Energy Saving Report

Of

Frigi-Tech Oil Additive

Application

In HKU Central Plant

Chiller No. 3

December 2003

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Energy Savings Report of Frigi-Tech Oil Additive Application.

Introduction

In the past few decades, concerns have increased over energy conservation and the usage impact on the environment. As a result of high economic growth and improvement in living standard in Hong Kong, a rapidly increase in energy consumption in the past 10 years has been recorded. Half of the energy usage over the past decade – particularly electricity consumption of commercial buildings due to the hot and humid climate- has been for air conditioning and refrigeration equipment. Hence a large amount of energy savings can be made to improve the operation efficiency of central chiller plants.

As compressor and heat exchangers are the most important components of chillers, the operating condition of the compressor, and the internal cleanliness of tubes of the heat exchanger are the key factors affecting the overall efficiency of the unit. Unfortunately, compressor efficiency will depreciate and like wise the internal surfaces of the heat exchanger, after the chiller unit begins to operate. The wear and tear of the mechanical moving parts of the compressor, that aging of the compressor lubricating oil, and the residual formation in the heat exchangers will all increase the frictional loss of the refrigerant circuit. In turn the work load of the compressor will wear off the surfaces of the moving parts, there by shorting the service life of the compressor. Furthermore, the formation of a thermal insulated layer on internal surface of the heat exchangers will lower the heat transfer coefficient of the heat exchangers. All this will result in a lower Coefficient of Performance (COP) of the chiller.

Objectives

The objective of this report is to explore the energy efficiency improvement of the No. 3 Chiller in the Central Plant, HKU after the Frigi-Tech application. The testing machine is a 500-ton Centrifugal Freshwater Cooled (Carrier) 5 Year old Chiller, using R-134A refrigerant, Model # 19XR5050. The changes of the COP of the chiller before and after the Frigi-Tech application were measured and the potential annual energy savings after the Frigi-Tech installation was then calculated.

Frigi-Tech Working Principal

Research presented by ASHRAE in 1994, showed conclusively that systems performance is degraded by as much as 30% due build-up of lubricants on internal surfaces throughout the refrigeration system. This build-up causes heat transfer degradation, increases pressure drops, elevates boiling points and reduces the latent heat capacity of the equipment. The end results of these problems are a substantial loss of cooling capacity, loss of lubricity, significantly increase operating cost and shorten equipment life.

Design engineers either oversize the equipment to compensate for future loss or accept the shortage of capacity at a future date. Insulated oil build-up typically begins to affect systems between the 6 and 12 month of operation. Normally by the 24th month of operation, system degradation is evident in the reduction of volumetric capacity and increase noise due to the loss of lubricity.

Theoretically, only refrigerant passes from the compressor to the condenser and the evaporator/cooler (heat exchangers). Particularly however, a small but significant amount of refrigerant oil is entrained with the refrigerant. This oil insulates the inner surfaces of the heat exchanger thereby impeding heat transfer, and the oil layer also increases the frictional loss of the refrigerant flow, both causing the equipment to operate at less than optimum efficiency; and since less lubricating oil circulates through the oil circuit, the moving parts of the compressor wear out more rapidly.

The Frigi-Tech Oil Additive migrates with compressor lubricating oil throughout the system. It has a Polar Compound which is highly charged at one end, gives it a stronger affinity for metal than compressor lubricating oil. This property enables it to displace the insulating build-up of compressor lubricating oil inside the refrigerant circuit and bond directly to the nearest metal surface to form a coat with single molecule thin layer.

Furthermore, the Frigi-Tech Oil Additive molecule does not allow the compressor lubricating oil build-up to reform. Consequently, heat transfer is no longer impeded in the heat exchangers coils since the displaced compressor lubricating oil must return back to the reservoir. The Frigi-Tech Oil Additive will also increase the lubricity of compressor lubricating oil and reduce wearing on compressor moving parts.

Analysis Approaches and Basic Theory

The testing period was from 26th September 2003 to 27th October 2003 and the date of applying Frigi-Tech Refrigerant Oil Additive into the chiller was the 7th October 2003 at 10:00 am. The operation data of the chiller No. 3 was collected by the data-logging machine in a per minute basis from Carrier Hong Kong Limited. The power consumption, the cooling capacity, the COP values, and the condensing water in and out temperature difference were then calculated. At the same time, the ambient temperature data was recorded by the Building Management System in the Bio Science Building of the HKU in a per hour basis.

The energy efficiency of a chiller is most commonly represented by the Coefficient of Performance (COP) value. Hence the data analysis in this report was "the change of COP value" approach. This approach compared the changes of COP value before and after the Frigi-Tech Oil Additive application, and the energy savings data were to be calculated.

The Scientific Equations for COP and Energy Savings calculations are listed as follows:

$$Qe = Me \times Cp \times (te - tl) \qquad (1)$$

$$WD = \sqrt{3} \times V \times I \times p.f. \qquad (2)$$

$$COP = \frac{Qe}{WD} \qquad (3)$$

$$\%Save'n = \frac{\frac{1}{COPo} - \frac{1}{COPn}}{\frac{1}{COPo}} \qquad (4)$$

$$\%Save = \sum (\%Save'n \times On) \qquad (5)$$

Where, Qe	=	Refrigeration effect of Chiller (kW)
Me	=	Mass flow rate of chilled water (kg/s)
Cp	=	Specific heat capacity of water (kJ/kg)
Te	=	Entering Chilled water temperature (°C)
tl	=	Leaving Chilled water Temperature (°C)
WD	=	Power consumption of chiller (w)
V	=	Voltage (V)
I	=	Current (A)
p.f.	=	Power Factor
COP	=	Coefficient of Performance
%Save'n	=	Percentage of energy Savings in particular load range (%)
COPn	=	Coefficient of Performance after Frigi-Tech application

COPo = Coefficient of Performance before Frigi-Tech application

On = Occurrence in particular load (%)

%Save= Average Energy Savings at particular condensing temperature (°C)

Results and Analysis

In the year 2003, on typical air-conditioning months from April to November, the daily mean temperatures were downloaded from the Hong Kong Observatory as shown in the Appendix A. The yearly mean temperature was then calculated and the recorded value was 26.51 °C. By adopting the same approach, the yearly mean temperature in the period of air conditioning months in year 2001 and 2002 were 26.21 °C and 26.45°C, respectively. Therefore, the chiller performance, which was represented by the COP values under the ambient temperature range of 26.5°C to 27.4°C, was used for the annual energy saving evaluation purpose.

Coefficient of Performance

The relationship between the average COP of the chiller vs. cooling capacity before and after the Frigi-Tech application at the ambient temperature range of 26.5°C to 27.4°C is shown in figure 6. As shown in this figure, the COP of the chiller before the Frigi-Tech application is significantly lower than that after the Frigi-Tech application.

Before and after Frigi-Tech application, the COP values in the cooling capacity of 1500kW and 5.16 and 5.63 respectively, and in the cooling capacity of 1800kW, the before and after Frigi-Tech application, the COP values are 5.41 and 5.63 respectively. The Percentage of Energy Savings in particular load range of 1500kW to 1800kW is from 8.15% to 8.35%. These values were calculated as the condensing water in and out temperature differences were kept constant before and after the Frigi-Tech application.

Heat Rejection

Since the testing specimen was a water cooled chiller, the heat rejection efficiency can be directly reflected by the condensing water in and out temperature difference and it affected the chiller performance significantly. The condensing water temperature differences, entering and leaving the condenser of the chiller were plotted against the outdoor air temperature under a particular cooling load of 1500 to 1600kW, 1600 to 1700kW, and 1700 to 1800 kW as showing in the figures 7,8,and 9 respectively.

In figure 7, the condensing water temperature differences are fairly steady at both before and after Frigi-Tech application period of time in different ambient temperature conditions. At ambient temperature range of 26.5°C to 27.4°C, the condensing water temperature differences before and after the Frigi-Tech application are more or less the same and the effect of the heat rejection efficiency of the chiller on the COP value can therefore be neglected.

However, in Figure 8, the condensing water temperature differences are much more affected by the ambient temperature before the Frigi-Tech Application than that after the Frigi-Tech application. In addition, the condensing water temperature differences at ambient temperature range of 26.5°C to 27.4°C, before the Frigi-Tech application values are from 4.58°C to 4.71°C when compared with the values of 4.25°C to 4.29°C for after the Frigi-Tech application.

Similar situation exists in figure 9, the condensing water temperature differences are less affected by the ambient temperature after the Frigi-Tech application. At the ambient temperature range of 26.5°C to 27.4°C, before the Frigi-Tech application condensing water temperature difference values are higher than the after Frigi-Tech application values.

It can be concluded that the COP values of the chiller at the cooling capacity of 1600 to 1800 kW should be even higher than that indicated in the figure 6 and the heat rejection of the chiller would be more stable after the Frigi-Tech application under different ambient temperature conditions. Therefore extended service life of the chiller, better control of the cooling tower and the condensing water pump can be expected.

Forecast Energy Saving after the Frigi-Tech Application.

In the light of the above observations after the Frigi-Tech application, the annual savings of the chiller in the most often operating capacity range should not be less than 9%. At the same time, the chiller does not need to be operated as frequently as before the Frigi-Tech application and the heat transfer performance of both the evaporator and the condenser were improved, resulting in higher efficiency and lower maintenance cost of the chiller.

Conclusion

Frigi-Tech has been proven to be an effective way to clean the internal tube wall of the heat exchangers in a refrigeration system, as well as to increase the lubricity of the compressor lubricating oil. These help to maintain peak efficiency , the best working conditions of the chiller, and hence save both energy and money.

It is recommended that Frigi-Tech be applied to other chillers in the Central Plant of the Hong Kong University.

Limitations and Tolerance

Since the COP data was calculated only under the same ambient temperature conditions but not at the same condensing water temperature difference conditions the exact COP values under the same condensing water temperature difference conditions can not be reflected, but in no case was it lower that that indicated in figure 6 i.e. the Percentage of Energy Saving should not be less than 9%.

Appendix A

Ambient Temp.		
Max. (°C)	Mean (°C)	Min. (°C)
27.9	25.5	24.2
26.8	25.8	24.9
27.4	26.2	24.7
26.3	23.7	20.9
21.2	20.2	19
20.2	19.4	18.7
24	21.1	18.8
24.2	21.6	18.7
20.1	19.1	18.2
20	18.8	17.8
24.4	21.8	19.8
27.6	25.8	23.5
28.6	26.6	25
27.2	23.3	21.6
22.2	21.4	20.8
22.9	21.6	20.4
26.2	23.5	21.5
27.5	24.9	23.3
27.8	25.4	24
27.5	25.4	24
27.5	25	23.8
28.2	24.5	22.6
29.5	25.8	23.6
29.8	26.5	24.3
29.2	27	25.3
28.8	26.3	25.1
26.7	25.	23.9
27.4	25.3	23.9
28.8	26.1	24.4
27.8	25.5	23.9

May , 2003		Ambient Temp.	
Date	Max. (°C)	Mean (°C)	Min. (°C)
1	24.9	23.5	21.3
2	25.2	24.1	23.1
3	25.9	24.6	23.9
4	28.8	25.5	23.5
5	27.2	24.9	23.3
6	29.1	28.1	26.5
7	29.6	28.5	27.6
8	30.9	28.7	27.4
9	27.5	25.5	24.4
10	27.4	25.4	24.3
11	28.3	25.9	24.5
12	28.1	26.3	25.4
13	29.9	27.2	25.8
14	32.1	28	26.1
15	31.5	28.6	26.2
16	31.2	29.1	27.8
17	31.3	29.2	27.7
18	28.4	26.7	25
19	27.2	25.4	23.8
20	29.9	26.9	25.2
21	29.6	27.2	25.6
22	29.3	27.5	26
23	30.3	28	26.4
24	30.5	28.5	27.1
25	30.7	27.5	25.3
26	29.1	27.1	26
27	27.7	26.4	25.7
28	26.3	25.8	25.3
29	27.6	26.4	25.4
30	30.9	28.1	26.2
31	31.3	28.1	26.5

Ambient Temp.		
Max. (°C)	Mean (°C)	Min. (°C)
30	27.3	25.8
30.7	27.5	25.4
30.1	27.4	25.7
29.4	27.6	26.2
29.8	27.7	26.2
30.3	27.8	25.9
29	27.2	34.8
28.5	27	26.2
27	25.7	24.8
27.9	25.9	24.2
28.2	25.7	24.3
29.2	26.5	25.5
27.3	26	23.9
28.4	26.5	24
27.6	26.1	25.5
25.8	25.2	24.6
30.3	27	24.3
31.8	28.7	26
33.3	29.5	27.5
29.2	28.2	27.6
28.4	26.7	25.1
30.1	28	25.6
31.1	28.9	27.5
31.9	29.4	28.1
30.9	29.4	27.5
31.9	29.6	28
30.4	29.5	28.3
31.2	28.8	24.8
31.9	29.4	28.1
32.7	29.6	28

July 2003		Ambient Temp.	
Date	Max. (°C)	Mean (°C)	Min. (°C)
1	32.1	29.3	26.7
2	32.7	29.8	27.8
3	33.6	30	27.8
4	33.3	30	28
5	33.1	30	28.2
6	32.4	29.9	28.3
7	33.4	30.2	28.1
8	33.1	29.9	26.9
9	33.3	30.2	28.4
10	32.8	29.6	27.6
11	32.1	28.9	27
12	32.9	30	28.1
13	33.2	30.4	28.8
14	32.9	30.3	28.2
15	33.4	30.3	28.5
16	33	30	28.2
17	32.9	29.8	27.8
18	32.7	29.7	27.8
19	33.3	30.1	27.8
20	30.7	29.2	27.5
21	30.1	28.2	26.3
22	32.7	29.8	26.9
23	32.9	29.4	26.3
24	29.1	28	26.4
25	31.3	28.6	27
26	30.8	28.9	27.5
27	31.6	28.7	26.7
28	32.7	29.2	27.2
29	31.9	29.3	27.4
30	31.4	29.3	27.7
31	32.7	29.7	27.8

Ambient Temp.		
Max. (°C)	Mean (°C)	Min. (°C)
32.6	29.7	27.8
32.8	30.1	28.4
33.7	30.4	28.3
32.6	29.4	25.4
30.7	28	25
29	27.9	26.6
32.7	29.5	27.6
32.1	29.8	27.5
33	30	27.7
33	30.5	28.5
31.7	29.8	27.9
29.3	28	26.4
31.3	29.3	27.4
31.7	28.8	26.6
32.1	29.7	28.3
29.5	28.2	26.5
30.2	27.8	25.6
31.8	29.2	27.4
32.1	29.4	26
32.4	28.5	26.7
28.1	26.7	25.3
29.8	26.9	24.7
31.3	28.9	26.5
29.3	26.9	24.8
28.3	27	25.6
30.5	28.5	27.4
31.1	28.7	27
31.3	28.7	27
31.2	29	27.2
31.4	29.2	27.4
32.1	29.6	27.8

July 2003		Ambient Temp.	
Date	Max. (°C)	Mean (°C)	Min. (°C)
1	31.8	29.5	27.5
2	29.9	27.1	24.2
3	27.6	26.1	24
4	26.9	26.4	25.7
5	29.1	26.9	25.9
6	27.7	26.4	25
7	28	26.2	25
8	29.3	27.4	25.4
9	30.4	28.3	26.9
10	31.4	28.7	26.5
11	31.1	29	27.4
12	31.3	28.8	27
13	31.1	29	27.7
14	28.5	26	24.7
15	26.6	25.6	24.6
16	29.2	27	25.4
17	29.7	27.9	26.4
18	31.7	29.1	26.9
19	32.1	29.3	27.4
20	32.6	29.9	28
21	30.6	27.8	25.9
22	26.5	25.1	23.6
23	27.5	26	24.9
24	28.6	26.8	25.4
25	29.2	27.3	25.4
26	29.9	27.8	26.1
27	29.8	27.9	26.7
28	30.3	28.2	27
29	29.9	28	26.8
30	29.2	27.6	25.9

Ambient Temp.		
Max. (°C)	Mean (°C)	Min. (°C)
29.3	27.5	26.5
29.8	27.8	26.3
29.6	27.9	26.7
28.7	27.1	25.1
28.6	26.8	24.7
28.8	26.5	24.5
28	25.9	23.5
28.6	26.7	25.2
28.4	27.3	26.2
27.2	26.8	25.6
29.1	26.7	25.3
29.6	27.6	26.2
29.7	27.2	24.3
24.3	22.1	20.7
23.3	21.7	19.9
26.3	23.7	22
25.8	24.1	22
25.9	24.3	22.6
25.6	24.3	22.5
26.2	24.1	22.4
27	24.6	22.7
26.8	24.7	23.1
26.1	24.4	23
25.7	23.9	22.8
26.4	24	22
26.	23.9	22
26.2	24.4	22.7
27.4	25	23.2
26.2	24.7	23.3

July 2003		Ambient Temp.	
Date	Max. (°C)	Mean (°C)	Min. (°C)
1	26.9	24.3	22.6
2	28.6	25.6	23.1
3	29.6	26.7	24.4
4	26.8	24.9	23.5
5	26.4	24.9	23.5
6	26.1	24.4	22.9
7	27.1	25.2	24.5
8	25.2	24.5	23
9	24.1	23.7	23.2
10	23.4	20.8	18.1
11	21.4	18.9	17
12	19.8	17.7	15.5
13	21.9	19.9	17
14	23.7	22	20.9
15	26.1	23.3	20.8
16	24.9	23.6	22.8
17	23.3	22.4	21.6
18	23.3	22.4	20.7
19	23.9	23.1	22.3
20	25.3	24.2	23.5
21	25.4	23	20.3
22	21	19.7	17.8
23	21.9	20.6	19.1
24	23.6	21.8	20.1
25	24.6	22.2	20.5
26	24.1	22.1	20.4
27	22.9	21.	19.4
28	22.3	19.5	17.3
29	18.4	16.4	13.9

Apr-Nov (A/C Months)	Max	Mean	Min
2003	28.68	26.51	24.80
2002	28.56	26.45	24.65
2001	28.40	26.21	24.36

EO/2/1

December 19, 2003

Compressor Oil Agent (COA)

To whom it may concern

The Compressor Oil Agent (COA) has been applied into the chiller No. 3 in our Central Plant at main campus of the University of Hong Kong since 7th October 2003 at 10 o'clock in the morning. Chiller No. 3 is a 500-ton "Carrier" centrifugal water cooled chiller (Model No.: 19XR5050) which using R-134A refrigerant. After 2 months of operation, we are completely satisfied with the performance of the COA.

The preliminary result is shown that in the ambient temperature range of 26.5-27.4oC, which is the mean temperature in the period of typically air-conditioning months from April to November in year 2003 (data from the HK Observatory), an average COP improvement of ~9% was recorded in the range of 80-100% full load of the chiller.

Thanks for your attention.

Yours sincerely

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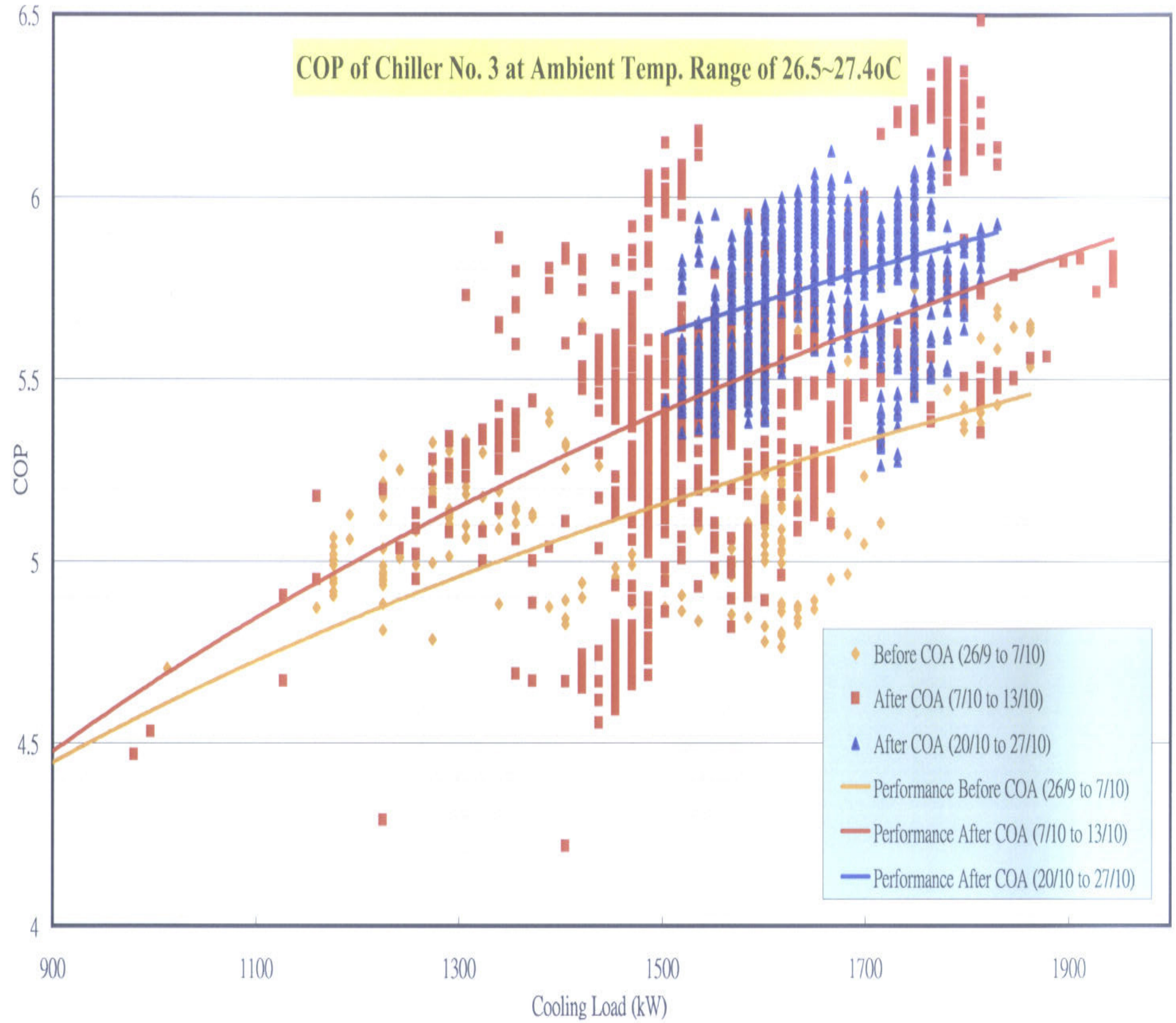


COP of Chiller No. 3 at Ambient Temp. Range of 26.5~27.4oC
6.5
6
5.5
5
4.5
4
COP
900
1100
1300
1500
1700
1900
Cooling Load (kW)
Before COA (26/9 to 7/10)
After COA (7/10 to 13/10)
After COA (20/10 to 27/10)
Performance Before COA (26/9 to 7/10)
Performance After COA (7/10 to 13/10)
Performance After COA (20/10 to 27/10)

Fig. 6

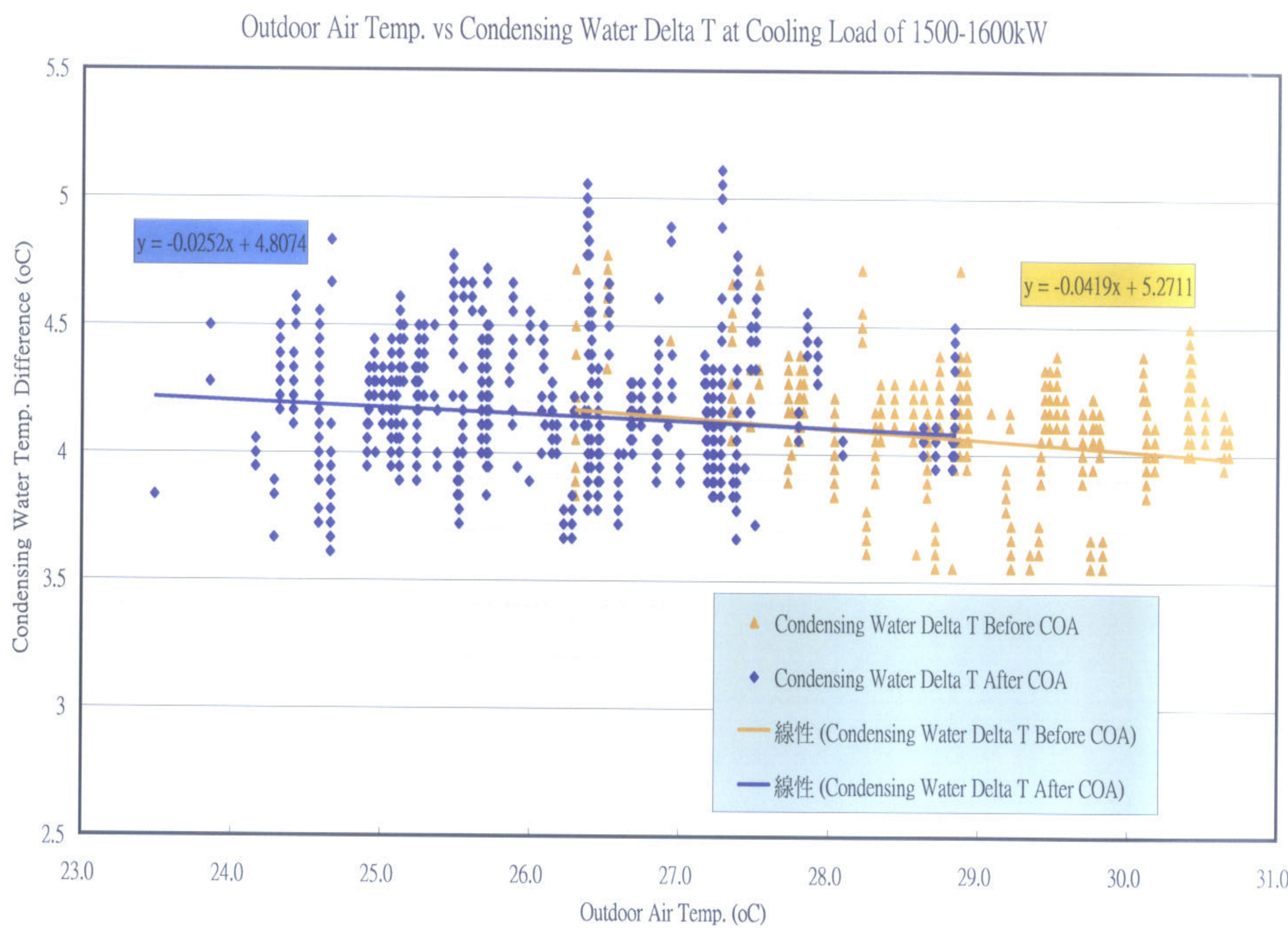
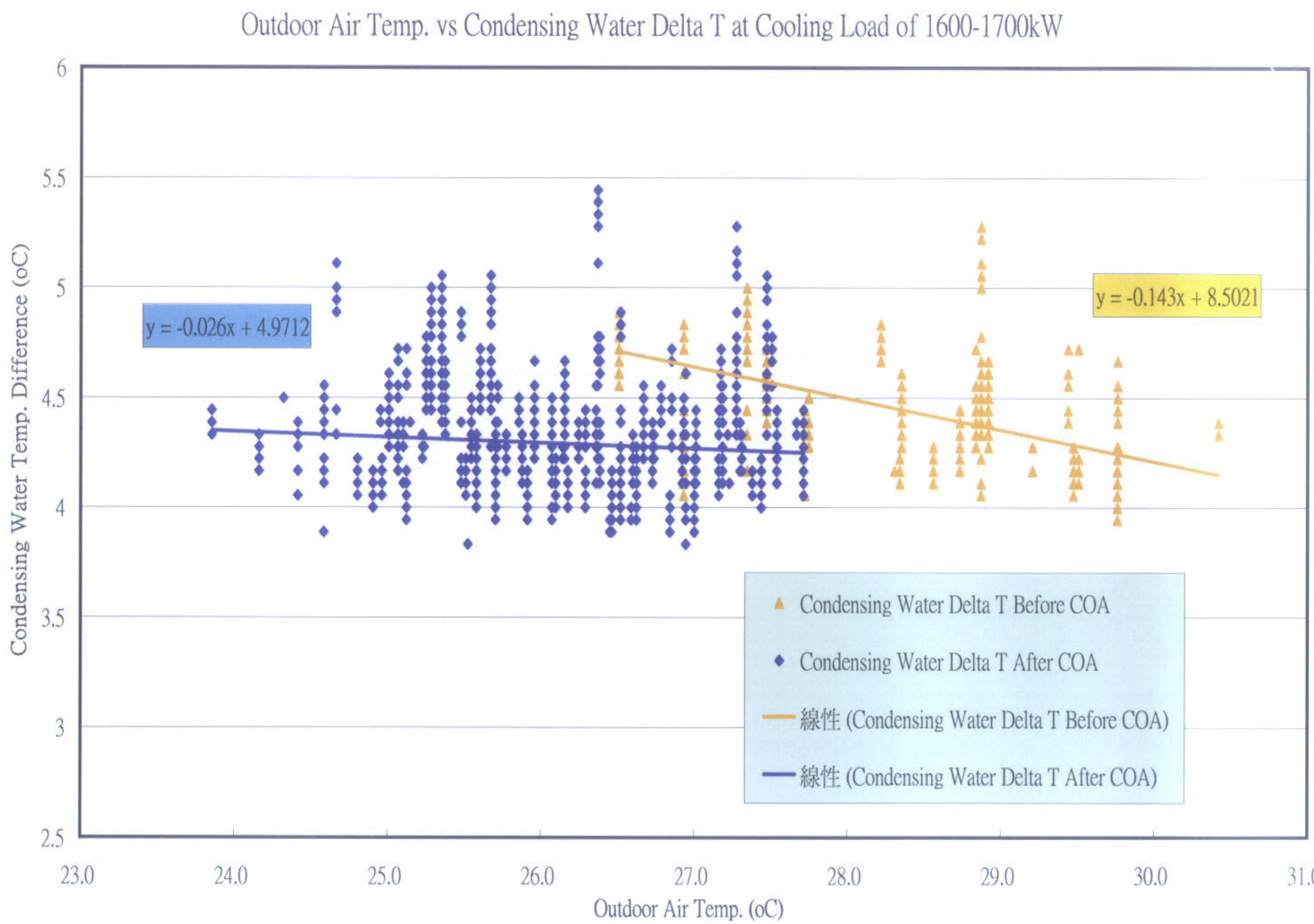
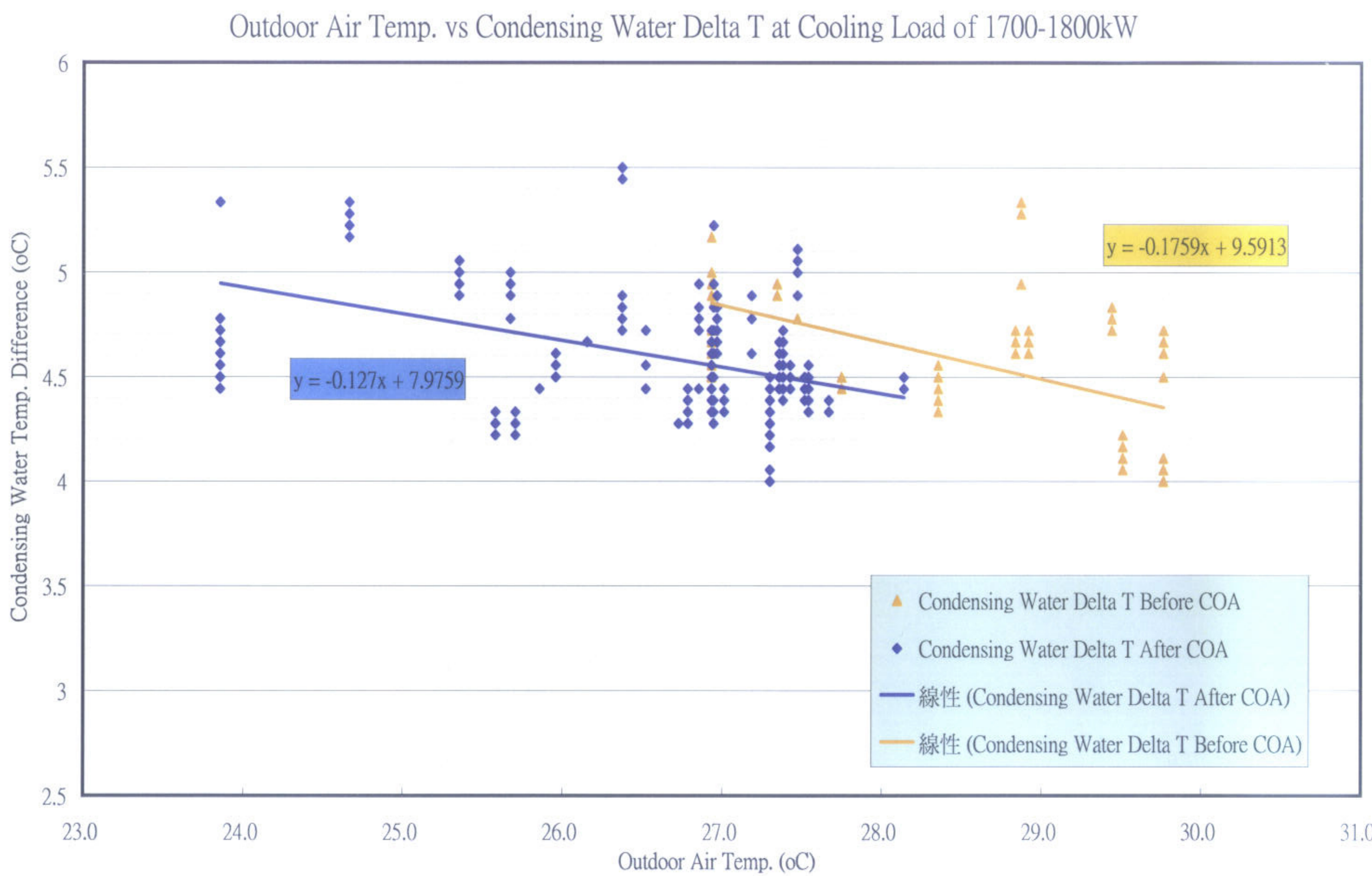

Outdoor Air Temp. vs Condensing Water Delta T at Cooling Load of 1500-1600kW
y = -0.0252x + 4.8074
y = -0.0419x + 5.2711
Condensing Water Delta T Before COA
Condensing Water Delta T After COA
線性 (Condensing Water Delta T Before COA)
線性 (Condensing Water Delta T After COA)
Condensing Water Temp. Difference (oC)
5.5
5
4.5
4
3.5
3
2.5
23.0
24.0
25.0
26.0
27.0
28.0
29.0
30.0
31.0
Outdoor Air Temp. (oC)

Fig. 7



Outdoor Air Temp. vs Condensing Water Delta T at Cooling Load of 1600-1700kW
Condensing Water Temp. Difference (oC)
6
5.5
5
4.5
4
3.5
3
2.5
y = -0.026x + 4.9712
y = -0.143x + 8.5021
Condensing Water Delta T Before COA
Condensing Water Delta T After COA
線性 (Condensing Water Delta T Before COA)
線性 (Condensing Water Delta T After COA)
23.0
24.0
25.0
26.0
27.0
28.0
29.0
30.0
31.0
Outdoor Air Temp. (oC)

Fig. 8



Outdoor Air Temp. vs Condensing Water Delta T at Cooling Load of 1700-1800kW
Condensing Water Temp. Difference (oC)
6
5.5
5
4.5
4
3.5
3
2.5
23.0
24.0
25.0
26.0
27.0
28.0
29.0
30.0
31.0
y = -0.127x + 7.9759
y = -0.1759x + 9.5913
Condensing Water Delta T Before COA
Condensing Water Delta T After COA
線性 (Condensing Water Delta T After COA)
線性 (Condensing Water Delta T Before COA)
Outdoor Air Temp. (oC)

Fig. 9