transfer and pressure drop and to analyze and optimize the operating parameters used in the design of absorption systems.

A standard PHE with ice slurry of different ice concentrations was tested by Norgaard et al. [6]. The results show increased heat transfer and pressure drop with increasing ice concentration. A map of operation was developed in order to enable the designer to avoid fouling and flow pulsation. Bellas et al. [7] reported the results of experimental investigations into the melting heat transfer and pressure drop of 5% propylene/water ice slurry (ice fraction 0 to 20% by wt.) flowing in a commercial PHE. The heat transfer capacity of the heat exchanger was increased by more than 30 % with melting ice slurry flow as compared to chilled water flow. In a practical application, for a given thermal load this would lead to 60% reduction in flow rate and pressure drop compared to conventional chilled water cooling systems.

PHEs are widely used in different industrial applications [8] like dairy and food processing plants, chemical industries, power plants, pollution control systems, heat recovery systems, heating and air-conditioning, and ice slurry refrigeration systems. The advantages of PHEs includes compactness, high effectiveness, easy cleaning, cost competitiveness, better heat transfer characteristics, lower fouling flexibility, wide range of temperature limit etc. The PHE manufacturers have developed exclusive design methods. Despite the large number of applications of PHEs, rigorous design methods are not easily available, unlike shell/tube or tubular exchangers. The available methods often have configuration limitations or depend on simplified forms of the heat transfer model of the PHEs. According to Jarzebski and Wardas-Koziel [9], designers find it difficult to determine operating conditions and unit dimensions for PHEs due to the large number of possible configurations and the complexities associated with performance and cost optimization. The traditional design method, either ε-NTU or logarithmic mean temperature difference (LMTD) method, consists of huge testing of different geometries because pressure drops are regarded as constraints [10, 11]. This is not only very time-consuming, but cannot guarantee optimal design with full utilization of allowable pressure drops.

The traditional ε-NTU design method was used by Jackson and Troupe [12], Kandlikar and Shah [13] and Zaleski and Klepacka [14] for the selection of the PHE configuration or pass arrangement for multipass applications. Focke [15] presented a method for selecting the optimal plate pattern of the PHE for minimizing the heat transfer area. Shah and Focke [16] developed a detailed step-by-step design procedure for rating and sizing a PHE and Thonon and Mercier [17] presented the "temperature-enthalpy diagram" method for the design of PHEs. A screening method has been presented by Gut and Pinto [18] for selecting optimal configurations for plate heat exchangers based on the minimization of the heat transfer area, subject to constraints on the number of channels, pressure drops, flow velocities and thermal effectiveness, as well as the exchanger thermal and hydraulic models. Zhu and Zhang [19] discussed the integrated optimal design of the materials, placement, size and flow-rate of a PHE.

Despite several advantages and wide applications, the simplified yet accurate design methods for PHEs using ice slurry as secondary fluid have not been developed in a similar significant way. In this regard, Wang and Sunden [20] proposed an optimal design method for PHEs considering with and without pressure drop specifications. The optimization is based on a thermal-hydraulic model, which represents the relationship between heat transfer, pressure drop and exchanger area. Compared to the other existing design methods in the literature, the proposed method require relatively less number of trial iterations. Instead, all heat exchanger parameters, including plate size, number of passes, path, fluid velocity, etc., are determined in a straightforward way. Moreover, the suggested method can guarantee that the optimized values of allowable pressure drops can be fully utilized simultaneously by the two streams. At present, experimental validation of thermo-hydraulic model proposed by Wang and Sunden [20] is not available in the literature. Therefore, the novelty of the present work is to explore the possibility of application of thermo-hydraulic modeling for design of PHEs.

Ice slurries can be used both as a secondary refrigerant and for cold storage in place of chilled water or ice. Despite the fact that ice slurry has now a days gaining wide acceptance, a little engineering information is available on fluid flow and heat transfer characteristics of ice slurry in PHE applications. The objectives of the present study are to validate thermo-hydraulic modeling [20] for PHE applications by collecting heat transfer and pressure drop data using chilled water and ice slurry as secondary fluids and experimental comparison of cooling duty and pressure drop of ice slurry with chilled water.

Fig.1. Schematic diagram of the experimental facility (1 = Ice Slurry Generator, 2 = Pump, 3 = Insulation, 4 = Ice Slurry Storage Tank, 5 = Drainage, 6 = Pump, 7 = Thermocouple, 8 = Agitator, 9 = Condensing Unit, 10 = Data Acquisition System, 11 = Rotameter, 12 = Plate Heat Exchanger, 13 = Pump, 14 = Mass Flow Meter, 15 = Water inlet, 16 = Water outlet, 17 = Sampling Point, 18 = Mass Flow Meter, 19 = Thermocouple, 20 = Pressure Transducer, V1, V2, V3, V4, V5, V6 = Valves).

2. DESCRIPTION OF EXPERIMENTAL SETUP

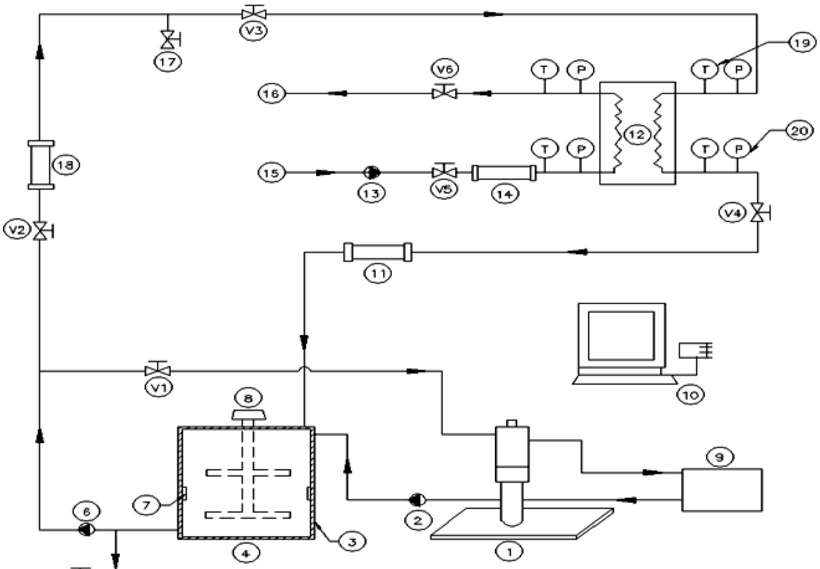


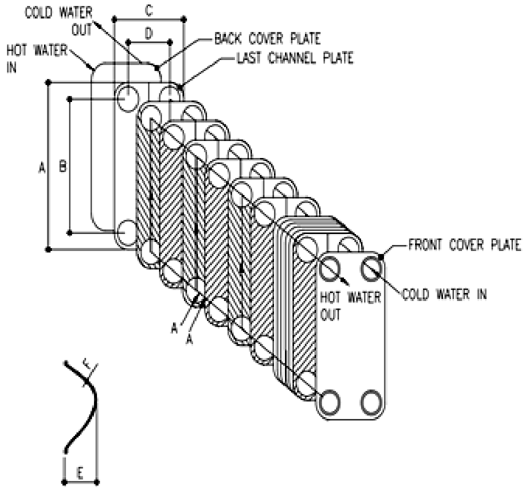
Fig. 1 shows a schematic diagram of the experimental facility, consisting mainly of two independent circuits: ice slurry formation circuit and ice flow circuit.

2.1 The Ice Slurry Formation Circuit

The ice slurry formation circuit consists of a 74 liter capacity scraped surface ice slurry generating system (Fig.1). The major components of this system are: ice slurry generator with spring loaded scraper, condensing unit, pumps and a storage tank with a mixer. A spring loaded scraper was installed to produce agitation inside the inner tank of ice slurry generator. The functions of scraper are to enhance the heat transfer between the slurry and the refrigerant, accelerate the nucleation, scrape the crystals adhering to the inner tank wall and ensuring the homogeneity of the generated slurry. This system produces fine ice crystals with diameters in the range between 150 and 200 μm.

2.2 Ice Slurry Flow Circuit

The ice flow circuit was designed, fabricated and assembled to enable pressure drop and heat transfer data measurements of ice slurry mixtures and water in pipes, bends and heat exchangers. A standard PHE (manufactured by Alfa Laval) normally used in traditional secondary loop systems was tested both thermodynamically and hydraulically with chilled water and ice slurry for wide range of flow. The heat exchanger has 24 plates with 11 channels on each side, see Fig. 2. Each plate is 480 mm in height and 150 mm width. The hydraulic diameter is 4 mm and the total heat transfer area is 0.6765 m^2. The cold fluid was forced to flow through the one set of 11 channels side, while the hot water prepared in a thermally insulated water tank, was used as the cold load and flowed counter-current on the other side. The entire pipe work and the storage tank are well insulated.



A =	0.480 m	D =	0.075 m
B =	0.410 m	E =	2.4 mm
C =	0.150 m	F =	0.4 mm

Fig.2. Dimensions of plate heat exchanger

Table 1. Geometrical parameters of plate heat exchanger

Geometrical parameters	Value
Number of plates (N)	24
Equivalent diameter (D_e)	0.004 m
Port diameter (d_p)	0.032 m
Pass number (n)	1
Projected plate length (l)	0.410 m
Path number of chilled water (m_1)	11
Path number of hot water (m_2)	11
Plate width (w)	0.150 m
Corrugation angle (θ)	60 °
Plate thickness (δ)	0.0005 m

2.3 Instrumentation

The temperatures for both flowing fluids were measured at the inlet and the outlet of the heat exchanger using resistance temperature detectors. One thermocouple was used to monitor the temperature of the mixture in the storage tank. Pressure drop across the heat exchanger streams was measured using pre-calibrated differential pressure transducers which were directly inserted into the fluid. Pressure sensors were located at the inlet and outlet of PHE to record the variation of the inlet and outlet pressures of the tested fluids and the pressure drop was then inferred. Mass flow meters connected at the upstream sides of respective fluids were used to measure the flow rates. All the temperature, pressure and flow rate sensors were connected to a PC based data acquisition system where data were automatically recorded in every thirty seconds for further analysis.

The various instrumentation used for measurements are shown in Table2.

Table 2. Specifications of measuring instruments

Instrumentation	Type/make/model	Range	Accuracy
Mass flow meter	OPTIMASS 8300C S25	0 to 5000 kg/h	± 0.1 % (of reading)
Differential pressure transmitter	SIEMENS	0 to 1000 mbar	± 0.01 bar
Resistance-temperature detectors	LTX-3000/D	-50 ºC to 0 ºC to 99 ºC	± 0.01 K
Data logger (Data Acquisition System)	DT80-2	16 terminal points (10) as shown in Fig. 2	± 0.01 %

3. EXPERIMENTAL PROCEDURE AND DATA COLLECTION

The plate heat exchanger was tested for water to water flow, and ice slurry to water flow. The hot (primary) fluid in the heat exchanger was water, obtained directly from a storage tank provided with an emersion heater. Chilled water and ice slurry was used as secondary fluid. The secondary fluid flow rate was measured upstream of the heat exchanger using a mass flowmeter while the main hot water flow rate was measured using a mass flowmeter just before the inlet to the heat exchanger. Experimental runs were performed using chilled water (approximately 4 ºC) at flow rates starting from 0.3 m^3/h to 3.0 m^3/h. The hot water, at approximately 17.4°C, was then allowed to flow through the heat exchanger and the flow rate was adjusted to obtain a 0.7 m^3/h of primary fluid flow. The pressure drop and heat transfer results from these runs would form the bases for validating and comparing the ice slurry results. Propylene Glycol (PG) and Mono Ethylene Glycol (MEG) are used as depressants (10%, 20%, 30% and 40% by weight) for formation of ice slurry. Once the percentage of ice in the storage tank reached the desired value, the slurry generation system was shut down and the mixer inside the tank was operated. This allowed proper mixing of the ice/liquid solution, producing a homogeneous mixture throughout the tests. The secondary fluid (ice slurry) was circulated through the heat exchanger by ice slurry circulation pump initially at a flow rate of 0.3 m^3/h adjusted using valve 3 (Figure 1). Simultaneously the data of temperatures and pressures across the PHE are collected at different flow rates up to the maximum flow rate of 3.0 m^3/h.

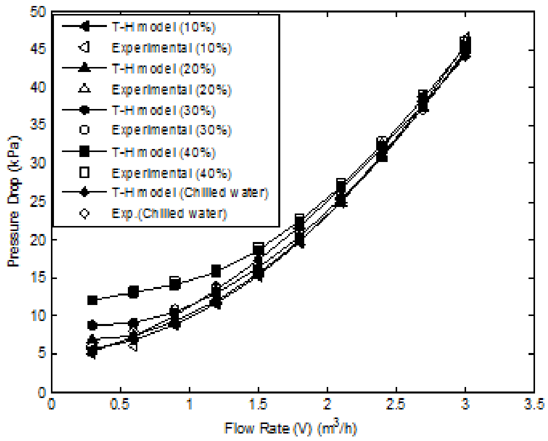
The ice fraction was measured during each test. The flowing mixture was sampled near the inlet (17) of the heat exchanger (Fig. 1). The ice crystals were separated from the mixture in separate container and the ice fraction was determined from the corresponding weight of the ice crystals collected separately. The ice fraction was kept 10% by weight for all the runs. In data reduction, calculation of fluid properties was based on the average fluid temperature across each circuit of the heat exchanger. The heat exchanger was insulated using polyurethane insulating foam and heat transfer across the walls to the ambient was neglected. Heat balance between the hot and chilled water sides revealed less than 5% difference between the two values for the range of flows tested.

4. RESULTS AND DISCUSSIONS

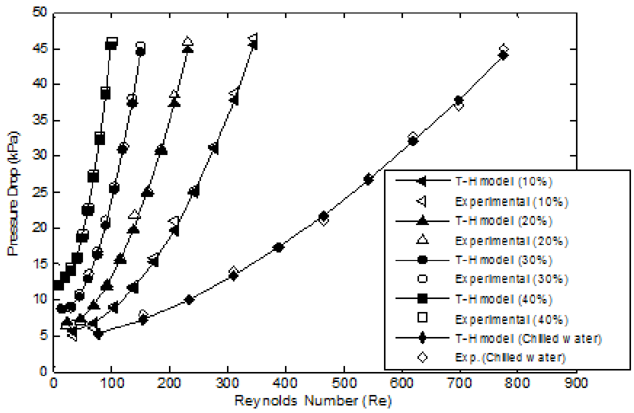
Experimental results of pressure drop and heat transfer for chilled water vs hot water and ice slurry vs hot water flowing in a plate heat exchanger is described below:

4.1. Pressure Drop

Comparison of predicted pressure drop using T-H modeling with experimental data using PG and MEG as antifreezes (10%, 20%, 30% and 40% concentration) is shown in Fig. 3 and 4 respectively. It can be seen that predicted ice slurry pressure drop matches reasonably well with the experimental data. For comparison purposes, pressure drop results for water to water are also presented. The ice slurry pressure drop increases with flow rate and antifreeze concentration.

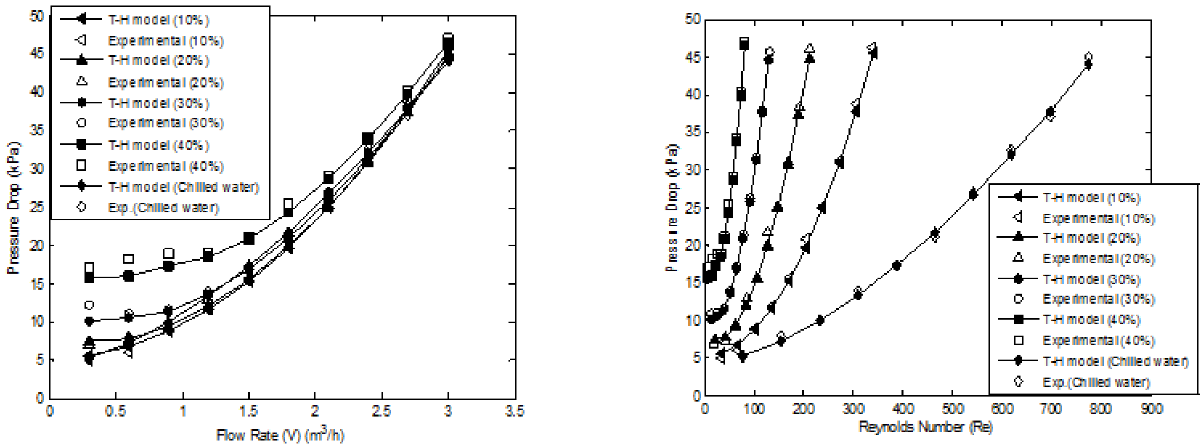


(a) Variation of pressure drop with flow rate



(b) Pressure drop versus Reynolds number

Fig. 3. Comparison of predicted pressure drop with experimental data using PG as antifreeze with 10%, 20%, 30% and 40% concentration



(a) Variation of pressure drop with flow rate

(b) Variation of pressure drop with Reynolds Number

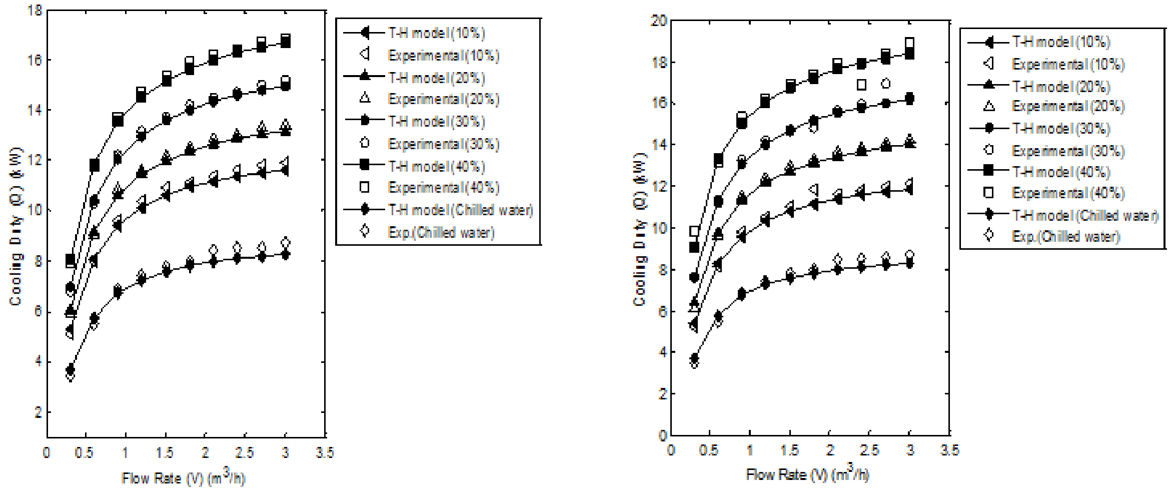
Fig. 4. Comparison of predicted pressure drop with experimental data using MEG as antifreeze with 10%, 20%, 30% and 40% concentration

The effect of antifreeze concentration is significant on pressure drop at lower flow rates. As shown in the figure 3(a) and 4(a), pressure drop of ice slurry (10-40% concentration) is between 5.0 - 48.0 kPa at the flow rate within 0.25-3 m^3/h which is about 1.1 to 3 times of that of chilled water since the apparent viscosity of ice slurry is much larger than that of water. In addition, the larger pressure drop could also be attributed to quite small and corrugated flow passage of PHE, which enlarged the constraint effect of the wall on the particles, consequently, inducing additional flow resistance. Effect of antifreeze concentration on pressure drop reduces with increase in flow rate.

Fig. 3(b) and 4 (b) presents the pressure drop results plotted against the Reynolds number as opposed to flow rate. It can be seen that for the same flow rate, the Reynolds number is much lower for the PG and MEG water mixtures compared to pure water. The Reynolds number reduces even further as the freezing concentration is increased. The reduction of the Reynolds number is mainly due to the increase of the viscosity of the ice slurry. As shown in Figure 8, overall T-H modeling predictions for pressure drop in ice slurries are within $\pm$ 15% limit.

4.2 Cooling Duty

Comparison of predicted cooling duty using T-H modeling with experimental data using PG and MEG as antifreezes (10%, 20%, 30% and 40% concentration) is shown in Fig. 5. It can be seen that predicted ice slurry cooling duty matches reasonably well with the experimental data. For comparison purposes, cooling duty results for water to water are also presented. It can be seen that ice slurry cooling duty is around 25-100% higher than that of chilled water for the selected flow rate. The ice slurry cooling duty increases with flow rate and antifreeze concentration.



(a) Ice slurry using PG as antifreeze (b) Ice slurry using MEG and antifreeze

Fig. 5. Variation of cooling duty with flow rate

The term "uncertainty analysis" refers to the process of estimating how great an effect the uncertainties in the individual measurements have on the calculated result [22]. In the present study, the overall uncertainty is associated with the measurement of the overall heat transfer coefficient and cooling duty for ice slurry and chilled water. The functional dependence of these parameters depends on measured value of inlet and outlet temperatures, mass flow rate and pressure drop. The maximum overall uncertainty in measurement of overall heat transfer coefficient and cooling duty is $\pm$10.3% and $\pm$10.1% respectively. The uncertainty in the measurement of the temperature, flow rate and pressure drop are $\pm$0.35%, $\pm$1.69% and $\pm$0.27% respectively.

5. CONCLUSIONS

Experimental studies using chilled water and ice slurry as secondary fluids have been performed to validate thermo-hydraulic modeling for prediction of pressure drop and cooling duty in a plate heat exchanger. The results can be summarized as follows:

By using ice slurry in place of chilled water in plate heat exchanger, cooling duty found to be higher and pressure drop is slightly higher in case of ice slurry. Cooling duty of ice slurry increases with increase in antifreeze concentrations 10%, 20%, 30% and 40%. By using ice slurry in plate heat exchanger cooling duty was found to increased by 50% at 0.3m^3/h and increased by 37 % at 3.0 m^3/h of 10% ice crystal PG ice slurry and pressure drop increased by 10% at 0.3m^3/h and increased by 7 % at 3.0 m^3/h.

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Corrosion and its Remedy in Dry Type Fire Sprinkler System in LPG Bottling Plant: A Case Study:

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A B S T R A C T

Internal corrosion in the security air pipeline is a major problem faced by the Delhi Bottling Plant (Indian Oil Corporation Limited) authorities which accounts for a surplus cost of about 1.97 million INR every year to the plant. The security air pipeline consists of compressed air, which remains stagnant in the pipeline for a long time, and is released only when there is a case of fire in the plant. This stagnant air comprises of water vapors, which after their condensation, starts the process of internal corrosion.

This surplus cost arises due to several effects of corrosion like:

1. *Cracks in pipeline leading to their repairing cost.*
2. *Plant shutdown cost while repairing.*
3. *Degradation cost of pipelines leading to its replacement after every 4-5 years.*
4. *Excessive running cost of screw air compressor.*
5. *Other miscellaneous cost*

After completion of this research, it was calculated that this huge amount of money can be saved by IOCL, if a system of nitrogen inserting, as proposed in this paper, is used for the pipelines.

1. INTRODUCTION

Indian Oil Corporation Ltd. (IOCL) is the flagship national oil company in the downstream sector. The LPG Bottling Plant of IOCL (Delhi Bottling Plant) is situated at Tikri Kalan, New Delhi. As the plant deals with LPG, it has high vulnerability to fires. Hence, a dry type fire sprinkler system is installed in the plant for automatic sprinkling of air.

(Fig.1- Schematic diagram of fire sprinkler system at Delhi Bottling Plant.)

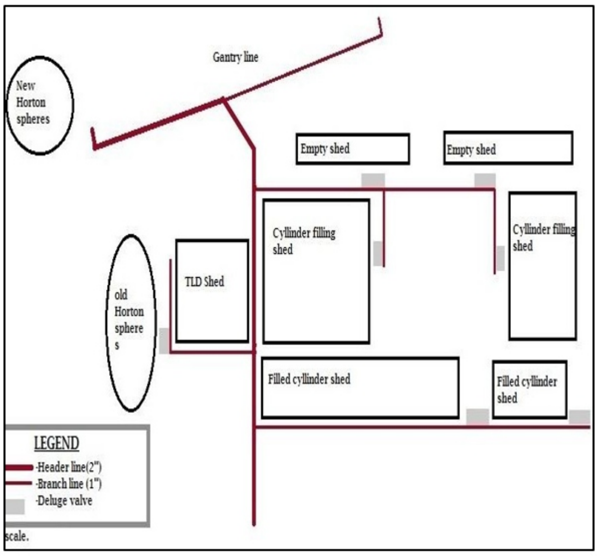

Table1- Specifications of compressed air line.

Property	Specification
Total length of piping	15000m
Material	Seamless pipe MS
Coating	Synthetic enamel
Diameter	Header: 2inches
	Branches:1inch
Operating pressure	5-6 kg/cm2
Sprinkler system coverage area	65 acres
Discharge	65cfm
Inlet temp.	36-40 deg. Celsius
Inlet Dew Point Temp.	14.5 deg Celcius

The Table-1 shows the specifications of the compressed air line.

Type of fire sprinkler system: Deluge valve dry type; gets activated at 79 Deg Celsius temperature.

2. PROBLEM

A major problem faced by the plant authorities was the internal corrosion of compressed air carrying security air pipeline. Due to this frequent rusting of piping, large amount of money was being spent on undue maintenance and repairing of cracks formed (due to corrosion).

The leaks and cracks in the piping's can also lead to leakage of air which may be disturbing in the operation of the plant.

The leaks in the piping's also caused loss in pressure drop by the compressor which increased the work done by compressor and hence it's running cost.

Some methods like using water drainers (to drain out the water causing corrosion) or draining out the whole air periodically were also tried but of not much use.

Fig 2. Internal corrosion in piping's:

3. EXPERIMENTS TO DETECT THE ROOT CAUSE OF THIS CORROSION

1. Dew Point Temperature, temperature and pressure of inlet air was noted down.

These readings were taken at a point just after the compressor outlet. Using a dew point analyser, the dew point was noted down as 14.4 deg Celsius. Hence, in the piping, moisture condensation (and corrosion) will start as soon as the air reaches14.4 deg Celsius.
Inlet temperature and pressure were noted down as 35.5 deg Celsius and 5.6 bar respectively.

2. TDS of groundwater- Quantity of total dissolved solids in the ground water was found out to be 13000 ppm.

3. History of pipe replacement and service.

The whole fire sprinkler system's piping was being replaced after 4-4.5 years with a new one.
Also, as there was no feasible method of repairing the leaks, that particular section of the piping was replaced with a new one, which involved new pipes, nipples, their welding, fitting etc. Analyzing last four years' data of the plant, approximately 250 meters of the piping was replaced annually.

4. Physical and chemical Analysis of the "rust" formed.

Physical analysis showed spots of reddish brown color rust, indicating Iron Hydroxide ($Fe(OH)3$) formed at particular areas of pipes. The concentration of the rusting was more at areas which were wet with liquid moisture in the pipeline, like, near the air water interface.

The precipitate was confirmed as Iron Hydroxide (both ferrous and ferric) by qualitative analysis, in which drops of potassium thiocyanate were added to the rust sample which gave a blood red colored precipitate, confirming ferric ions.

4. THE MAIN CAUSE OF CORROSION

As visible from the formation of Iron (II and III) hydroxides as the precipitate (the "rust"), and also [7], attack of oxygen and moisture on the metal pipes is the main cause of corrosion in pipelines.

Following reactions take place: Anodic Reaction

$Fe^o \rightarrow Fe^{+2} + 2e^-$ iron becomes a water soluble ion

Cathodic Reaction

$\frac{1}{2}O_2 + H_2O + 2e^- \rightarrow 2OH^-$ oxygen creates demand for e^-

Electrochemical Reaction

$FeO + \frac{1}{2}O_2 + H_2O \rightarrow Fe(OH)_2\downarrow$ iron hydroxide precipitate

The further oxidation of the ferrous hydroxide gives ferric hydroxides which forms the reddish brown rust in the pipes. The iron oxide can also exist as two different forms, hematite (Fe_2O_3) or magnetite (Fe_3O_4), in presence of excess oxygen in the piping. All of these corrosion reactions produce solids that are trapped within the fire sprinkler system piping.

Also, the solids that are produced by the action of oxygen on the metal piping produce conditions that favour the proliferation of some bacteria in the system [7], which can also indicate towards microbiologically influenced corrosion (MIC) in the piping. But, the attack of oxygen still remains as the primary cause of corrosion. Hence, focus will be on preventing the oxygen from entering the piping's instead of killing the bacteria.

Also, there is a very small percentage of CO_2 in the air, CO_2 being readily soluble in water can form Carbonic Acid which can also contribute towards corrosion according to the reaction:

$CO_2 + H_2O \rightarrow H_2CO_3$ carbonic acid

$H_2CO_3 \rightarrow H^+ + HCO_3^-$

$HCO_3^- \rightarrow H^+ + CO_3^=$ yields 2 hydrogen ions

$2Fe^o + 2H^+ + O_2 + 2H_2O \rightarrow H_2 + 2Fe(OH)_2\downarrow$ iron hydroxide precipitate.

But again, the quantity of CO2 being very loin (refer to pie chart showing composition of air) air, the main ingredient of corrosion still remains Oxygen. Hence, to solve this problem of corrosion, there can be two perspectives [2]:

4. A) One perspective of preventing corrosion can also be to remove moisture from the piping by applying regenerative and dessicant dryers that can lower the dew point of entering air and prevent moisture in air from condensing. Yes, this can stop corrosion if all of moisture is completely removed from the piping. But to remove all the moisture, it is virtually impossible because of the reasons:

1. The temperature changes throughout the length of the piping will cause moisture to condense at some or other point.

2. Dryers cannot remove water that is already trapped in the system piping and the air in the sprinkler pipeline remains stagnant most of the time.

3. Dryers and piping will require very tight maintenance schedule to maintain no moisture condition throughout piping.

4. Even a small amount of moisture present in the air can combine with oxygen and lead to aggressive corrosion.

Hence, the bottom line is that the air in the piping is persistently moist and oxygenated.

4. B) Replace the compressed air with an inert, dry, supervisory gas that can prevent the electrochemical reaction of oxygen, moisture and iron.

5. USING NITROGEN AS THE INERT GAS TO PREVENT THE CORROSION REACTION

The air comprises of Nitrogen, Oxygen and Carbon Dioxide as its main constituents with the composition shown in Fig3. These three gases dissolve in water when come in direct contact with it. However, these have different solubilities in water (Annexure with table with Solubility values), Nitrogen being the least and Carbon Dioxide being the most. Hence, the composition of these gases, when dissolved in water changes significantly as shown in figure.

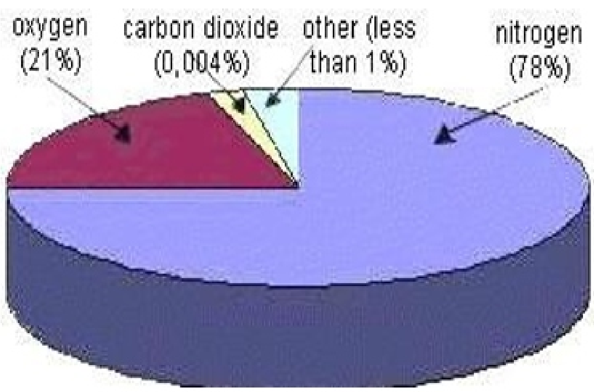

Fig 3 - Pie chart showing composition of air.

Also, to participate in corrosion and react with the metal, a gas must dissolve in water. And out of the dissolved gases, only oxygen and carbon dioxide react with metal, nitrogen being an inert gas does not participate in corrosion.

Hence, increasing the amount of dissolved Nitrogen (and simultaneously stripping off oxygen and carbon dioxide from water) in the water, can prevent oxygen from reacting with the metal and hence can be a preventive measure against corrosion.

Following Henry's Ideal Gas Law, amount of dissolved oxygen in water can be decreased by decreasing the amount of oxygen in the air in piping or by increasing the amount of nitrogen. The objective of adding nitrogen gas to fire sprinkler piping that contains water is to displace the oxygen and replace it with nitrogen. For each percent of nitrogen that is added to the space above the water, the corresponding amount of oxygen is reduced. If the nitrogen in the space is increased to 97-99% the percentage of oxygen drops proportionately to 1-3%.

Water that has been stripped of its dissolved gases, particularly oxygen and carbon dioxide, is no longer corrosive. So even if water remains in the pipe, if it is under an atmosphere that is 97-99% nitrogen it will be essentially non-corrosive water.

Also Nitrogen being an inflammable and inert gas is safe to use in this plant.

6. REPLACING COMPRESSORS WITH NITROGEN GENERATORS

The most effective way to introduce Nitrogen in the piping's was found to be Nitrogen Generators. Nitrogen generators are nitrogen producing complexes that produce dry compressed nitrogen. A general type of nitrogen generator has the following major components:

1. Air Compressors
2. Refrigerated dryer
3. Nitrogen Cabinet (which houses the membrane)
4. Nitrogen Storage Tank

Atmospheric air is compressed in the compressor to the desired pressure. Compressed air from the compressor is dried in the refrigerated dryer to lower the required dew point temperature. After this, dried, conditioned and compressed air passes through a semi-permeable membrane.

Oxygen, moisture and other components permeate the membrane and about 98-99% pure Oxygen is given out.

According to the type of fire sprinkler system here in the plant, the following major specifications for the Nitrogen Generator were decided :

Power- 11 kW **Capacity**- 65cfm
Op. Pressure– 8 bar
Nitrogen - 98-99% pure.
Dew point temp - 4-5 deg Celsius.

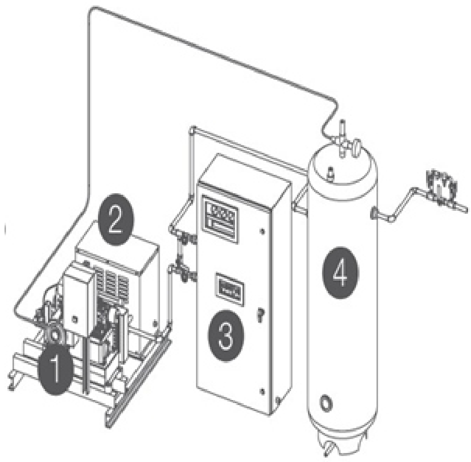

Fig 4 - Parts of nitrogen generators.

7. ESTIMATED MONETARY SAVINGS THROUGH THIS STUDY AND QUANTIFYING THE LOSSES DUE TO CORROSION

1. Annual Repairing cost From pipe repairing history, Pipe section replaced annually = 250 metres

i. Pipe Cost :-
Cost of pipe = Rs. 210 per metre Total cost = 210x250= Rs. 52500

ii. Pipe accessories
Nipples and others cost = Rs. 70 per nipple I nipple needs in every 5 metre of pipeline.
Hence, 50 nipples replaced every year. Total cost of nipples = 50x70 = Rs. 3500

iii. Welding
Cost of welding = Rs 25 per metre Total welding cost = 25x250 = Rs 6250

iv. Labour cost and other miscellaneous cost = Rs. 10000

Total annual repairing cost = 52500+3500+6250+10000= Rs 16265. (i)

2. Increased running cost of compressor

Ideal running time per day= 1 hour Actual running time per day= 7 hours

Extra running time per day = 7-1= 6 hours

Extra running time per year= 6x365=2190 hours

As there are two compressors in parallel, one works as secondary when the primary one cannot produce the desired pressure drop. Hence, approximating the running time of secondary compressor as half that of primary,

Total extra running time of compressor per year= 2190 + 2190/2 =3285 hours.

Rating of compressor= 11kW

No. Of extra electricity units consumed per year= 3285x11= 36135 units.

Electricity rate= Rs 6.8 per unit.

Total extra electricity cost = 6.8x36315= Rs. 246942 (ii)

3. Pipe degradation cost

Whole pipeline gets replaced in every 4 years, which costs around 2 crores. Hence, degradation cost per year = 2/4 = 0.5 crores.

If the pipe is made rust free, the degradation of pipe will be reduced and the life of pipeline will be increased. Assuming a minimum increase of 2 years in the life of pipeline.

Degradation cost per year will be then = 2/6 =.33 crores.

Reduction in degradation cost= .5-.33
= .17 crores= Rs.17 lakhs (approx) (iii)

Hence, total estimated monetary losses due to corrosion in one year =

(i) Annual repairing cost+
(ii) Annual increased cost of compressor +
(iii) Annual degradation cost =16265+246942+1700000 = Rs. 19.7 lakhs (approx.).

8. CONCLUSION

The severe problem of internal corrosion in pipelines is adding to the expenditure of the plant as well as delay in productivity. The estimated excess cost is about 19.7 lakh rupees per annum, due to this corrosion. This huge amount of money can be saved by employing a Nitrogen inserting system (which involves nothing but just adding a nitrogen membrane after the screw compressor) in the plant.

Nitrogen, being an inert gas, will not allow the metal in pipelines to come in contact with oxygen and moisture in the air, preventing the process of corrosion.

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Current World and Indian Energy Scenario: The Challenges of Achieving 175 gw of Renewable Energy by 2022.

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ABSTRACT

Energy is the basic need and is one of the major inputs required for the development of nation. Today majority of this energy demand is met through fossil fuels which have created a major problem for mankind in form of global warming. World has decided to move towards sustainable way of development in form of recent growth in worldwide renewable energy power generation plants. In last 2 decades only fossil fuel based sources were developed throughout world at very fast rate resulting in problem of Global warming and climate change. After Paris climate change summit in 2015, whole world decided to lay more emphasis on carbon free sources of generation for electricity purpose to have sustainable development of whole world. During recent times, the CO2 emissions shows that new generation sources mainly came from Renewables (hydro, solar, wind, other), Nuclear and Gas based sources. India's energy demand has grown exponentially in last few decades which are directly related to its recent economic and population growth. Recent trends like urbanisation and industrialization has fuelled the energy demand in India. With 18% of total world population, per capita energy consumption is still very low at 1/3rd of world average which allows for a strong energy demand growth. Main reason for this low energy consumption is that large population.. 240 million people still remains without modern energy as they are out of reach of power system. India has third highest coal reserves. The heavy reliance on coal for primary energy demand has associated environmental costs with it like land degradation, deforestation, erosion and acid water runoff. Natural gas has small 6% share in domestic energy demand. Current hydro power based generation capacity stands at 45 GW with 10% of it falling in small hydro power (SHP) category. Bio energy is responsible for 25% share of total energy consumption of India with major usage in cooking in rural households. This traditional use of biomass has given rise to major issues like adverse effects on heath due to indoor polluting.

Renewable energy is rapidly growing in India to achieve targets of 175 GW renewable energy by 2022. Solar power and wind & biomass power are major constituents of these targets set by government of India with 100 GW and 75 GW target respectively. India is currently 4th in wind power installed capacity in the world with 26 GW as of 2016 and in solar power its capacity is over 8 GW as of 2016. Gujarat, Rajasthan, Tamil Nadu are three states with more than 1 GW of solar power alone. Out of 100 GW, 40 GW target has been setup in the target of rooftop which will help in reducing distribution and transmission losses. Also cost of both solar and wind has been under Rs 6 crore per MW with tariff Between Rs 5 to 6 per unit. The current share of nuclear power in the generation mix is very small at 3%. India has limited low-grade uranium reserves. The nuclear industry in India is also subject to the challenges faced by worldwide nuclear industry.

1. INTRODUCTION

Energy is the basic need of human life. Also it is one of the major inputs required for the development of nation. In fact energy is used as a parameter to compare development levels of developing nation with those of developed countries. As the population of the world is increasing day by day, energy demand is also increasing exponentially. Today majority of this energy demand is met through fossil fuels (coal, oil and natural gas) which have created a major problem for mankind in form of global warming. Limited nature of these sources of fuel and relatively high prices has forced the world to make huge investments in the field of alternate sources of energy (wind, solar, tidal, etc).

Energy can be classified as:-

1. Renewable energy: - energy obtained from the sources that are inexhaustible in nature i.e. energy from sun, biomass, wind, oceans, etc. these energy sources can be harnessed without any release of harmful pollutants.

2. Non-renewable energy: - energy obtained from the sources that are exhaustible in nature i.e. energy from conventional fuels like coal, oil and gas which will be gone by next 50 to 75 years.

Despite major dependence on fossil fuels in power sector and transportation sector, now world has decided to move towards sustainable way of development in form of recent growth in worldwide renewable energy power generation plants.

2. WORLD ENERGY SCENARIO

International organisations like international energy agency have published the World Energy Outlook 2015: global energy trends to 2040. Important highlights of this report show the recent trends and current energy consumption data of the world. Analysing this data will help us to understand the current issues in the energy sector and associated problems with current energy scenario. We will use this analysed data to find out useful solutions to this current problem which is sustainable and environment friendly in nature.

2.1 Global electricity generation by source

Worldwide electricity is generated from variety of different sources like fossil fuels like coal, oil and natural gas, Nuclear power and renewable energy sources like hydro power, wind power, solar power, other renewable sources, etc. majority of power still comes from fossil fuel based power plants with an share of 67% in total electricity generation for year 2014 which is equivalent to 15000 TWh and more units generated. Related CO2 emissions with fossil fuel based generation source for year 2014 was 12 gigatons. Following table gives the 2014 vs. 2040 scenario of world electricity generation based on different sources [1]:-

Table1:- Global Electricity Generation by source for 2014 vs. 2040 (source: - IEA)

source	Global electricity Generation by source (2014)	Global electricity Generation by source(2040)
renewables	5000	13500
coal	10000	11800
gas	4800	9000
nuclear	2500	4500
oil	750	1250

Following data shows that after fossil fuels, Renewable energy and Nuclear Energy sources are major sources used worldwide for electricity generation with a share of 22% and 11% respectively. Following pie chart Gives the percentage share of different sources in worldwide scenario:-

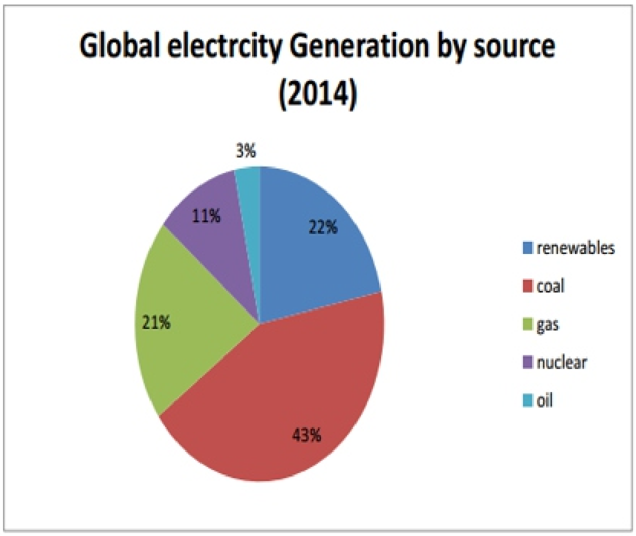

Figure1:- percentage share of different energy sources 2104 (source: - IEA)

Also high share of fossil fuel based electricity generation is directly related to high levels of CO2 Emissions annually. From the last 2 decades, CO2 Emissions have increased from 6 Gt in 1990 to 12.50 Gt in 2015 i.e. Greenhouse Gas emissions have doubled with total electricity generated from 11000 TWh in 1990 to 23000 TWh in 2015. This shows that in last 2 decades only fossil fuel based sources were developed throughout world at very fast rate resulting in problem of Global warming and climate change.

After Paris climate change summit in 2015, whole world decided to lay more emphasis on carbon free sources of generation for electricity purpose to have sustainable development of whole world. Therefore it is clear from table 2 that after 2015 till 2030 the CO2 emissions have become constant at around 12 Gt or more but electricity generation has increased from 23000 TWh in 2015 to 33000 TWh in 2030. This constant CO2 emissions shows that new generation sources mainly came from Renewables (hydro, solar, wind, other), Nuclear and Gas based sources. Following figure gives the comparison between total electricity generation by different source for year 2014 vs. 2040:-

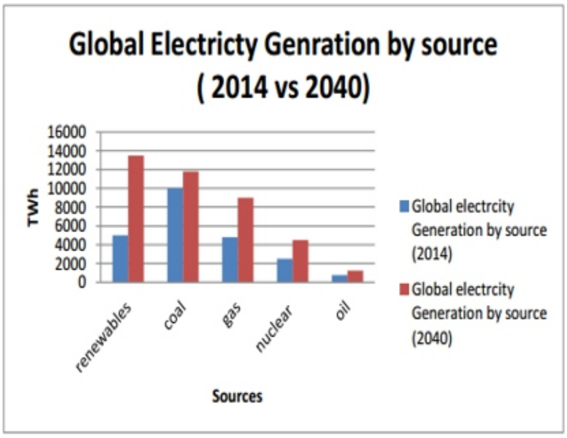

Figure2:- Global electric generation for year 2040 (source: - IEA)

Electricity generation from Renewable energy sources have changed from 5000 TWh in 2014 to 13500 TWh in 2040 i.e. almost it has become 3 times from 2015. Percentage share of fossil fuel based generation has gone down from 67% in 2015 to 55% in 2040 and at the same time renewable energy based sources has gone up from 22% in 2015 to 34% in 2040 which shows that 12% in fossil fuels usage in next 25 years to 12% more renewable energy usage in next 25 years. This historic shift in world energy scenario is directly linked with stabilization of world CO2 Emissions from 2015 t0 2030 as shown in this figure:-

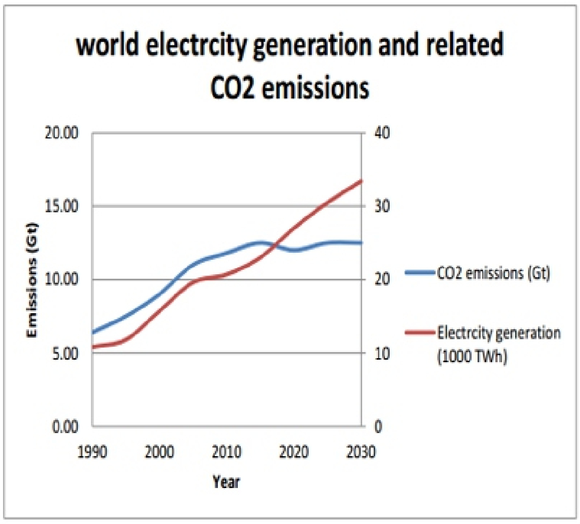

Figure3:- world electricity generation and related CO_2 emissions (source: - IEA)

3. INDIAN ENERGY SCENARIO

India's energy demand has grown exponentially in last few decades which are directly related to its recent economic and population growth. Recent trends like urbanisation and industrialization has fuelled the energy demand in India. Keeping in view of this situation government of India are making efforts to invest heavily in energy sector to supply energy for all its population. Energy demand in India has a percentage share of 5.7% in global energy demand for year 2013. With 18% of total world population, per capita energy consumption is still very low at 1/3rd of world average which allows for a strong energy demand growth. Main reason for this low energy consumption is that large population i.e. 240 million people still remains without modern energy as they are out of reach of power system. Following figure gives the comparison between per capita energy consumption between India and world [2]:-

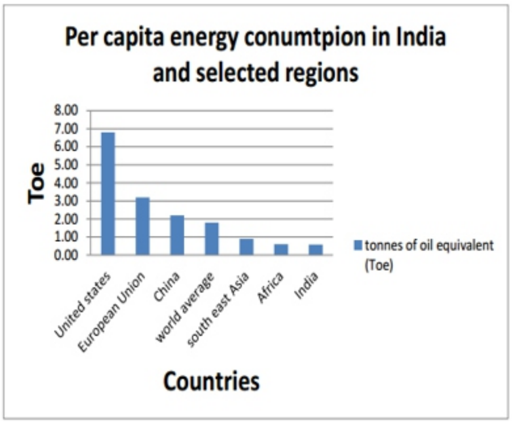

Figure4:- Per capita energy consumption in India and selected regions (source: - IEA)

Primary energy demand and Gross domestic product (GDP) in India is related directly as GDP of India has resulted in growth from 3600 Billion US dollars in 1990 to 7800 billion US dollars in 2013 along with primary energy demand from 260 Million tonnes of oil equivalent in 1990 to 680 Million Toe in 2013. Also India GDP growth for 2015 was at 7.5% with an equivalent growth in Energy demand. Following figure gives the relationship between GDP and total primary energy demand as discussed above:-

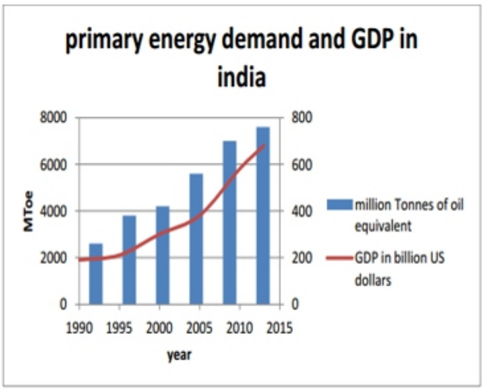

Figure5:- primary energy demand and GDP in India (source: - IEA)

3.1 Primary energy demand in India by fuel

70% of the Indian energy demand is met by fossil fuels due to rapid rise in consumption of coal with a share of 44% in total energy demand of 775 MToe for year 2013. On the other hand demand for bio energy i.e. solid biomass like fuel wood, straw, charcoal, or dung have decreased as households have moved to Liquefied petroleum gas (LPG) for cooking purposes. Oil consumption is mainly for transportation sector with diesel having 70% share in oil market. Natural gas has small share about 6% in energy mix used mainly for power production and fertilizer industries. Hydropower, nuclear power, renewable sources like wind, solar, geothermal is used at very small scale in power sector. Following pie chart gibes the current scenario of India energy mix:-

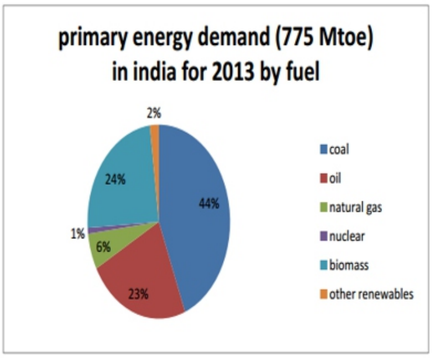

Figure6:- primary energy demand in India by fuel (source: - IEA)

3.2 Fossil fuel balance in India

Fossil fuel balance in India is more on the import side than export side with 200 Mtoe of crude oil imports, 120 Mtoe of coal imports and 15 Mtoe of natural gas imports for year 2013. All these imports have a very acute effect on India economy as high fuel prices means high economic trade deficit for India. Also domestic production of fossil fuels in India is not at very high level to ensure energy security for India in recent future. Following figure gives the balance between fossil fuels export- import for year 2013:-

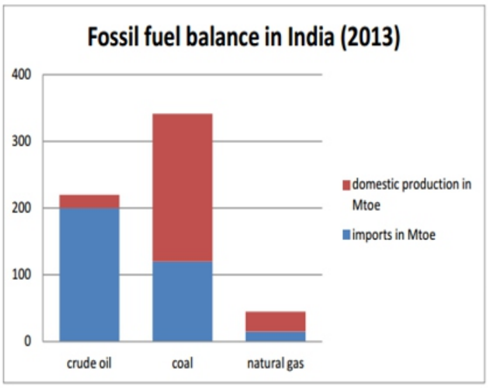

Figure7:- fossil fuel balance in India 2013 (source: - IEA)

3.3 Coal

India has third highest coal reserves in the world i.e. 12% of the world total but these deposits are of low quality due to less calorific value and high ash content; hence India faces major problems in meeting the coal demand of its country with current resources. In 2013, India produced a 340 million tonnes of coal equivalent (Mtce) and imported 140 million tonnes of coal equivalent from Indonesia, Australia, and South Africa. To curb imports Government of India has ordered to double its coal production by 2020. Coal sector is dominated by government organisations like Coal India limited (CIL) with 80% of total coal production in India. This heavy reliance on coal for primary energy demand has associated environmental costs with it like land degradation, deforestation, erosion and acid water runoff. Also coal reserves are mainly concentrated in eastern and central India, while demand centres are mainly in North West India, south India which makes it mandatory to transport this coal from source to demand centre via railways which makes energy process high. OIL India mainly depends upon crude oil imports for primary energy demand fulfilment as domestic crude oil production is just 900,000 barrels per day and demand is nearly 4.4 million barrels per day. India has low oil reserves i.e. around 5.7 billion barrels mostly located in western part of country like Rajasthan, Gujarat, Maharashtra , in northeast India like Assam , etc. oil sector is dominated by state owned agencies like Oil and natural gas corporation (ONGC) and Oil India Limited (OIL).

3.4 Natural Gas

Natural gas has small 6% share in domestic energy demand. Main onshore gas producing fields are located in states of Assam, Gujarat, Tamil Nadu, and Andhra Pradesh. Offshore field include Krishna Godavari basin. Total natural gas production was 34 billion cubic metres in 2013. Major gas producing companies are state owned like Gail authority of India limited (GAIL). Also unconventional sources of gas like coal bed methane and shale gas are still in early stages of development in India.

3.5 Hydropower

Current hydro power based generation capacity stands at 45 GW with 10% of it falling in small hydro power (SHP) category. Only 1/3 rd of total hydro potential has been harnessed and future has much more to achieve mostly in north east India. But major issues in the development of these plants are technical and environmental problems like public opposition. Apart from being clean source of power, hydro power projects also help in water management for flood control, irrigation and domestic proposes. High upfront costs especially for large hydro projects with long term dept financing issues have stalled the further growth in last decade. Hence government has laid more emphasis on small hydro project with upper limit as 25MW for power generation with total installed capacity as of 2016 over 4GW.

3.6 Bioenergy

Bio energy is responsible for 25% share of total energy consumption of India with major usage in cooking in rural households. This traditional use of biomass has given rise to major issues like adverse effects on heath due to indoor polluting. As of 2016 nearly 8 GW of biomass base power in India is operational i.e. mainly bagasse co-generation. National bio energy mission has been launched by government to popularise use of biomass gasifiers, bio fuels, etc. blending of bio fuels in conventional fuel up to 20% has been set up as target of National Bio energy mission.

3.7 Wind and Solar

Renewable energy is rapidly growing in India to achieve Re Invest 2015 targets of 175 GW renewable energy by 2022. Wind power and solar power are major constituents of these targets set by government of India with 100 GW and 60 GW target respectively. India is currently 4th in wind power installed capacity in the world with 26 GW as of 2016 and in solar power its capacity is over 6.5 GW as of 2016. Gujarat, Rajasthan, Tamil Nadu are three states with 1 GW of solar power alone. Out of 100 GW, 40 GW target has been setup in the target of rooftop which will help in reducing distribution and transmission losses. Also cost of both solar and wind has been under Rs. 6 corers per MW with tariff Between Rs. 5 to 6 per unit.

3.8 Nuclear Power

India has 21 operating nuclear reactors at seven sites with a total installed capacity of 6 GW as of 2016. Another 6 nuclear power plants are under construction stage with capacity around 4 GW. The operation of the existing nuclear plants has been low in the past due to severe fuel shortages i.e. the average load factor was at 40%. This problem was solved after India became a party to the Nuclear Suppliers Group in 2008, allowing access to uranium. The average plant load factor rose to over 80% in 2013. The current share of nuclear power in the generation mix is very small at 3%. India has limited low-grade uranium reserves. The nuclear industry in India is also subject to the challenges faced by worldwide nuclear industry, including project economic difficulties like financing and the consequences of the Fukushima Daiichi accident in Japan.

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