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TITLE	:	**FIELD PERFORMANCE TESTS OF BALL TECHNIC HEAT EXCHANGER TUBE CLEANING SYSTEM**
REQUESTED BY	:	**BALL TECH PERFORMANCE**
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SUMMARY

The Ball-Tech Energy Ltd automatic heat exchanger tube cleaning system was tested on an underground refrigeration machine. The refrigeration plant was operated for two periods of two months with and without the cleaning system in use. Results of the investigation showed clearly that the measured performance of the plant deteriorated by 18 % over a relatively short time when operated without the tube cleaning system.

The refrigeration plant performance remained stable when operated with the tube cleaning system in use. The reliability of the system during the entire monitoring period was excellent. The refrigeration plant was run continuously and no maintenance or adjustments were made to the automatic tube cleaning system.

The Ball-Tech Energy automatic heat exchanger tube cleaning system clearly demonstrated that a substantial saving in operating costs can be achieved. In the case of the plant tested, a 1,8 MW unit, an annual cost saving in electrical energy of R58 000 was predicted. Additional significant cost savings can be achieved in terms of lower chemical use (mine records indicated that chemical dosing was reduced by 50 %), reduced labour and improved plant utilisation.

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1. INTRODUCTION

Vapour compression refrigeration machines use mechanical work to absorb heat at a low temperature and reject the heat at a higher temperature. The rate of heat rejection is crucial in defining the efficiency or coefficient of performance (COP) of vapour compression refrigeration machines.

It is practice to reject heat from the system by the process of condensing refrigerant vapour in refrigerant to water, shell and tube heat exchangers. The rate at which heat transfer occurs between the refrigerant and water is dependant upon the overall heat transfer coefficient and the contact area between the two fluids. Fouling, which often occurs on the water side of the condenser tubes, reduces the overall coefficient of thermal conductivity. A reduction in the overall thermal conductivity reduces the rate of heat transfer between the fluids which has a negative effect on the performance of the refrigeration plant.

One of two methods are typically employed to limit or reduce fouling. The first involves periodically opening up the heat exchanger and physically removing deposits from the water side of the tubes with a combination of chemicals and brushes. The second method attempts to prevent or limit the formation of fouling by chemically treating the water that circulates through the heat exchanger.

Another option is to install an automatic mechanical cleaning system which cleans the water side of the heat exchanger tubes without the need for down time. This report describes the performance of a cyclical automatic tube cleaning system, installed on the condenser of an underground vapour compression refrigeration plant on a South African gold mine.

2. SCOPE OF WORK

To evaluate the performance of the heat exchanger tube cleaning system described in the report, the South African agents of Ball Tech Energy Ltd, Ball Tech Performance, commissioned CSIR Mining Technology to carry out field trials on the system. A request was made to install the tube cleaning system on a refrigeration plant operating on a South African gold mine.

This report describes the performance of the Ball Technic heat exchanger tube cleaning system operating on a refrigeration machine installed underground on a South African gold mine. The report is summarised below:

With the tube cleaning system **not in operation** the performance of the refrigeration plant was measured at regular intervals for approximately two months. This was to enable the normal performance characteristics of the plant to be established. (During this time it was necessary to remove the condenser end plates and clean the water side of the condenser tubes).

The refrigeration plant performance characteristics were again measured for two months with the tube cleaning system **in operation**. Prior to the plant start up, the condenser end plates were removed and the tubes cleaned.

The performance characteristics of the plant, operating at the two conditions, namely with and without the tube cleaning system in operation, were compared.

3. GENERAL DESCRIPTION OF THE BALL TECHNIC SYSTEM

The system is designed for the automatic, continuous cleaning of heat exchanger tubes. The process introduces sponge rubber balls, with a diameter slightly larger than that of the tubes, into the inlet of the condenser water stream. The balls pass through the tubes of the heat exchanger and as they do they wipe the tube surfaces clean before any deposits can harden. The balls are retrieved, at the heat exchanger discharge, and returned to the inlet side of the heat exchanger. The sponge balls which carry any deposits with them are automatically washed before being introduced to the inlet water stream.

3.1 System Elements (Referring to Figure 1)

<u>Ball injector unit (1)</u>

The injector unit is installed in the main inlet pipe and performs the following functions:

Introduction of the balls into the inlet water stream.

Cleaning the balls after passage through the heat exchanger tubes.

<u>The ball trap (2)</u>

The ball trap collects the dirty balls and is installed in the main return pipe from the heat exchanger.

<u>Drain valve (3)</u>

Automatic operation of the drain valve facilitates the transfer of the balls from the ball trap to the injector unit and the subsequent scrubbing of the balls.

3.2 System operation

The heat exchanger cleaning system operates cyclically, injecting balls into the water stream at intervals, dependent upon signals received from the programmable controller. The system is normally set to operate every 40 minutes, with each cycle approximately 2 minutes in duration.

<u>Operation sequence</u>

1. The balls are in the injector unit prior to the initiation of the cleaning cycle.
2. An initiation signal is received, thrust valve (4) opens, and water from the main inlet water pipeline flows through the system upper pipe into the injector unit. The water carries the balls through the system injector unit lower pipe and introduces them into the main inlet water pipeline.

Table 1 Condenser and evaporator design specifications

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3. The balls move through the heat exchanger and remove accumulated deposits from the tube walls. The balls exit the heat exchanger and are collected in the ball trap (2).
4. A signal from the controller opens the drain valve (3) for eight seconds, and a pressure differential is created which allows the balls to travel out of the ball trap (2) and back to the injector unit (1).
5. The small quantity of water used to carry the balls back to injector is also used to rinse off the soft deposits which attach to the balls in the tube cleaning process. This water is then drained away through a mesh which ensures that the balls remain in the injector.
6. The cycle repeats itself at the interval programmed into the controller.

4. DESCRIPTION OF THE SITE AND REFRIGERATION PLANT

The investigation was carried out at a depth in excess of 3 000 m at 58 K sub-incline shaft on 58 level East Rand Proprietary Mine, South East Vertical shaft.

4.1 Refrigeration plant design specifications

Compressor

Make and model: 515R Hitachi model RF6 2 stage centrifugal

Capacity: 1810 kW

Motor output 510 kW

Refrigerant R11

		Evaporator	Condenser
Inlet water temperature	(°C)	22	
Outlet water temperature	(°C)	12	
Number of tubes		510	765
Inside tube diameter	(mm)	14	14
Outside tube diameter	(mm)	19	19
Passes		4	3
Area water side	(m^2)	110	165
Area refrigerant side (including fins)	(m^2)	396	595
Flow rate (l/s)		45	83
Fouling factor	(m^2°C/W)	0,0001	0,0004
Max. working pressure	(kPa)	1080	1080

Table 1 Condenser and evaporator design specifications

Condenser spray design specification

Type	Vertical open spray
Water flow rate	83 l/s
Water temp. inlet	49,6 °C
Water temp. outlet	43 °C
Airflow	24 m^3/s
Air temp. inlet	28,0 °C wet bulb and 32,5 °C dry bulb
Air temp. return	42,0 °C wet bulb and 42 °C dry bulb

5. MEASUREMENTS AND INSTRUMENTATION

Water flow rates. Clamp on ultra sonic liquid flow meter. (Instrument was compared on site to installed orifice water flow meters)

Condenser and evaporator water flows

Temperatures. Calibrated mercury in glass thermometers.

Evaporator inlet and outlet

Condenser inlet and outlet

Refrigerant condensing temperature

Compressor discharge and suction

Pressures. Calibrated pressure gauges.

Evaporator and condenser water at inlet and return

Refrigerant evaporating pressure

Refrigerant condensing pressure

Electrical power consumption kW hour meter. (Reading checked against ammeter and power factor meter).

Compressor power consumption

6. RESULTS

Plant performance data, measured with the tube cleaning system in operation, were analysed using the CSIR Mining Technology computer program PERFRIG. Data to assess the plant performance without the tube cleaning system in place was collected some months earlier. At this time insufficient instrumentation was installed to allow a PERFRIG performance analysis to be made. However it was possible to evaluate the measured data using conventional analytical methods.

The comparison of performance for both operating conditions is valid. Adequate information was available to determine the plant performance in terms of COP in both instances. Plant performance (COP), with and without the tube cleaning system in operation, is presented in Figure 2.

PERFRIG analysis of plant performance, measured with the tube cleaning system in operation, is shown in Tables 2,3 and 4 respectively.

Survey date	12 08 96	21 08 96	04 09 96	02 10 96	09 10 96
Suction temperature (°C)	10,0	2,4	3,5	0,7	1,4
Carnot C.O.P.	6,9	6,6	6,6	6,0	6,0
Actual C.O.P.	2,8	3,2	3,0	3,1	3,0
cycle efficiency (%)	40,7	49,3	45,4	52,2	49,4
Heat balance error (%)	7,1	0,2	2,1	9,0	3,5

Table 2 Refrigeration compressor data

Survey date	12 08 96	21 08 96	04 09 96	02 10 96	09 10 96
Absolute operating pressure (kPa)	44,0	43,0	46,0	41,0	42,0
Operating temperature (°C)	2,1	1,5	3,1	0,4	1,0
Inlet water temperature (°C)	20,4	19,6	19,4	20,2	21,4
Outlet water temperature (°C)	14,6	12,0	11,5	12,0	13,1
Water flow rate (l/s)	44,8	43,5	42,3	41,6	41,0
Fouling factor ($m^{2\circ}C/W$))	0,0001	0,0001	0,0001	0,0001	0,0001
UA value (W/°C)	139,8	194,7	230,5	182,6	175,5
Operating duty (kW)	1087,4	1384,5	1398,9	1428,1	1425,3

Table 2 Evaporator data

Survey date	12 08 96	21 08 96	04 09 96	02 10 96	09 10 96
Absolute operating pressure (kPa)	186,0	194,0	204,0	212,0	214,0
Operating temperature (°C)	42,0	43,4	45,0	46,3	46,6
Inlet water temperature (°C)	36,2	37,2	37,8	38,9	39,5
Outlet water temperature (°C)	39,8	41,2	42,0	43,6	44,0
Water flow rate (l/s)	105,3	108,4	108,4	105,3	104,8
Fouling factor ($m^{2o}C/W$))	0,0004	0,0004	0,0004	0,0004	0,0004
UA value (W/°C)	560,2	621,7	517,6	582,5	575,5
Operating duty (kW)	1587,9	1815,5	1905,9	2073,6	1974,6

Table 3 Condenser data

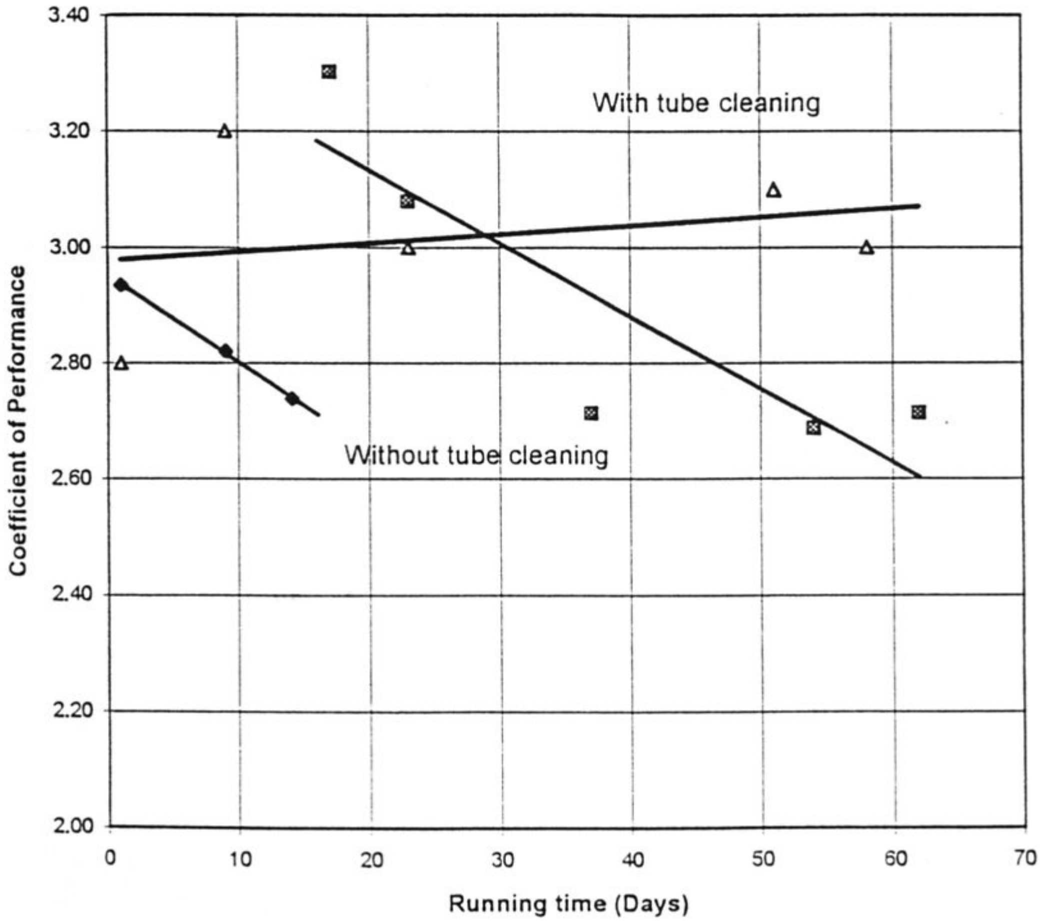

Figure 2 COP versus time for the refrigeration plant operating with and without the tube cleaning system

The mine records showed that an average of 210 litres of "CT 50" chemical dosing was added the condenser water circuit per month. During the period that the tube cleaning system was in operation this quantity was successfully reduced by 50 %.

7. COMMENT ON RESULTS

Figure 2 clearly shows that the performance of the plant deteriorated during periods when the tube cleaning system was inoperable. At a point, which corresponds to 17 days on the chart, it was necessary to open the condenser and clean the tubes.

In contrast the plant performance essentially remained stable for the time that the tube cleaning system was in operation.

Using the specified design operating duty of 1 810 kW and COPs of 3,3 and 2,7 as the measure of performance deterioration over 40 days (Figure 2), it can be shown that the compressor power consumption increases from 548 kW to 670 kW for that period. Assuming that the average increase in the electrical power consumed lies between these two figures (61 kW), and the present day cost of electricity, including a maximum demand component is 11c per kWhr, then the average cost penalty, in terms of electrical energy, of running the plant without the system in operation is R58 800 per annum. If the cost of cleaning the tubes on a regular basis and of adding chemical fouling inhibitors is taken into account, the overall cost penalty will increase considerably.

8. CONCLUSION

The Ball-Tech Energy tube cleaning system tested performed well. The measured refrigeration plant performance remained stable during the entire monitoring period. The tube cleaning system operated continuously, no maintenance or adjustments were needed to achieve the consistently high level of performance and reliability.

Quantifiable benefits of operating the tube cleaning system included:

reduced overall energy consumption (18%)

reduced chemical dosing (50%)

improved refrigeration plant utilisation

reduced overtime.