Ergonomic Redesign of Coil Assemblies for Effective Maintenance

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Summary: The conventional practice of replacing corroded coil assemblies in air handlers is to revert to the original manufacturers for the new fins. However, problems are usually encountered, notably long delivery period, and unacceptable cost incurred for the original replacement products. The present research investigated an alternative approach to solve these problems in three typical shopping complexes in Malaysia having poor indoor cooling.

A complex walk through was initially conducted to obtain a general idea of the cooling problems suffered by the business operators and shoppers. Ergonomics methods were utilized to gather information to ascertain the major complaints. This included unstructured interviews [6] , Direct observations (DOs) [7] . Visual inspections into the air handlers of the complexes as well as their associated air distribution ductworks were also conducted.

Participative assessments (PAs) [8] were designed and tested upon the business operators. Current and archival data [7] and cost accounting figures with regard to expenditure on air handler maintenance were retrieved and analysed. Appropriate ergonomic interventions were implemented by integrating applied basic sciences into rectifying the identified problems. The design data from the original manufacturer were modified to produce revised specifications for the new make. Follow-up studies after new installations were then conducted using similar methods (i.e. DOs, PAs, current and archival data) to determine the effectiveness of the interventions.

The redesigns were cost effective. The new installations improved cooling comfort through effective heat removal process. There were also savings in coil assemblies maintenance.

Keywords: Ergonomics, Direct Observation, Participative Assessment, Applied Basic Sciences.

1. Introduction

Coil fins become corroded (due to moisture attack) after almost a decade of operation of air handlers in a central air conditioning system. In such a situation, the assemblies are found to be not performing the desired cooling load. It becomes an uphill task to maintain an effective cooling comfort for the human occupants in the air conditioned space by means of any state-of-the–art coil maintenance service procedures. In many cases, a properly maintained air handler will have its casing and other components, such as fan assembly, drain-pan and the associated supporting structures in fairly good conditions, while its coil assembly required to be replaced.

The usual practice of replacing coil assemblies is to adopt the similar manufacture, which incurs high costs and long delivery periods. This presentation, however, highlights a contrary to conventional practice. The intervention exercise was conducted via ergonomics practices, and had included cooling load calculations and selection of other coils of different design features, with subtle alteration of fin series to achieve better performance from the coil assemblies, thereby from the modified air handling systems as a whole. The brief preliminary findings of this research were presented by the principal researcher in Loo and Yeow [1,2,3,4,5]. This presentation delivers the final findings.

2. Method

2.1. Procedures

A complex walk through was initially conducted to obtain a general idea of the great discomfort and distress experienced by the human occupants due to poor cooling systems. Ergonomics methods were utilized to gather information to ascertain the major complaints. This included unstructured interviews [6] carried out in the presence of managers, engineers, supervisors, and selected employees. Those involved in the process in Complex *A* included an operations manager, 2 maintenance supervisors , whereas Complex *B* involved one complex manager and one maintenance engineer, and Complex *C* involved one maintenance manager, one maintenance engineer and a senior technician. Direct observations (DOs) [7] were made on several complaint shoplots by taking four temperature readings (based on dry bulb psychrometer readings) right at the centre point of each shoplot at chest height, one in the morning between 10.00 am – 11.00 am, another in the afternoon between 1.00 pm - 2.00 pm and 4.00 pm – 5.00 pm while the fourth reading in the evening between 7.00 pm – 8.00 pm. Visual inspections into the air handlers of the complexes for the condition of cooling equipment as well as their associated air distribution ductworks were also conducted.

Participative assessments (PAs) [8] by means of questionnaires for ergonomics assessment of air conditioned environments were designed and tested upon the business operators in the complexes to further confirm the observations. Current and archival data [7] from the maintenance department (on latest building maintenance methods and schedules, equipment history, capacities and specifications, etc), and cost accounting figures with regard to expenditure on air handler maintenance were retrieved and analysed to study the extent of the complex problems. Appropriate interventions were implemented. Follow-up studies were then conducted using similar methods (i.e. DOs, PAs, current and archival data) to determine the effectiveness of the interventions.

2.2. Ergonomic assessment of air conditioned environments

Interviews were conducted with one business operator per shoplot at a time, and each interview took about ten minutes to complete. The interviewer was knowledgeable of building air conditioning services so that he could easily understand the subjects' responses and record them in the questionnaire.

2.3. Analysis

The data collected from the interviews were analysed for trends of problems related to air conditioned environments in the shoplots for the three complexes. Temperature readings obtained and the visual inspections conducted on air handler equipment during the direct observations were analysed to further investigate the trends. The response of the participants with regard to shopping patronage as well as business performance were noted as a major evaluation judgement on the magnitude of the problems and the extent of improvements, before and after ergonomic redesigns.

2.4. Steps in ergonomic coil redesigns

Economical air handler coil assemblies were designed by integrating applied basic sciences into ergonomics concepts and methods. This section presents a method of ergonomically redesigning of an air handler coil assembly. The method employs a series of steps to achieve the desired results for a central air conditioning system as follows:

1. Determine the enthalpy of the system based on a given entering wet bulb (EWB) temperature into the air handler coil assembly and the leaving wet bulb temperature (LWB) out of the assembly respectively, and take the difference in enthalpy.

2. Estimate the air-side load (Q) of the system based on the determined enthalpy difference and a given air flow rate of the system.

3. Determine the liquid temperature rise based on the estimated load and a given liquid flow rate.

4. Determine the size of the air handler coil assembly by measuring the interior of an existing air handler coil section where the coil assembly is to be replaced, and preferably with particular reference to the original face area, following the number of tube rows and the number of fins in the original specifications.

5. Determine the coil tube velocity and its associated liquid pressure drop in the header and the tubes based on the given liquid flow rate and measured finned width.

6. Determine the cooling load (Qt) for the coil assembly based on the data above, and thermodynamics and heat tables.

7. Adopt the new design if the calculated cooling load (Qt) is about 5% - 10% higher (to cater for the effect of global warming) than that in the original specifications. If Qt is not within 5% – 10% higher, go to OPTION 1. If Qt is more than 10% higher (i.e. over capacity) than that in the original specifications, go to OPTION 2.

OPTION 1

Increase 2 fins per inch to improve the cooling capacity. If the increase is not viable, go to *OPTION 3*.

Repeat the sixth step calculations. Adopt the new design if the calculated cooling load (Q_t) is about 5% - 10% higher than that in the original specifications. If Q_t is not within 5% – 10% higher, go to *OPTION 3*.

OPTION 2

1. Decrease 2 fins per inch to reduce the cooling capacity.
2. Repeat the sixth step calculations to obtain a viable Q_t.

OPTION 3

1. Install phosphor bronze spring turbulators to all the coil tubes to double the effective liquid velocity in the tubes.
2. Repeat the fifth and sixth steps calculations to obtain a viable Q_t.

The ergonomic design method minimizes the need for guess work, thus providing a dependable sequence of process steps to derive the new data for the new design which has a better cooling load than the original.

2. Results

The results of the findings are tabulated in Tables 3.1a, 3.1b, 3.1c, and 3.2 as below:

Table 3.1a. Results for *AH-A.*

Particulars	LSR before Interv. (Mean ± SD)	LSR after Interv. (Mean ± SD)	t - value	p - value	Result
1. Quality of cooling	1.75 ± 0.46	3.88 ± 0.64	-9.379	< 0.05	Significant difference
2. Level of patronage	1.63 ± 0.52	3.38 ± 0.52	-5.584	< 0.05	Significant difference
3. Business performance	1.75 ± 0.46	3.25 ± 0.46	-7.937	< 0.05	Significant difference
4. Satisfaction	1.75 ± 0.46	3.63 ± 0.52	-15.000	< 0.05	Significant difference

Table 3.1b. Results for *AH-B*

Particulars	LSR before Interv. (Mean ± SD)	LSR after Interv. (Mean ± SD)	t - value	p - value	Result
1. Quality of cooling	1.70 ± 0.48	4.00 ± 0.67	-15.057	< 0.05	Significant difference
2. Level of patronage	1.60 ± 0.52	3.40 ± 0.52	-13.500	< 0.05	Significant difference
3. Business performance	1.60 ± 0.52	3.40 ± 0.52	-9.000	< 0.05	Significant difference
4. Satisfaction	1.50 ± 0.53	3.50 ± 0.53	-13.416	< 0.05	Significant difference

Table 3.1c Results for *AH-C*

Particulars	LSR before Interv. (Mean ± SD)	LSR after Interv. (Mean ± SD)	t - value	p - value	Result
1. Quality of cooling	1.83 ± 0.41	4.17 ± 0.41	-11.068	< 0.05	Significant difference
2. Level of patronage	1.83 ± 0.41	3.33 ± 0.52	-6.708	< 0.05	Significant difference
3. Business performance	1.83 ± 0.41	3.33 ± 0.52	-6.708	< 0.05	Significant difference
4. Satisfaction	1.67 ± 0.52	3.50 ± 0.55	-11.000	< 0.05	Significant difference

Table 3.2. Maintenance and repair costs comparison.

Maintenance

Air Handler Coil Assembly	Chemical Cleaning (RM)		Saving (RM)
	Before Intervention	After Intervention	
AH-A	5,000 / year	0	5,000 / year
AH-B	7,800 / year	0	7,800 / year
AH-C	4,200 / year	0	4,200 / year

Repair

Air Handler Coil Assembly	Original Coil Assembly (RM)	Redesigned Coil Assembly (RM)	Saving	
			(RM)	(%)
AH-A	12,500	8,500	4,000	32.0
AH-B	14,000	8,800	5,200	37.1
AH-C	10,000	6,000	4,000	40.0

4. Conclusions

The redesigned coil assemblies successfully improved cooling comfort through effective heat removal in the shoplots under study. The new installations were cost effective. There were also savings in coil assemblies maintenance.

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