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ENERGY CONSERVATION IN THE OPERATION OF BUILDINGS

DP/HUN/80/001

HUNGARY

Technical report: Different aspects of energy conservation*

Prepared for the Government of Hungary
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of: K. Cena and R. Kjerulf-Jensen
UNIDO Consultants

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United Nations Industrial Development Organization
Vienna

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INTRODUCTION

The visit comprised a number of working sessions with an emphasis on discussions with the staff of the Microclimate Laboratory of the Hungarian Institute for Building Science in Szentendre on possibilities for updating the performance of their environmental chamber:

1) the ETI (Hungarian Institute for Building Science) Laboratory for Microclimate in Szentendre on October 13, 14 and 16
(dr L. Bånhidi, mr F. Svåb, mr L. Fabő and mrs G. Kintses)

The thermal manikin, funded by UNIDO, was demonstrated in detail. Possibilities for utilizing spare capacity in the attached microcomputer for control purposes were discussed.
Our discussions otherwise mainly dealt with two subjects:

a. Use of microcomputers for data-collection and -reduction:
I informed about the current trend i.e. to use IBM or compatible computers with standard hardware and software for data-collection, -storing, -reduction and -presentation.

b. Possibilities for updating the performance and control quality of their environmental chamber.

./. My recommendations are enclosed.
It was aggreed upon, that the detailed plans for future alterations could be checked by me via mail if need arise.

2) the ETI Air Conditioning and Ventilation Deprtment in Budapest on October 15 and 17
(mr G. Pences and mr L. Kun Gazda)

I presented new control strategies to minimize energy use in climatic systems.

Current solar heating projects in Hungary were discussed.

One project utilizes an open indoor swimming pool as heat storage. Means to minimize condensation problems associated with this type of system were suggested.

3) the Institute of Thermal and Systems Engineering of the Technical University of Budapest on October 17
(professor L.L. Kiss and coworker)

This lab. has developed a number of advanced measuring principles and instruments in the fields of heat transfer and thermal properties of materials.
Several instruments for these purposes were demonstrated and their features discussed.
A portable Schlieren device developed at the lab. was demonstrated in detail. The device incorporates a number of features that makes it useful for field studies as well as laboratory work.
A built in laser simplifies setup and adjustment and the system can be supplied with strobed light for transient studies.
All in all the work going on gave the impression of being at a high theoretical and technical level, and should be able to lend valuable support to R&D in the fields of heating and climatization in Hungary.

RECOMMENDATIONS

According to information from the staff at the Microclimate Lab. the performance of radiation panels and air temperature at inlet to the chamber in particular needs improvements to streamline future research.

My recommendations therefor mainly cover these two points.

1. RADIATION PANELS.

To ensure optimal performance of the thermal radiation panels the following items have to be taken into consideration:

a. waterflow through panels
b. static and dynamic characteristics of temperature sensors
c. pressure differential over control valves
d. temperature of hot and cold water upstream from valves
e. controller performance

item a:

The waterflow through each panel should be as large as practically possible.

This ensures the least possible temperature change of the water flowing through the panel, which first of all results in an even temperature over the panel surface.

It also smoothens out the water temperature over time at the panel outlet, which gives the least possible dynamic disturbances at the mixing point, where hot or cold water from the control valves is mixed with recirculated water.

Any unnecessary restrictions in the flow path through panels and their connections should be removed and pump performance reconsidered.

item b:

It is obvious that the static accuracy of temperature sensors and their electronic circuits must be able to fulfill the requirements for control accuracy.

The electronic circuits used for control purposes in the chamber are generally based upon operational amplifiers from the 741-series. They were a sensible choise seen from a performance/cost view point, when the chamber was designed, but might now be exchanged with more temperature stable amplifiers from for example the 356-series.

The exact location of the sensors are also of importance, when considering the overall measurement accuracy.

They should be positioned far enough downstream from the mixing points to ensure sufficient mixing before the temperature is measured but not further away than necessary - to minimize the time delay from the mixing point to the sensor.

As is common in temperature control circuits there is a contradiction between the static and dynamic considerations on the point of sensor position. One therefor has to choose the best possible compromise.

Without means to force through an efficient mixing in a shorter length of piping (by screens or other obstructions in the water path) the distance between mixing point and sensor should be in the order of 20 times the inner pipe diameter. This usually gives reasonnably good mixing without unnecessary long time delays.

The sensor timeconstant should be chosen to be equivalent to approximately 10 times the above mentioned time delay.

This will ensure a reasonably good "controlability" of the mixed water temperature.

Brochures on temperature sensors from DDR have been sent to dr. Bánhidi by separate mail.

item c:

The pressure drop over each control valve are secondary parameters, which should be kept reasonably constant to ensure a good control quality of the primary parameters i.e. mixed water temperature.

If measurements or calculations show that pressure differentials over the control valves vary more than approximately ± 20%, they should be stabilized.

In the attached figure 1 this is achieved by returning hot and cold water from the respective distribution pipes through valves controlled by the pressure difference between a representative distribution point and the common return pipe.

As attachment 1 I enclose photocopies of DANFOSS-brochures (in danish) on Δp-controlled valves.

If investigations show that the pressure drop in the connections from distribution pipes to control valves and back to the common return vary too much to maintain the suggested Δp over each valve, these pipe connections should be exchanged by connections of a larger size.

item d:

The pipe connections from distribution pipes to each control valve are quite long. Since only one of the control valves will be open at the same time under steady state conditions, the water in the connection to the closed valve will - given enough time - approach room temperature due to heatloss to the room.

When the setpoint for a panel is changed, so that the previously closed valve opens, all the water in the respective connection must be exchanged before hot or cold water starts flowing through the control valve.

Experience shows this to have a degrading influence on control quality.

To avoid this problem, small volume flows of water should be allowed to bleed constantly through manually adjusted valves (manometer needle valves or the like) from a point just before each control valve to the return connection (see figure 1).

From the same point of view it is also advisable to minimize the volume (=length) of the pipe connection from each control valve to the recirculation water path.

item e:

To avoid control offsets one must use controllers incorporating an integrating function (PI or PID control).

Integration however has a negative effect not only on the general dynamic performance (which may be counteracted by D-action) but also on the performance just after setpoint changes.

The integration - which continues as long as the error signal has not yet reached zero - has a tendency of overcompensating valve movement, so that overshoots become unduely large. The effect is exemplified in figure 2.

This may be counteracted by including a "HOLD"-action in the integration function of the control circuit.

The "HOLD"-action should be turned on manually or by an automatic action governed by the numerical value of the error signal.

The effect of this is, that the controller acts as a P- (or PD-) controller for large errors, and only ads to the integration action, when the error signal is smaller than a given limit.

2. AIR INLET TEMPERATURE TO CHAMBER.

There seems to be two problems in connection with the air inlet to the chamber. The temperature field is not sufficiently homogenous and the mean temperature is not constant in time.

To counteract the first problem, the following items should be considered:

a. surface temperatures of heating/cooling coil
b. distribution of power in electric heater
c. air distribution over coil and heater
d. local hot spots in the air system
e. influence of radiation panels on local air temperatures in the chamber

item a:

If the water circulation through the heating/cooling coil is not sufficiently large to ensure an even temperature distribution over the entire coil surface, then interconnections in the coil itself and/or pump performance should be investigated.

item b.

The electric heater should be checked by measuring local surface temperatures of the heater elements.

item c:

The air flow to the chamber is adjusted by bypassing variable volume flows from the pressure side of the blower to the inlet side of the heating/cooling coil

This will tend towards creating an uneven velocity profile after the point in the system, where bypassed air is mixed with return air from the chamber.

Even if the temperature distribution over the heating/cooling coil and the power distribution over the electric heater are absolutely even, an uneven velocity profile will cause uneven temperature changes of the air flowing through different sections of coil and heater.

To avoid this problem the air should be mixed as well as possible and also be forced to be distributed evenly over the coil surface.

The latter may be accomplished by inserting a perforated screen in the duct system just before the coil.

item d:

At small air volume flows through the chamber and high humidification rates, the air might locally be heated by convective heat transfer from the steam armature in the humidifier.

If this is the case, the armature should be insulated.

item e:

Convective heat transfer between the unprotected radiation panels and the air in the chamber is unavoidable.

The problem may however be partly overcome by mounting thin foils of Polyethelene (25-30 μm) at a distance of 40-50 mm from the panel surfaces.

This foil is highly tranparent for IR-radiation and will therefor only influence the radiative exchange of heat slightly.

The still air trapped between the panel surface and the foil will however decrease the convective heat transfer considerably.

To counteract the problem with unstable air temperature over time the following items should be considered:

f. temperature sensors
g. control valves
h. compensating features in the control loop
i. ajustable controller parameters

item f:

In spite of improvements as mentioned above, there may still be small temperature variations in the cross sections after the heating/cooling coil and after the electric heater.

To measure the best possible mean temperature of the air after these two components it may therefor be necessary to consider special arrangements.

One possibility is to use more than one sensor. As an example four sensors may be used in a given cross section of the duct.

When using Ni- or Pt-sensors it is possible to obtain the same electrical signal by series connection of sensors two and two, and parallel connection of the two pairs.

Another possibility is to construct an averaging sensor by mounting Ni- or Pt-wire in an even grid arrangement over the entire cross section

The sensors should in any case be an order of magnitude faster than the rise time of the air temperature in question.

item g:

Since criterions for temperature and humidity stability in the chamber are quite demanding, the control valves for steam humidification and for the heating/cooling coil must have the best possible resolution.

It is therefor advisable to improve the existing valve configuration by adding a small valve in parallel to each of the three valves in question.

They shall have k_v-values in the order of 1/10 of the present valves. They shall have linear characteristics and the least possible opening step.

Each pair of valves shall be coupled in cascade, so that the larger first begins to open, when the smaller valve is fully open and vice versa.

item h:

It is advisable to consider compensating control features to obtain the best possible performance, when dealing with demanding control circuits as the present.

An obvious possibility is to use the water temperature T4 at the coil inlet as a secondary control parameter for the air temperature T3 after the coil.

Instead of letting the controller for T3 (RT3) position the control valves for hot and cold water directly, it determines the setpoint for T4.

A fast temperature sensor in the coil circuit then measures T4 and controls valve position by a P- or PD-controller (RT4).

Figure 3 shows the overall principle for this configuration.

item i:

Since air flow through the chamber may vary considerably, it is necessary to set up provisions to adjust the parameters for the main temperature and humidity controllers (RT1 and RH) with air flow.

If the manikin controller (ABC 80 + interface boards) has sufficient spare inputs and outputs, it may be a good idea to include controllers RT1 and RH in the ABC 80 software.

This way it will be easy to let the controller parameters be preprogrammed and obtain the correct configuration by typing in the relevant volumeflow via the ABC 80 keyboard.

Inputs for the software controllers would be:

I. Volumeflow through chamber (from keyboard)

II. Setpoints for temperature and humidity in the chamber (from keyboard or programmed to vary in time)

III. Chamber temperature and humidity (measured by T1 and H)

Outputs would be:

I. Setpoints for controllers RT2 and RT3 (voltage 0-10 V)

II. Position of steam valve(s)

The volumeflow of air through coil and heater may vary, when the flow through the chamber is adjusted.

If the variations are significant, it may also be necessary to set up provisions for adjusting parameters for temperature controllers RT2 and RT3.

Since the flow variations will be much smaller than through the chamber, it may suffice to set up provisions for 2-3 sets of parameters by switches connected to the analog control prints.

November 1 1986

P. Kjerulf-Jensen
associate professor

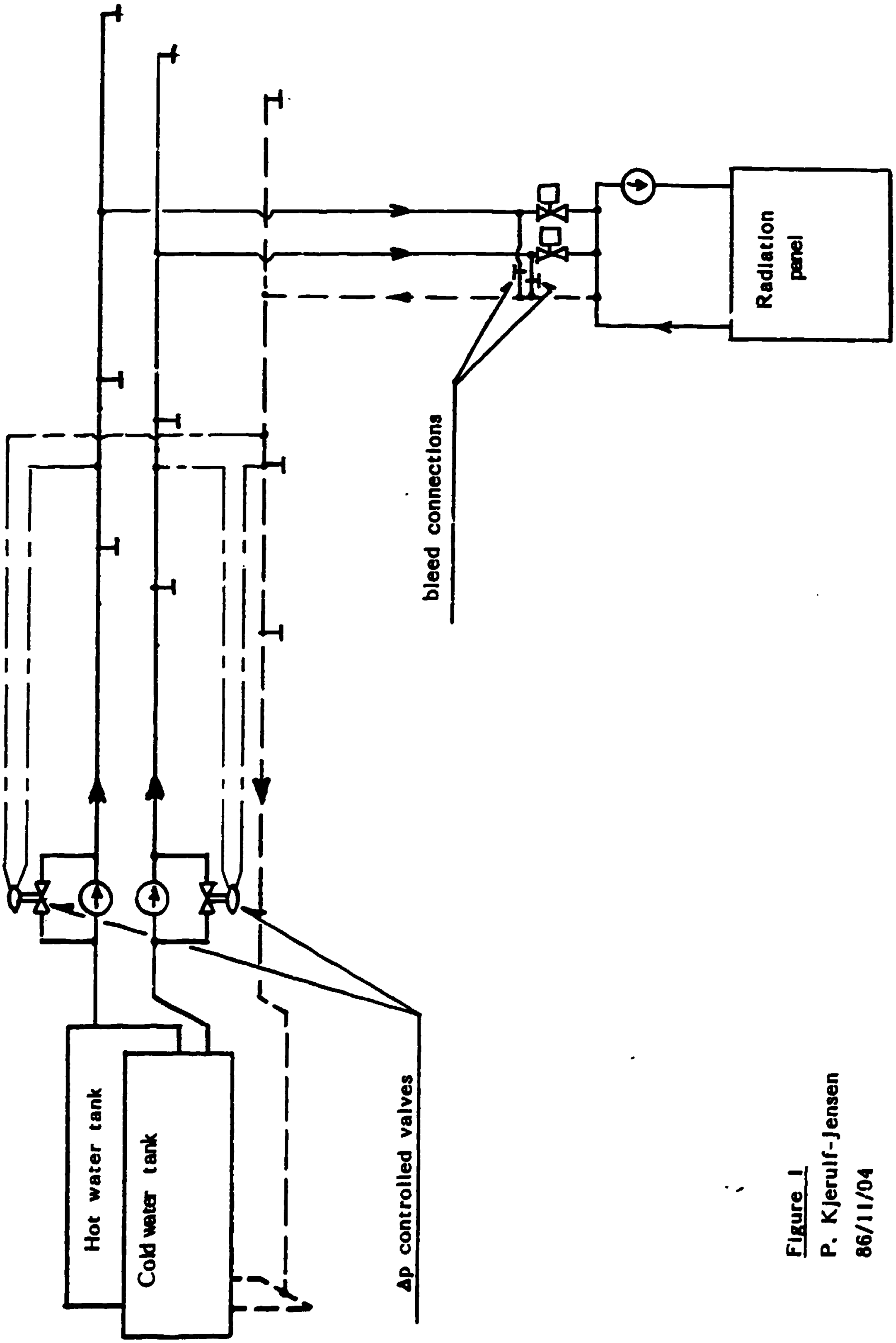

Figure 1
P. Kjerulf-Jensen
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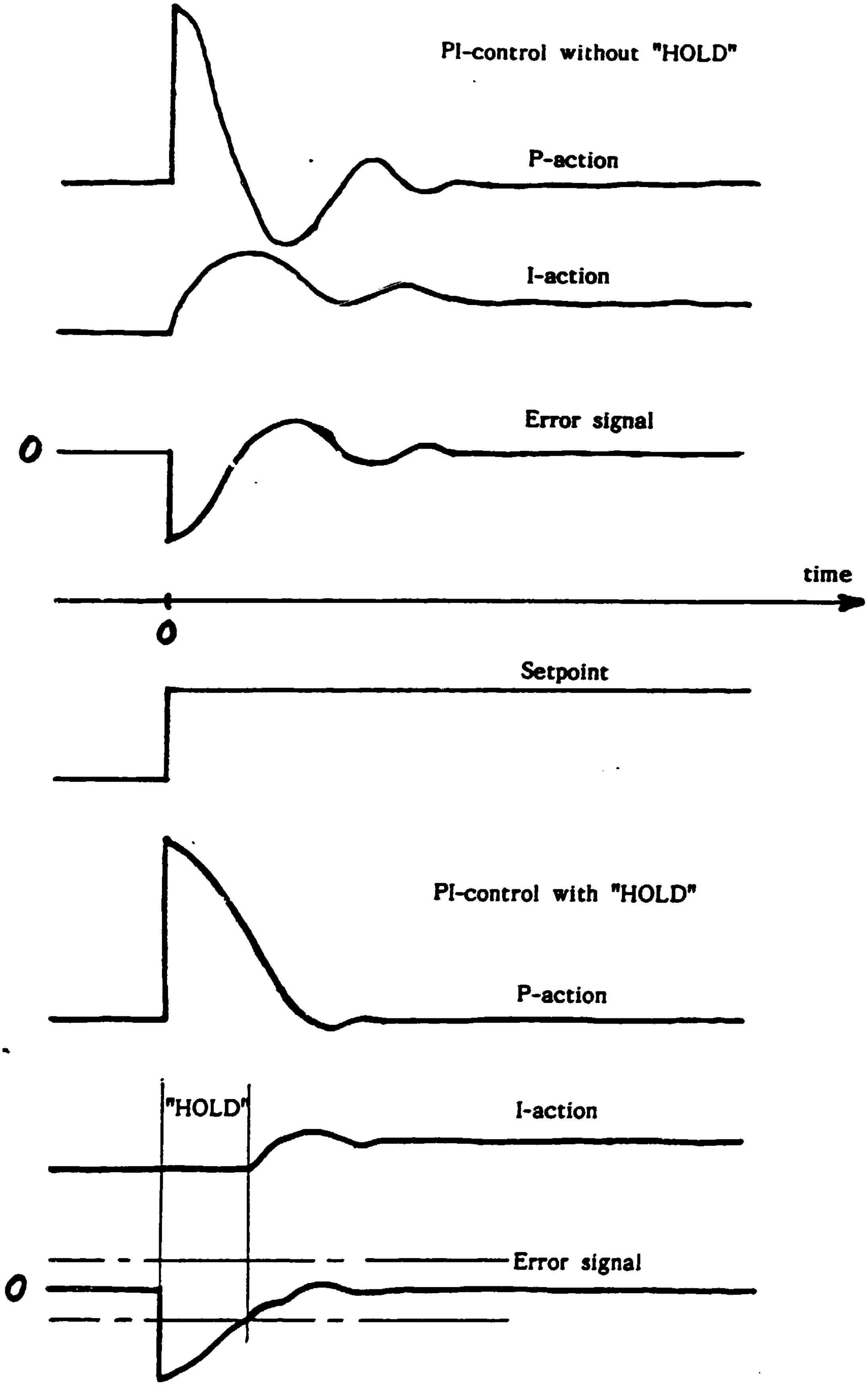

Figure 2

P. Kjerulf-Jensen

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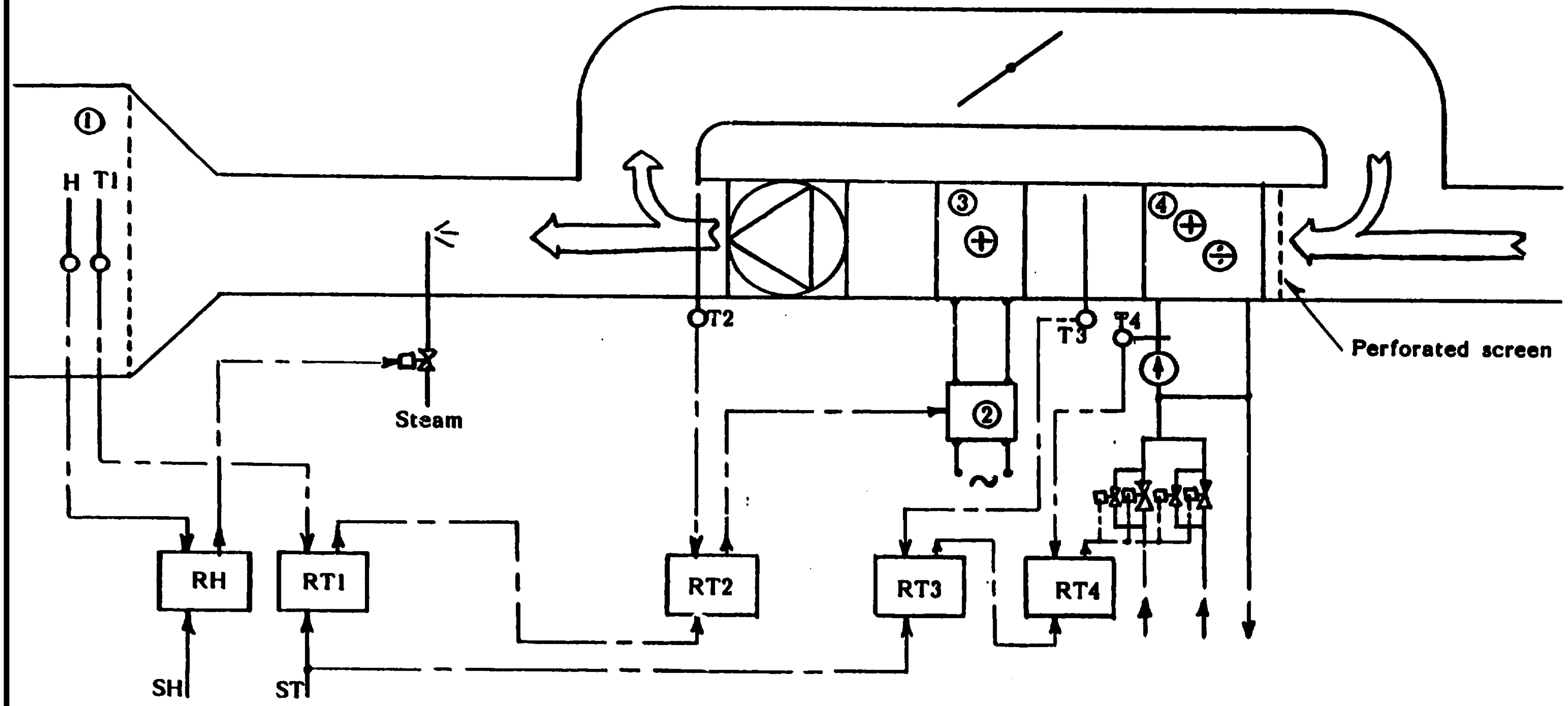

1: chamber
2: SCR-unit
3: electr. heater
4: heating/cooling coil

H: humidity sensor
T: temperature sensor
RH: humidity controller
RT: temperature controller
SH: setpoint humidity
ST: setpoint temperature

Figure 3
P. Kjerulf-Jensen
86/11/04

INTRODUCTION

Duty Station: Budapest, Hungary

Hungarian Institute for Building Science (ETI)

Post title: Consultant on economization of energy consumption in ventilation, air conditioning and indoor microclimatic conditions

Duration of stay: 5 days, October 26-31, 1986

Author: Krzysztof M. Cena, Ph.D., D.Sc., Professor, Technical University of Wroclaw, Wyb. Wyspianskiego 27, 50-370 Wroclaw, Poland.

During my stay in Budapest I visited ETI laboratories and offices both in the city and in Szentendre. A brief visit to the laboratories of the Institute of Thermal and Systems Engineering, Technical University of Budapest was also arranged. On October 29, I presented a formal seminar at the ETI headquarters in Budapest. The topic was: *Short and long term trends of international research in thermal comfort and associated problems of energy conservation.* This was well attended and followed by extensive discussion.

Throughout of my stay I was looked after by representatives of ETI who arranged for my hotel bookings and necessary formalities. I consider their hospitality to be exemplary and wish to express my thanks, particularly to Dr Laszlo Banhidi.

Findings of the mission

The Microclimate Laboratory of the Hungarian Institute for Building Science is a major research facility equipped with a modern climatic chamber built to international standards. The chamber is adequatly instrumented. A heated thermal manikin has been constructed by the local technicians with only a minimum of parts imported from abroad. I believe that both the chamber and the manikin are the only installations of their kind in Eastern Europe and have only a relatively few others in the world matching their performance.

I found the skills of the local designers and technicians in creating a high performace - low cost laboratory system to be very effective. Both the chamber and the manikin are fully operational and offer exellent research facilities for those countries or institutions who do not possess such equipment. The Laboratory at Szentendre is an up-to-date facility ideally suited for methodological support of international or national projects related to microclimate and energy conservation in built environments.

Data aquisition and processing in the Laboratory are computer-aided but it is apparent that lack of hard currency funds prevents the Laboratory from upgrading its computer technology. This is particularly evident in the low data storage capacity. I have noticed, however, that the electronic technicians working in the Laboratory are fully capable of working with modern computers and that they are able to utilize them to their maximum.

The Laboratory is very active in research and the scope of current projects is scientifically and practically important. The main research approach is focused upon the work efficiency and reflects the current international trends. The Laboratory concentrates its work on optimization of microclimatic standards effecting in the optimal physical and intellectual work conditions for humans, rather than on the more idealistic objective of achieving maximal thermal comfort. The former involves in-depth studies of ergonomical, mental and physical performance factors.

During my stay at ETI I was consulted on the following topics:

1. Current international trends and problems in the broad area of work efficiency and thermal comfort. This was in relation to short and long term research objectives of the Laboratory. In particular, I presented in detail the state of research in the US and Canada where I worked for the last several years on similar research topics. I consider the stress on work on ergonomics and mental and physical performance to be well chosen. The thermal manikin offers substancial opportunities to carry the research into various practical and basic aspects of clothing science.

2. Interdisciplinary character of the research and necessity of collaboration between specialists from various countries. In particular, I discussed the possibility of cooperation between Hungarian and Polish specialists. The Department of Building and Environmental Physics of the Technical University of Wroclaw, Poland would be the best suited partner. The two groups would compliment each other both in expertize and in the equipment available. The Wroclaw group can offer a laboratory of infrared thermography.

3. Equipment requirements of a modern microclimate and energy savings laboratory. A collaboration with the Wroclaw group would allow access to thermographic (and some physiological) techniques, usefull both in laboratory and in the field studies concerned with energy efficiency of built environments.

4. Possibilities of collaborative projects with the Third World countries, both in training of specialists and in specific projects.

Recommendations

1. The Microclimate Laboratory of the Hungarian Institute for Building Science should be accepted as an East European international centre of research into thermal comfort and energy optimalization of built environments. This is justified by the local expertize and the equipment available. Related future projects funded by UNIDO might be based in the Laboratory or arranged in collaboration with the Laboratory. This will allow proper utilization of the climatic chamber and the thermal manikin without duplicating the expensive facilities in other East European or Third World countries.

2. It is therefore desirable to maintain and expand the existing equipment of the Laboratory by special UNIDO grants towards upgrading the computer facilities. Similarly, a sweating model of the thermal manikin should be built at Szentendre if a similar hard currency grant from UNIDO were made towards a purchase of essential components from abroad. This would be the most effective way of constructing a sweating manikin. Other major pieces of expensive equipment (e.g. infra-red Thermography) can be arranged through collaborative projects.

3. The research staff of the Laboratory is currently too small to create a critical mass for projects beyond the current specialization. The number of researchers should therefore be increased by one or two persons at the Ph.D. level and the necessary funds provided locally. The Laboratory can also be most effectivelly increased in strength by accepting suitable scientists seconded for limited periods from other East European countries. There is a particular opportunity in arranging for a long term cooperation with the Department of Building and Environmental Physics of the Technical University of Wroclaw, Poland who would compliment the Laboratory in manpower, know-how and equipment. Necessary steps to allow for such collaboration should be initiated as soon as possible. UNIDO should come forward and help this by sponsoring a collaborative research project based wholly or

partially at the Laboratory.

4. The Laboratory, with a collaboration of the Department of the Technical University of Wroclaw, should be organized to serve as a centre for dissemination of expertize and training of specialists from the Third World countries. Special workshops or seminars on energy savings related topics for East European and Third World countries could be organized in Hungary or in Poland.

K. Cena

December 10, 1986