AN EVALUATION

OF

THE EFFECTS OF

THE BALLTECH ON - LINE CLEANING SYSTEM

ON

CHILLER # 3

AT

THE ALFRED HOSPITAL - MELBOURNE

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Introduction

The aim of this report is to examine the effects of the BallTech on-line condenser tube cleaning system on the performance of Chiller # 3, Trane Model RTHC3LF at the Alfred Hospital, Melbourne.

Scale and fouling deposits such as biofilm in the condenser tubes of water chillers reduce the heat transfer efficiency and performance of the chiller. The extent of performance loss depends on the extent and thickness of the scale and fouling deposits inside the tubes. Removing the deposits and maintaining the tubes free of deposits will measurably improve heat transfer and energy consumption.

The nature and extent of deposition varies in accordance with climate, the quality of cooling water supply and local environmental conditions surrounding each cooling tower. In Australian coastal cities biofilm fouling is often the more important factor and the most difficult to treat. It is not completely removed by water treatment with chemicals or with conventional brush cleaning methods; it re-builds quickly and is generally invisible to the naked eye.

From an efficiency viewpoint, biofilm removal is important because it tends to coat the tube wall and has approximately one quarter of the thermal conductivity of scale. This means a biofilm coating that is only one quarter the thickness of a comparable scale deposit will cause an equivalent degradation in heat transfer and energy efficiency. Biofilm also accelerate corrosion and harbor pathogens. The secretions they produce bind them to tube walls regardless of flow rate and are an effective barrier to both anti-corrosion treatments and biocides

The current industry practice to control scaling and fouling in condensers is to carry out the following steps:

- Chemical treatment of the cooling water to retard the rate of scale and fouling build-up
- Periodic "bleed off" of the cooling water to reduce the total dissolved solids (TDS) in the water.
- Annual manual cleaning of the condenser tubes.

An alternative to the above practice is the installation of an automatic on- line mechanical cleaning system such as the BallTech System.

Description Of The BALLTECH System®

The BallTech system is designed for automatic, continuous cleaning of the heat exchanger tubes using hydro-mechanical principles. The system injects sponge rubber balls into the condenser cooling water at a suitable point just upstream from the chiller. The balls are made of soft rubber and are slightly larger than the inside tube diameter of the water-cooled condenser. They quickly pass through the condenser, wiping the tube surfaces clean before scale or biofilm deposits can develop. The balls are collected by a uniquely designed trap that is installed on the down-stream side of the condenser. They are returned to the injector through a small diameter by- pass pipe where they are rinsed clean and stored ready for the next cycle. The system operates continuously and the cleaning frequency can be set at the control panel installed with the system.

Test Methodology

The testing procedure included an analysis of the chiller performance on two occasions:
1) Before the condenser tubes on the chiller were cleaned, and
2) After the condenser tubes on the chiller were cleaned by the BallTech system

To measure the performance of the refrigeration system of the chiller, Trane Australia provided the data of the operating conditions of the chiller during the testing. For each test, data on the following operating parameters at **70% of the full load condition** were collected over a period of 3 to 5 hours at fifteen minute interval:
- Compressor motor current
- Condenser cooling water inlet & outlet temperatures
- Evaporator chilled water inlet & outlet temperatures
- Evaporator and Condensing Pressures

The cooling capacity was calculated from the evaporator chilled water inlet and outlet temperature data and the flow rate obtained by the measurement of the chilled water pressure drop across the chiller during each test. The power input of the compressor motor was calculated from the electrical supply voltage and the motor running current based on an assumed power factor of 0.98. The coefficient of performance of the chiller was then calculated from the cooling capacity and power input data.

Test Procedure

The BallTech system was first installed on chiller # 3 in January 2004. For the purpose of the testing the BallTech system was turned off in January 2006. The chiller then remained in operation for five months (1,800 hrs) without the BallTech system in operation. During this period the normal water treatment regime remained unchanged.

The first test was carried out on May 25, 2006 to determine the chiller performance.
Immediately after this test, the condensing water pump was removed for repair and the chiller re-commissioned in early July 2006. In mid July, the BallTech system was re-activated. The second test was then conducted on August 30, 2006.

Due to variation in the ambient air temperature, the operating conditions of the chiller fluctuate. An increase in ambient air temperature, resulting in the increase of the temperature of cooling water entering the condenser, will increase the condensing pressure. The increase in condensing pressure will increase the power input and reduce the cooling capacity and hence the COP.

It is normal practice to use the condensing pressure as the "yardstick" for comparing the performance of the chiller by keeping the condensing pressure constant by maintaining the condenser cooling water inlet temperature as near constant as possible.

On the first (pre-BallTech) test, the average temperature of the cooling water entering the condenser was 26.53°C and the average condensing pressure was 686.20 kPa (Gauge). On the second (post-BallTech) test, the average temperature of the cooling water entering the condenser was 27.37°C and the average condensing pressure was 707.89 kPa (Gauge).

Result of Testing

Detailed results of the operating conditions are provided in the following charts, all found in Appendix A:

1. **Pre-BallTech Test (May 25, 2006)**

Chart 1A: Cooling Capacity, Power Input & Coefficient of Performance
Chart 2A: Chilled Water and Condenser Water Entering & Leaving Temperatures
Chart 3A: Condenser and Evaporating Pressures

2. **Post-BallTech Test (August 30, 2006)**

Chart 1B: Cooling Capacity, Power Input & Coefficient of Performance
Chart 2B: Chilled Water and Condenser Water Entering & Leaving Temperatures
Chart 3B: Condenser and Evaporating Pressures

Observations

A comparison of the mean operating conditions for each of the tests are summarised in table below:

Test Results : Operating Mean Values

	Pre-BallTech Test	Post-BallTech Test	% change
Cooling Capacity (kW)	1321.93	1439.27	8..88
Power Input (kW)	326.71	327.96	0.38
Coefficient of Performance, COP	4.05	4.39	8.36
Chilled Water Entering Temperature (℃)	10.98	13.38	21.87
Chilled Water Leaving Temperature (℃)	6.10	8.20	34.35
Chilled Water Temperature Difference (K)	4.88	5.18	6.15
Condenser Water Entering Temperature (℃)	26.53	27.37	3.15
Condenser Water Leaving Temperature (℃)	30.81	31.82	3.29
Condenser Water Temperature Difference (K)	4.28	4.45	3.97
Condensing Pressure (kPa)	686.20	707.89	3.16
Evaporating Pressure (kPa)	262.20	287.7	9.73

From the above table, a number of observations can be made about the effects of the BallTech System on Chiller # 3 running at 70% loading:

- The cooling capacity increased by 8.88 % in the post-BallTech test. ***This indicates a significant improvement in heat transfer in the chiller.***
- The COP (a ratio of the cooling capacity and power input) increased by 8.36 % in the post-BallTech. ***This indicates a significant improvement in the overall system performance.***
- The increase in the chilled water and condenser water temperature difference by 6.15 % and 3.15 % respectively indicates improvement in heat transfer in the chiller.
- The condensing pressure increased by 3.16 % respectively as a result of slightly higher ambient temperature.
- The evaporating pressure increased by 9.73 % respectively as a result of higher entering chilled water temperature.

CONCLUSION

The tests carried out on the chiller indicated an increase in cooling capacity of 8.9 % and an overall improvement in the system performance of 8.4 % after the BallTech system was back in operation. **The increase in cooling capacity and system performance will result in the compressor motor using less energy to achieve the same cooling effect.** This is achieved by a reduction of the compressors run time to produce the same cooling effect on the chiller.

During the post-test the condensing pressure was 3.2 % higher than the pre-test due to higher ambient temperature. The higher condensing pressure will normally result in a decrease in the system performance due to the fact that compressor work against a higher pressure differential. If the condensing pressure were similar during both tests it could be expected that the increase in system performance on the chiller would be slightly better than the value of 8.4 % obtained. Furthermore, the increase in system performance will also be greater than 8.4 % had the condenser tubes not been cleaned for 12 months instead of 5 months.

The improvement of the performance depends on the thickness of the scale and fouling deposits on the condenser tubes that has been removed. However, it is apparent from the tests conducted that on-line cleaning of the condenser tubes using the BallTech system improves the performance of the chiller. This will result in reduction of the energy consumption of the chiller. The decrease in energy usage by the compressor will correspond approximately to the increase in the system performance.

The salient results of the tests are summarised in the bar graphs in Appendix B.

APPENDIX A

Contents:

1. Pre-BallTech Test (May 25, 2006) - results of 4 months operation with-out the BTS

Chart 1A: Cooling Capacity, Power Input & Coefficient of Performance
Chart 2A: Chilled Water and Condenser Water Entering & Leaving Temperatures
Chart 3A: Condenser and Evaporating Pressures

2. Post-BallTech Test (August 30, 2006) - results with the BTS in operation

Chart 1B: Cooling Capacity, Power Input & Coefficient of Performance
Chart 2B: Chilled Water and Condenser Water Entering & Leaving Temperatures
Chart 3B: Condenser and Evaporating Pressures

3. Data logs of chillers # 3, 25th May, 2006(with out the BTS) and 30th August, 2006 (with the BTS)

3. Photographs of condenser tubes of chillers # 3 (with the BTS) and # 4 (with out the BTS)

4. Installation photograph chillers # 3 (BHS 6")

Chart 1A - Alfred Hospital Chiller # 3 : Cooling Capacity, Power Input & COP [Pre - BallTech]

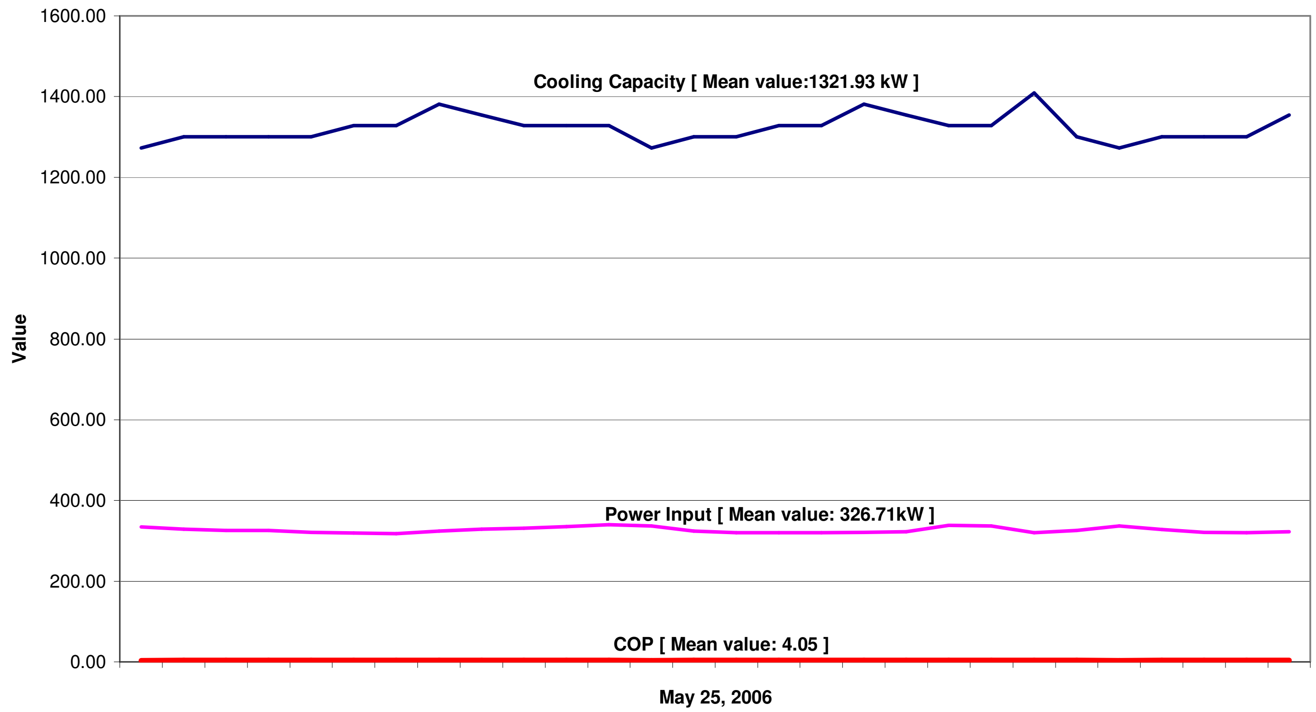


Chart 1B - Alfred Hospital Chiller # 3 : Cooling Capacity, Power Input & COP [Post - BallTech]

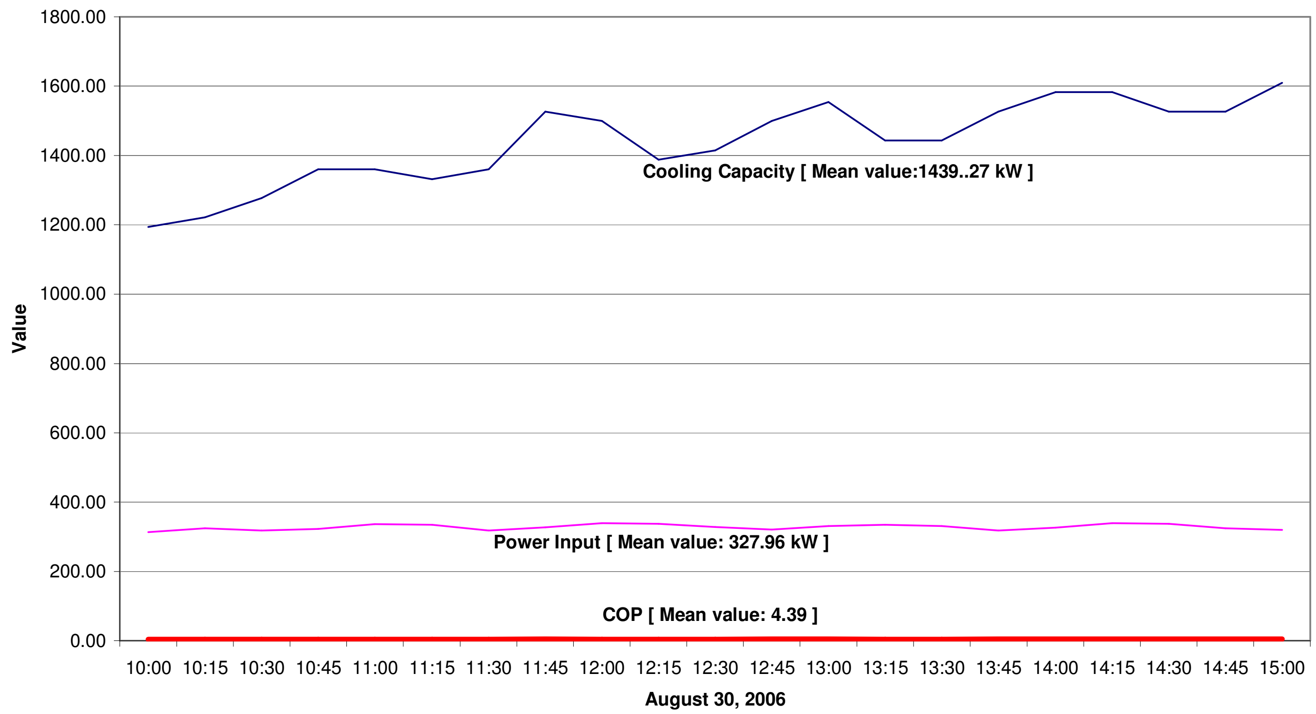


Chart 2A - Alfred Hospital Chiller # 3 : Operating Temperatures [Pre - BallTech]

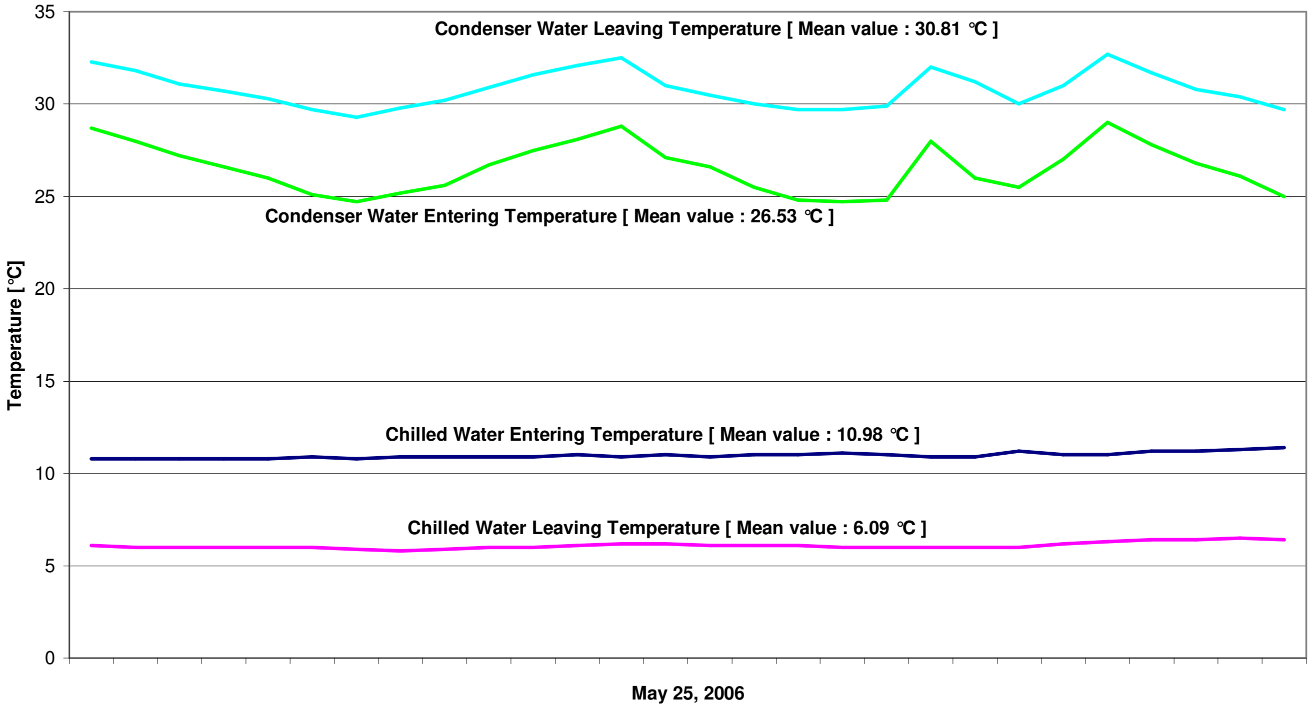


Chart 2B - Alfred Hospital Chiller # 3 : Operating Temperatures [Post - BallTech]

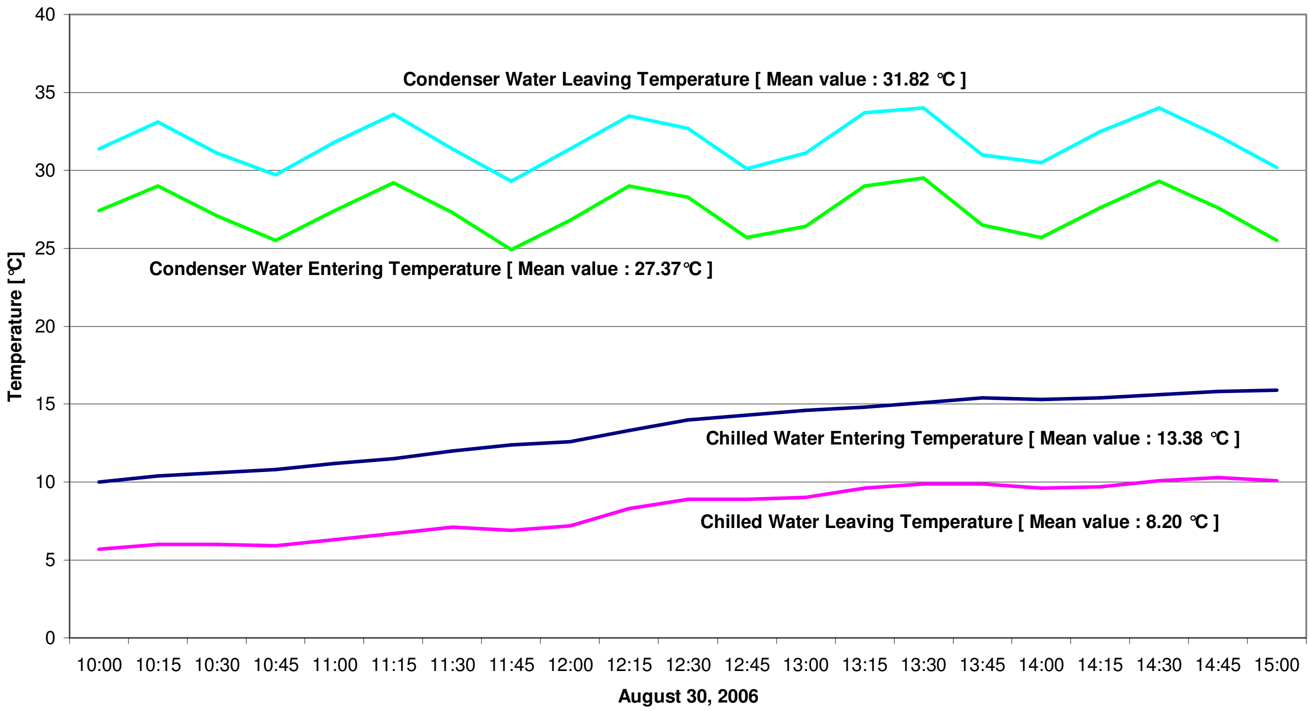


Chart 3A - Alfred Hospital Chiller # 3 : Operating Pressures [Pre - BallTech]

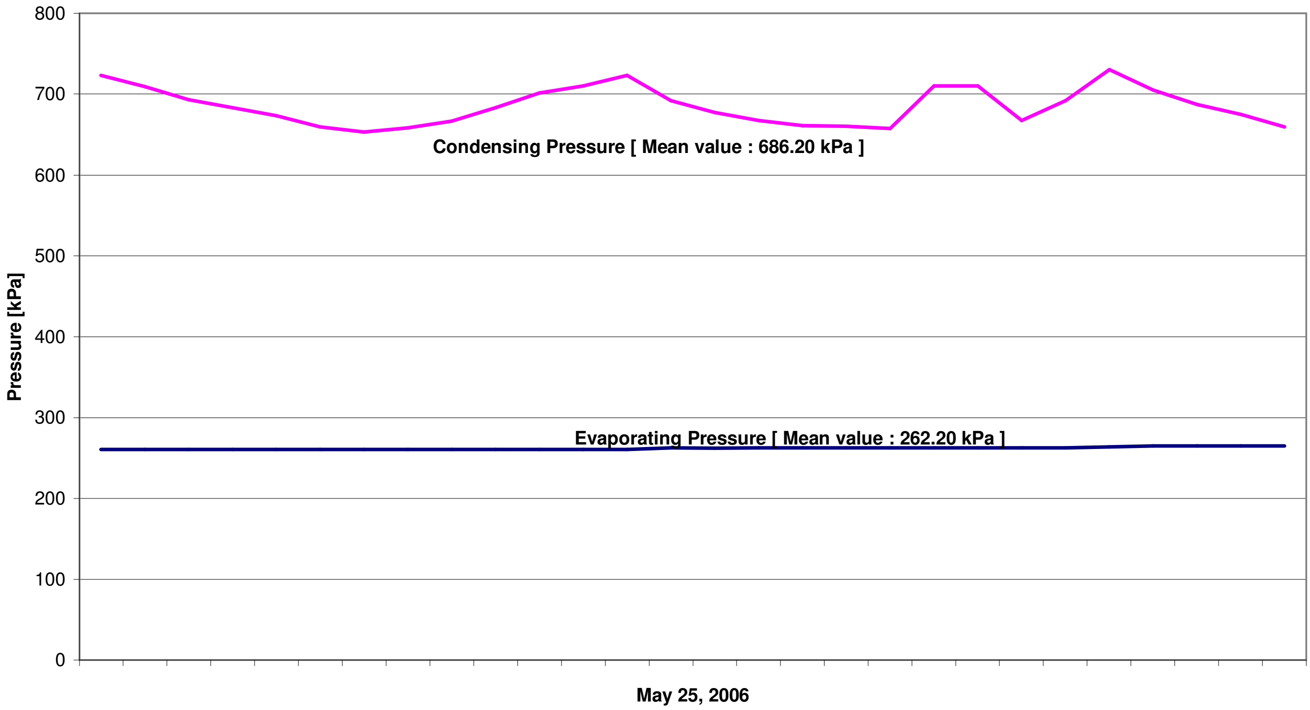


Chart 3B - Alfred Hospital Chiller # 3 : Operating Pressures [Post - BallTech]

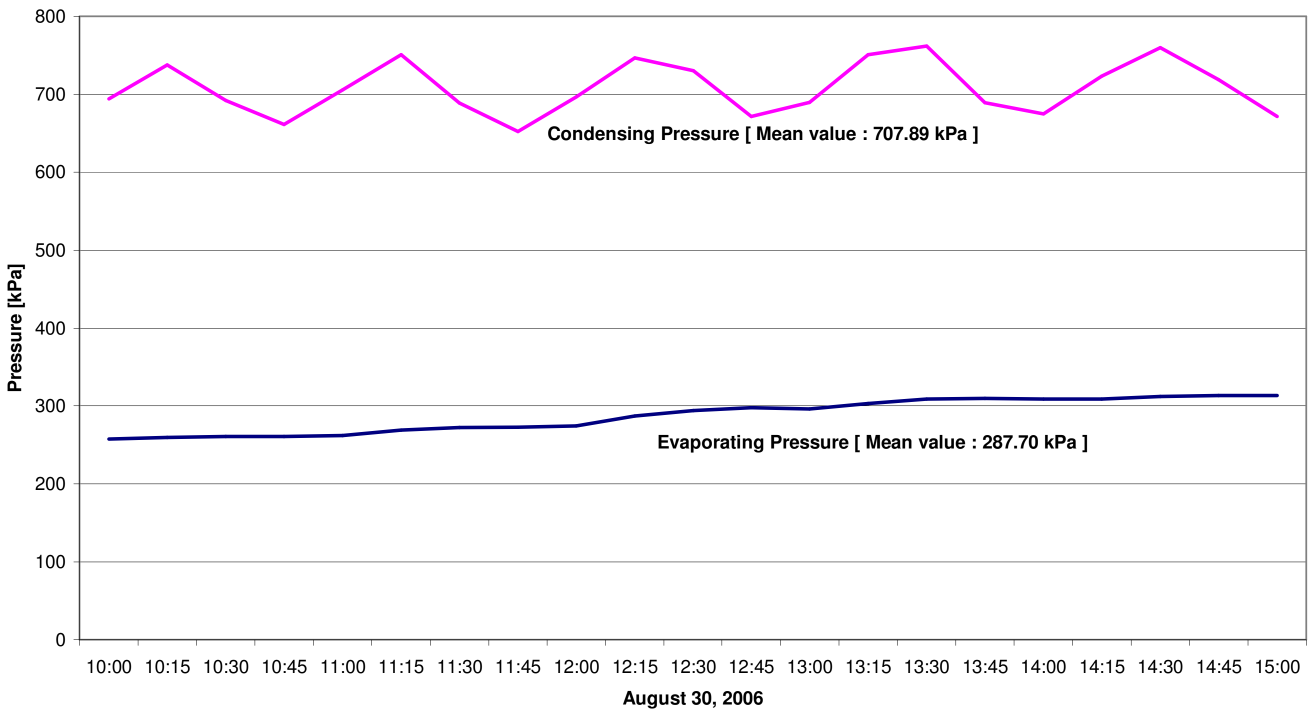


Chart 1C - Comparison of Cooling Capacity of Chiller 3 resulting from BallTech installation

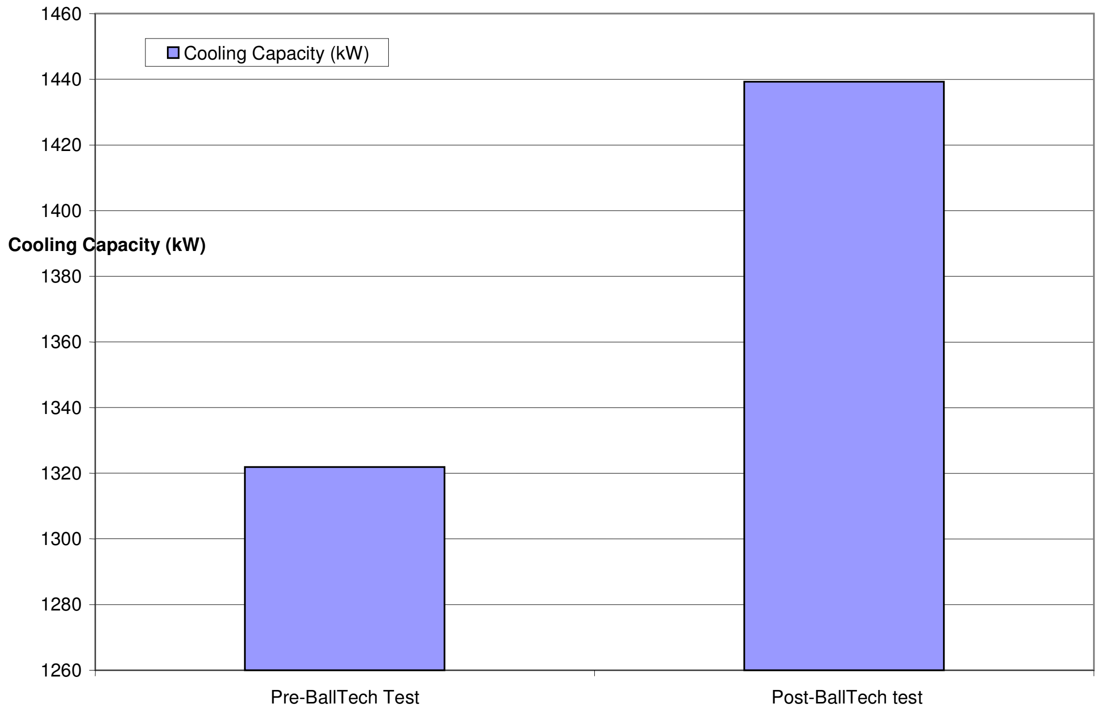


Chart 2C - Comparison of Power Input of Chiller 3 resulting resulting from BallTech installation

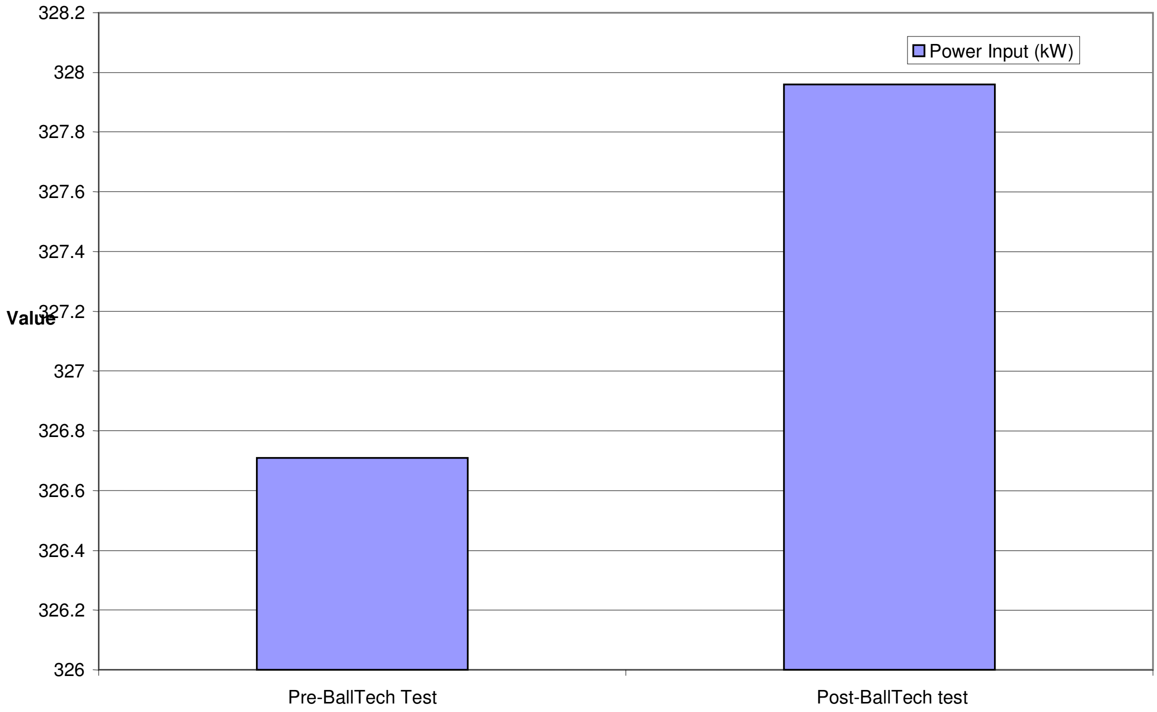
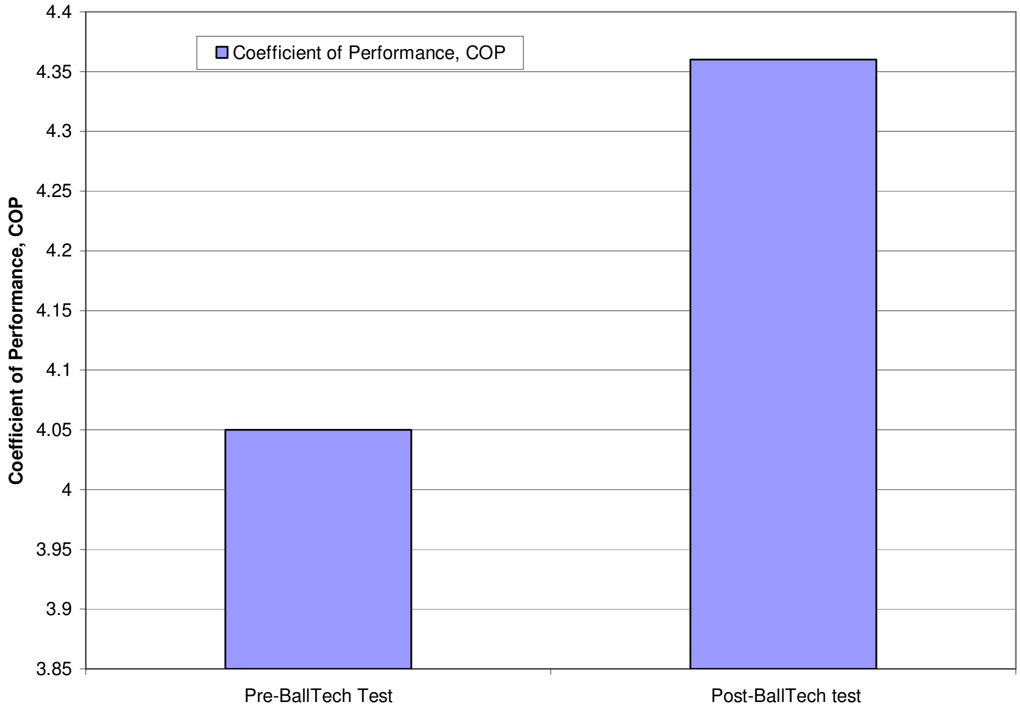


Chart 3C - Comparison of COP of Chiller 3 resulting from BallTech installation



Alfred Hospital, Chiller # 3,(Trane 1400kW) Model : RTHCIE3UOHOG3LFOQOOD Serial : UO2KO6891

Date: 25th May 2006	11:45	11:50	11:56	12:01	12:06	12:12	12:16	12:22	12.28	12:34	12:40	12:46	12:51	13:05	13:10	13:16	13:21	13:30	13:37	13:45	13:51	13:58	14:06	14:12	14:18	14:24	14:30	14:36	Average
Chilled Water Setpoint	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4°	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.40
Evap Leaving Setpoint	6.1	6	6	6	6	6	5.9	5.8	5.9	6	6	6.1	6.2	6.2	6.1	6.1	6	6	6	6	6	6	6.1	6.3	6.4	6.4	6.5	6.4	6.09
Evap. Entering Water Temp.	10.8	10.8	10.8	10.8	10.8	10.9	10.8	10.9	10.9	10.9	10.9	11	10.9	11	10.9	11	11	11.1	11	10.9	10.9	11.2	11	11	11.2	11.2	11.3	11.4	10.98
Evap. Leaving Water Temp.	6.1	6	6	6	6	6	5.9	5.8	5.9	6	6	6.1	6.2	6.2	6.1	6.1	6.1	6	6	6	6	6	6.2	6.3	6.4	6.4	6.5	6.4	6.10
Cond. Entering Water Temp.	28.7	28	27.2	26.6	26	25.1	24.7	25.2	25.6	26.7	27.5	28.1	28.8	27.1	26.6	25.5	24.8	24.7	24.8	28	26	25.5	27	29	27.8	26.8	26.1	25	26.53
Cond.Leaving Water Temp.	32.3	31.8	31.1	30.7	30.3	29.7	29.3	29.8	30.2	30.9	31.6	32.1	32.5	31	30.5	30	29.7	29.7	29.9	32	31.2	30	31	32.7	31.7	30.8	30.4	29.7	30.81
Current Limit	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70.00
Evap. Refri. Pressure kpa	260.7	260.7	260.7	260.7	260.7	260.7	260.7	260.7	260.7	260.7	260.7	260.7	260.7	262.8	262	262.8	262.8	262.8	262.8	262.8	262.8	262.8	262.8	263.7	265	265	265	265	262.14
Cond. Refrig. Pressure kpa	723.5	709.7	693.3	683	673.1	659.7	652.9	658.8	666.6	683	701.1	710.1	723.5	692	677.4	667.5	661.4	660	657.5	710.1	710.1	667.5	692	730.4	705.4	687.3	675.2	659.7	685.42
Evaporator Liquid Level	0.4	0.2 cm	0.2 cm	0.2 cm	0.1 cm	0.7 cm	0.3 cm	0.2 cm	0.1 cm	0.2 cm	0.2 cm	0.2 cm	0.2 cm	0 cm	0 cm	(-)0.2 cm	(-) 0.2 cm	(-)0.2 cm	0.2 cm	(-) 0.2 cm	(-) 0.2 cm	(-) 0.2 cm	0.2 cm	0.3 cm	0.2 cm	0 cm	(-) 0.2 cm	(-) 0.2 cm	0.40
Expansion Valve Position	36.8	36.70	37.10	37.10	37.10	38.40	38.10	38.10	38.10	38.00	38.00	38.00	36.80	37.10	37.10	37.40	38.40	38.40	38.40	37.80	37.80	37.40	37.10	37.30	37.30	37.60	37.90	38.30	37.63
Expansion Valve Position	992	1014	1023	1023	1023	1061	1051	1052	1052	1048 Steps	1048	1048	1017	1025	1025	1033	1059	1059	1059	1043	1043	1033	1025	1029	1029	1039	1047	1056	1037.33
Saturated Evap. Refrig. Temp	5.8	5.9	5.9	5.8	5.8	5.8	5.6	5.7	5.7	5.8	5.8	5.9	6	5.9	5.9	5.9	5.9	5.8	5.7	5.8	5.8	5.8	5.8	6.1	6.2	6.2	6.2	6.2	5.88
Saturated Cond. Temperature	32.4	31.8	31.2	30.8	30.4	29.7	29.4	30	30.4	31.1	31.8	32.3	32.7	31.2	36.5	30.1	29.8	29.8	29.6	32.2	31.2	30	31	33	31.6	31	30.5	29.7	31.11
Compressor Discharge Temp.	45	44.8	43	44.3	43	43	42	42.8	43.2	43.4	45	45.6	46.5	44.1	44	42.3	42.4	43	42.6	44.1	43.9	42.4	43.9	44.8	45.2	43	43.2	41.6	43.65
Discharge Superheat	12.9	13.2	11.6	13.6	12.9	13	11.9	12.8	12.9	11.6	13.2	13.4	12.8	13.1	13.2	12.5	12.9	13	12.9	11.6	11.7	11.9	13	12.2	13.5	11.4	12.8	11.5	12.61
Evap. Approach Temp.	0.2	0.10	0.10	0.20	0.10	0.20	0.20	0.10	0.10	0.20	0.10	0.20	0.20	0.20	0.20	0.20	0.10	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.16
Cond. Approach Temp.	0.1	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.00	0.10	0.10	0.00	0.10	0.10	0.10	0.10	0.00	0	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1	0.1	0.1	0.08
Comp. Line - RLA A	70	68.9	68.5	68.2	67.5	66.5	66.8	67.8	68.5	69.6	70.2	70.6	70.6	68.2	67.2	67.2	67.2	67.2	67	70.9	70.8	67.8	68.2	70.9	68.9	67.8	67.2	67.8	68.51
Comp. Line - RLA B	69	68.2	67.5	67.2	65.8	65.5	65.5	66.8	67.8	68.2	69.6	69.9	69.9	66.8	65.8	65.8	65.8	66.5	66.6	69.6	69.7	65.5	66.5	69.2	67.2	66.1	65.8	66.5	67.30
Comp. Line - RLA C	71	69.9	69.2	68.9	68.2	67.5	67.5	68.5	69.9	70.6	71.3	72	71.3	68.9	67.8	67.8	67.8	66.5	68	72	72	66.5	66.8	71.3	69.2	68.5	67.8	68.5	69.11
Comp. Line - AMPS A	274	270	267	267	264	260	260	266	270	272	276	278	276	267	262	262	263	264	265	278	278	262	268	278	270	266	263	266	268.29
Comp. Line - AMPS B	270	266	264	263	259	258	258	263	266	268	271	276	272	263	259	259	259	259	262	274	273	259	264	271	264	260	258	259	264.18
Comp. Line - AMPS C	278	274	270	270	266	266	264	270	272	275	279	282	280	268	266	266	266	266	266	282	277	266	268	278	271	265	266	267	270.86
Chilled Water Pressure drop	24.51						24.7					23.99				23.77				24.2				23.99					24.19
Cond. Water Pressure drop	32.32						31.94					30.5				30.5				30.3				30.2					30.96
Cooling Capacity	1273.55	1300.64	1300.64	1300.64	1300.64	1327.73	1327.73	1381.93	1354.83	1327.73	1327.73	1327.73	1273.54	1300.64	1300.64	1327.73	1327.73	1381.93	1354.83	1327.73	1327.73	1409.02	1300.64	1273.54	1300.64	1300.64	1300.64	1354.83	1321.93
Power Input	334.31	329.43	325.77	325.36	320.89	318.85	318.04	324.95	328.61	331.46	335.93	340.00	336.75	324.55	320.07	320.07	320.48	320.89	322.51	339.19	336.75	320.07	325.36	336.34	327.39	321.70	320.07	322.11	326.71
COP	3.81	3.95	3.99	4.00	4.05	4.16	4.17	4.25	4.12	4.01	3.95	3.91	3.78	4.01	4.06	4.15	4.14	4.31	4.20	3.91	3.94	4.40	4.00	3.79	3.97	4.04	4.06	4.21	4.05

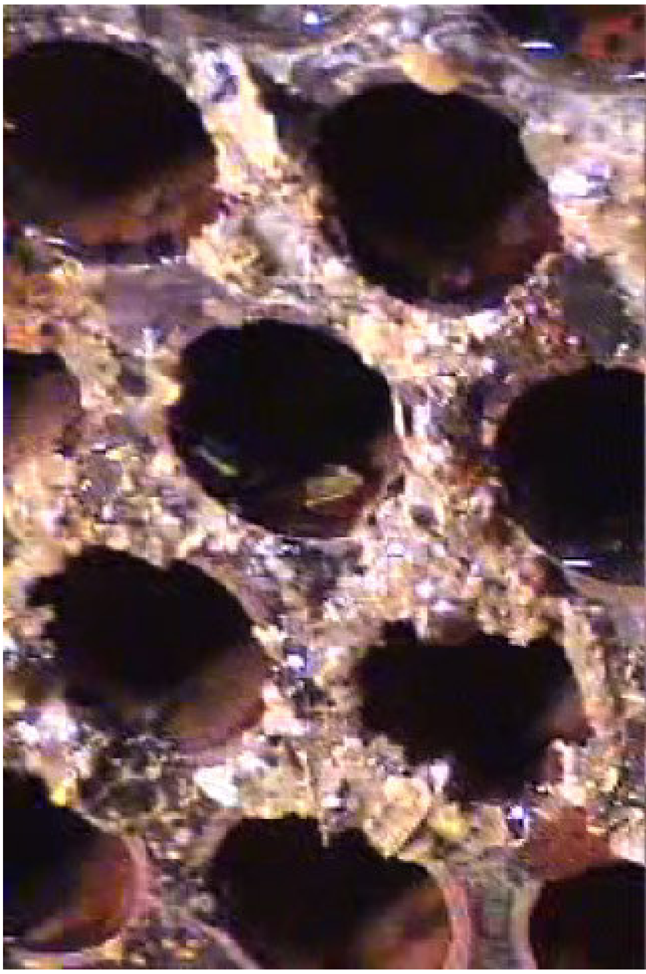
From Pressure Drop vs Flow Chart provided by Trane, based on chilled water pressure drop of 24.19 kPa (i.e. 8.09 ft.) chilled water flow rate is 1025 gpm(US) or 64.67 L/s.

Alfred Hospital, Chiller # 3,(Trane 1400kW) Model : RTHCIE3UOHOG3LFOQOOD Serial : UO2KO6891
Date: 30th August 2006

	10:00	10:15	10:30	10:45	11:00	11:15	11:30	11:45	12:00	12:15	12:30	12:45	13:00	13:15	13:30	13:45	14:00	14:15	14:30	14:45	15:00	**Average value**
Chilled Water Setpoint	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5							
Evap. Leaving Setpoint ℃	5.7	6	6.1	6	6.3	6.7	6.9	7	7.2	8.2	8.7	8.9	9	9.6	9.9	9.9	9.6	9.7	10.2	10.3	10.1	**8.19**
Evap. Entering Water Temp ℃	10	10.4	10.6	10.8	11.2	11.5	12	12.4	12.6	13.3	14	14.3	14.6	14.8	15.1	15.4	15.3	15.4	15.6	15.8	15.9	**13.38**
Evap Leaving Water Temp ℃	5.7	6	6	5.9	6.3	6.7	7.1	6.9	7.2	8.3	8.9	8.9	9	9.6	9.9	9.9	9.6	9.7	10.1	10.3	10.1	**8.20**
Cond Entering Water Temp ℃	27.4	29	27.1	25.5	27.4	29.2	27.3	24.9	26.8	29	28.3	25.7	26.4	29	29.5	26.5	25.7	27.6	29.3	27.6	25.5	**27.37**
Cond Leaving Water Temp ℃	31.4	33.1	31.1	29.7	31.8	33.6	31.4	29.3	31.4	33.5	32.7	30.1	31.1	33.7	34	31	30.5	32.5	34	32.2	30.2	**31.82**
Current Limit %	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	**70.00**
Evap Refrigerant Pressure kpa	257.6	259.8	260.7	260.7	262	268.9	272.3	273.2	274.5	287	294.1	298	296	303.3	308.5	309.8	308.5	308.5	312	313.2	313.2	**287.70**
Cond Refrigerant Pressure kpa	694.2	737.3	692	661.4	705.8	750.6	688.5	651.9	696.8	746.3	729.9	671.3	689.9	750.6	761.8	689.4	674.8	723.5	759.7	718.7	671.3	**707.89**
Evaporator Liquid Level cm	-0.4	0.2	0.1	-0.7	0.2	-0.7	-0.5	-0.7	0.2	0	-0.2	-0.2	0.2	0.4	-0.3	-0.2	0	0.2	0.4	0.2	-0.2	**-0.10**
Expansion Valve Position (%)	30	30.1	31.4	34.3	33.4	33.2	33.6	37	36.4	33.9	34.5	37.2	37.5	36.1	35.5	37.4	38.8	38.4	30.5	36.6	39	**34.99**
Expansion Valve Position	829	830	867	946	921	917	927	1041	1004	936	951	1026	1035	995	1008	1031	1071	1059	1008	1010	1077	**975.67**
Saturated Evapo Refrigerant Temp	5.5	5.8	5.9	5.8	6	6.6	6.8	6.7	7	8.1	8.7	8.7	8.8	9.3	9.7	9.6	9.3	9.5	9.9	10	9.8	**7.98**
Saturated Cond Temp ℃	31.5	33	31.1	30	32.1	33.7	31.2	29.8	31.8	33.7	32.7	30.2	31.4	34	33.9	31	30.8	32.8	34.1	32.2	30.4	**31.97**
Comp.Discharge Temp ℃	45.5	46.8	45.1	42.6	43.7	46.3	44.4	40.9	42.6	44.8	45.3	42.4	42.1	46.6	44.7	43.1	41.1	44.6	46.6	43.1	41.6	**44.00**
Evaporator Approach Temperature	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.1	0.2	0.2	0.2	0.2	12.1	0.3	0.3	0.2	0.2	0.2	**0.77**
Condenser Approach Temperature	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.2	0.2	0.2	**0.14**
Comp. Line - RLA A	66.5	68.5	67.8	68.2	70.9	71.3	67.5	69.2	71.6	71	69.9	67.8	69.9	71.3	70.2	67.8	69.2	71.6	71.3	68.9	67.8	**69.44**
Comp.Line - RLA B	64.1	66.5	65.1	65.8	68.9	68.9	65.5	69.1	69.9	69.6	67.9	65.8	68.2	68.9	67.8	65.5	66.8	69.2	69.2	66.8	65.8	**67.40**
Comp. Line - RLA C	65.5	68.5	67.8	68.5	70.9	70.9	67.2	69.2	71.6	71.3	69.2	67.5	69.9	70.9	70.2	67.2	69.2	71.6	71.3	68.9	67.2	**69.26**
Comp. Line - AMPS A	260	270	264	268	278	278	264	272	280	279	272	267	275	279	274	264	271	282	280	268	266	**271.95**
Comp. Line - AMPS B	251	260	255	259	270	268	255	262	272	272	264	257	267	268	266	256	262	271	271	262	257	**263.10**
Comp. Line - AMPS C	260	268	264	267	278	278	263	270	282	280	271	264	274	278	274	263	270	282	280	268	264	**271.33**
Chilled Water Pressure drop	27	30.2	28.6	28.2	27.8	26.8	26.4	25.6	25.8	28	24	25.2	24.6	25.1	24.6	25.4	25.8	25.9	25.2	24.8	24.4	**26.16**
Cond. Water Pressure drop	33	34.2	33.6	32	30.2	30	29.2	30.6	29.2	29.2	26.4	27.2	29.6	27	27.1	28.8	29.2	29	28.8	28.8	28.8	**29.61**
Cooling Capacity	1193.45	1221.20	1276.71	1359.97	1359.97	1332.22	1359.97	1526.50	1498.75	1387.73	1415.48	1498.75	1554.26	1443.24	1443.24	1526.50	1582.01	1582.01	1526.50	1526.50	1609.76	**1439.27**
Power Input	313.57	324.55	318.45	322.92	335.93	335.12	318.04	326.99	339.19	337.97	328.21	320.48	331.87	335.53	331.05	318.45	326.58	339.59	337.97	324.55	320.07	**327.96**
COP	3.81	3.76	4.01	4.21	4.05	3.98	4.28	4.67	4.42	4.11	4.31	4.68	4.68	4.30	4.36	4.79	4.84	4.66	4.52	4.70	5.03	**4.39**

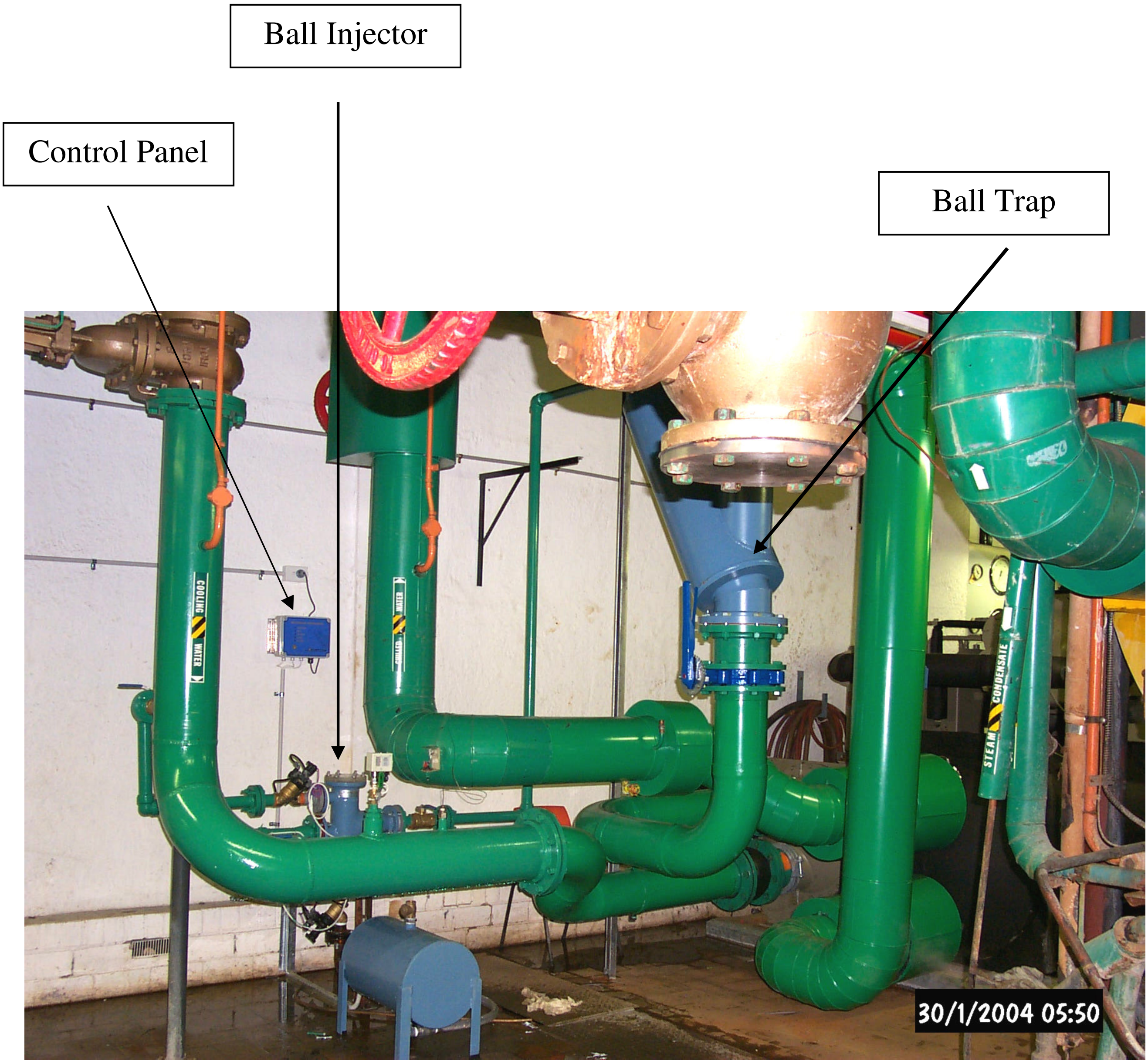
From Pressure Drop vs Flow Chart provided by Trane, based on chilled water pressure drop of 26.16 kPa (i.e. 8.76 ft.) chilled water flow rate is 1050 gpm(US) or 66.24 L/s.

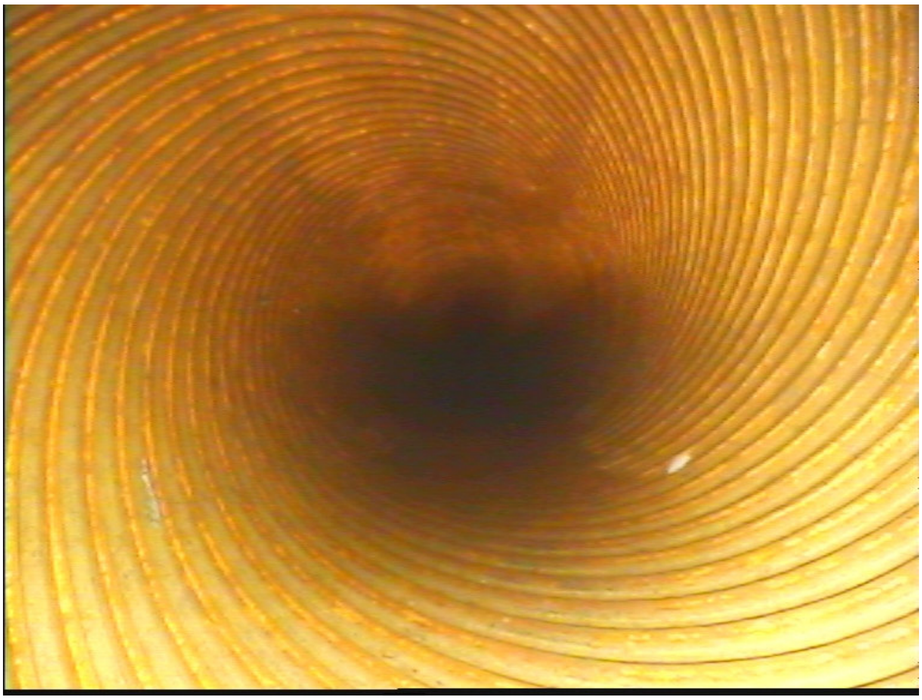
Alfred Hospital Chiller #4.
(Trane 1400kWr)
August 2004
Last brush cleaning conducted
January 2004
BallTech system not installed



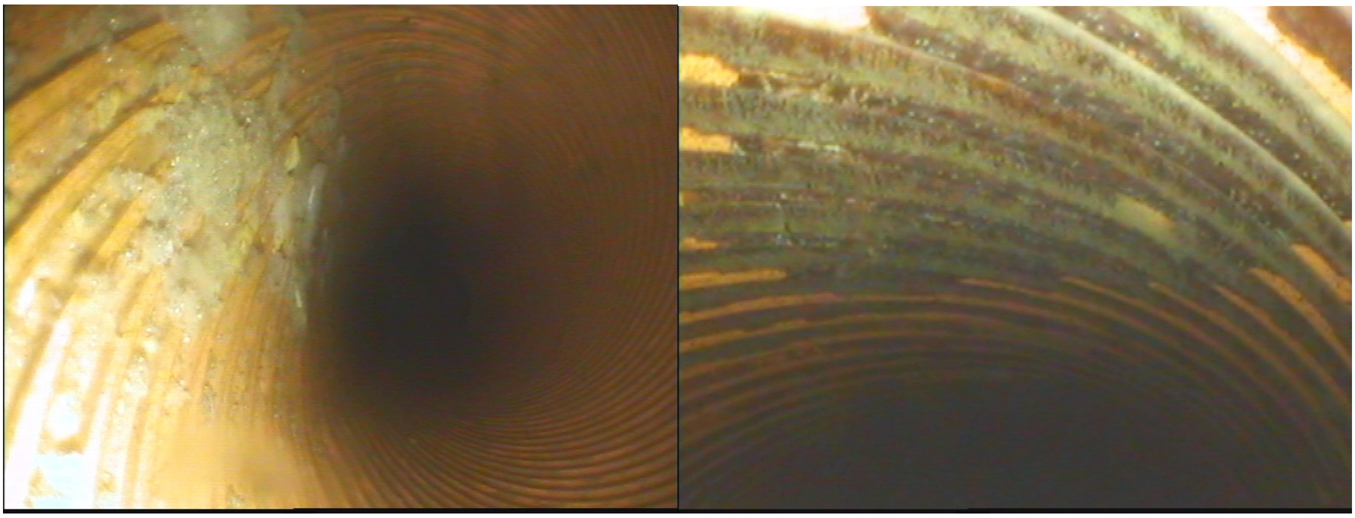
Alfred Hospital Chiller # 3
(Trane 1400 kWr)
August 2004
Last brush cleaning
conducted January 2004
BallTech system installed
January 2004

BALLTECH SYSTEM INSTALLATION (BHS 6”)
CHILLER NO. 3 THE ALFRED HOSPITAL - MELBOURNE





Boroscope Photos at Alfred Chiller #3 <u>AFTER</u> BallTech system installed



Boroscope Photos at Alfred Chiller #4 <u>WITHOUT</u> BallTech system installed

Andrew Pang: Brief Curriculum Vitae

Andrew Pang has twenty-seven years of teaching experience in the refrigeration and air conditioning field in both the trade, para-professional and undergraduate levels. Andrew has also over thirty years of consulting engineering experience in the same field.

He graduated from Canada in 1970 with a Diploma in Mechanical Engineering and added a Graduate Diploma in Air Conditioning (Swinburne University) in 1981 and a Bachelor of Education (La Trobe University) in 1985, the latter two in Australia.

Since graduation in 1970, Andrew has worked in Canada, Singapore and Australia, New Zealand and Egypt on a variety of refrigeration and air conditioning projects.

In 1973, Andrew migrated to Australia and started teaching at the RMIT (Royal Melbourne Institute of Technology) University in 1974. Andrew gained experience in assessing the needs for courses, course structuring and implementation, curriculum and computer-based learning development for the university, government bodies and private enterprises.

From 1977 to 1991, Andrew was the refrigeration and air conditioning consultant on a part-time basis for Technisearch Ltd. and responsible for a host of design and construct projects. These include cooling machines for open-heart surgery at St. Vincent Hospital, beverage-chilling equipment for Actrol and environmental testing chambers at the Australian Defence Industries.

In 1992, Andrew took temporary leave of absence from RMIT University and was responsible for the installation and commissioning of the various refrigeration and air conditioning plants at the state-of- the-art, blood plasma processing facility at CSL (Commonwealth Serum Laboratory) Ltd. CSL is a multi-national company that specialises in the provision of vaccines and blood products to the world market. Since then, Andrew has remained as a consultant to CSL on a part-time basis and is responsible for the design and modifications of new and existing refrigeration and air conditioning installations.

In the last five years, he has been a full time consultant in refrigeration and air conditioning. Amongst his clients are AMP, Allied Beer Dispensing Equipment, Coles Myer (Supermarket Division), Carrier, Crown Casino, Danfoss, GlaxoSmithKline, HRH Biosciences, Honeywell, Mayne Pharma, Nestle, Pfizer, Western Mining Corporation, Royal Melbourne and Frankston Hospitals and Municipal Councils.

Andrew is also a presenter of refrigeration courses such as the Refrigeration Plants Operation and Ammonia Emergency Training for the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH)

Andrew is a member of AIRAH and the American Service Engineers Society.