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Basic Design of a Data Bank System Aimed at the Energy -Efficient Utilization and Application of Heat Pumps and Other Energy Recovery

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BASIC DESIGN OF A DATA BANK SYSTEM AIMED AT THE ENERGY-EFFICIENT UTILIZATION AND APPLICATION OF HEAT PUMPS AND OTHER ENERGY RECOVERY SYSTEMS

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ABSTRACT:
The technique used to generate heat for heating purposes becomes more and more complex. In order to estimate a practicable solution a very comprehensive complex of tasks has to be considered, and a comprehensive system of information is needed to integrate the demands simultaneously in order to achieve a solution which is an optimum with respect to different points of view.

The idea is put forward to develop a data bank system together with a program package aimed at collecting information about heat pump systems and other energy recovery installations.

The exergetic concept is recommended to be used as the basic principle to optimize the working parameters with respect to savings in primery energy.

The actual state of the work is described and further steps are outlined in order to make the system available to the public.

1. INTRODUCTION

The technique available to generate simoultaneously electricity, heat and cold becomes more and more complex. New products apear on the market and it becomes more and more difficult to find a solution which shows an optimum regarding technical, economic and ecological aspects.

Therefore models and computer programs may contribute to solve the tasks mentioned above.

2. MODELS THAT MAY BE USED TO DESCRIBE AND EVALUATE THE TECHNOLOGICAL SOLUTION

Fig. 1 shows in a generalized view those demands that have to be considered.

10. Evaluation of Ecological Parameters	1. Application-specific Characteristic	2. Evaluation of Heat & Cooling Load. Evaluation of Alternative Demands
9. Savings in Primary Energy Achieved	ENERGY MANAGEMENT, SAVING OF ENERGY,	3. Distribution System
8. Costs Estimation Analysis	REDUCING THE EMISSION OF HARMFUL COMPOUNDS	4. Heat & Cold Generating Technique
7. Analysis of Different Solutions	6. Optimization of Process Parameters	5. Standard Reference System

Fig. 1 - Overview of demands influencing the design of heating, cooling and cogenerating systems

2.1 APPLICATION-SPECIFIC CHARACTERISTIC

The application of heat pump systems and other energy recovering systems show a large diversity as concerns the technique available. In order to demonstrate the purpose of the data bank system which is expected to be developed we will concentrate ourselves on compression-type heat pumps used to generate heat for residential areas and industrial purposes as well.

2.2 EVALUATION OF THE HEATING LOAD

Many models considering steady-state and dynamic behaviour exist which may be used to estimate the heating load of buildings. We will concentrate ourselves on the estimation of the annual heating demand based on the ISO-Standard 9164 which is equivalent to the European Standard CEN/TC89. This model is based on the heat balance of a building and is designed to estimate the heating demands in steps for every month of a year. The heating demand for a total year results from adding up the monthly portions. This value achieved so far represents the net heat load necessary to keep the room temperature constant at the desired level in case the outdoor temperature falls below the indoor air temperature expected.

The model takes the following energetic factors into account:

- losses by means of heat transmission through walls and heat exchange between surfaces
- losses resulting from ventilation and infiltration of fresh outdoor air into the indoor air
- yields in heat resulting from the short wafe radiation of solar energy through transparent elements of the construction, and from the absorption of the radiation on surfaces of nontransparent elements
- internal heat sources, e.g. electric appliances, illumination, human heat, and losses resulting from heating systems.

The annual heating demand is estimated by means of equation (1)

$$Q_{H,M} = Q_{L,M} - \eta_M \, Q_{Y,M} \qquad (1)$$

where $Q_{L,M}$ represents the heat losses per month, $Q_{Y,M}$ the yields of heat achieved per month, and η_M the socalled "usability of heat" which desribes the portion of usable heat gained from solar energy and internal heat souces. The efficiency factor η_M is calculated by means of equation (2)

$$\eta_M = \frac{1 - (Q_Y/Q_L)^a}{1 - (Q_Y/Q_L)^{a+1}} \qquad (2)$$

where a is a factor representing the time constant τ of the building.

Heating losses are determined by means of equation (3)

$$Q_{L,M} = H(\vartheta_i - \vartheta_{a,M}) \, t_M \qquad (3)$$

with
H - specific heating losses, $\vartheta_i - \vartheta_{a,M}$ - monthly difference in temperature between indoor and outdoor temperature resp.

The annual heating demand results from adding up the portions of the monthly heat demand showing a positive character whereas portions with a negative sign will be neglected.

$$Q_H = \sum_M Q_{H,M} \big|_{positive}$$

2.3 DISTRIBUTION SYSTEM

In order to analyse heating systems the whole technological process of energy conversion must be taken into consideration. This comprises the heat generating system, the distributing system, the power station, and the mains system. Fig. 2 shows as an example a heating system using an electrically driven heat pump. Losses which occure at the conversion process are expressed by means of an efficieny factor η.

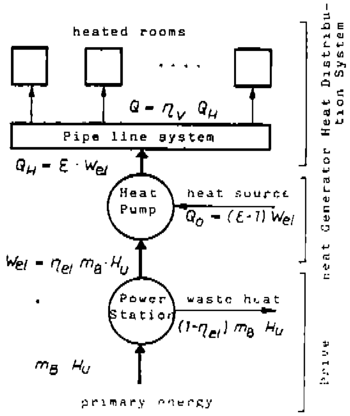

Fig. 2 - Schema of an electrically driver heat pump system

2.4 COLD AND/OR HEAT GENERATING TECHNIQUE

Such systems are

- by means of electricity or heat driven compression-type heat pumps
- absorption machines
- cogeneration appliances
- fuel cells
- gas or oil fueled boilers, etc.

2.5 STANDARD REFERENCE SYSTEMS

In order to be able to evaluate the technology selected we need a reference system described physically. Because of the difficulty to compare the different solution due to different physical working principles we will need several reference systems.

Examples to be applyed are demonstrated in Fig. 3 together with their conversion losses.

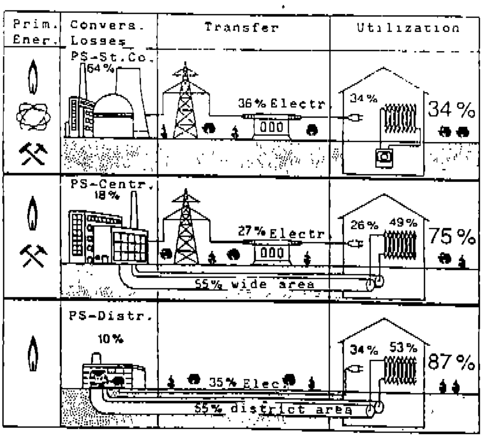

Fig. 3 - Examples of different reference systems

2.6 OPTIMIZATION OF PROCESS PARAMETERS

In order to optimize the process parameters of a heat pump system the utilization of the exergy concept is recommended. The basic idea of the exergy concept is shortly outlined at the following paragraph.

A common procedure to estimate the annual heating load is based on the average frequency of the open air temperature z(Tu). The function z(Tu) is measured by meteorologists and may be available for different places. Taking the function z(Tu) into consideration the heating load of buildings may be determined by equation (4)

$$\frac{Q}{Qmax} = \frac{1}{T_R - Tu_{min}} \left[(T_R - T_G)\ z_H + \int_{Tu_{min}}^{T_G} z(Tu)\ dTu \right] \qquad (4)$$

where T_R is the wanted indoor air temperature and T_G the outdoor air temeperature. The heating starts if Tu falls short of T_G. Z_H is the number of days where heating is necessary.
Qmax is calculated according to the German Standard DIN 4701 that is used to estimate the size of the heating installation.

The energy needed to operate a heat pump driven electrically is calculated by means of equation (5)

$$\frac{W_{HP}(T_A, T_G)}{Qmax} = \frac{1}{T_R - Tu_{min}} \left[G(T_G) - G(T_A) \right] \qquad (5)$$

with

$$G(T_n) = (T_R - T)\ z(T) \int_{Tu_{min}}^{T} z(Tu)\ dTu)$$

Primery energy needed to operate an electrically driven heat pump is expressed by means of equation (6)

$$W_{Pr_{EHP}} = \frac{W_{HP}}{\eta_{EL}} \qquad (6)$$

The exergetic efficiency of the heat pump driven electrically is

$$\eta_{ex_{HP}} = \frac{Hu}{e_B}\ \beta_{EHP}(Tu)\ (1 - \frac{Tu}{T_R}) \qquad (7)$$

and for a boiler fueled directly by gas or oil

$$\eta_{ex_{oil}} = \frac{Hu}{e_B} \beta(Tu)\ (1 - \frac{Tu}{T_R}) \qquad (8)$$

Taking a bivalent system into account which consists of a heat pump driven electrically and a boiler fueled directly the outdoor air temperature T_{Aopt} will be defined where the heat pump is switched off and the boiler starts to operate. See Fig. 4.

We learn from Fig. 4 that the part load efficiency of the heat pump $\eta_{ex_{HP}}$ and the lowest outdoor air temperature Tu_{min} have a decisive influence on the temperature T_{Aopt}.

In Fig. 5 the exergetic efficiency is demonstrated versus the ambient air temperature Tu. The diagram explains that the heat pump is able to supply a great part of the anergy together with the exergy needed for the heating purpose by showing a high value of exergetic efficiency. Only below a certain temperature Tu the direct fueled boiler shows a better efficiency than the heat pump driven electrically. But the additional boiler is working only during a short period of the year.

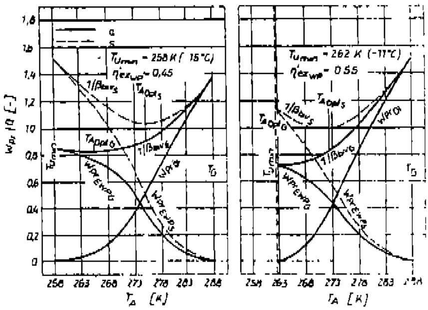

Fig. 4 - Consumption of primery energy based on the application of a bivalent operating heating system (heat pump combined with a boiler) G - good part load behaviour, S - mean part load behaviour of the heat pump driven electrically

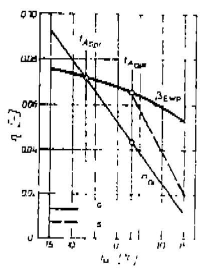

Fig. 5 - Exergetic efficiency of a combined heat pump/boiler system G - good and S - mean part load behaviour resp.

2.7 ANALYSES OF DIFFERENT SOLUTIONS

Cogeneration systems which allow to produce simultaneously electricity and heat or alternatively cold are becoming widely used. Heat pump systems may be integrated in different manner as shown in Fig. 6 (3).

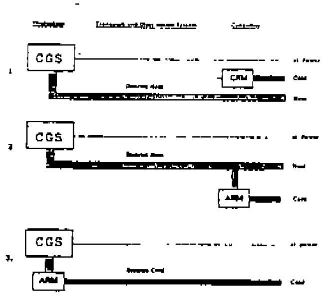

Fig. 6 - Possibilities to integrate a heat pump into a cogeneration system /CGS - cogeneration plant, CRM - compression refrigeration machine, ARM - absorption refrigeration machine

The system has to be studied thoroughly as concerns the working parameters.

Based on an extraction condensing turbine the cogeneration of electricity, heat and cold will show certain limits: If we introduce (3) the

refrigeration rate $\beta = Qo/P^{*}el$

heat rate $\gamma = Q_H/P^{*}el$

electricity rate $\delta = Pel/P^{*}el$

with Pel being the electricity produced actually, and $P^{*}el$ being the nominal output of electricity, we obtain the diagram shown in Fig. 7.

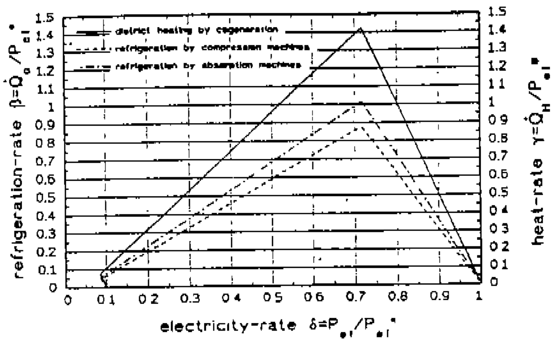

Fig. 7 - Rated diagram for the cogeneration using an extraction-condensing turbine showing different solutions (3)

2.8 COSTS ESTIMATION

The costs occuring as the result of the heating system to be operated, will be determined by means of equation (7) including fixed K_f and variable costs K_v resp. Q_H is the total quantity of heat generated annually.

The specific costs c_H allow to compare diferent solutions of installations.

$$c_H = \frac{K_f + K_v}{Q_H} \qquad (7)$$

2.9 SAVINGS IN PRIMARY ENERGY

As already shown in paragraphs 2.6 and 2.7 the different solutions have to be compared with an appropriate reference system. Results achieved on this basis allow to estimate real savings achieved. Pros and Cons of the different solutions may be considered as well.

2.10 EVALUATION OF ECOLOGICAL PARAMETERS

The evaluation of the quantities of different compounds emmited into the ambiends which troubling the ecological balance - like O_2, CO_2, NO_x, SO_2, CFCs - must be based on data resulting from measurements in the field. A data base is necessary to collect those data.

3. DATA BASE TO BE USED IN ORDER TO COLLECT DATA OF DIFFERENT SOLUTIONS

As demonstrated above we have available a system to classify different solutions of heating systems. Measurements on installations carried out in field are necessary in order to compare theoretical data with those resulting from measurements.

Therefore a data base will be needed for collecting all information about those installations and to make these data accesible to qualified people.

Because of the complexity of the task which will be accomplished close research work has been organised involving experts and experiences from

Bristol University (UK)
Fernwärme-Forschungsinstitut Hannover (Germany)
intCom GmbH Dresden (Germany)

An application has been forwarded to the European Community in Brussel in order to include the study at the R&D program NON-NUCLEAR-ENERGY, JOULE II.

The integrated design system which will be developed is shown in Fig. 8. Resulting from the joint R&D project a software package will be developed and tested. This package will include an expert system which will assist architects and engineers in designing technically correct and economic heating and cooling systems.

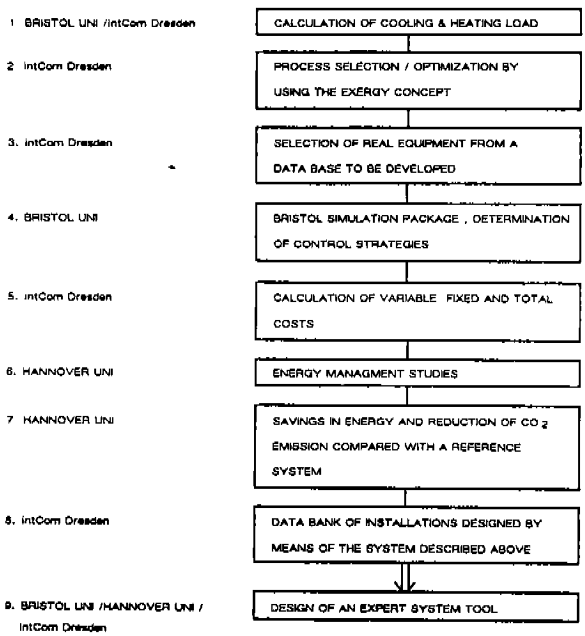

Fig. 8 - Schema of an integrated design system to be developed aimed at selecting energy and costs efficient equipment for HVAC

4. CONCLUSION

The idèa was explained to develop a data bank and a program package aimed at designing installations and collecting information about heat pump systems and other energy recovery systems.

The exergy concept will be used as the basic principle to optimize the working parameters with respect to savings in primary energy.

An application has been forwarded to obtain assistance from the Europaen Community. Cooperation with research centres interested in the project is expected. The power generating industry will be involved as well.

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