# CAPACITY-CONTROLLED VS. ON/OFF AC & DC AIR CONDITIONING FOR ELECTRONICS COOLING

EHSAN B. HAGHIGHI
PHD, THERMAL SPECIALIST
DANTHERM COOLING AB

CHRISTIAN SAKSTRUP
SENIOR PROJECT MANAGER, ELECTRONICS
DANTHERM COOLING A/S

ORLA LANG SØRENSEN
SENIOR MECHANICAL ENGINEER
DANTHERM COOLING A/S

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## WHAT YOU NEED TO KNOW - IN BRIEF

- **This white paper compares three types of air conditioning in a real-life test: DC air conditioner, capacity-controlled. DC air conditioner, on/off-controlled. AC air conditioner, on/off-controlled.**
- **Test design: time span: 14 days, heat load: 800W, set point: 25°C, parameters: power consumption and temperature fluctuations, tested units: Dantherm AC and DC air conditioners, on/off- and capacity-controlled**
- **Results: the capacity-controlled DC air conditioner showed significantly lower power consumption than the other tested units, as well as lower temperature fluctuations.**
- **Recorded power consumption for the full test period:**

| | |
|---|---|
| **DC air conditioner, capacity-controlled** | **= 62 kWh** |
| **DC air conditioner, on/off-controlled** | **= 74 kWh** |
| **AC air conditioner, on/off-controlled** | **= 131 kWH** |

## 1. INTRODUCTION

Air conditioning is a common choice for excess heat removal in Telecom shelters, cabinets and enclosures because of their precise and efficient cooling performance. For some applications, the use of an AC air conditioner is seen as the obvious choice because of available power sources. For others, budgets determine the choice of AC air conditioning.

DC air conditioning, however, offers wider possibilities in terms of energy savings and operational stability in weak power networks, especially when capacity-controlled. Inspite of this, the industry still demonstrates a preference for AC air conditioning - even where DC air conditioning is a viable option.

This white paper discusses the differences of AC and DC air conditioning in terms of on/off versus capacity-controlled cooling. Furthermore, the results of a real-life test are presented to illustrate the functions of the investigated technologies and to support related conclusions about power consumption and temperature stability.

# 2. COMPARATIVE STUDY BACKGROUND

Air conditioners are a common choice for excess heat removal in the Telecom and electronics cooling industry, because of their precise and efficient cooling performance. For some applications, AC air conditioning is the ideal choice. For others, a DC-based solution offers more benefits. Common to the choice of one or the other are often non-affectable factors such as location or available power sources.

But in some areas of the electronics cooling industry, there is a tendency to choose AC air conditioning inspite of the fact that DC air conditioning is an option. The main reasons for this are quite simply price and availability. Among those who do choose DC-based air conditioning solutions, the trend shows a preference for on/off control, as known from AC-based solutions. This leaves the option of capacity-controlled DC air conditioning, which in the industry remains relatively unexploited inspite of the strengths of this technology in terms of maintaining stable temperatures and generating energy savings.

# 3. TEST OBJECTIVES AND DESIGN

The aim of this study is therefore to clarify and illustrate the difference between applying on/off-controlled AC air conditioning, on/off-controlled DC air conditioning and capacity-controlled DC air conditioning in terms of power consumption and temperature variations.

The study is based on real-life testing of three identical enclosures (cf. figure 1) cooled by three different air conditioning solutions (cf. table 1). The internal temperature set point was 25°C and to model heat generation from ICT equipment, two 400W electrical AC heaters (in total 800 W) were installed inside each enclosure. For each setup, enclosure and supply temperatures (exit from the air conditioning unit), power consumption and compressor RPM were recorded every minute for 14 days.

Figure 1: Test enclosures. Dimensions: 2.25*1.75*0.9m. Wall thickness: 60mm.

## 3.1 OPERATIONAL LOGIC

Common to all three enclosures are a constant internal heat load (cf. section 3) and variable external temperatures. The three air conditioners were all activated when the internal temperatures increased above set point. Being on/off-controlled, two of the tested air conditioners would be activated with 100 % fan and compressor speed. The capacity-controlled air conditioner fan and compressor would be running continuously, controlled according to the cooling demand.

## 3.2 TEST COMPARABILITY

With a view to ensuring comparability, the test is based solely on Dantherm air conditioners representing the same cooling capacity (cf. table 1). With reference to section 3, all three units are required to remove an equal heat load of 800 kW.

| Cooling type | Model | Cooling capacity (W) | Power |
|---|---|---|---|
| AC air conditioner, on/off-controlled | Dantherm AC Air Conditioner 4000 | 1055* | 230V, 50 Hz |
| DC air conditioner, on/off-controlled | Dantherm DC Air Conditioner 1000 | 1000* | 48V DC |
| DC air conditioner, capacity-controlled | Dantherm DC Air Conditioner 1000 | 1000* | 48V DC |
| * at 35°C internal/ 35°C ambient | | | |

Table 1: Test unit characteristics

# 4. TEST RESULTS

The displayed data in table 2 represents the entire test period.

| Cooling type | Power consumption (kWh) | Index |
|---|---|---|
| AC air conditioner, on/off-controlled | 131 | 211 |
| DC air conditioner, on/off-controlled | 74 | 119 |
| DC air conditioner, capacity-controlled | 62 | 100 |

Table 2: Power consumption for the 14-day test period.

## 4.1 TEMPERATURE AND RPM RECORDINGS

Figures 2-5 represent a time period of 24 hours of the test period. Recorded weather data for this period: 10-20 ºC.

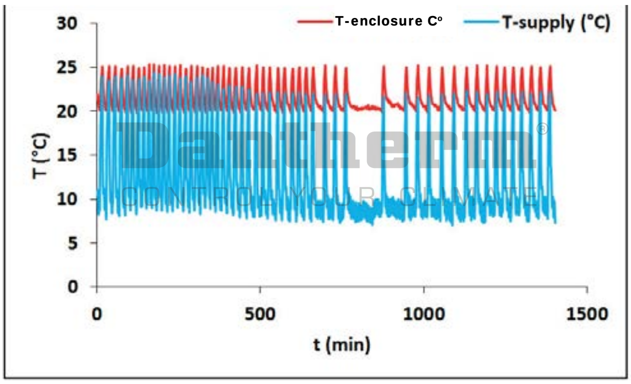


Figure 2: Supply air / enclosure temperatures for AC on/off.

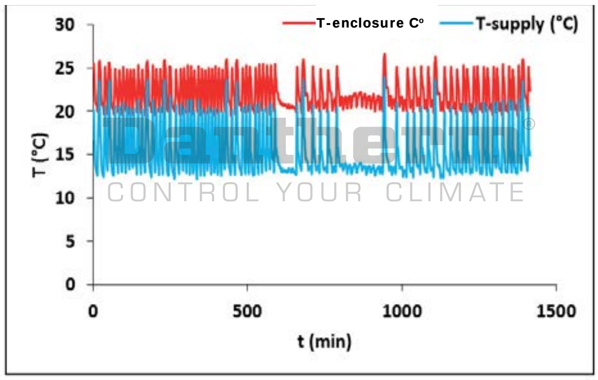


Figure 3: Supply air / enclosure temperatures for DC on/off.

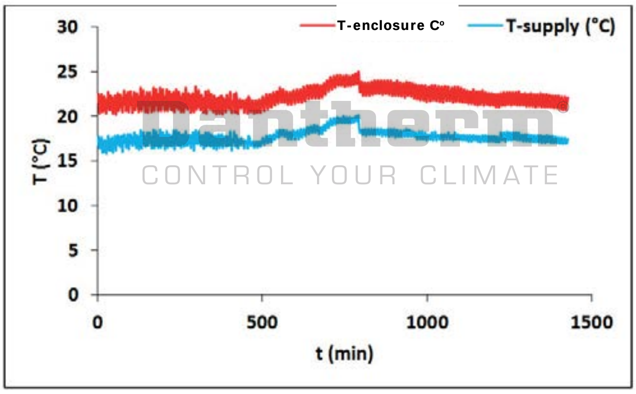


Figure 4: Supply air / enclosure temperatures for DC capacity control

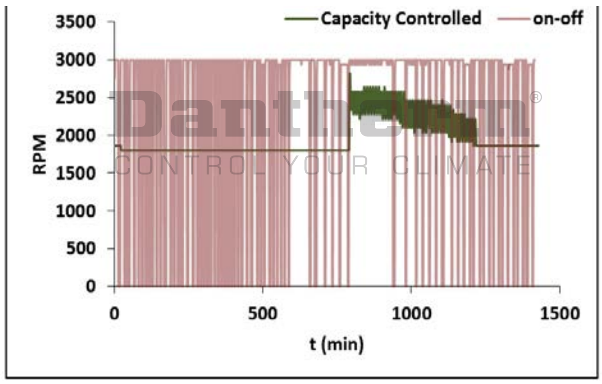


Figure 5: Compressor RPM for all units

| Test unit | Supply air temperature | Enclosure temperature | Compressor RPM |
|---|---|---|---|
| AC air conditioner, on/off-controlled | 8-24°C | 20-25°C | 0-3000 |
| DC air conditioner, on/off-controlled | 12-22°C | 20-25°C | 0-3000 |
| DC air conditioner, capacity-controlled | 16-20°C | 20-25°C | 1800-2800 |

Table 3: Recorded temperature and compressor RPM for 24 hours of the test period.

# 5. COMPARATIVE STUDY SUMMARY AND CONCLUSIONS

## 5.1 AC AIR CONDITIONING, ON/OFF-CONTROLLED

The test shows how the AC on-off air conditioning system generates a stable internal set temperature with a high amount of cooling over correspondingly short activation periods (cf. figures 2 and 5 + table 3). In other words, the temperature variations are high and the set temperature is reached quickly. Figure 5 illustrates the operational logic of the compressor, activated on/off at 100 % for this unit.

## 5.2 DC AIR CONDITIONING, ON/OFF-CONTROLLED

The DC on-off air conditioning system generates a stable internal set temperature with lower temperature fluctuations than those of the AC on/off air conditioning system (cf. figure 3 + table 3). Like discussed in section 5.1, figure 5 equally illustrates the operational logic of the compressor, activated on/off at 100 % for this unit.

## 5.3 DC AIR CONDITIONING, CAPACITY-CONTROLLED

The results of the DC capacity-controlled air conditioning system show the exact same internal temperature range as the other two units - a good demonstration of the uniform efficiency of all three tested technologies (cf. figure 4 + table 3). Interesting about these final test results, however, is the supply air temperature, which for the capacity-controlled unit varies significantly less than those of the other two units (cf. table 3). This is a clear demonstration of the result of capacity-regulated compressor and fan speed.

Illustrated in figure 5, the compressor RPM is regulated according to the present cooling demand. This means that the compressor runs continuously at the exact pace needed to maintain the cooling set point, except for a limited time period when excess cooling is needed. For the limited period of RPM increase for this unit, it is evident that not compressor nor fans operate at full speed. The result of this operational logic is more stable temperatures and significantly lower power consumption, illustrated in table 2.

## 5.4 CONCLUSIVE NOTES

The aim of the present study was to clarify the differences between three different, equally efficient air conditioning systems, yet with different power sources and control strategies in terms of the investigated parameters of temperature variations and power consumption. The test results clearly support the claim that capacity-controlled DC air conditioners generate much higher savings than on/off-controlled DC air conditioners and traditional AC air conditioners.

In a real-life test conducted for 14 days, the DC air conditioner (capacity-controlled), DC air conditioner (on/off-controlled) and AC air conditioner (on/off-controlled) applied 62, 74 and 131 kWh respectively to cool identical enclosures and heat loads. This is a maximum difference in power consumption of more than 100% (cf. table 2 indexation), resulting in significant energy savings and reduced wear of compressor and fans. Finally, DC air conditioning is generally a more environmentally friendly, safe choice in unstable power networks. In conclusion, capacity-regulated DC air conditioning creates higher savings and increased stability for Telecom and electronics cooling applications in DC-ideal environments, compared with the related technologies of this study.

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