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# PASSIVE ELEMENTS FOR PRECISE DIRECTION AND MANAGEMENT OF AIR IN DATA RACKS

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**Abstract:** *The goal of the presented work is to enable the increase of energy load in one data rack up to 15 kW. The work aims to find and subsequently optimize such passive elements for directing the air flow inside the data rack, which lead to the mass flow rate increase in the data rack while keeping the pressure loss. Target value of the mass flow rate in the data rack was 1* $m^3s^{-1}$ *of air assuming a fifteen-degree temperature drop on IT devices fitted in the data rack. The work resulted in two optimized deflectors that serve for directing the air flow through the floor to the front of the IT device. Further increase of the mass flow rate in the data rack was solved with the help of additional side zones. All passive elements were first verified with the help of numerical simulations and subsequently also by experiments. The final optimized variant indicates, at the same pressure drop, an increase of the mass flow rate by 79%; the resultant mass flow rate of 0.97* $m^3s^{-1}$ *enables to fit the data rack with device with a total capacity of 15 kW.*

**Keywords: Data rack, Side zones, CFD, Measurement, Simulation.**

## 1. Introduction

Solving the problem of passive elements for directing the air flow inside the data rack is included in a three-year TAČR project called: Research and development of data rack, cooling and transport systems for data centers. Solving the problem is currently very topical with regard to growing demands on increasing the density of heat flow rate in the data rack (AlLee, 2007; Demetriou, 2011; Hassan 2012, 2013). Based on last two years of solving the project several variants of data racks with passive elements for directing the air flow (Novotny, 2012) have been proposed. For subsequent optimization of the passive elements, data racks with cooling air supply to data rack within a double floor were selected where a greatest impact of optimization on the resulting energy consumption was anticipated. At this variant, cold and hot aisle are separated (see Fig. 1). In this data rack configuration the air cooled by CRAC unit is supplied through the floor into space under the data rack and conducted by deflector into space in front of particular IT devices, which consume the cold air in order to cool the produced heat output. Within the original solution, the air was improperly directed to the data rack space by 1U and 3U deflectors that were completely unsuitable from the

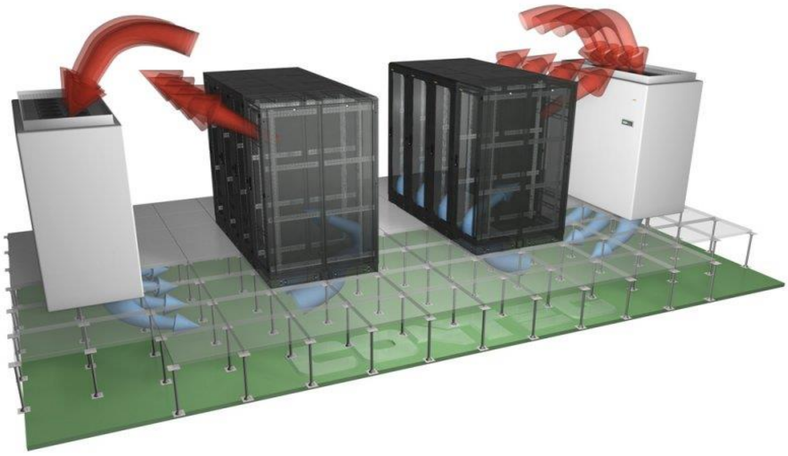

*Fig. 1: Arrangement of data center with air supply to data rack within a double floor.*

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aerodynamic point of view. For this reason, it was necessary to optimize the deflectors in order to minimize the pressure loss at the data rack inlet. Since the resulting increase of the mass flow rate was insufficient, it was necessary to look for other ways to increase the total mass flow rate in the data rack. The new solution of distribution of cooled air inside the data rack through additional space proved to be such solution. This solution consists in using the side walls that are "hollow" in the original variant of the data rack and are not used for distribution of the cooled air inside the data rack. By using these side walls together with optimized deflectors the cooled air flow rate was increased by 100% according to first numerical simulations. Since the proposed solution satisfied the original aims, it was necessary to proceed to final development of particular components with respect to the production capacity of the manufacturer.

## 2. Deflectors by Optimized Side Zone

The original proposed solution of the side zones inside the data rack anticipated the use of the entire depth of the data rack cabinet. The resulting solution uses only the front part of the data rack. The reason for the change was the effort to propose uniform solution that can be installed into data rack of any depth, including the data racks already installed and in operation. The newly proposed solution of deflectors including the side cooling zone is shown in Fig. 2. The side zone is indicated by yellow and the front zone by blue color. Effects of supporting braces at the inlet were also included in the numerical model so that the results corresponded to the final solution as much as possible.

A new numerical model was created out of the newly proposed shape of the side cooling zones, which respect the production capacities and enable to install the side zones in all types of data rack.

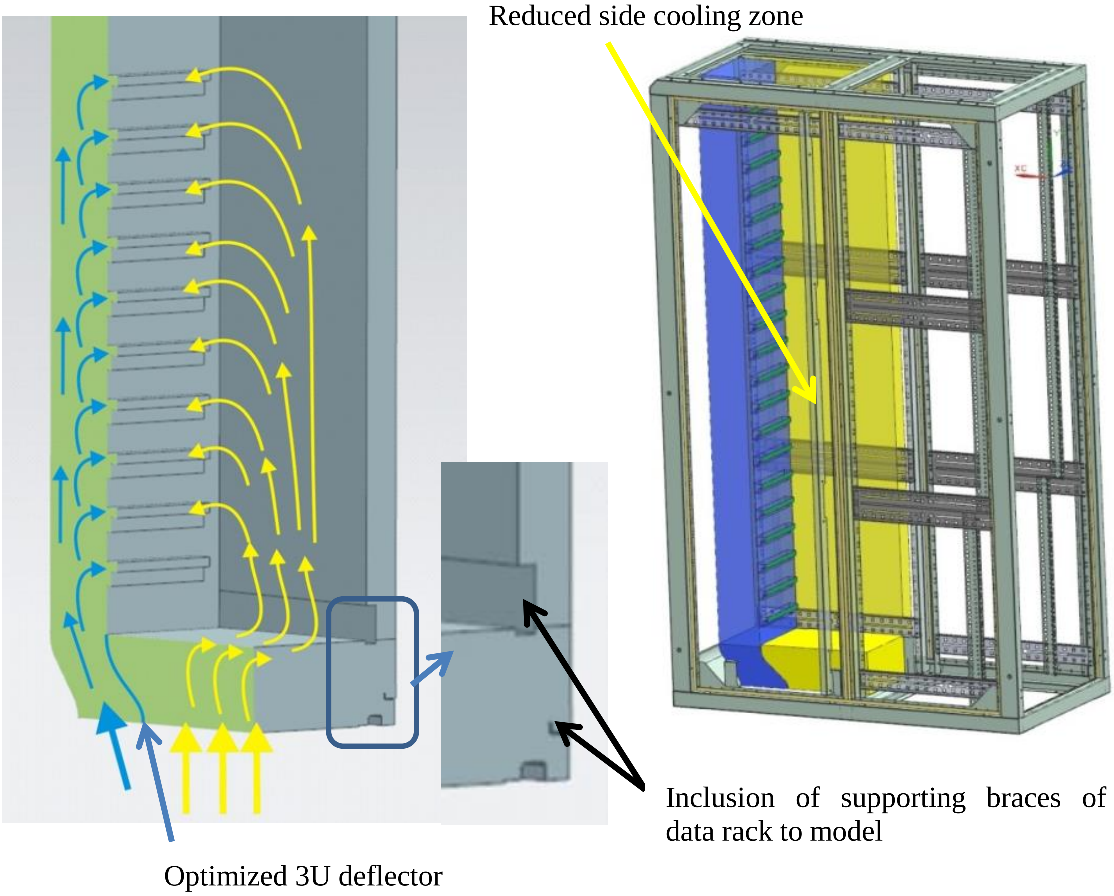


*Fig. 2: Newly designed solution of side zones. Reduction of active depth, including supporting braces of data rack. On the left - volumetric model from which numerical model was subsequently developed. On the right - indication of location of side cooling zone and optimized deflector including splitter of air inside data rack.*

*Tab. 1: Comparison of original and optimized variants of the data rack. The resulting mass flow rate of particular variants and mutual comparison for final variants of deflectors and side zones.*

| Deflector | $\dot{m}$[kgs$^{-1}$] | Position of *U* in data rack without recirculation | $\dot{m}/\dot{m}_i$ |
|---|---|---|---|
| 1U original | 0.512 | 15-42 | 100 % |
| 1U optimized | 0.664 | 9-42 | 129 % |
| **1U Optimized with a side zone** | **0.79** | **3-42** | **154 %** |
| 3U original | 0.54 | 15-42 | 100 % |
| 3U optimized | 0.72 | 9-42 | 133 % |
| **1U Optimized with a side zone** | **0.97** | **3-42** | **179%** |

Unlike the original model, the model of the air inlet into the IT devices was modified, in addition to modification of the shape of the side zones. Setting of numerical solver was performed identically as in the previous solution. In the simulation, a "pressure" condition at the inlet to the IT devices - underpressure related to the atmosphere – 100 Pa was used. IT devices are once again not part of the numerical model and are replaced by the "pressure outlet" condition. The inlet to the space under the data rack is replaced by the boundary condition of pressure inlet type (atmospheric pressure at the inlet). The task is solved as stationary using a two-equation k-epsilon model (realizable). The boundary layer is simulated with a minimum wall thickness of 0.02 mm, the number of layers 10 with a growth factor 1.1. The calculation was terminated when the value of the mass flow rate in the data rack was constant. Heat flow rate in the data rack was not considered. When calculating the flow characteristics for other modifications, the same boundary conditions at the inlet and outlet surfaces were used. Consequently, the total mass flow rate in the data rack was determined from the calculated flow characteristics in front of the IT devices together with estimation of the percentage difference in pressure loss at the same mass flow rates in the data rack.

## 3. Measurement of the Mass Flow Rate in Data Rack

Verification of numerical analyzes has been performed in previous years only with the help of measurement of the velocity fields inside the data rack by the PIV method. The results of the PIV measurement do not allow for obtaining information on the mass flow rate of cooling air in the data rack. This was the reason why the resulting increase of the mass flow rate for new solution of air distribution in the data rack had to be verified by experiment. For the purpose of verification of numerical simulations an experimental setup allowing for measurement of the mass flow rate entering the space under the data rack was built. The mass flow rate was measured using the pressure drop across the nozzle against the atmosphere. The pressure at the narrowest point of the nozzle was measured with the help of a pressure transducer as a mean value of four samples of static pressure. View of the experiment is shown in Fig. 3. The 27U tested data rack was fitted with ten heat simulators. During the actual measurement of dependence of the mass flow rate on particular configurations 14 variants were measured. The mass flow rate was also measured depending on set performance of heat simulators.

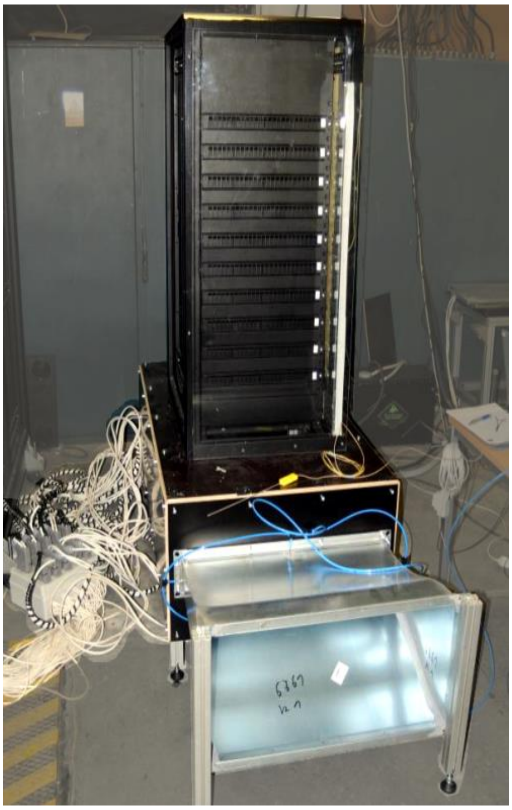

*Fig. 3: Measurement of the mass flow rate in data rack using the pressure drop measurement across the nozzle.*

## 4. Conclusions

Based on the performed numerical experiments new optimized shapes of deflectors, which direct the air flow from the bottom part of the data rack in front of the IT device fitted in the data rack have been proposed. The original shaping of deflectors was proposed with regard to minimum production costs. Due to this requirement, however, the influence of the deflector shape on the total pressure loss was ignored. New optimized deflectors reduced the pressure loss and allowed for an increase of the mass flow rate in the data rack at same energy requirements for air distribution by 29 %, with data rack fitted with a 1U deflector. With a data rack fitted with 3U deflector, the mass flow rate increase is by 33%. The mass flow rate increase of 30 percent may be significant but it allows fitting the data rack with IT device of capacity up to 10 kW. One of the main requirements of customers ordering data centers is to increase the maximum value of IT device capacity, which a single data rack can be fitted with. However, the optimized deflectors do not satisfy this requirement. For this reason, using side zones for controlled air distribution was proposed. When using the side zones together with optimized deflectors the mass flow rate in the data rack increased by 54%, alternatively 79% for 3U deflector. The resulting variant of 3U optimized deflector together with the usage of side zones thus provides the mass flow rate of the cooling air about 1kgs-1. The mass flow rate is already sufficient so that the data rack could be fitted with IT device with a total capacity of 15 kW.  Comparison of resulting variant with the original deflectors are shown in Table 1: Energy savings of the proposed solution consists in the fact that the already existing data center, which will be fitted with new deflectors and side cooling zones, can be fitted with a more powerful IT device and this will provide primary energy savings in production of the new data center. The proposed solution, however, in addition to reduced one-off production costs, also reduces the fixed costs of electrical energy consumption necessary for the air distribution. Since the pressure loss is proportional to second power of velocity and considering the fact that the mass flow rate increase for new solution is known to be about 80 %, it is possible to count the energy performance requirements of the new solution and its change compared to the original solution. It follows that if the original data rack was to be fitted with IT device with a total capacity of 15 kW the costs of air distribution in the IT device would increase up to three times compared to the original state where the data rack is fitted with IT device with a capacity of about 8 kW. With a 15% efficiency of fans fitted in IT devices the resulting consumption of these fans is 1800 W. Electric power consumption necessary for power supply of the fans for the newly proposed solution, where the data rack is fitted with IT device with a total capacity of 15 kW, is only 550 W. The energy savings of the newly proposed solution is, compared to the original solution, 1250 W for one fully fitted data rack. The energy savings when fitting the data center with forty data racks with a total installed capacity of 600 kW shall be 50 kW. The energy savings with fully loaded data center for one year period shall be 438 MW hours.

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