Application of Physical Scale Prevention Technologies for Chiller Condenser

物理防水垢技術於冷凍機冷凝器的應用

機電工程署
EMSD

Introduction

A typical condensing water system for water-cooled central air conditioning system consists of pumps, condenser, condensing water pipework and a heat rejection unit such as cooling tower or heat exchanger etc.

Some physical scale prevention technologies such as automatic tube cleansing system, magnetic and electromagnetic devices have emerged on the market in recent years. This pamphlet aims to introduce these scale prevention technologies for chiller condenser in HVAC system as well as their application limitations. For further information, please contact the Energy Efficiency Office of the Electrical and Mechanical Services Department.

Scale - Where and Why?

In fresh water cooled air-conditioning system, fresh water contains traces of mineral ions, in which calcium carbonate is a dominant component because natural water is rich in Ca^{2+} and carbonic species (CO_2, HCO_3^-, CO_3^{2-}). Calcium carbonate ($CaCO_3$) is only slightly soluble in pure water but more soluble when carbon dioxide is present in water. This could be represented by the following equilibrium equation:

引言

水冷式中央空調系統的冷凝水系統通常包括水泵、冷凝器、冷凝水管道和散熱裝置(如冷卻塔或熱交換器)。

近年來，一些物理防水垢技術相繼於市場上出現，如冷凝器管道自動清洗系統、磁力場和電磁場防積垢裝置。本小冊子旨在介紹這些物理防積垢技術於空調系統冷凍機冷凝器的應用和相關的限制。有關進一步資料，請與機電工程署能源效益事務處聯絡。

水垢 — 在那裡及原因？

一般而言，在淡水冷卻空調系統內所用的淡水會含有微量礦物離子，其中碳酸鈣是主要成份，因為天然水含有豐富的鈣（Ca^{2+}）和碳物種（CO_2, HCO_3^-, CO_3^{2-}）。碳酸鈣（$CaCO_3$）只能微微溶於純淨水，但若水中含有二氧化碳，它的可溶性會提高，這可以下列化學方程來代表：

$$Ca(HCO_3)_{2\,(aq)} \Leftrightarrow CaCO_{3\,(s)} + CO_{2\,(g)} + H_2O$$

When condensing water approaches the heat exchanger (condenser), the temperature rises and solubility of CO_2 gas decreases. The solution will tend to restore the equilibrium by shifting towards $CaCO_{3(s)}$ precipitation and therefore the formation of $CaCO_{3(s)}$ occurs (in the form of calcite) on heat exchanger surface. This is why hard scale is usually found on the heat exchanger of condensers. As scale is a good insulator of heat, the heat transfer efficiency of the chiller condenser is reduced affecting the energy performance of the chiller.

Scale Prevention and Energy Efficiency

The primary aim of scale prevention is to upkeep the condition of inner surface of condenser tube of chiller so that the heat exchange at condenser tube of chiller could be maintained in good condition. As such, chiller could operate more efficiently.

It should however be noted that the achievable energy saving is site specific which depends on the mineral content of condensing water, the conditions of the plant equipment, the operation pattern and the maintenance of the chiller plant, etc.

當冷凝水接近熱交換器（冷凝器）時，二氧化碳在水中的溶解度會隨著溫度上升而減低，為了恢復上述的化學方程之平衡，溶液會傾向於轉化為碳酸鈣沉澱物（$CaCO_{3(s)}$）。因此，$CaCO_{3(s)}$（方解石的型態）就會在熱交換器表面形成了，這也解釋了為什麼堅硬的水垢通常於熱交換器內表面出現。由於水垢是良好的熱絕緣體，冷凍機組傳熱效率因而降低，影響了其能效表現。

防水垢與能源效益

防水垢的主要目的是保持冷凍機冷凝器管道內表面的狀況，以維持冷凝器管道內的熱交換於良好狀態，使冷凍機運作得更有效率。

然而，需留意節能效果於不同冷凝水系統是不同的，這取決於冷凝水內礦物含量、冷凍機組的狀況、運作模式和維修保養情況等等。

Automatic Tube Cleansing System (ATCS)

This technology (ATCS) makes use of specific cleansing balls to regularly wipe the inner surface of the chiller condenser for maintaining its clean surface condition with a timer control. A simplified diagram is shown in Figure 1.

冷凝器管道自動清洗系統

這項技術（冷凝器管道自動清洗系統）使用特定的清潔球，在配備時間掣一起使用下，它會定時把清潔球放進冷凝水中，用以擦拭冷凍機冷凝器管道內表面，保持管道內壁清潔狀況，簡化圖如圖1所示。

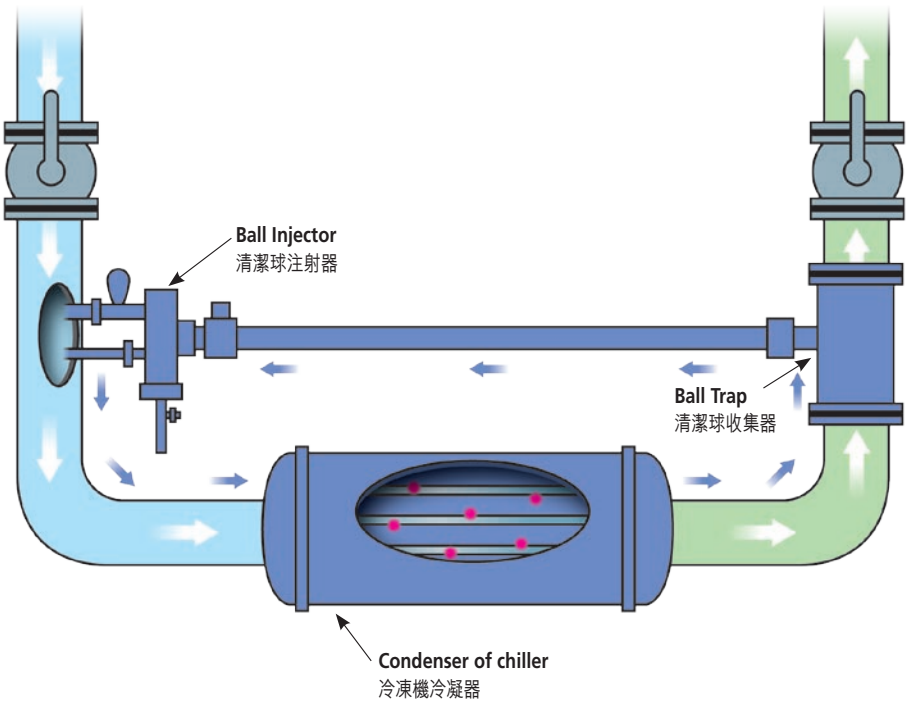


Figure 1 – Simplified diagram of a typical configuration of Automatic Tube Cleansing System
圖1 - 典型的冷凝器管道自動清洗系統配置簡化圖

Energy saving tips: Turn off the air-conditioning in offices, meeting rooms, etc. right after use

The choice of ball size is crucial to the effectiveness of this technology in maintaining the chiller condenser condition and hence the energy performance of the chiller. If the ball size is too large, it may easily be blocked in the tubes of the condenser. On the contrary, if it is too small, it may not be able to scrub the tube surface to inhibit formation of scale and upkeep the clean condition of the tube surface.

As the addition of the ATCS will involve retrofit of the existing condensing water pipes, the feasibility of such modification on site should be considered. In considering its implementation, the existing condition of the chillers should be evaluated. It is suggested to have a visual inspection on the inner surface of condenser of chillers to ascertain the existing condition of the condenser tubes e.g. extent of scale accumulation. If there is a thick layer of scale, this may affect the choice of ball size and some balls may block the condenser tubes. To ensure the condition of each tube of the condensers, it is also advisable to have condenser cleansing before the use of ATCS.

選擇清潔球的大小，對此技術能否有效保持冷凍機的狀況，以至相關冷凍機的能效表現，尤其重要。太大的清潔球可能容易堵塞在冷凝器管道內。相反，如果清潔球太小，它可能無法擦拭冷凝器管道內壁，以抑制水垢的形成，從而保持管道內壁清潔狀況。

於現有設備加裝冷凝器管道自動清洗系統時，會涉及更改現有冷凝水管，因此有關工程應考慮此等改動是否可行。在考慮應用技術時，應評估冷凍機的現有狀況，為冷凍機冷凝器管道內壁進行目視檢查，以確定冷凝器管道內壁的現時狀況，例如水垢的聚積情況。如有一層厚厚的水垢，會影響清潔球大小的選擇和阻礙清潔球通過冷凝器管道。因此，為確保冷凝器每條管道的狀況，建議在使用冷凝器管道自動清洗系統前應對冷凝器進行清洗。

Besides, the cost of regular maintenance of the ATCS should be also considered as balls may wear out and need replacement once every few months, depending on the condition of condenser inner surface, mineral contents of condensing water and operation profile. Moreover, the choice of chemical used in condensing water treatment is also important as some chemical may affect the material property of the balls (e.g. hardness). As a result, this may increase the chance of the balls being stuffed in the condenser tubes or else the service life of the balls.

此外，視乎冷凝器管道內壁表面狀況、冷凝水內礦物含量和機組運作模式，清潔球因會損耗而需每幾個月便更換一次，故需考慮該自動清洗系統的定期維修成本。另外，選擇冷凝水處理的化學劑也很重要，因為某些化學劑可能會影響清潔球的物料特性（如硬度），因而會增加清潔球堵塞在冷凝器管道內的機會或影響清潔球的壽命。

Magnetic or Electromagnetic Devices

磁力與電磁防積垢裝置

There are three typical devices that apply an electric field or magnetic field or electromagnetic field to condensing water systems with a view to inhibiting or preventing scale formation on chiller condensers. They are: i) Single Coil Electromagnetic Device, ii) Permanent Magnet Device and iii) Electromagnetic Induction Device.

在冷凝水系統，用以抑制或防止於冷凍機冷凝器內形成水垢的典型裝置有三種：i）單線圈電磁裝置、ii）永久磁裝置及iii）電磁感應裝置。

i) Single Coil Electromagnetic Device

An alternating magnetic field is generated around the coil wound on the pipe near the chiller condenser water intake, which is illustrated in figure 2.

i) 單線圈電磁裝置

線圈安裝在近冷凍機冷凝器入水處的接駁喉管上，用作產生一個交變磁場，如圖2所示。

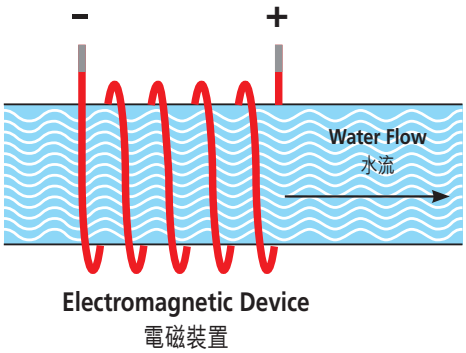


Figure 2 – Simplified diagram of single coil electromagnetic device
圖 2 — 單線圈電磁裝置簡化圖

Fresh water contains traces of mineral ions, in which Ca^{2+} and carbonic species (CO_2, HCO_3^-, CO_3^{2-}) are dominant components. When the negative ions and positive ions flow through the magnetic field, they experience a force depending on the water flow rate and the magnetic field strength. The negative ions and positive ions are moving in opposite direction. They will collide with each other and form aragonite crystal (a softer and less adhesive form of calcium carbonate), which will cause less calcium ions available for formation of hard scale (calcite, a harder form of calcium carbonate). That is why this technology requires a particular flow velocity in order to have adequate force to cause collision. For detail about the flow velocity requirement, please consult respective manufacturers.

淡水含有微量礦物離子，其中鈣（Ca^{2+}）和碳物種（CO_2, HCO_3^-, CO_3^{2-}）為主要成份。當負離子和正離子流過磁場時，它們所遇到的力量，取決於水的流速和磁場強度，這力量會使負離子和正離子呈相反的方向移動和互相碰撞對方，並形成文石晶體（較軟和較少粘性的碳酸鈣），這也引致冷凝水中較少的鈣離子可供形成較硬的水垢（方解石 — 較硬型態的碳酸鈣），這解釋該項技術為何需要一特定流速，以產足夠的力量導致正負離子碰撞。有關對流速要求的詳情，請查詢相關製造商。

A major advantage of this technology for retrofit application is no modification of pipe work is required because the coil is externally mounted to the pipe. However, the technology is restricted to pipe made of non-ferrous material like copper and plastic because ferrous pipe, such as iron and steel pipe, does not allow magnetic field to penetrate and magnetic field could not reach the water inside.

該技術對改裝工程的主要優點是由於線圈安裝在冷凝水管之外，而無需改動現有冷凝水管道。然而，該技術只能應用於非含鐵的水管，如銅水管和塑膠水管，此因含鐵的水管（如鐵水管和鋼水管）不讓磁場穿過，磁場便不能達到管道內的水。

ii) Permanent Magnet Device

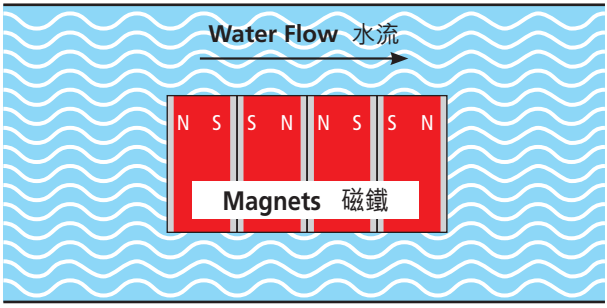
This is similar to the single coil electromagnetic device as discussed above except that the magnetic field is produced by permanent magnet, which is incorporated in specially designed pipe as illustrated in figure 3. The device is invasive and requires some minor modification work to existing condensing pipe to fit device into the system. As such, shutdown of the chiller is required for installation and cause inconvenience to end-users. Special caution should also be taken if it is connected to ferrous pipe, in which a magnetic insulation needs to be installed to avoid magnetic field disturbance. The addition of the device may also increase the pump head to overcome the water resistance of the device.

ii) **永久磁鐵裝置**

該裝置類似上述的單線圈電磁裝置，分別是它把永久磁鐵嵌入特別設計的水管中，用以產生磁場，詳情如圖3所示。該類裝置是有一定破壞性，要把現有冷凝水管作出輕微改裝，使現有冷凝水管得以配合這裝置的安裝，因此，冷凍機也需於改裝時停止運作，對終端用戶造成不便。如把該裝置連接到含鐵的水管，需特別留意於連接端安裝磁場絕緣設備，以避免所產生的磁場受到干擾。此外，加裝該裝置也可能會增加系統水壓的要求，以克服該裝置引致的水阻力。

In addition, the change in magnet field along the section of the pipe depends on the change of magnetic pole physically, which is less frequent than the magnetic field generated by electromagnetism. Hence, less collision takes place, which eventually affects the formation of aragonite and the performance in scale prevention. For optimization, this kind of device is designed for a particular flow velocity in the condenser pipe in order to have adequate force to cause collision. For detail about the flow velocity requirement, please consult respective manufacturers for recommendation.

另外，這裝置內沿管道的磁場變化取決於實際磁極的變化，其變化較由電磁產生的磁場變化為少。因此，正負離子的碰撞也會少一點，從而影響該裝置防水垢和文石形成的表現。為達優化效果，該裝置需配合特定冷凝水管內的流速，以確保有足夠的力量導致正負離子碰撞。有關流速要求的詳情，請查詢相關製造商。



Invasive Device
永久磁鐵裝置

Figure 3 – Simplified diagram of device using permanent magnet method
圖 3 — 永久磁鐵裝置簡化圖

iii) Electromagnetic Induction Device

A typical electromagnetic induction device for treatment of condensing water flowing in a pipe comprises core elements of magnetically conductive material surrounding the pipe spaced from one another lengthwise of the pipe (as illustrated in figure 4). The device establishes radio frequency electric fields in the fluid in the pipe originating at spaced positions along the pipe.

iii) 電磁感應裝置

一個處理喉管內冷凝水流的典型電磁感應裝置，是由一些導磁電材料所組成的元件，圈套著水管，並沿水管相互間隔而安裝（如圖4所示），這裝置會於沿水管相互間隔的位置，在水管內的流體產生無線電頻率的電場。

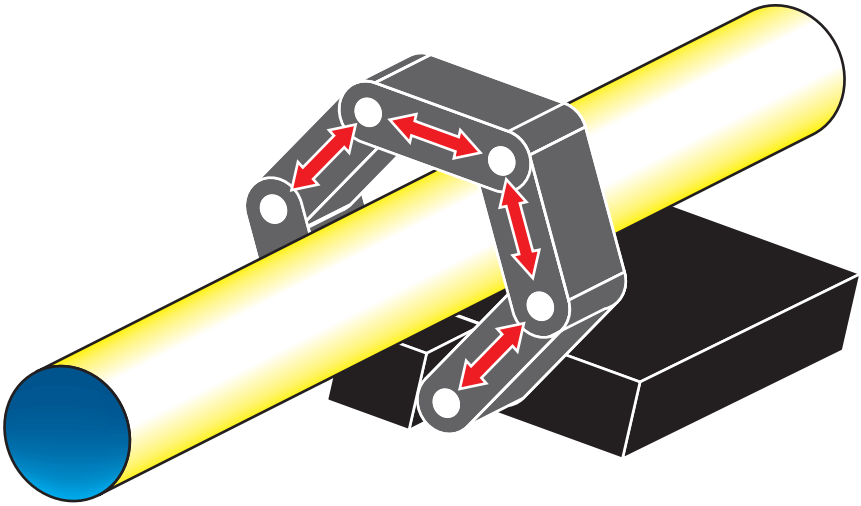


Figure 4 – An electromagnetic induction device externally mounted on a condensing water pipe.
圖 4 — 安裝於冷凝水管外的電磁感應裝置

With the use of this technology, mineral ions in water will experience a force when they are under an electric field generated by the device. Particles will be positively and negatively charged. They are forced to collide and form aragonite crystal (softer form of calcium carbonate), which will cause less calcium ions available for formation of hard scale (calcite, a harder form of calcium carbonate).

The application of this technology to existing condensing water circuit is simple and has no particular water flow velocity requirement. Besides, the device is externally mounted to an existing pipe work without any invasive modification to the existing installation and hence no shutdown of chiller plant is needed. This causes minimal disturbance to end-users. The application of this technology is also independent of the pipe material.

在使用了這項技術，當水中礦物離子流過該裝置所產生的電場時，它們會受到一股力量所牽動，而微粒被帶上正電荷和負電荷，迫使它們互相碰撞，形成文石晶體（較軟型態的碳酸鈣），這將導致冷凝水中較少鈣離子可供形成硬水垢（方解石 — 較硬型態的碳酸鈣）。

應用此技術於現有冷凝水系統是簡單和沒有特定的水流量要求。此外，由於這裝置安裝在水管之外，而無需對現有設備進行破壞性的改動，故冷凍機無需停止運作，這對終端用戶造成最少的不便。還有，應用這項技術對水管材料並沒有特別的要求。

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