## 6.5 CONTAINMENT AIR RECIRCULATION AND COOLING SYSTEM

### 6.5.1 DESIGN BASIS

The function of the Containment Air Recirculation and Cooling System is to remove heat from the containment atmosphere during normal plant operation. In the event of the occurrence of a LOCA, the system functions to limit the containment pressure rise to a level below the design value. In such an instance, the system also functions to reduce the leakage of airborne and gaseous radioactivity by providing a means of cooling the containment atmosphere.

The containment air recirculation and cooling system is independent of the SI and Containment Spray Systems. It is sized such that, following a LOCA, three of the four cooling units will limit the containment pressure to less than the containment design pressure even if the Containment Spray System does not operate.

The original sizing of the containment air coolers for design and procurement was based on the heat removal capability, using three coolers, ($240x10^6$ Btu/hr) required to maintain the post-LOCA containment atmospheric pressure within the containment design pressure. Likewise, the original sizing of the containment spray system for design and procurement was based on the heat removal capability ($240x10^6$ Btu/hr) required to maintain the LOCA containment atmospheric pressure within the containment design pressure. The analysis of these systems operating together post-LOCA in accordance with the Technical Specification requirements is presented in Chapter 14.

All system components are designed to withstand Seismic Category I loadings.

### 6.5.2 SYSTEM DESCRIPTION

The containment air recirculation and cooling system (Figure 9-20A) includes four two speed cooling units located entirely within the containment. Service water is circulated through the air cooling coils.

Each coil house is equipped with 12 individual coils piped to supply and return manifolds which connect to the SRW System.

The SRW supply line for each cooler has an air-operated valve which is normally open and de-energized. Each of these valves is designed such that it would fail in the open position. A redundant line to the coolers is normally valved off by a local, manually-operated valve.

The SRW return line for each cooler has two air-operated stop valves and one local, manually-operated valve, all in parallel. The air-operated control valves can be operated from the Control Room. One control valve is used for normal cooling requirements and the other control valve opens automatically upon receipt of SIAS. The third, parallel, local, manually-operated valve is provided to permit passage of sufficient SRW in case the full flow SIAS-actuated valve should malfunction.

Air is drawn through the coils by a vane-axial fan driven by a direct coupled two-speed motor. Normal containment recirculation requirements are satisfied at high speed operation, whereas, after a LOCA, the low speed setting is used. All fan motors may be manually started or stopped from the Control Room. Upon occurrence of LOCA, all four fan motors start automatically upon receipt of SIAS.

Upon evacuation of the Control Room due to fire, control of all fan motors may be transferred to local control stations in the electrical penetration rooms. Upon selection of local operation, the ESF signals (SIAS and under-voltage) are overridden.

Performance data for the cooling units is given in Section 6.5.3. The materials of construction are listed in Table 6-8. The equipment is designed to withstand Seismic Category I accelerations and to operate in the LOCA environment.

Service water flow is shown in Figures 9-9 (Unit 1) and 9-27 (Unit 2).

### 6.5.3 SYSTEM OPERATION

a. Normal Operation

The number of operating coolers is temperature dependant. Three cooling units are normally in operation during the warmer months and two cooling units are normally in operation during the cooler months. Each unit is sized to remove in excess of one-third of the total normal cooling load. The maximum average temperature inside the Containment is limited to 120°F by operation of the three cooling units. The maximum expected SRW inlet temperature to the coolers is 95°F. During normal operation, the full-size SRW outlet valves, which are used following a LOCA, may be closed, while the smaller (4" diameter) valves are open. Occasionally, during extended periods of high outside temperature, all four coolers are used to limit the average containment temperature to 120°F. Service water flow to the containment air coolers may be supplemented by using the 8” full size SRW outlet valves.

<u>Performance Data for Normal Operation</u>

| | |
|---|---|
| Total heat removal capacity | $2.27x10^6$ Btu/hr[a] |
| Motor horsepower | 125 hp high speed (normal) |
| Air flow, each | 110,000 cfm[a] |
| Fan horsepower, each | 100 bhp |
| Fan speed | 1,200 rpm |
| Cooling water flow, each | 550 gpm[a] |
| Air temperature, inlet/outlet | 120/99°F[a] |
| Water temperature, inlet/outlet | 95/102.8°F[a] |
| Fan static pressure | 3.2" $H_20$ |
| Fan total pressure | 4.2" $H_20$ |

[a] Cooler heat removal capacity is a function of SRW flow and temperature, fouling, air flow, and containment temperature and pressure.

b. Plant shutdown operation

During plant shutdown, i.e., Modes 4, 5, 6 and defueled, the cooling units operate as necessary, based on availability and containment conditions. The availability of the cooling units is directed by administrative controls.

c. Emergency Operation

Upon receipt of a SIAS, any idle cooling unit is automatically started on the low speed setting and, simultaneously, any running fan is switched from their normally operating high speed setting to low speed operation. The full flow (8" diameter) SRW outlet valves for each cooler are opened upon receipt of a SIAS. The SRW inlet valves move to a throttled position upon receipt of a SIAS, and return to the full open position upon receipt of a RAS.

With off-site power available under this mode of operation, the operating cooling unit fans are switched to low speed and the idle fan(s) are started on low speed as described above. If off-site power is not available, the associated emergency diesel generators are started. Each emergency diesel generator supplies power to an independent safety-related bus. Each bus carries the load of two cooling units.

The evaluation of post-incident containment pressure/temperature response is provided in Section 14.20. These evaluations consider the actual heat removal capacity of the containment air coolers which is a function of SRW flow and temperature, fouling, air flow, and containment pressure and temperature.

With respect to long-term cooling after a LOCA, the cooling units are designed to operate for at least one year under air-steam mixture conditions of 5 psig and 160°F.

Performance Data for Emergency Post-LOCA Conditions

| | |
|---|---|
| Motor horsepower | 63 hp (low speed) |
| Fan horsepower (max.), each | 33 bhp |
| Fan speed | 600 rpm |
| Mixture temperature, inlet/outlet | 275/270°F[a] |
| Water temperature, inlet/outlet | 105/204°F[a] |
| Cooler, capacity at 273°F and 47 psig, each | $90.45x10^6$ Btu/hr[a] |
| Cooler mixture flow, each | 55,000 cfm[a] |
| Maximum fin side pressure drop | 0.5" $H_20$ |
| Maximum tube side pressure drop | 15.6 psi |
| Fan static pressure | 1.2" $H_20$ |
| Fan total pressure | 1.445 in $H_20$ |
| Water flow, each | 1,900 gpm[a] |

[a] Cooler heat duty will vary with flow, temperature, and humidity.

### 6.5.4 DESIGN EVALUATION

a. The coil capacity is based upon 95°F SRW inlet during normal operations and 105°F SRW inlet during LOCA. These values represent the maximum expected temperatures. The water velocity through the coils is 7.4 fps at 1,900 gpm flow.

b. Total effective face area in each cooler is 144 $ft^2$. With a normal operating air flow of 110,000 cfm, the velocity entering the coils is 765 fpm. With the emergency mixture flow of 55,000 cfm, the entering velocity is 382 fpm.

c. The fin spacing is 6 fins per inch of coiled length. With this pitch, water clogging of the coil fins is avoided.

d. A fouling factor of 0.0005 for the water side is included in the coil ratings. The water side of the cooling coil tubes is equipped with removable plugs on the return bends of the coils to permit cleaning in the field.

e. The cooler housing is designed to ensure no loss of function when subjected to a pressure differential of 2 psi.

f. Components are designed to be compatible for operation in an environment of borated water spray. The three- to four-hour short-time temperature exposure rating during a LOCA is about 280°F. The three- to four-hour short time humidity exposure rating is 100% relative humidity in a slightly acid atmosphere. Additionally, components which are considered susceptible to radiation damage, such as the gasket and motor, are designed to withstand a dose of $10^8$ rad of gamma radiation. It has been calculated that these components will receive a dose of less than $5x10^7$ rad during the year following a LOCA.

g. With respect to normal containment recirculation and cooling, the cooler assemblies are designed for a life of 40 years.

h. The condensate leaving the coils is conveyed over individual stainless steel drip pans to the sides of the coils out of the mixture flow stream. These pans cascade the liquid into the main sump of the housing from which it is drained via the Containment sump to one of the Auxiliary Building sumps, from which it is pumped to the Waste Processing System.

### 6.5.5 AVAILABILITY AND RELIABILITY

a. The cooling units are located outside the secondary shield. In this location they are protected from being flooded at post-accident conditions and they also are protected against credible missiles.

b. The original design heat removal capability of three of the four cooling units was to provide the same heat removal capability as the containment spray system. The analysis of these systems operating together post-LOCA in accordance with the Technical Specification requirements is presented in Section 14.20. The single failure characteristics for the cooling units are listed in Table 6-9.

c. Each fan discharge duct is provided with a fusible link door. These doors open at an abnormally high containment temperature such as would occur under a LOCA. This assures the free flow of the cooled air-stream mixture to the containment environment even if the ducts collapse during or following the LOCA.

d. The cooling units are designed to operate for the life of the plant. There are no belts or flexible couplings; the motor is directly connected to the fan wheel.

e. Upon loss of off-site power during a LOCA, the containment cooling fans are automatically sequenced onto the emergency diesel generator buses.

f. All associated system equipment, such as piping, valves, and instrumentation are also located outside of the secondary shielding to minimize the possibility of missile damage.

### 6.5.6 TESTS AND INSPECTIONS

a. The manufacturer has developed a computer program to size cooling coil units for saturated steam-air mixtures. This program was used to size the Calvert Cliffs cooling units. Tests performed on the coils manufactured for Palisades, Fort Calhoun, Three Mile Island No. 1, Kewaunee, and Oconee have confirmed the validity of the program.

   These tests were conducted with coils of material and configuration identical, except for shorter length, to those used in each specified large-scale containment system. Three of the coil tests were made with the air flow horizontal and the condensate drainage perpendicular to the air flow. Water-logging problems did not arise. The coil section drainage characteristics were identical to those which were predicted for the full-size units, and therefore provide assurance that the full-size coils will adequately drain condensate from the coil surfaces.

   The coil was tested at a pressure loading equal to a free velocity pressure of 500 fps to demonstrate the structural integrity of the coil. This loading test was performed to simulate a pressure wave which may occur during the initial phase of containment pressure buildup in the event of a LOCA. Upon examination, the coil showed only very minor deformation of some intermediate stiffeners; hence, the structural design of the coil was proven to be adequate.

b. A fan and motor have been tested to prove their ability to operate satisfactorily under conditions existing within the containment after a LOCA.

   Fans and motors also were tested by the fan manufacturer to assure the same characteristic performance curve for all fans.

c. Cooling unit performance can be tested with thermometers, manometers and a Pitot tube in the field at any time the containment is accessible.

d. The valves in the normal cooling water outlet lines (4") will be open during normal operation and the valves in the parallel emergency outlet lines (8") can be opened from the Control Room and the flow rate can be monitored at any time.

e. All equipment and associated components are arranged so that they can be inspected at any time the containment is accessible.

f. The containment air cooler blowdown door fusible links will be replaced every refueling outage to ensure that the links perform their design function.

## TABLE 6-8

## COOLING UNIT MATERIALS OF CONSTRUCTION

| | |
|---|---|
| Tubes (seamless) | 90/10 copper-nickel, ASTM B111-69, Alloy 706 |
| Fins | ASTM B152 |
| Headers | ASTM B466 |
| Coil Frame | ASTM A525 |
| Structure | ASTM A501, A36, and M1020 |
| Motor | NEMA Class B, TEAO |

## TABLE 6-9

## SINGLE FAILURE CHARACTERISTICS FOR COOLING UNITS

| | COMPONENT | MALFUNCTION | COMMENTS AND CONSEQUENCES |
|---|---|---|---|
| 1. | Unit Circulating Fan | Fails to operate | Three (or four) coolers and fans are normally operating. Fans may be tested for emergency mode of operation at any time. |
| 2. | Cooler | Failure to tubes | Tube failure is considered unlikely during emergency operation since the tube water to air side $\Delta P$ is less than during normal service. If failure does occur, SRW will be spilled into the cooler since SRW pressure is above containment pressure. Tube leakage can be detected by indication of increased SRW flow to the cooler, decreased SRW head tank level, and the failed cooler can be isolated. Note: Passive failures are only considered post-RAS.<br><br>In the event of tube failure associated with any one cooler after the LOCA, it is assumed, as an upper limit, that one subsystem of Service Water leaks into containment. The leak volume from one subsystem is approximately 16,000 gallons. Boron dilution, therefore, would be negligible, because the total volume of borated water in the containment structure is in excess of 400,000 gallons. |
| 3. | SRW Emergency Outlet Valve | Fails to open | For those coolers in operation, the valve in the normal cooling water outlet line will be open. The normal operation valve will be open. If the emergency valve fails to open, the unit will operate at reduced heat removal capability. The Containment Spray System will supplement the heat removal capability of the cooling units. |
| 4. | SRW Inlet Valve | Inadvertently left throttled | Valve status will be apparent from reduced flow, and the valve may be opened by operator action. If the valve fails to respond, the Containment Spray System will supplement the cooling requirements. Each cooler is provided with flow indication on the main control board. |
| | | Fails to throttle | Does not adversely affect containment heat removal. May result in emergency diesel generator service water inlet temperatures in excess of 105°F under certain conditions with elevated bay water temperatures. Containment spray system remains available to supplement heat removal capability of the cooling units. |

## TABLE 6-9

## SINGLE FAILURE CHARACTERISTICS FOR COOLING UNITS

| COMPONENT | MALFUNCTION | COMMENTS AND CONSEQUENCES |
|---|---|---|
| | Inadvertently closed | Valve status will be apparent from lack of flow and position indication, and the valve may be opened by operator action. If the valve fails to respond, the Containment Spray System will supplement the cooling requirements. Each cooler is provided with flow indication in the Control Room.<br><br>Note: Mechanical stops are installed on valves to limit stroke. The stops should prevent inadvertent full closure. |