Chapter 2

Detail of Research

In this chapter, the objective, scope, procedure and methodology of the study are discussed in detailed. Expecting benefit, literature survey standard and referenced regulation is refereed.

2.1 Objective of Study

The objective of this study is "To improve the current design, verify and test the new design of the high competitive, high cleanliness level double skin air-handling unit for use and manufacture in Thailand."

2.2 Scope of the Study

To achieved the objective of thesis the following issues need to be addressed:

- ✓ Develop Regional customers requirement model for using as design guideline
- ✓ Analyze and Benchmark the competitors in the market to the customer requirement
- ✓ Develop the product ranges, sizing distribution
- ✓ Study the regulation, standards for reference
- ✓ Study the technical background of each AHU equipment for design verification
- ✓ Verify the limitation of production facility in Thailand
- ✓ Improve or re-design new Air Handling Unit (AHU) for local production
- ✓ Build prototype for design verification

2.3 Procedure & Methodology

The procedures to conducting the Air Handling Unit (AHU) design improvement are:

1) Use Quality Function Deployment (QFD) to transform the customer verbatim to usable statement of demands

2) Use Quality Function Deployment (QFD) to develop the customer requirement modal, key substitute characteristic, key function, key reliability and failure mode

3) Use Quality Function Deployment (QFD) to benchmark the competitor in the industries

4) Study, Define, Collect the regulations and references standard

5) Study, Define, Collect the technical background, design knowledge database

6) Verify the limit of local manufacturing facility

7) Generate new concept by referred to demands, functions, regulation, standard and design knowledge database.

8) Verify new concept by using Quality Function Deployment (QFD)

9) Detail design and selection of equipment by referred to standard, regulation and design knowledge database

10) Use CAD tools to aid the detail design

11) Build prototype for design verification

2.4 Expected Benefits to the academic & Industries

2.4.1 Academic Benefit

1) Implementation of Quality Function Deployment (QFD) in the Air Handling Unit (AHU) design

2) Technology background for Air Handling Unit (AHU) design

3) Air Handling Unit (AHU) product development model

2.4.2 Industries

1) Customer Requirement Model: Quality, Function, Reliability Demanded and Unacceptable Failure Mode

2) New design of Air Handling Unit (AHU) that meet the customer demand

3) New methodology of product development process (QFD)

4) Introduction of 3D CAD design to product development process

5) Prototype Unit

2.5 Literature Survey

Randall Scasny,1999

This article in Appliance detailed the new insulation material that can reduce the cost without forfeiting performance. The new foam insulation that has the higher thermal insulation and higher strength of the foam constructions.

From this article, we found that the insulation suppliers are continuing develop the insulation foam that will increase the operation ranges of the foam insulation. This improvement will effect the design of the AHU wall panel. Wall panel can lower the thickness with higher thermal insulation property.

Bayer Corp, 1999

This article discussed the advantages of the polyurethane foam insulation over other kind of insulation material. The wider ranges of foam operating temperature and reduction of water adsorbent rate of PU are improving its thermal insulation in HVAC equipment application.

The PU foam that developed by the Bayer increases the flexibility and the thermal operation ranges of the PU insulation. The higher operation range

improve its fire code rate, can use in the heating coil sections. Lower water adsorbent of PU will improve the quality of the wall panel; lower thermal conductivity is achieved.

Pace Inc, 1997

The technical paper studies the rate of bearing failure when use the Variable Frequency Drives (VFD) in the motor and fan speed control. The study show that the VFD caused the capacitive couple voltage to ground across the baring and the spark is damaging to bearing surface and lead to bearing failure.

This technical paper show the unforeseen damages of the baring that the AHU designer should aware off when selecting the VFD as the fan speed controller.

Brackin Pasty, 1999

This thesis study the strategy to develop the design specification from VOCT (Voice of Customer Table) and House of Quality. The IDEF0 approach is used to improve the semi-quantitative House of Quality. Also using the case study in automotive industries tests the strategy.

From the case study, the QFD shows its extended capability to improve the design process. This paper shows good example of using QFD in the design process and can be used as the guideline for implementing the QFD in designs the AHU.

F. A. Karen, 1999

This technical article is discuss about the design of the telecommunication equipment rack steel structure that can withstand the low frequency, high magnitude vibration from earth quake. The article also recommends the reinforcement of the structure.

AHU and the electronics telecommunication component cabinets are based on the same structure. This example of the reinforced is another idea for improving the strength and stiffness of the AHU structure.

Tawee Vechaphutti, 1994

This article states the requirement of the HVAC design for the high rise building and the requirement of the air distribution systems. The calculation of load, selection of equipment and the schematics of the air conditioning systems are clearly described. The paper provide better understand of how design engineer will select the equipment in the high rise building.

Pawat Vituraprakorn , 1994

This paper is the study of the various types of insulation materials in HVAC application. The technical comparison between the Open Cell, Interconnection Cell, Semi-closed Cell and Closed Cell types, provide the better understand of the insulation material property. Limits of insulation are clearly stated. This paper also focuses on the effects of water penetration into the insulation material. Penetrated water will develop the thermal conduction link which will caused the thermal insulation failure. Different insulation materials have each own water resistance rates. The comparisons on the thermal insulation breakdown show the advantages and disadvantages of each insulation material.

From reviewing this article, designers need to carefully select the insulation materials for each application requirements. Each unique material property, insulation property and water repellent properties give broad ranges of advantages and disadvantages. In selecting the insulation for designing AHU or design the sandwich panel, insulation material installation must be concern to avoid the thermal insulation breakdown problems.

Pitoon Kripornsak et al 1999

The study paper states about Thailand's air condition and the conditioning part industries. The size and the structure of the air conditioning market in Thailand and the total export value. The study focus on the small-mini split air conditioning equipment's, industries, product development.

The clear picture of the air conditioning industries in Thailand provided from reviewing this article give researcher broader view of this industry. The historic records of the exports show the air conditioning industries economic trends and the opportunity to grow in the future. The study also provides good assessment of the manufacturing capability of the air conditioning unit industries. Thailand air conditioning factory are using only 30% of it total capacity. If the market grow rapidly Thailand can increase the output rate within short period.

Chao Benjaapiku, 1999

The technical paper discuss about the function and standard of the adhesive material that use to adhere the insulation material to the sheet metal, duct, pipes. The paper also describes the fire resistance classes of the insulation material adhesives. This paper illustrates the industrial practice of insulation material installations. The methodology and the accessory that used to installed the insulation material into the duct, AHU and chilled water pipes. This paper is a good source for insulation material installation. The fire resistance class of adhesive is used as the AHU design reference.

Pakawat Puascmbat, 1999

The technical paper discusses the methodology and approach to the HVAC system commissioning. The detail in Air Handling Unit (AHU) standard commissioning process and the check list for field inspection of Air Handling Unit (AHU) installation.

This paper illustrates the project management and consultant point of view in the commissioning of AHU installation. The detailed of AHU component inspection provide clear understanding of the customer demands and the unacceptable failure mode of the air conditioning systems engineers and designers.

Somsak Chaiyapinunt, 1999

The technical paper is expressed the calculation of the transfer function cooling load calculation using transfer function method. The paper discussed about the methodologies that used to calculate the cooling load: the heat balance method, transfer function and the total equivalent temperature differential and time-average method. Though this article is not relate directly to the AHU design development but the basic understand to the cooling load requirement calculation is necessary for AHU designer. The cooling load calculation will be basic of cooling coil selection. Knowing the load of the building provides the key information for coil selection, humidifier selection and dehumidifier selection. Also airflow requirement and the fan selection are start from this cooling load analysis.

Somsak Chaiyapinunt, 1999

The technical paper discusses the usage of computer air engineering software that use to calculate the energy load of the building. In the paper the discussion of the new Thailand energy control regulation and discussion about the regulation of the control building.

The usage of computer analysis in the AHU design in Thailand is undistinguished. The designers are estimating the building load base on their experience and rules of thumb. The estimation caused the "Foster Effect" where the cooling load is estimated and multiplied by safety factors. Series of safety factor are used and the result is the over designed, which effect the in efficient energy consumption and over investment. The computer cooling load calculation will ease the designer on cooling load calculation and can virtually optimized the cooling load so the systems have better energy consumption and sound investment.

Mike Franklin, 1998

This article provides the necessary technical background of fan technology to help the engineer solving the fan problems and selecting the fans for

ventilation systems. The article concludes the fan laws and power calculation for fan. It is also recommend the variety of fan installation in the ventilation and AHU. In the final section of the article, the fan testing standards and methods is discussed.

From this article, Fan technology background is obtained. The installation tips is clearly discussed. This article can be used as the AHU fan section design reference and guideline for fan installation and selection.

Joanna R Turpin, 1998

The author of this article points the defect in most architect design of the building that lack of the attention of the mechanical system. The space for the mechanical systems in the building is neglected and eventually not enough space. This scenario develops new opportunity of *the build to the demand and space HVAC systems*. The innovated made to space increase the capability of the HVAC systems especially AHU to be fitted into the oblique shape of the space without compromising the capacity.

Joanna R Turpin , 1998

The article show the evidence that the old fiber glass insulation in the AHU are the source of poor IAQ. From the test the 3 years old system is internally insulated with the fiber glass material. Microbial samples are taken and evaluated. The result found out that the fiber glass material contain the fungi colony forming unit (CFU) at 1,190,000 CFU/sq. in. of the fiber glass material. This large amount of CFU is the cause of the sick building syndrome. Same type of test is conducted on the double skin AHU that stand side by side on the same building where the internal surface is the galvanized steel sheet, the result shows that the CFU us at 8 CFU/sq. in.

From the article, the insulation material is the key factor for the better IAQ. In order to achieve the better IAQ in buildings proper insulation material must be chosen. Double skin AHU is also alternative solution for dramatically air cleanliness improvement. Though there are also another factor concerned the IAQ such as filters, drain pan and gas filter but this study show the effect of the insulation material to the IAQ.

Dilbert D. Thomas, 1998

This article discusses the problem of the air conditioning engineer in selection the proper coil for the specific cooling load requirement. This paper shows one example of the coil selection for a pizza restaurant that initially the system designers are not taken the heat of the cooking process into account. The problem solving is to replace the coils that have the same size with the different circuit. From

the coil selection base on new cooling load calculation, new coil with the tighter fin pitch and the coil depth provide better cooling capacity.

This example shows that the coil variation in capacity is not depended only on the size of the coils, but also on the other factors. Designer must understand the relation ship of the coil component, proper select the coil will improve the total system efficiency. This article also provides the good checklist and guidelines for coil selection basic that AHU designer can be the design references.

W. C. Trent, 1999

This article discusses the effective design and selection of the drain pan for collecting the condensed water from the cooling coil. Factors of drain pan problems is listed and discussed. Solution and recommendation for improve the drain pan problems is explained with some technical background. The major concern of the drain pan cleanliness that effects the IAQ problems in the buildings is discussed. Example of solution to improve old drain pan that equipped into the old AHU to increase its cleanliness is shown. Finally this article also provide good recommendation on designing the drain pan, material selection and the installation.

The recommendation on drain pan sizing, slope, flow rate and the material recommendations are used as the design guideline for the AHU design improvement.

J. B. ReVelle, et al, 1998

This article shows the approach to address the expected quality from the customer demands. The customer demands that described in the "Kano model of quality" are derived into three groups, Expected Quality, Normal Quality and Excitement Quality. The discussions of three groups of quality are clearly made. This article also addresses the step needed to take to complete the "Voice of Customers Tables" (VOCT).

From reviewing this article, the QFD process referenced is derived. Steps to complete the VOCT from this article are used as the QFD process references and generate the VOCT in AHU design.

J. B. ReVelle, et al , 1998

This article discussed the implementation of the QFD into the quality systems of the organization. The QFD is adapted to work with the TQM, ISO9000 and QS9000 in Japanese automaker industries. The successfully integration of the quality systems and QFD approach increase the company's ability to improve the quality systems to suit to the process demands with minimum time in implementation.

From reviewing this article, the approach and methodology that the automaker company use QFD in the process is a industrial breakthrough in quality systems implementation. The integration of the TQM, ISO and QFD show the flexibility of the QFD tools in implementing to any process improvement. The case in the article is a good guideline in implementing the QFD to the existing process and can be adapted to AHU design improvement process.

J. W. Moran, et al 1998

This article states the potential and the methodology to implement the QFD to the service industries in America. The methodology discussed is cover from the nature of service industries, methodology to get the customer demands and how to implement the QFD in the service industries. Charts and table is given for example and guideline for implementing the QFD to the service industries.

From reviewing this article, the very clear approaches in implementing the QFD to the product and service are stated. Systematically, the implementation processes and recommendations of QFD in this article give clearer picture of QFD implementation. The flow, step and key note provided in the article are used in the AHU product design QFD implementation.

2.6 Standards and Regulations

2.6.1 Standard References for Designing Air Handling Unit (AHU):

Following list are the designation and name of the standard that the design needs to verify the design of the equipment in the Air Handling Unit (AHU) with. The standard is using the American References since this standard is well known and acceptable in Thailand Industrial Practice.

AMCA 99	Standard Reference Handbook
AMCA 210	Laboratory Method of Testing Fans for Rating Purposes
AMCA 301	Method of Publishing Sound Rating for Air Moving Devices
AMCA 500	Test Methods for Louver, Dampers and Shutters
ANSI/AFBMA 9	Load Rating and Fatigue Life for Ball Bearings
ANSI/U.L. 900	Test Performance of Air Filter Unit

ARI 410	Forced Circulation Air Cooling and Air Hearing Coils
ARI 430	Standard for Central-Station Air Handling Units
ARI 435	Standard for Application of Central Station Air Handling Unit
NFPA 90A	Installation of Air Conditioning and Ventilation Systems
SMACNA	Low Pressure Duct Construction Standards

In searching for the Thai Industrial Standard (TIS) there is not standard relate to the designing and constructing the Air Handling Unit (AHU). This is one of the major problems for Thai industries in improving the quality of local products.

From assessing the international standard that used to govern the AHU design, the AHU designer needed a lot of effort to achieve the design that compatible with the standard. Many parts and article according to standards are not necessary for design AHU in Thai market. If Thailand have own industrial standard that use for AHU design references, that meet the Thai operation and environmental requirement, the local AHU industries will then standardized and can directionally improved the product to meet the local standard.

2.6.2 The Government Regulation

In the thesis proposal one of the focus area is the government regulation of the design, installation and using the Air Handling Unit (AHU). The regulations shall cover to the energy limitation or requirement that enforce the Air Handling Unit (AHU) design.

In searching the information of the energy control of the HVAC equipment, the latest energy control regulation/law that released and enforced in 1995, are focus on the Chiller, Package Air Conditioning and etc. None of regulations directly related to the Air Handling Unit (AHU) equipment.

Interestingly, Air Handling Unit (AHU) can be using the energy upto 20% of all HVAC systems or about 10-14% of over all building energy consumption but no articles related to the energy control of the Air Handling Unit (AHU) existing in regulation.

2.7 Manufacturing Limitation in Thailand Manufacturing Facility

To know the limit of the production facility is one of the key design success factors. Further more, the designer should understand how to manufacture the product that they design. The more concern on the manufacturing capability, the better robustness of the design.

For Air Handling Unit (AHU) design improvement, the researcher received the cooperation from Thailand leading air conditioning manufacturers and sub-contracted manufacturers for factory visit and question of the limits of the facilities. Three month on the site of manufacturing facilities of various brands provides broad understand in the nature of local AHU manufacturing facilities.

In the hand on study in the production by actual work on assembling the AHU, many Manufacturing limits are listed. He production staff interview, the production engineer interview and factory manager interview increase the understanding of the production concepts and processes in local AHU production facility.

Moreover, the researcher have a opportunity to visit one of the south east Asia largest sub-contracted Air Handling Unit (AHU) factory in Kuala Lumpur, Malaysia, which have the maximum capacity of approximate 20 unit of large Air Handling Unit (AHU) per day.

Three days factory visit at the KL base company expanded the knowledge and understanding of the Air Handling Unit (AHU) manufacturing process, which is a vital information for improving the local manufacturing facility. For two years ago, the researcher did visit one Air Handling Unit (AHU) unit manufacturing factory in United Kingdom. The process at the UK factory is also used as the references on comparing the limits of the Thailand Manufacturing Facility.

2.7.1 Manufacturing Process

Thailand Air Handling Unit (AHU) reference factory are equipped with better CNC machine for sheet metal process because of new investment of the factory in 1997. Compare to other local Air Handling Unit (AHU) factory, KL Factory and UK factory, the equipment and machines in Thailand are newer. The CNC machines are individually run on separate cellular cell. The Air Handling Unit (AHU) production line is built in job shop style. Parts are running in to the assembly area from the parts production cells and from inventory to assembly at a job shop area. The area of the 200sq.m job-shop is capable for manufacturing 4 Air Handling Unit (AHU) at the same time. The average capacity of Air Handling Unit (AHU) production is 10 units per day.

Comparing with the KL and UK base factory, both factories are using the flow line, instead of the job-shop. The Air Handling Unit (AHU) is manufacturing on the roller conveyer. The production areas are about the same size but the capability of output rate is higher. In flow assembly line the AHU is built from the base up, each station are taking care of single group of repeated task such as station one, base and post assembly, station two, fan assembly station three coil assembly and station four panels and accessories assembly.

All other sheet metal process is about the same, CNC machines do all the major sheet metal work and delivered the equal level of product output in all three factories. Material handling systems are almost the same.

From the assessment of the local AHU manufacturing facility compare with the two references international AHU manufacturing facilities, the production concept is different and that cause a major different in the output rate of AHU production. Due to the advantages of the flow assembly line, the production capacity in KL and UK factories is higher. Flow line also give the opportunity to the production manager to see the bottle neck in operation, measuring the work load and improve the assembly easily. Quality control in the flow line is easier and more systematic than the job-shop.

2.7.2 Material

The material that required producing the Air Handling Unit (AHU) is the sheet metal and the cold rolled steel profile. Some additional material such as plastic, aluminum profiles and wood is also used in air handling unit part. The limits of important material will be addressed one by one from the assessments.

Sheet Metal

There are several sheet metal factories that setup to support the automobile industries in Thailand. The sheets metal that locally produce met all the international standards such as DIN, ASTM, JIS, and BS. The quality of the sheet metal is very good with variety of material property, coating, and form. Difference roll width, size and thickness can be individually order. From the discussion with several manufacturing facility Thailand have no material limit in the sheet metal steel, stainless steel.

Cold Rolled Steel Profile

Thailand has local factories that produce such steel profiles, and also some are imported from China, Japan, USA and others. The standard size steel profile are available in the market, which we found that all type of profile, thickness and grade are available for production.

Aluminum Extrude / Injection / sheet

The aluminum extruded profile and mold injection is mostly subcontracted to the specialty. There are limit in the variety of the aluminum grade that available in market. Some aluminum alloy are not imported due to the minimum use and need to specific order which take time and expensive than standard alloy. Most of the aluminum alloy that available in market are the low strength use for producing the door frame and window frame. Not much engineering aluminum alloy available.

The pricing of the aluminum is very fluctuate, same as copper. Thus, cost control in the production is varying. Often, the supplier are ran out of stock for the sheet aluminum for fin production so large buffer stock is needed to prevent the material shortage in production. The quality of the aluminum is at the world class standard by the variety of suppliers. From assessment the major limit on aluminum material is only on the variety of alloy.

Copper tube and Connector

The copper tubes are locally produced by several factories, and also imported from China and Japan. The availability of the copper tube size and thickness is not the limits to the industries. The standard tube size such as 5/8 or ½ inches is available in the market. Standard connectors of the copper tube for the coil production are also locally produced. Many of local supplier are stock and supply those fitting and tubes to the manufacturer.

Engineering Plastic

There are increasing trend for the usage of engineering plastic in the Air Handling Unit (AHU) production though it already long used in the small air conditioning. Some plastic/polymer material is locally made but mostly general purpose plastic. The engineering plastic price is still expensive due to the need of imports and the low volume of usage. All suppliers can provide the plastic/ polymer to the specification but the limit is the cost of acquiring the material.

2.7.3 Workmanship

Workmanship of Thai workers needs to improve in skills, knowledge of using the hand tools, machine operations and safety. Many workers are not proper trained to the acceptable level to handling the machine, tools and equipment. Improper tools used in the work reduce the quality of work, thus, effect the quality of the product.

Quality oriented is not in the logic of the workers, or even the production engineer. The output is racing with the time and some quality concern

subjects are neglected such as, precision of the work piece, color finished the quality of welding seam, the bolt tightening and others. Those bits and pieces of small neglected quality issues reduce the value of the product in the customer senses. Most of the workmanship error caused rework, which is costly and timely.

Thailand must improve the Air Handling Unit (AHU). The Air Handling Unit (AHU) manufacturers improvement in limited areas will increase the competitive advantages and can compete in the world market. The improvement of AHU factory will lead the Thailand air conditioning industries to higher engineering level. In future more heavy industries air conditioning unit equipment can be locally developed and manufactured in order to supply the world market.