

Displacement Ventilation for an Industrial Production Hall: Savings of Energy, Improvement of Air Quality

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The examined assembly hangar (165 m x 90 m x 8.6 m) of a gearing manufacturer in Friedrichshafen is ventilated by mechanical means with supply-air and exhaust-air systems. Additionally, there are smoke- and heat-extracting systems, which are opened in the warm (and cold) season, weather permitting.

The following problems have arisen in the assembly hangar:

1. The employees complain of high room temperatures in the warm season. In the summer of 2003, room temperatures reached more than 30°C at an outside temperature of 36°C.
2. There are complaints concerning the air quality in at least parts of the assembly hangar.

To improve the air conditions, alternative concepts for air conditioning have been developed by examining the current installation design and construction as well the airflow in the assembly hangar.

The assembly hangar is equipped with 7 supply-air systems and 5 exhaust-air systems with a total volume flow of 625,000 m³/h. The installation was designed in 1979. The air supply enters through approx. 50 swirl air outlets of the type VD 775 (produced by Fa. Trox GmbH, with adjustable fins) arranged in the ceiling area. The distance between 2 swirl air outlets is approx. 15 m. The exhaust air is extracted directly under the ceiling via ventilation ducts.

The supply-air systems contain air preheaters, air afterheaters and ventilators. There is no air cooler. The supply-air systems normally operate with 100 % external air in both summer and winter.

The internal cooling load of the hangar is made up of the heat emission generated by people, machinery and lighting. The lighting installation (picture 1) still consists of approx. 30% older fluorescent tubes with 2 x 65W and upstream throttle. The other tubes (approx. 70%) are equipped with 2x 58W and electrical control gear. On the basis of these specifications, the lighting electrical power can be estimated at approx. 210 kW.

Apart from machines with engines, the assembly hangar also contains heated devices with high surface temperatures, e.g. workstations for shrinking the gearbox parts onto the axles. The heat emitted by these devices and the substances released from them are extracted by local systems and then emitted again under the ceiling. Because of the very special work performed here, the total load of the hangar can only be estimated. The cooling load is approx. 500 kW.

The examination of the airflow in the hangar shows that the supply air only flows into the working area to a very small extent. Picture 2 presents the flow visualization carried out with fog.

The reason for this is the almost horizontal emission of the supply air from the air outlets combined with a very slight insufficient supply-air temperature compared with the surrounding hangar air. Because the return air inlets are installed above the **suspended ceiling**, a short circuit occurs between the supply and the exhaust air.

The calculated air exchange in the hall is approx. 5 1/h. Assuming perfect mixing, the specific cooling load of 80 W/m (original planning basis) requires an insufficient temperature of approx. 5,7 K. Put simply, this means that, if the outside temperature is higher than 20°C, the hall temperature rises above 26°C. This approach still neglects the warming by transport and the warming in the ceiling and in the distribution. The fact that this calculated approach cannot be determined in practice (the warming starts later) is due to the free flow in the hall itself. A sort of “natural” displacement ventilation occurs which transports the thermal loads into the ceiling area and is fed by flows from the outlets into the lower area of the hangar (transport systems). This airflow should be supported by mechanical airflow.

Various alternative concepts of airflow pattern and climate control are proposed and discussed (table 1). A comparison of the present installation with partially reduced airflow, modified positioning of the air outlets, displacement ventilation and cooling with cooling sails is undertaken, including a cost-benefit analysis. The comparison shows that a consistent application of displacement ventilation with significantly reduced air flow (-80%) is the most effective measure. The only disadvantages compared to other solutions are in the area of flexibility.

This solution has been implemented in the meantime and the results of the first months of operation are extremely favourable. Both the air quality and the thermal conditions have been improved. Consumer satisfaction is high. A detailed comparison of the costs (investment and operation) is still to be carried out.



Picture 1: Lighting installation in the assembly hangar



Picture 2: Working area below the suspended ceiling; supply air only flows into the required area to a very small extent

Alternative	Air flow in cbm/h	Thermic Situation	Air Quality	Flexibility	Downdraught	Basics costs modernisation, control and shutdown appliance (approx.)	Additional charges (approx.)	Total charges (approx.)	Economisation per year of transport energy (approx.)	Additional charges for cooling (assumption: 500 h/a)	Ratio: Total charges / economization	
1a	Utilization of present ventilation system, without cooling	312.500	no advancement	small advancement	+++	---	\$420.000,00	\$0,00	\$420.000,00	\$58.000,00	\$0,00	no cooling
1b	Utilization of present ventilation systems, cooling by cooling ceiling	312.500	extensive advancement	small advancement	+	---	\$420.000,00	\$560.000,00	\$977.000,00	\$58.000,00	\$12.000,00	17,0 years
2a	Part of the air outlets mounted in the suspended ceiling, without cooling	200.000	no advancement	explicit advancement	+++	-	\$335.000,00	\$184.000,00	\$517.000,00	\$93.000,00	\$0,00	no cooling
2b-1	Part of the air outlets mounted in the suspended ceiling, with cooling by supply air	200.000	explicit advancement	explicit advancement	+++	--	\$335.000,00	\$403.000,00	\$737.000,00	\$93.000,00	\$12.000,00	7,9 years
2b-2	Part of the air outlets mounted in the suspended ceiling, with cooling by cooling ceiling	200.000	extensive advancement	explicit advancement	+	+	\$335.000,00	\$743.000,00	\$1.076.000,00	\$93.000,00	\$12.000,00	11,6 years
3	Utilization of present ventilation system, air outlets mounted at the bottom, installation cooling	125.000	extensive advancement	extensive advancement	-	+++	\$172.000,00	\$742.000,00	\$913.000,00	\$150.000,00	\$6.100,00	6,1 years

Table 1: Cost overview of the alternatively proposed solutions

