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HVAC DESIGN REQUIREMENTS FOR DATA CENTERS

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Abstract: *One of the things definitive for the HVAC system of a Data Center is represented by the potential, major, risk of uncontrolled heat release. Typically, these applications are vital to equipment installed, imply continuity in supply and impose special requirements for temperature, humidity and air filtration so that their failure could cause overheating and damage. Together, these parameters, called limit parameters, are required for the optimal functioning of these equipment types.*

Key words: *HVAC system of a Data Center, parameters, sample calculation.*

1. Introduction

In the design of a data center one must take into account that the equipment is periodically replaced with newer technologies during the period of existence. Equipment is supposed to have between 1 and 5 years lifetime, while the data center itself has an estimated lifespan of 10-25 years [1]. So, during its existence, there may be several cycles of replacing equipment, which leads to the need of changing infrastructure or technological requirements (higher installed power need greater cooling, etc.).

Parameters to achieve in a data center vary according with equipment manufacturer standards, but ASHRAE, 2011 edition, introduced a classification of equipment types depending on the applications they serve [2]:

• Class 1: telecommunications equipment servicing critical applications, located in a building with controlled atmosphere (dew point, temperature, relative humidity);

• Class 2: telecommunications equipment serving media applications placed in a space, office or lab, having a selective control over certain parameters (dew point temperature, and, possibly, relative humidity);

• Class 3: telecommunications equipment serving small applications , set in spaces , offices or mobile environments having control over a small number of parameters (temperature);

• Class 4: POS equipment and industrial applications, with special requirements for protection against climatic factors, special requirements for operation in winter and minimum conditions of ventilation in summer.

2. General Design Criteria

The following are interior design parameters for Classes 1 and 2 as defined

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Design parameters Table 1.

Design parameters for Class 1 and Class 2		
Parameter	**Permissible limits**	**Recommended limits**
Range of temperature control	15°C - 32°C (Class 1) 10°C - 35°C (Class 2)	18°C - 27°C
The maximum rate of change of temperature	5 K/h	
Range control relative humidity	20% - 80% 17°C max. Dew point (Class 1) 21°C max. Dew point (Class 2)	Dew point 5°C - 15°C relative humidity <60%
The filtration	65%, minimum 30% (MERV 11, minimum MERV 8)* *cf. ASHRAE* (Filter M6, minimum Filter M5)* *equiv. EU*	

in ASHRAE, 2011 edition, both tabular and diagram ix.

Acceptable limits of temperature control represent a matter of functionality, while recommended limits temperature control are a matter of reliability.

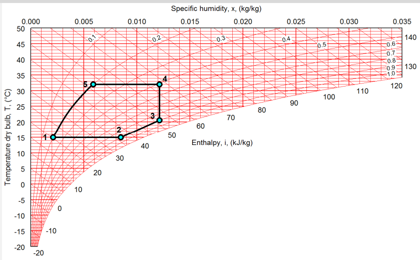
Consequently, operating equipment subject of high temperatures (and / or sudden changes in temperature gradient) is exposed to a higher rate of failure, decrease of service ability or frequent stops caused by built-in thermal protection [3].

Exceeding the recommended limits for short periods is not a threat, but nearly operation permissible limits for a long time can affect system integrity [4], thus, it is recommended that design of infrastructure conditioning ensure continuous operation within recommended instead of allowed parameters.

In Table 2 design parameters are represented by diagrams for permissible limits ix and recommended temperature for

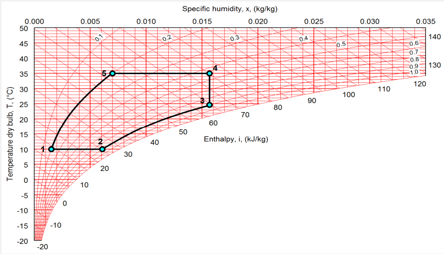
Class 1 and Class 2. Table 2.

Diagram i-x -Clasa 1 - allowable limits



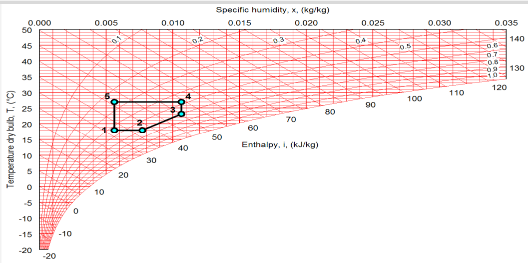
Poin	Temperature(°C)	Temp. Dew point (°C)	Relative humidity (%)	Moisture content (g/kg)
1	15 °C	- 6.9 °C	20 %	2.10 g/kg
2	15 °C	11.6 °C	80 %	8.48 g/kg
3	20.6 °C	17 °C	80 %	12.13 g/kg
4	32 °C	17 °C	40.8 %	12.13 g/kg
5	32 °C	6.2 °C	20 %	5.89 g/kg

Diagram i-x for Class 2 - allowable limits



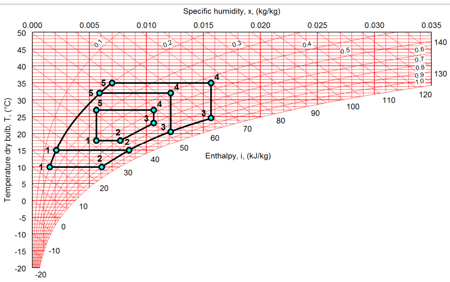
Point	Temperature(°C)	Temp. Dew point (°C)	Relative humidity (%)	Moisture content (g/kg)
1	10 °C	- 10.6 °C	20 %	1.51 g/kg
2	10 °C	6.7 °C	80 %	6.09 g/kg
3	24.7 °C	21 °C	80 %	15.65 g/kg
4	35 °C	21 °C	44.2 %	15.65 g/kg
5	35 °C	8.7 °C	20 %	6.98 g/kg

Diagram i-x -Clasa 1 and Clasa 2 - recommended limits



Point	Temperature(°C)	Temp. Dew point (°C)	Relative humidity (%)	Moisture content (g/kg)
1	18 °C	5.5 °C	43.8 %	5.60 g/kg
2	18 °C	10.1 °C	60 %	7.70 g/kg
3	23.2 °C	15 °C	60 %	10.64 g/kg
4	27 °C	15 °C	47.8 %	10.64 g/kg
5	27 °C	5.5 °C	25.4 %	5.60 g/kg

Diagram i-x - Class 1 and Clasas2 - allowable and recommended limits (overlapping areas)



Air density affects the efficiency of cooling equipment. Most equipment installed in data centers are designed to be used up to a maximum altitude of 3050m. Over an altitude of 900m, a correction is applied to the allowable temperature limit, respectively, a decrease of the upper limit of 1K for each 300m, according to the chart.

The maximum temperature variation rate

Some equipment manufacturers have established explicit criteria for indoor climate variation rate in order to prevent eventual shocks. Maximum temperature input can have a maximum variation of 5 K / h, according to ASHRAE, 2011 edition, for Classes 1 and 2. Humidity variation rate is important in storage units, where conditions are more stringent: variation of 2K/ h and relative humidity 5%/h.

Standard emergency procedures had been developed, considering the main cooling system becomes inoperative, while vital equipment is still operating - a sudden increase in indoor temperature occurs. It is important that the procedure will restore in due time the climate conditions at recommended values in order to avoid thermal shock - overheating.

Generally, when not in use, the equipment can be installed in an environment with a wider range of limitations for control parameters, but it is recommended maintaining them within the limits required in order to avoid thermal shock on the components themselves, even if changes in temperature, humidity, etc. do not occur instantaneously.

Humidity conditions

A high value of relative humidity can lead to defects, excessive wear and corrosion, caused mainly by the appearance of conductive anode filaments (CAF - conductive anodic failures) on electronic boards and deposits of hygroscopic dust (HDF - hygroscopic dust failures) and thus salts. In extreme cases, condense can also occur, especially when equipment are liquid cooled [5].

A low relative humidity can lead to electrostatic discharge (ESD - electrostatic discharge) that can irreparably damage equipment.

The filtration

Before being introduced into the equipment room, the outdoor air should be filtered to remove impurities (dust, etc.). The particles can affect the integrity of the equipment, thus requiring a higher degree of filtration and an adequate maintenance of the filters installed in the air conditioning system. Classification of filters and correlation between ASHRAE specifications and applicable European Norms (EN 779: 2012 and EN1822: 2009) is shown below:

Ventilation

• The interior must have a constant supply of fresh air to ensure:

•pressure in the room;

•correct dilution of pollutants (particularly volatile organic compounds - VOC);

•maintaining conditions required by ASHRAE 62.1 standard;

•maintaining conditions required by national and European standards;

Providing overpressure will prevent pollutants penetration indoors. Calculations regarding pressurization are highlighted in Chapter 9 of ASHRAE edition 2009. In general, the presence of people inside spaces intended for equipment is minimal, but nonetheless this factor should be taken into account during the design of air conditioning system.

Considerations on coating

The criteria for choosing the coating type must comply with the requirements of national and European standards, but the main factors to be considered are:

•The pressurization: a minimum pressure level is provided in order to prevent pollutants penetration inside;

•Degree of isolation: the rooms are isolated both in terms of indoor climate conditions and safety;

•Steam absorption: in order to maintain optimum relative humidity, the difference between vapor pressure inside equipment room and adjacent rooms will be taken into consideration, so that moisture migration is controlled;

•The tightness: crossing cables and pipelines are insulated with non-hygroscopic materials and access routs are perfectly sealed;

•The condensation: regarding exterior envelope, for buildings located in very cold areas, the use of double or triple glazed windows and sealed doors is recommended as to prevent condensation and infiltration. It is recommended to design the data center without windows. If an existing building is used, measures for covering the windows will be taken.

Conditions for human comfort

In data centers, comfort conditions specific to persons are not covered, their presence being a transitory and short-term. Consequently, human comfort is not one of the criteria to be considered in the design theme of the HVAC system.

HVAC system flexibility

As I stated in the introduction, the technology is under continuous and accelerated transformation, so that equipment is frequently changed, rearranged and added during the period of existence of a data center and as a result, the HVAC system serving the unit must be flexible enough to support changes and expansions without major impact on current activity. For critical applications, the system must be modified without interruption. It is then recommended a modular system that will allow efficient cooling of the various tasks.

Acoustic criteria

Total acoustic emission on site is given by the sum of IT equipment emissions and HVAC. With increasing power density and thermal loads of IT equipment, HVAC noise emission had also increased. The limit values are regulated in Europe by the European Directive 10/2003 (EC Directive 2003/10) and subsequent amendments setting out maximum values of noise emissions at work and exposure to them.

Anti- vibration insulation and seismic conditions

The HVAC system must be installed independently to prevent the transmission of vibration to the IT equipment. All the necessary measurement will be taken so that system will be installed in maximum seismic safety and using functional vibration isolators.

3. Heat Release Calculation

Heat release calculation for a data center will take into account that the main releases are the sensible heat from IT equipment, representing a major proportion of the total heat cavities (85-90 % to 100 %).

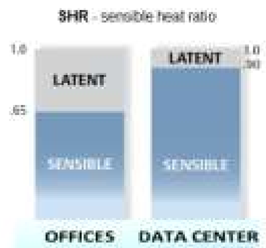


Fig.1. *Main heat release*

$$SHR = \frac{q_s}{q_t} \tag{1}$$

wher:

q_s -is sensibile heat;

q_t -is the total heat;

Depending on the ratio of sensible heat, cooling systems can be classified into two categories:

- Cooling systems to achieve thermal comfort (human);
- Precision cooling systems;

Therefore, in the case of data center cooling system we will consider a precision system designed to remove the heat released by the sensitive equipment, and possible moisture (much less).

Calculation procedure of heat release must consider that there may be other heat sources alongside IT equipment, and dimensioning based on W / m2 principle or W/equipment, can leave aside a significant amount of heat (emitted by network of electrical wiring, lighting, other related equipment - UPS, heat inputs from other rooms, etc.).

A proper design of a HVAC system account for all kinds of interior heat sources, and establishes long-term energy strategy, in order to identify the degree of modularity of the system.

For example, in a new data center, designed to be upgraded regularly, operation in the first part of its life is performed at a partial load capacity and the heat gains through the envelope, the lighting and other sources can be important, not at all negligible in partial capacity operation.

To assess the heat releases in the area, there have been developed different methods for fast calculation based on the total amount of emissions of heat from components of the data center : Basic releases - IT equipment , UPS , power distribution system , lighting , human and other HVAC related equipment and possible- releases and other contributions (coating and adjacent spaces) [6];

Evaluation implies a set of standardized rules and principles. Effectiveness of UPS and power distribution systems determine fixed heat values, proportional with the workload. Releases from lighting and humans are calculated using standard values.

Heat dissipation of IT equipment can be concentrated, irregular, distributed or variable. Equipment that generates an important amount of heat has own fans and active cooling system that intakes air from the room and passes it through the machine.

Heat from HVAC related equipment present in the room (fans, compressors) are assumed to be discharged directly outside, therefore, they are not usually taken into consideration. Instead, these emissions are taken into account when calculating the total efficiency of the cooling system (it drops by discharging more heat from its own subcomponents).

Other heat inputs may exist in a lower percentage: the coating, the adjacent spaces, etc. and it must be quantified only if it is to believe they can influence in a considerable degree over indoor climate.

Depending on the input, heat release results will lead to a first conclusion on the cooling system requirement.

In general, data centers operate at a reduced electric load factor, electrical power absorbed hovering around an average of 30 % (start value - the first 2 years) and 80-90 % (the end - after 5 years). The efficiency of electrical distribution and UPS decreases once the power absorbed decreases, thus influencing on the amount of heat released and increasing their percentage of the total heat emission.

4. Sample Calculation for a Data Center

with the following features:

-IT equipment power: 250 kW

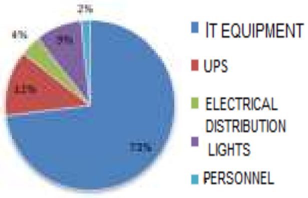
-UPS installed power: 250 kW

-electrical power distribution system: 280 kW

-surface: 465 m².

-personnel: 20 people

-resulting cooling thermal load: kW 113.63 at 30 % and 265.57 kW at 90%.
Weighted load 30% (113.63 kW)



Weighted load 90% (265.57 kW)

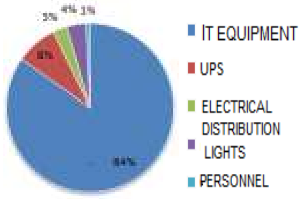


Fig. 2. *Share of heat release*

The share of total energy consumption is the energy consumption of IT equipment, with a typical value of about 52% of the total, followed closely by energy consumption of HVAC system, with a typical value of 37 %. The remaining 10 % represent consumption with other systems, including energy losses due to electrical conversion.

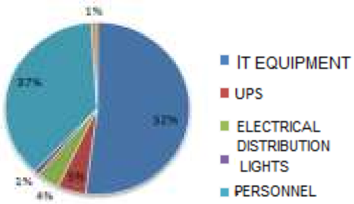


Fig. 3.*The shares of the total consumption - typical values for a data center*

According to the chart, the amount of power use efficiency (PUE) would be 1.92. The current trend in the field is the steady growth of installed power equipment per square meter, which implicitly leads to higher heat release and the need for accurate projections based on thermal footprint (W / square meter).

An unfair practice resulting from such a chart would be using the data for a quick dimensioning method, W / square meter, without taking into account the type of equipment served by the system.

Fig. 4. *History of IT equipment installed power impressions (W / square meter)*

5. Heating and Reheating

Thermal heating demand in a data center is minimal, if we refer only to the equipment room, due to important sensible heat released by them. However, HVAC system design must take into account that these releases may be minimal in the first operational period and may not cover the necessary heat to maintain internal conditions within the recommended range. Therefore, the system must be equipped with a heating mode to compensate for thermal differences in exceptional cases (e.g. small releases of large equipment and envelope losses).

Some systems can use reheating to adjust humidity. This process should be closely monitored and controlled as successive processes of heating and air cooling can lead to energy waste.

Humidification

Humidification and / or dehumidification play an important role in the treatment of indoor air. In most cases, the main contributor of moisture is the outdoor air.

Where there is no supply air humidification process, measures against discharges are taken, such as special equipment for earthing personnel.

Thermal density

Some equipment that can power a data center may exceed the 30-40 kW heat released. This leads to the need for detailed knowledge of the setup and heat density releases in order to properly design the HVAC system. In such cases, a local cooling system will be provided conjunct with the central system.

To conclude, even if the HVAC system as a whole, is covering all cooling demand, uneven heat release neglect can lead to overheating in certain areas and the inability to maintain an appropriate climate.

Following the technological advancement of equipment, as well as increased cooling requirements, there may be situations where cooling air no longer represent a viable solution. This is where liquid cooling techniques intervene, which may include: cooling water, refrigerant, or biphasic dielectric fluids.

6. Conclusions

A proper design of the HVAC system must take into consideration all types of interior heat sources, focusing on establishing a long-term energy strategy and identification of the modularity degree of the system. The HVAC system serving the unit must be sufficiently flexible, capable to handle changes and expansions without a major impact on the activity.

The current trend in the field is the steady growth of installed power equipment per square meter, which implicitly leads to higher heat releases and the need for accurate projections based on thermal impression (W / square meter).

In the first period of operation of a data center , the average ratio of cooling load installed and the real demand is five (times) , decreasing as the average load capacity increases, and reaching a final value of approximately 2 (times) . The latest data centers are using variable air volume systems, operating based on inlet temperature and / or actual workload.

The most significant share of total energy consumption is the energy consumption of IT equipment, with a typical value of about 52% of the total, followed closely by energy consumption of HVAC system, with a typical value of 37 %. The remaining 10 % represent consumption with other systems, including energy losses due to electrical conversion.

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