Technical Requirements for Thermal Management Systems
In Network Equipment Environments

This practice provides guidelines and requirements for cooling network equipment space.

**Audience:**
All network (including Telco, Video, Technical Space Organization, Mobility, AT&T Corp., etc.) Infrastructure Design Managers

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**Related Documents:**
- **ATT-TELCO-812-000-155**, Network Equipment Space/DC Building Infrastructure Design Requirements
- **ATT 812-000-003**, Standards for Network Equipment Environments
- **ATT-TP-76300**, AT&T Installation Guidelines
- **ATT-TP-76400**, AT&T Design Guidelines
- **CRE-23-00-00-ATP-001** - Guidelines for Design and Selection of Heating, Ventilation and Air Conditioning Equipment
- **CRE-50-09-01-IOP-001**, CRE Alarm Management Strategy
- **NFPA 70**, National Electrical Code
Cancelled Documents: This document supersedes and replaces the following:

**ATT-TP-76405**
Technical Requirements for Supplemental Cooling Systems In Network Equipment Environments

**BSP 800-003-101MP**
Thermal Management Requirements
High Heat Equipment In The Central Office

Issuing Departments: NP&E, U.S. Common Systems, Corporate Real Estate Design & Construction

Business Unit: AT&T Services, Inc.

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1 INTRODUCTION

1.1 Scope

1.1.1 This standard shall apply to thermal management in all AT&T network equipment spaces managed by NP&E (e.g. Central Offices, Mobility Tower Switching Offices, SHO/VHOs, Network Technology Centers, Regional Technology Centers, etc.) and all AT&T network affiliates (e.g., Independent Local Exchange Carriers, Mobility, AT&T Corporation, Internet Services, Mobility Services, Technical Space Organization, etc.).

1.2 Purpose

This standard provides NP&E’s requirements for the cooling of network equipment environments. These integrated guidelines shall be followed to reduce risks of network equipment failure and improve efficiencies, cost, and space utilization in these spaces.

1.3 General

1.3.1 This standard supersedes and consolidates previous cooling standards BSP 800-003-101MP and Supplemental Cooling ATT-TP-76405 into a single comprehensive standard.

1.3.2 This standard update introduces a significant change in the direction of cooling requirements. Previous standard releases based cooling requirements primarily on a 100 Watts per sq. ft. maximum heat signature. Higher heat loads were primarily handled by the spacing of equipment over a larger area (Thermal Management Space (TMS)). Equipment heat loads have continued to rise substantially making the use of TMS impractical in many situations with spacing required to meet high heat loads has growing to the point that floor space utilization and cooling system functionality have been significantly impacted. While the use of TMS may still be a viable and cost effective solution in some cases, this standard introduces additional cooling options in support of higher heat equipment. This fundamental change requires careful consideration and coordination between CRE PD&C and U.S. Common Systems to determine the most cost effective, efficient and timely cooling solution.

1.3.3 AT&T standards are in support of and in compliance with local, state and federal standards as they apply to network equipment facilities.

1.3.4 While AT&T may choose to adopt ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) standards in whole or in part, all references shall be to AT&T standards for specific use within the AT&T network.
1.4 Organizations Responsibilities

1.4.1 Groups within AT&T that have integrated responsibilities for thermal management within network equipment space include but are not limited to:

- AT&T Labs
- Global Network Planning
- Strategic Infrastructure Planning (SIP)
- Corporate Real Estate Design & Construction (CRE PD&C)
- Corporate Real Estate Property Management (CRE PM)
- U.S. Common Systems (U.S. CS) - Also Support for Most of World
- Equipment Engineers (EI)
- Global Engineering Support (GES)

1.4.2 No single work group can effectively provide for a continuity of service for thermal management issues. The process requires an integrated team, each with specific responsibilities, clear input and output channels, consistent information and common documentation.

1.4.3 Groups outside AT&T, but supporting AT&T work groups (e.g., Architectural and Engineering firms, OTV's, etc.) shall also be responsible for integrated planning and deployment of thermal management systems in support of network equipment.

1.4.4 U.S. Common Systems and CRE PD&C shall utilize the applicable Table 3 – Deployment Flow Chart and Table 4 - Cooling System Advisory Matrix as a definitive guide to determine the appropriate primary cooling technology(ies) required to support new equipment deployments.

1.4.5 All work groups impacting thermal management, cooling system designs and deployment shall adhere to deployment requirements specified on Product Approval Notices (PAN’s) or Product Environmental Reviews (PER’s) for thermal management considerations.

1.5 Coordination Between CRE PD&C and Network

1.5.1 Following a request from U.S. Common Systems engineers for deployment of network equipment, CRE PD&C Project Manager shall coordinate space cooling requirements to accommodate the equipment floor plan and heat loads.

1.5.2 CRE PD&C cooling design shall take into account guidelines communicated by this standard as well as pertinent input from the affected work groups (e.g., U.S. Common Systems, Engineering & Installation engineer (EI), Strategic Infrastructure Planning (SIP), etc.).

1.5.3 CRE PD&C shall document and provide architectural drawings in electronic CAD format to U.S. Common systems as the reference for creation of formal equipment floor plans.
1.5.4 U.S. Common Systems shall lay out the formal equipment floor plan(s) utilizing standard CAD blocks representing cooling elements based on specification(s) provided by CRE PD&C.

1.5.5 U.S. Common Systems shall show specific reserved space for cooling elements and thermal management space if any, on the floor plans. Changes to these reserved spaces shall be communicated, documented and actively coordinated with CRE PD&C.

1.5.6 U.S. Common Systems shall identify on floor plans the thermal signature of each equipment cabinet and any other heat generating equipment such as UPS’s, PDU’s etc.

1.5.7 The installation of cooling elements shall be accomplished by a contractor hired by CRE PD&C.

Exception: For DC powered cooling elements, power cabling and fuse assignment from BDFB shall require coordination with CRE PD&C and U.S. Common Systems. CRE PD&C shall be responsible for the start-up and commissioning of the cooling system.

1.5.8 U.S Common Systems shall reserve space for cooling system elements (e.g., Distributed Refrigerant Cooling (DRC), etc.) within the equipment space at the time that network equipment lineups are documented on the site floor plan.

1.5.9 When network equipment lineups are installed, space for cooling system elements (e.g., DRC, etc) shall be reviewed, confirmed and updated on the site floor plan(s) as necessary by COLD. CRE PD&C shall provide U.S. Common Systems with “As-built” drawings to reflect updated alignments.

1.5.10 Space reserved for cooling system components that are integrated into equipment line-ups (e.g., In-Row Coolers, Back of Cabinet (BoC), etc) shall be confirmed with CRE PD&C, U.S. Common Systems and EI/Operating Territory Vendor (OTV). The EI/OTV has the responsibility to assure that the assigned space (by COLD) is available for cooling system (e.g. in-row cooler) elements or to communicate with COLD if there were changes required due to site conditions.

1.5.11 Due to potential space conflicts, CRE PD&C and OTV contractors shall closely coordinate the lay-out of building and network infrastructure (e.g., hard copper pipe runs, flexible hoses, electrical conduits, auxiliary framing, cable racks and cables). CRE PD&C and OTV should use tools such as CAD layers, elevation views or Building Information Models (BIM) models to facilitate this coordination effort. One goal of the coordination is to minimize conflict in the overhead or under floor space.

1.5.12 CRE PD&C’s consultant shall show future remote cooling units (e.g., XDH, XDR, etc.) in plans for the initial permit submission (designated as future) to minimize future permit filing requirements for each new remote unit installation.
1.5.13 CRE PD&C’s contractor shall, for the initial deployment project, be required to install only cooling elements to meet either the minimum operational or capital efficiency threshold or the three year forecast (if defined and available) as commonly agreed to by SIP, CRE PD&C and U.S. Common Systems.

1.5.14 When DRC is deployed, refrigerant piping and ports shall be planned and installed for all projected cooling unit deployments as part of the initial installation. This minimizes the disruption to working service required by shutting down the system to add ports in the future.

1.5.15 When adding equipment cabinets the responsible network engineer/planners shall provide a forecast in advance of the required equipment in-service date. Forecasts shall include specific information regarding the floor space, power and heat load requirements of the equipment to be deployed. The official forecast interface is Central Office Equipment Forecast (COEF).

1.5.16 U.S. Common Systems shall use this forecast information to determine if the request can be accommodated. If U.S. Common Systems concurs with the request, then U.S. Common Systems shall update the floor plan to reflect the new equipment cabinet line-up and associated heat loads. This information shall then be made accessible to CRE (see Figure 1 - Space Design Collaboration Process).

1.5.17 All work performed overhead of equipment space shall be in compliance with ATT-TP-76300 requirements with all necessary precautions taken to avoid service outage when working over live equipment.

1.6 Site – Space Assessments

1.6.1 U.S. Common Systems and CRE PD&C shall utilize the following site evaluation process to facilitate communication/coordination between U.S. Common Systems and CRE PD&C to determine the most appropriate floor space design and/or equipment placement in Network Equipment Space.
1.6.2 Space Evaluation Process

Steps:
1. U.S. Common Systems shall review Space Assignment requests and Forecasts (SAF), Technology Planning Repository (TPR), COEF, FESPA

2. U.S. Common Systems shall evaluate new heat load requirements

3. U.S. Common Systems shall utilize Standard Drawings on Woodduck documents as a foundation for equipment floor plan configurations and equipment spacing
   a. U.S. Common Systems may consider that there is sufficient cooling system capacity to support an average of 850 Watts per cabinet/frame within network equipment space (where not more than 50% of the active equipment space (frame/rack/cabinet and ½ of the front and rear aisles) is occupied by heat generating equipment).
   b. If equipment is not considered high heat producing (<850 Watts per cabinet/frame)
      - U.S. Common Systems Planners will assign/plan normally
   c. Where the cooling system level is unknown or unclear
      - U.S. Common Systems shall verify the cooling level with the CRE PD&C Project Manager.
      - U.S. Common Systems and CRE PD&C shall negotiate handoffs and information delivery timelines

Figure 1 - Space Design Collaboration Process
4. U.S. Common Systems and CRE PD&C determine floor space requirements
   a. COLD shall contact the local CRE PD&C representative to advise them of the need for cooling of the affected space.
   b. Where possible and cost effective, CRE PD&C shall utilize existing cooling systems for all or part of the cooling solution recommendation. Some locations may have sufficient existing cooling (without major modification) to provide sufficient cooling for the low end of the high heat equipment range.
   c. CRE PD&C project manager shall coordinate space cooling requirements to accommodate the equipment floor plan and heat signature evaluations.
   d. If CRE PD&C recommends spreading out the equipment footprint, U.S. Common Systems may plan/assign equipment space using thermal management guidelines and update the floor plans accordingly.

5. CRE PD&C shall evaluate the designated space to determine the most cost effective cooling solutions
   a. CRE PD&C and U.S. Common Systems shall utilize the Cooling Technology Matrix (Section 4.3.9 Table 2 & 3) as a definitive guide to determine the appropriate primary cooling technology(ies) required to support new equipment deployments.
   b. The adopted solution shall be based on the option that provides AT&T with the best life-cycle cost (e.g., use of sunk costs or existing cooling systems to optimize first costs). The life-cycle cost analysis shall include the cost of conditioning additional floor space (e.g., ~$250 per sq. ft.) required if the loads are distributed to reduce the average watts per sq. ft.
   c. CRE PD&C shall determine if new cooling equipment is needed or existing cooling equipment needs to be upgraded or modified.

6. CRE PD&C shall respond with a detailed scope of work and high level estimated costs to the Cost Causer or Originator of request/forecast
   a. If funding is not available to upgrade the cooling system
      i. Thermal Management Space shall be used where applicable.
      ii. If the use of Thermal Management Space is not feasible, a waiver request may be submitted by U.S. Common Systems to GES asking for deviation from thermal management standards and practices.
      iii. If the space will not support the requested equipment and a waiver request has been denied and no other space is available, then U.S. Common Systems shall advise network planning that no suitable space is available and another site should be selected.
   b. If funding is available to upgrade the cooling system
      i. U.S. Common Systems Planner shall layout the requested floor plan utilizing standard CAD models representing cooling elements. Where models do not exist, dimensions provided in
this standard may be used or specifications may be obtained from the CRE PD&C contact responsible for the cooling element.

ii. U.S. Common Systems Planner shall identify on floor plans specific reserved space for cooling units and thermal management space if any. Changes to these reserved spaces shall be communicated, documented and actively coordinated with CRE PD&C.

iii. CRE PD&C shall coordinate the final design criteria in compliance with this standard and input from the affected work groups (e.g., U.S. Common Systems, EI. SIP, etc). The final design of required cooling system is the responsibility of CRE PD&C with concurrence from each of the affected work groups.

1.6.3 For conditioning of new sites for network cooling the following guidelines shall be used:

- Slab vs Raised Floor
- Use of Existing Air Handlers, CRAH/C’s
- New Air Handlers, CRAH/C’s (low heat demand areas)
- Use of Distributed Refrigerant Cooling (DRC) for Extreme Heat Applications –
- Alternate – Supplementary

1.6.4 CRE PD&C shall provide an estimated time for site ready - including if applicable key dates if the site requires construction/revision activities.

1.6.5 CRE PD&C's evaluation shall consider the costs of annual operating expenses of the product installation compared to initial capital costs to condition/construct the space (e.g., NPV / Life Cycle evaluations, EDGE Guidelines).

1.6.6 CRE PD&C shall respond back with a scope of work and estimated costs to U.S. Common Systems/originator of the space conditioning request. CRE PD&C shall coordinate with the originator to establish a mutually agreeable delivery date.

1.6.7 The Network Planner shall make the final decision on a path forward for equipment space development in collaboration with U.S. Common Systems and CRE PD&C. CRE PD&C and/or U.S. Common Systems shall be responsible for communicating the required funding level to the planner responsible for requesting the equipment deployment.

1.6.8 Funding of modified, added or new cooling systems shall follow the AT&T Cost Causer model.
2 TEMPERATURE & HUMIDITY (LATENT AIR) MANAGEMENT

2.1 General

2.1.1 The operating temperature of network equipment has a direct relationship to network reliability and longevity. Equipment manufacturers are required to test equipment that will be placed in network equipment space to Telcordia GR-63-CORE, Issue 3, NEBS Requirements: Physical Protection standards. These standards set upper and lower extreme temperatures. Typically these extreme upper and lower temperature ranges are outside of the normal operating range of network equipment space. This additional range provides a reliability and performance buffer for all equipment placed in the space.

2.1.2 Temperature readings shall be made in accordance with Telcordia GR-63-CORE, Issue 3, NEBS Requirements: Physical Protection standards, Table 4-4, Note 1 (59” above the floor and 15.8” from the face of the network equipment).

2.1.3 Humidity, or the percent of moisture in the air, is an important condition that affects all cooling system design and operation. If the relative humidity level in a network equipment space is too low, static electricity may become an issue. This electrical discharge can cause significant harm to network equipment. This is one of the primary reasons for the use of static discharge wrist bands and destat-floor mats.

2.1.4 Humidity in an equipment area may also be too high raising the potential of moisture (dew) forming on and within equipment. This moisture can cause extensive damage and outages to network equipment.

2.2 Temperature and Humidity Requirements

2.2.1 Design Levels for temperature and humidity control (active or passive) in a cooling system manages both the upper and lower end of the established limits. Both upper and lower limits shall be designed by CRE PD&C and actively managed by CRE Property Management (CRE PM).

2.2.2 Continuous readings outside of the specific range over a period of 15 days shall be captured and reported to CRE PM. CRE PM shall take appropriate actions to bring the network equipment space environmental conditions (Temperature and Humidity) into compliance with ranges identified in Table 1 – Operating Temperature and Humidity Levels.

2.2.3 The following table represents the temperature and humidity requirements for Network Equipment, Next Generation Network and Power Room Spaces.

CRE PD&C shall design the cooling systems to meet the following requirements:
### Table 1 – Operating Temperature and Humidity Levels

For Communications Equipment Areas, Huts & CEV

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Temperature Occupied</th>
<th>Temperature Un-Occupied</th>
<th>Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communications Equipment Space (including Transport, IS)</td>
<td>60 – 78°F</td>
<td>55 - 85°F</td>
<td>15 - 55%</td>
</tr>
<tr>
<td>Switch Area (general)</td>
<td>60 - 78°F</td>
<td>60 - 78°F</td>
<td>20 - 55%</td>
</tr>
<tr>
<td>Switch Area – 1A, 4E, &amp; Exceptions per Section 2.1.4 of this standard</td>
<td>65 - 75°F</td>
<td>65 - 75°F</td>
<td>20 - 55%</td>
</tr>
<tr>
<td>Power Room W/ Batteries</td>
<td>60 - 77°F</td>
<td>50 - 77°F</td>
<td>5 - 55%</td>
</tr>
<tr>
<td>Power Room W/O Batteries</td>
<td>60 - 77°F</td>
<td>50 - 85°F</td>
<td>5 - 55%</td>
</tr>
</tbody>
</table>

**Notes:**
1. Supply temperature readings used to determine compliance with Table 1 are to be measured at 59” above floor level and 15.8” from the face of the equipment. System set point readings shall not be used as a substitute for supply temperature readings at the indicated test point.
2. When spaces are shared by technologies, the most conservative criteria will be used.
3. Rate of change for controlled temperature change within the space shall not exceed 15°F per hour.
4. VHO/SHO deployments threshold limits may currently be set below the limits identified for Network Equipment Space. These limits were initially established in support of extended network reliability. All VHO/SHO deployments shall transition toward the standard threshold limits identified for Network Equipment Space utilizing the VHO/SHO Thermal Transition Checklist (below)
5. See also 8.2.6 DRC relative Humidity limit

**2.2.4** In spaces utilizing DRC cooling systems, the relative humidity upper limit shall be set to limit the possibility of condensation – typically no higher than 45%.

**2.2.5** Operating inlet temperature indicates the central office aisle temperature as measured 59” above floor level and 15.8” from the face of the equipment in the cold aisle rather than return air or thermostat temperature. The operating inlet temperature shall be maintained by CRE PD&C to the levels stated in the table.
2.2.6 Humidity control requires site specific evaluation and implementation. Certain temperate areas – where humidity is fairly stable – may not require active management. Conversely, there are geographic areas that have significant high, low or swings in humidity that shall require active management to stay within AT&T standards.

2.2.7 Humidity levels may be maintained by building management systems, local CRAC/Hs or standalone humidification management systems.

2.2.8 Humidity levels may change based on seasonal variations. Standards are applicable for all seasons.

2.2.9 If required, humidity control systems shall be provided to assure compliance at all times. DRC systems do not provide integral humidity control capability. Humidification systems, if required, shall be provided external to the DRC system.

2.2.10 CRE PD&C may consider both strategic and technical requirements for thermal management of space (strategic example: Support for a small deployment of high heat equipment may be best served through the use of TMS vs the deployment of additional cooling system capacity. Conversely, an office with limited remaining space may require the deployment of additional cooling system capacity rather than use TMS to conserve the remaining floor space.) A holistic review is required to assure best price and best/available use of floor space are considered.

Table 2 - VHO/SHO Thermal Transition Checklist

<table>
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<tr>
<th>Step</th>
<th>Action</th>
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<tbody>
<tr>
<td>1</td>
<td>Operations, in coordination with CRE, shall evaluate and document existing temperature readings for each deployed frame/rack/cabinet in the office. Measurements shall be performed at 59” above floor level and 15.8” from the face of the equipment. This temperature “map” shall be utilized as a base comparative point for changes to cooling system. Baseline temperature measurement processes are considered non-volatile to the network. Measurements shall be taken with no direct contact or influence to equipment in the proximity of the measurement. A general testing guideline and Excel measurement recording template shall be provided by GES. Measurements may be captured with locally provided equipment or with equipment provided by GES, which is available on a rotating loan basis. Training on the use of tools shall be provided by GES upon request. Site evaluations/testing shall not proceed prior to the development and approval of a detailed MOP by Operations and CRE.</td>
</tr>
<tr>
<td>2</td>
<td>Verify that no frame/rack/cabinet reading is above the maximum transitional temperature threshold of Network Equipment Space – 75°F. If a frame/rack/cabinet is found to be above the maximum threshold, action shall be taken to resolve the problem before continuing with the thermal transition checklist. If no rack/frame/cabinet is above the threshold, continue with the</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>3</td>
<td>Supply temperatures may vary within the affected space as long as no value exceeds the maximum threshold for Network Equipment Space.</td>
</tr>
</tbody>
</table>
| 4 | CRE shall target two maximum threshold limits:  
1) All VHO/SHO offices maximum 75°F (Occupied)  
2) Cooling System Optimized Offices – 78°F (Occupied)  
( Optimized offices shall be analyzed and updated as commonly agreed upon by Operations and CRE on a site by site basis to support enhanced temperature and improved efficiency) |
| 5 | CRE and Operations shall jointly develop and document a transition plan, MOP(s) and site-specific schedules to incrementally increase temperatures in the affected space by no more than 2 degrees per week until the targeted threshold is reached. The plan shall include a step back process should issues arise with the increase of temperatures in the space. The plan shall incorporate a confirmation test of supply temperatures at each frame/rack/cabinet. |
| 6 | CRE and Operations (required for the coordination of Site Scan alarm monitoring and set points) shall be responsible for system modifications and set point changes to accomplish the transition plan. System modifications and set point changes shall be scheduled and approved through Change Management. |
| 7 | Network Operations shall develop and initiate a monitoring program to track temperatures and related events for 30 days after each adjustment. If the increased temperature causes network trouble or outage, Network Operations shall advise CRE and temperature set points shall be immediately returned to the previous set points. No further modifications shall be made until the specific cause of the problem has been identified and rectified. The transition process shall restart at step 6. |
| 8 | Changes to temperature set points will cease when the 75°F threshold limit has been reached. |
| 9 | CRE shall optimize each SHO/VHO to enable the thermal transition to a maximum supply temperature of 78°F (analyzed and updated as required to support enhanced temperature and improved efficiency). Where applicable and with concurrence from Operations, CRE shall start the second transition at step four (4) of this process. |
| 10 | CRE and Network Operations shall review and concur that each offices is stable before closing the transition project. |
3 COOLING SYSTEM OPTIONS

3.1 General

3.1.1 Cooling system options are impacted by several factors such as expected equipment heat loads, building construction (e.g., slab-to-slab height), existing cable-racking and ironwork congestion and existing cooling system infrastructure.

3.1.2 In case of a forced air cooling system, higher equipment heat loads translate into an increased amount of air to cool the equipment to the required temperature and humidity levels. This cooled air may be provided via different methods including forced air systems, ducted systems, raised floor systems or close coupled cooling systems. Regardless of the cooling source, the temperature of inlet air shall be designed to the standards listed in Table 1 – Operating Temperature and Humidity Levels.

3.2 Equipment – Frame/Cabinet Heat Classifications

3.2.1 Equipment heat levels have traditionally been referenced from a watt per sq. ft. perspective (W/ft²). Going forward, when designing cooling systems, heat density in equipment space shall be viewed as total Watts per frame/cabinet rather than watts per sq. ft. This allows for consideration of the overall heat signature when establishing regional heat loads as well as overall demand.

3.2.2 Equipment heat loads shall be classified in one of three groups:

- Standard - < 850 Watts per cabinet/rack
- High heat – 850 Watts to 4k Watts per cabinet/rack
- Extreme Heat - > 4kWatts per cabinet

3.2.3 Estimated equipment heat loads are provided by manufacturers as part of their ATT-TP-76200 filing. Equipment reviews moving through this process will receive a heat classification. This heat classification shall be available in the Product Approval Notice (PAN). Final designation of a deployed rack/cabinet of equipment shall include all equipment heat totals.

3.2.4 Where actual or estimated heat loads are not available, a value of 90% of List 1 power load shall be used to provide an estimate of realized heat load.

3.2.5 When determining the heat load for a specific area, equipment mounted in more than one frame or cabinet may be averaged over the combined footprint. This footprint may be extended in low heat per cabinet installations and more limited (e.g., 3 bays either side) on higher heat per cabinet installations. This averaging is especially valuable when considering low end heat loads that will not require supplemental cooling units (DRC etc.). Consideration shall be made to the average heat load vs. high heat spot load areas.
3.2.6 For reference, the traditional method of determining watts per sq. ft. shall be as follows:

- Aisles shall be shared with equipment in adjacent lineups; only one-half of the aisle space shall be used in determining the thermal footprint of equipment in square feet.

- An example in calculating heat release of equipment in a typical network frame, a nominal frame width of 24” and a depth of 20” (15” + 5 Equip Overhang) should be used. For heat release of equipment in a network cabinet, a nominal width of 32” depth of 36” should be used.

- Frame - Determine overall equipment footprint by multiplying (equipment & base plate) (Width 2’ x Depth 2’ = 4 ft²) plus half of the front aisle depth + one half of the rear aisle depth (e.g., (4 ft² + 2.5 ft²+2 ft² = 8.5 ft²).

- Cabinet - Determine overall equipment footprint by multiplying (Width 32’ x Depth 36”” = 8 ft²) plus half of the front aisle depth + one half of the rear aisle depth (e.g., (8 ft² + 2.5 ft²+2 ft² = 12.5 ft²)

3.2.7 For reference, cooling system capacity may be referred to as follows:

- The majority of AT&T offices are supported with cooling systems with a capacity of 30 Watts to 50 Watts per sq. ft. Typically this figure applies to the entire equipment area. The system also has a designed total load capacity for the space. CRE PD&C may provide the overall system capacity to COLD/USCS. A quick reference is the Watts per sq. ft. x # of sq. ft. (50 Watts sq. ft. x 1000 sq ft = 50,000 Watts or 50kWatts). This is the maximum capacity available to cool equipment and may be affected by factors (e.g., duct size/locations, etc.) that reduce it.

- A portion of the equipment space will be occupied by heat generating equipment (e.g., equipment bays/racks, etc.) and a portion of the space will be occupied by non-heat generating equipment/space (e.g., Main Frames, fiber bays, walkways, space between aisles, etc.) This balance of heat generating equipment space and non heat generating areas combine to provide an average heat level for the space occupied by equipment. This average will vary based on the initial Watts per sq. ft. and the actual non-heat generating/open space. The smaller the amount of non-heat generating space (i.e., high concentration of equipment lineups) the lower the average cooling level.

3.3 Primary (Base) Cooling

3.3.1 Primary or Base cooling provides the first level of support for normal day to day equipment heat load within network equipment space. It may be comprised of one or more cooling options.
3.3.2 For legacy network equipment space, the prevalent cooling technology is ducted air. Building central air handler units (AHU) have been, and may continue to be, used to provide a primary level of cooling. Traditionally this cooling has been provided in the range of 850 watts per cabinet/frame. It can however be designed to provide a higher level of base cooling if required.

3.3.3 The level of cooling provided is “N” or “Needs”. This is the assessed or estimated level of all network equipment heat loads deployed in the space with an additional designed growth factor. The “N” level of support may or may not be complemented by a “+1” redundant design.

3.3.4 The immediate and long term use of planned network equipment space shall be considered when determining cooling solutions. Most cooling solutions have some design limitations or minimum / maximum capacity constraints. U.S. Common Systems shall provide CRE PD&C with initial and long term estimates of network equipment demand when developing space. If the long term estimates are not available, U.S. Common Systems shall provide a best estimate (e.g., trending, etc.).

3.3.5 N Plus One (+1) Cooling

3.3.6 N Plus One (+1) cooling provides a back-up level of cooling support for critical equipment heat loads within network equipment space. N+1 is a configuration where N represents the number of equipment elements (e.g. chillers, CRAC/Hs, Air Handlers, DRC Pumps, etc.) required to sustain the load. The +1 element is a spare element which is required to be on line and operating in the event that one of the N elements fails. The +1 element is always considered to be the largest single element to ensure that N elements will sustain the load.

3.3.7 All deployments over N+1 shall require concurrence from SIP, U.S. Common Systems and CRE PD&C with SIP initiating the concurrence.

3.3.8 Systems may be deployed with complete or only partial cooling system redundancy. Specific guidelines for redundancy are provided in Section 8.

3.3.9 Not all systems require redundant or Plus One support. The project lead or planner shall be responsible to identify and communicate cooling redundancy requirements for network equipment deployments.

3.3.10 Where “N” and “+1” cooling is deployed for network equipment space, consideration shall be made by U.S. Common Systems and CRE PD&C to diversify the type of technology used for each layer of cooling. CRE PD&C shall provide recommendations and associated cost estimates of each consideration. CRE PD&C, in coordination with U.S. Common Systems shall make the final determination of the cooling technology choice.
3.4 Supplemental Cooling

3.4.1 Supplemental cooling designs are intended for conditions where primary cooling is insufficient or localized cooling is required to support high or extreme heat network equipment. High and extreme heat network equipment levels are outlined in Section 3.2.2.

3.4.2 Supplemental cooling may be provided by one or more cooling options depending on the level of cooling required. The impact to network equipment space shall be considered when determining the appropriate cooling technology.

3.4.3 Supplemental cooling may utilize the same cooling systems that support the “N” and “+1” cooling.

3.4.4 Supplemental cooling may be limited in scope (i.e., one to a few cabinets) or be more inclusive of an entire area. Where limited supplemental cooling is required, additional capacity from the “N” and “+1” systems may be available to support the need.

3.4.5 Supplemental cooling is intended to be applied in conjunction with existing base space cooling system. For sites with overhead duct diffusers or under access floor air distribution, diffusers or perforated floor panels may remain in place aided by the supplemental cooling units. Use of these existing systems may improve overall life-cycle costs and efficiencies.

3.4.6 Distributed Refrigerant Cooling (DRC) is well suited for deployment as a supplementary cooling system for specific extreme heat deployments (e.g., CRS-1) or for larger scale support of high and extreme heat network equipment space deployments. DRC systems have a low end cost/performance threshold of approximately 20KW (total expected equipment deployment load). Deployments of less than 20kW may be better supported using alternative technologies. See Section 5.4 for more information on DRC.

3.4.7 DRC units allow for the placement of additional cooling capacity directly where high heat load cabinets are located. In-row, above cabinet and back of cabinet cooling coils transfer heat directly from the network equipment before being discharged into the hot aisle. This direct mitigation of heat at the equipment works well to isolate the additional heat load from the rest of the network equipment space.

3.4.8 Cooling systems utilizing DRC provide only sensible cooling for the equipment and must work with space cooling systems such as CRAC units or air handling units for control of room humidity. Other cooling systems may provide sensible cooling (e.g., ducted air distribution).

3.4.9 DRC systems are the only liquid cooled distributed cooling system that is approved for integration within equipment line-ups in network equipment space. Distributed water/glycol or systems that create/require removal of condensate water are not
approved and shall not be considered for distributed cooling systems within network equipment space.

3.4.10 Reduction of required floor space use is another benefit with supplemental cooling because thermal management spacing of network equipment would not typically apply. Thermal management spacing rules are established to spread high heat equipment across a larger floor area to stay within heat density limits. Supplemental cooling systems allow for higher heat density within each equipment cabinet and/or in certain area(s) on the floor than previously permitted.

3.4.11 When supplemental cooling is used, coordination in design/construction shall be required with the primary cooling system to ensure effective interoperability.

3.5 Space Pressurization and Ventilation

3.5.1 Equipment areas shall be designed and provisioned with a slight positive pressure relative to the pressure outside of the equipment area.

3.5.2 CRE PD&C shall ensure that cooling system air handlers have a minimum filtration level as defined by CRE-23-00-00 ATP Section 5.7 or provide in duct air filtration for the equipment space.

3.5.3 Local authorities having jurisdiction (AHJ) may require a set amount of outside air (OSA) to be delivered based upon gross square footage and/or head count of people in the space. ASHRAE’s current equipment space requirement for OSA is 0.06 CFM per sq. ft. and 5 CFM per person - ASHRAE 62.1 Indoor Air Quality (IAQ) requirements.

3.5.4 All duct or air transfer openings that penetrate a perimeter wall of network equipment space room shall have a combination smoke-fire damper at the point of entry.

4 COOLING OPTION SELECTION STRATEGY

4.1 General

4.1.1 Cooling system deployment requires a fundamental knowledge of network equipment cooling requirements and the available cooling system(s) to meet those requirements. Often there is more than one way to cool a network equipment space. A clear strategy and adherence to deployment standards can assure a cost effective and efficient system.

4.2 Design Approach Network Equipment Space

4.2.1 General

4.2.1.1 The option selected to cool network equipment is dependent on factors such as the amount of space made available for deployment (e.g., Central Office equipment...
space, repurposed administration space, conventional concrete tilt-up or other mixture of construction and facilities) and expected heat density. Not all cooling options are best suited for all locations (e.g., large ducted air handlers in low ceiling height admin space, etc.)

4.2.1.2 Space cooling in existing equipment buildings is generally provided by overhead ducts and common air handling equipment with actual building cooling capacity designed for 30 to 50 Watts per sq. ft. This is the maximum heat load supportable for a highly concentrated frame deployment.

4.2.1.3 Typical equipment deployments include non-heat generating frames/space (e.g., fiber frames, cross connect frames, walk ways etc.). The mixture of active heat generating frames and non-heat generating frames/space typically allows for heat loads of up to 850 watts per cabinet/frame (where not more than 50% of the active equipment space (frame/rack/cabinet and ½ of the front and rear aisles) is occupied by heat generating equipment). Heat loads greater than 850 Watts in a cabinet/frame may require added floor space for distributing heat across a larger floor footprint or larger or more extensive ducts to get the appropriate amount of air to the higher loads.

4.2.1.4 More recent equipment space, such as Network Equipment Space/DC, has often utilized perimeter CRAH/C units and cooling air distributed via raised access floor and perforated floor panels. Heat density limits for these spaces may be extended above 850 Watts per cabinet/frame based on parameters such as floor height, CFM capacity, etc. CRE PD&C may provide site specific design capacity for legacy installations.

4.2.1.5 In general, primary heat loads above 4 KW per frame may be difficult to cool using conventional space cooling techniques (e.g., air distributed via either overhead ductwork or raised access floor). Alternate or supplemental cooling methods may provide either a more effective means of cooling or help augment the capacity of existing conventional systems.

4.2.1.6 Heat load considerations shall include initial expected heat load, as well as the total 3-year forecasted load in the equipment area (as provided by COLD/U.S.C.S). In the absence of an official forecast a best estimate may be provided.

Example, an area may be designed to support a future total average heat load of 6kW per frame/cabinet while the initial realized equipment load may be significantly lower. The combination of cooling options selected for this scenario must take into account both the future load as well as the very low initial load.

4.2.1.7 Best available heat load information/projections shall be provided by U.S. Common Systems to CRE PD&C at the inception of a project.

4.2.1.8 Cooling systems shall be laid out to make the most efficient balance and utilization of factors such as floor space, power, and cooling/energy consumption.
4.3 Demand Matched Cooling Design Process

4.3.1 General

4.3.2 AT&T Network equipment space has traditionally assumed the availability of 100 Watts per sq. ft. of cooling capacity. This assumption allowed for standardization of equipment deployments as reflected on WoodDuck documents. U.S. Common Systems planners have utilized these documents as deployment guidelines in laying out equipment space.

4.3.3 High heat producing equipment deployments have led to the need to space racks further apart in order to spread out the heat load. This spreading of equipment or use of Thermal Management Space (TMS) allowed higher heat equipment to be placed in existing equipment space with fairly minor upgrades to the existing cooling system thus extending the usefulness of available network equipment space.

4.3.4 Use of TMS with ever increasing equipment heat loads has triggered the need to space racks/cabinets farther apart (i.e., from inches to many feet). This increasing space required between equipment has accelerated the overall use of conditioned floor space; in some cases driving offices to floor space exhaust. The practice has also contributed to air flow issues within equipment space due to the poor containment and separation of hot and cold air (i.e., openings between cabinets allowing hot and cold air to mix). While the practice extended the use of 100Watts per sq. ft. network equipment space, practical limits may have been reached in many cases (e.g., CRS-1 deployments, etc).

4.3.5 AT&T is revising the entire equipment deployment process, to meet the cooling demands of new equipment and to extend the usefulness of existing floor space.

4.3.6 TMS shall no longer be used as the default solution to achieve a targeted average heat load in new equipment layouts. AT&T Labs personnel shall work with representatives from GNP, GES, CRE PD&C and U.S. Common Systems to identify the best balance of equipment layout and resulting heat signatures. Consideration shall always be made to designs that utilize existing conditioned space without upgrade or modification that meets the minimum cooling design parameters for the deployment.

4.3.7 The PAN/SAN shall clearly identify heat signatures as provided by AT&T Labs and/or ATT-TP-76200 manufacturer filings. Installation methods, e.g., Standard Drawings (aka Woodduck drawings) shall depict placement configurations of equipment in accordance with best overall deployment considerations.

4.3.8 Deployment Flow Chart and Advisory Matrix

4.3.9 General

The Deployment Flow Chart and Advisory Matrix following are guidelines for the deployment of cooling systems in Network Equipment Space. Each category and
associated cooling option takes into account a weighted balance of the attributes / drawbacks of each technology and the overall impact/benefit of the overall project. The final recommendation should be the best overall deployment from a One AT&T perspective.

Table 3 – Deployment Flow Chart

Following full pages
Building Space Cooling Option Selection Process

<table>
<thead>
<tr>
<th>AT&amp;T Labs</th>
<th>GNP/MEI/Network Planning</th>
<th>U.S. Common Systems</th>
<th>CRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define network architecture for new technologies and provide associated electrical/heat load and FSV information.</td>
<td>Use AT&amp;T Labs information to design new technology platforms in AT&amp;T network.</td>
<td>Coordinate collection of forecasted growth vs. capacity data from GNP, CRE and USCS.</td>
<td>Craft and manage an integrated plan based on the forecasted growth vs. capacity data.</td>
</tr>
<tr>
<td>Select deployment sites based on planning (e.g., SIP) integrated plan.</td>
<td></td>
<td>Receive request for site-specific network equipment deployment from client organization.</td>
<td></td>
</tr>
<tr>
<td>Provide funding authorization based on the estimated implementation cost provided by CRE D&amp;C Project Manager.</td>
<td></td>
<td></td>
<td>Coordinate equipment installation with CRE D&amp;C Project Manager.</td>
</tr>
</tbody>
</table>

Notes:
1. Highest expected full bay load should include the initial plus ultimate number of equipment shells that can be installed in a bay or cabinet based on WorkDuck or AT&T Labs.
2. Assume new future deployment if no forecasts are available (i.e., current baseline only).
3. Examples of minimal modifications are addition or modification of limited ductwork or the addition of one to two CRAH/ORAC's. Addition of fan rooms with air handlers or chillers is not considered minimal modification.
4. Some examples of existing site conditions that may restrict cooling option selection are inadequate floor space to ceiling slab height to accommodate equipment, cable trenching as well as ductwork or raised floor necessary to get sufficient air to the cabinet line-ups based on heat loads.
5. Base assumption is that the equipment will be installed without the use of Thermal Space Management to spread the heat load across a larger area.
### Building Space Cooling Option Selection Process

<table>
<thead>
<tr>
<th>AT&amp;T Labs</th>
<th>GNP/MEI/Network Planning</th>
<th>U.S. Common Systems</th>
<th>CRE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **AT&T Labs**
  - Provide fundingauthorization based on the estimated implementation cost provided by CRE D&C.

- **GNP/MEI/Network Planning**
  - CRE D&C Project Manager, Common Systems, and Client Organization to review options in Table 5 — Cooling System Advocacy Matrix and select options to institute in life-cycle cost analysis.
  - If cooling system handle current + forecasted* loads with minimal modifications, go to Yes.
  - If no, go to No.
  - If are there existing site conditions that limit the number of cooling options, go to Yes.
  - If no, go to No.
  - Estimate cost of primary cooling using: Option 1) Conventional central air handlers or multiple CRAH/CRAC.
  - Option 2) DCR systems.
  - Run a life-cycle cost analysis comparing options 1 and 2 per the recommended LCC parameters and select the lowest life cycle cost option.

---

Life-Cycle Cost (LCC) Parameters:
1. Analysis Interval or Period = 5 Years
2. After Tax Weighted Average Cost of Capital (ATWACC) = 9%
3. Annual Operating Expenditure (OPEx)/Expenditure Rate = 5%
4. Initial implementation cost (CAPEX) shall include all design and construction expenditures associated with the implementation of the cooling system.
5. Annual OPEX shall include annual cooling system energy and, if available, maintenance costs.
6. The same aisle widths and cabinet/caby spacing shall be used for analysis of both options.
## Building Space Cooling Option Selection Process

<table>
<thead>
<tr>
<th>AT&amp;T Labs</th>
<th>GNP/MEI/Network Planning</th>
<th>U.S. Common Systems</th>
<th>CRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide funding authorization based on the estimated implementation cost provided by CRE D&amp;C</td>
<td>Provide client organization with the estimated implementation cost (design and construction) for the selected option</td>
<td>Design and construct the selected option based on provided funding</td>
<td>From Page 3</td>
</tr>
</tbody>
</table>

**END**
## Table 4 - Cooling System Advisory Matrix

<table>
<thead>
<tr>
<th>Cooling Infrastructure</th>
<th>Network Equip Space (Avg Watts/Cabinet or Rack)</th>
<th>Network Equip Space/DC (Avg Watts/Cabinet or Rack)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;850W</td>
<td>850≤4kW</td>
</tr>
<tr>
<td>AIR HANDLER SLAB</td>
<td>Preferred (4)</td>
<td>Preferred (4)</td>
</tr>
<tr>
<td>Raised Floor</td>
<td>(7) Not Recommended</td>
<td>(6) As Required</td>
</tr>
<tr>
<td>CRAC or CRAH SLAB</td>
<td>Acceptable (5)</td>
<td>Acceptable (5)</td>
</tr>
<tr>
<td>Raised Floor</td>
<td>(7) Not Recommended</td>
<td>(6) As Required</td>
</tr>
<tr>
<td>DRC SLAB</td>
<td>(7) Not Recommended</td>
<td>Acceptable (5)</td>
</tr>
<tr>
<td>Raised Floor</td>
<td>(7) Not Recommended</td>
<td>(6) As Required</td>
</tr>
</tbody>
</table>

### Notes:

1) Advisories noted in the matrix are for typical deployments. Site specific conditions may influence the final cooling system. Use of the application matrix does not preclude the use or require the removal of existing facilities.

2) This matrix concerns cooling technologies as opposed to methodologies such as the use of Thermal Management Space (TMS). TMS continues to be a viable option as is covered in section 6.3 of this document.

3) Each entry is defined by a hierarchy of recommended alternatives. Designers should follow the hierarchy when evaluating the majority of the space. If the installation has a mixture of unique equipment cooling requirements, consideration should be made.
first to the general overall space, then with consideration for a limited design to support the unique equipment. The final cooling design should be the best for the overall deployment.

Example: An installation has 100 cabinets and three free standing servers. The servers require cold air feeds from the bottom. The designer should not automatically determine that a raised floor is required. The predominance of space of the installation should establish the initial cooling options. Support for the small deployment of the three servers should be developed as an adjunct where feasible.

Hierarchy of Matrix Options:

- Preferred
- Acceptable
- As Required
- Not Recommended

4) **Preferred** – This is the preferred option if it can be implemented within the constraints posed by existing field conditions (e.g., available overhead space for required ductwork) and may be determined to be the best choice based on life-cycle cost analysis

5) **Acceptable** – This option can be considered if it can be implemented within the constraints posed by existing field conditions (e.g., available overhead space for required ductwork) and may be determined to be the best choice based on life-cycle cost analysis

6) **As Required** – This identifies an option that is not the preferred choice but may be considered based on special circumstances or unique needs of a specific deployment.

   Example: A raised floor system may be required to provide cable running space in addition to supplying cooling. If the raised floor is not used for cable or power routing, deployment designs should consider Preferred or Acceptable solutions before considering this option.

7) **Not Recommended** – This identifies an option that has been reviewed by AT&T and determined that it is typically not cost effective, feasible or appropriate for the specific application.

   Example: DRC systems are typically deployed in support of higher heat loads. Low heat loads are typically more effectively served by alternate cooling system designs.
4.3.10 Advisory Matrix Application

Recognizing:

- A number of locations may have site specific issues that may drive a different cooling solution. In these cases, coordination between the affected work groups shall be required to determine the best alternative. Each work group shall retain documentation identifying the reason(s) for variance from the cooling option recommended in the matrix.

- The best overall solution may be a hybrid of one or more options. This does not preclude the identified option, but rather requires the impacted organizations (e.g., U.S.CS, CRE PD&C) to coordinate efforts in selecting the best combination of options and document the reason(s) for variance from the recommended option.

- The best overall solution may include a phased approach to deployment. Initial equipment heat loads may be only a fraction of the targeted growth figure. In these cases, a phased approach may be considered as long as the intermediate option (e.g., overhead air distribution) effectively transitions to the final option (e.g., DRC).

Example:
An area to be conditioned will have an average frame/cabinet heat load of 1.5kW growing to 6kW over time. A minimally ducted air handler system may support an initial deployment of equipment to approx 1.5kW per cabinet/frame but may not handle the long term heat load of 6kW. The long term design requirement is to use DRC on slab (Preferred choice - Table 4 - Cooling System Advisory Matrix).

A phased approach may include the following steps:
- An upfront floor plan layout accounting for the eventual deployment of the DRC option
- Spacing reserved for pumping units
- Aisle spacing reserved for in-row or BOC thermal panels
- Ambient air – Latent cooling capacity (humidity control) and +1 support as required
- Limited ducting to air handlers sufficient to handle load required with ultimate equipment heat loads and after the DRC system has been activated
- Hard copper piping and ports over equipment areas
- Air blocking materials to plug slots reserved for in-row coolers (if utilized)
- Air handler sized to meet final design capacity requirements

A phased approach shall NOT include:
- Air handlers sized to try to stretch capacity to ultimate primary load of 6kW per cabinet, unless the projected deployment is limited to very few
extreme density (heat load) cabinets placed in an existing space using air distribution as primary cooling.

- Raised floor distribution system when not required for reasons other than air handling or cable management.

5 COOLING SYSTEM TECHNOLOGIES & DEPLOYMENT

5.1 General

5.1.1 Although various technologies are used to cool network equipment, they can generally be divided into three stages as follows:

- **Stage 1:** Cooled air provided to the space is run across equipment circuit boards thus collecting heat resulting in hot air.

- **Stage 2:** The hot air is run thru a fan and coil combination (e.g., central air handler, computer room air conditioning (CRAC), in-row cooling or package unit) where it is cooled using chilled water or refrigerant. The cooled air is then returned to the space (see stage 1).

- **Stage 3:** The heat picked up by the chilled water or refrigerant is directly or indirectly dissipated to the environment outside the building thru condensers or cooling towers.

In many cases, the boundaries between these three cooling stages are clearly defined as shown in the following example:

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooled air delivered to the equipment space via overhead ducts moves across equipment collecting heat.</td>
<td>Hot air from the equipment space is cooled by the building chilled water system</td>
<td>Building heat is dissipated to the external environment.</td>
</tr>
</tbody>
</table>

![Figure 2 - Cooling Stages](image-url)
However, in some instances the cooling stage boundaries are less obvious as shown in the next example:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Space / Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Stage 2/3</td>
</tr>
<tr>
<td>Forced air from perforated tiles in a raised floor flows over equipment moving heat into the equipment space where it is picked up by a CRAC.</td>
<td>Hot air from the equipment space is cooled by a refrigerant loop in a CRAC that delivers the heat to an outside condensor which then dissipates heat to the external environment.</td>
</tr>
</tbody>
</table>

**Figure 3 - Alternate Cooling Stages**

5.1.2 **Cooling Stages:** A number of different options are used to implement each of the three stages of this cooling model.

5.1.2.1 **Equipment Heat Rejection Options:**
- Un-ducted Forced Air (only used when cooling demand is very small and widely distributed)
- Ducted Forced Air
- Forced Air via Raised Floor Plenums
- Chilled Water into equipment space (CRAH, DRC; chilled water into equipment lineups is not acceptable for NP&E space)
- Refrigerant into equipment space (DRC) via:
  - Refrigerant Piping
  - In-Row Cooling Units
  - Back of Cabinet (BOC) Cooling Units
  - Over Cabinet Cooling Units
  - Over Aisle Cooling Units
  - Spot Thermal Transfer Panels
  - Other
5.1.2.2 Equipment Space Heat Rejection Options

- AHU’S (Forced Air) – equipment space heat rejection to/from chiller or DX unit via water or refrigerant loop
- CRAH/C’s (Force Air) – equipment space heat rejection to/from chiller or DX unit water or refrigerant loop
- Pumping Units (DRC) – equipment space heat rejection to/from chiller via water loop
- DX Pumping Units (DRC) – equipment space heat rejection to/from outdoor condensing unit
- Other

5.1.2.3 Building Heat Rejection Options

- Chillers to Cooling Towers for water evaporation
- DX condensers
- Air Side Economization
- Water Side Economization
- Other

5.1.3 Cooling units shall be designed in accordance with national and local ordinances. Where possible, primary air handling units shall be placed in separately designated areas or along the perimeter of the equipment area. Where possible, and in accordance with manufacturer recommendations, cooling units shall be placed with zero rear clearance.

5.1.4 Cooling options listed in Table 3 – Deployment Flow Chart and Table 4 - Cooling System Advisory Matrix shall be used as guidelines for determining cooling methods to be used for deployment in AT&T NP&E equipment spaces.

5.2 Ducted Air Cooling Systems

5.2.1 General

5.2.1.1 Ducted Air Cooling system refers to a traditional cooling option most abundant in AT&T Network Equipment Offices. The system typically utilizes a chilled water system, large air handlers (e.g., coils, filter-banks, fans) and ducted distribution to move the air to the desired locations. These systems provide either a blanket of cool air to all equipment or direct air to specific cold aisles. The hot air (typically with some cool air mixed in) is routed back to the cooling system for rejection to outside of the building.

5.2.1.2 Ducted air cooling systems, as deployed in network equipment space typically provide from 30 to 50 Watts per sq. ft. of cooling capacity. When non-heat generating frames and empty space are considered, the heat load capacity may equate to as high as 100 Watts per sq. ft. This capacity can be improved by deploying a hybrid of flooded air and ducted air flows to specific equipment.
5.2.1.3 Ducted air cooling systems have adequately cooled traditional network equipment deployments. However ducted air systems pose challenges in areas with limited overhead space. Therefore, newer systems utilizing under floor air distribution and close-coupled cooling have replaced standard ducted systems in many high heat instances.

5.2.1.4 As stated in Table 4 - Cooling System Advisory Matrix a combination of cooling options may be selected for a network space. The use of building central air handlers as part of a hybrid cooling solution may be advantageous and provides the following benefits:

- Substantial energy savings may be realized through the use of outside air (free cooling) in cooler periods of the year.
- Provide redundancy to a system other than the DRC system resulting in added diversity, lower risks and potentially reduced costs.
- In most AT&T Central Offices this plant has already been paid for (sunk costs) and therefore leads to savings in first costs (i.e., CAPEX).

5.2.2 Architecture

5.2.2.1 The first choice in ducted air deployment is the use of building air handlers where available. Air handling units (AHU) may be utilized to support the deployment guidelines. If air conditioning redundancy is required, refer to Section 8.

5.2.2.2 In cases where the building central air handlers are not available or are insufficient for primary cooling, or the use of outside air is limited by local conditions (e.g., high humidity), consideration may be given to the use of ducted, slab mounted CRAH/Cs (or raised floor mounted as required) for primary cooling to support standard/high heat equipment deployments.

5.2.2.3 The selection of CRAH/CRAC units for primary cooling shall utilize the Table 3 – Deployment Flow Chart and Table 4 - Cooling System Advisory Matrix for preferences to assist in determining the best option.

5.2.2.4 AHU units may be used for backup if available, have sufficient capacity, are not back-up units for other space and will not affect the equipment operation of other spaces in the building.

5.2.2.5 If AHUs are not available without redundancy, CRAH/CRAC units may be used as back-up capacity.

5.2.2.6 The option of ducted, slab mounted CRAH/CRACs (or raised floor mounted as required) has many of the same advantages of the building central plant but often lacks the energy efficiency and redundancy advantage that results from the use of outside air as well as the lower first cost from redeployment of existing plant. Consideration may also include use of a hybrid cooling solution utilizing a combination of distributed refrigerant based cooling elements and CRAH/C units.
5.2.2.7 In applications making use of a raised floor plenum, static air pressure capacity for each CRAC or AHU must account for the return air duct, filter, and sufficient pressure for the raised access floor plenum to accommodate the air flow rates through the perforated floor tiles. Designers shall take into account that leakage can be as low as 10% and upwards of 25%.

5.2.2.8 In cases where CRAH/C units are used to provide primary capacity for the space, the capacity of these units may pick up all or part of the redundancy for the space.

5.2.2.9 Ultimately high heat loads may be best supported by a hybrid of DRC and ducted cooling facilities. The matrix found in Table 3 – Deployment Flow Chart and Table 4 - Cooling System Advisory Matrix shall be used for reference to assist the deployment team in determining the best overall cooling option. Typically CRE PD&C, in consultation with the other affected work groups will make the final determination of the cooling solution.

5.2.2.10 This standard is not intended to provide full details on the design and deployment of ducted air systems. CRE PD&C, in coordination with U.S. Common Systems, shall be responsible for the overall design and deployment of cooling systems in network engineering space. While specific design details are not listed here, fundamentals, specific limitations and impacts of a cooling system are important to understand and are provided.

5.2.2.11 For CRAH/C standalone or augmented systems, CRE PD&C in coordination with U.S. Common Systems shall design systems with appropriate cooling capacity and with redundancy in each network equipment room/space (as required).

5.2.2.12 When CRAH/C units are deployed in support of UPS rooms, N+1 provisioning shall not be required if an automatic alternative heat release system (e.g., automatic fan, etc.) is provided.

5.2.2.13 All CRAH/C units within, or in support of, network equipment space shall be designed to always be operating in coordinated cooling and humidification mode (except N+1 units which shall be in the “Remote Off” mode during normal operating conditions). Refer to Section 12 for control requirements.

5.2.2.14 CRAH/C system performance shall be tested on in-place and operational systems to ensure that measured temperatures (supply & return) and humidity readings are consistent with AT&T standards (refer to Table 1 – Operating Temperature and Humidity Levels) design parameters.

5.2.2.15 The following CRAC manufacturers are deemed acceptable for use unless otherwise directed: In the interest of maintenance, a single manufacturer’s product will normally be deployed in each equipment space.

- Air Flow/APC.
- Compu-Aire, Inc.
• Data Aire.
• IPAC, Inc.
• Liebert Corp.

5.2.2.16 Directional diffusers (e.g., barrel, etc.) shall be utilized with ducted air systems to assure efficient and targeted delivery of cooled air. Diffusers shall be provided at vertical height of not less than 7'-3" and not greater than 8'-0" from building floor.

5.2.2.17 To improve overall air flow distribution, linear diffusers with two way throw shall be provided for desired delivery of cooling air in front of every equipment frame in a supported lineup.

5.2.3 Placement

5.2.3.1 Air Handlers

5.2.3.1.1 Building air handlers are typically placed adjacent to network equipment space. The layout design of the space shall be the responsibility of CRE PD&C.

5.2.3.2 CRAH/C Cooling Units

5.2.3.2.1 Where CRAH/C units are utilized, units shall typically be placed against the surrounding wall. A typical clearance of three (3) feet in front of the units is required.

5.2.3.2.2 If circumstances require, CRAC units may be placed up to 4’ off the wall to accommodate chilled water piping but that decision must be agreed to by U.S. Common Systems and CRE PD&C.

5.2.3.2.3 Slab mounted CRAH/C systems may be placed outside or within the network equipment space. When placed outside of the space, CRE PD&C shall be responsible for the design and placement. When the units are placed within network equipment space, CRE PD&C, in coordination with U.S. Common Systems, shall determine the most effective placement of the cooling units. U.S. Common Systems shall document the placement on the floor plan.

5.2.3.2.4 When CRAH/Cs are used in raised floor systems, piping below the floor shall be placed at least three feet in front of the unit to minimize air deflection. Chilled water piping placed underneath the floor directly in front of the CRAC units may create an air dam. In this event, other techniques such as running piping overhead, in the adjacent room, or off-set from the front of the CRAC unit shall be utilized to avoid placing the CRAC away from the wall.

5.2.3.2.5 Cooling units or duct penetrations shall be placed at the end of the equipment rows wherever feasible.

5.2.3.2.6 Air diffusers shall be placed to assure a clear air flow path is available past overhead auxiliary framing, cable rack, cables and light fixtures.
5.2.3.2.7 Coordination between CRE PD&C, U.S. Common Systems and EI shall be required to assure that diffuser placement is not blocked by or in conflict with cable rack, fiber tray or other distribution facilities. CRE PD&C, U.S. Common Systems and EI shall review clearance conformity at 80% design completion to assure compliance with this standard.

5.2.3.2.8 U.S. Common Systems shall coordinate with the EI/OTV to assure that floor planning and racking installations placed after an initial installation does not conflict with established air flows as defined by CRE PD&C. If conflicts are unavoidable, U.S. Common Systems shall notify CRE PD&C of the conflict; requesting a cooling review.

5.2.3.2.9 Vendors, regardless of other direction, shall not deploy common systems facilities that block or otherwise degrade existing cooling facilities. CRE PD&C shall be consulted to assist in rearranging, modifying or extending any embedded cooling infrastructure that could be compromised by U.S. Common Systems facilities (e.g., ironwork or cable-racking). U.S. Common Systems and or equipment designs shall take into account existing and future (where known) cooling facility air flows on every equipment deployment.

5.2.3.2.10 CRE PD&C shall limit the maximum cooling unit / feeder duct / diffuser throw distance to 40 feet.

5.2.3.2.11 CRAH/C units should be aligned with hot air return paths for improved cooling efficiency wherever possible.

5.2.3.2.12 To improve cooling systems efficiency, placement of a positive (i.e., unobstructed) return air path is recommended down each hot aisle of a ducted air cooling system.

5.2.3.2.13 When ducted air systems are employed, provision shall be made to control airflow when using a common plenum to allow for active control/shut down of cooling system elements for overall economic system functionality and accessibility in case of service or failover support.

5.2.3.2.14 Newly placed return air or supply air ductwork space shall not have duct liner, exterior duct insulation, or be painted.

5.2.3.2.15 Flexible air ducting may be utilized in drop connections to air registers.

5.2.3.2.16 Flexible air ducting may be utilized in retrofit work to provide supplemental spot cool air feeds and extensions rerouting return air venting.

5.2.3.2.17 When air return paths exceed 40’ in length for high heat equipment deployments, CRE PD&C in coordination with U.S. Common Systems, shall consider active air return paths (e.g., Ducted Return, transfer fan, etc.) down each hot aisle from each CRAH/C or AHU. Extreme heat equipment deployments shall require active air return paths.
5.2.3.2.18 Active return path design may incorporate the use of the space created above a suspended ceiling system as a functional equivalent of ducting. Use of this space as a return plenum shall require that all cabling in the space be listed as Plenum Rated or placed in conduit and listed in the National Electrical Code.

5.2.3.2.19 The active return path shall be connected to the return air opening of the CRAH/C unit with provisions for changing of filters as required. Placement of motorized back-draft damper in the return duct to prevent air by-passing through an offline CRAH/C is recommended.

5.3 Raised Floor Systems

5.3.1 General

5.3.1.1 Raised floor distributed cooling systems are an enhancement to the conventional ducted air cooling systems. Each system is comprised of key elements as listed below. In many cases some of these elements may be combined into a single cooling element.

5.3.1.2 Cooling – heat transfer source and distribution:
- Chiller Plant – Chillers, cooling towers (for water cooled only) pumps and associated chilled water and condenser water piping or; DX Unit (e.g., CRAC, package unit)
- Air Handler – A combination of fans and coils with or without filters (e.g., CRAH)
- Raised Floor Plenum system – distributes cooled air
- Perforated tiles or open grates
- Return air management system

5.3.1.3 Use of perforated floor tiles typically allows for more accurate distribution of cooled air to the network equipment with minimal heated air intermixing. Each tile may be adjusted to meet the demand of the equipment supported. Careful design can improve overall system efficiency by managing the available cooling system.

5.3.1.4 Raised floor systems are may be designed to support heating loads of 1kW to 8kW. Special designs may improve load capacity to over 10kW.

5.3.1.5 Design and deployment of raised floor cooling systems shall utilize the Table 4 - Cooling System Advisory Matrix.
5.3.2 Design

5.3.2.1 Design of effective raised floor systems depends on the total air volume/temperature required to enable the transfer of heat from within the equipment area. As a general rule: Approximately 160 CFM is required for each 1 kW of server load at 20°F temperature rise.

5.3.2.2 Raised Floor systems incorporate different finished floor height depending on room height limitations, air volume required, cable load or other air blocking facilities and associated earthquake zone. The standard stand alone plenum raised floor deployment height shall be 2’ or 3’ depending on CRE design requirement. For high/ extreme heat applications floor heights of 30” may be considered.

5.3.2.3 All raised floor systems shall be designed and installed in accordance with the applicable flooring technical practices ATT-TP-76402.

5.3.2.4 U.S. Common Systems shall advise CRE PD&C of the network equipment space that may require a raised floor system in advance of the floor ready date to allow for effective design interval.

5.3.2.5 CRE PD&C shall provide U.S. Common Systems with a CAD drawing of all proposed floor tile alignments. U.S. Common Systems shall layout equipment and aisle
spacing in alignment with the tile grid placement. U.S. Common Systems shall provide floor plan layout in standard AT&T CAD formatted file to CRE PD&C. An AT&T approved AutoCAD reader is available in the Software Store for those that do not have the full AutoCAD application.

5.3.2.6 CRE PD&C, in coordination with U.S. Common Systems, shall resolve floor alignment issues and concur on an initial floor plan layout before construction begins.

5.3.2.7 The capacity of a raised floor system to deliver cooled air is a function of the height of the floor, obstructional blockage, and the pressure of the forced air (as measured in inch H20).

5.3.2.8 Consideration shall be made when placing anything (e.g., cable, conduit, piping, etc) in the air flow path under the raised floor which would impact the system’s cooling performance. Cable loading may have an impact on system performance. CRE PD&C shall be notified by U.S. Common Systems of pending large scale installations that could impair the functionality of the under floor air flow.

5.3.2.9 CRE PD&C’s mechanical design engineer shall calculate the required room, aisle and rack cooling capacity. CRE PD&C shall provide adequate air conditioning for the specified equipment based on the data provided plus redundancy (as required).

5.3.2.10 Air flow from raised floor systems is directly affected by under floor conditions and overall pressurization. Raised floor systems shall be balanced to these conditions upon initial installation.

5.3.2.11 CRE PD&C shall design raised floor systems with a minimum pressure of 0.02 as measured at any floor tiles.

5.3.2.12 Additional perforated tiles or grates shall not be added or flow rates increased (e.g., swap out 56% for 25%) unless a floor pressure capacity evaluation is available or concurred with CRE PD&C.

5.3.2.13 Under floor air pressure can be negatively affected by leaks that allow the air to flow through unintended openings (e.g., Holes cut in the floor for cables, edges around stanchions or columns, etc.) Floor penetrations shall be treated/sealed to minimize air leakage. Where the affected floor tiles are not normally removed (e.g., around a CRAC), a sealant may be hard setting (e.g., silicone). Where the tiles are subject to movement, the gap may be closed with intumescent putty or other replaceable seal. Refer to Appendix for additional containment information

5.3.2.14 CRAH/C units shall not be supported by the raised access floor system. CRAH/C units shall be placed upon their own support frame. When installing CRAH/C units within a seismic zone, support stands shall be installed meeting seismic requirements for lateral loads and per the written instructions of the manufacturer.

5.3.2.15 Raised floor systems may be installed just for cable and pipe routing. Raised floor systems that are used as part of a cooling system are classified as plenum space. If
the room meets the conditions of NEC Article 645.4 1- 6, plenum cabling is not required unless local code specifies otherwise.

5.3.3 Perforated Tiles & Grates

5.3.3.1 General

5.3.3.1.1 Raised floor cooling systems distribute pressurized cool air under the equipment floor. The floor is typically comprised of square drop in tiles. In the US, these tiles are most often 2 foot square. System designers strategically place perforated tiles and grates to distribute the cooled air where needed.

5.3.3.2 Design

5.3.3.2.1 System designers select cooling tiles based on the calculated air flow. NOTE: The amount of air pressure under the floor is (often) capped – too many large flow tiles may cause the overall floor pressure to drop – resulting in lower cooling capacity.

5.3.3.2.2 Placement of down-flow units CRAH/C units shall be coordinated with the location of equipment aisles and cooling tiles/grates to assure that no perforated tile/grate is placed closer than 4’ to the CRAH/C.s. Similarly, the location of under-floor outlet(s) from an AHU shall be coordinated with perforated floor tiles to assure that no tile is closer than 4’ from the outlet.

5.3.3.2.3 Placement of twenty-five percent (25%) perforated floor tiles may be optimized (i.e., placed where most effective) to handle support loads of under 2kW (@.02 H₂O). Above 2kW demand, consideration shall be made to judiciously utilize 56% perforated floor tiles with dampers.

5.3.3.2.4 New raised floor systems designs shall consider including 56% grated floor tiles with adjustable louvers. These tiles may be adjusted in the field to the precise air flow required. The tiles may be initially set to near zero flow (approx 5% leakage) up to the full 56%. Unless otherwise noted, floor installation vendors shall set floor tiles at the default 25% air flow rating and use aluminum sealing tape to secure the position. The tape may be easily removed for adjustment at a later time.

5.3.3.2.5 Air flow from perforated tiles is not linear. A conventional 25% perforated tile flows on average 700 CFM (Max 1000CFM). A 56% fully open non-louvered grate tile will typically have a flow rate 3x that of a 25% at the same floor pressure.
### Table 5 - Air Flow - Raised Floor Tile - Tate

<table>
<thead>
<tr>
<th>Perforated Panels</th>
<th>GrateAire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Pressure (In. H₂O)</td>
<td>Air Volume (CFM)</td>
</tr>
<tr>
<td>0.010</td>
<td>225</td>
</tr>
<tr>
<td>0.020</td>
<td>300</td>
</tr>
<tr>
<td>0.030</td>
<td>390</td>
</tr>
<tr>
<td>0.040</td>
<td>450</td>
</tr>
<tr>
<td>0.050</td>
<td>525</td>
</tr>
<tr>
<td>0.060</td>
<td>590</td>
</tr>
<tr>
<td>0.070</td>
<td>625</td>
</tr>
<tr>
<td>0.080</td>
<td>680</td>
</tr>
<tr>
<td>0.090</td>
<td>710</td>
</tr>
<tr>
<td>0.100</td>
<td>725</td>
</tr>
</tbody>
</table>

#### 5.3.3.3 Where required or CRE PD&C design specifies, directional floor tiles may be used to support more specific use of the cooled air to network equipment inlets. See Appendix for vendor specific information.

#### 5.3.3.4 Under floor control vanes may be utilized to control the flow of air through designated floor tiles. This control feature may be used in conjunction with variable speed fan air handling units to improve system efficiencies. Control vanes may also be used to manage air flow on failover designs. See Appendix for vendor specific information.

### 5.4 Distributed Refrigerant Cooling (DRC) Systems

#### 5.4.1 General

#### 5.4.1.1 Distributed Refrigerant Cooling (DRC) systems improve on basic ducted air or plenum cooling systems by bringing the cooled air source closer to the equipment generating the heat. This proximity provides a close coupling of the heat and associated cooling. This improves functionality and on going costs by minimizing the fan energy required to deliver the cold air and also reducing the cross mixture of hot and cold air typically found with ducted air systems.
5.4.1.2 DRC systems may be used for primary cooling, supplemental cooling, +1 back up cooling or any combination of the above. Refer to Section 3.3 for guidelines for primary cooling.

5.4.1.3 DRC systems provide only sensible cooling. This means that humidity control, as required, is dependant on other cooling system units. Building central air handlers, CRAH/C’s in support of the network equipment space, or stand alone humidification systems shall be used to control humidity.

5.4.1.4 DRC systems continuously measure temperature and humidity levels to ensure the pumped refrigerant does not approach the Dew Point level of the network equipment space. System capacity can be greatly affected by increased humidity levels. CRE PD&C shall design system performance to ensure humidification levels are maintained within standard approved levels as documented in Section 2.

5.4.1.5 When DRC systems are used for primary cooling (N) the pumping units shall be labeled with “Primary” on the outside of each unit in a location that is easily viewable. This labeling will assist service personnel in quickly determining the interworking of system elements.

5.4.2 System Functionality

5.4.2.1 DRC systems are comprised of four primary parts:

- Chilled Water System or DX System (Compressor, Evaporator, and remote condenser)
- Pump/transfer cabinet
- Refrigerant lines and connecting ports
- Remote Cooling units (e.g., In-Row, Back of Cabinet, Overhead, etc.).
5.4.2.2 Logical Flow – Cooling Loop

A. Building Chilled Water System – This system is typically found in an existing central office building. The systems effectively transfer heat from the equipment space to the outside of the building. The building system utilizes chillers, cooling towers, or other devices to chill a volume of water. This chilled water is pumped throughout the building. Specific floor cooling systems tap into the chilled water to transfer equipment heat load to the exterior of the building.

B. Direct Expansion – (i.e., Compressor Based System) – This system is typically placed where building chilled water system is not available, undersized or to provide diverse sources of cooling (i.e., both chilled water and DX based) resulting in higher reliability. The system uses a pair of compressors collocated with the refrigerant pumps (similar to a CRAC) and connected via piping to an external condenser. This condenser is mounted on the outside of the building and transfers the equipment heat to the open air.

C. The refrigerant pumping unit includes a heat transfer plate. This transfer plate is used to remove the heat from the refrigerant loop that serves the
equipment cooling modules (e.g., In-Row, Back of Cabinet, etc.). The unit also includes redundant pumps that circulate the refrigerant in the lines out to the cooling modules.

D. The refrigerant loop connects the pumping/heat exchange unit to the cooling modules near the equipment. There is a constant flow of refrigerant circulating through these lines.

E. Cooling modules contain at least one thermal transfer panel. Some units contain fans to move air across the thermal panels (e.g., In-Row), other rely on the fans of the equipment (e.g., Back of Cabinet). Heated air from the equipment exhaust is drawn across the thermal transfer panel where the transfer of heat to the refrigerant cooling loop occurs. The air now having the heat removed (cooled) is then redistributed to the room to support required equipment inlet temperatures.

5.4.2.3 To accommodate the greater heat density demands of current, transitional and future equipment technologies, DRC cooling may be required beyond traditional overhead ducted room cooling systems or perimeter Computer Room Air Conditioner (CRAH/C) units. The primary cooling deployment choices outlined in Section 2 shall be used by CRE PD&C, in coordination with U.S. Common Systems to determine the proper cooling technology(ies) for a network equipment space.

5.4.2.4 Remote cooling units integrated in network equipment lineups or placed immediately above equipment lineups shall not use or contain water, liquid coolant and condensate drainage or require the removal of any of these fluids.

5.4.2.5 Equipment framework shall be configured in continuous lineups with front-to-front and back-to-back layout in order to provide distinct hot and cold aisles.

5.4.2.6 All cost effective efforts to reduce air mixing between hot and cold aisles shall be implemented. Deployment of equipment lineups and cooling units such as DRC shall take into account containment requirements and provide integrated support. See containment Section 7 for additional information.

5.4.2.7 Deployment of DRC requires close coordination between CRE PD&C, U.S. Common Systems Engineers and EI’s because cooling units are either integrated into or placed above equipment lineups. It is strongly recommended that elevation (side-view) section and cut-out (top-down view) CAD drawings showing both Network and CRE PD&C infrastructure be developed to assure clearances and identify obstructions between projected overhead structures.
5.4.3 Refrigerant Pump

5.4.3.1 General

5.4.3.1.1 DRC pumping units have three primary purposes:

- Distribute cooled refrigerant to remote cooling units
- Maintain refrigerant temperature levels above the Dew Point threshold
- Remove the captured equipment heat and transfer it to outside of the equipment space

5.4.3.1.2 There are two primary types of DRC refrigerant pumping systems:

- Chilled Water – Interfaces into building or standalone chilled water system
- Air Cooled – Compressor (DX) based with associated remote condenser

5.4.3.1.3 DRC pumping units typically contain a heat exchanger, redundant circulating pumps, control valve(s), receiver, controls, valves and piping.

5.4.3.1.4 DRC pumping units are typically rated at 160KW (~45 Tons sensible cooling) See the Appendix for manufacturer specific information.

5.4.3.1.5 Refrigerant pumping systems may require a minimum heat load to operate effectively.

5.4.3.1.6 The following guidelines are for standard deployments using the Liebert XD product. Site specific issues such as low initial load conditions may require additional coordination with the manufacturer to determine if a system will function properly out of the ranges listed. Note: Other manufacturer’s products may have different minimum load requirements than those listed below.

<table>
<thead>
<tr>
<th>Design</th>
<th>Adjustment</th>
<th>Minimum Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Water Cooled</td>
<td>Non-Lite Load</td>
<td>40kW</td>
</tr>
<tr>
<td>Standard Water Cooled</td>
<td>Lite Adjusted</td>
<td>20kW</td>
</tr>
<tr>
<td>Extended Water Cooled</td>
<td>Lite Design</td>
<td>20kW</td>
</tr>
<tr>
<td>Air Cooled</td>
<td>None</td>
<td>64kW</td>
</tr>
</tbody>
</table>

1) Depending on specific site installation parameters, may be as low as 5kW
2) No lite demand adjustments are available

Table 6 - Typical Minimum Heat Load - DRC Pump - Liebert

5.4.3.1.7 The low end load capability of a pumping unit is a function of the overall capacity, refrigerant load and percentage of gas to liquid of a system. Capacity is also affected by the total length of the refrigerant piping and pump reservoir capacity. Applied loads below the minimum rating may cause the DRC system to go into alarm. As part
of the overall system design, CRE PD&C shall coordinate with planning groups to determine an accurate load at start up as well as maximum projected heat load.

5.4.3.1.8 Some manufacturers offer extended range DRC pumps which include additional refrigerant reservoirs allowing the system to effectively handle a near zero load condition. The current footprint of an extended chassis is 2 x the base footprint of a standard DRC pump.

5.4.3.1.9 Initial system refrigerant levels shall be set in accordance with manufacturers’ recommendations for the required initial load.

5.4.3.1.10 When turning up the system for the first time, load banks shall be utilized to provide testing of each circuit at the maximum heat load.

5.4.3.1.11 Final adjustments to refrigerant levels shall be based on a heat load that approximates the expected startup load of the supported equipment.

5.4.3.1.12 If initial loads are less than manufacturer indicated lower limits, CRE PD&C, shall evaluate if other means of cooling (e.g., central air handler, CRAH, CRAC) are sufficient to handle the initial load (as provided by U.S. Common Systems) until it increases past the indicated lower load limit.

5.4.3.1.13 Failure to appropriately load the overall DRC system may cause an under charge or over charge condition. Over charging the system will directly impact the effectiveness of the system to transfer heat. Under charging the system may cause alarm conditions or failure to cold start.

5.4.3.2 Chilled Water Refrigerant Pump

5.4.3.2.1 In buildings with available chilled water capacity, using a chilled water refrigerant pump unit shall be the preferred DRC pump option; and in most cases, the most economical solution.
5.4.3.2.2 Pumping units typically come standard with two-way chilled water control valve(s). As such, a pressure activated bypass valve shall always be specified and installed by CRE PD&C when the units are added to constant volume (i.e., primary pumping only) chilled water systems in order to prevent dead-heading of the chilled water pump.

5.4.3.2.3 Isolation valves shall be provided in supply and return pipes between the pumping unit and building chilled water headers.

5.4.3.2.4 Any water carrying piping shall be routed to ensure leakage will not pose a problem to equipment in the area or below. Overhead piping shall be avoided where possible. Water carrying piping run under a raised floor shall be panned unless specific area curbing is provided. Water carrying piping external to a raised floor shall be contained (e.g., panned, curbed, walled, etc.). Piping in network equipment spaces shall in all cases be outfitted with a leak detection system tied into the building facility alarm.

5.4.3.2.5 CRE PD&C shall design and install supply and return pipes to pumping unit(s) tapped off of the closest chilled water lines.
5.4.3.2.6 Pumping units have design limitations of the total equivalent refrigerant pipe length. CRE PD&C shall design DRC distribution piping per manufacturer provided specifications. See the Appendix for manufacturer specific information.

5.4.3.2.7 Pumping unit chilled water circuit setters and refrigerant levels may be adjusted to optimize low end heat level performance. Refer to manufacturer specific recommendations in the Appendix.

5.4.3.3 DX Based Refrigerant Pump Unit

5.4.3.3.1 In buildings where chilled water capacity or supply is not available or where diversity is desired, DX based refrigerant pumping units may be installed. Refrigerant chiller units have two distinct circuits each utilizing different refrigerants and mechanical parts.

5.4.3.3.2 The R-134a circuit is the pumped circuit between the network equipment remote cooling units and the chiller. The R-407c circuit of an air cooled pump unit is a dual direct expansion (DX) circuit connected to an outdoor condenser. Either an air-cooled condenser or water/glycol condenser for colder climates is available to match each of these units. Each pumping unit is typically rated at 160KW, ~45 Tons sensible cooling.

![Figure 7- Typical DX DRC Pumping – Heat Exchange Unit](Liebert XDC)
5.4.3.3 **XD-based pumping systems shall not** be specified for spaces where the initial heat load is expected to be less than the manufactures low heat load specifications as the units will not run under these conditions. There is currently no low load version of DX DRC pumping unit available.

5.4.3.4 For air-cooled condensers, CRE PD&C **shall** design and install refrigerant piping in compliance with the manufactures guidelines. Pipe runs cannot exceed 175 feet equivalent piping length. Shorter runs **shall** always be considered a preference in system layout. The CRE PD&C Contractor must install 400 psig pressure relief valves in the R-407c refrigerant circuit. Shutoff valves **shall not** be installed between the compressor and the pressure relief valve.

5.4.3.5 As with chilled water versions of the pumping unit, relative humidity (RH) levels in spaces with DRC cooling **shall not** be allowed to exceed 40% RH.

5.4.3.4 **Placement**

5.4.3.4.1 Design/placement of pumping units is a joint activity between U.S. Common Systems and CRE PD&C. Once the U.S. Common Systems Engineer has completed the equipment line-up floor plan (including forecasted growth), CRE PD&C, in conjunction with U.S. Common Systems **shall** coordinate the number and location of refrigerant pumping units in the space. CRE PD&C **shall** provide this information in CAD format to U.S. Common Systems.

5.4.3.4.2 DRC pumping units **may** be placed in mechanical rooms outside of the served equipment area or within the equipment area. When placed within the equipment area, cooling units **shall** typically be placed against exterior walls. This placement minimizes piping conflicts and limits the exposure of chilled water pipe leaks.
5.4.3.4.3 Water cooled pumping units shall normally be located near building chilled water sources. DX pumping units shall normally be located near the perimeter of the network space. Ideally, each unit should be installed perpendicular to and aligned with a hot aisle in order to minimize refrigerant pipe runs and bends. Units may also be placed in adjacent space to the equipment area served; with the refrigerant piping passing through the separation wall.

5.4.3.4.4 When circumstances require, DRC pumping units may be placed in centralized areas within the equipment space. Chilled water piping, if used, shall be in compliance with manufacturer recommendations.

5.4.3.4.5 Pumping unit cabinets placed on slab shall be secured to the building floor slab with concrete expansion anchors in accordance with building code seismic requirements.

5.4.3.4.6 Pumping unit cabinets placed on raised floor systems shall be installed with a structural frame that penetrates the floor and is secured to the slab below with concrete expansion anchors in accordance with building code seismic requirements.

5.4.3.4.7 Electrical and plumbing access requirements shall have no less than 36" inches of maintenance clearance in front of each unit. While the units allow for zero side clearance, best practice provides some clearance to the left side (facing from the front). The clearance allows better access to the compressor connections.

5.4.3.4.8 Condenser units shall not be placed in locations lower than 15 feet below the pumping unit per the device specifications. Condenser units shall be secured in accordance to building seismic code requirements.

5.5 Distribution Piping

5.5.1 General

5.5.1.1 Refrigerant distribution hard copper pipes are used to connect remote cooling units to the primary coolant pump. Lines are routed overhead from the refrigerant pump to the port connections above individual cooling units.

5.5.1.2 Routing design of distribution piping shall be typically down the center of the hot aisle separating the two aisles of equipment and cooling units. Cold aisle alignment may be implemented if hot aisle alignment is unavailable. When cold aisle alignment is utilized, specific planning and care shall be taken in routing hose connections over the supported equipment racks/cabinets.

5.5.1.3 CRE PD&C shall design and build supporting infrastructure for the distribution piping as an independent structure. Conventional auxiliary framing and cable racking shall not be utilized to support DRC piping. The same supporting structure may be utilized to support remote cooling AC power and controls conduits.

5.5.1.4 All refrigerant pipes shall be assembled with high temperature brazed joints. The lines being brazed must be filled with flowing dry nitrogen during brazing to prevent
oxidation and scale formation inside of pipe. Brazing operations shall be very limited in equipment space with in-service equipment and shall comply with ATT-TP-76300 installation requirements (e.g., bagging or shut-off of smoke detectors and associated fire watch, detailed MOP’s, etc).

5.5.1.5 Bypass flow controllers and shut off refrigerant grade ball valves shall be provided in pipe runs for servicing and emergency shutdown.

5.5.1.6 The distribution header assembly shall be equipped with approved ports and valves to allow for the connection of current/future remote cooling units and extension of the refrigerant piping to adjacent aisles as capacity permits. Future unit location(s) shall be based on the ultimate equipment layout provided by the U.S. Common Systems Engineer.

5.5.1.7 Header distribution assemblies with approved port fittings and valves shall be provided in the piping run where remote cooling units are to be installed. The header distribution assembly shall provide a connection port to remote cooling units for all current or future units via quick connect couplings without disrupting refrigerant flow.

5.5.1.8 Preconfigured header distribution assemblies are available. Typical distribution provides multiple ports to fixed lengths of piping. Use of preconfigured distribution assemblies may save construction time by minimizing the number of field welded joints. Header distribution assemblies may also be custom built on site to meet manufacturer requirements.

![Figure 9 – Typical Refrigerant Line with Ports - LIEBERT](image-url)
5.5.1.9 Refrigerant pipe runs shall normally be located between 11’-7” and building ceiling clear of all cable rack runs. Refrigerant pipe runs are allowed between 9’-4” and 11’-7” level when placed in the reserved central hot aisle space. Piping shall be coordinated with the U.S. Common Systems/EI/OTV to eliminate conflict with cable piles extending 12 inches above cable rack. Site coordination with U.S. Common Systems/EI and CRE PD&C shall be required to minimize structural conflicts.

5.5.1.10 Ball valve “T” units shall be placed at the end of piping sections that may be used for future growth. This allows for an extension of the piping without purging the entire line.

5.5.1.11 When flexible refrigerant pipes are used to connect remote cooling units, installations shall be run vertically up to distribution assembly with support provided at approximately every 3 feet. The longest unsupported run of flexible pipe shall not exceed 4 feet. Support may be provided by securing a pipe clamp to side of support framing channels. See Figure 11 - Cooling Hose Support Brackets for pipe support details.
5.5.1.12 Flexible pipe supply lines typically range from ½” to 1”. Lines may be protected with stainless steel braid and/or insulating material.

5.5.1.13 Flexible pipe is available with straight connector or 90 degree connector if needed on the pipe end connected to remote cooling unit. Due to reduced headroom clearance, designs shall typically specify straight fitting only for the top attachments to the in-row cooling units.

5.5.1.14 A tag, typically provided by the manufacturer shall be affixed to each end of the flexible connecting pipe advising of refrigerant content, the need for eye protection when servicing and warning of gas discharge / low temperature risks when disconnecting.

5.5.2 Piping Specifications

5.5.2.1 Supply refrigerant piping designs vary by manufacturer. The standards contained herein are supportive of all primary manufacturer requirements and may be in addition to manufacturer design requirements. Manufacture specific guidelines shall be followed.
5.5.2.2 Main supply and return lines shall be installed sloping downward toward the pumping unit at a rate of 1”-2” per 20 feet of pipe run. Horizontal connector lines shall also be sloped downward from the remote cooling units toward the main supply and return lines. The pipes shall be ASTM Type “L” copper pipe intended for refrigerant service at maximum operating pressure of 90 psi.

5.5.2.3 Piping shall be protected with minimum ½” thick elastomeric foam (black) pipe insulation (i.e., AeroCell). The foam shall conform to ASTM E 84 Surface Burning Characteristics of Building Materials with a flame spread rating of 25 or less and a smoke developed rating of 50 or less. This covering provides additional protection from condensation and some physical protection.

5.5.3 Piping Limitations

5.5.3.1 Refrigerant lines installation lengths shall not exceed manufacturer refrigerant pump guidelines. This not to exceed limit varies based on manufacturer. CRE PD&C shall confirm the maximum design limit associated with the specific equipment for each installation. Typically, systems function more efficiently with shorter runs.

5.5.4 Remote Cooling Units

5.5.4.1 General

5.5.4.1.1 Remote cooling units interface into the DRC pumping unit through distribution piping. Each unit contains at least one thermal panel and may include active fans. In a DRC system, these units are the first point of thermal transfer of the network equipment heated exhaust air.

5.5.4.1.2 Selection of the specific cooling unit is the primary responsibility of CRE PD&C. (Selection should be based on initial/future loads floor plan from COLD).

5.5.4.2 In-Row Cooler

Freestanding in-row remote cooling units typically combine three functions:

- Thermal panel(s) that circulate refrigerant via the main pumping units and distribution piping/hoses.
- Distribution fans that pull air from the back of the unit, through the cooling panels and out the front distribution grill.
- Controls and system interfacing equipment
5.5.4.2.1 In-row cooling units are typically equipped with casters for general transport and movement to the assigned position. These casters shall be removed prior to sliding the unit into position.

5.5.4.2.2 In-row units shall be leveled and weight removed from all internal casters.

5.5.4.2.3 In-row cooling units are provided in a variety of different nominal cooling capacities. The default choice for paired aisle deployment is 20kW range for low heat loads and 32kW range for high heat loads.

5.5.4.2.4 Some In-row units have a single cooling coil while others have multiple cooling coils. The overall (rated) in-row unit cooling capacity is the sum of the cooling coil capacities.

5.5.4.2.5 In-row cooling units have the ability to control fans (shed or lower fan speed) automatically when the load does not require full capacity. Controls shall be set to take advantage of economy settings (e.g., shed fans).

5.5.4.2.6 Some in-row cooling units are provided with multiple coils to provide system redundancy and load management. To improve network reliability and allow greater system load control, it is recommended that multi-coil units be interlaced to multiple pumping units.
5.5.4.2.7 System controls shall be configured to assure that in-row cooling unit fans are disabled if the pumping unit goes off line. This minimizes the transfer of hot exhaust air to the cold aisle in front of the unit and inlets of the equipment.

5.5.4.2.8 In-row cooling units shall be attached to adjacent equipment cabinets when installed in the equipment lineup. Cooling unit cabinets are to be attached to equipment cabinets at each top corner using brackets provided with each unit. Secure cooling unit(s) as necessary to the support floor with the same attachment process utilized for the adjacent racks/cabinets.

5.5.4.3 Placement

5.5.4.3.1 In row cooling units are typically placed adjacent to and within equipment lineups. Sufficient space (See Manufacturer Specifications in Appendix 54) shall be provided to allow units to be placed or removed after the equipment cabinets have been installed. Placement and alignment of in-row cooling units shall be a coordinated effort with CRE PD&C and COLD/U.S. Common Systems.

5.5.4.3.2 The front of in-row cooling unit(s) shall be placed so as to extend past the front of equipment cabinets (typically 1 ½") to allow for unobstructed airflow from the front air flow director grill. The rear of the cooling unit(s) may not align and extend beyond the depth of equipment cabinets if equipment frames are less than 42 inch depth. Cooling units shall be configured so that heated exhaust air is drawn into the rear of the unit, passes through the thermal panel(s) and cooled air is then introduced into front/common aisle.

5.5.4.3.3 In-row cooling units should be placed at a minimum of every two or typically at a maximum of every third equipment cabinet in equipment rows depending on the heat mitigation plan. Cooling units in opposing equipment rows shall be staggered with the cooling unit in the opposing equipment row as shown in Figure 13 - Typical In-Row Air Flow Pattern.
5.5.4.3.4 Placement of in-row units shall take into consideration both the capacity (CFM and kW Rating) and velocity of the available air.

Example:

In-Row Unit 20kW – 2500 CFM approximately 20kW cooling
In-Row Unit 32kW – 4000 CFM approximately 32kW cooling

5.5.4.3.5 Greater effectiveness may be achieved with an in-row cooling unit located at end of lineup to reduce warm air recirculation to the front of a cabinet by air moving around the end of a cabinet. End of row units shall incorporate unidirectional air director grills unless otherwise specified by CRE PD&C.

5.5.4.3.6 Templates may be made from Unistrut and cut to specific design spacing. (e.g., Typical In-Row = 12’1/4”) and used to provide uniform spacing. At minimum, two pieces are required one for the front and the other for the back.

5.5.4.3.7 In-row cooling units may be used to cool standalone equipment cabinets. In-row cooling units shall not be located more than 3 feet from a supported equipment cabinet. Standard containment guidelines shall be followed.

5.5.4.3.8 Clearance and access shall be provided at the top back portion of the in-row cooling units to enable refrigerant line connections, power cord routing and control seal tight connectivity. These connections shall be routed to accommodate cable racking or fiber trays. At all times 12” of space over the in-row unit shall be provided for placement of flexible cooling lines.
5.5.5 Back of Cabinet Cooler (Rear Door Heat Exchanger Panel(s))

5.5.5.1 General

5.5.5.1.1 The back of cabinet door (BoC) cooling unit is a heat exchanger module or refrigerant coil that installs as a rear door of an equipment cabinet providing up to 32 KW (depending on manufacturer and unit installed) of room-neutral cooling.

5.5.5.1.2 BoC deployments are unique in the way they mitigate equipment heat. Typical cooling units provide cold air to the equipment inlet and transfer the heat from the returned heated exhaust. BoC installation design focuses on the mitigation of the heat close to the source – at the equipment cabinet. The heated exhaust passes through the thermal panel and the heat is rejected (removed) at that point. The resulting temperature of the air leaving the thermal is at or even below the inlet temperature (room neutral). This results in a room at an ambient temperature in-line with the inlet temperature of the equipment. Both the “cold” and the “hot” aisles have a neutral ambient temperature.

5.5.5.1.3 BoC thermal panels do not have a provision for +1 backup. Support for +1 (when required) must come from another source such as adjacent in-row coolers or forced air system. The illustrative Figure 16 - Rear Door Thermal Panel (BOC) N+1 Floor Plan reflects a system using in-row coolers for +1 support. The system layout utilizes hot/cold aisles and containment to assure effective backup cooling. Like other DRC systems, BoC does not provide humidity control. When required to meet humidity requirements, humidification shall be provided by another cooling system.
5.5.5.1.4 Typically lower wattage doors have a single coolant loop, with higher wattage doors supported by multiple loops. Air movement across the BoC door refrigerant coil is provided by the fans of equipment mounted in the cabinet or by integrated auxiliary fans that pull the air through the thermal panel.

![Diagram](image)

**Figure 15 – Typical Rear Door Thermal Panel - Liebert XDR**

5.5.5.1.5 Cabinets using passive (no-fan) back of cabinet door cooling units **shall** be sealed to the extent possible to avoid escape of warm air through paths other than the rear door. These seal points include, but are not limited to, front to back, top, top to top of mounting rails, bottom to bottom of mounting rails, mounting rail side and penetrations and spacing between equipment mounted in the rails.

5.5.5.1.6 Cabinets using active back of door cooling units (i.e., door equipped with auxiliary fans as well as coil(s)), **shall** be sealed to avoid escape and intrusion of air through paths other than the rear door. All reasonable effort **shall** be incorporated to effectively seal the rear of the unit to direct the exhausted equipment air through the thermal panel door.

5.5.5.1.7 Single coil units typically connect to the refrigerant distribution systems with only one supply and one return refrigerant connection. High heat doors (e.g., 32kW) typically are fed by single taps but must be fed by dual sets of refrigerant lines with an “F” connector to meet the heat transfer demand. Multiple coil doors are typically fed by a pair of refrigerant lines for each panel.
5.5.5.1.8 Alternating connections to different pumps of every other cooling door within a lineup may provide a certain level of diversity in case of the loss of one pumping unit. Along the same lines, use of multi-coil cooling door assemblies provides diversity at individual cabinet level by interleaving the coils to different pumping units. Use of cold and hot aisle alignment minimizes intermixing of hot air with cool air entering cabinet inlets.

5.5.5.1.9 Back of cabinet door cooling units may be fitted to a variety of data cabinets with door adapter kits supplied by either the door manufacturer or the specific cabinet manufacturer. Cooling units may be field installed as a retrofit or as part of a new installation. Deployments on existing cabinets shall require updates to limit openings from air escape such as open base, tops, sides, and front.

5.5.5.1.10 A front-to-back device airflow path within a cabinet is required for the most effective movement of air across cooling door. For passive door deployments, fan volume of mounted devices shall be evaluated to assure enough air will move across the coils. Fan-less devices will not move air out of cabinet or across rear door for removal of heat. Airflow resistance of a back of cabinet door cooling unit is not more than standard perforated cabinet door. Consideration shall be given to how well the heat load is spread across the cooling surface of the door. The cooling door may be less effective in overall cooling if there is a high concentration of heat on a limited surface of the door.

5.5.5.1.11 Back of cabinet door cooling units may provide minimal sensible cooling to devices in other cabinets.
5.5.5.2 Rear Door Heat Exchanger – Example Layout

5.5.6 Over Aisle (Overhead) Cooler

5.5.6.1 General

5.5.6.1.1 Remote overhead located cooling units may be installed to cool equipment aisles when overhead space is available. Overhead cooling units draw heat from hot aisles, cool the air and then discharge the cooled air downward into the cold aisle. Careful consideration of air flow is required due to the distance from the cooling unit to the equipment to be cooled.

5.5.6.1.2 Overhead cooling units are designed with cooling capacity for multiple equipment cabinets or for deployments of extreme heat equipment aisles. They may be installed in tandem to provide continuous air flow the length of a cold aisle.

5.5.6.1.3 Units are comprised of the same basic building blocks as other remote cooling units; thermal transfer panel(s) and transfer fans. Note that while the typical arrangement is positioned over a cold aisle, the internal thermal coils also work in a reverse...
alignment – pulling heated air from the center of a hot aisle and dispersing cold air out either side. Fan direction may be changed to enable the reverse air flow.

5.5.6.1.4 Overhead cooling units shall only be installed where the cooling unit will not interfere with cable rack runs or cable entrance into top of cabinets. Network equipment overhead space is typically reserved for one to three levels of cable racks from 7’-5” up to 11’-8” height. Cable racks and cross aisle cable runs may be impacted by space required to support overhead cooling units.

5.5.6.1.5 Overhead cooling units shall typically be placed in rows directly above the cold aisle. When placed directly over a typical cabinet line-up, each cooling unit can provide cooled air to an area approximately equal in width to the cold aisle spacing and two cabinets along the equipment aisle. The number of racks/cabinets cooled is also limited by the capacity (e.g., 20kW) of the unit. Return (hot) air is drawn from the sides of unit and cold air discharged into the cold aisle. Specifications for overhead units may be found in the Appendix.

5.5.6.1.6 Overhead cooling units shall not be installed above equipment cabinets at a height greater than 30 inches when measured from bottom of cooling unit to top of cabinet unless ducting is provided to effectively distribute the air.

5.5.6.1.7 Overhead cooling units shall be supported by threaded rod hangers from building ceiling anchors or mechanical designed/approved Unistrut systems. In high seismic zones, hanger rod lengths longer than 2 feet require diagonal bracing to protect cooling unit against sway. Diagonal bracing may be provided by rigid structural steel braces or wire rope cables in two directions. Cooling units shall be braced for side-to-side movement and front-to-back displacement. In high seismic risk locations, building code requirements shall be followed for bracing designs.

5.5.6.1.8 Overhead cooling units incorporate mounting points (Typically 3/8”) on top of each unit. A minimum 3/8” diameter threaded rod hanger shall be used to support each cooling unit to ceiling anchors or surface mounted Unistrut channel. Empty weight (no refrigerant charge) of an overhead cooling unit is 150 pounds.

5.5.6.1.9 Overhead units are typically connected by hard pipe connections (no quick connections).
5.5.7 Over Cabinet Cooler

5.5.7.1 General

5.5.7.1.1 Cabinet top mounted cooling units function similarly to overhead suspended units except the units are installed directly on top of equipment cabinets. Cabinet top cooling units may interfere with cable management systems and cable access in and out of equipment cabinet. Network equipment overhead space is typically reserved for one to three levels of cable racks from 7’-5” up to 11’-8” height. Cable racks and cross aisle cable runs may be impacted by space required to support over cabinet cooling units. Cabinet top cooling units shall only be applied where cable access is not an issue.

5.5.7.1.2 Cabinet top mounted cooling units shall be secured to cabinet by through-bolts. Mounting clips supplied by cooling unit manufacturer typically permits attachment to cabinets with field drilled holes in cabinet top. Cooling units shall be secured to cabinet with a minimum of four ¼” diameter bolts.

5.5.7.1.3 Cabinet weight loading capacity shall be verified to confirm the ability to support a cooling unit (approx 80 pounds) and installed internal equipment weight.
5.5.8 Spot Panel Cooler

5.5.8.1 General

5.5.8.1.1 Spot panel coolers are comprised of a pumped refrigerant thermal transfer panel, support frame, mounting hardware and soft wall containment attachment points (hook-loop optional). The spot cooler is intended to be used in locations where other remote cooling units will not fit or function well.

Examples:
- Top venting equipment (e.g., RNC/Ericsson 3820)
- Retrofit to specific hot spots on frame/rack mounted equipment

5.5.8.1.2 Spot thermal transfer panels connect to a refrigerant distribution system with standard flexible hoses. Two units may be daisy chained onto a single port connection. Daisy chain connection hardware is available from the manufacturer.

5.5.8.1.3 Spot panel cooling units provide only passive cooling. Panels shall be utilized only in locations with active fan equipment sufficient to move the heated air through the thermal transfer panel.

5.5.8.1.4 Panel mounting depends on the specific use application. Units are provided with an adjustable frame assembly to facilitate mounting to the holes of a standard 19” and 23” rack.

5.5.8.1.5 Critical to the function of the panel is containment of the heated equipment exhaust air. Provisions are included to use hook and loop fastening or a soft wall containment
material (See Section 7.3.4). Containment design is unique to each use application. Materials and design shall be coordinated locally.

Figure 19 - Spot Thermal Transfer Panel

5.5.9 Mixture of Remote Cooling Units

5.5.9.1 A mixture of remote cooling units from a single manufacturer may be intermixed within a single refrigerant system. Consideration shall be required to assure total heat dissipation demand load shall not exceed the refrigerant pump capacity of the pumping system.

5.5.9.2 Example:

- Three 20kW in-row cooling units
- Two 20kW back of cabinet cooling units
- Three 20kW overhead cooling units
- Total design load = 160kW -> OK for 160kW pumping unit

The overall design shall meet the minimum heat load requirement, if any, of the associated pumping system.

5.5.9.3 Not all DRC systems function the same way and are fundamentally incompatible. A mixture of remote cooling units from multiple manufacturers shall be limited to those certified by the pump manufacturer to be used in an integrated system.

5.5.10 Capacity Management of DRC Cooling Elements
5.5.10.1 The capacity of intelligent remote cooling units and pumping units (e.g., XDH, XDO, XDV, XDP, etc.) is monitored by the supporting pumping unit and stored in active registers. These registers may be accessed through the pump control panel or through a remote polling by the DDC system. System designers shall include active register polling/monitoring and utilization threshold notification to CRE PM of DRC cooling resources. Notification to CRE PD&C shall be required if a cooling resource exceeds a 80% utilization threshold. Manufacture specific information may be found in the Appendix.

5.6 Demand Based Cooling

5.6.1 General

5.6.1.1 Demand based cooling may be used with primary or supplementary cooling. The system determines the need for cooling via sensors and/or contact closures and adjusts the level of support to the specific need identified by the sensors. The system is designed to provide additional cooling only when predetermined conditions are met.

5.6.1.2 Demand Based cooling systems may be localized (no external management system) or integrated into the overall cooling system controls. Local management systems may be “dumb” where each unit is independent or may have an intelligent local controller. These localized controllers shall be integrated into the overall system management controller when feasible.

5.6.1.3 Demand Based Cooling units are available for both slab floor and raised floor deployments; although primary market support is for raised floor installations.

5.6.2 Raised Floor Support

5.6.2.1 Raised floor demand based cooling comes in two basic types:

- Fan augmented tiles
- Powered louvers

5.6.2.2 Fan augmented tiles are installed in place of standard perforated tiles. The basic functionality of the tile is to allow a certain passive level of air flow (typically 5% to 25%) with no power to the tile. This assures that in the case of a power interruption the tile will continue to provide a basic level of air flow. Sensors are placed locally or control is provided from the building system to sense predetermined heat levels. Once the threshold is reached, fan units are engaged to increase air flow through the tile.

5.6.2.3 Powered louvers are installed in conjunction with perforated tiles. The functionality of the louver system is to adjust the amount of under floor pressurized air available through the perforated tile or grate. Under low demand scenarios, the powered louver will proportionally close off air to the equipment. This in turn allows air
handling units, when equipped with variable speed fans, to ramp down to save energy.

5.6.2.4 Demand based cooling devices shall follow standard “N” and “+1” design standards.

5.6.3 Overhead Air Management Applications

5.6.3.1 Supplemental Distribution Fans

5.6.3.2 One primary issue associated with both overhead cooling and raised floor cooling is effective management of heated return air. When this heated air is allowed to mix with entering cooled air, the resulting pre-warmed air is not as effective in cooling equipment.

5.6.3.3 Efficiency of a CRAH/C unit is negatively affected by precooling the heated return air. These cooling units work more efficiently with hotter return air.

5.6.3.4 Supplemental distribution fans may be deployed to assist in effective distribution of heated air, hot spot relief. Units may be required to equalize air pressure in a fully enclosed containment area.

5.7 Economizer - “Free” Cooling

5.7.1 General

5.7.1.1 Large geographical areas in the United States have sufficiently low enough outdoor temperature ranges that some or all of a network equipment load be cooled using ambient outside air (with no additional cooling) as cool supply air to the equipment space.

5.7.1.2 This “free” use of natural cooling can significantly lower overall energy consumption. The term free is relative – typically systems still require either powered fans or pumping units to transfer the thermal energy. Even with this requirement, savings can still be significant as the chiller portion of the plant is a key energy user.

5.7.1.3 Economizer systems are generally grouped into to two sub-categories:

- Air Side (i.e., plate frame) – This solution utilizes the natural availability of ambient air that is cool enough (with the right humidity) to be distributed directly to the network equipment. This solution may only be available during a portion of the year or only a portion of a day. Air filtration is required to assure particulate load aligns with the standard as defined in CRE-23-00-00 ATP-002.

- Water Side – (i.e., water towers or drycooler heat exchanger loops for chiller based systems). The system takes advantage of a thermal transfer loop – “free” transfer of cooler outside temperature. As long as the ambient outside temperature is at least a few degrees cooler than the chilled water loop, the system will function.
5.7.1.4 Economizer systems may not be able to provide 100% of the required equipment cooling and humidification. New or existing cooling infrastructures may be coupled to provide sufficient cooling. Integrated cooling controls are required to assure efficient utilization of the available cooling system(s).

5.7.1.5 Care shall be taken to assure the most effective use of natural resource cooling as well as the reliability of the network equipment is supported.

5.7.1.6 Since natural cooling may not always be reliably available, economizer systems shall be designed with automated control to initiate standard base cooling if environmental conditions cause the economizer system to drop off line.

5.7.1.7 CRE PD&C, in coordination with U.S. Common Systems shall review the effectiveness, cost and ROI of deploying economizers for all new and retrofit network equipment space projects. CRE PD&C shall provide costs to U.S. Common Systems/Planning to determine funding levels. Deployment shall be in compliance with accounting guidelines for Discounted Payback Period (DPP).

6 NETWORK EQUIPMENT DEPLOYMENT

6.1 General

6.1.1 Network Equipment Lineups shall be laid out per ATT 812-000-003 Standards for Network Equipment Environments to take advantage of the facilities available at the site. Facilities include but are not limited to space, power and cooling. All three of these facilities are required for the proper and reliable operation of the network. A significant imbalance of any of these three will drive either underutilized capital investment or limited use of the improved space.

6.1.2 U.S. Common Systems shall coordinate with CRE PD&C for an initial site review to determine key floor space requirements, if any. U.S. Common Systems, in coordination with CRE PD&C, shall determine the final network equipment layout.

6.1.3 Floor space may be reserved to assure proper cooling system equipment placement. CRE PD&C shall proactively advise U.S. Common Systems of reserved space requirements, if any. COLD shall identify the reserved space on floor space drawings based on CAD drawing documentation supplied by CRE PD&C.

6.2 Equipment Orientations - Hot Aisle – Cold Aisle

6.2.1 General

6.2.1.1 Effective cooling design isolates and contains hot exhaust air and cooled inlet air. Equipment shall be deployed in an orientation of cold aisle – inlet side of equipment and hot aisle – exhaust side of equipment configuration. Where multiple cabinets/frames are deployed, equipment framework shall be configured in
continuous lineups with front-to-front and back-to-back layout. All efforts to reduce air mixing between hot and cold aisles shall be made.

6.2.1.2 In extreme heat density environments, when possible, network equipment shall be housed in consistent height, width and depth frameworks such as data cabinets configured in continuous lineups.

6.2.1.3 Air containment devices such as blocking panels, side panels, between cabinet panels, etc. shall be installed and maintained to reduce mixing of air.

6.2.2 Non Standard Configurations

6.2.2.1 Where equipment has an irregular cooling air path specific air cold aisle – hot aisle integrity shall be maintained. Additional cooling system(s) or air flow management techniques (e.g., containment curtains, air deflectors, etc.) shall be included in the cooling design to mitigate the cross contamination of cooled and hot air flows (e.g., front to top, front to front, back to back etc.).

6.2.2.2 Where space considerations dictate use of back to back deployments in the same row (i.e., RNC), specific cooling units shall be required to assure adequate cooled air inflow to both sides of the line-up. Evaluation and mitigation of heated exhaust from adjacent aisles shall be included in the cooling solution. U.S. Common Systems shall note the special handling requirements of equipment affected by the non-standard deployment.

6.2.2.3 Side or up flow equipment is considered non-standard and requires active airflow management. When non standard air flow equipment is deployed in cabinets, air flow redirectors (i.e., baffle that redirects the air flow to the preferred front to rear alignment) shall be required to maintain hot aisle/cold aisle integrity

6.2.2.4 Aisle containment typically improves performance of these cooling designs and should be incorporated where possible. Installations where average heat load per cabinet exceeds 10KW shall require appropriate aisle containment to avoid air mixture within and between aisles (Back of Cabinet systems do not typically require containment).

6.3 Thermal Management Space

6.3.1 General

6.3.1.1 Thermal Management Space (TMS) is contiguous space that is designated for no heat load. When space is reserved next to high heat equipment, the overall footprint (including ½ front and rear aisle) shall be considered in heat calculations thereby allowing higher heat equipment to be placed in network equipment space originally designed for lower heat equipment.

6.3.1.2 While TMS has been used effectively to extend the ability to cool some higher heat network equipment, the design has limitations. By design, Thermal Management
Space utilizes additional space to spread the heat load. This spreading of equipment drives a faster exhaust of conditioned floor space.

6.3.1.3 When the space between network equipment racks/cabinets is left open, the thermal open space allows unintended thermal transfer of heat between aisles. This mixture of cooled and heated air diminishes the efficiency of the resulting mixed air. This reduction in efficiency reflects back on the original calculation by lowering the average watts per sq. ft.

6.3.1.4 Going forward, TMS shall no longer be used as a default for deployment of equipment. U.S. Common Systems, in coordination with CRE PD&C, shall determine the best integrated solution based on: floor space utilization, cooling system availability, cost and timing. TMS may be included as a viable and cost effective alternative is the determination of the best integrated solution.

6.3.1.5 Space identified and reserved for thermal management space shall not be used for placement of heat generating equipment. Non heat generating equipment (e.g., fiber frame, etc.) may be placed in TMS.

6.3.1.6 Thermal management space may be utilized to extend the viability of existing cooling system(s). However, a full understanding of the TMS impacts shall be assessed and mitigation actions such as soft wall containment shall be integrated into the deployment plan to assure the benefits.

6.3.2 Documentation

6.3.2.1 Thermal management space shall be documented by U.S. Common Systems on the site drawings. Space shall be labeled as “Thermal Management Space”.

6.3.2.2 U.S. Common Systems shall document the reasoning for use of TMS in the job documentation (i.e., NPV, space availability, etc.).

6.3.3 Determining Required Thermal Management Space Requirements

6.3.3.1 Determination of required TMS is based on the availability of cooling capacity and the heat load of the supported network equipment.

6.3.3.2 U.S. Common Systems shall provide to CRE PD&C in writing a synopsis (e.g., floor plan drawing with heat loads, etc) of the equipment heat load(s) and the desired space assignment. CRE PD&C shall respond with a determination of the supportable heat load for the identified area. CRE PD&C shall also provide feedback to U.S. Common Systems on the availability of cooling capacity in adjacent available space (if the support level is significantly different).

6.3.3.3 If CRE PD&C determines that cooling system capacity is insufficient to meet high heat equipment heat demand, U.S. Common Systems may then employ TMS to meet specific network equipment requirements.
6.3.3.4 U.S. Common Systems in coordination with CRE PD&C shall determine required TMS by:

Step 1. Determine the effective total per rack/cabinet heat load
   a. Divide the Identified Watts per Cabinet by the Watts per sq. ft. cooling capacity (provided by CRE PD&C).
      i. Should the sq. ft. cooling level capacity not be readily available from CRE PD&C, the following capacity per square foot may be substituted:
         1. 100 Watts per Square Foot For spaces where 50% or less of the total equipment floor space is utilized with heat generating equipment (See Step 4 for effective foot print).
         2. 50 Watts per Square Foot For spaces where more than 50% of the total equipment floor space is utilized with heat generating equipment
   b. This calculation will provide the total sq. ft. required to cool the equipment @ the cooling level capacity that CRE PD&C identified as available or defined as above (Consideration for de-rating may be appropriate for large TMS deployment)

Step 2. Determine the foot print of the equipment rack/cabinet in square feet
   a. Width of rack/cabinet (e.g., 24") x Depth of rack/cabinet)

Step 3. Determine the front and rear aisle space (1/2 of each space)
   a. Front (Width x depth / 2) + Rear (width x depth / 2)

Step 4. Add the sq. ft. of the rack/cabinet and aisle spaces = effective foot print

Step 5. Subtract the total effective foot print from the total in Step 1.
   a. The result will be the total Thermal Management Space required

Step 6. Divide the result in Step 5 by 2 to calculate how much square footage on each side of the network equipment rack/cabinet is required.

Step 7. To determine the required side spacing
   a. Divide the result from Step 6 by the combined depth of the Rack/Cabinet as determined in Step 3.

6.4 High Heat – Isolated Space Design

6.4.1 General

6.4.1.1 Equipment designated as high or extreme heat may be installed in isolated areas portioned off and supplied with a higher level of cooling as long as the additional heat does not detrimentally affect other equipment in the adjacent space.
6.4.1.2 Equipment placement in these spaces is dependant on the overall layout design, aisle spacing, concentration of equipment and the associated cooling system capacity. Cooling designs shall take into account short term ambient temperature ratings for network equipment as noted in Table 1 – Operating Temperature and Humidity Levels

7 AIRFLOW IDENTIFICATION AND MANAGEMENT

7.1 General

7.1.1 Identification and understanding of air flow to, within, and out of equipment is a critical part of understanding the dynamics of a cooling system. Some equipment utilizes traditional front (in cool) out rear (heated exhaust) air flow. Other equipment may utilize side-to-side air flow. Understanding where cooled air needs to be provided and where heat air exhausts assists the design engineer where to place and how to align equipment and associated cooling units.

7.2 Airflow Identification

7.2.1 Air flow directions have been standardized and published by the Alliance for Telecommunications Industry Solutions (ATIS) and Telcordia.

7.2.2 The following standard designations shall be used when communicating network equipment air flow paths. Inlet air (source) shall be listed first. Where more than one inlet source exists, each path shall be listed and separated by a comma.

Examples: Inlet is front middle = F2
Inlets are front bottom and right side = F1, SR2

7.2.3 Exhaust air (return) shall be listed last and separated from the inlet path(s) with a hyphen.

Examples: Exhaust is rear top = R3
Exhaust is rear bottom and left side = R1, SL2

7.2.4 Where multiple separate paths exist (e.g., card cooling, power supply cooling, etc), separate designations of inlet and exhaust shall be made.

Examples: Power Supply is front bottom to rear bottom = F1-R1
Card Supply is front middle to rear top = F2, R3
7.3 Airflow Management

7.3.1 General

7.3.1.1 Effective management of cooling systems requires a comprehensive understanding of air flow within the system. Air flow is a principle element in thermal management. As noted in the introduction, air is used to transfer heat from network equipment. That heat is then transferred away from the equipment area through other cooling elements.

7.3.1.2 Air flow management for raised floor cooling applications is focused on three primary areas:

- Air Inlet temperatures – not to exceed network equipment space limits as outlined in Table 1 – Operating Temperature and Humidity Levels.
- Effective removal/treatment of heated exhaust air from the equipment air
- Intermixing of heated exhaust air and inlet air—causing a rise in inlet air temp
7.3.1.3 Air flow management for slab floor – overhead ducted air installations is focused on three primary areas:

- Air Inlet temperatures – not to exceed network equipment space limits
- Effective removal/treatment of heated exhaust air from the equipment air
- Intermixing of heated exhaust air and inlet air from overhead distribution registers – causing a rise in inlet air temp.
7.3.1.4 Air flow management for typical multi-aisle network equipment installations is focused on three primary areas:

- Air Inlet temperatures – not to exceed network equipment space limits
- Effective removal/treatment of heated exhaust air from the equipment
- Intermixing of heated exhaust air above cabinets and around the end of aisles – causing a rise in inlet air temp in the cold aisle.

7.3.2 Computational Fluid Dynamics (CFD)

7.3.2.1 Understanding and predicting air flow within an equipment space can minimize or eliminate problems or hot spots which affect equipment cooling and performance. PC based software is available to accurately model the airflow patterns and related air temperature throughout an equipment area.

7.3.2.2 The use of CFD software is approved and recommended for use in designing and troubleshooting cooling system performance. Time and cost spent on upfront evaluations can provide overall cost and time savings by assuring the effectiveness of the design/deployment before it is built.
7.3.3 Ducting – Vents/Registers

7.3.3.1 Ducting may be used to route air flow to and within a network equipment area.

7.3.3.2 Overhead ducting, when utilized, shall be placed with the top of air distribution ducts hung as close as possible and no more than 6 inches from ceiling.

7.3.3.3 A minimum of 11 feet from finished floor height to the lowest point of air ducts shall be available for equipment racks/cabinets and overhead cable racks. This clearance shall exist across the entire network equipment floor space area.

7.3.3.4 When CRE PD&C estimates that there will less than 11 feet from the bottom of a new ducting installation to the finished floor surface, CRE PD&C shall provide U.S. Common Systems notification of the estimated available height in writing. Where alternatives are available, CRE PD&C shall provide high level design(s) to U.S. Common Systems. U.S. Common Systems, in coordination with CRE PD&C and OTV shall determine if the space can be utilized with modifications.

7.3.3.5 Supply ducting, when required, shall be routed within areas defined as cold aisles. Cold aisle, Hot aisle, and Common Areas shall be designated by U.S. Common Systems in coordination with CRE PD&C on network engineering space floor space records.

7.3.3.6 The area over the designated hot aisle space is reserved for routing of return air ducting or DRC support facilities (e.g., piping, power, controls, etc.). Routing of supply ducting in hot aisle areas shall be limited to last resort options.

7.3.3.7 CRE PD&C, in coordination with U.S. Common Systems, shall be responsible for the final design, layout and deployment of ducting.

7.3.3.8 Ceiling hangers shall be designed and installed to support HVAC ducts in conformance to applicable code requirements. Earthquake bracing shall be provided where required.

7.3.3.9 At no time shall an auxiliary framing threaded mounting point be covered by ductwork unless notification (CRE PD&C) and confirmation (U.S. Common Systems) has been provided in writing. Placement of ducting over existing auxiliary framing threaded mounting points may be required. However, all reasonable effort and coordination shall be undertaken to identify placement conflicts and resolve them before cooling systems and auxiliary frame designs are finalized.

7.3.3.10 If auxiliary framing threaded mounting point(s) must be covered, CRE PD&C, in coordination with U.S. Common Systems, shall provide alternative mounting points as required.
7.3.3.11 No drilling or installation of HVAC duct hangers shall be permitted over in-service equipment without proper precautions to protect equipment from service outage. Physical protection as well as cooling support shall be considered.

7.3.3.12 Air flow from registers/vents and beneath raised flooring needs to be unobstructed to effectively deliver the cooled air. Where obstructions occur, U.S. Common Systems/EI and CRE PD&C shall coordinate the deployment of some means to assure adequate cooling is provided to network equipment.

7.3.4 Containment

7.3.4.1 General

7.3.4.1.1 In typical network equipment space, cold air is supplied from ducting above the equipment. Since cold air tends to settle down while warmer air tends to rise, crossing of air flows tends to pre-heat the cooled air entering the equipment inlet and cools the exhausted air leaving the equipment. This condition leads to inefficient cooling and may require designed management of the air flow to assure proper cooling levels are provided in a cost effective manner. One active air management technique is called containment. As the name implies, the primary focus is to contain the air (hot or cold) so it can be managed or utilized more effectively.

7.3.4.2 Containment designs

7.3.4.3 Containment is designed to isolate cooled inlet air from heated exhaust air.

7.3.4.3.1 Containment should not be considered an all or nothing undertaking. Even small improvements to overall air flow can be cost effective and add to a cooling system’s efficiency. Key to improvement is the understanding of key areas where leakage occurs and implementing cost effective mitigations.

Containment shall be designed and implemented at the rack level for all new and retrofit network equipment deployments to assure effective cooling system utilization and to provide support for network reliability. U.S. Common Systems, in coordination with CRE PD&C, is responsible for containment design. The OTV and EI have the responsibility for containment installation within a cabinet/rack and between cabinets/structures. CRE PD&C is responsible for containment installation above the lineups and between aisles.
7.3.4.3.2 Containment designs may be compared to a six sided box. Visualizing each of the six sides of the box:

- Side 1 of the box - is the floor (slab or raised floor surface)
- Side 2 of the box - is the left aisle of equipment
- Side 3 of the box - is the right aisle of equipment
- Side 4 of the box - is the front space between equipment aisles
- Side 5 of the box - is the back space between equipment aisles
- Side 6 of the box - is typically the ceiling (dropped or structural)
7.3.4.3.3 Full six sided containment is the most efficient design to minimize cross contamination of chilled inlet and heated exhaust air. However, there are significant design issues and drawbacks to the design. Coordination with CRE PD&C is required for all containment deployments to assure proper airflow and code compliance.

Benefits

- Most effective at minimizing cross contamination
- Provides best cold air temperature management
- Due to limited air mixing, the distributed air temp may be raised lowering demand and saving energy
- Allows air to be channeled more efficiently
- When used in a cold aisle – the air pressure and temperature tends to equalize over the entire area.
- May allow larger distance between in-row cooling units

Drawbacks

- Full six sided construction are often difficult to construct (doors, over cabinet – between cable racks, etc.)
- Additional installation costs
- Containment materials can hinder normal work activities
- Temperatures rise significantly in hot aisle contained areas – extended work in the area can be difficult
- Air pressure equalization (air pulled in by equipment vs. air expelled from contained area) is difficult to achieve. If the pressure does not match, the containment will flutter or not seal properly
- The area is isolated from the rest of the room – back up air sources may have to include significant ducting
- The area is isolated from the rest of the room – potentially affecting ride through timing.
- The area is isolated so special designs need to take into account smoke detection, annunciation – warning, etc.

7.3.4.3.4 Alternate containment designs are available providing much of the benefit while minimizing the drawbacks.

7.3.4.3.5 Using a similar model, five sided containment, which eliminates the top side, may provide up to 85% efficiency when compared to full six sided containment.
7.3.4.3.6 Use of five sided containment **shall** be the preferred engineering solution unless otherwise indicated by CRE PD&C for a specific use.

7.3.4.3.7 Typical deployment of five sided containment includes 18” to 24” of soft wall sheeting above the top of the cabinet level unless otherwise noted by CRE PD&C.

7.3.4.3.8 Cabinet layout may contribute to natural air containment (provided the equipment bays/cabinets are adjacent to each other). Sides one (bottom), two and three (equipment cabinets to the approx top-of-the-cabinet level) provides reasonable containment. U.S. Common Systems **shall** take into consideration placement of racks/cabinets to utilize and reinforce this natural air containment benefit by arranging equipment to assure controlled airflow.

7.3.5 **Containment is classified into three primary categories:**

- Within a rack or cabinet
- Within and between aisles
- Transport to/from the air handling/cooling system

7.3.6 **Containment within racks or cabinets**
7.3.6.1 The primary focus of containment within a rack/cabinet is to prevent the unintended flow of air from one side to the other. Reasonable efforts shall be undertaken to limit cross flow of air.

![Image of airflow through cabinet with and without blanking panels]

No Blanking Panels                      Blanking Panels No Gaps

Figure 26 - Air Flow Through Cabinet

7.3.6.2 Blanking panels shall be deployed in support of all new equipment deployments. On initial installations, the OTV shall include the cost of providing and installing required blanking panels as identified by the EI to meet 100% fill status. Where fill ratios are not identified, 100% of the RUs deployed shall be provided with blanking panels.

7.3.6.3 Blanking panels shall be deployed in support of all existing equipment moves or relocations. The equipment installation vendor shall include the cost of providing and installing required blanking panels as identified by the EI to meet 100% fill status. Removed blanking panels shall be stored on site.

7.3.6.4 Containment functions best when deployed in an entire localized region. Considerations shall be made to upgrade airflow within a reasonable proximity of any new or retrofit network equipment deployments by retrofitting blanking panels within adjunct racks and/or aisles.

7.3.6.5 Aluminum or fire rated plastic blanking panels shall be used in network equipment space.
7.3.6.6 Blanking panels shall be deployed using secure mounting techniques including but not limited to screws, clips, snap in brackets, etc. Taping or adhesive methods shall not be utilized to mount blanking panels.

7.3.6.7 Temperature sensing strips shall be placed, one to a rack, when blanking panels are deployed. When provisioned by OTV, strips shall be placed on a blanking plate (or reasonable alternative) at, or as close as possible to the Issue 3, NEBS Requirements: Physical Protection standards test point of 59" (1.5M).

7.3.7 Containment within and between equipment Line-ups

7.3.7.1 The primary focus on containment within and between equipment line-ups is to prevent the unintended flow of air from one aisle to the other resulting in tepid air ineffective cooling. All reasonable efforts shall be undertaken to limit cross flow of air.

7.3.7.2 Containment between racks/cabinets shall be required for placement or rearrangement of network equipment. U.S. Common Systems, in coordination with CRE PD&C is responsible for the design and placement of between rack/cabinet containment.

7.3.7.3 Containment shall be provided by hard (e.g., metal, sheet rock, etc.) or soft (Vinyl sheet) for all new and retrofit network equipment deployments where spacing between the equipment rack/cabinet and adjacent structures (e.g., other racks/cabinets, columns, etc.) exceeds 2”.

7.3.7.4 Containment between equipment racks and adjacent structures shall start at floor level and meet or exceed the height of the network equipment rack/cabinet.

7.3.7.5 Containment between aisles (e.g., end of aisle – hot aisle containment, over rack aisle to aisle containment) shall be considered for all new installations with average heat loads per cabinet rated as Extreme (>4kW). Between aisles containment shall not be deployed without review, design and approval of the CRE PD&C representative(s) responsible for the network equipment space (e.g., D&C, etc.).

7.3.7.6 Hard frame containment (solid panel) doors may be installed for end of aisle containment. Containment units may be standalone or integrated into/mounted on the rack/cabinet assembly. CRE PD&C shall, in coordination with U.S. Common Systems, design and deploy hard frame containment systems.
7.3.8  “Soft” wall containment

7.3.8.1  Soft wall containment includes end of aisle strip containment entry “doors”. Strip doors **shall** be constructed of no less than .060” fire/smoke rated material for light duty passageways. It is recommended to use .120” for optimal cooling support (less floating or flap due to air pressure) and longevity. Refer to CRE 13-60-00 ATP 001 Hot Aisle / Cold Aisle & Return Air Containment Application for Fire Protection and Life Safety Compliance.

![Figure 28- Completed End of Aisle Slat Doorway](image_url)

7.3.8.2  Soft wall doors **shall** be supported using fusible links as required by local fire code. Fusible links **may** be considered for installations when not required by fire code.

7.3.9  Over cabinet containment

7.3.9.1  When cabinet containment is required care in design, materials selection and installation **shall** be considered. The primary goal, like other containment, is to minimize the mixing of cooled and heated exhaust air. Impacts to cable access **shall** be considered in the design.

7.3.9.2  Only soft wall containment **shall** be utilized for above cabinet air flow management.
7.3.9.3 Over cabinet soft wall shall be securely supported (e.g., chain, separate support structure, auxiliary framing, etc.)

8 SYSTEM DESIGN CAPACITY & REDUNDANCY

8.1 General

8.1.1 The general reference for the amount of cooling units required to meet a specific demand is “N” (Need). This reference applies whether the need is described in CFM, kWatts, or BTU. System design “N” refers to the cooling sources required to assure the network engineering space does not exceed the maximum temperature range as identified in Table 1 – Operating Temperature and Humidity Levels and associated Telcordia GR-63-CORE, Issue 3, NEBS Requirements: Physical Protection standards.

8.1.2 Additional cooling units may be required to enable service back up or failover support. This additional capacity is referred to as a “+ X” where “X” is a number. For example, a system with cooling units required to meet demand and provide redundant capacity to cover the failure of one cooling unit is referred to as “N+1”. The reference of +1 is specific to each part of the cooling system.

8.1.3 The default design criterion for AT&T networks is N. N+1 (or greater) may be deployed with review and concurrence of SIP, U.S. Common Systems and CRE PD&C.

8.1.4 When utilized, N+1 consideration shall be reviewed to ensure there are no single undocumented points of failure in the entire cooling system. This review shall include, but is not limited to, pump arrangements, chillers, dry coolers, control systems, piping arrangements, fire alarm interfaces (effect of trouble conditions), and other design/system attributes to determine what can be included into the project to mitigate a single component or device from rendering the system inoperative.

8.1.5 New deployments of equipment such as large routers in the traditional network may require N+1 cooling support. Specific guidance for the design of N+1 systems for each site shall be required. Refer to CRE-23-00-00 ATP-002 Standard for implementation specifics.

8.1.6 When all cooling equipment is doubled to provide redundancy the reference shall be referred to as “2N” or twice the required need.

8.1.7 Provision of cooling redundancy is an expensive undertaking and may not serve to significantly improve upon other redundancies in a system (e.g. geographic/location to location failover of equipment). CRE PD&C shall evaluate and understand the cost vs. benefit (e.g., reliability, availability, etc.) for proposed cooling redundancy during the design phase of all major cooling projects. CRE PD&C shall review
findings and gain concurrence with COLD / U.S. Common Systems and equipment customers prior to execution of these projects.

8.1.8 Default or failsafe modes **shall** not be designed to shut down any cooling system equipment unless specifically required by code or other life safety situations.

**8.2 Forecasted Demand**

8.2.1 The number of operating and installed cooling units in support of network equipment space **should** be based upon a 3 year forecast of equipment loads. Cooling units reserved for future growth can be used for redundancy. Additional units **shall** be added as loads increase thus exhausting the reserve for redundancy. Redundant (+1) units **shall not** operate to meet “N” load conditions.

8.2.2 N+1 CRAC units are usually not required for UPS or battery rooms. Specific project or site requirements may require additional cooling units.

8.2.3 Provisions for main ducts (supply and return), piping risers and manifolds (e.g., (chilled water) **shall** be based on CRE-23-00-00 ATP-002 Standard.

8.2.4 Initial loads are typically less than the 3-year forecasted levels. CRE PD&C **shall** therefore determine the optimum number and configuration of cooling units required to carry the reduced load while operating efficiently. The deployment or activation of cooling units **may** be staggered to meet actual demand. If this sequencing is not followed, short cycling may occur or some units may not function properly.

8.2.5 Staged deployments **shall** be considered due to the Cost Causer Accounting practice.

8.2.6 If the dew point of the room passes a predetermined point the refrigerant pumping unit will go into alarm and reduce cooling capacity. In order to avoid this lower capacity and alarm condition, relative humidity (RH) levels in spaces with distributed refrigerant based cooling (e.g., Liebert XD system) **shall not** be allowed to exceed 40% RH.

8.2.7 A detailed humidification review and action plan **shall** be undertaken and provided by CRE PD&C for all DRC deployments. Reviews and action plans **shall** be provided by CRE PD&C on an as-requested basis to assure system functionality.

8.2.8 CRE PD&C designs **may** include additional provisions for space thermal management (e.g., failure-mode triggered exhaust fans or floor tiles) in response to strategic requirements noted by the SIP organization.

8.2.9 When air handlers/CRAH/Cs are used for latent cooling (humidity control) in an N+1 design, a minimum of two units **shall** be deployed.
9 AIR FILTRATION

9.1 General

9.1.1 Minimum filtration requirements shall comply with CRE-23-00-00 ATP-002 Standard.

10 POWER

10.1 General

10.1.1 Non-movable cooling units (e.g., AHU, CRAH/C, etc.) power connections shall be hardwired.

10.1.2 Movable cooling units (e.g., In-Row, etc.) power connections shall be provisioned through locking style NEMA (e.g., L5-20) connectors. Plug connectors provided by the factory that do not include locking style connectors, shall be replaced or converted to locking style by an approved vendor or replaced with an appropriate cord cap.

10.1.3 CRE PD&C shall design and install AC power feeds and protective devices for each cooling unit using the manufacturer's provided rating and in compliance with the latest adopted version of NFPA 70: National Electrical Code (NEC) requirements. The design and installation shall comply with all applicable state and local codes and ordinances.

10.1.4 All connections and terminals shall be tightened in accordance with the manufacturer’s recommended torque values.

10.1.5 All conductors, wires, cables and connectors shall be constructed of copper and be no less than 98% conductivity unless otherwise specified.

10.1.6 Location of power wire/cable and raceways shall be coordinated between disciplines before placement to avoid interference with piping and telecommunications cabling for network equipment.

10.1.7 All electrical raceway or conduit supporting equipment such as hangers, angle iron, straps, brackets, clamps etc., shall be directly attached to the overhead concrete ceiling structure or building walls and shall not be supported or attached to network overhead cable racks, cable rack supporting structure or other ironwork intended for network equipment use only.

10.2 Grounding

10.2.1 Electrical grounding of all cooling equipment and enclosures shall be in accordance with the current version of NFPA 70: National Electrical Code.

10.3 Essential – Back-up Power
10.3.1 Primary and secondary cooling systems shall be backed up by essential circuit connections and stand by generators where emergency backup power is provided to the facility unless the application is intended to be non redundant.

10.4 Air Handler - Cooling Units
10.4.1 CRE PD&C shall be responsible for the design and placement of power to these units in compliance with CRE-23-00-00 ATP-002, NEC and local municipal codes.

10.5 CRAH/C
10.5.1 CRE PD&C shall be responsible for the design and placement of power to these units in compliance with CRE-23-00-00 ATP-002, NEC and local municipal codes.

10.6 Air Cooled Refrigerant Chiller Units
10.6.1 CRE PD&C shall be responsible for the design and placement of power to these units in compliance with CRE-23-00-00 ATP-002, NEC and local municipal codes.

10.7 Chilled Water Refrigerant Pumping Units
10.7.1 CRE PD&C shall be responsible for the design and placement of power to these units in compliance with CRE-23-00-00 ATP-002, NEC and local municipal codes.

10.8 Remote Cooling Units
10.8.1 CRE PD&C shall be responsible for the design and placement of power to these units in compliance with CRE-23-00-00 ATP-002, NEC and local municipal codes.

10.8.2 Standalone - passive thermal panels do not require power connectivity.

10.9 Power Routing Conflicts
10.9.1 In-Row, close coupled cooling units are typically placed within network equipment space. CRE PD&C shall be responsible for the design and placement of power to these units in compliance with NEC and local municipal codes and routed to not interfere with cable rack/auxiliary framing structures.
10.10 Demand Based Cooling

10.10.1 CRE PD&C shall be responsible for the design and placement of power to these units in compliance with CRE-23-00-00 ATP-002, NEC and local municipal codes.

10.10.2 Network equipment space requiring remote cooling units to be powered by DC power source shall obtain power from network BDFB or secondary power distribution unit supplying power to the lineups. Specific power solutions and fuse assignments shall be obtained by the U.S. Common Systems planner (not COLD) for remote cooling units.

10.10.3 Power cables shall be routed to remote cooling units following similar practices as power for AC network equipment. Cable racks established for secondary power cables of network equipment may be used for routing DC power cables of remote cooling units.

11 ENERGY CONSERVATION

11.1 General

11.1.1 Minimizing energy usage is an essential business objective for all of AT&T. Cooling systems can easily reach one third of the overall energy consumption of an equipment deployment site. Efficiency and efficacy shall be considered on all network equipment cooling designs and deployments.
11.1.2 CRE PD&C shall be responsible for the design and placement cooling systems in compliance with Energy Design Guidelines for our Environment EDGE Standards.

12 CONTROLS

12.1 General

12.1.1 Active and well designed controls are critical to the proper functioning of an integrated cooling system. Improper or incomplete control systems drive inefficiencies or in worst case, can jeopardize network reliability.

12.1.2 Uncoordinated CRAH/C units operating in opposing modes (i.e. dehumidifying and humidifying) called “demand fighting” leads to wasted operating costs and reductions in the system cooling capacity. Effective control systems bring together the operations of disparate cooling units into a single integrated solution.

12.1.3 Control instruments sensitive enough to respond to +/- 2º F temperature and +/- 5 percent relative humidity shall be installed.

12.2 System Controls

12.2.1 “Smart” controls to actively control and effectively utilize a reduced number of active cooling units shall always be considered during the planning phase of a deployment project. Standard cost effective deployment analyses apply.

12.2.2 The Direct Digital Control (DDC) system shall be designed to ensure failures of its main or sub panels does not cause systems to shut down or compromise the operation of the cooling systems. DDC system shall generate alarms for all major and minor system failures affecting network engineering space.

12.2.3 CRE PD&C shall provide a written sequence of integrated operations for each new and revisited multi-element cooling system deployment. The document shall be actively updated with system changes and retained with the job design information on site.

12.2.4 In rooms with multiple redundant cooling units, the units shall be designed with lead and lag configuration.

12.2.5 System controls for CRAH/C systems shall be integrated to assure the systems do not “fight” each other for system balance (cooling or humidity).

12.2.6 Chilled water temperature reset control methods shall not be exercised in building systems feeding chilled water based refrigerant pumping units.

12.2.7 System controls for DRC pumping units is similar to conventional cooling interfaces. Associated control shall be installed as required to achieve the desired sequence of operations. In general, terminal strip connections are available for temperature and humidity sensor inputs.
12.2.8 DDC controls shall be specified by CRE based on the most current controls ATP.

12.3 System Restart

12.3.1 Re-start of room HVAC shall be prioritized, staggered and in sequential order to provide air circulation as quickly as possible.

12.3.2 Building chiller systems shall be designed for priority restart to provide cooling air to equipment room as quickly as possible.

12.3.3 Hybrid cooling systems utilizing DRC as the primary “N” cooling system and forced air (ducted or raised floor plenum) as +1 support shall require coordination of transferring the equipment heat load between cooling units. With the system in a failure mode (+1 - running on forced air), the DRC may not have sufficient heat load needed for a system restart. CRE PD&C shall provide active system management (control system) to phase heat load transfers to assure system restart.

13 ALARMS

13.1 General

13.1.1 All alarms required for monitoring performance of supplemental cooling system shall comply with procedures described in document IOP (Internal Operating Procedure) CRE PD&C Alarm Management Strategy - CRE-50-09-01-IOP-001.

13.1.2 Control wiring for associated alarming points shall be installed as required to achieve the desired sequence of operations. In general, terminal strip connections are available for temperature and humidity sensor inputs, remote cooling unit alarm and condensation detection inputs, and remote general alarm and shutdown outputs. Remote general alarm output may be tied in with the general environmental alarms.

13.1.3 Alarm and control cabling associated with the supplemental cooling devices shall be in accordance with the manufacturer’s recommendations or as defined in the drawings and specifications for the specific project. Consideration shall be made to place the control circuits in a protective flexible conduit from the feed conduit(s) runs.

14 CONSTRUCTION PERMITTING – CODE COMPLIANCE

14.1 General

14.1.1 All designs for cooling systems and work to install systems described in this document shall be performed in compliance with applicable permits and code requirements.
15 SYSTEM MAINTENANCE

15.1 General

15.1.1 CRE PD&C Property Management shall be responsible for performing all preventative maintenance (PM) and repairs on cooling systems inclusive of remote and on demand cooling units.

15.1.2 CRE PD&C Property Management shall follow established AT&T facility maintenance guidelines for cooling systems (e.g., Air Handlers, Chillers, CRAC/CRAHS, DRC, etc.) in support of network reliability.

15.1.3 Maintenance of cooling systems shall be coordinated with the local Operations site team to identify network reliability vulnerabilities and assure the work performed does not coincide with critical network activity (during freeze periods).

15.1.4 Maintenance requirements for refrigerant pumping units and remote cooling units are minimal. Refrigerant pumping unit do not use belts or have fans.

15.1.5 Refrigerant level shall be checked on a regular basis not to exceed a semi-annual period. Refrigerant level is critical to the proper function of DRC systems. DRC systems too low in refrigerant will shut down or fail to restart due to low pump pressure. Property Management shall coordinate service based on BMSE guidelines.

15.1.6 Refrigerant capacity check procedures are manufacturer specific and may be found in the Appendix.
16 GLOSSARY (Definitions /Acronyms)

16.1.1 ASHRAE
American Society of Heating, Refrigerating and Air Conditioning Engineers - Nationally recognized standards organization for thermal management issues

16.1.2 BIM
Building Information Model – Database/CAD program that documents and displays information regarding building infrastructure (e.g., Cooling Systems, Lighting, etc.)

16.1.3 BTU – British Thermal Unit
A traditional unit of energy – approximately 1 BTU is required to heat 1 pound of water 1 degree Fahrenheit

16.1.4 Celsius
Scale and unit of measure for temperature – International

16.1.5 Close Coupled Cooling System (C³S)
A system where the active cooling component(s) (e.g., cooling coil) are located in close proximity to the equipment to be cooled. This is in comparison to a cooling system with remote air handlers that moves cooled air some distance (through ducts or under floor) to cool equipment. DRC is an example of a C³S.

16.1.6 COEF – Central Office Equipment Forecasting - Interface
This program is used to capture Network Planning forecast requirements for equipment floor space power and heat load at the relay rack level.

16.1.7 Cooling Load
This is the total amount of heat energy that needs to be removed from a given area (e.g., room, building, etc). The load is comprised of two parts Latent Heat Load and Sensible Heat Load

16.1.8 COLD
Central Office Layout and Design Engineering team with floor space planning layout responsibility.

16.1.9 Cost Causer Model
AT&T employs a financial funding process that requires the organization or project that is generating the need for capital funding to provide that funding as part of the overall project. If a project is to be deployed in a space, the first user or cost causer – is required to secure infrastructure funding for the space.

16.1.10 CRAC – Computer Room Air Conditioning Unit
An air conditioning system that utilizes an internal cooling source (e.g., compressor) in conjunction with a remote heat exchanger. The unit blows air over cooling coil(s). The unit may be updraft or down draft.
16.1.11 **CRAH – Computer Room Air Handler**
Air conditioning system that utilizes a remote cooling source such as building chilled water. The unit blows air over cooling coil(s). The unit may be updraft or down draft.

16.1.12 **Dew Point**
The temperature where water vapor becomes saturated and condensation begins

16.1.13 **Distributed Refrigerant based Cooling (DRC)**
A close coupled cooling solution utilizing a refrigerant loop to transfer heat from cooling units located near equipment to a remote pumping heat transfer unit.

16.1.14 **Down Draft**
Air enters the cooling unit typically from the top or front of the unit and distributes pressurized air out the bottom or front bottom.

16.1.15 **Dry Bulb Temperature**
Temperature of air that is isolated from radiation or moisture (not considering humidity). Normal reference to air temperature

16.1.16 **Ducting**
Material (usually sheet metal) that contains and directs air within a cooling system

16.1.17 **Ducted Air**
Forced air cooling systems utilize fan(s) to distribute air to specific points in equipment space. This system typically has specific registers aligned with (cold) aisles of equipment.

16.1.18 **EDGE**
Energy Design Guidelines for our Environment is a standard intended to provide some high-level parameters and suggestions for energy efficient design of building infrastructure (e.g., air conditioning)

16.1.19 **EI**
Engineering and Implementation engineer.

16.1.20 **Electronic Job Folder (EJF) - Previously referred to as the “Yellow Wallet”**
Documentation prepared, in an electronic format, by the installation vendor prior to performing work within the immediate equipment area. A copy of the detail specifications, all office drawings (i.e. floor plan and front equipment views, etc.) as well as a copy of all job forms shall be included in the job folder. Refer to Section “E” of ATT-TP-76300 for additional information and applicable forms.

16.1.21 **Fahrenheit**
Scale and unit of measure for temperature – USA

16.1.22 **Flooded Air**
Flooded air cooling systems utilize fan(s) to widely distribute air to an overall equipment space. This system typically does not have specific cold aisle registers
but rather provides cooled air to a general region of equipment space. Equipment exhaust air is typically returned to the system through a common return grill.

16.1.23 **Forced Air**
Forced air cooling systems utilize fan(s) to distribute air to specific points in equipment space. This system typically has specific registers aligned with (cold) aisles of equipment. Forced air systems may be located above the equipment or utilize a raised floor for distributing cooled air. Equipment exhaust air may be returned to the system through a common return grill or specific return air ducting.

16.1.24 **High or Extreme Heat**
AT&T classifies equipment exhaust heat ranges for individual pieces of network equipment. Exhaust heat ranges from 850 Watts - 4kWatts per cabinet are classified as High Heat. Equipment exhaust heat above 4kW per cabinet is classified as Extreme heat. Equipment with High or Extreme exhaust usually requires special cooling considerations.

16.1.25 **Heat Rejection**
The natural flow of heat (air, etc) is from hot toward cold. Cooling systems typically utilize this natural flow to transfer heat that is generated by network equipment to outside of the building where it is released or “rejected” into the atmosphere.

16.1.26 **Inside Air Quality – (IAC)**
A term used to refer to the air quality within a structure supporting human occupants. This addresses such topics as containment source control, proper ventilation, humidity management and adequate filtration.

16.1.27 **In-Row Cooling Unit**
A remote cooling unit associated with DRC that typically is placed in the equipment row alongside of racks or cabinets. The unit has active powered fans that pull air from the rear (typically hot aisle) pass the air through cooling coils and distribute cooled air to the front of the unit (typically cold aisle). Units come in varying kW heat transfer capacity.

16.1.28 **Latent Heat**
The heat released or absorbed by a chemical substance or a thermodynamic system during a change of state that occurs without a change in temperature, meaning a phase transition such as the melting of ice or the boiling of water. In HVAC, Latent Heat refers to the heat content of air resulting solely from humidification.

16.1.29 **List 1**
Power demand rating of equipment.

16.1.30 **NPV**
In finance, the Net Present Value (NPV) or Net Present Worth (NPW)\([1]\) of a time series of cash flows, both incoming and outgoing, is defined as the sum of the present values (PVs) of the individual cash flows. In the case when all future cash flows are incoming (such as coupons and principal of a bond) and the only outflow of
cash is the purchase price, the NPV is simply the PV of future cash flows minus the purchase price (which is its own PV). NPV is a central tool in discounted cash flow (DCF) analysis, and is a standard method for using the time value of money to appraise long-term projects. Used for capital budgeting, and widely throughout economics, finance, and accounting, it measures the excess or shortfall of cash flows, in present value terms, once financing charges are met.

16.1.31 **OTV**
Operating Territory Vendor – Vendor assigned to support network deployments in office

16.1.32 **PAN**
Product Approval Notice – Documentation providing specific product information and formal approval to use equipment in AT&T network.

16.1.33 **PER**
Product Environmental Review. This is an informal review of the thermal environment (cooling system support and heat management/extraction. It provides guidance to COLD, CRE and SIP to determine applicability of deployment in a given space.

16.1.34 **Rear Door Cooling Coil (aka Back of Cabinet or BOC)**
A passive or active cooling coil panel associated with DRC which is installed on the rear of an equipment cabinet. The passive coil system depends on the equipment fans in the cabinet to push exhaust air to the coils. The active system has its own fans to move the air. Hot air is absorbed by the refrigerant in the coils and cooler air is discharged into the rear aisle. The panel is built into a framework which allows the coil encased in a door structure panel to be pivoted or opened like a door. The coil and frame have adaptors developed to allow mounting to standard cabinet enclosures.

16.1.35 **Ride Through**
The amount of time that elapses from a cooling system failure until the inlet temperature of equipment increases to the point of equipment shutdown or failure.

16.1.36 **Plus One (+1)**
A plus one designation is the redundant capacity to continue operations in the case of a component failure. (e.g., If a system requires three cooling units to meet cooling demand, then a fourth unit may be required to pick up the load if one of the three units fails)
Note: +1 may apply to all or a portion of the overall equipment elements

16.1.37 **RNC / RAN**
Radio Network Controller / Radio Access Network

16.1.38 **Register**
An outlet attached to ducting that distributes air
16.1.39 **Sensible Cooling**  
The ability of an air conditioning system to remove dry heat (not humidification) within a space.

16.1.40 **Thermal Conductivity**  
The property of a material to conduct heat

16.1.41 **Up Draft Unit**  
Air enters the cooling unit typically from the bottom or front of the unit and distributes pressurized air out the top or front top.

16.1.42 **Watt / kWatt**  
A measure of power - work performed - 1kW = 1,000 Watts

16.1.43 **Watt-hour(s) / kWatt-hour(s)**  
Unit of measure for energy = level of power (Work Performed) expended over time

16.1.44 **Wet Bulb Heat Load**  
The temperature of air including the affect of contained moisture.

16.1.45 **Woodduck**  
An AT&T server that has equipment specific documentation, including equipment configuration and interconnection drawings.

16.1.46 **Yellow Wallet – See Electronic Job Folder**