LowEx

LOW EXERGY SYSTEM CONCEPTS
AND AN EXAMPLE OF A DESIGN STRATEGY

This issue contains descriptions of existing system concepts, a design strategy and an idea how to use cool radiant exergy. The Japanese example of how radiant cooling exergy can be used for cooling of buildings is an excellent example of an innovative solution of the use of exergy analyses to reduce the environmental impacts. Two system concepts are presented: Are Sensus® which is even more than a system concept – it is an integrated solution for building services and it can even cover e.g. maintenance solutions. ThermoNet® system concept for grocery stores is presented on page 5. The design strategy is written for designers that need guidelines for designing low-exergy systems for buildings. This issue is the second last issue of the LowEx news and the last one will be published in December 2003.

Participants of the meeting together with students that participated in the workshop.

The Seventh Expert Meeting of Annex 37 was held in Yokohama, Japan from April 14th to 16th, 2003. Musashi Institute of Technology hosted the meeting. Participants from Canada, Finland, France, Japan, Netherlands, Norway and Sweden attended the meeting.

The meeting consisted of working sessions to review the work of the Annex. One session was also devoted to discuss the outcomes of a meeting in Stockholm where the design guidebook and final report was planned. The report will be a booklet of about 40 pages, which includes a CD-ROM. The CD-ROM will be interactive, user friendly and the results will be presented visually. It will contain all the material produced within the project; newsletters, publications, the tools and the full version of the design guidebook. In addition a web-site containing the same information as the CD will be set up. After the meeting a workshop was organised for students, engineers and representants from the industry.

As one of the concrete results we also see the conclusions of the discussions about the new Annex that this group might apply for. The Annex 37 group considered it very important to continue the work together. The new Annex would be a continuation of this Annex and it would deal with the economical aspects of exergy ("exergy of money") and also with dynamic systems concerning exergy. In general the possible new Annex would focus more on system applications, their detailed analysis and system optimisation. The possible follow up Annex will be discussed more detailed during the next expert meeting.

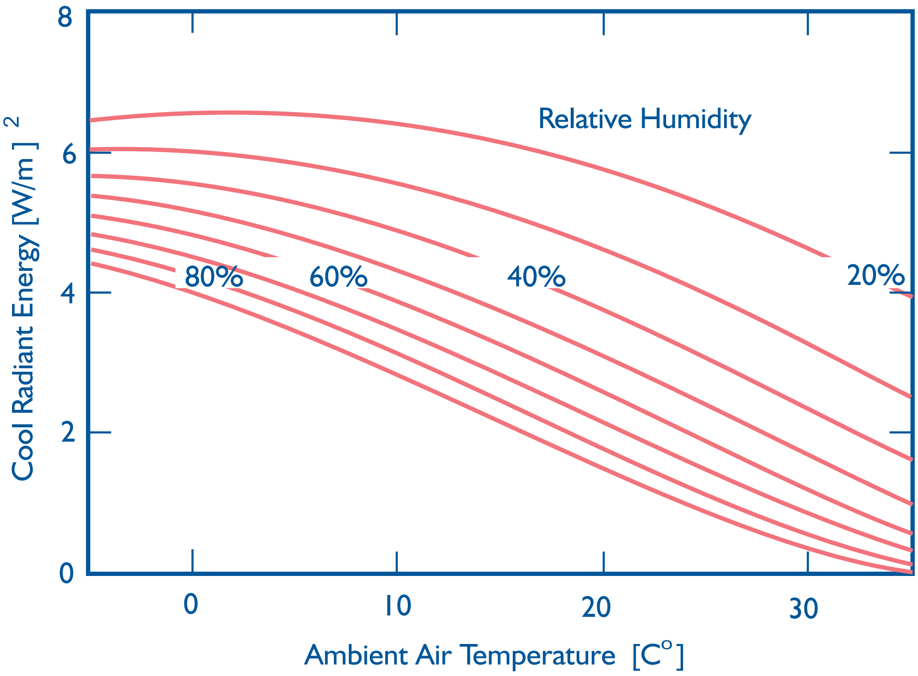

Figure 1. Cool radiant exergy available from the sky as a function of ambient air temperature and relative humidity (Shukuya, 1994).

Looking at things surrounding us with the concept of exergy helps us to find a new or forgotten source for low exergy heating and cooling of buildings. The sky is a cool radiant source while at the same time it is the diffuse solar radiant exergy source. Designing a built environmental space so that we can make use of cool radiant exergy available from the sky would be a challenge for architects and engineers concerned about environmental architecture and technology.

Basic requirements to realize low exergy systems for heating and cooling of buildings are to have thermally well insulated building envelopes and also appropriate thermal-exergy storage capacity depending on its necessity. For heating, there are quite a few actual examples of low-exergy strategies applied in various types of buildings over the last two decades. On the other hand, there are not many examples for cooling yet.

Among the features to be taken into consideration to realize low exergy cooling systems, the most important is to reduce the solar heat gain by using the external shading devices over the glass windows that result in lower surface temperature and the interior wall-surface temperature. It is also important to reduce the heat caused by electric lighting during daytime as much as possible by extensive use of daylighting.

It eventually becomes effective to have a natural air flow path within the built environment, that is, two openings which bring the outdoor air flowing in and out either by buoyancy or by wind especially during nighttime. Slightly cool wall surfaces provided by such cross ventilation may bring about a condition that is thermally comfortable enough. A similar condition may be realized by slightly cool panel surfaces conditioned by ground water and others.

In order to make such cross ventilation really work, one essential thing that we need to consider is whether we can find patches of trees with green leaves that can produce cool ambient air to be brought into the built environment. The trees can shade solar radiation effectively in summer. Green leaves perspire water vapor very much to be a natural air conditioner while at the same time they can be a cool radiant source due to their temperature decrease compared to the surrounding temperature. Planning, growing and managing such green patches should be incorporated in sustainable town and architectural planning.

An other thing that we should take into consideration is to see the sky as a cool radiant source. As described in a research note on "Introduction to the Concept of Exergy" (its copy is available from our website http://www.vtt.fi/rte.projects/annex37), a surface whose temperature is lower than its environment can emit cool radiant exergy.

Figure 1 shows cool radiant exergy available from the sky as a function of the environmental temperature and relative humidity [1]. The amount of radiant exergy is very small compared to that of solar exergy, which is about five hundred times larger (400–600W/m^3), but a half to one W/m^2 of cool radiant exergy, that is typical in summer. That is not a negligible amount to cool off our built environmental space. Imagine that your body is surrounded by the surfaces with the temperature of 25°C. You would feel cool enough. According to radiant exergy calculation, a black surface with its temperature of 25°C emits about 1 W/m^2 of cool radiant exergy under the condition of environmental temperature of 30°C. Compare this value with the cool radiant exergy available from the sky under a summer condition shown in Figure 1.

Figure 2 shows an example of the sky temperature variation obtained from infra-red radiation photography taken early in the afternoon on a summer day in Yokohama area, Japan [2][3]. The sky condition was very clear. The sky temperatures shown here are modified temperature values based upon the infra-red radiation photograph taken and black-body radiation theorem with an estimation of the sky emissivity from the ambient temperature and humidity. There is a distribution of the sky temperature according to the angle of view from the horizon. The sky temperature goes down as you look up gradually from the horizon. A patch of the sky near the zenith emits a relatively large cool radiant exergy.

It would be a challenge to design our built environment so that we can make use of cool radiant exergy available from the sky for moderate cooling, especially from the upper part of the sky, while cutting down the intense solar exergy with effective external shading devices and hence avoiding the warm exergy storage within the building envelope systems. ■

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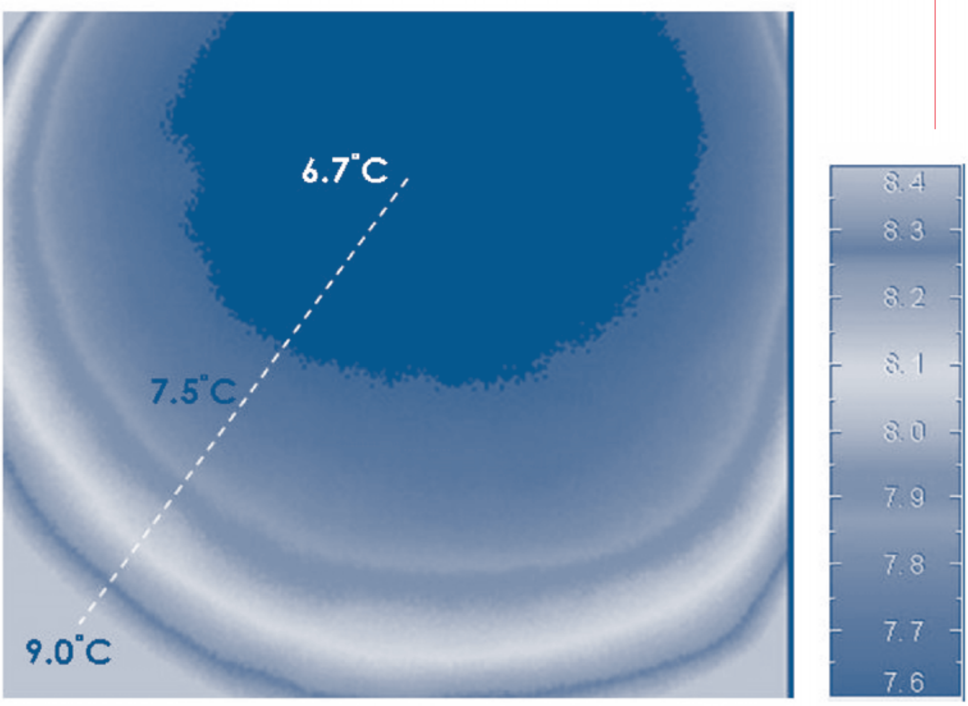


Figure 2. An example of sky temperature distribution.

References

1. M. Shukuya, "Energy, Entropy and Exergy Balances at the Exterior Surface of Building Envelope Systems", Proceedings of the Annual Meeting of Architectural Institute of Japan, Building Environmental Science Section, 1994, pp.429–430.

2. M. Tsumura, M. Nishiuchi, and M. Shukuya, "Comparison of Radiant Exergy between Urban Areas with Little Greenery and with Much Greenery on a Hot Summer Day (Part 1. The Outline of Measurement and the Estimation of Sky Temperature)", Proceedings of the Annual Meeting of Architectural Institute of Japan, Building Environmental Science Section, 2003 (to be presented).

3. M. Nishiuchi, M. Tsumura, and M. Shukuya, "Comparison of Radiant Exergy between Urban Areas with Little Greenery and with Much Greenery on a Hot Summer Day (Part 2. Calculation of Cool and Warm Radiant Exergies Available from the Surrounding Surfaces Outdoors)", Proceedings of the Annual Meeting of Architectural Institute of Japan, Building Environmental Science Section, 2003 (to be presented).

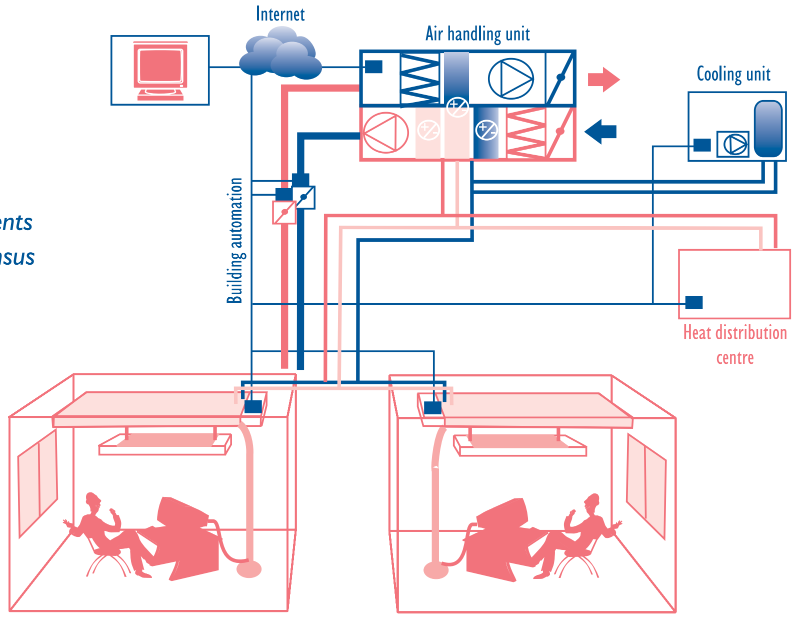
EXERGY SAVING WITH ARE SENSUS®

The exergy consumption of the Sensus® building servicessystem is lower than in comparable high-standard systems.

Office ventilation employs a Sensus® ventilation unit connected to the Sensus panels with a three-pipe network. The ventilation units utilise surplus heat collected from the rooms with the cooling water system for the heating of intake air whenever heating is needed there. This conserves heating exergy. The ventilation machine also has an efficient rotating heat collector for the exhaust air (over 70% heat efficiency).

The Sensus® ventilation unit utilizes outdoor air for cooling the cooling water for the rooms when outdoor temperature is sufficiently low (under +12 – 14°C). This free cooling carried out with ventilation units operates alongside mechanical cooling when necessary. It has a considerably longer annual period of utilisation (over half of the year's working hours) than conventional free cooling. This lowers the electricity consumption of cooling unit in the Sensus® system in comparison with conventional solutions.

Main components of the ARE Sensus system.



HEATING AND COOLING

The office space is heated and cooled with Sensus panels installed on the ceiling. Hot or cold water circulates to heat or to cool the room according to the need. Heating and cooling are transferred from the panel to the room most often via thermal radiation. Sensus® is draught-free, since it does not circulate air. This has been noted in practice and verified with measurements carried out by the Finnish Institute of Occupational Health and Safety in premises where the Sensus® system has been installed.

There is thermal radiation from the panel into the air of the room and the surfaces of the room (floor, furniture, windows), which changes into heat upon contact with the surface. Therefore the panel produces a more even distribution of heat in the room than radiator heating. This has also been noted in studies by the Finnish Institute of Occupational Health and Safety comparing the Sensus® system with radiator heating.

International studies have showed that ceiling cooling is the most pleasant way to cool office and work space. Sensus® follows the same principle as ceiling cooling. People in the space will feel coolness but no draught.

VENTILATION

Supply air is conducted into the rooms through supply air diffusers. The diffusers are installed beneath a panel and the air is conducted along the surface of the panel. Ventilation is draught-free, because the air keeps well to the smooth panel and will not "fall down". At the same time the surface of the panel will heat or cool the intake air according to the requirements of the room. The air flow is dimensioned to maintain high air quality in the room.

LIGHTING

Sensus lighting fixtures together with the Sensus panels provide high quality indirect lighting. The lighting fixture is installed under the panel. The lighting fixtures use energy-saving T5 fluorescent tubes. Indirect lighting is a highly flexible solution for modern offices, which are mainly intended for computer monitor work. The lighting is suited to different types of furnishing and relocations of partitions without alteration work. The light is not reflected from the computer monitors. Although the panels have a high reflectance of light, they are not shiny or glossy. Therefore, the required electrical power for the lighting is low and electricity consumption is also low.

TEMPERATURE CONTROL

Room temperature control functions considerably better than in conventional designs. A single electronic temperature control unit regulates heating and cooling in series. There is no simultaneous heating and

SYSTEM DESCRIPTION

EXERGY SAVING WITH ARE SENSUS®...

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cooling in the same space, as in solutions with thermostat-valve radiators and separate controls for cooling. This improves interior conditions and lowers exergy consumption. Control is also improved by the fact that both heating and cooling are mainly provided through thermal radiation. Heating or cooling is focused directly where it is needed, i.e. on people and the surfaces in rooms. Adjustment is quick, because the radiated temperature of the panel is felt immediately. In traditional designs heat and cooling are conducted through the air with slow effect on room temperature.

Temperature control in office spaces is carried out with electronic room controls regulating the valves for heating and cooling. The controls have dials with which the office workers can set the desired temperature. Each room has a separate control unit. In the open office, temperature is regulated independently in sections. Each panel has its own regulator valve and piping, permitting alterations to the walls without changes to the piping.

ELECTRICITY

Electrical and computer connections in the office space are realised by distribution from above employing socket columns. The connection cables of the work stations are placed freely above the Sensus panels. The socket columns can be placed or moved where desired in the work station area. ■

SYSTEM DESCRIPTION

THERMONET® SYSTEM TECHNOLOGY FOR GROCERY STORES

ThermoNet system can be applied to many of building types including hospitals, swimming halls, offices, industrial buildings, residential high-rise buildings and grocery stores. The exploitation of condensation heat, waste heat, and excess energy in a Thermonet system is based on two factors: an air heating system that utilises low temperature technology, and efficient energy recovery. By applying ThermoNet technology, the consumption of purchased energy may be cut by more than one half when compared to conventional solutions, and electrical consumption may be reduced to one third.

ENERGY SYSTEMS

Heating

In grocery stores, the relative size of grocery departments is large. Consequently, a large volume of condensation energy is abundantly available, and its temperature is well suited for utilisation by the ThermoNet air heating system. Primarily for this reason, shop spaces are heated by air through the Dirivent impulse system. The air heating system is also able to control the rapid load fluctuations typically found in grocery stores. Vestibules are fitted with air circulation equipment connected to the ThermoNet network.

Heat Sources and Heat Recovery

Heat sources include heat recovered from exhaust air, condensation heat from refrigerated grocery department display cases, and supplementary energy sources such as district heating, electricity, natural gas, or oil. In the ThermoNet system, the connection to district heating can be made in an exceptionally economical fashion: ThermoNet is able to take advantage of return water flowing from other properties to the combined heat and power plant. This water contains sufficient energy that can be utilised by the ThermoNet system.

Cooling

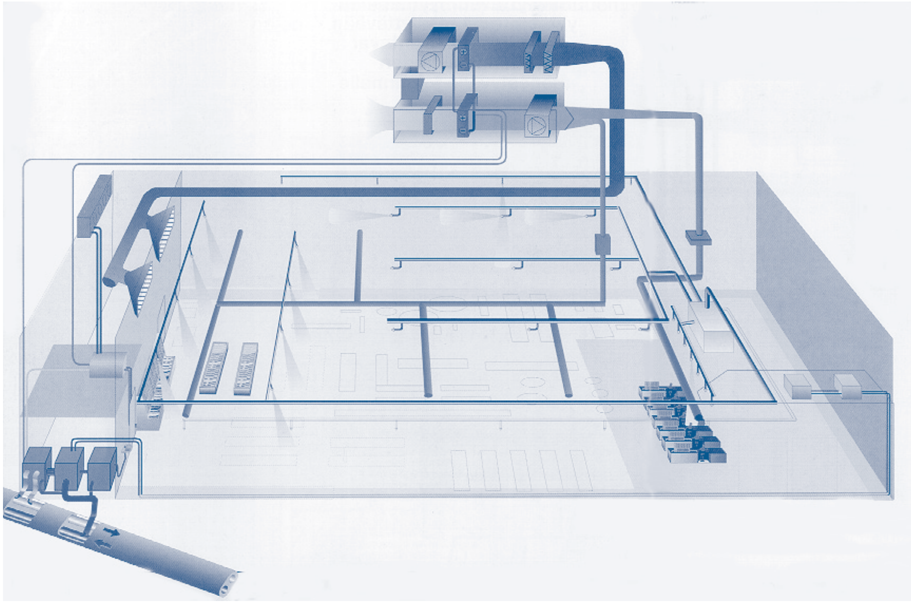
The cooling efficiency given off by refrigeration equipment, together with indirect evaporative cooling, is usually sufficient to provide cooling energy.

AIR SYSTEMS

Air heating is implemented by using the Dirivent impulse system that improves the operation efficiency of heated air. Heated air is the most effective alternative, because it can be quickly adjusted and controlled.

In grocery stores air conditioning is controlled from a single technical unit. If necessary, air conditioning operates during the day by using either return air or fresh air and during the night by using return air. The air flow and temperature are controlled so that the total benefit derived from the recovery of condensation heat, as well as from the savings in fan energy will be as big as possible.

THERMONET® SYSTEM TECHNOLOGY FOR GROCERY STORES...



A Low Exergy system for a grocery store.

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Air distribution

Efficient air distribution can be used to achieve an economical heat balance. Air distribution is implemented to maintain temperature layers in cooling situations. In heating situations, the formation of temperature layers is blocked by using Dirivent impulse system (vertical distribution for indoor air).

CONTROL SYSTEM AND REMOTE SUPERVISION

The ThermoNet system's ability to control the indoor climate while effectively utilising heating energy created in grocery stores is based on an energy utilisation and control system designed for that purpose. Additionally, through the programme, the system can be controlled and supervised remotely in real time, and necessary adjustments and alterations to the ThermoNet system can be made by experts from remote locations. ■

STRATEGIES FOR DESIGN OF LOW EXERGY SYSTEMS FOR HEATING AND COOLING OF BUILDINGS

The design process is or at least should be an iterative process. Even if we follow a certain order the complexity of our decision process is such that we can not in every step foresee the consequences of the choices we make. There will always be a need to go back to earlier step and revise the choices made.

The maximum annual energy use for heating is specified directly or indirectly in most national building codes. Even if we use the exergy approach for design of buildings this does not have to be in conflict with an effort to reduce the energy use. Since our aim is to produce low exergy systems for heating and cooling in buildings the exergy use is obviously a parameter we consider to be a major output of our design work. It is however difficult to set a limit for the real exergy consumption since we in a real project are depending on the energy sources which are available at present. The exergy consumed for distribution and emission of energy in the building reveals the potential for future low exergy generation systems on a community level.

The design should also be based on clear performance specifications for indoor comfort such as the operative indoor temperature and even in more details the radiation asymmetry, temperature gradients, maximum surface temperatures, minimum surface temperature for floors etc.

Usually the environmental impact of building materials is relatively small compared to the environmental impact of the operational phase. Specifications for low energy use and low exergy consumption therefore account for a dominating part of the total impact. Other specifications that should be regarded are the overall material efficiency with minimum waste and the long term durability of the building constructions and materials, and the chemicals needed for cleaning and maintenance.

Theoretically the flexibility to use different energy sources should follow automatically from the specifications of the maximum exergy consumption within the building. However the practical consequences of converting from one energy source to another should be addressed in the system design.

The design of a low exergy system may include the use of tap water or water from a ground well as an energy source for heating and/or cooling. This directly affects the quality of water by a temperature change which in turn can influence biological growth or chemical emissions in the piping system. Also there is a conflict between low exergy design and the risk for legionella in the domestic hot water system. Wrong design of the pipe systems with still water over a long period of time can also create risks of this type.

Normally the air quality is provided with minimum exchange rate for indoor air, filter class for inlet air and ventilation efficiency. Several attempts have been made to set up specifications for air quality that not only specifies the number of air changes per hour, but allows a time varying ventilation that can be coupled to parameters such as CO_2, moisture, emissions etc to provide the means to promote demand controlled ventilation. Some systems solutions such as recirculation of outlet air and regenerative heat exchange can have negative effect on air quality.

Since artificial lighting has to be provided with high quality energy the access to daylight is an important factor in the planning of a low exergy building. Fenestration, interior planning and the coloring of surfaces are factors that are of importance. Daylight access can be in conflict with the effort to reduce the need for cooling in summertime. ■

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FOLLOWING NEWSLETTER

LowEx News no 8

The next issue of LowEx News will be published in December and it is the last issue of Low Ex News. It will include detailed information on the design guidebook and promote the use of LowEx systems in buildings.

The Design Guidebook will be published in the turn of year.

NEXT MEETINGS OF ANNEX 37

Eighth Expert meeting

The eighth expert meeting will take place in Kassel in September 2003 and the almost completed design guidebook will be reviewed and commented in order to be published shortly. The possible follow-up of the Annex will also be discussed more in detail during this meeting.

Final Meeting

The final meeting of Annex 37 will be held in January 2004 in Finland.

ANNEX 37 WEBSITE

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

On the Annex 37 website we have collected information about Annex 37: background, objectives and working methods as well as information on participants, meetings and publications. The website is updated continuously, so the latest information will always be found on the website. There you can find the

- Contact information
- Status reports
- Previous issues of LowEx News (in pdf format)
- Technical Presentations about Annex 37 issues in ECBCS ExCo meetings
- Links to other useful sites

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LowEx

Annex 37

LOW EXERGY SYSTEMS FOR HEATING AND COOLING OF BUILDINGS

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