Technical Article

How the air throw of air coolers is influenced by the spatial geometry and by air cooling

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Main topics:

- Air throw of an air cooler: Measurements at ideal conditions vs. actual conditions on site
- Description of the development of a calculation model taking into account the influence of parameters like Coanda effects, air cooling and spatial geometry
- Comparison of the results of the calculation model with test measurements

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Summary

The air throw of an air cooler is the distance to the air cooler where a minimum air speed of 0.5 m/s can be measured in the centre of the penetrating air current. The indications in the manufacturer's data sheets are based on measurements at ideal conditions and do not take into consideration the influence of spatial geometry and of the temperature of the ingoing air.

The air throws indicated in the data sheets are often not achieved in practice, because low ceiling height reduces the air throw or because the temperature difference between the ingoing air jet and the air in the room causes premature flow separation at the ceiling.

Based on theoretical calculations and laboratory measurements, we have developed a model for calculation that allows determining the depth of penetration of the air jet for each specific room individually. Here the influences of the spatial geometry are considered as well as the influences of low temperature of the incoming air.

For measuring the air throw in a room, the measuring technology has to satisfy very high requirements. In our laboratory measurements, we have recorded with state-of-the-art measuring methods the velocity and the direction of air flow in every measuring point and have transferred this data in a flow model.

In the presentation we will show how the spatial geometry and air cooling influences the air throw of air coolers and give a comparison of the measurements with the results of our calculation model.

Key words: air throw, spatial geometry, air cooling, Coanda effect, depth of penetration

Introduction

For planning a cold room, customers need data for the penetration depth of the air cooler's air jet. The penetration depth is in general described as air throw of the air cooler. The manufacturer's indications about the air throw are based on measurements and theoretical calculations at ideal conditions in large rooms (the room is larger than the air throw, isothermal air circulation without cooling, no installation parts disturbing the air flow).
The arrangement of the coolers, the spatial geometry, the air cooling and the installations in the cold room can not be considered in the manufacturer's data sheets, because the specific data of the rooms is not known.
The air throw data indicated in the data sheets are thus only reference values that have to be adapted for the specific cold room.
In many planning projects, however, these values are adopted without correction; this leads in consequence to the fact that the planned air throw of the air jet is not achieved in the cold rooms.
For estimating the air throw that is effectively achieved in practice, a detailed knowledge of the room’s geometry, the temperatures and a high degree of experience are required.
For achieving a higher planning reliability for estimating the air throw, we have created a calculation model that takes into consideration the influences of the Coanda effects, the air cooling and the spatial geometry.
With this calculation program it is possible to determine approximately the penetration depth of the air jet for each air cooler for a defined room.

1 Task and objective

1.1 Task
Creation of a calculation program for spread of the air jet in a defined room in consideration of the Coanda effects, the air cooling and the spatial geometry.

1.2 Measurement of the air flow

Measurements of the air flow in the penetrating air jet with indication of the air velocity and direction.
Visualisation of measurement results

1.3 Comparison of measurement results

Comparison of measurement results with theoretical calculations of the new calculation model.

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1.4 Objective

Creating a calculation program that allows determining the air throw of the air coolers for different rooms during planning. Here the influences of cooler arrangement, air cooling and spatial geometry shall be taken into consideration.

2. Air throw and state of the art

2.1 How is the air throw of an air cooler defined?

According to the current definition, the air throw of an air cooler is the distance between the air cooler and the furthest away point, where an air flow velocity of 0.5 m/s can be measured in the penetrating air jet (see Figure 1).

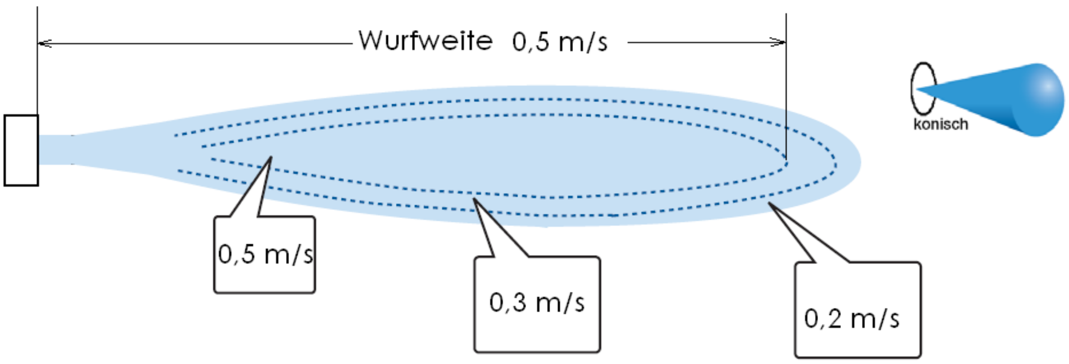

Figure 1: Definition of the air throw of an air cooler

DE	EN
Wurfweite 0,5 m/s	Air throw 0.5 m/s
konisch	conical

2.2 Previous measurements of the air throw

For determining the air throw, the air cooler is installed on a plane surface (on the floor or below the ceiling). The fan of the air cooler is turned on and the boundary layer of the air flow is determined at a minimum velocity of 0.5 m/s.
For achieving the length of the possible air throw, the measurements are carried out in rooms that are in any case longer than the possible air throw. In these mostly high and broad rooms, the air flow is from experience rarely influenced by back-flowing air. Cooling of the air is not taken into consideration. The thus determined air throw is the maximum attainable air throw according to the draft 328 by the VDI (Association of German Engineers).
The measurements are in general carried out with measurement instruments that only record the velocity, but not the air flow direction. These measurements give reference values for the possible penetration depth of the air jet, but they are very theoretical and often do not give practice-relevant information for a cold room (see Figure 2).

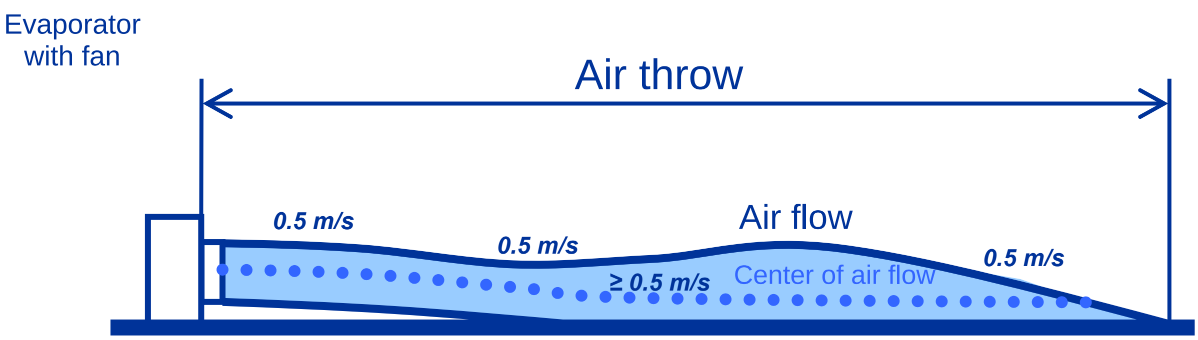

Figure 2: Measurement of air throw with previously used procedures

2.3 Why is the air flow velocity often not achieved in practice?

In practice, cold rooms have very different designs:

- The air flow is disturbed by racks, installed components, lamps or girders below the ceiling.
- Depending on the design, the air is often cooled down in the air cooler by 2 K to 5 K, and reaches prematurely the point of flow separation at the ceiling.
- The penetrating air jet is influenced by back-flowing air that is caused by a low ceiling height or by installed components in the room.

3. Creation of the calculation model

For the calculation model the following was required:
Calculation of the spread of the air jet in a pre-defined room by taking into consideration the Coanda effects, air cooling and the spatial geometry.

3.1 Influence of the Coanda surface effect

The Coanda surface effect occurs if a unit is installed close to a plane surface, e.g. in a cold room below the ceiling. The air flow streams close to the plane surface and does not spread conically, but semi-conically. This effect increases the air throw by up to 40 % (see Figure 3). If the air coolers are not placed directly below the ceiling, the Coanda surface effect can only be achieved in part or not at all.

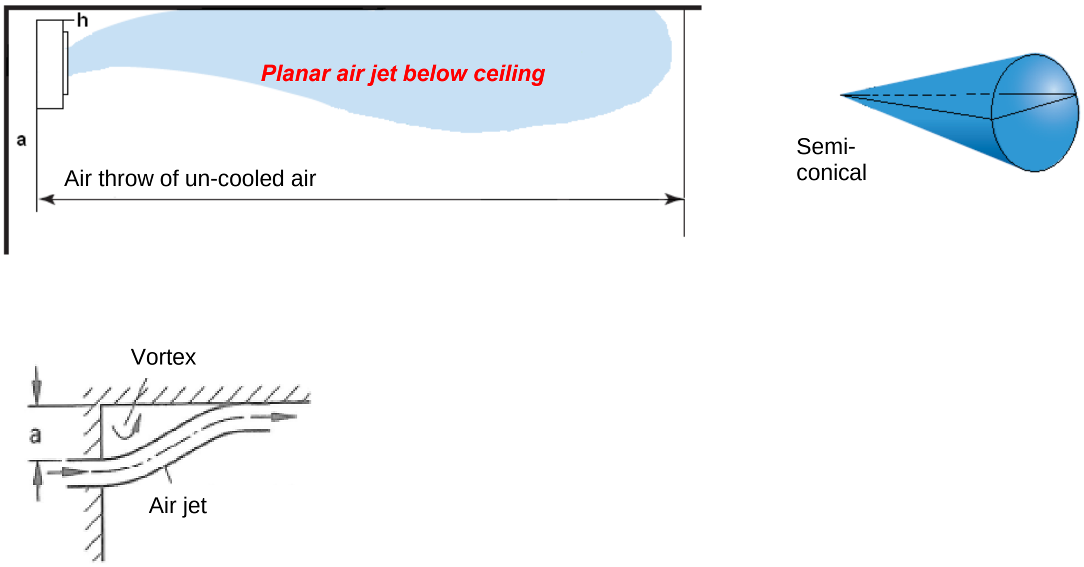

Figure 3: Influence of the Coanda surface effect

3.2 Influence of the Coanda parallel flow effect

If several air coolers are mounted close to one another, the penetrating air flow of the individual fans flows together. This effect increases the air throw by 10 - 20 % (see Figure 4).

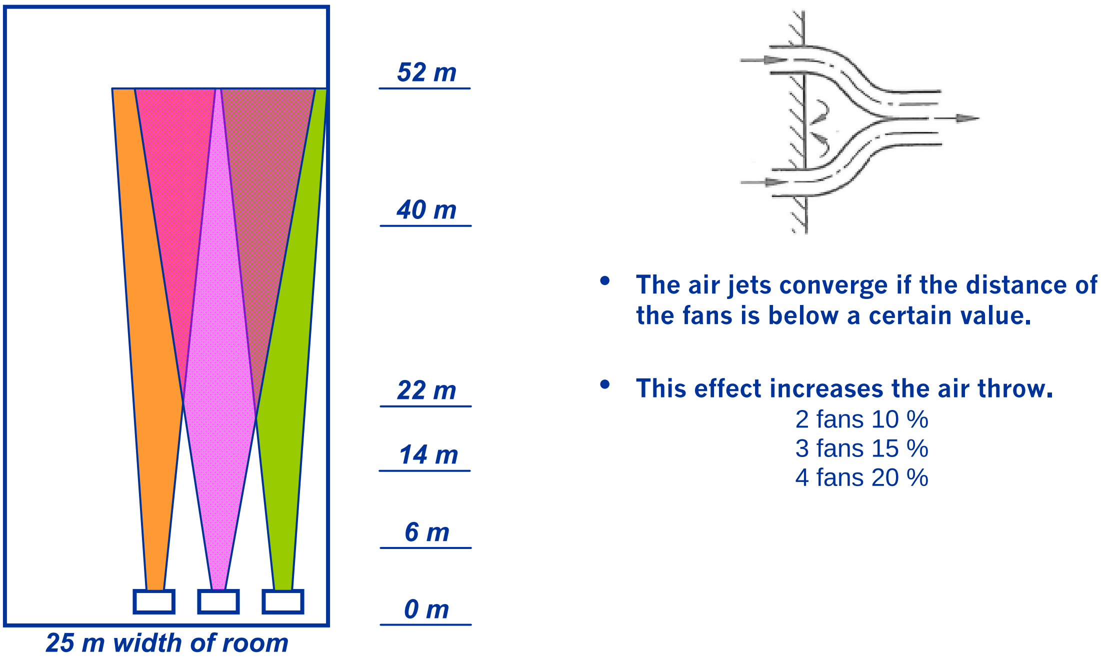

Figure 4: Influence of the Coanda parallel flow effect
In the calculation model both Coanda effects shall be taken into consideration for calculating the spread of an air jet.

3.3 Influence of air cooling

Besides the influence of the Coanda effect, also the influence of air cooling will be considered in the calculation model. Compared to isothermal air circulation, the separation point of the air jet at the ceiling occurs prematurely with cooled air. After the separation point, the semi-conical air jet at the ceiling becomes an almost conical free air jet (see figure 5). Especially at distances over 40 m, the air throw can decrease by up to 25 % due to air cooling (see Figure 6).

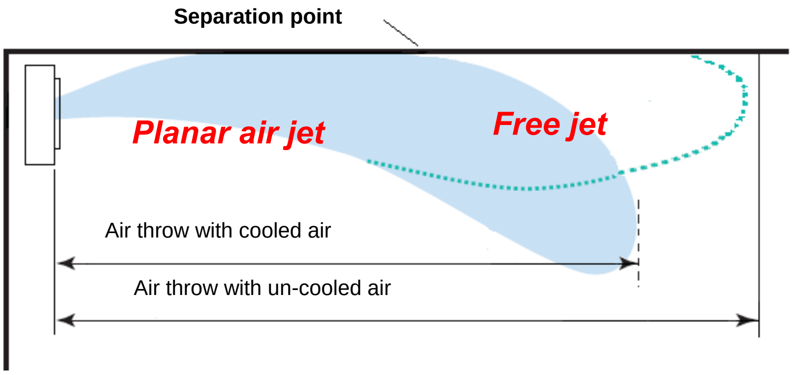

Figure 5: Consideration of Coanda effects and air cooling in air spread calculation of air throw

Einfluss der Luftabkühlung auf die Wurfweite bei einem definierten Luftkühler

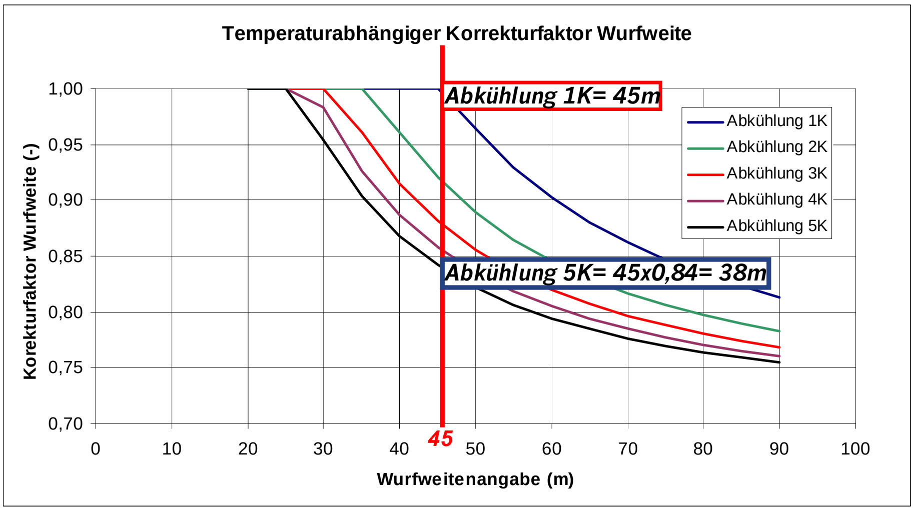

Figure 6: Influence of air cooling on air throw with a defined air cooler.

The calculation program considers the temperature of the incoming air compared to the ambient air in the room and calculates the separation point x of the planar air jet at the ceiling and the effectively achievable air throw.

DE	EN
Temperaturabhängiger Korrekturfaktor Wurfweite	Temperature-dependent correction factor for air throw
Abkühlung	Cooling
Abkühlung 1 K = 45 m	Cooling 1 K = 45 m
Abkühlung 5 K = 45 x 0.84 = 38 m	Cooling 5 K = 45 x 0.84 = 38 m
Korrekturfaktor	Correction factor
Wurfweitenangabe (m)	Air throw in meters (m)

3.4 Influence of the spatial geometry

The cross-section of the room in longitudinal direction of the air flow has influence on the penetration depth of the air jet.
The penetrating air jet spreads ellipsoidally below the ceiling and is influenced at increasing distance by the back-flowing air, especially in the case of small room cross-sections.
The calculations have led approximately to the following result:
If the cross-section of the incoming air jet achieves approximately 40 % of the room cross-section, the air flow is disturbed by the back-flowing air and the air changes its direction and flows back (see Fig. 7).

Figure 7 Room cross-section in air direction
With the calculation model, the form of spread of the incoming air flow is calculated approximately as semi-circle and not as ellipse. Comparative measurements have shown that with this procedure sufficiently precise results are achieved.

DE	EN
Raumbreite B	Width of room B
Platz für rückströmende Luft	Room for back-flowing air
Raumhöhe H	Ceiling height H
Grenzschicht mit Geschwindigkeit von 0,5 m/s	Boundary layer with air velocity of 0.5 m/s

The height of the room has influence on the penetration depth of the air jet.

Separation point X
If the separation point X of the planar air jet at the ceiling is attained, the free jet, that forms subsequently, still has an effective penetration depth of once or twice the ceiling height (see Figure 8).

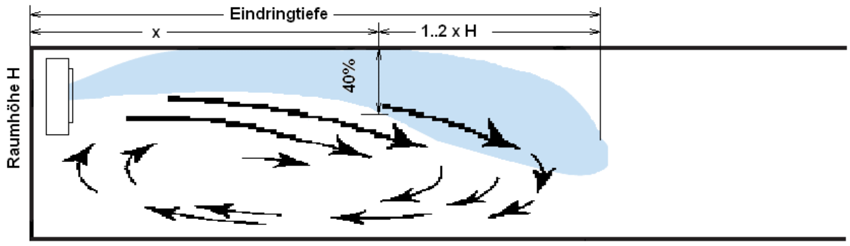

Figure 8: Separation point X and effective penetration depth

DE	EN
Eindringtiefe	Penetration depth
Raumhöhe H	Ceiling height H

Primary vortex:
The driving force for the primary vortex is the penetrating air. The flow energy that is contained in the air jet is dissipated by aspirating ambient air from the room and mixing it with the air jet (induction). This means that the air jet increases its air volume on its passage through the room, and thus its velocity decreases, while the different temperatures equalize (see Figure 9).

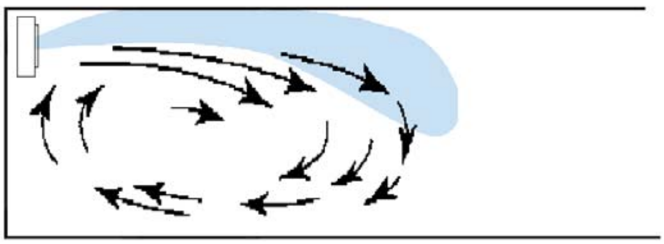

Figure 9: Effective length of primary vortex
The maximum extension of the primary vortex is according to today's experience at approx. 3 – 4.5-times the ceiling height, after this, secondary vortices occur.

Primary and secondary vortex:
If the relation of the room length to the ceiling height is larger than 4.5 : 1, a perfect air flow through the cold room by primary vortex is not possible (see Figure 10).

Figure 10: Primary and secondary vortex

DE	EN
Raumhöhe H	Ceiling height H
Eindringtiefe 4,5 x Raumhöhe H	Penetration depth 4.5 x Ceiling height

3.5 Summary

With the calculation model, the penetration depth of the air flow in a room can be determined individually.
For calculation, the following is taken into consideration

- the Coanda effects,
- air cooling
- and the spatial geometry**.**

4. Measuring the air throw with a 3D measuring system

When measuring the air throw, it is important to consider, besides the air velocity, also the air direction. Common measuring instruments, e.g. revolving vane anemometers or thermal anemometers are not suitable for this.
Both measuring methods record only the air velocity and do not give any information about primary or secondary vortices or turbulences in the air flow.
For our measurements we have used a new 3D measuring system.
This 3D measuring sensor (see Figure 11) is a ball with openings in different places. This complex measuring sensor records smallest air velocities as well as their direction of flow.
With a computer model a three-dimensional graphics of the air flow of the penetrating air jet can be created (see Figure 12).
A clear distinction of primary and secondary air flow is thus possible.

Figure 11: Measuring sensor of the 3D measuring system

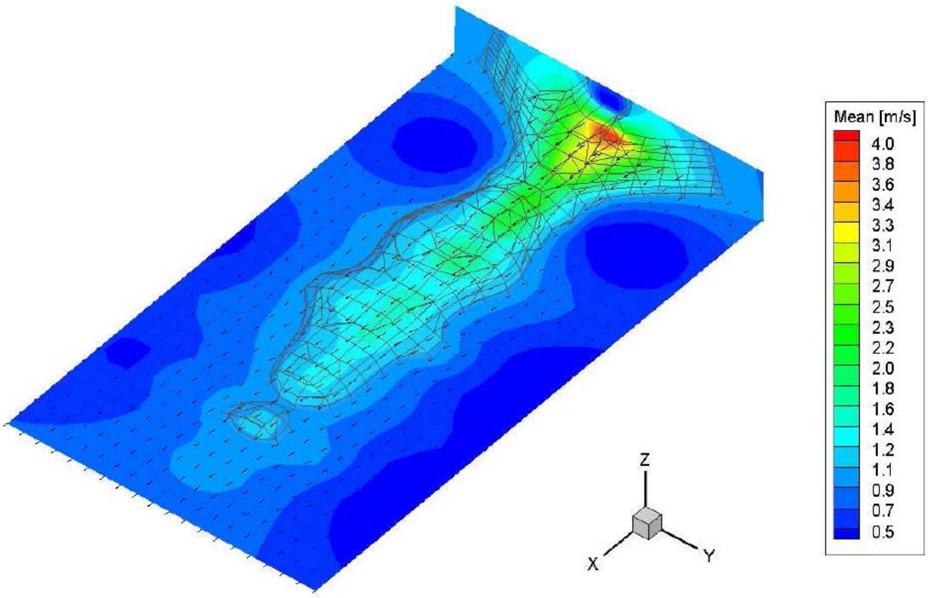

Figure 12: Three-dimensional graphics of air flow

5. Comparison of measuring results with calculations

5.1 Comparative measurements of Coanda effects

First comparative measurements show a good consistency between the calculated data from the new calculation program and the measured data from the 3D measuring system.
The influence of the Coanda surface effect is sufficiently well recorded by the calculation program (see figure 13).

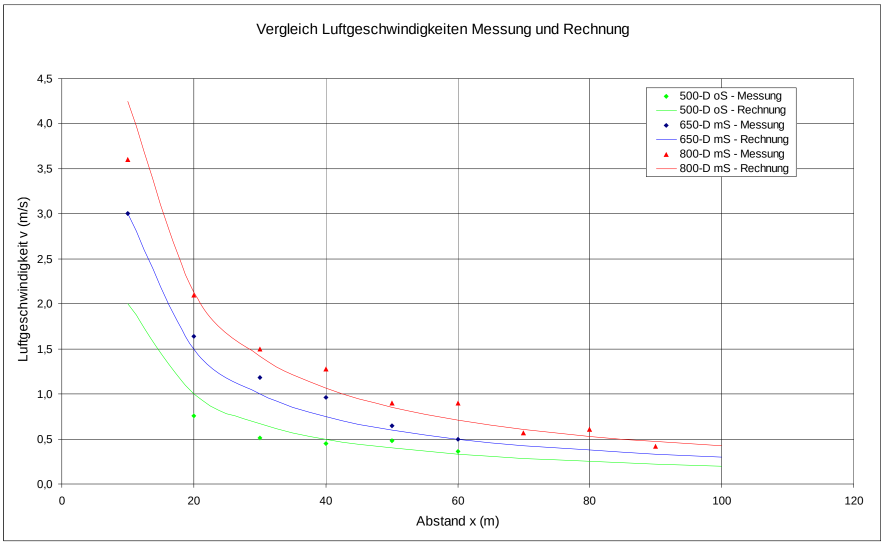

Figure 13: Comparison measurement / calculation

The Coanda parallel air flow effect is sufficiently well represented (see Figure 14).

DE	EN
Vergleich Luftgeschwindigkeiten Messung und Rechnung	Comparison Air velocities Measurement/Calculation
Messung	Measurement
Rechnung	Calculation
Luftgeschwindigkeit v (m/s)	Air velocity v (m/s)
Abstand x (m)	Distance x (m)

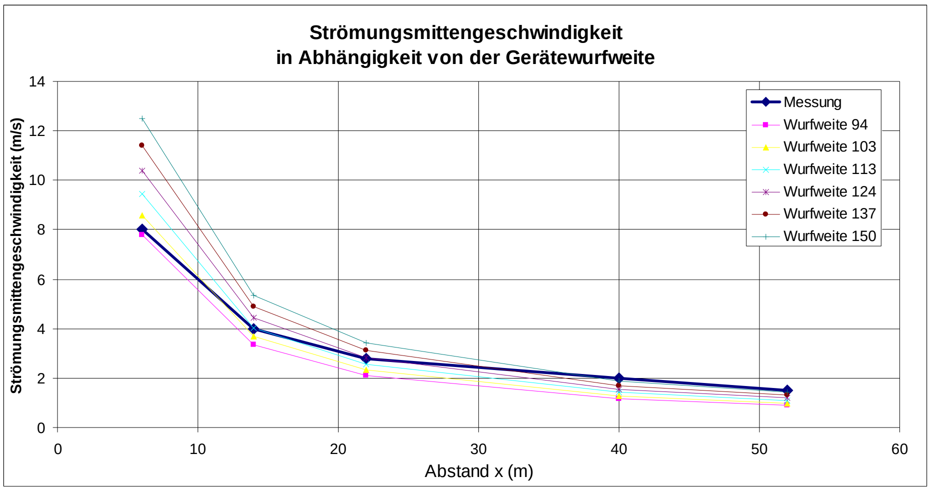

Figure 14: Comparison measurements / calculations

DE	EN
Strömungsmittengeschwindigkeit in Abhängigkeit von der Gerätewurfweite	Velocity at center of air flow depending on air throw of unit
Messung	Measurement
Wurfweite	Air throw
Strömungsmittengeschwindigkeit (m/s)	Velocity at center of air flow (m/s)
Abstand x (m)	Distance x (m)

5.2 Comparative measurements of the air flow profile

The air flow profile has been measured at 5 m distance and at 16 m distance. The discrepancy between the measured surface (semi-ellipse) and the calculated surface (semi-circle) is very small.
Also in this point the calculation model is sufficiently precise.

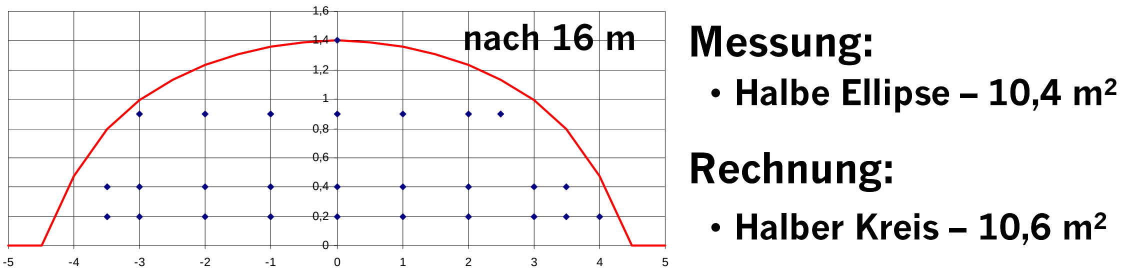

Figure 15: Comparison measurements / calculations

DE	EN
nach 16 m	at a distance of 16 m
Messung: halbe Ellipse – 10,4m²	Measurement: semi-ellipse – 10.4 m²
Rechnung: halber Kreis – 10,6 m²	Calculation: semi-circle – 10.6 m²

5.3 Summary

The developed calculation model gives reliable reference values for determining the effective penetration depth of the air jet in a defined room.
The Coanda effects as well as the air cooling and the spatial geometry have in part a considerable influence on the penetration depth of the air flow and the air throw of the air cooler.
All above-mentioned factors are recorded in the calculation program and their influence is, according to our current experiences, calculated sufficiently precisely.

5.4 Outlook

For determining the accuracy of the calculation model, further measurements have to be made.
These measurements, however, should not only be executed in a laboratory, but also in practice.
After this, the calculation program will be available at Güntner.
Then we can give our customers for precise applications a much better estimation of the penetration depth of the air jet in a defined cold room.

Reference list

- Recknagel Sprenger Schramek ,
  Taschenbuch für Heizung und Klimatechnik 03/04 (pocket guide for heating and air conditioning 03/04)
- Draft ENV 328
- Systemair@com: Theory air conditions