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Air Flow in Industrial Buildings

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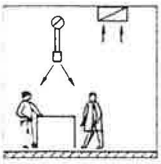
In industrial buildings, people relate differently to the infrastructure than is the case for open-plan offices equipped with comfort air conditioning systems. The differences in the main are due to the space dimensions and the large distances from the windows to the workforce which frequently exist. Moreover, it must be acknowledged that people have to remain at their own workplaces for the duration of the working period and cannot escape from the conditions which prevail there. Air conditioning is therefore a means by which the working conditions can be improved. Industrial health regulations contain appropriate limiting values for the emission of substances which are hazardous to health. Sulzer engineers have been working for many years on improving air conditioning at workplaces (*Figs. 1, A*). In this way the performance of both people and machines can be enhanced. Since there are no standardised engineering concepts, careful planning and the close cooperation of all concerned with the project are required. Tests carried out in the Sulzer Flow Dynamics Laboratory at either full size or on scale models can be used to confirm the engineering design solutions.

Occupation of industrial buildings

Industrial buildings are constructed within a wide range of spatial layouts and structural forms. In addition, infrastructural systems and machinery requirements corresponding to the particular purpose or process are required. These aspects, together with the transportation routes and equipment, play a large part in establishing the form of air conditioning systems to be applied. The choice of the system naturally has a considerable bearing on the investment and operating costs. Industrial buildings can be divided into three main groups, depending on the rôle of the workforce:

- Those suitable for continous occupation, whereby the air conditioning is designed as far as possible for this purpose.
- Those where priority is given to the working process, in which personnel have to adapt to the requirements of the process.



A Air supplied via slot outlets and removed via extract air light fittings or ducts.

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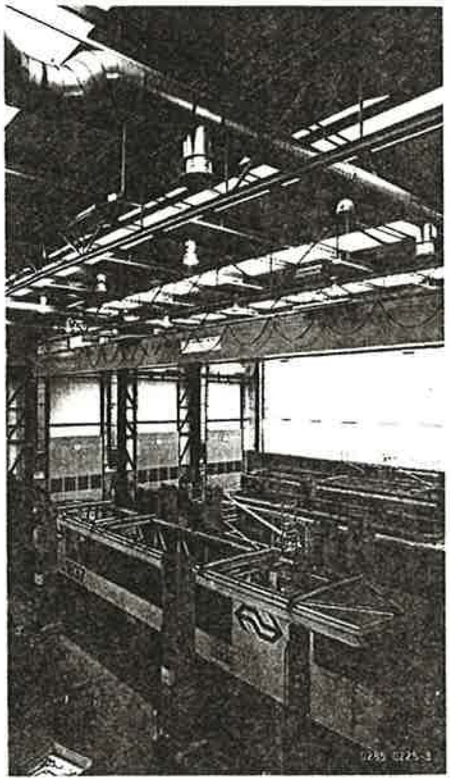
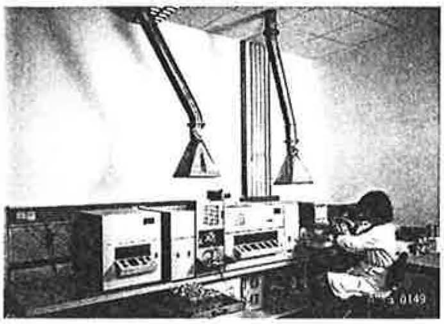
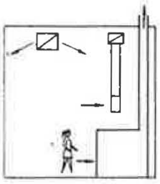
1 Product packing in a Swiss chocolate factory. The air enters via slot outlets installed beneath the air duct and is removed via extract air light fittings.

2 Locomotive repair workshop — Nederlandsche Spoorwegen, Tilburg (NL). The outside air is introduced via wall ducts located close to the floor. Exhaust air is extracted at the ceiling. Radiant ceiling heating is also provided. ►

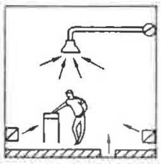




3 **Removal of particulate matter during material testing by means of individual exhaust hoods. This prevents contamination of the room air (metal refinery in the Federal Republic of Germany).**



B **Induction outlet via grille, enclosed emission source and individual workplace extraction.**

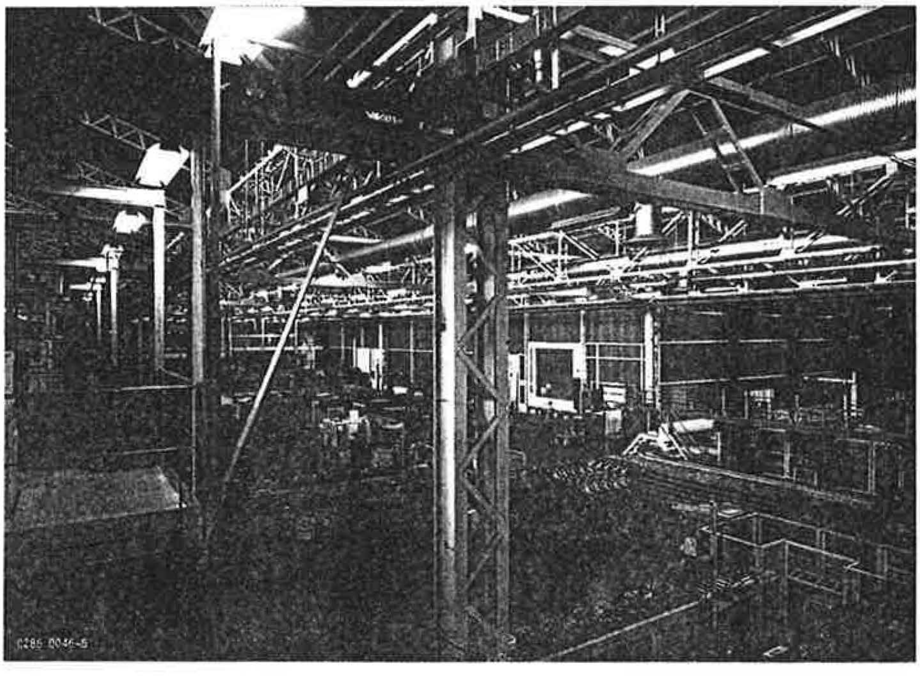


C **Adjustable ceiling extraction, air introduction at low level.**

- Those suitable for only short duration occupation, where the presence of personnel is only slightly relevant to the air conditioning design concept.

Buildings suitable for continuous occupation [1]

All industrialised countries have standards and industrial health regulations (Factory Acts) in which maximum values for the concentration of hazardous substances in air are laid down. These regulations apply irrespective of whether the building is used for production, processing, assembly or servicing (*Figs. 2, F*). The room air conditions are designed to correspond as far as possible to the nature of the activity undertaken by the occupants. In the case of seated activities, in particular precision operations or indeed any working procedures involving little physical activity, the air conditions required are defined as being in the comfort range. Each person is provided with a minimum outside air flow rate in the range 10 to 50 m³/h conditioned air, i. e. outside air which has been filtered and brought to the required temperature without taking into account additional recirculated air. As a consequence of this, the air within the building has on average to be renewed at least twice per hour. The exclusion of noxious substances is the main consideration. These can be either harmfull substances contained within the outside air, or indeed dust, vapours or gases released within the building itself. It is necessary to deal with these either by disposing of them locally at source or by diluting them with conditioned air. In addition to the danger to health and the nuisance of the odour, hazards of corrosion and explosion must also be dealt with. These factors have a significant influence on the choice of system and system capacity.



4 **Distribution of air from the ceiling by means of swirl-type outlets in the transmission production shop of a motor car manufacturing works in Spain.**

5 **Plastics production in an Austrian works fitted with ceiling mounted recirculated air heat exchangers.**

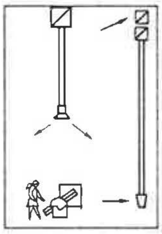
When the occupied zone is required to be draught free, careful design of the room air flow is required. In extreme cases this can mean the provision of a micro climate at the workplace. This is achieved either by supplying conditioned air to the individual workplace (*Figs. 3, 11* and *B*) of by enclosing the emission source. In these circumstances the ventilation plant should be designed to produce low velocity air movement. This has two consequences, firstly less energy is required for transport and secondly temperature stratification is reduced. Two design solutions have demonstrated their effectiveness in this respect:

- decentralized air treatment, i. e. individual plants for the various sections of the building or area
- centralized air treatment with extensive ductwork distribution. This system approach should, however, provide individual zone control (*Fig. 4*).

Air introduction

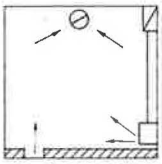
Conventionally, supply air is introduced beneath the ceiling, whereby swirl-air outlets are often used in high bay buildings (*Figs. 4, D*). During the heating cycle, the air is supplied at a higher temperature than the room air and is well mixed with the ambient air in order to obtain the required space temperature. When cooling is required, the air is supplied at a temperature lower than the space condition. The air distribution outlet therefore has the important function of influencing direction and penetration depths in such a manner that good mixing with the room air is obtained. This ensures a rapid resolution of the supply air temperature above or below the control set point.

In some cases, extraction of the air is also carried out at high level in the roof zone (*Figs. E, F*). In these instances, the air traverses the hall whereby dust is deposited on the floor, either due to its weight or due to the low velocity of the air movement. Gaseous pollutants are distributed throughout the building and are considerably diluted. Where possible, extraction should take place via wall ducts mounted close to the floor or via floor grilles (*Figs. D, G*). Extraction directly from the roof zone to atmosphere is generally unacceptable, irrespective of whether heat recovery is applied or not (*Fig. 5*). Where the configuration of a particular zone does not permit unimpeded air flow, the air supply system has to be designed to overcome air distribution difficulties.

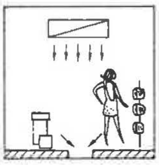


D Swirl-air outlet lowered into the occupied zone, air extraction via wall and ceiling.

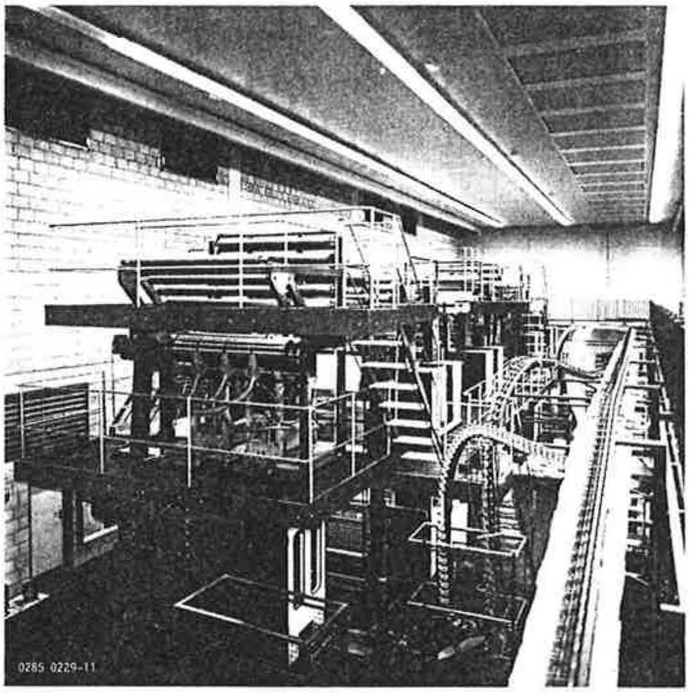
E Nozzle outlets; ceiling extraction.



F Flow arrangement with floor or wall outlet, extraction via the ceiling.



G Floor extraction, e.g. in knitting and spinning mills, air supply via ceiling-mounted duct.



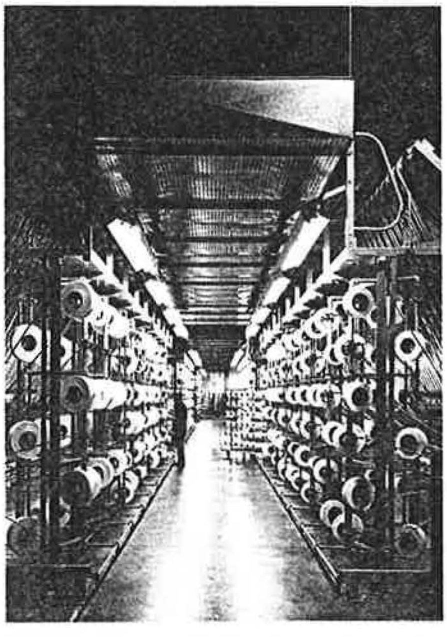
6 De Limburger printing and publishing works in Roermond (NL): The hall is supplied with treated air via a perforated ceiling.

Sometimes the air flow has to be directed transversely to the thermally-induced buoyancy forces. In these circumstances large volumes of air can rise rapidly into the roof zone if the supply air momentum is weak.

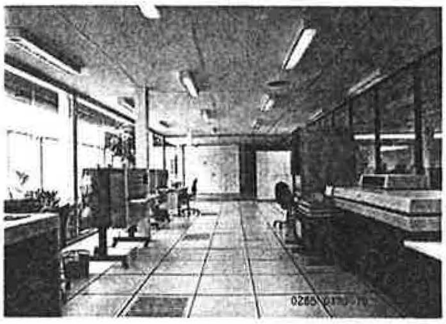
Where induction outlets with low air flow velocities such as small nozzles or perforated sheet metal (*Fig. G*) are present, a relatively large hall area of the ceiling is taken up by the airflow distribution system. Therefore, a uniform relative humidity can be maintained in the room due to the low air flow velocity (*Figs. 6* to *8*). The extract air is then removed at several locations in the room, in order to improve the flow characteristics. The local extraction of dust through openings in the floor then ensures that this type of installation is inherently suitable for production processes requiring low dust levels (i. e. printing).

Recently, industry has moved towards introducing air via the floor (*Figs. 2, 9* and *F*). The advantages of this configuration, which is well known in commercial comfort installations, are in the low air flow velocity and rising extract air flow. This upward air movement is supported by the thermal

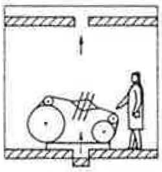
7 Stocking knitting mill: supply air via perforated ceiling ducts; air extraction via floor grilles.



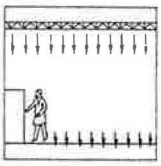
8 Viscose yarn production: temperature and relative humidity of air to remain constant, Supply air via perforated ceiling ducts over the corridor.



9 Microfilm production room with floor air outlets (source ventilation). The cooling air is supplied to the machines directly via perforated floor tiles and rises to the ceiling.



H Condifil® process zone air conditioning.



I Filter ceiling and floor grid for extraction: clean room with low turbulence displacement flow.

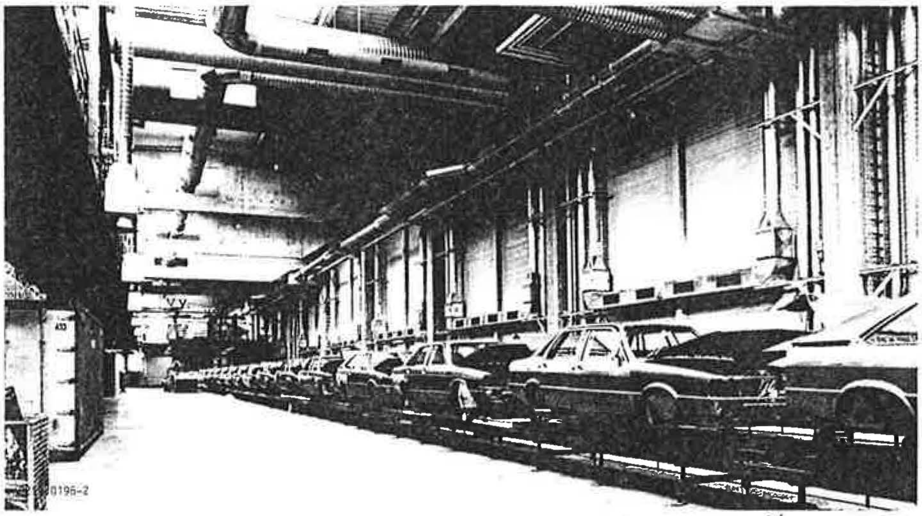
buoyancy forces arising from the heat sources [2]. A prerequisite for such systems is that the floor has to be kept clean and the floor ducts be equipped with cleanable air supply outlets. If such an air distribution system cannot be accomplished, then the traditional ceiling supply system has to be used. With the assistance of suitable ducting, the air outlets should then be located as near as possible to the occupied zone (*Figs. 10* to *12* and *D*). If, due to structural reasons, the spacing between ducts is considerable, then additional adjustable horizontal swirl outlets or air nozzles are required. These can also be assembled into groups in order to satisfy a large zone of the building. As required, the air can then be discharged at the appropriate angle to the floor. The required air flow can, if necessary, be adjusted with the aid of a variable volume flow rate controller. After long shutdown periods such as week-ends, the unoccupied building or zone can be rapidly heated up using recirculation air and high speed drive if necessary. In summer the opposite effect is required and the building can be cooled down during the night using outside air (free cooling).

In weaving mills, the Condifil®-System has contributed to improving the air conditions for the people working there. The air required is fed in via a floor outlet located under the weaving machine (for natural fibres). This air has a high relative humidity and is supplied directly from the under floor duct such that the condition of the air at the heart of the weaving process is improved (*Fig. H*). Wear and yarn breakage frequency are decreased accordingly and the zone of high air relative humidity is limited to the process zone only. The zone occupied by the machine operators has, by comparison, a lower relative humidity. The waste heat emitted by the machines causes the warmed air to rise rapidly towards the roof zone, from where it can be extracted. Dust and fibres are carried with it. A combination of Condifil and a conventional system, known as Condifil-Mix, enables a separation of the air treatment process to take place, i.e. the air is either supplied to the process zone or to the room. This results in cost savings relating to humidification of the air.

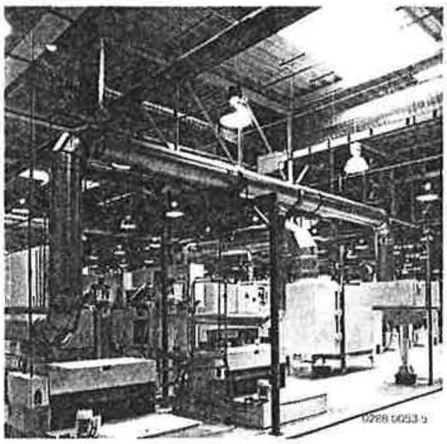
In other industrial sectors, the relative humidity of the air has to be kept at a constant level over the whole room. For example, paper shrinks when the air humidity drops and printing quality is poor. The product humidity and air humidity have to be in equilibrium.

Induflow® – a modular air-jet system

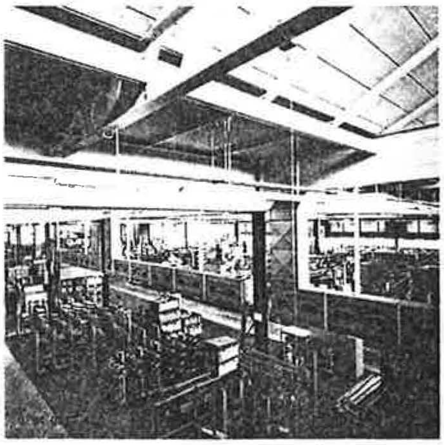
Induflow, unlike conventional air handling systems for industrial buildings, is an air-jet system, with concentrated, ductless air supply (*Fig. 13*). It can be installed on a modular basis and the air movement is generated by means of a primary air handling unit



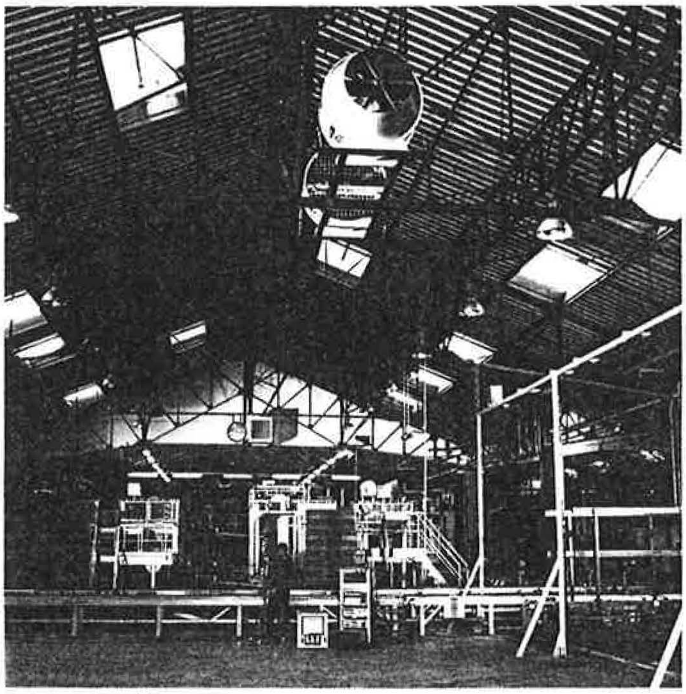
10 Ventilation of the working zone (lacquering) with lowered supply air ducting, long-throw grilles and ceiling air extraction (motor car production works in the Federal Republic of Germany).



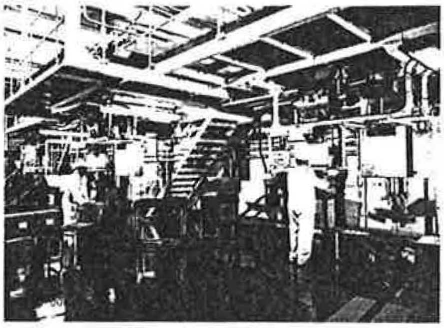
11 Fabrication of motor vehicle components in Austria. Swirl-air outlets and individual workplace extraction located above emission sources.



12 Air distribution via ceiling ducts and grille outlets for the manufacture of textile machine components in Switzerland.

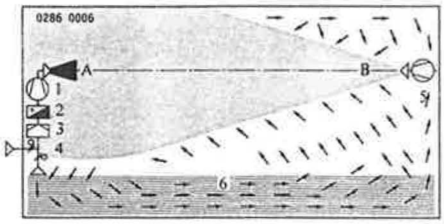


13 Bottling plant, floor area 10 630 m², Eaux de Vittel (F), with Induflow air-jet system.



15 Filling plant for powdered foods in England – reduction of air relative humidity to 25% and air temperature to 15 °C.

A Primary air flow
B Secondary air flow
1 Primary air fan
2 Heater battery
3 Air filter
4 Outside/recirculated air intake
5 Secondary air fan
6 Working area

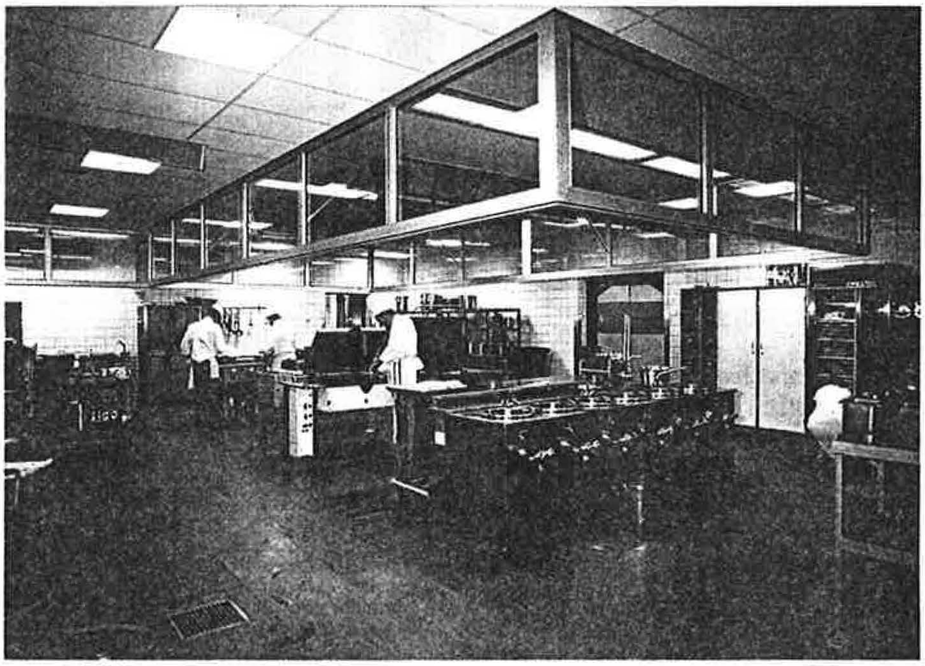


K Schematic diagram of Induflow® system.

and a secondary air fan which is mounted at the same height (*Fig. K*). The primary air unit supplies treated outside air, recirculated air or a mixture of the two into the room. The secondary air unit directs a recirculated air jet of high momentum towards the primary air jet. The weaker primary air jet is thereby entrained , producing an effective room air circulation.

The fans are located in the roof zone, thus avoiding a build-up of warm air at high level. The air circulation also entrains the total waste heat in the room, e. g. from machines and lighting. Since the occupied zone at floor level is within the air circulation zone, the warmed air can be fully utilized.

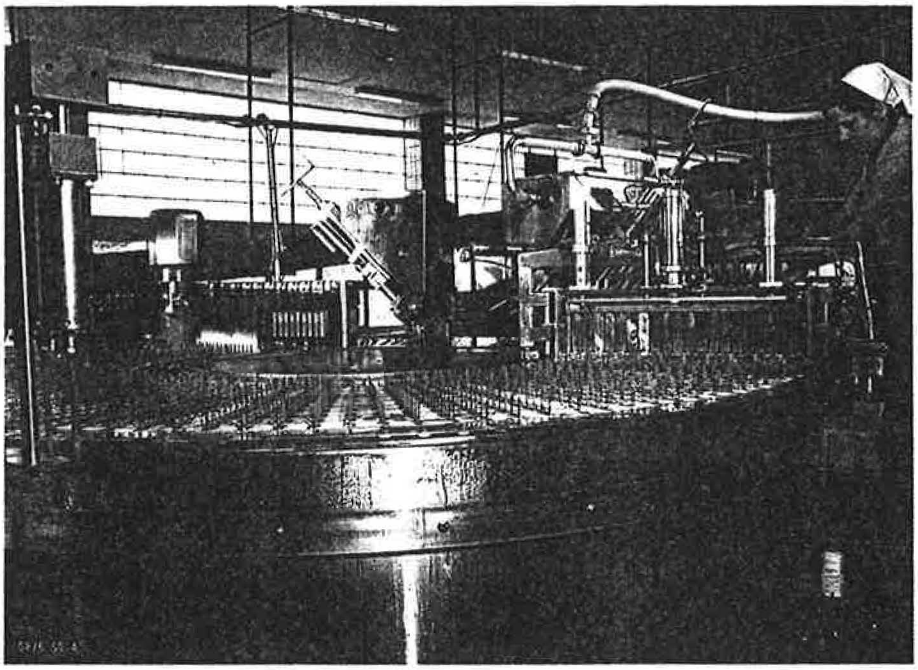
A special heat recovery system is therefore superfluous. During the intermediate periods between summer and winter, the total transmission losses can be offset by the internal heat gains. Induflow is particularly suitable for buildings with large floor surface areas. The total area is divided into several rectangular zones. Each zone can then be operated autonomously by means of its own module. Tests on site have demonstrated that temperature stratification over the height of the room is <0.2 K/m. This is a significant improvement over conventional systems, where this value is typically in the range 1 to 2 K/m. The transmission losses of the enclosing walls and roof clearly decrease with decrease in temperature difference between inside and outside.



14 Kitchen – a hot environment with special requirements; extract air exhausted via grease filters mounted in the ceiling to improve working conditions.

Buildings where priority is given to the process requirements

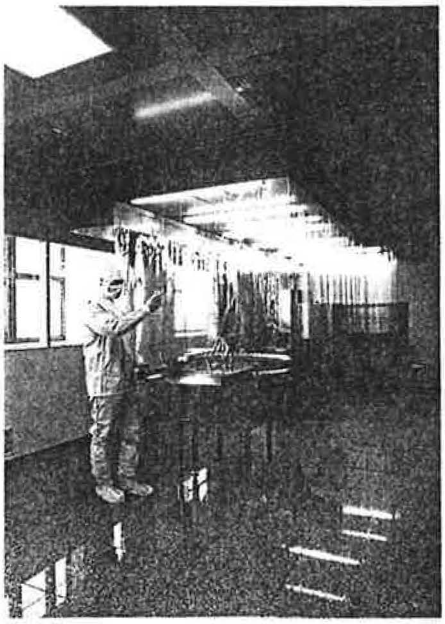
Where, due to the requirements of the process, the room air temperature cannot be maintained within the comfort range, the personnel present have to adapt themselves to the conditions (*Figs. 14* to *16*). In cold stores, fresh meat preparation areas etc., this takes the form of warm clothing. Air for breathing has to be carried with the person entering a store having gas stor-



16 Circular refrigeration equipment used in the manufacture of ice cream: room temperature lowered.

age facilities. The air flow velocity is either decreased or indeed static cooling (without mechanical circulation of the air) is applied. In such a case only thermally-induced buoyancy forces are utilized to provide air movement.

Other criteria are applied for processes where air of a particularly high cleanliness is required. These "clean rooms" have, in general, air conditions within the comfort range, however with higher air flow velocities. In such rooms, the air even has to be protected from particles emitted by the occupants (*Fig. 17*). Hence the source of the particles, namely the occupants, have to be "encapsulated", i.e. special clean room clothing is worn. In rooms classified as having a low degree of cleanliness, non-laminar air flow is used. Where a high cleanliness classification has to be complied with (Classification 100, 10 or lower, as defined in US Federal Standard 209 c), low-turbulence displacement flow is applied, so that any recycling of pollutant into the process is prevented. The air flows either vertically downwards (*Fig. 1*) or horizontally at high velocity. Particles are thus removed by the shortest path.

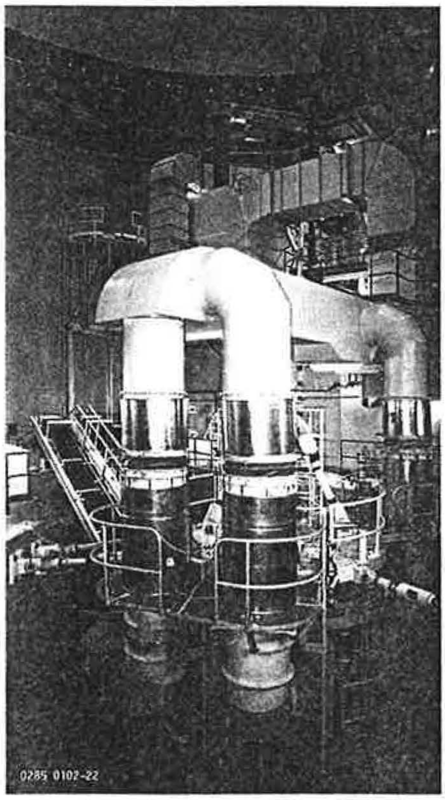


17 Blood plasma filling station in a separated area with low turbulence displacement flow, clean room class 100.

Buildings where personnel can remain for only a short time

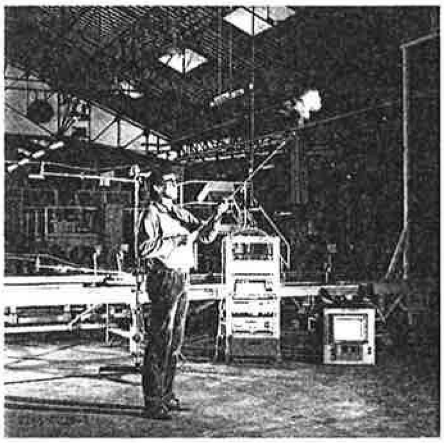
(*Figs. 18* and *19*)

Robots and other automatic equipments function in such areas. The condition of the room air, i.e. temperature, velocity, cleanliness etc. match the requirements of the production process. When personnel have to enter the area, suitable preparations have to be made. The air handling installation is required to maintain the specified values of temperature, moisture content, and pressure (above or below atmospheric) and to deal with waste heat, paint mist, vapours and other pollutants by either removal, filtration or dilution. Outside air is treated and supplied only to the minimum required. Components relating to air handling have to be such that safety and functional reliability are guaranteed. As is the case for all air handling plants (these can also be made up of several individual components), they operate automatically usually in conjunction with modern monitoring systems featuring direct digital control (DDC). A similar situation also applies for areas which are entered for short periods only, e.g. for material handling or for inspection of operating conditions. The condition of the air can therefore be outside the limits applying for comfort. In particular, the air flow velocity and the flow direction are established from process operating considerations.



18 Reactor room in a nuclear power station in Belgium. The room air is treated in plants featuring high redundancy (multiple provision) and the extract air is passed through HEPA filters. There is a separate cooling circuit for the drives which position the reactor fuel rods.

19 Lacquering hall of an aircraft manufacturer in the Federal Republic of Germany. The air handling is program-controlled (filter ceiling, below — air extract via floor grid complete with paint mist separator).



20 Mobile test stand for on-site air flow measurements. In the background can be seen the data logging equipment providing graphical and numerical presentation of results (part of the acceptance test certification).

Importance of servicing

The air ducts together with their regulating equipment, pressure-reducing devices and adjustable air supply outlets, have to be matched precisely to oneanother as far as their function is concerned. Functional reliability of mechanical components can only be guaranteed by regular servicing. The same applies to the monitoring of leakage and for the maintenance of hygienic air conditions. Should only one item in this system function unreliably, complaints will arise from the user and the economic performance of the installation will be impaired. Servicing and inspection work are carried out by specially-trained SULZER service personnel. Lack of operating precision is unpleasant, and is noted particularly under part load conditions or where climatic extremes are present. For example an undesirable increase in air velocity is identified sooner during cold weather than on hot summer days. Odours often present a problem in summer and particulate matter can contribute the spreading of germs. Moreover, the physical layout in the conditioned area has to be inspected from time to time. Revisions to the hall spatial layout can too often lead to undesirable influences with respect to the air flow and can produce changes in air flow direction. In order to be able to carry out such room air flow measurements, mobile test equipment from the Flow Dynamics Laboratory of the Plant and Building Services Group is employed. With the help of electronic measurement equipment, a test report can be drawn up on site, complete with numerical or graphical representation. This can take the form of a temperature distribution diagram (temperature profile) or an air flow pattern. The path of the air flow can, moreover, be made visible by means of paraffin smoke (*Fig. 20*). By this means the influence of disturbances or the throw characteristics of air nozzles, etc. can be established and photographed.

SULZER undertakes the preventive maintenance of installations via its national companies and their comprehensive branch networks. For example, 200 local offices in Europe alone provide the required proximity to the client.

Summary

Ventilation and air conditioning installations for industrial buildings have to comply with requirements which are at variance to those placed on comfort systems. This means that here also great care has to be taken during the design phase. A wide choice of systems is available. Both spatial layout and the requirements of the particular application can also differ widely. Hence the design of a project represents an optimised solution, the attainment of which requires the cooperation of all concerned. Only identical systems with identical operating conditions can be effectively compared with one another. Correct servicing plays an important part in ensuring trouble-free operation of the plant and equipment.

The most important factor is the acknowledgement of progressive technology, which takes into account both the human and the technical aspects (e.g. minimum environmental pollution, energy efficiency). In addition, economic performance, operational reliability and life cycle valuation of the installations have also to be considered and play a major part. Ω

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