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Design of a chiller system for specific theatre air-conditioning application

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Nowadays, cooling system is an indispensable part of every social building and centers. Increasing requirements for cold has to be satisfied by economic and regardful way to environment. It can be effectively realized when cheaply adventitious cold can be storage at time of reduced requirement and reapply at time of increased requirement.
The contribution is devoted to this solution – design of a chiller system with an accumulator of cold. Such solution allows decreasing the size of a chiller system thereby decrease costs of source of cold. Moreover, it is possible to use this storage of cold in case of possible failure of cold source. The source of cold thus can be repaired without let-up run of total chiller system. The contribution presents design stages of such chiller system for town theatre air-conditioning application, where daily chilling requirements are very specific.

1. Introduction

The production and storage of the cold create important trend in recent era of modern society. Increasing requirements of living standard are accompanied by increasing requirements for chilling especially of housing and nonentity precinct and also producing technologies necessarily requiring chilling. Among these technologies belongs very large portfolio from for example technologies of heavy industry to technologies for medicine. The specific area of cooling technologies is cooling of building. The cold requirements belong to indivisibility part of daily life of modern society. Cooling systems creates indivisible part especially of every social building.
Theatre is a building, which inherently belongs to them. For the comfort of all visitors, it must be here, of course, also air conditioning facilities combined with cooling facilities. Since in the theatre is placed a lot of technologies producing big amount of heat, such facilities must be considerable large. Hence, conceptual proposal becomes quite expensive in such case. Possibility of using of a cold accumulator (Storage Thermal Latent) based on

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utilization of latent heat seems to be quite a good way for making the particular cooling facility cheaper.

2. Chiller system design

The applied chiller system design contains following main design stages:
- Acquisition of input parameters;
- Design of cooling facility and creation of cooling facility configuration;
- Selection of the chiller unit;
- Heat exchanger design;
- Accumulator design;
- Dimensioning of pipelines and determination of pump operating parameters.

2.1 Acquisition of input parameters

Client, eventually a standardised procedure, specifies the requirement dealing with temperature inside given room. Also it is necessary to determine the cooling capacity, required for cooling down of the air needed for ventilation, in order to assuring thermal comfort of persons who will be inside particular rooms. Inside a solved theatre, described here, 3 individual air–conditioning units are installed. Daily chilling requirements are very specific in the theatre and they are (for afternoon theatre production) presented in Figure 1.

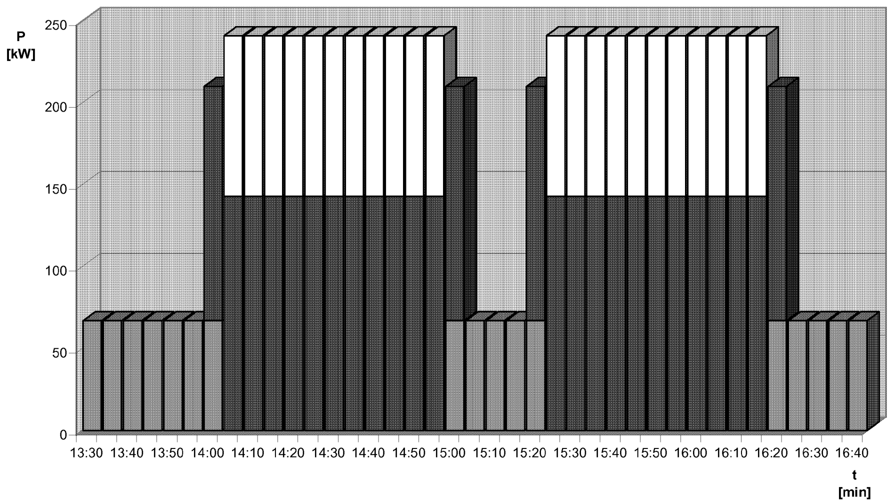

Figure 1 The cold requirement balance during afternoon theatre production (Legend: blue color - cooling of foyer, violet color – cooling of amphitheatric, yellow color – cooling of proscenium)

2.2 Design of cooling facility and creation of cooling facility configuration

Before designing of cooling facility and creation of cooling facility configuration, it is necessary to evaluate all possible arrangements carefully. In this particular case, two-loop (primary /secondary loop) cooling facility with separate condensers was chosen. Advantage of this arrangement can be seen in one main aspect. From point of view of necessary repair or planned maintenance of this facility, it is advantageous to place it inside a machine room. In such case, there is no need for operators to go in the open air, in order to supervise the plant. On the other hand, outside plant supervision should be the necessity, when cooling facility compact arrangement would be chosen. In case of compact arrangement, the compressor should have to be installed in the open air, as well. Control facilities, as well as measuring instrumentation, are also very often installed in the machine room. Vicinity of this equipment assures its better operability. Separate condensers will be installed on the roof of machine room. This cooling facility will be connected to the glycol loop.

Separate storage tank (accumulator) is connected to this loop. Accumulating modules, being able to store cooling energy due to change of state, are placed inside the storage tank. Treated cooling water is envisaged as cool carrying medium in the second loop. Heat exchange is carried out by the plate heat exchanger, furnished with profile plates. Temperature gradient being 7 ÷12 °C is quite sufficient. Two compound circulating pumps have been incorporated into the primary glycol loop.

The first compound circulating pump is used for charging of the storage tank (accumulator) with cooling energy. Compound circulating pump is used due to assuring reliable operation in case of its malfunction or failure. Shut-off ball valves for easier dismantling in case of maintenance or repair, are installed upstream the pump. So the filter prevents the plugging of pumps. Check valve preventing backflow in the loop is installed downstream the pump.

The second compound circulating pumps supply the storage tank. These pumps are so called discharge pumps and they are installed with shut-off ball valves, filter and check valve preventing back flow as well. On this loop is installed expansion tank as near as possible against the pumps.

Volume of expansion tank is designed like 30% volume of medium in the loop, according to design standards. Expansion tank balanced pertinent overpressure or under pressure in the loop. The safety valve and drain valve are also installed. Accumulator is connected so that we can load it or turn round the flow in loop and discharge it, if needed.

In the secondary loop are installed compound circulating pumps, which guarantee flow in every heat exchanger of all air-conditions units. In front of every heat exchanger of the air-condition unit is created control loop to guarantee correct flow and temperature needed to another distribution of cold. There are placed the expansion tank, safety valve and servo valve again, which will be connected to filter plant.

2.3 Selection of the chiller unit

The type of chiller is chosen according to the input parameters. The chiller is considered with separated condensers. In the solved category of chillers only few suppliers are available on the market. There is selected a chiller with minimal 141 kW of cooling power. Chiller must be designed in higher level, to be able to add required power about lower potential. Most of these units are designed on temperature gradient 7/12 °C. In this case must be a chiller able to cooling down medium up to -10°C. Unit is able to work at this scheme with outside temperatures up to -20°C. Pump of condenser with variable rotation speed change flow medium automatically so that will be guaranteed optimal conditions of condensation. By the intelligent optimal control of rotation speed of condenser water pump the economical and reliable work is guaranteed. Design of the chiller provide for safe place in machine room. Medium to connection condenser and chiller is specified by chiller producer. In this case the type of medium R407c is used.

2.4 Heat exchanger design

Efficient utilization of fluid thermodynamic properties is realized by the plate type heat exchanger (Hewitt, 1994). Calculated heat duty of heat exchanger is 241 kW.

2.5 Accumulator design

First of all must be located the movement of people in the theater (foyer, auditorium and proscenium) and what part of theatre is occupied. On the basis of this fact will be found out what part of air-condition unit should work for make environment comfortable for them. Situation of the solved theatre is illustrated by the Figure 1 presented above in chapter 2.1. Figure 1 shows how people at first come to the foyer, so the unit will cool down only this part of building. Next visitors start move to the auditorium, unit will cool down foyer plus auditorium. After start of production will cool down of foyer switch off and at the same time will start cool down of proscenium.

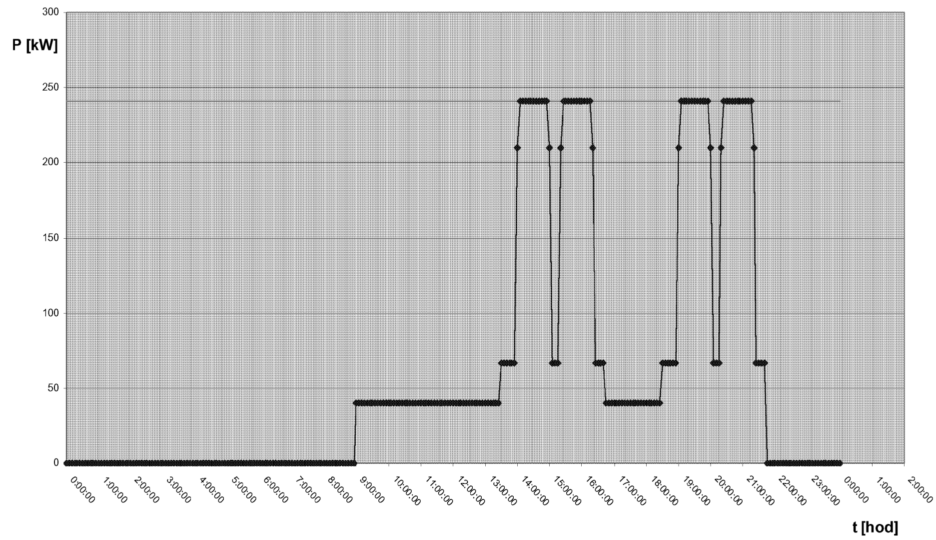

Figure 2 Profile of cooling load during one representative day

The information contained in Figure 1 is very important for sizing of the accumulator. There're several possibilities, how to design the storage battery with reference to its maximum usage:

- Transposition of cooling time (running using night regime);
- Modification of size of cooling sources;
- Small cooling source with covering of peaks of cooling duty.

Last possibility, „ Small cooling source with covering of peaks of cooling duty" is the optimum solution for solved theatre from roominess point of view, because the small cooling machine-room is available. Calculation of thermal stress requires, in this case, requires history for one day of consumption of cold only (see Figure 2 and Figure 3).

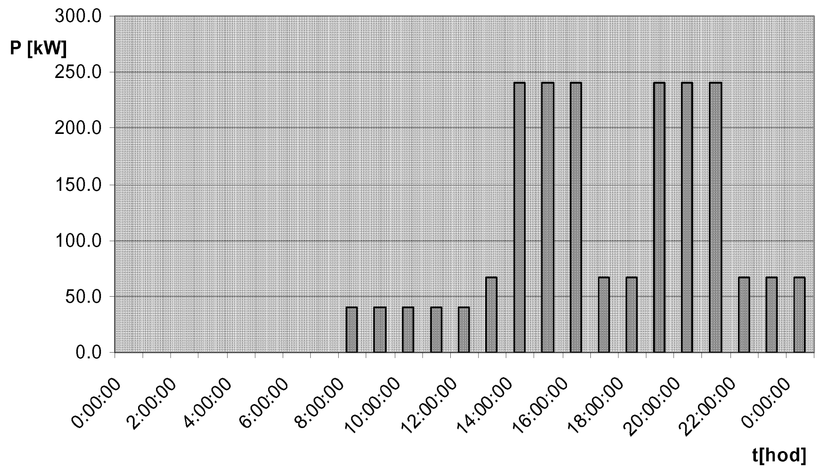

Figure 3 Histogram of load for one representative day

Solution of accumulator results in accumulator design with volume 11m3 and power of chiller on 141kW.

There are four different modes of operation:

- Charge mode of storage tank
- Charge and chiller operation mode
- Discharge and chiller operation mode
- Discharge mode only

2.6 Dimensioning of pipelines and determination of pump operating parameters

Last design stage of chiller system starts with determination of pipelines diameters. The solution is based on known fluid flowrates identified in heat exchanger design stage and fluids velocities in pipelines in range 1÷2 m/s. For determination of pump operating parameters the calculation of fluid pressure drops in the system was performed based on designed pipeline and equipment lay-out in machine-room (see Figure 4).

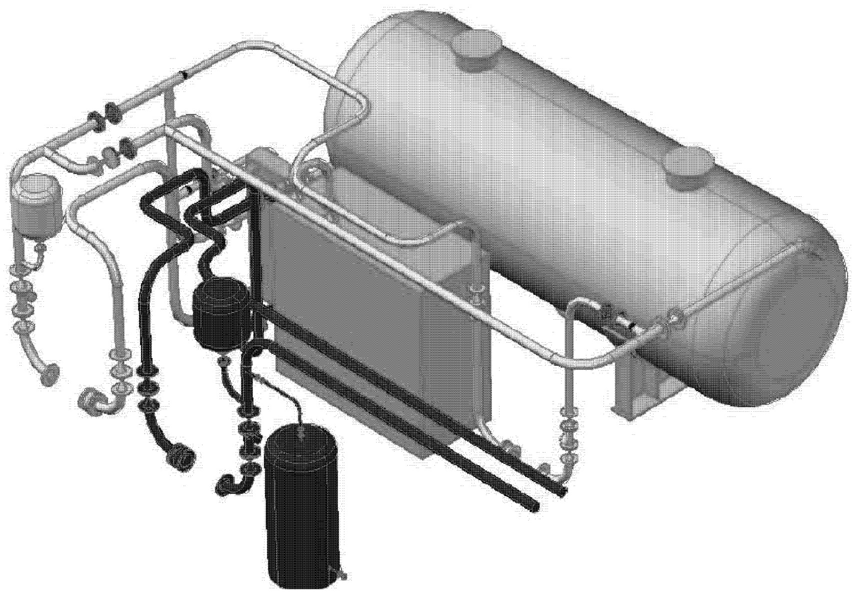

Figure 4 Lay-out of individual components of chiller system in machine-room

Arrangement of machine-room considered necessary requirements for available service or maintenance of individual components placed in machine-room.

3. Conclusion

The contribution presents design stages of chiller system for town theatre air-conditioning application with specific daily chilling requirements. The presented design of chiller system (which was used as a basis for practical realization) includes complex design of individual equipment such as heat exchanger, accumulator, etc. Selected accumulator of cold substantially decreases the size of required cold source and thus realization costs.

References

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