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OPTIMAL DESIGN OF THE SAME LENGTHS OF GLASS CONDENSERS

C. M. GONAH[1], C. E. GIMBA[2], A. D. GARKIDA[3] AND D. S. YAWAS[4]
[1 &3]Department of Industrial Design, Faculty of Environtl Design, Ahmadu Bello University, Zaria
[2]Department of Chemistry, Faculty of Science, Ahmadu Bello University, Zaria
[4]Department of Mechanical Engineering, Faculty of Engineering, Ahmadu Bello University, Zaria
[nomhat2003@gmail.com]

ABSTRACT
The study explored solid modelling for possible optimization of conventional laboratory heat exchangers. 240mm, 360mm, 480mm, 600mm and 720mm lengths conventional and unconventional Allihn, Graham, Liebig and Zigzag condensing models were designed and fabricated. An automated coolant system for test running the condensing models was sketched, constructed and used for test running the models using tap water as purification liquid in distillation flasks and coolant from the automated system for condensing vapour. Distillation temperatures range between 93-110^{o}C; while differences between inlet and outlet temperatures were between 6-10^{o}C. Optimal designs for 240mm, 360mm, 480mm, 600mm and 720mm based on distillation rates were Model Nos. 43=BZBZBWB (TA) with distillation rate (WDR) of 477mLs/hr, 38=SBSBS (TB) WDR of 458mLs/hr, 18=BSB (TB) WDR of 438mLs/hr, 18=BSB (TB) WDR of 422mLs/hr and 38= SBSBS (TB) WDR of 428mLs/hr respectively. The models could potentially be used for separation, purification, extraction and teaching aids in science and engineering laboratories and tertiary institutions of higher learning.

INTRODUCTION

Heat exchangers are complicated devices [1] broadly classified into surface and direct contact condensers. In a surface condenser, the coolant is separated from the vapour by tubular heat transfer. The coolant and the condensed vapour leave the device by separate exits. The temperature of the coolant is increased, so the device is also a heater. On the other hand, a direct contact condenser, both the coolant and vapour stream are physically mixed. Both the compressed vapour and the coolant leave the condenser as a single exhaust stream. It should be noted that actual applications of heat exchangers determine the design, size and materials selected for construction. Therefore, design is critical to maximum and effective heat transfer from the exhaust incoming vapour entering the heat exchanger to the circulating coolant, determined by the heat exchanger, pressure, coolant flow rate, coolant inlet temperature, and maintenance of correct and thermal gradient [1,3-4].

Stewart [5] highlighted that the commonest figure-of-merit for most heat exchangers is the efficiency; which is usually a focal point of optimization in both industrial and laboratory scale processes [3, 6-8]. Largest part of optimization researches conducted on heat exchangers concentrate more on theoretical methods with attention to large plants. Majority of these theoretical researches are basic in nature and have constraints that make their applications to a real world design problem impractical. Besides, theoretical detailed models of heat exchangers have been developed with good accuracy compared to experimental data; however, most of these models are rarely employed even industrially [3,9].

Jensen [10] and Anonymous 11-12] viewed that Liebig, Allihn and Graham glass condensers in spite of being the commonest heat exchangers in most of the teaching and research laboratories; there is still little or no improvement in terms of efficiency apart from Friedrichs and Dimroth condensers. The latter were improvements on coil condensers, but are rarely available or even used in most laboratories. Their unpopularity is not unconnected to their complexity, high cost of production, maintenance cost and coupled with the fact that they are not better off than Graham condenser.

Despite the advances in science and medicine which have reduced the demand for scientific glassware, new and modified methods of scientific research are still being developed daily and most of the experimental instruments involved are glassware which must be researched, designed, redesigned, fabricated, modified and maintained for improved performance. Moreover, laboratory glass ware (SGT), which is the bedrock of scientific glass instruments, especially heat exchangers do not receive the desired attention indigenously, where custom designed and fabricated laboratory glassware have usually been imported [13-17].

The study aimed to improve the performance of conventional laboratory heat exchangers for optimum and effective removal of latent heat in the exhaust vapours stream entering the heat exchangers, as well as their heat transfers into the circulating coolants, determined by the heat exchangers' pressures, coolant flow rates, and coolant temperatures. The research was delimited to design and fabrication of 240mm conventional and unconventional surface glass condensing Allihn, Graham, Liebig and Zigzag models.

MATERIALS AND METHOD

Conventional and unconventional 240mm, 360mm, 480mm, 600mm and 720mm condensing models were designed, fabricated and characterized using an improvised automated coolant system. Characterization of the condensing models was carried out in Glass Technology Laboratory, Department of Industrial Design, Ahmadu Bello University, Zaria. A simple distillation principle and procedure were adopted for the experiment. Five SEARCHTECH electric heating mantles, twelve 1000mls Wurtz (distillation) flasks, twelve 10mls and twelve 100mls graduated cylinders for collecting and measuring distillates and four 250mls volumetric flask for measuring liquids into distillation flasks. Twelve of 250mls conical flasks were used for collecting distillates. Two of 300literes GP tanks with accessories, an electric water pump, a water level sensor, eight clamps and stands, a table of 150cm by 128cm and a height of 101.5cm, two S-TEK electric blowers of 350watts and metallic frame housing for the two GP tanks.

A system of four simple distillation sets were assembled and run concurrently (Figure 1). A set was made up of a laboratory jack, a heating mantle, 1000mls distillation flask, a condenser, two thermometers, two rubber bungs, a delivery adaptor and two distillate collectors (two 50mls measuring cylinders). Tap water was employed as both distillation solvent and coolant in the characterization test because of its availability, economy and position as a universal solvent. Besides, water has a high specific heat index of one than many common materials, for example, glass with specific heat index of 0.12. It takes much more heat to raise the temperature of a volume of water than the same volume of air and other common materials. This was why water was employed as a coolant. To avoid the risks of water bumping over the flasks, the distillation flask was 2/3 filled with tap water and 50 glass beads were put in it.

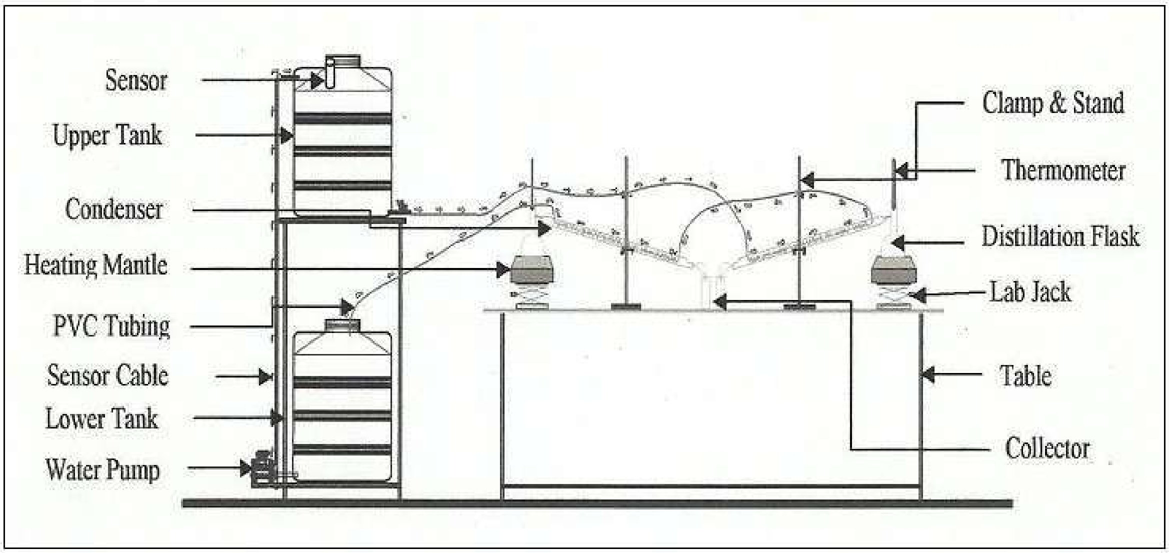

Figure 1: Automated Coolant Recycling and Distillation System [3]

Coolant flowed through the four distillation sets. The upper and the lower water tanks served as the source and destination of the coolant respectively. The flow was a continuous process; four distillation sets were assembled which operated concurrently. Two distillation sets per side were arranged in series with common coolant supply pumps from a split main pump coming from the upper 300litres GP tank. The outlet-coolant for one set became the inlet coolant for the second set, and then the coolant returned to the lower tank from the outlet of the second set through PVC tubing by gravity force. 750mls tap water and 50 glass balls or beads were put into each 1000mls Wurtz flasks. With the aid of rubber bungs, the glass condensing models were fitted to the stems of the Wurtz flasks, thermometers were inserted into the mouths of the four Wurtz flasks and adaptor deliveries to distillate collectors with the aid of rubber bungs and corks. Coolants were first turned on, followed by turning SEARCHTECH Instrument heating mantles on. Distillates were collected in 50mls measuring cylinders. Readings of distillates were taken in every five minutes for one hourly basis per glass condensing models.

RESULTS AND DISCUSSION

Graph and chart are employed to underscore the differential distillation of condensing models of 240mm, 360mm, 480mm, 600mm and 720mm of different designs (Figures 2-6). 48 designs of the same lengths are compressed to a single graph and bar chart for easy-to-understand format that clearly and effectively communicate the highest and lowest distillates at a glance. Numbers 1-48 on the abscissa on the coordinate plane on the graphs represent condensing models of 240mm, 360mm, 480mm, 600mm and 720mm lengths, viz: 1=LIEBIG (TA), 2=LIEBIG (TB), 3=LIEBIGWB (TA), 4=LIEBIGWB (TB), 5=ALLIHN (TA), 6=ALLIHN (TB), 7=ALLIHNWB (TA), 8=ALLIHNWB (TB), 9=GRAHAM (TA), 10=GRAHAM (TB), 11=GRAHAMWB (TA), 12=GRAHAMWB (TB), 13=ZIGZAG (TA), 14=ZIGZAG (TB), 15=ZIGZAGWB (TA), 16=ZIGZAGWB (TB), 17=BSB (TA), 18=BSB (TB), 19=BSBWB (TA), 20=BSBWB (TB), 21=SBS (TA), 22=SBS (TB), 23=SBSWB (TA), 24=SBSWB (TB), 25=ZBZ (TA), 26=ZBZ (TB), 27=ZBZWB (TA), 28=ZBZWB (TB), 29=BZB (TA), 30=BZB (TB), 31=BZBWB (TA), 32=BZBWB (TB), 33=BSBSB

(TA), 34=BSBSB (TB), 35=BSBSBWB (TA), 36=BSBSBWB (TB), 37=SBSBS (TA), 38=SBSBSWB (TB), 39=SBSBSWB (TA), 40=SBSBSWB (TB), 41=BZBZB (TA), 42=BZBZB (TB), 43=BZBZBWB (TA), 44=BZBZBWB (TB), 45=ZBZBZ (TA), 46=ZBZBZ (TB), 47=ZBZBZWB (TA) and 48=ZBZBZWB (TB).

Optimal designs for 240mm, 360mm, 480mm, 600mm and 720mm based on distillation rates were Model Nos. 43=BZBZBWB (TA) with distillation rate (WDR) of 477mLs/hr, 38=SBSBS (TB) WDR of 458mLs/hr, 18=BSB (TB) WDR of 438mLs/hr, 18=BSB (TB) WDR of 422mLs/hr and 38= SBSBS (TB) WDR of 428mLs/hr respectively (Figures 2-6). Model Nos. 38=SBSBSWB (TB) WDR of 443mLs/hr, 45=ZBZBZ (TA) WDR of 426mLs/hr, 21=SBS (TA) WDR of 423mLs/hr and 22=SBS (TB) WDR of 420mLs/hr ranked next in descending order to the optimum design of the 240mm; the same ranking was done for other designs of the same lengths.

Therefore, models Nos. 33= ZBZBZ (TA) WDR of 445mLs/hr, 28= ZBZWB (TB) WDR of 436mLs/hr, 27= ZBZWB (TA) WDR of 432mLs/hr and 17= BSB (TA) WDR of 431mLs/hr for 360mm lengths; 17= BSB (TA) WDR of 431mLs/hr, 34= BSBSB (TB) WDR of 425mLs/hr, 41= BZBZB (TA) WDR of 419mLs/hr and 46= ZBZBZ (TB) WDR of 413mLs/hr from 480mm lengths; 33= BSBSB (TA) WDR of 413mLs/hr, 27=ZBZWB (TA) WDR of 411mLs/hr, 42= BZBZB (TB) WDR of 410mLs/hr and 28= ZBZWB (TB) WDR of 403mLs/hr from 600mm lengths; 17= BSB (TA) WDR of 413mLs/hr, 18= BSB (TB) WDR of 412mLs/hr, 22= SBS (TB) WDR of 411mLs/hr and 41= BZBZB (TA) WDR of 409mLs/hr from 720mm lengths are all in descending order. Least efficient designs based on distillation rates for 240mm, 360mm, 480mm, 600mm and 720mm lengths were models Nos. 10= GRAHAM (TB) WDR of 179mLs/hr, 10= GRAHAM (TB) WDR of 271mLs/hr, 38= SBSBSWB (TB) WDR of 247mLs/hr, 13= ZIGZAG (TA) WDR of 260mLs/hr and 6= ALLIHN (TB) WDR of 253mLs/hr respectively.

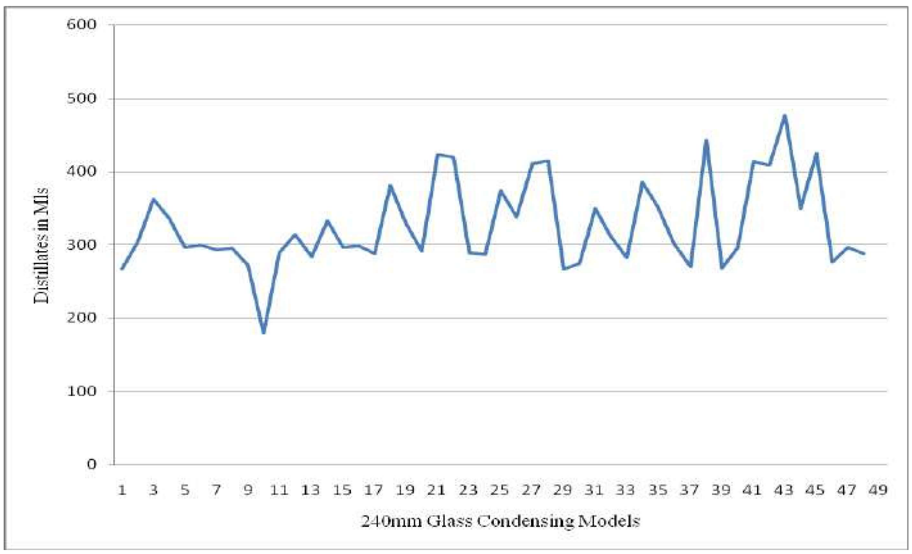

Figure 2: 43 BZBZBWB (TA) Graph Optimum Design of 240mm

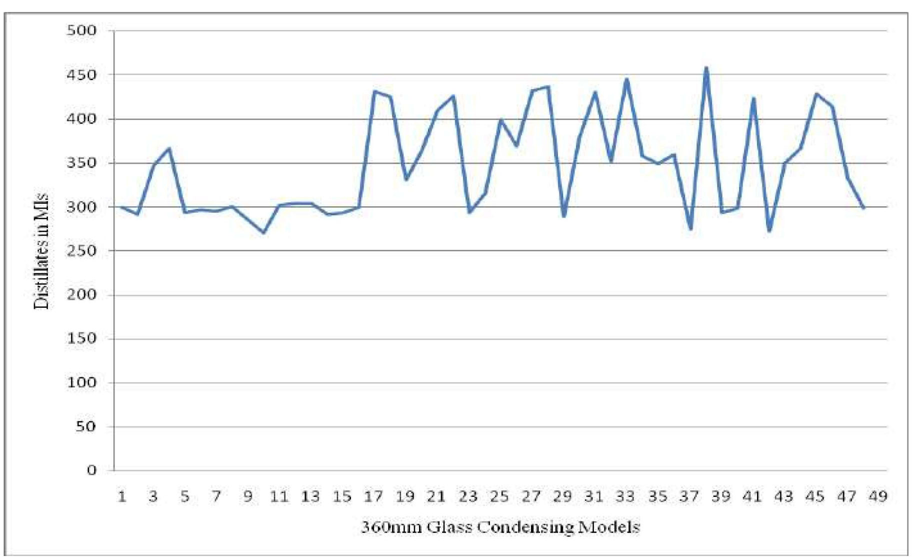

Figure 3 : 38 SBSBS (TB) Graph Optimum Design of 360mm

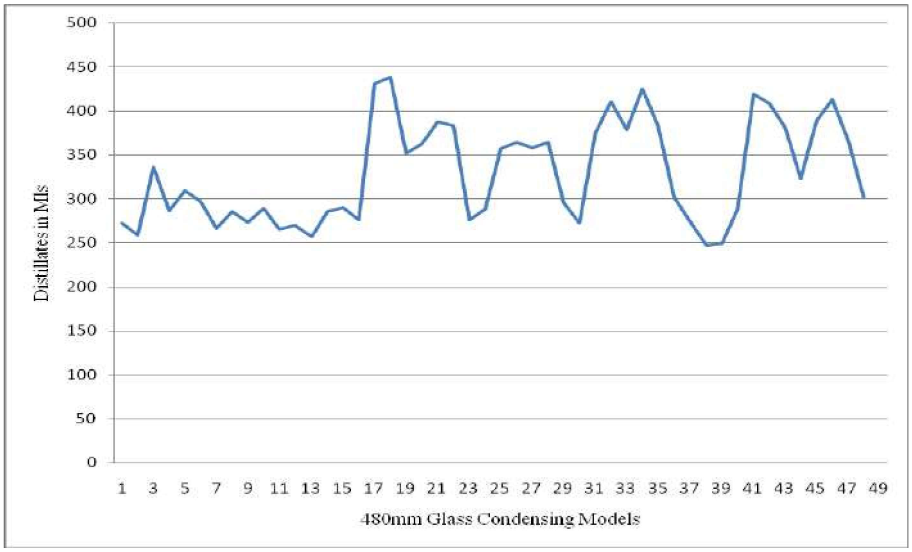

Figure 4: 18 BSB (TB) Graph Optimum Design of 480mm

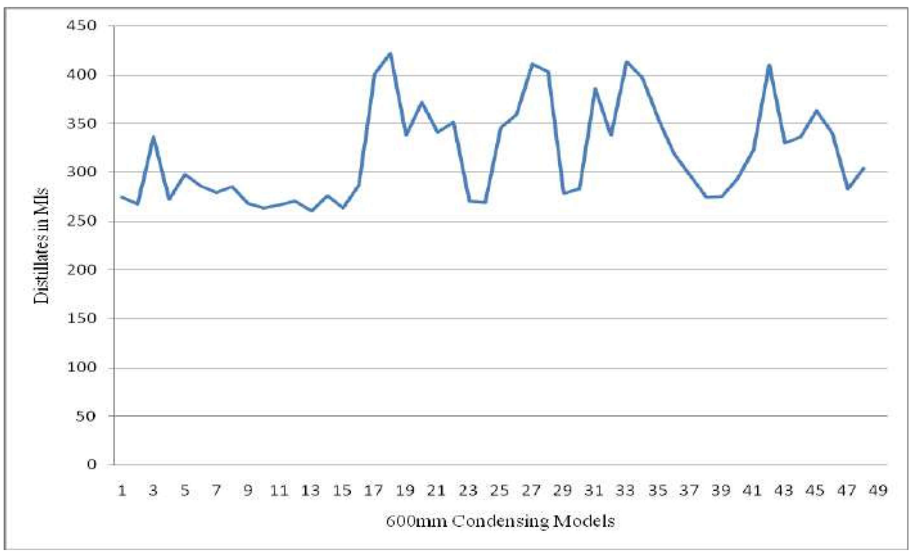

Figure 5: 18 BSB (TB) Graph Optimum Design of 600mm

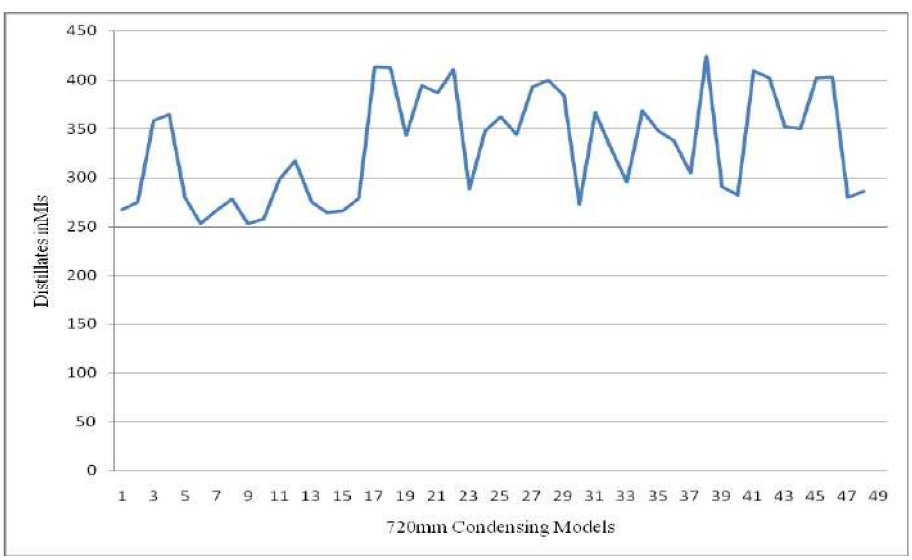

Figure 6: 38 SBSBS (TB) Graph Optimum Design of 720mm

Efforts were made to ensure optimal operating factors throughout the experiments. However, design, accuracy of fabrication according to specified design, length, coolant and mode of coolant flow, fouling factor from accumulation of deposits on heat transfer surface, leak-tight, power supply and handling skills of the researchers could have contributed more or less to the performance of the condensers.

CONCLUSION

Based on the above, optimal designs should be emphasized in choice of condensers. This will save time, cost, maximize profit, reduce losses and sustains, perhaps the business. Further research should be carried out on re-fabricating the solid models with attention to spiral pitches, bulb sizes and spacing. Again, the current models should further be characterized by differential distillation of two or more mixed liquids.

REFERENCES

1. Y. A. Cengel, R. H. Turner and J. M. Cimbala. Fundamental of Thermal Fluid Sciences, 2008. McGraw- Hill Companies, 3rd Ed., London.P. 968.
2. W. L. Badger and J. T. Banchero. Introduction to Chemical Engineering, 2005. Tata McBraw-Hill Pub. Co. Ltd, New Delhi, New Yorek. Pp120-399, 257-463.
3. C. M.Gonah. AutoCAD Drawing of a Coolant Recycling Distillation System. Unpublished PhD Research, Optimization of Laboratory Heat exchangers by Solid Modelling, 2013. Glass Technology, Department of Industrial Design, Faculty of Environmental Design, Ahmadu Bello University, Zaria.
4. W. C. McCabe, J. C. Smith and P. Harriott. Unit Operations of Chemical Engineering, 2005. McGraw Hill Intl. Ed., Singapore. Pp299-486, 663-703.
5. E. W. Stewart and and S. V. Shelton, S. V. Finned-Tube Condenser Design Optimization Using Thermo Economic Isolation, 2003. Unpublished Ph.D. Dissertation; George W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, Ga 30332-0405,USA.
6. T. F. Edgar, D. M. Himmelblau and L. S. Lasdon. Optimization of Chemical Processes, 2001. *McGraw Hill*, New York, pp20-24
7. D. Mikielewiez, J. Wajs and M. A. Glinkski. Model of Dry Out in Annular Flow, Proceeding, 2007. 6th International Conference on Multiphase Flow, ICMF, Leipzig, Germany, pp10.1, 18.7
8. Rao, S.S. Engineering Optimization: Theory and Practice, 2003. New Age International Ltd; Delhi, pp1-30 www.lynxsys.net/bookreview/bkrv960802.pdf.
9. A. Ford. Modeling the Environment, 2009. Island Press, Washington D.C. PP.1-36. http://serc.carleton.edu/introgeo/models/WhatIsAModel.html 28/05/2014
10. W. B. Jensen. The Origin of the Liebig Condenser . Journal of Chemical Education. 2006. (83), p23. http://jchemed.chem.wisc.edu/Journal/Issues/2006/Jan/abs23.html. 24/02/2012.
11. Anonymous. "Condensor." CU Boulder Organic Chemistry, Undergraduate Courses, 2011b. http://orgchem.colorado.edu/equipment/glassware/cond.html. 17/11/ 2011.
12. N. J. Niancoli. Kinetic Theory Applied: Evaporation, 2005. Vapour Pressure, and Boiling Point. Physics for Dorks, 3rd Ed. Pearson.pp.1, 2.
13. C. M. Gonah, C.M. Analysis and Synthesis of Scientific Glass Technology Studios, 2011. Ahmadu Bello University, Zaria. Unpublished Seminar Term Paper - INDE 908: Industrial Design Advanced Studio Theory; Course Lecturer: Dr. S.U. Dakyes. Ph.D/Env-Design/10575/2007- 08; pp2-23.
14. A Macfarlane and G. Martin. Beyond The Ivory Tower, Glass: A World History, 2004. Chicago Univ. Press, Chicago, pp.1-229. http://www.alanmacfarlane.com/12/04/2012
15. H. K. Mensah. Development of the Art of Glassblowing in Ghana; Prospects and Challenges of Selected Glassblowing. A Thesis Submitted to the School of Graduate Studies, KNUST in Partial Fulfillment of the Requirements for the Award of the Degree of Master of Philosophy in African Art and Culture, 2009. Faculty of Fine Art, College of Art and Social Sciences. Ghana.
16. Organomation Associates. Extraction Glassware - Liquid/Liquid for *ROT-X-TRACT-L; 2007.* Online Catalog (Organomation Associates), p125 *w*ww.organomation.thomasregister.com 10/04/2012.
17. Salem Community College, USA. Scientific Glass Technology Programme Entry Requirements, 2012. Salem Community College, USA. Salem Community College *Website,USA*. 856, 299, pp21-31.http://www.salemcc.edu/glass/programs/scientific.php 11/04/2012