Hospital Steam Humidification Systems and the Chemicals they Use

Safety and regulatory considerations when choosing a humidification system for a health-care setting

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In preparation for the code analysis, which typically begins during the conceptual design stage, for a new medical center in Southern California, we stumbled on the Code Application Notice (CAN) issued by the Office of Statewide Healthcare Project Development (CAN #4-406.2.1), which, in part, reads: "If steam from a central boiler plant will be injected directly into air stream, the design professional should verify that the boiler water will not be treated with chemicals or contain minerals which are known to be hazardous to health or which might contribute to an indoor air quality problem."

The challenge became not only to find out what chemicals are used to treat boiler water, but also to verify that they are not hazardous and will not cause IAQ problems, as well as to verify that hazardous chemicals will not be used in the future. The only way to achieve such a goal is to design and specify only equipment and systems that do not need such chemicals. However, this requirement presents a host of questions that should be answered before one begins to specify equipment. For example, what are the advantages and disadvantages of such systems? Are there significant first-cost and maintenance-cost impacts? Why are chemicals that have been used by the industry for more than fifty years now considered hazardous, making direct injection steam humidification questionable in the health-care facilities in California? What regulations and guidelines apply to these chemicals? What kind of safeguards should be in place to use chemicals safely? How should consulting engineers deal with this issue and properly advise their clients?

The following article is an attempt to answer these questions. The purpose of this article is to discuss issues that consulting engineers and owner's representatives should consider during the decision-making process regarding the selection of the humidification system for a new health-care facility.

HOSPITAL HUMIDITY

Humidity control is required in health-care facilities. The most economical humidification system is direct injection of the steam from the central boiler plant. This steam carries anti-corrosion chemicals. Chemicals in steam used for humidification are suspected to have adverse health effects for humans exposed to high concentrations of these chemicals in ambient air. Chemicals are carried via humidifiers into room air, where they are inhaled and/or ingested.

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One of the first questions we set out to answer was should humidification systems be chemical-free or, should safeguards be implemented to assure safe use of chemicals?

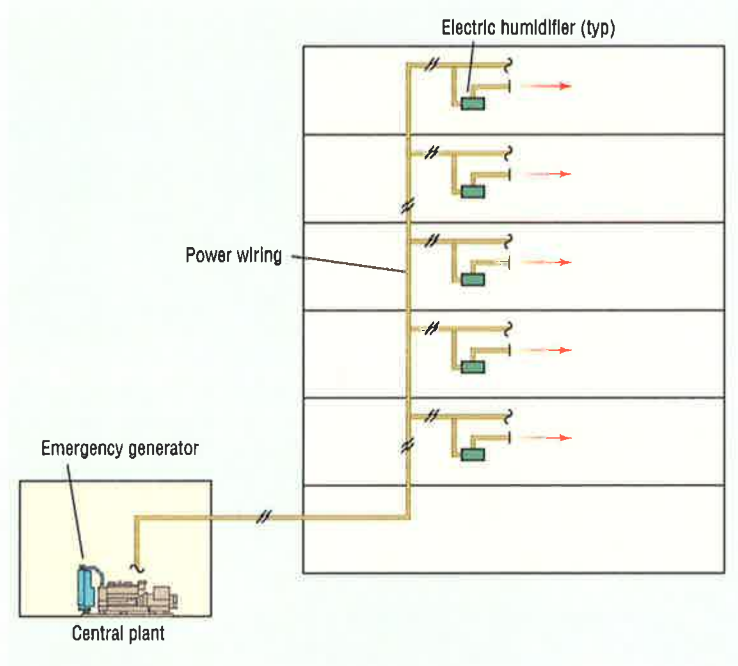

FIGURE 1. Electric-type humidifier system.

WHERE IS HUMIDIFICATION REQUIRED?

According to California Mechanical Code, humidification is required in operating rooms, cyctoscopy, cardiac cath lab, delivery rooms, recovery rooms, newborn nursery, intensive care newborn nursery, and in intensive care rooms.

Typically, humidification is achieved in two stages: primary and secondary. The primary humidifier, installed in the air handling unit, adds moisture to maintain relative humidity in non-critical patient areas of the facility at approximately 35 percent RH. The secondary humidifiers are located downstream of the final filters and downstream of the terminal unit with the reheat coil serving each space where individual temperature and humidity controls are required. Due to the mild California climate in most locales, only secondary humidifiers are provided.

TYPES OF HUMIDIFIERS

The following dry-steam types of humidifiers are acceptable in health-care facilities in California:

- Boiling water vapor injection type, with steam generation chamber. These include gas-fired, electric-type or steam-to-steam converters
- Injector type jacketed (double wall distribution tube) with steam generated in the central boiler plant or in the "clean steam" generator.

Gas-fired. There are a number of gas-fired evaporative humidifiers on the market, but they present several problems for hospital applications. Because of the problem of not being able to vent the flue or provide combustion air, the use of gas-fired humidifiers is often limited to primary humidification. There is also the problem of available space required by gas-fired equipment.

Electric-type. At least two major types of electric humidifiers are available on the market: electrode-type and heating-element type. Steam is generated in the wall-, floor-, or ceiling-mounted humidifier and delivered into the supply air stream via a dispersion assembly.

The disadvantages of the electric-type humidifiers include:

- Additional space needs.
- The cost of equipment.
- Wiring and controls.
- Additional costs of the make-up water piping and drainage piping.

Water impurities adversely impact the operation of both types of electric humidifiers. For the electrode-type humidi-

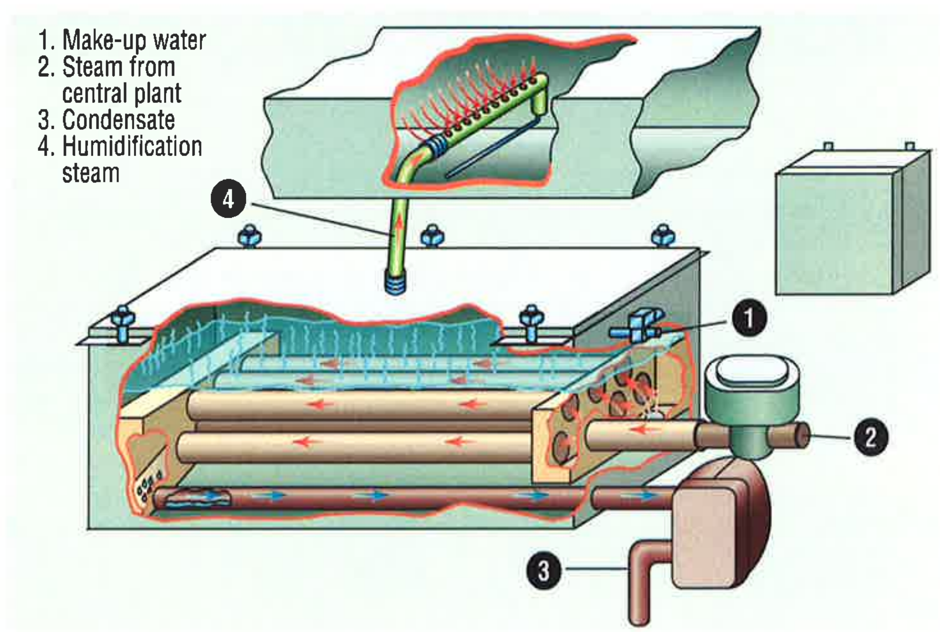

FIGURE 2. Steam-to-steam convertor.

fier, use of water with a high mineral content will result in frequent cleaning or replacement of canisters; water with a low mineral content will likely cause an electrode humidifier to malfunction, as the electrodes rely on water conductivity (via dissolved minerals) to operate.

For heating element-type devices—because the current doesn't pass through water—purified water may be used to improve performance and greatly reduce maintenance.

Finally, because electric humidification system must be on emergency power (Figure 1), additional costs of emergency power generators and related switchgear present a disadvantage.

As a result, electric-type humidifiers are used mostly in the existing facilities where only a few units are needed and where the emergency power system has sufficient capacity.

Steam-to-steam. As shown in Figure 2, the steam in steam-to-steam converters arrives from the central boiler plant and is delivered to the wall-, floor- or ceiling-space-mounted converter, where it passes through a heat exchanger, causing make-up water to boil and generate secondary steam (Figure 3). The vapor hose or piping to the duct then conveys this humidification steam, where it is dispersed into the air stream. Since water is boiled in the converter, the quality of make-up water is important. When using unsoftened, potable water, impurities can deposit as scale, so cleaning is required. But the use of softened water along with regular surface skimming greatly reduces scale buildup. Scale deposited on the heating coil reduces the efficiency of the humidifier. Response to the control input is slower than it is in the direct-injection system because it may be impacted by the time needed to boil water. To reduce concen-

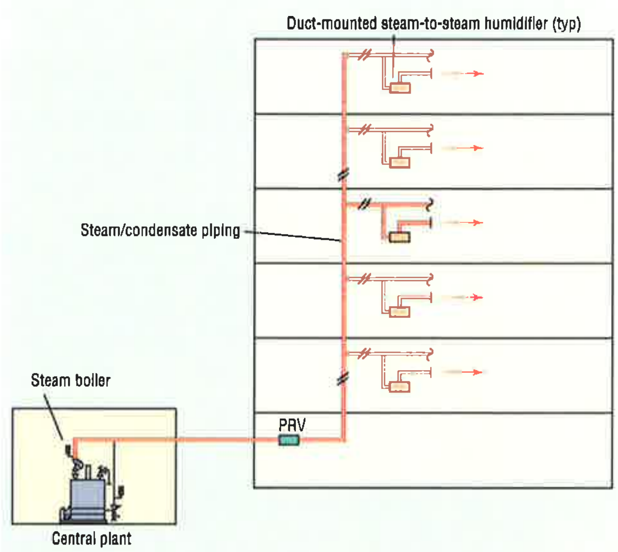

FIGURE 3. Steam-to-steam convertor system

tration of solids left behind, automatic flush valves are used to lower mineral buildup. Some units skim a bit of surface water with each fill by overfilling to a surface-level drain, thus removing precipitated minerals and significantly reducing cleaning requirements. Use of the softened or de-ionized water is recommended to minimize this problem.

The disadvantages of the steam-to-steam converters include:

- Additional space needs.
- High cost of equipment.
- Wiring and controls.
- Additional costs of the make-up water piping and drainage piping.
- Water treatment equipment in addition to steam and condensate piping.

If there is on-site steam, the advantages are:

- On-site steam.
- Minimal energy costs.
- Humidification vapor that is as pure as the makeup water if using an evaporative steam-to-steam system.

Direct-injection type humidifiers (Figure 4) offer the lowest initial and operating costs, and the most efficient and best level of controls with precise control of output. These types of humidifiers may be used to disperse "clean" steam, as well as the steam from the central boiler plant.

"Clean" steam system with direct injection type humidifiers (Figure 5)

Clean steam is generated in a dedicated gas-fired boiler, steam-to-steam converter, or electric steam generator. The disadvantages of the clean-steam system include the need for stainless steel steam and condensate system components, and the make-up water must be treated in the reverse osmosis or de-ionization equipment.

Central plant steam system with direct injection type humidifiers. This type of system (Figure 6) has the lowest initial cost, the lowest operational cost, and is the best controlled. This system, however, has a major drawback—boiler steam carries chemicals used for corrosion control within the steam and condensate systems. Volatile neutralizing amines easily pass through the humidifiers. The non-condensed amine passes through together with steam to the distribution tube. The condensed amines dissolved in the condensate exit via the steam trap.

Steam may be generated in the gas-fired boiler, steam-to-steam generator, or electrical boiler. Due to the nature of the steam-production process, corrosion control is imperative regardless of the type of the steam-producing equipment.

WHY DOES CORROSION OCCUR?

There are three reasons for corrosion in the steam and condensate piping:

- The primary source of corrosion is carbon dioxide (CO_2). When CO_2 dis-

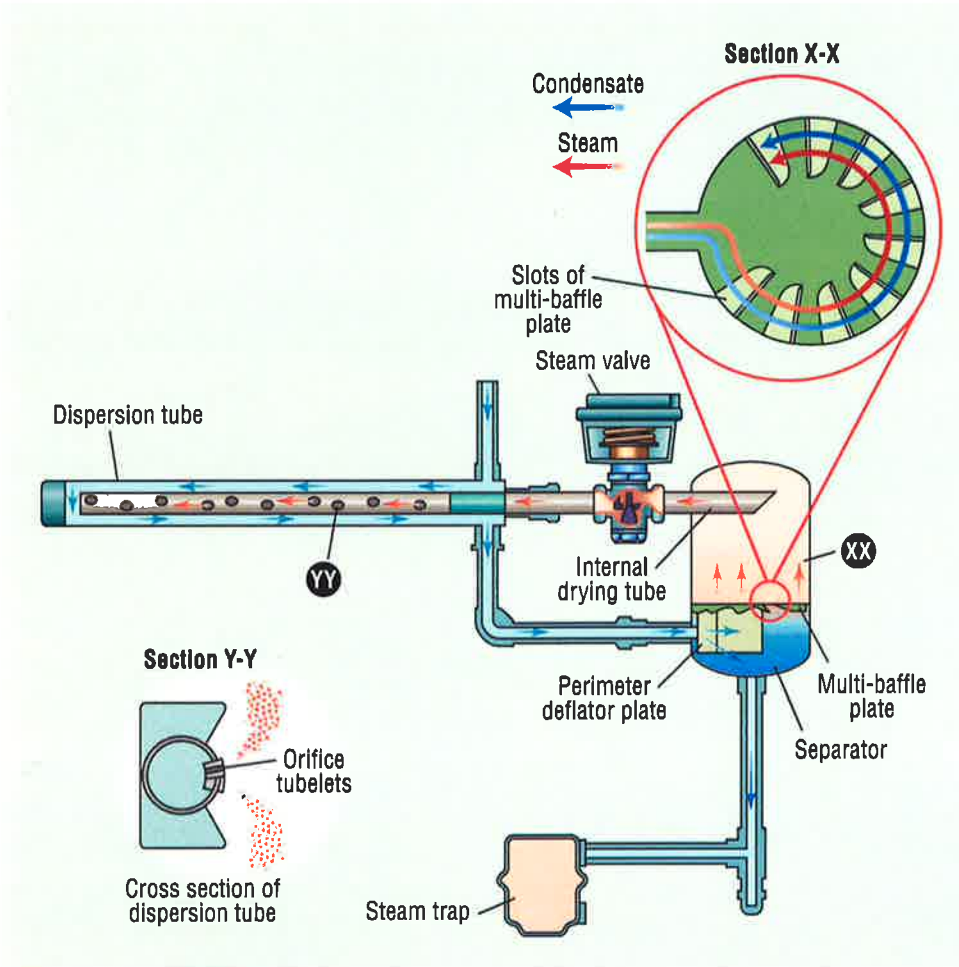

FIGURE 4. Direct-injection steam humidifier.

solves in water, it forms carbonic acid (H_2CO_3). The main source of CO_2 is the thermal breakdown within the boiler of the carbonate and bicarbonate present in the feed water. Also, some CO_2 is dissolved in the boiler feed water.

• The second source of corrosion is caused by oxygen present in the condensate. This type of corrosion might be controlled by the use of deaerator and oxygen scavenger chemicals.

• The third source of corrosion is ammonia in the condensate.

CORROSION INHIBITION CHEMICALS AND TECHNIQUES

Corrosion inhibitors, by design, have to be volatile to be carried throughout the steam and condensate systems to protect them from corrosion while all other chemicals stay in the boiler. Together with steam, these chemicals are then released by the humidifiers into the ambient air.

A group of chemicals called amines has been in common use as corrosion inhibitors since the 1940s. Amines are ammonia derivatives.

There were several cases where IAQ problems were attributed to these chemicals in the steam used for humidification.

There are two types of amines:

Neutralizing: includes cyclohexylamine (CHA), diethylaminoethanol (DEAE), and morpholine (M).

Filming: includes octadecylamine (O).

To provide corrosion protection throughout the condensate system, blends of neutralizing amines with different vapor/liquid distribution ratios are used.

Amines are fed into the feed water or the steam header. In large complex systems, satellite feed of neutralizing amines may be required.

The filming amine, Octadecylamine, provides defense against both carbonic acid and oxygen corrosion by creating a continuous film barrier on the metal surfaces.

OSHA REQUIREMENTS

The Occupational Safety and Health Administration's (OSHA) Hazard Communications Standard (HCS 29 CFR 1910.1200) states that employees have both a need and a right to know the hazards and identities of the chemicals they are exposed to in the work place.[1] Under HCS, if a "Subpart-Z" chemical exists in the workplace, the employee must be warned of the exposure, regardless of the level of the concentration and the degree of compliance with "safe" exposure limits.[2]

HCS 29 CFR, subpart Z, includes only two out of four common corrosion-inhibitor chemicals. They are DEAE and morpholine. Both are subject to the HCS rules and regulations. CHA and octadecylamine are not listed.[3]

To read clarification letters by OSHA Directorate of Compliance Programs Director Patricia K. Clark, regarding chemicals used in humidification system, visit www.osha.gov and search under "humidification system".

These letters clarify that HCS does not apply to the general public and employees who may be incidentally exposed to the chemicals in trace amounts from the humidification system. However, the requirements do apply to employers of personnel such as maintenance workers, building engineers, or any other employees who would be exposed or potentially exposed by handling or storing the anticorrosion chemicals, or adding them to the humidification system.[4,5]

The following amines are the only amines approved by the FDA (Code of Federal Regulations, 21 CFR 173.310) for use in boilers in which steam comes in direct contact with food (except milk and milk products) with maximum level of amine permitted as follows:	
CHA (cyclohexylamine)	10 ppm
DEAE (diethylaminoethanol)	15 ppm
Morpholine	10 ppm
Octadecylamine	3 ppm
Permissible exposure limits (PELs)	
Based on an 8-hour day and 40-hour week, OSHA, the American Conference of Governmental and Industrial Hygienists (ACGIH) and FDA have established PELs as follows:	
CHA (cyclohexylamine)	10 ppm
DEAE (diethylaminoethanol)	15 ppm
Morpholine	10 ppm
Odor complaints	
The odor thresholds for the amines are substantially lower, by an order of magnitude, than their OSHA PELs:	
CHA (cyclohexylamine)	.90 ppm
DEAE (diethylaminoethanol)	.04 ppm
Morpholine	.14 ppm
As a result, the odor of amines may be noticed and odor complaints may be triggered well before any regulatory limit is reached. It was determined that the concentration of amines that is typically maintained to provide system corrosion protection is yet another order of magnitude lower than the odor threshold. Hence, if any odor is detected there is substantially more amine in the system than is needed, in other words, the system is overfed.	

TABLE 1. Allowable boiler water additives and exposure limits defined by the Food and Drug Administration, the Occupational Safety and Health Administration, and the American Conference of Government and Industrial Hygienist.[9]

MONITORING AND MEASUREMENTS

There are no known methods of directly measuring concentration of amines in the air; hence, it is derived from the concentration of amines in the condensate and related amount of supply air.

A steam/condensate system must be continuously monitored via multiple condensate coolers for corrosion problems, leaks, as well as the amine concentration. Sample points should be installed throughout the system, including at problem areas, such as flash tanks, condensate receivers, and heat exchangers. Condensate samples should be tested for pH, conductivity, corrosion products, dissolved CO_2, and oxygen. In addition, hardness, silica, and organics should be monitored and evaluated.

Corrosion coupons may be used to monitor the level of corrosion in the condensate system.

Where steam/condensate systems are extensive, attempts to maintain proper concentration for corrosion inhibition in the remote piping may lead to system overfeed. Also, there is potential for human error that may lead to higher concentrations of chemicals in the supply air.

TESTING

In response to growing IAQ concerns, a leading humidifier manufacturer partnered with a chemical treatment service provider to test a humidification system that utilized direct injection steam humidifiers using amine-treated steam to determine concentration of the volatile amines. The study confirmed that amine concentration was well below the FDA/OSHA limits.[6,7]

Several studies and tests were undertaken to determine amine concentrations in the air. The studies[8,9] reported ambient air amine concentration, which were orders of magnitude less than regulatory limitations. It was confirmed that low ambient air amine concentration levels can be guaranteed with careful maintenance and monitoring, including metered introduction of the treatment chemicals into the steam system.

Practical considerations to achieve low ambient air amine concentration levels include[10]:

• Continuous feeding of chemicals via metered feed pumps.

• Not permitting slug feeding.

• Daily checking and adjustment of the feed rates.

•Providing coupons and/or sample ports to enable frequent checking.

RECOMMENDATIONS

The consulting engineer should present all humidification options to the owner's representative and evaluate advantages and disadvantages for each option.

Use of corrosion inhibitors should be discussed, including requirements for proper maintenance and cost of chemicals.

If the use of chemicals is acceptable to the owner, then recommend the use of a direct injection system in conjunction with a good maintenance program.

If use of chemicals in the humidification steam is deemed unacceptable, then consider other humidification systems, such as a steam-to-steam evaporative humidifier using on-site boiler steam, a gas-fired evaporative humidifier, a steam-fired "clean-steam" generator, or an electric-element humidifier. Other relevant issues such as ability to vent gas, provide combustion air, on-line performance requirements, and equipment and energy costs will weigh into choosing a humidifier.

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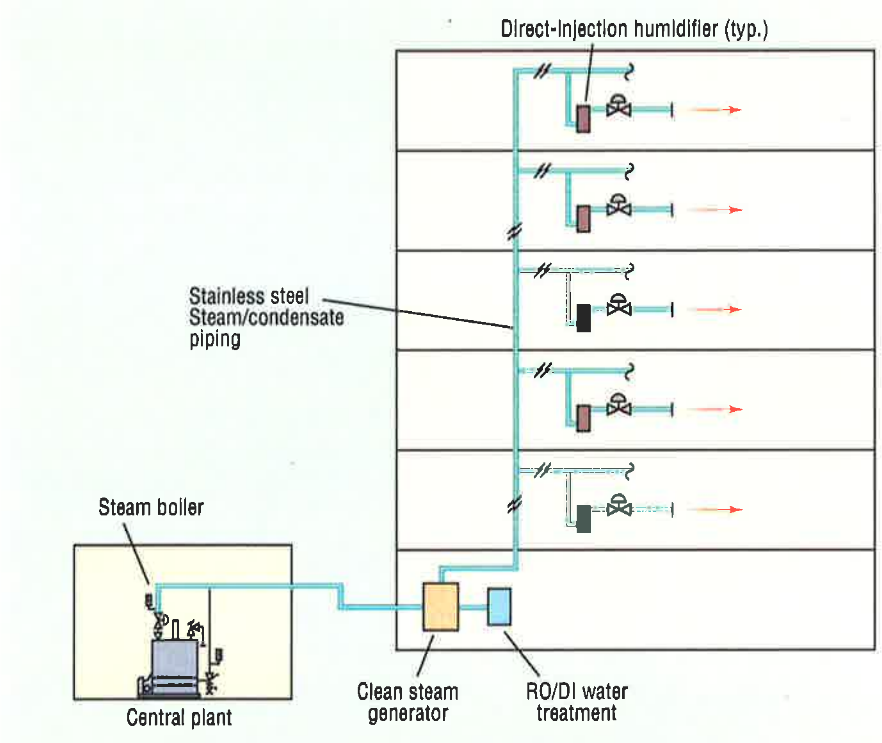

FIGURE 5. "Clean" steam system with direct-injection type humidifiers.

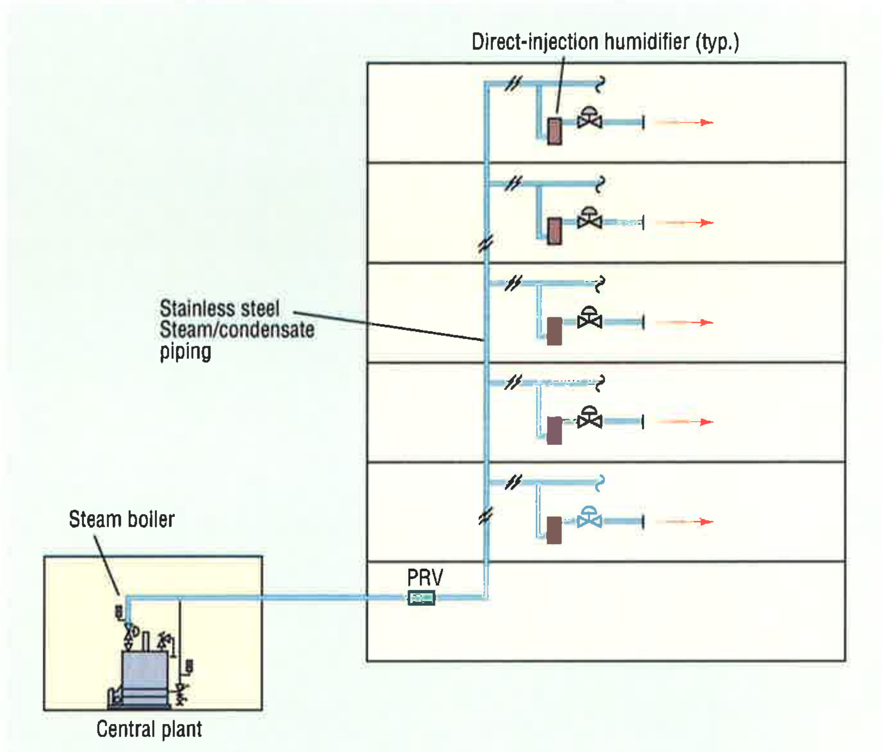

FIGURE 6. Central plant steam system with direct-injection type humidifiers.