Automated Evaporator Coil Cleaning for Elimination of Mold and Bacteria

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***Abstract*— Pathogens can thrive in the damp environment of an evaporator coil or cooling tower in an air conditioner. To ameliorate this problem, an automatic fluid-delivery prototype is built to mix three constituent parts of a cleaner in prescribed amounts then spray the solution onto an evaporator coil. Flow rates, system geometry, and chemical compatibilities are all considered. The prototype is part of the Internet of Things (IoT) and costs $1,000. The machine is designed for a two-ton air conditioner but is expandable for larger systems.**

Keywords—embedded system, HVAC, mold, IoT

I. Introduction

Mold (a fungus) and bacteria in a building's heating, ventilation, and air conditioning (HVAC) systems can cause serious health problems for the occupants, including sick building syndrome (SBS) [1] and Legionnaires' Disease [2]. These pathogens can be present in evaporator coils and cooling towers of residential and commercial systems [3] [4]. The present work describes an automated system for introducing a three-part cleaning solution to the evaporator coil or cooling tower by waiting for HVAC operation to cease then pumping the cleaner through an array of spray nozzles. The device is patented by both the United States and European Patent Offices.

The cleaner, a fungicide and bactericide, is of a proprietary formulation and is billed as organic, coming from no genetically modified organisms (non-GMO), and nontoxic. Chemical compatibility with the cleaner is an important consideration for mechanical components of the system. Another requirement is that wireless monitoring and control of the system be possible both locally and remotely. This is achieved via Wi-Fi and the system is thus a part of the Internet of Things (IoT).

The design of a prototype for a two-ton evaporator coil is detailed in sections II-A through II-C. The design requirements are as follows:

- Mix cleaner constituents in prescribed amounts
- Use no-spill containers for cleaning components
- Maintain chemical compatibility between cleaning constituents and wetted surfaces
- Allow easy, in-field installation
- Shut off HVAC during cleaning
- Provide wireless control

II. Method

The main design considerations are reliability and price. For viability on the residential market, the system cost is limited to one thousand United States dollars (USD).

A. Hydraulics

The cleaning components are to be combined in prescribed ratios. To meet this need with minimal cost and complexity, a positive-displacement pump is used in lieu of a centrifugal pump and flow meter. A peristaltic pump is selected; with 0.375 inch inside-diameter tubing it provides a flow rate of 1.59 gpm at 20 psi. These data are used for spray nozzle selection.

Figure 1 shows a 3D model of the evaporator coil with four spray nozzles mounted on the wall of the cabinet. The pyramids show the spray given by four, full-cone, 120°, square-pattern nozzles. The square spray pattern is chosen instead of circular in order to reduce overspray inside the cabinet. Based on Figure 1, eight nozzles are needed to clean both sides of the evaporator coil, which results in 0.198 gpm per nozzle at the pump's maximum flow rate. A commercially available nozzle is selected that provides 0.18 gpm at 20 psi.

Cleaning components are stored in separate containers, with closed-loop-system dispensing caps and inserts, from which measured amounts are drawn into a mixing vessel by the pump. A triad of two-way, normally closed, solenoid valves is used to govern which liquid the pump draws. The valve manifold has two outlets: one to the mixing vessel and the other, outfitted with a one-way valve, to the spray nozzles. The pump direction is reversed to spray the solution.

These components are pictured in Figure 2. A 1 L mixing vessel is at the left and the one-way valve leading to the spray nozzles is at the right. The three containers for cleaner components are out of the picture but the tubing coming from each can be seen entering the image at the bottom. All wetted parts are either Viton, CPVC, stainless steel, or aluminum to maintain chemical compatibility with the cleaner. The spray nozzles are screwed into drilled and tapped CPVC pipe fittings according to standard industry practice [5]. Since CPVC is easily cut and bonded, using this material also allows for simple field installation for varying evaporator-cabinet geometries.

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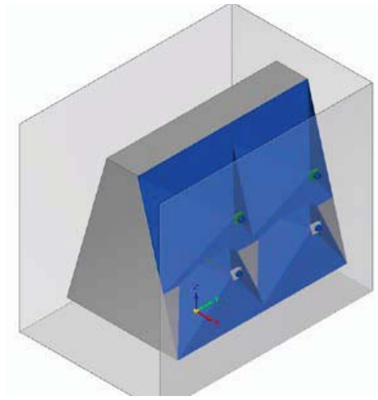

Figure 1: Four, square-spray-pattern nozzles in evaporator cabinet

Figure 2: Mixing vessel, pump, and valves

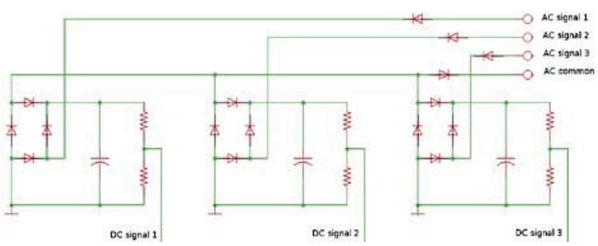

Figure 3: Circuit for converting 24 VAC signals to DC

B. *Sensing*

To ensure that the cleaning solution is not sprayed during HVAC operation, three, 24 VAC signals from the thermostat are sensed. The computer described in §II-C requires that these signals be converted to DC, for which the circuit shown in Figure 3 is used. When the cleaning system is to operate, the lines connecting the thermostat to the HVAC control board are broken using mechanical relays (the Omron G5LE-14-DC5).

The system also detects when the liquid level in a bottle of cleaner is low. This is effected by positioning a capacitive sensor against a bottle. When the liquid level reaches the sensor, the DC output voltage changes. As opposed to some other liquid sensors, this arrangement has the advantage of working with the closed-loop dispensing system mentioned in §II-A since it does not require access to the interior of the bottle.

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C. *Computer*

The Particle Photon is employed to provide discrete output controlling the valves and relays, PWM for the pump, digital input for the thermostat, and analog input for the liquid sensors. This board uses a Cypress Wi-Fi chip and an STM32 ARM Cortex M3 microcontroller [6].

In order to get communication between the computer and an operator, a simple web page is created using HTML forms and JavaScript. This page can be used to adjust the cleaning schedule, start a cleaning cycle manually, obtain system information, and perform other functions.

III. SUMMARY

Design considerations for an IoT evaporator-coil cleaner are presented. Dispensing prescribed amounts of cleaning components is effected by use of a peristaltic pump, which also has a favorable cost impact. Industry-standard closed-loop components ensure no-spill fluid dispensing. Chemical compatibility is assured from storage to spraying, with CPVC pipe also providing simplicity in field installation. A circuit is designed to convert 24 VAC thermostat signals to DC for the cleaner to sense when the HVAC system is operating, and relays block the signals from reaching the HVAC control board during cleaning. The embedded computer has a Wi-Fi chip to provide remote control and monitoring of the system through a custom web page.

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