LowEx

IEA ECBCS ANNEX 37

START OF THE WORK UNDER ANNEX 37

As a result of the Future Buildings Forum Workshop "Low Temperature Heating Systems in Buildings" held in June 1998 in Sweden, a new IEA Annex was proposed to the IEA ECBCS ExCo in November 1998. After that, a 1 year preparation phase started. Finland agreed to lead the Annex preparation phase and invited the countries to the kick-off meeting in Espoo, Finland in March 1999. The second preparation phase meeting was held in Montreal, Canada in October 1999. During the preparation period a complete programme of activities, structure and deliverables was compiled.

The Experts of Annex 37 in the Second Preparation Phase meeting in Montreal (from left): Itaru Takahashi, Dietrich Schmidt, Alain Legault, Masanouri Shukuya, Gudni Jóhannesson, Markku Virtanen, Winston Hetherington, Mia Leskinen, Niels-Ulrik Kofoed, Peter Op't Veld and Edward Moforsky standing in front of a low exergy application: a solar wall.

FIRST EXPERT MEETING

After the one year preparation phase, the work of Annex 37 was started at the beginning of year 2000.

The First Expert Meeting of Annex 37 was held in Maastricht, The Netherlands on April 5 to 7. It was hosted by Novem and Cauberg-Huygen R.I. and attended by participants from Canada, Finland, France, Germany, Netherlands and Sweden. Also, Hermann Halozan, the Chairman of the Executive Committee of IEA Implementing Agreement for Heat Pumping Technologies, attended the meeting. At this First Expert Meeting, the progress of work was reviewed and the actions for the next six months were decided.

MILESTONES

Introduction to the concept of exergy document has been prepared in Subtask A. It is now being commented by the other participants and will be published in the end of the year.

The work on the Database of low exergy technologies, concepts, system solutions and their impacts is under way. At the Maastricht meeting, the participants divided the work and each participant will contribute to the

START OF THE WORK UNDER ANNEX 37...

work by filling in one or two pages about one or more low exergy concepts or technologies. The working group decided that the database should contain information about traditional heating or cooling systems for comparison. Traditional in this context would mean the systems widely used in the participating countries.

A draft for a report of the side effects of the low temperature heating systems was presented in the Maastricht meeting. The idea is to demonstrate that, in addition to the desired heating or cooling effect, low exergy systems can provide occupants with a comfortable, clean and healthy environment. An article of this subject is presented in this Newsletter.

DESCRIPTION OF ANNEX 37

'LOW EXERGY SYSTEMS FOR HEATING AND COOLING OF BUILDINGS'

Energy saving and emission reduction are both affected by the energy efficiency of the built environment and the quality of the energy carrier in relation to the required quality of the energy. Taking into account qualitative aspects of energy leads to introduction of the exergy concept in comparison of systems, which is the key idea of Annex 37. Exergy is the part of energy, which is entirely convertible into other types of energy. High valued energy, such as electricity and mechanical workload, is almost purely exergy. Energy, which has a very limited convertibility potential, such as heat close to room air temperature, is low valued energy. Low exergy heating and cooling systems use low valued energy, which is delivered by sustainable energy sources (e.g. by using heat pumps, solar collectors, etc.). Common energy carriers like fossil fuels deliver high valued energy.

Future buildings should be planned to use or to be suited to use sustainable energy sources for heating and cooling. One characteristic of using of these energy sources is that only a relatively moderate temperature level can be reached, if resonably efficient systems are desired. The development of low temperature heating and high temperature cooling systems is a necessary prerequisite for the usage of alternative energy sources.

Low temperature heating and high temperature cooling systems are integrated systems. The different parts of the system are the source, the distribution systems outside the building and the system within the building. The basis for the needed energy supply is to provide occupants with a comfortable, clean and healthy environment.

OBJECTIVES

The general objective of the Annex 37 is to promote rational use of energy by means of facilitating and accelerating the use of low valued and environmentally sustainable energy sources for heating and cooling of buildings.

Specific objectives are:

- to investigate the technical and market potentials for replacing high valued energy (e.g. fossil fuels and electricity) by low valued energy sources and to assess its impact on global resources and environment;
- to assess existing technologies and components for low exergy heating and cooling in buildings, to enhance the development of new technologies and to provide the necessary tools for analysis and evaluation of low exergy systems;
- to develop strategic means for the introduction of low exergy solutions in buildings by case studies, design tools and guidelines.

SCOPE

The interest of the Annex will cover:

- All type of buildings excluding industrial processes (industrial processes as energy source are included in the scope)
- New and retrofitted buildings
- Small scale and distributed community systems
- The impact of the building on the whole energy chain from energy source (via the district heating/cooling system) to building as a system
- A spectrum of different climates
- A spectrum of different interest groups and stakeholders
- Different energy sources (favourable temperature ranges)
- Practical solutions of air and water based heating and cooling systems
- Life cycle aspect of systems
- Environmental impacts of systems
- End users point of view and behaviour

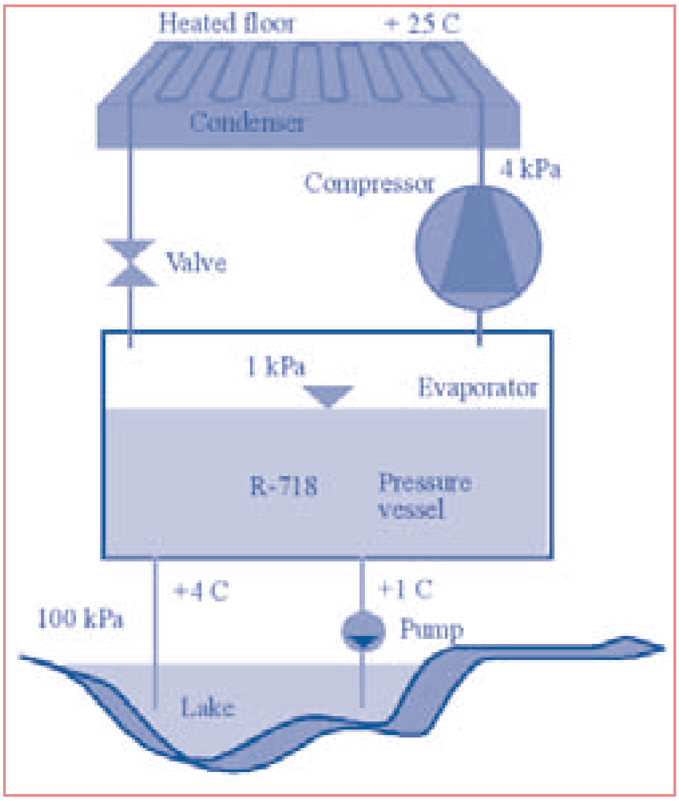
STRATEGY

Four subtasks will be carried out in order to reach the objectives.

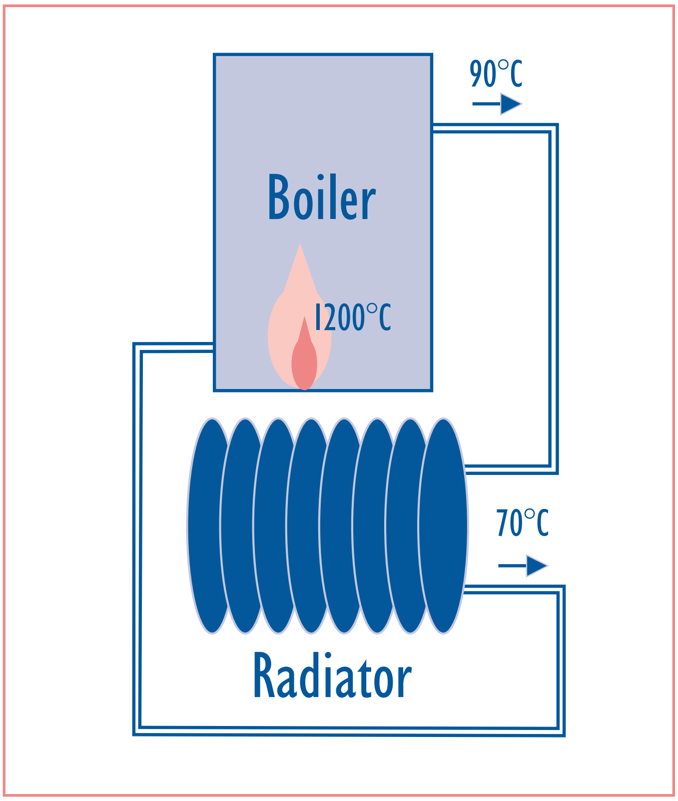
(1) Subtask A:
Exergy Analysis Tools for the Built Environment

Co-ordinator: Canada, represented by Alain Legault, NRC

The main objective of this Subtask is to assess and develop a comprehensive set of tools to enable an assessment of low exergy technologies, components and systems.



Example of low exergy heating system: heat production with heat pump and distribution with floor heating system



Example of traditional heating system: heat production with gas-fired boiler and distribtuion with high temperature radiator

(2) Subtask B:
Low Exergy Concepts and Technologies
Co-ordinator: Sweden, represented by Gudni Jóhannesson, Royal Institute of Technology.

The main objective of this Subtask is to create a comprehensive database of low exergy concepts, and to assess their advantages, requirements and limitations.

(3)Subtask C:
Case Studies and Market Potentials
Co-ordinator: Netherlands, represented by Peter Op't Veld, Cauberg-Huygen R.I.

The main objective of this Subtask is to collect practical experiences gained from the installed low exergy systems and to analyse the market potential of low exergy systems in different countries.

(4)Subtask D:
Documentation and Dissemination
Co-ordinator: Finland, represented by Markku Virtanen, VTT Building Technology

The objective of this Subtask is to compile and widely disseminate the Annex research results and to identify the means of influencing the energy policies and regulations in order to promote the use of low exergy systems.

ANNEX BENEFICIARIES

An analysis of case studies together with the rationale of the exergy concept and recommendations concerning regulations in the building sector and energy tariffs are expected to be helpful for real estate builders, building maintenance managers, political decision makers and the public at large.

Designers of heating and cooling systems in buildings are the main target group and the most potential users of the guidebook developed in the Annex. The design guidebook will include: database of low exergy components, developed system concepts for different buildings and climates and a comprehensive set of tools for analysis. All of these components, completed with the guidelines for selection of products, are expected to attract the interest of engineering firms, consultants and architects.

DISSEMINATION OF RESULTS

In addition to regular technical reports and conference papers, each of the Subtasks A-C will deliver a written summary reporting on the work carried out within the Subtask during the Annex. These reports will be compiled and completed in Subtask D to form a design guidebook. The design guidebook will be a final product of the Annex and will be produced in two forms: a traditional book and a CD-ROM. The dissemination of each Subtask is listed below.

Subtask A: **Exergy Analysis Tools for the Built Environment**

- Introduction to the concept of exergy
- Set of models and tools for exergy analysis
- Directories describing appropriate models and tools for design of low exergy systems
- Report of the potential for exergy reduction of various heating and cooling systems for buildings

Subtask B: **Low Exergy Concepts and Technologies**

- Database of low exergy technologies, concepts, system solutions and their impacts

Subtask C: **Case Studies and Market Potentials**

- Report of the practical experiences in low exergy heating and cooling, lessons learned
- Report of the market potential of low exergy technologies
- Report of the benefits and positive side-effects of low exergy technologies

Subtask D: **Documentation and Dissemination**

- Design guidebook (in form of traditional book and CD-ROM)
- Report of the analysis of national policies
- Recommendations for national strategies and policies
- Recommendations for international strategies and policies
- Industry workshops
- Newsletters and other information packages
- Web-site

ANNEX 37 WEBSITE

HTTP://WWW.VTT.FI/RTE/PROJECTS/ANNEX37/

All the infromation about Annex 37 will be found on our website. It is updated continuously. There you can find the

- Status Reports
- information about the meetings and publications
- contact information
- links to other useful sites etc.

IMPACT ON IAQ, THERMAL COMFORT AND ENERGY CONSUMPTION

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Major savings in energy consumption can be realised by fully utilising the potential of *Low Valued Energy*. *Low Valued Energy* is available from residual heat, ambient heat and renewable sources. It can be used for Low Temperature Heating (LTH), but the buildings and installations should be designed for low temperature distribution systems. Appropriate distribution systems, like floor and wall heating, have a life cycle of 40 to 50 years. Therefore to implement *Low Valued Energy* sources within the next half century, heat distribution systems should be designed for lower temperatures as soon as possible. Aware of this need for quick action, the Netherlands Agency for Energy and the Environment (NOVEM) initiated an implementation program in 1996. This program has demonstrated that, besides the argument of savings in energy supply, there are additional benefits in the fields of:

- Indoor Air Quality lower air ;
- Thermal Comfort ;
- Energy Consumption.

LTH-DESIGN

Due to a better insulation of new and retrofitted buildings and new techniques for reducing ventilation losses, the heating demand of modern buildings is decreasing. This ongoing trend enables a broader application of LTH-designs for the smaller heating capacities needed. Wall and floor heating systems fit very well into an LTH-design, but also air heating, enlarged radiators and enlarged convectors can be applied. LTH-designs can be defined according to the design temperature ranges given in Table 1.

THERMAL COMFORT

Radiant heat transmission

The radiant heat transmission component of LT-systems is much higher than for other systems. Therefore the convection heat transfer is reduced and the air temperatures can be 1 – 2 °C lower and provide the same comfort level. It is presumed that radiant heat transfer (i.e., relatively cool air and warm surrounding surfaces) better satisfies the comfort needs of human beings because it is more 'natural' (like solar radiation on the skin).

Vertical temperature gradients

In computer simulations and laboratory and field experiments, a clear difference was found in vertical temperature gradients between floor and HT-radiator heating. With floor heating, practically no temperature distribution is found in well-insulated buildings, but the temperature distribution resulting from radiator, wall and other heating systems are very dependent on the design. Normally, gradients range from 2 – 3 °C between floor and ceiling, while poorly designed systems show gradients up to 7 °C. In particular, the gradient between ankle and head levels influences the perceived thermal comfort.

Temperature asymmetry

Cold window surfaces can cause discomfort by radiant heat losses, which are not in balance with radiant heat flows in other directions. Complaints occur when differences exceed 23 W/m² or 10 °C. Conventionally, compensation was provided by placing hot radiators close to the cold surfaces, but due to better insulating windows, this aspect is becoming less important. At higher U-values, the height of the window can be restricted or compensation, for instance by extra heating in the outer circle of floor heating system, is recommended. Discomfort from heated floor or wall surfaces does not occur.

Surface temperature of heated floors

A heated floor increases the comfort in many applications. Floor covering, like carpets, is not needed for walking bare-foot or sitting on the floor (e.g., at home, nurseries and swimming pools). Optimal floor temperatures range from 20 – 28 °C with shoes and 23 – 30 °C with bare feet depending on the flooring material.

Temperature fluctuations

Temperature fluctuations around a constant mean value are annoying for occupants. LTH-systems provide fewer fluctuations because LTH-systems have a greater inertia and the driving forces are smaller due to large surfaces and low temperature differences.

System	Supply flow	Return flow
High temperatures (HT)	90 °C	70 °C
Medium temperatures (MT)	55 °C	35 – 40 °C
Low temperatures (LT)	45 °C	25 – 35 °C
Very low temperatures (VLT)	35 °C	25 °C

Table 1. Definition of temperature ranges for heating designs

The absence of radiators gives more space for the interior decoration.

Inertia is often considered to cause discomfort during solar gains or sudden changes in internal gains, but in fact, LTH-systems have 'self-regulating' abilities. Since LTH-systems operate at small temperature differences, any change in the indoor temperature has a relatively large effect on the heat supply and therefore the heat supply reacts almost instantly to temperature changes in the interior.

Heating up period

Conventional heating systems have a shorter heating-up period (after cooling down e.g. for 8 hours) due to the inertia of direct connected thermal mass for floor and wall heating systems. The temperature raise for LTH-systems, however, is much lower than for HT-systems. Moreover heating up is often associated with air temperatures, but considering operative temperature (mean value of air and radiant temperature) reduces the differences between LT and HT- heating systems.

Cooling abilities

Increasing the insulation grade of buildings together with reducing ventilation losses and utilising solar gains, increases the risk of overheating during the summer. LTH systems can be often adapted for cooling easily and inexpensively, especially when combined with a ground collector (and heat pumps).

Air velocities and draught

Draught can be caused by cold (window) surfaces, at which the air in the boundary layer cools down and flows downwards. This can be avoided for instance by placing hot radiators under the window. Laboratory studies show that mean air velocities for HT radiators and floor heating are in the same order within the living zones. The fluctuations around the mean value however (turbulence-intensity) are about 20 % higher with HT radiators. Applying well-insulated glazing and limited window heights (max. 1.7 m for clear double-glazing) reduces sufficiently the risk of draught with floor (and likely for other LT) heating systems. Special attention is needed for natural supply grills in the facade for ventilation.

INDOOR AIR QUALITY

Suspended particles

In a field study in Finland, visible dust on floors was found to correlate to neurotic complaints like headache, fatigue, and concentrating problems, etc. LT-heating was found to give less eye-irritation and throat and other mucous diseases. Also a correlation was found between the temperature of the heating surface and particle deposition. It is assumed that the lower air fluctuations from LTH-systems results in a lower quantity of suspended particles in buildings.

Mites

Many studies show a positive effect from floor heating on reduction of the mite population in dwellings. This is mainly caused by a lower relative humidity (RH) in the boundary layers above the floor (within the floor covering). The mite survival threshold is 45 % RH during long term. Floor heating systems have been calculated to reduce the RH in the boundary layer by about 10 % RH, which just suffices to bring the RH under the threshold value.

Room Air temperature

As a result of the high contribution of radiant heat transfer, the room air temperature can be

1 – 2 °C lower for LTH systems. Several studies show a better performance for stuffiness and perceived air quality at lower air temperatures. Mucous irritation complaints increase significantly at air temperatures over 22 – 24 °C. The annoyance from all kinds of emissions (TVOC etc) is correlated to the air temperature and a correlation has been found for Sick Building Syndrome and the air temperature.

Dust singe and odour annoyance

Inhaling dust can cause allergic reactions and the sensitivity of humans to inhaled particles is more dependent on the quality of the particles than on the quantity. At temperatures exceeding 55 °C, the process of dust singe starts. The particles get more reactive and irritating from the higher temperatures that occur at HT heating elements. So LTH systems not only give less suspending particles in the air but moreover the particles spread are less aggressive due to absence of dust singe.

ENERGY CONSUMPTION

Transmission losses

Due to floor and wall heating, the mean temperatures in the heated constructions are higher during the heating season. Heated walls in the outer envelope have up to 50 % large heat losses, but applying a thicker insulation layer (2.5 – 5.0 cm thicker) in heated constructions can easily compensate for these extra losses. Transmission losses from hot air flowing along window surfaces are reduced with LTH.

Venting and infiltration losses

In buildings with LTH, the ventilation losses are lower due to the lower air temperatures. Especially infiltration and natural ventilation cause less energy consumption. For ventilation systems with balanced air exchange and heat recovery the savings are smaller.

Transport energy

Larger flows of the heating medium might need to be transported because of lower temperature intervals (especially with floor heating). In combination with a heat pump a continuous heat flow is preferred at the lowest possible supply temperatures. Therefore the duty cycle of the transport pump often will be higher for LTH systems. Extra transport energy can be restricted by a good hydraulic design.

Utilisation of gains

In buildings with average insulation levels, solar and internal gains are utilised 100 % for reduction of auxiliary heat demand. In light mass buildings with improved insulation, the utilisation of gains decreases. The energy saving from better utilisation is also dependent on the layout of the heating system and thermal zoning in the building (e.g. through transport of solar gains by a floor system from south to north zones).

CONCLUSIONS

The application of low exergy systems provides many additional benefits besides energy supply benefits such as: improved thermal comfort, improved indoor air quality and reduced energy consumption. Other possible benefits include: reduction of burning risk, extra space due to the absence of radiators and other equipment, reduction in mould growth, etc. By highlighting these additional benefits a quicker and broader introduction of LTH-systems may occur. In addition, application on a broader scale will also lower the prices of these systems.

Many disadvantages can be avoided by proper designs and compensating measures. Arguments against LTH-systems often appear to be based on negative experiences in the past (poor design or installation) or a lack of knowledge.

These aspects will be promoted to increase the application of low exergy systems for heating and cooling of buildings.

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NEXT MEETINGS OF ANNEX 37

2nd Expert Meeting
The Second Expert Meeting of Annex 37 will be held in Stockholm, Sweden on 25th to 27th September 2000.

3rd Expert Meeting
The Third Expert Meeting of Annex 38 will be held in Hamburg, Germany on 9th to 11th May 2001.

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Annex 37

LOW EXERGY SYSTEMS FOR HEATING AND COOLING OF BUILDINGS

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