OCCUPANT INTERACTION WITH VENTILATION SYSTEMS

7th AIC Conference, Stratford-upon-Avon, UK
29 September - 2 October 1986

PAPER 8

VENTILATION HEATING SYSTEM OF SMALL HOUSES

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SYNOPSIS

The buildings built according to the latest construction technology aiming at energy saving are as tight as possible. The ventilation of a tight building has to be completely mechanical (supply and exhaust air system). The heating of the building can also be included in the mechanical ventilation system with small additions. The new warm air heating system developed at the Laboratory of Heating and Ventilating of the Technical Research Centre of Finland is therefore called ventilation heating system.

The ventilation heating system has several properties that can be achieved only when the heating effects needed by both heating and ventilation are completely adjustable on a room by room basis. Then the factors influencing room climate can be controlled with only one system.

The ventilation heating system has sufficient sound insulation and sound attenuation due to the structure of the central unit and right selection of air terminal devices. The exhaust air flows are controlled by the inhabitant according to his local and temporal needs. The pressure ratios of the building, and the outdoor and exhaust air flows, are under control in the different fan operation conditions. The temperature of each room can be controlled with one adjusting knob accordin to the needs of the inhabitant. The heating system is suitable for upper-distribution (blowing of warm air from the wall or ceiling). The room-based air flows do not have to be controlled accurately according to the heating need. The supply air ducts need not be heat insulated.

The ventilation heating system particularly gives better changes to meet the inhabitants' expectations on the heating and ventilation systems, and gives bases for industrial production of a new generation of warm air heating and ventilation systems.

1 INTRODUCTION AND BACKGROUND

1.1 Need for development in warm air heating

As a heat distribution system for small houses warm air heating came to the markets in its present form in Finland in 1976. It soon became more popular and reached the top of its success in 1981. Since then the proportion of warm air heating has considerably decreased in small house production due to failed system applications and strong increase in direct electric heating.

The investigation /1/ has evaluated the need for development of warm air heating systems on the basis of field tests on the existing warm air heating systems. Much need for development has also been found in the laboratory tests of warm air heating central units.

Future ventilation and heating systems must take particularly into account the inhabitants' expectations on flexible heating and ventilation systems /5/: stable room-controlled ideal temperature, silent and effective demand-controlled ventilation.

In building of new ventilation heating systems special attention was paid to the development and experiments of the following: the tightness and acoustics of ventilation heating system, room-based temperature control, the special properties of high sidewall supply outlets, control of the outdoor air and exhaust air flows in the different fan operation conditions, local and temporal control of exhaust air ventilation.

The operation of the ventilation heating system developed on the basis of laboratory tests has been studied in the tight (1,1 air changes per hour at 50 Pa) 1,5-story experimental house (88 W/K thermal conductance of building envelope) of the Technical Research Centre of Finland.

1.2 Why ventilation heating?

According to the latest construction technology the buildings have been made as tight as possible. The ventilation of a tight building has to be completely mechanical (mechanical supply and exhaust air system). With small additions heating of the building can also be included in mechanical ventilation.

If outdoor air is not supplied into the building mechanically, sufficient supply air openings for outdoor air have to be arranged in the building envelope, mostly by leaving supply air openings without weather strip in the upper sashes. Thus, in order to guarantee sufficient ventilation the building has deliberately been made leaky.

The sound insulation of a tight building equipped with mechanical ventilation is significantly better than that of a deliberately leaky building. Tightness is one of the most important properties of a building when we try to reach good sound insulation.

2 OPERATION OF THE VENTILATION HEATING SYSTEM

Figure 1 shows the air technical operation diagram of ventilation heating system. When water heated room-based warm air heating coils and boiler plants are used a suitable operation diagram for heating is presented in Figure 2.

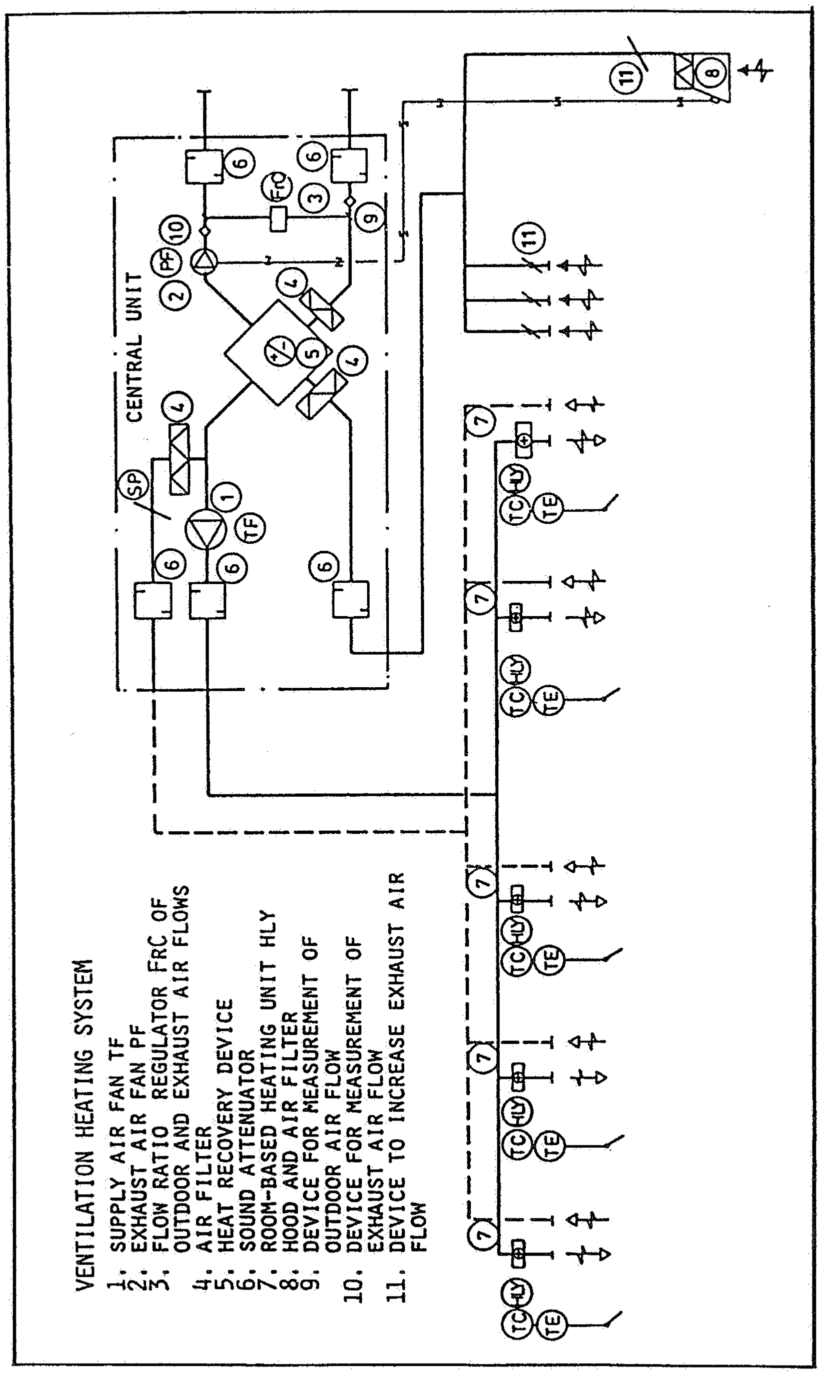

Figure 1. Air technical diagram of the ventilation heating system /3/.

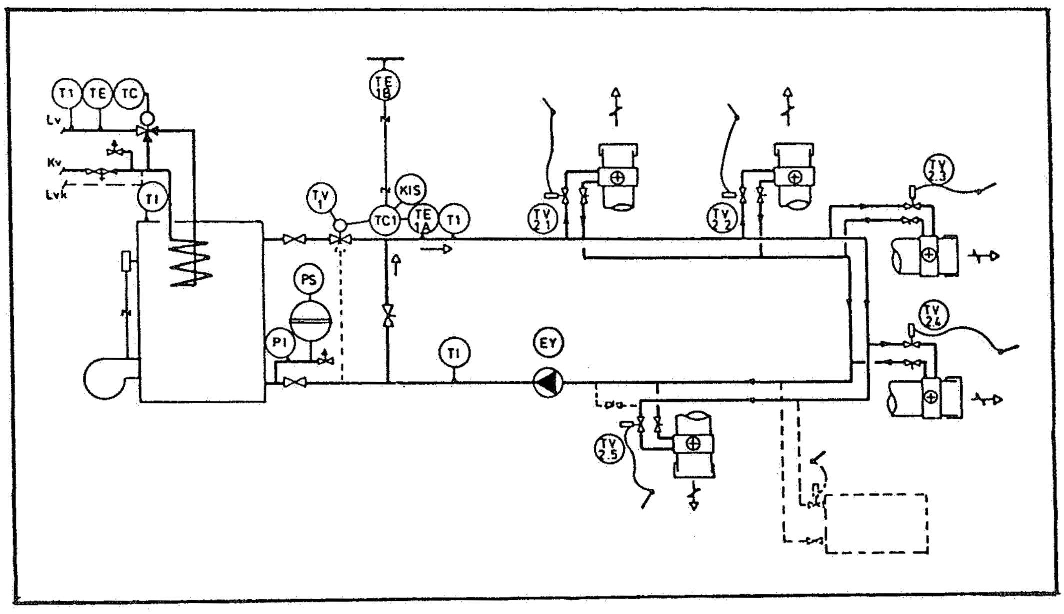

Figure 2. Operational diagram of the warm water heating network of the ventilation heating system. Boiler plant, two-pipe reverse-return system /3/.

2.1 Air technical operation

Supply air fan (heating air and outdoor air fan) TF operates in two different positions (rotation speed or voltage control), of which the control position with higher air flow is used under the heating season and the saving position with smaller air flow at other times. The minimum air flow needed by the supply air fan at other times is adjusted with the aid of recirculation air damper SP thus that the maximum outdoor air flow is reached when the supply air fan is at its minimum when the exhaust air fan operates at its maximum.

The flow ratio regulator FrC of the outdoor air and exhaust air flows keeps the difference between the exhaust and outdoor air flow constant, even though the air filters get dirty, and protects the heat recovery device from freezing. The regulator FrC controls the outdoor air flow according to the exhaust air flow and keeps negative pressure in the house. The flow ratio regulator is adjusted so that the maximum outdoor air flow is about 70 - 80 % of the maximum exhaust air flow. The difference between exhaust air flow and outdoor air flow remains almost constant within the whole flow range.

The exhaust air fan PF operates continuously with an air flow corresponding to minimum ventilation rate. The exhaust air terminal devices of moist rooms (e.g. toilet and bathroom) are silent devices equipped with a possibility of increasing air flow. Their dampers enable easy spatiotemporal control of exhaust air ventilation. Kitchen ventilation can be increased with the damper of the hood. Total ventilation can be increased with the control knob in the hood by increasing the rotation speed of the exhaust air fan. When the exhaust air fan stops the tight damper of the outdoor air duct closes.

The room-based air flows of an air ductwork are adjusted with the aid of sufficiently high pressure (> 50 Pa) and silent air terminal devices. The recirculation air is circulated on a room by room basis (sound insulation) or led centrally through individual room transfer openings under the doors and hallways to the central unit.

Outdoor air is preheated primarily in the heat recovery device and when mixed with the recirculation air. In addition, air is heated 1 - 2 K in the supply air fan. The recirculation air flow is adjusted with the aid of recirculation damper SP thus that at maximum outdoor air flow the temperature of the air blown into the ductwork does not with design outdoor temperature sink below the dew point temperature of the air surrounding the not thermally insulated ductwork. A practical design value for the recirculation air flow could be twice the outdoor air flow.

In the tight 1,5-story experimental house the total warm supply air flow was 119 dm^3/s, mechanically supplied outdoor air flow was 34 dm^3/s and the exhaust air flow was 52 dm^3/s. The warm supply air flows of the different rooms were 15 - 21 dm^3/s.

A room-based terminal heat transfer unit HLY heats the low temperature (> 10°C) air in the supply air duct and the room. The rooms can be heated with warm water or electrical heating coils. The terminal heat transfer unit comprises room temperature sensor TE and control unit TC.

The structure of the central unit of the ventilation heating system is simple. After the preadjustments of the air flows the system works automatically. The desired room temperature can be adjusted with the control knob in the heating unit in each room.

2.2 Heat technical operation

Control centre TC 1 of the heating water network controls the regulating valve (e.g. two- or three-way valve) on the basis of the measurement values of supply water temperature sensor TE 1A and heat need sensor (e.g. outdoor air sensor) TE 1B and keeps the supply water temperature according to the set points of TC 1. The set points of the temperature of the water going to the terminal heat transfer units are selected thus that in normal loadings each room can always have enough heating effect for heating and ventilation. A bypass pipe equipped with flow control valve is installed in the water heating network for a small bypass flow in order that there is always fast enough heat available for each heating coil and at the same time the disadvantageous pressure conditions of coil regulator valve are avoided. The water flows of the heating coils are limited according to the design conditions. The roomwise temperature controlled valves TV 2.1 - TV 2.5 throttle, when needed, the water flow of the heating coils according to the need for heating.

Even water radiators can be installed in the heating, network, e.g. for the kitchen, garage and wind chamber.

The heating water network according to two-pipe reverse-return system presented in Figure 2 should technically be dimensioned thus that the pressure loss of the pipe is lower than 100 Pa/m and the pressure losses of the coil or radiator valves are higher than 2 kPa /2/.

3 ADJUSTMENT OF ROOM TEMPERATURE

In the ventilation heating system there is during the heating season for each room simultaneously available both heating and cooling effect and room temperature can simply be selected with a control knob in the wall. Figure 3 shows a typical control situation of a room temperature in the experimental house on a spring day.

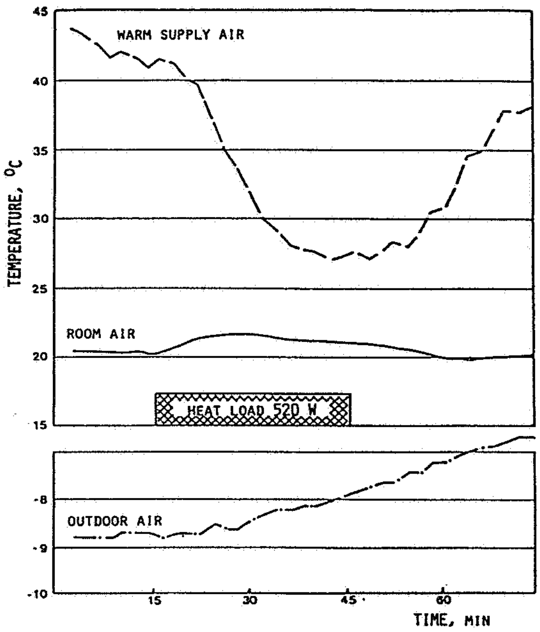

Figure 3. Properties of room-based temperature control in the ventilation heating system on a sunny spring day.

4 PREADJUSTMENT OF AIR FLOWS

In the ventilation heating system the central unit is placed in the middle of the building. The sound attenuated and low temperature air from the central unit is supplied and distributed at high level along short uninsulated air ducts at a high enough pressure to the silent air terminal device on the back or side wall of each room. No other sound generating dampers are needed in the ducts. The heating coil in each room can be in the air duct right outside the room or in the air terminal device.

At an air flow corresponding to maximum heating effect or maximum exhaust air ventilation rate the sufficiently high pressure and silent supply and exhaust air terminal devices should meet the following requirements:

- total pressure loss > 50 Pa
- highest accepted sound pressure level in a room (10 m^2 sound absorption) 25 dB(A).

A small air temperature gradient is reached in the room when the throw corresponding to the terminal velocity 0,2 m/s of the supply air device's warm air flow is at least the free length of the room and the supply air terminal device has good air mixing properties, figure 4.

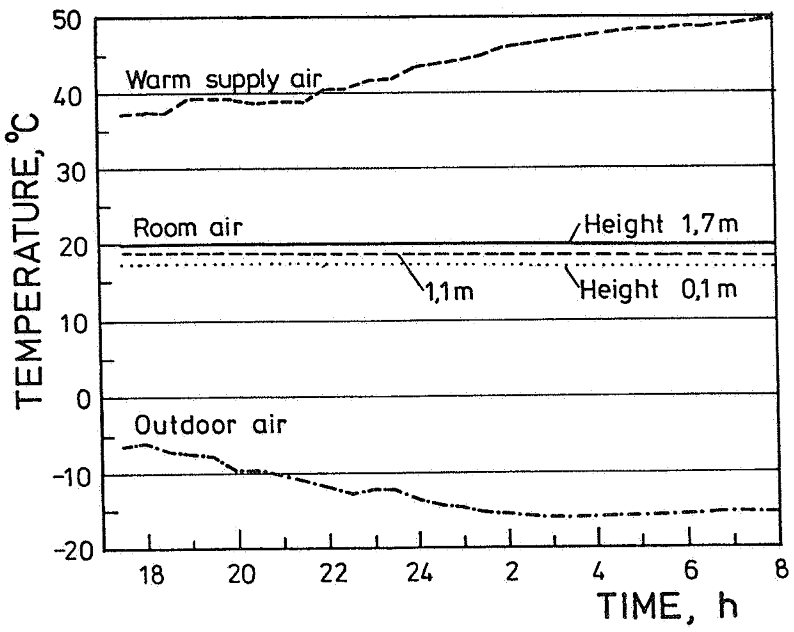

Figure 4. Indoor air temperature gradient in a bedroom heated by the ventilation heating system on a winter night.

The preadjustment and sound technical properties required of the air terminal devices combined with good air distributing properties make a great part of the marketed supply air devices, e.g. grilles and registers, unsuitable for the ventilation heating systems.

In the ventilation heating system the room-based warm air flows do not have to be exactly according to the heat losses of the rooms, because the heating effects needed by the rooms are transferred to the air from separate heating coils. The heating air flow in the room shall be sufficient in order that the heating effect corresponding to the design situation can be transferred to the room from the heating coil. The warm air flows of the rooms shall be limited thus that the sound levels of the air terminal devices are low enough.

Figure 5 /4/ shows the interactions between the supply air temperature and warm air flow rate in an upper distributed warm air heating system. By selecting the right supply air temperatures and air flows we can obtain good room climate.

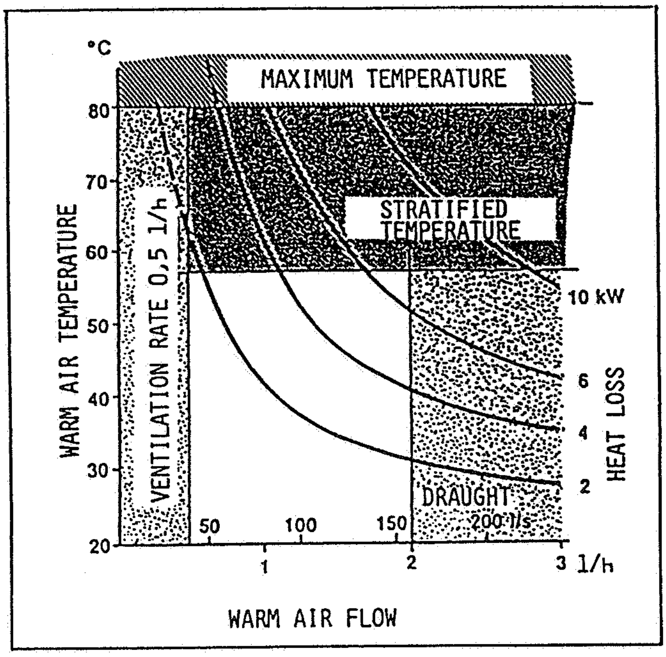

Figure 5. Interactions between supply air temperature and warm air flow rate in an upper distributed warm air heating system /4/.

5 NOISE CONTROL

At maximum air flow the total sound power levels are about 79 - 87 dB at the inlets and outlets of the fans of the ventilation heating system. This means use of very effective noise control in order to reach the noise levels accepted in rooms, 25 - 30 dB(A). In bedrooms the sound level should be 25 dB(A) at most.

In the ventilation heating system all the noise control (vibration isolation and sound attenuation of fans and sound insulation of the casing) have been made in the central unit. In addition, the right type of sufficiently high pressure and silent air terminal devices are selected for preadjusment of the air flows in the rooms and max 3 - 4 m/s flow velocities are used in the air ducts.

6 AIR FILTRATION

The need of filtering the outdoor, recirculation and exhaust air used in the ventilation heating system can be esitmated on the basis of both equipment and room soiling and sanitary viewpoints.

In the ventilation heating system the efficiency and structure of the air filters can freely be selected according to need of filtering. Bypass flows of the air filters must be prevented.

6.1 Outdoor air filters

At least the largest dust particles have to be filtered from the outdoor air to keep the heat recovery device clean. A good prefilter is sufficient. If the outdoor air has high dust content and plenty of small particles at least a fine filter of Eurovent air filter class EU4 has to be used.

6.2 Recirculation air filters

The development of dust in the apartment is decisive for the dust content of the recirculation air. The dust and textile fibres developed due to friction are relatively large. A good prefilter should be sufficient for filtering them. The particles of cigarette smoke are < 1 µm while the average particle size is about 0,1 µm. Efficient filtering of these particles as well as other small particles hazardous to health requires very good fine filters (at least EU7).

6.3 Exhaust air filters

Exhaust air contains in addition to recirculation air dust also grease from the kitchen. A kitchen grease filter protecting the ducts and a good prefilter protecting the heat recovery device should be sufficient for exhaust air filtering.

7 CONCLUSIONS

7.1 The advantages of the ventilation heating system

The ventilation heating system has several properites that can be achieved only when the heating effects needed by both heating and ventilation are completely adjustable on a room by room basis. Then the factors influencing room climate can be controlled with only one system.

The special advantages of ventilation heating systems are:

- The ventilation heating system has sufficient sound insulation and sound attenuation due to the structure of the central unit and right selection of air terminal devices.

- The exhaust air flows are controlled by the inhabitant according to his local and temporal needs.

- The pressure ratios of the building, and the outdoor and exhaust air flows, are under control in the different fan operation conditions.

- Each room can be both heated and cooled.

- The temperature of each room can be controlled with one adjusting knob according to the needs of the inhabitant.

- The room-based air flows do not have to be controlled accurately according to the heating need.

- The heating system is suitable both for a high and low temperature system.

- The heating system is suitable for a so-called mixed system (it is not profitable to heat all the rooms with air).

- The heating system is suitable for upper-distribution (blowing of warm air from the wall or ceiling).

- The supply air ducts need not be thermally insulated.

- The air filters can be selected according to need.

7.2 Needs for further development

Several needs for development of single devices have emerged during the development of the ventilation heating system. The small air heating coils with room thermostats and suitable flow ratio regulator for outdoor and exhaust air flows needed are not on sale. The cost of the prototypes developed have, however, been small, Figure 6 /6/. The industry should develop, for instance, the following sufficiently cheap components suitable for the ventilation heating system:

- flow ratio regulator of outdoor and exhaust air flows,
- tight dampers for air flow,
- small air heaters for each room,
- sufficiently high pressure and silent air terminal devices,
- vibration isolators for small fans.

The development of ventilation heating system gives bases for industrial production of a new generation of warm air heating and ventilation systems.

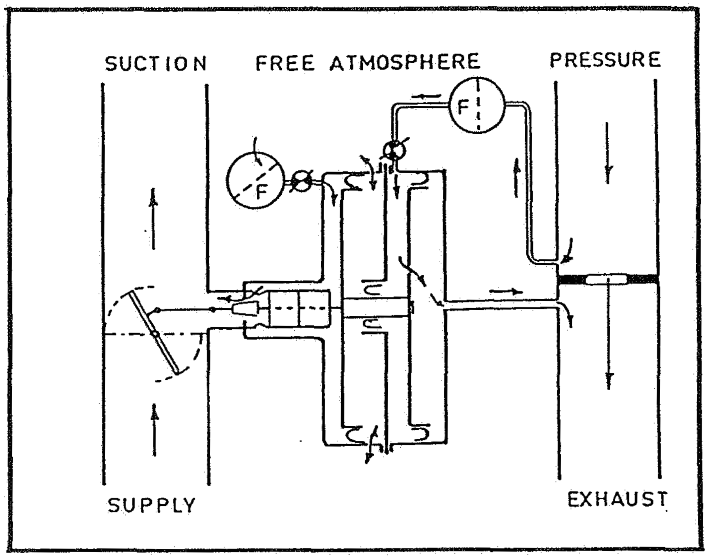

Figure 6. Flow ratio regulator of outdoor and exhaust air flows in the ventilation heating system, principle of selfcontained cascade control /6/.

The ventilation heating system particularly gives better changes to meet the inhabitants' expectations on the heating and ventilation systems.

Acknowledgements

The author wish to acknowledge the support of Ministry of Trade and Industry, Finland (KTM).

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