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Ventilation system at the cinema hall with different customer loading

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DESCRIPTION

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Ventilation system at the cinema hall with different customer loading

Abstract

Ventilation system at the cinema hall is tough, but very interesting and exciting task. Cinema hall it is the place which thousands of people visiting every day. The main purpose of the ventilation system at the cinema hall is creating the perfect microclimate conditions.

The cinema hall which is considered in this Bachelor thesis located in the Saint Petersburg. It is the part of the big entertainment centre in the Saint-Petersburg. So this is the real existing cinema hall.

The aim of this Bachelor thesis is to study energy efficiency of the ventilation system at the cinema hall which is counting on 300 persons.

In this Bachelor thesis there is also the assessment of the quality of microclimate at the cinema hall through making measurements of the temperature level and the values of the air humidity.

Results of this bachelor thesis could be applied into the Russian construction area and in the future will be useful for the HVAC engineers in Russia.

Subject headings, (keywords)

Ventilation system, cinema hall, mechanical conditioner, supply and exaust ventilation, microclimate, temperature and relative humidity device

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CONTENTS

1 INTRODUCTION

Ventilation system plays the main role of creating of comfortable conditions for human living and working. In the countries with cold and very changeable climate the adequate ventilation system is very sophisticated. Ventilation system affects the microclimate conditions including indoor air quality (temperature and air humidity).

The maintenance of good microclimate parameters influences on the occupant health and comfort. Also ventilation air is necessary to dilute odors and limit the concentration of carbon dioxide and airborne pollutants such as dust, smoke and volatile organic compounds. Nowadays there is one very important task, which is required for ventilation system. This is the question of the energy saving.

Cinema hall is the place where thousands of people visit every day so the proper work of the ventilation system is created the ideal microclimate conditions. Ventilation system at the cinema hall is the system which requires the special approach not only in technical decisions, but also in the aesthetic sense. Cinema hall as the object for ventilation and air conditioning have a few complexities, for example the ceiling height of the cinema hall and unsteady cinema hall loading

The aim of this Bachelor thesis is to study energy efficiency of the ventilation system at the cinema hall with different customer loading. This cinema hall is the part of the big entertainment center in the Saint-Petersburg, which is counting on 300 customers.

This Bachelor thesis also contains the investigation of the quality of microclimate at the cinema hall through making measurements of the temperature level and the values of the air humidity. Also Bachelor thesis includes the questionnaire. The main question is: How are the customers feeling during the movie session. It is also very important and useful investigation because a lot of persons for example have made complaints about the high temperature level at the cinema hall.

The practical part contains a comparison of the results of air temperature and air humidity values. The measurement is received from measuring two different conditions of the hall loading, in the case when there are 5 customers at the cinema hall and in the case when

there are 200 customers at the cinema hall during the session. According to the results of the measuring of these two cases and according to the questionnaire, Bachelor thesis contains the assessment of the energy efficiency of the ventilation system at the cinema hall. In the practical part there are calculations of the heat, light and moisture emissions at the cinema hall with hall loading 5 and 200 customers according to Russian requirements.

In the theoretical part there is given the requirements for the ventilation and air conditioning system of the entertaining center, including cinema hall and a description of the equipment, which is provided the cinema hall by the fresh air. Also in the theoretical part there is information about the cinema hall.

2 METHODS

This Bachelor thesis is about the ventilation system at the cinema hall. The main question of the Bachelor thesis is to study of the energy efficiency of the ventilation system at the cinema hall. The cinema hall is a part of the entertaining center, which is located in the Saint-Petersburg city and it is really existing object, which is functioning.

In the first part of the Bachelor thesis there is given the requirements for the ventilation and air conditioning system of the entertaining center, including cinema hall and a description of the equipment, which is provided the cinema hall by the fresh air.

Bachelor thesis contains a comparison of the results of air temperature and air humidity values. The measurement is received from the measuring by two different conditions of the hall loading, when it there are 5 customers at the cinema hall and in the case when there are 200 customers at the cinema hall during the film session. The measurement is made by the Data logger equipment. Also Bachelor thesis includes the questionnaire, so the main question is: How are the customers feeling during the movie session.
Also the Bachelor thesis contains the calculations of the heat and light emissions at the cinema hall with hall loading 5 and 200 customers according to Russian requirements.

3 THEORETICAL BACKGROUNDS

In this chapter is given the requirements for the ventilation and air conditioning system of the entertaining center, including cinema hall and a description of the equipment, which is provided the cinema hall by the fresh air.

3.1 Requirements for the ventilation and air conditioning system of the entertaining buildings in Russia

In the cultural and entertainment buildings like cinema, theatre, clubs are considered mechanical and exhaust ventilation and also air conditioning system. At the cinema halls, clubs and theatres in the viewer area, parameters of the air should be provided by air conditioning system or by ventilation system. Type of ventilation system depends of quantity of the viewers and also of the climatic zone, in which entertainment building locates. In the application form of air conditioning systems and ventilation systems for the viewer hall the quantity of supply outdoor air should be at least $20m^3$/h on person. /1/

At the cinema hall with the ongoing show or movies and also in clubs, this type of separate system could not be considered. Cinema centre which is counting on 800 customers or more considers that only one air conditioning and mechanical ventilation system may provide a few cinema halls by the fresh air. Also it is very important to design for each cinema hall the ventilation system according to calculations of air heating zone. /2.p.51/

For the first and second climate areas, the air capacity of the air conditioning and mechanical ventilation is defined by providing the viewers of special amount of outdoor air in the winter time about $20m^3$/hour on person. The air conditioning systems have to be with recirculation of the air for providing the requirement conditions of clean air at the cinema hall. /1/

In the stage of the designing of the customer halls the opportunity of the night aeration in summer time has to be considered. For this goals in the low zone of the halls design the spaces, which are equipped by the unmoved grills and little gate. Calculations of the square of the space makes by the quantity of the supply air, which is equal, like a double value of air change per one hour with the gravity pressure.

In this case the air removing has to be proceeded through the shaft of the main ventilation system. In the exhaust shafts for this purpose is very important to design the special valves with distance control. Also is very necessary to envisage the opportunity of unorganized supply of outdoor air through the exhaust shafts.

The placement of the ventilation and air conditioning equipment, compressors, cold equipment is not recommended to place after the walling of the customer halls. In the walls which divided the customer halls is not allow the setting of ventilation canals and laying of the airways through the customer hall, if this airways intended for the other premises. At the customers hall which is counting on 800 seat places the air supply have to implemented by the air flow with the maximum speed, permissible level of the noise at the hall and also with standard air movement in the work area. /2. p.51/

3.2 Mechanical conditioner

Mechanical conditioner is found out the huge application in the comfortable and technology air conditioning. This mechanical conditioner is no autonomous conditioner, so it is necessary to provide it by the outside cold (supply the cold or non-freezing liquid), heat (supply the hot water or the steam) and also by the electricity to drive the fans, some regulations devices for air and liquid communications. The appearance of the mechanical conditioner is shown on the Figure below.

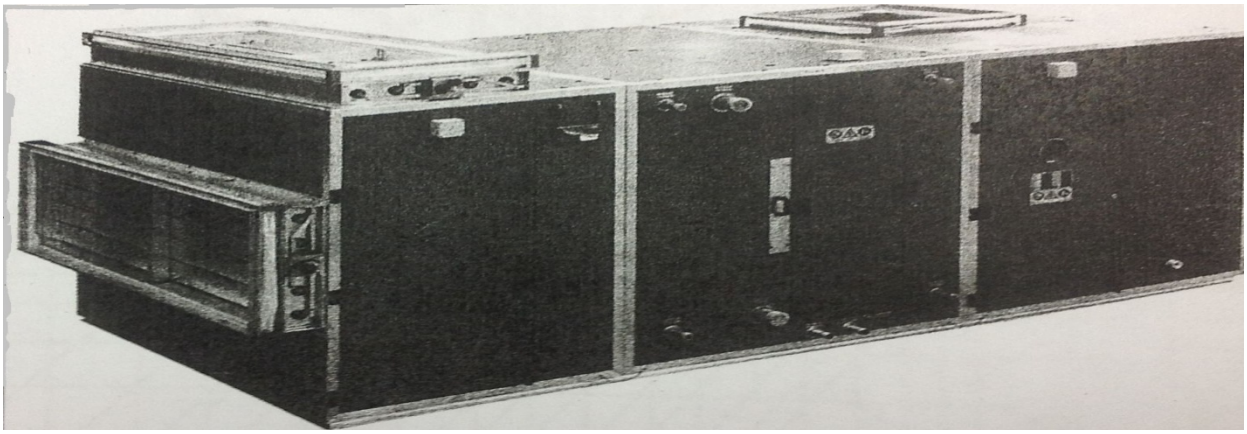

Figure 1. Mechanical conditioner /2.p 180/

Mechanical conditioner is intended to serve a few premises or only a huge one. Sometimes a few mechanical conditioners serve only one, but rather big premises such as theatre or cinema hall, close stadium.

Modern mechanical conditioner releases in the one big section. This section consist of uniform typical section (3 dimensional modules), which is intended for regulating, mixing, heating, cooling, purification, humidification and air supply.

Mechanical conditioner has a lot of advantages such as: effective temperature and humidity maintaining in the very high square premises.
Mechanical conditioner has also a lot of disadvantages including the carrying out of the quite complex construction works, lying of the building extended communications including airways and air pipes. /2 p.180/

3.3 Classification of the mechanical conditioners

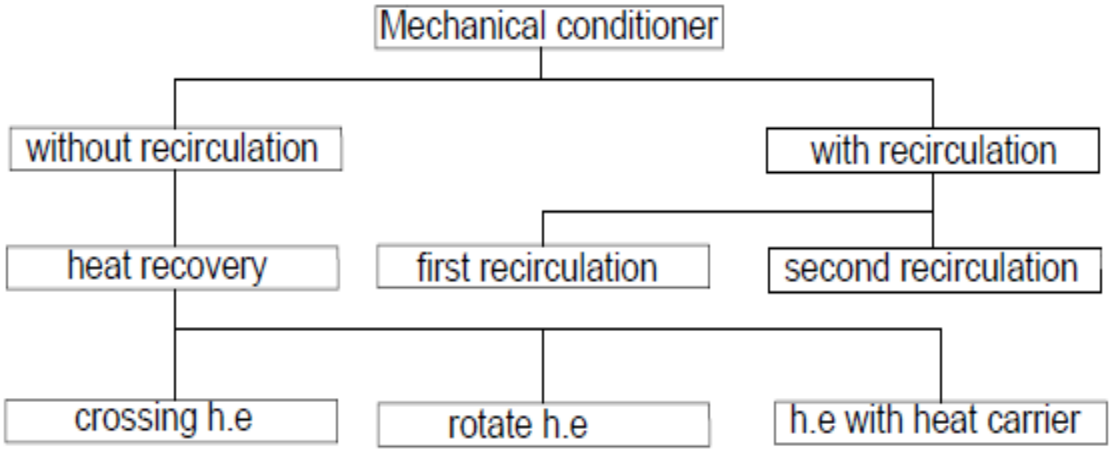

Figure 2. Classificarion of the mechanical conditioner /2. p180/

Mechanical conditioner can be with or without recirculation. Mechanical conditioner without recirculation can be with heat recovery. Mechanical conditioner with heat recovery can be with crossing, rotate or with heat carrier heat exchangers. Mechanical conditioner with recirculation can be with the first or with second recirculation.

Mechanical conditioner without recirculation recycles only the outside air. The first recirculation is the adulteration of the recycle air to outdoor before heat exchanger of the first heating. It reduces heat consumption on the first heating stage. The second recirculation is the adulteration of the recycle air to outdoor air, which past the recycling in the air cooler or in the chamber of irrigation before the ventilator. So, there is no any need to switch on the heat exchanger of second heating in the summer time.

Mechanical conditioner with heat recovery is the conditioner without recirculation, but with central heat exchanger, in which there is no mixing of outside and recirculation flow. Heat transfer from the removing air occurs in the special heat exchanger.

By the way the represented classification of the mechanical conditioners include only the main classes of that type of the equipment, which can also subdivided into to two main points. First of all according to the pressure level of build-in ventilators with different pressure range: low pressure is up to 100kg/m^2, medium pressure is from 100 to 300 kg/m^2 and high pressure is more than 300 kg/m^2. Secondly according to the work season it can be season and annual./2/

Also, there are different combination systems, which are based on the work of mechanical conditioners. In the conditioning systems, which are combined with air heating system of the building or the premises and purposed for the annual operation, as the rule, fixing at least two conditioners with 50 per cent capacity of the whole system productivity. In this case heating section should have the heat productivity enough for heating the premises.

Mechanical conditioners with recirculation, completed by the mixing chambers, which allow the supplying the variable volume of outdoor (fresh) air and recirculation air. In this case for the air recirculation is recommended to apply the separate ventilator.
Using in the mechanical conditioner and heat recovery allow to reduce heat energy losses, which are connected with the air heating in winter time. In the cases when air recirculation is unacceptable due to technology features of serving premises. Mechanical conditioner without recirculation is applied in this case. /3/

3.4 Construction and mode of the mechanical conditioners

Mechanical conditioners consist of typical separate sections, which are hermetically connected between each other. The housing of the conditioner is based on the frame, which is made from aluminum profiles. The constant and removable panels are fixed to this aluminum profiles.

Panels consist of the zinc sheet. Mineral wool which is used like a thermal insulation layer, set up between this zinc sheets. Removable and opened viewing windows are considered with the purpose to relief the access for the main points of the equipment.

Requirements for the air conditioning parameters are based on the technologic composition, so in that reason the set of section is quite variable. Section can be composited in the different execution or according to the plans of the premises, in which the conditioner is settling.

Beside the typical standard compositions there is the opportunity to create for the building a unique composition of the conditioner. Size of the section is unified and depends by the capacity and by the speed of recycled air in the conditioner.

The main sections, which are used in the composition of mechanical conditioners including: section of the fan, heating, cooling, humidification, filtration, sound attenuation and heat recovery sections.

Choosing the right composition of the mechanical conditioner depend on the different factors. First of all it depends on the purpose and mode of the using, constructive features of the building and also hygienic, architectural, operating and economical requirements. /4/

3.5 Cooling section of the mechanical conditioner

Cooling section is presented water or Freon heat exchanger –air cooler, which is made of copper pipes with aluminum ribs. There can be different types of the refrigerant: cooled water, glycol and water mixture and so on. Depending of the type of working area refrigerant can supply from the chiller, cooler or from artesian well. Collector is made of the steel zinc pipe. Inlet and outlet branch pipes of the collectors have an external thread. According to standard of the quality collectors are equipped by the branch pipes for lifting down of the refrigerant and air diversion.

Distributing and return collector of the Freon heat exchangers are made of copper pipes. Branch pipe of the collector locates in the outside of the section. Air cooler has the housing, which is made of the steel. Shell can be equipped by the special transport holders, which relieves the installation and transportation.

The ribbed of the pipes of the air cooler is made from the platens ribs, which provide the high level of the heat transfer according to the low level of the aerodynamic resistance of the heat exchanger. The quantity of the rows of the pipes and the distance between the ribs in dependence of the size can be variable.

According to the standard in the cooling section is fixed the pallet for condensing water which is made of stainless steel. This pallet is equipped by the branch pipe which is located outside. The special overflow siphon is linked to the branch pipe. Water air coolers are equipped by the unfrozen thermostat. The appearance of the water air cooler of the pipes type is shown below on the Figure below. /2. p187/

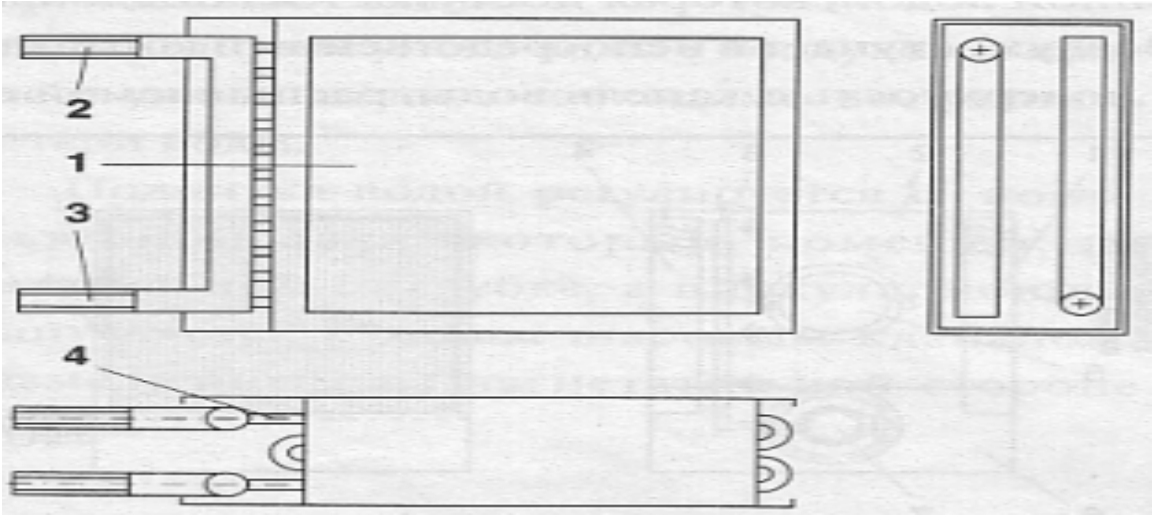

Figure 3.The construction of the water air cooler of the pipes type /2 p.187/

1 the shell of zinc steel

2, 3 the inlet and outlet branch pipes with thread

4 the copper pipe with the aluminum ribbed platens

Water coolers experienced on the endurance with the strain 2,1 MPa, Freon with the strain 2,9 MPa. Beside the cooling productivity and refrigerant capacity, water coolers are characterized by the follow parameters: minimum temperature of the work area (water) is 3 degree Celsius, maximum pressure of work area is 1,6 MPa and hydraulic resistance is 5-30 kPa.

For example the Freon air coolers characterized by the follow parameters: minimum temperature of Freon boiling is 2 degree Celsius and maximum Freon work pressure is 2,2 MPa. The special separators are fixed in the mechanical conditioner, if the speed of the recycling air is more than 2,5 m/s. /2. p187/

3.6 Heating section of the mechanical conditioner

Steam, water or electric heaters can use in the air heating section. Constructively air heaters made from the aluminum pipes with aluminum ribbed. Collectors and branch pipes which have the diameters 25 mm made from copper pipes. Collectors and branch pipes which have the diameters 32 mm made from the steel pipes with anticorrosion cover.

Collectors are equipped by the additional branch pipes with the thread, which are purposed for lifting down the water and air diversion. Branch pipes of the collector are located in the outside of the section. The end of the branch pipes of supply and return collectors also have the thread.

Shell can be equipped by the special transport holders, which relieves the installation and transportation. The ribbed of the pipes of the air heater made from platens ribs with the step from 1.6 to 4.0 mm.

There can be water or steam in the type of heat carrier. Water heaters experienced on the endurance with the strain 2.1 MPa, steam with the strain 1.5 MPa. /2/
If the water heater has a pre-heating function, there is an anti-freeze protection section situated behind it. The water heated is mounted in the housing by means of guides allowing its removal in case of defect or damage. Thus a free area of a width at least 1.3 times the external width of the mechanical conditioner is to be provided at the unit access side. /5/

In the case when the water is the heat carrier maximum water temperature is 150 degree Celsius, maximum work pressure of the water is 1,6 MPa and hydraulic resistance is 5-25 KPa. In the case when the steam is the heat carrier maximum steam temperature is 185 degree Celsius and maximum work pressure of the water is 1,0 MPa.
Electric heaters are made in the cuboids shape with the heating elements (spirals), which are fastened to the trunk. Electric heaters are connected to the electric net. The elements of the heater are fastened vertically and the contacts are located on the trunks side of the heater. Heater has the safety thermostat, which is restricted the fast temperature increasing and also the switching off the heaters in the case of the stopping of the air supply. /2. p188/

3.7 Humidification section of the mechanical conditioner

Air humidification is fulfilled in the irrigating section of water humidification or in the section of the steam humidification (injector section).The irritating section consist of the trunk, in which the combs pipes is fixed, pallet and the pump. The appearance of injector section is shown on the Figure below.

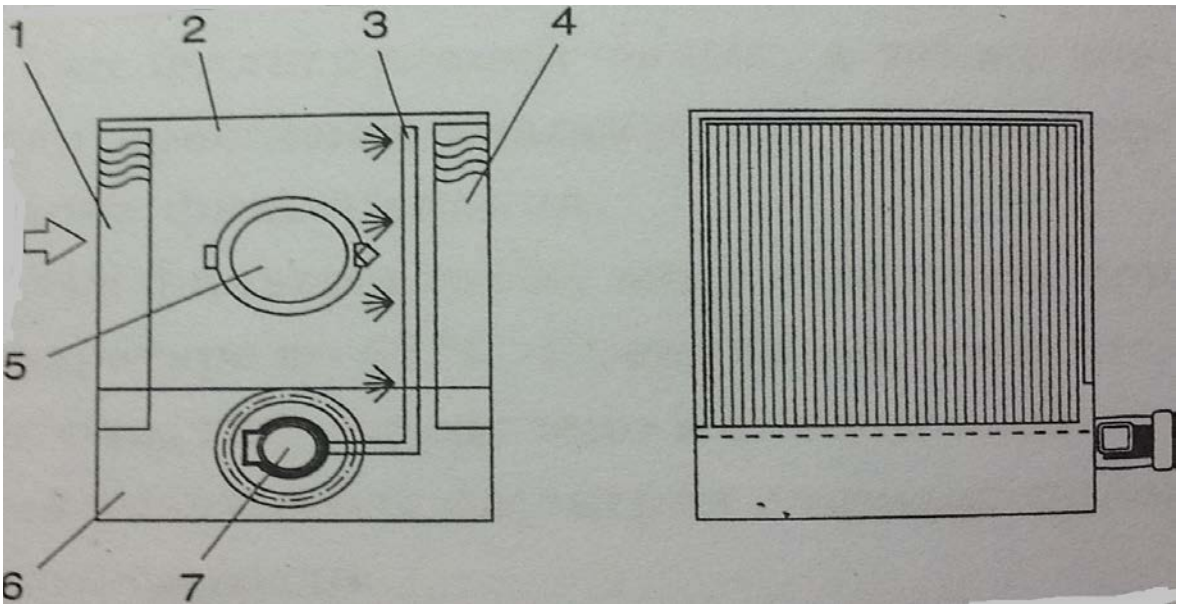

Figure 4.Injector section of the mechanical conditioner/2/

In the injector section is occurred adiabatic air humidification by the circulation water, which supply from the pallet. Air has the contact with the surface of the water drop, which is sprayed by the injectors. Air is conversed in to the mist of the small drops, which is passed through the air, absorbing the water steam.

The capacity of the injectors depends of the diameter of the out holes, pressure and temperature before the hole. The settling of the injectors in the cross section is fulfilled on the pipe combs. Circulation water is supplied to the pipe combs from the pallet. The spraying injectors are made in the way, which allow reducing the pollution deposit.

The function of the pallet is the tank of the reserve water volume, which is providing the smooth work of the pump. The pallet is equipped by the spillway with the float valve for lifting down the return water and also by the water input which allow the addition of the

evaporated water. The circulation pump is located near the pallet on the bracket. The cell filter is fixed on the input pipe branch of the pump. /2/
The construction of the injector chamber is adding two drop separators, which are prevented the drops carrying out to the next sections of the mechanical conditioner.
The first separator is working on the exit of the section, while the second separator is the directive. These separators are the effective elements of the equipment. The separator is made from the plastic panels and has the supporting structure from the stainless steel.
In the process of the humidification it is necessary to provide the adding of the water losses in the consequence of the carrying out of the water and air.

The adding water is regulated by the float, which is located on the branch pipe and the circulation water is released by the valve. This valve is located on the supply side of the branch pipe of the pump.
The shell of the section of the humidification is made from the stainless sheet. This fact is absolutely except corrosion. Also it has window for the control and lighting of the internal volume.

The humidity efficiency of this section is 90%. This section consists of the follow parts: shell of the section, steam separator, filter, thermodynamic condenser diverter, filter, injector and engine. /4/
The appearance of the steam circulation in the steam humidifier is shown on the Figure below.

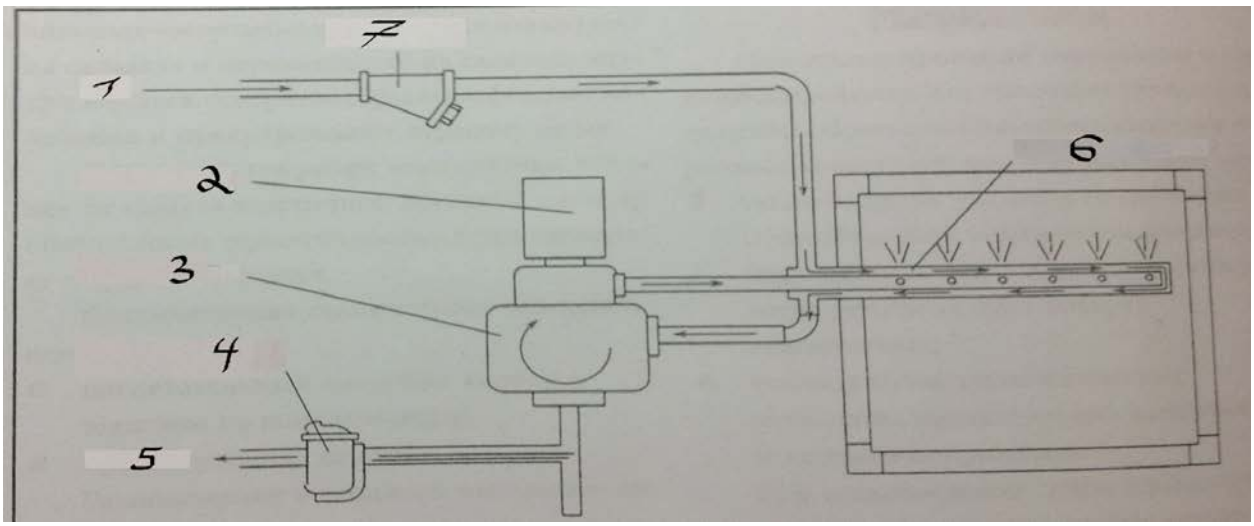

Figure 5.The scheme of the steam circulation in the steam humidifier/2 p.190/

1 steam

2 engine

3 steam separator

4 thermodynamic condenser diverter

5 condensate

6 injector

7 steam filter

This figure is described the main principle of the work of the steam humidifier. Type of the steam generator is chosen in dependence with required quantity of the steam capacity.

The air humidification by the dry overheated steam has a lot of advantages: quick mixing of the water steam with air, easier to regulate the quantity of the spreading steam, it allows the accurate regulating of the air humidity, dry overheated air does not contain any mineral particles or bacteria, minimum operational costs and the conservation of the steam humidifier is minimum. /4/

3.8 Sound attenuation section of the mechanical conditioner.

The main purpose of the silencer section is the reducing of the noise level, which is creating by the mechanical conditioner.

Sound absorption platens are fixed inside the silencer section. These platens are made from mineral wool with the certain density. The outside surface of the mineral wool is forced by

the fiber glasses cover. Section of the silencer is made of the different sizes from 0,5 to 2,0 meter, with different amounts of the sound absorption platens**.**

It required of the applying the special section with the air dissector which allow the aligning of the speed and direction of the air flow in the cross section of the silencer in according to technology composition if it necessary to set the ventilating section before the silencer section. The appearance of the sound attenuation section is shown below. /2 p.191/

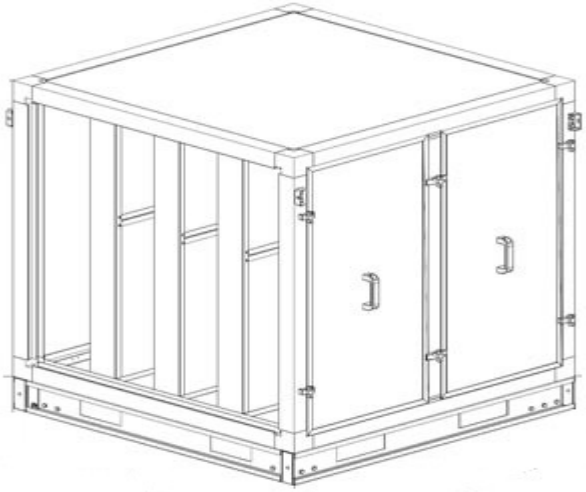

Figure 6.The sound attenuation section of the mechanical conditioner /2. p.191/

3.9 Filtration section of the mechanical conditioner

For providing the high quality of filtration there are can be added 2 sections: the section of the first filtration and the section of the second filtration.

Usually filters are located in the parts, in which the whole recycled air is pasted. The main purpose of the filters is to defend from the dust each section of the conditioner, if it possible.

In the section of the first filtration can be installed the cells filters of the EU1 class or the bag filters of the EU3 class. Cell filters is the fabric filter. This fabric is reinforced by the aluminum cell and installed in to the shell of the zinc stainless sheets.

Filter is installed in the equipment by the directive parts, which allow reinstallation quite easily. Bag filter is assembled from the few filter elements with the standard size. The quantity and the size of filter elements are applied in the equipment, independent of it model. The appearance of the filtration section is shown on the Figure below.

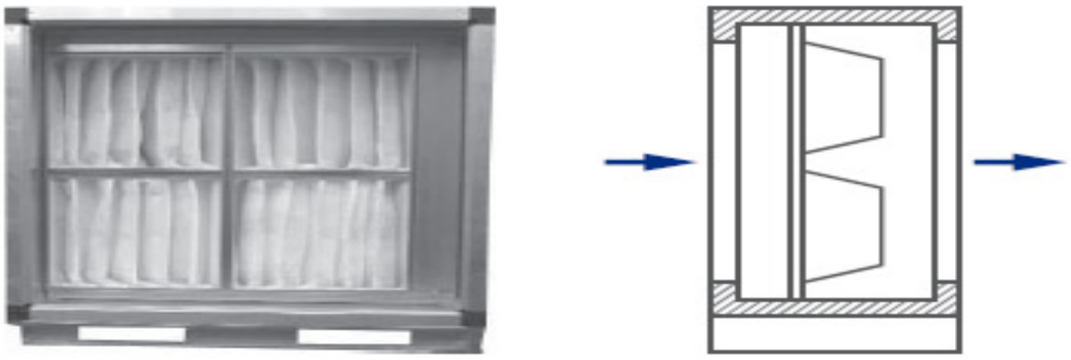

Figure 7. Filtration section of the mechanical conditioner /6/

Filter elements of the bag filters are fixed in the frame by the spring holder which is providing hermetic fiber. Filter fabric is made from the think synthetic.
All filters are working in the temperature from o to 60 degree Celsius. The average value of filter efficiency, which means the percent share of delayed dust of the filter of the EU1 classes is achieving up to 60 percent, and for the filter of the EU3 classes is achieving up to 80-90 percent.

In the section of the second filtration is applied bag filter of the EU5-EU9 class. Size and the quantity of the filter elements depend of the equipment model. Type of the filtration fabric and also the installing elements are the same as in the section of the first filtration.

This type of filter can also is worked in the temperature up to 60 degree of Celsius. The average value of the treatment degree is defined by the researching method of air filters with application of the quartz dust.
The average value of the filtration efficiency is subdivided on to three categories: filter of the EU5 class from 40 % to 60 %, filter of the EU7 class from 80 % to 90 % and filter of the EU9 class more than 90 %. /6/

3.9.1 Control of the filter pollution

The application of the differential pressure gauge is recommended with the purpose of the controlling of the filter pollution. Differential pressure gauge is made the electric signal according to the certain pressure drops. It means that this filter should be replaced because

of this filter is polluted. Acceptable value of pressure drop for cell filters is 120 Pa and for bag filters is 200-250 Pa. /2 p.191/

3.10 Fan section of the mechanical conditioner

Fan section is applied in ventilation and air conditioning system. They are installed in the mechanical conditioner, or applied as separate elements, built into different distribution ducts to maintain the required or specified flow rate**.**

The fan with its drive mechanism is mounted on the section housing guides by means of vibration insulators, while on the pressure side it is connected to the housing by means or a flexible duct connection. Such installation prevents the transmission of vibrations to the housing. /5 p.38/

The main function of the fun section is the air transporting and the air supply to the serving premises. The appearance of the fan section is shown on the Figure below.

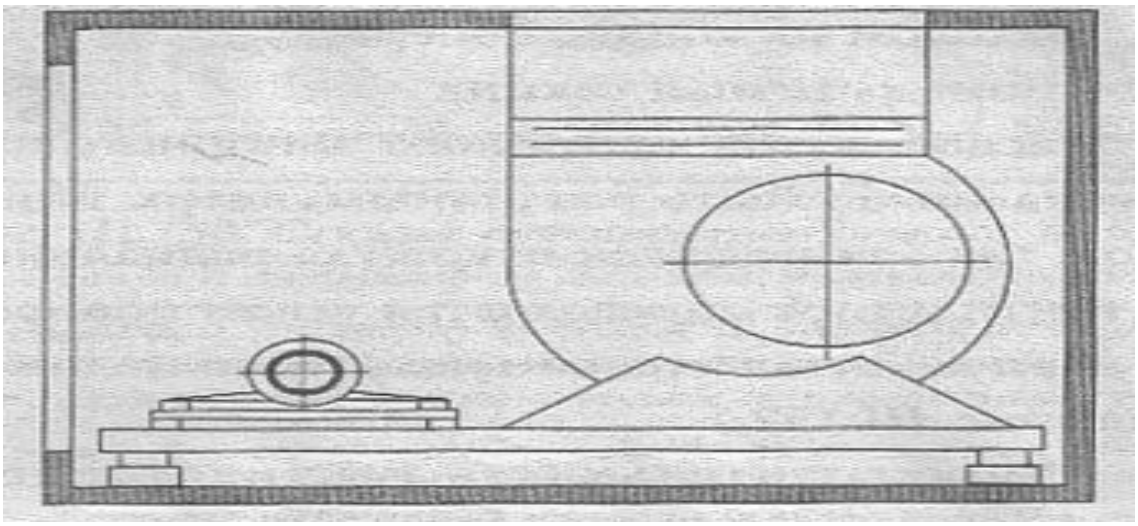

Figure 8. Fan section of the mechanical conditioner /2 p.191/

Radial centrifugal fan of the one and two sided suction are applied in the conditioners. Fans with work vanes, which are bended forward and downward that provides the regulation of the capacity by the changing the quantity of the wheels, are used independence of the requirement capacity and pressure.

Fan wheel is turning around by the electric engine through the belt gear. Independence of the capacity different types of the belts are used. The engine of the ventilator changes very easily and fast, in the cases when it out of order.

Ventilator with the engine and belt gear is replaced on the general frame inside the section, creating the fan group. The whole group is mounted on the springs or on the rubber vibration isolator. This isolator is reduced the fluctuation and supply of the noise.
The pressure pipe branch of the ventilator is separated from the shell by the elastic inside, which is provided the impermeability and prevent vibration transfer. Ventilator section can be implemented into two performances. In the first case when the branch pipe is the exit of the conditioner and in the second case when it represented like a transitional section. Placement of the supply exit branch pipe can be various. Different orientation of the output branch pipes of the fan section is shown on the Figure below.

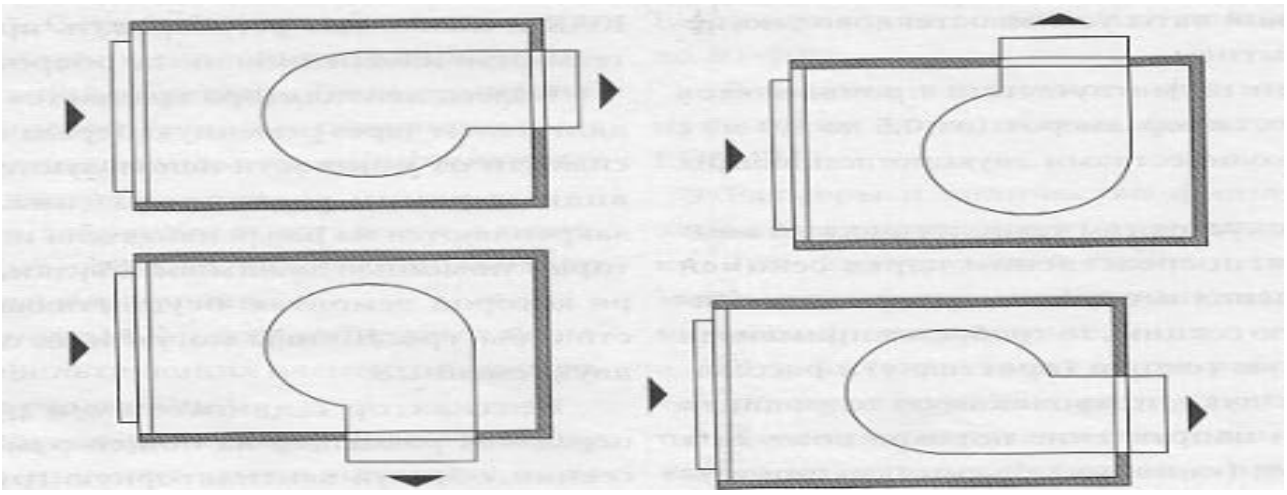

Figure 9. Different orientation of the output branch pipes of the fan section /2 p.192/.

Capacity of the fan section is corresponded to the power of the mechanical conditioner. Maximum temperature of the fan work is 85 degree Celsius, maximum temperature of the work of the standard engine is 40 degree Celsius and range of the operational temperatures is from 30 to 80 degree Celsius. Fan pressure is from 200 to 2500 Pa. /2. p.192/

3.11 Heat recovery section of the mechanical conditioner

Recuperation section is purposed to return back the input energy in the system. Cooling in the summer season and heating in the winter season. The efficiency of the system with the recuperation is from 50 to 90 %. It means a huge savings of energy and money.
There are different types of the second heat sources. The first type is when the heat removed by the ventilation and air conditioning system while he air recirculation is prohibited. The second type is when the heat and cold of the technology equipment, which is used for ventilation and air conditioning system. /5p.38/

Heat exchangers are applied for using the heat which is removed from the air premises. These heat exchangers are divided on to two main types: cross flow heat exchanger and rotate heat exchanger. Type of heat exchanger is defined the type of mechanical conditioner. /2/

3.11.1 Cross flow heat exchanger

Cross flow heat exchanger consist of the aluminum plates, which are creating the system of channels for passing of the two air flows. In the heat exchanger occurs the heat transfer between these two separate flows with different temperatures. Exhaust air which removes from the premises, passing in the each second channel between two platen of the heat exchanger, heating it. Supply, conditioning air is passing through the other channels of the heat exchanger and absorbs the heat of the heating platen. /2. p.192/

Supply, conditioning air is passing through the other channels of the heat exchanger and absorbs the heat of the heating platen. The cross flow heat exchanger operates on the cross flow principle. The appearance of the cross flow heat exchanger is shown on the Figure below.

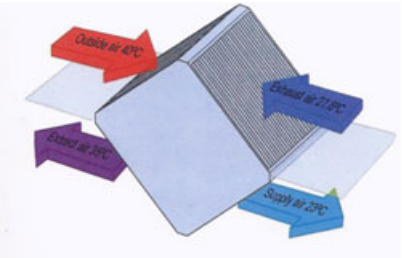

Figure 10. Section of the cross flow heat exchanger/6/

Due to turbulent flow of the air in the heat exchanger channels, heat exchanger is achieving the high efficiency level of the heat recovery according to quite low level of the hydraulic resistance. Thermostat is fixed on the heat exchanger for exception of the winter freezing. /6/

3.11.2 Rotate heat exchanger

Rotate heat exchanger is the equipment in which the air change is occurred as the result of heat accumulation by the rotating regenerative nozzle. Nozzle is the steel sheet which is twisted to create the channels for the horizontal air passing. Nozzle is made from the wheel shape and rotating by the engine with the reduction gear and belt gear.
Exhaust removed air has the high temperature is passing through the nozzle and heating it. Regulating of the efficiency of the heat recovery is making by the changing of number of the turns of the engine. The appearance of the rotate heat exchanger is shown on the Figure below. /5/

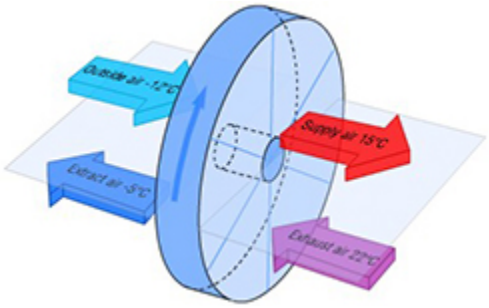

Figure 11. Rotate heat exchanger /6/

Rotary heat exchangers are also employed as a well proven and efficient means of heat recovery providing up to 80% energy savings. The rotating wheel is made up of an air penetrable heat transfer matrix which picks up heat from the exhaust air and releases it as the wheel passes through the cooler supply air. Depending on the air condition heat recovery wheel can also transfer moisture providing both sensible and latent energy recovery. /6/

4 INFORMATION ABOUT THE CINEMA HALL PROJECT

In this chapter there is information about the cinema hall: location of the cinema hall, quantity of the seat places and some different basic information about the project. There is shown which type of the ventilation equipment deliver the fresh air from the outside to the cinema hall.

Today there are a lot of cinema halls which are counting on certain amount of customers. At the cinema hall which are counting up to 200 customers is allowed to install only the exhaust ventilation system if the internal volume of cinema hall on the one seat place no more than 3.5 m^3 (according to the Snip). At the cinema hall with the cinema hall which is counting from 200 to 600 customers, it should be mechanical and exhaust ventilation (air conditioning system applied in some cases), but for the cinema hall with more than 600 seat places air conditioning system have to be. /1/

Cinema hall is the part of the big entertaining center which is located in the Saint-Petersburg city. The entertainment centre is made of metal construction with hinged panels and metal girder. Cinema hall is counting on 300 persons. The square of the hall is 191 m^2. The height of the hall is 6.5m. The volume of the cinema hall is 1242 m^3. /7/

4.1 The source of the heat and cool supply

Heating of the cinema hall is providing by the existing heating plant.

The cool supply of the whole entertaining centre is providing by the existing cooling plant. The specials chillers AWS by McQuay Company are set up in the cooling plant. This type of the chillers is presented on the Figure below.

Figure 12. Chiller AWS by McQuay Company /7/

These compressors have low value of vibration, which is very important for long –term operation and there no problems with the security elements of the building which are exposed by the depreciation due to constant vibration strain. For providing the required cooling capacity there are four chillers used including three chillers of - AWS 303.2 SE ST and one chiller- of AWS 184.2 SE ST.

Each chiller is based on two compressors and two independent refrigerant circuits which increases the overall reliability. Also each chiller is equipped with an evaporator, condenser- one for each circuit of refrigerant. Changing of cooling productivity is carried out smoothly which is influenced on the energy efficiency. The main feature of these chillers is the using of special system capacity control. The system of the asymmetric unloading spools control is applied for this type of chillers.

Also the new types of ventilators are applied on this type of chillers which allow the reducing of the noise from equipment. It is very important, if the object located in the dwelling district. This type of the handling equipment is presented on the Figure below.

Figure 13. Handling equipment./7/

Handling of the machine is based on the controller by Siemens, which work on the PID logic and has the ability to maintain a temperature of the liquid which outcome from the evaporator with the accuracy about 0, 2 degrees Celsius. Each unit is equipped with an electric board, which is divided into the power and controls part, which allows you to operate and maintain the equipment. It can help to implement the quick access to the interest elements I mean controlling and power elements./7/

4.2 Ventilation system at the cinema hall

Cinema centre is equipped by the mechanical exhaust ventilation system. Equipment "A-Clima" is adopted as an air handled system. Air change for the cinema hall is calculated on the heat and moisture assimilation. In the summer and in the transition period the supply of cooling air is considered. Air after cooler is reheated in the special electric heater and supplied with the temperature near 18 degree Celsius. In the winter time, there is considered the evaporator for maintaining of moisture content.

All system is equipped by the silent dumpers to prevent the noise. Air recirculation system is considered with the economical benefit point.
In the supply vent cameras considers the location of the supply and exhaust ventilation and in the exhaust vent cameras is locating the exhaust ventilation.
The air pipes of the whole supply and exhaust systems are made from steel.
The supply air pipes are considered in the heat isolation for preventing the moisture condensation. /7/

4.3 Equipment "A-Clima"

Equipment "A-Clima" is the combination of mechanical and exhausts ventilation. This type of the ventilation equipment is used for providing by the fresh air of the whole entertainment center, including the considering cinema hall. The principal scheme of the equipment "A-Clima" is presented on the Figure below.

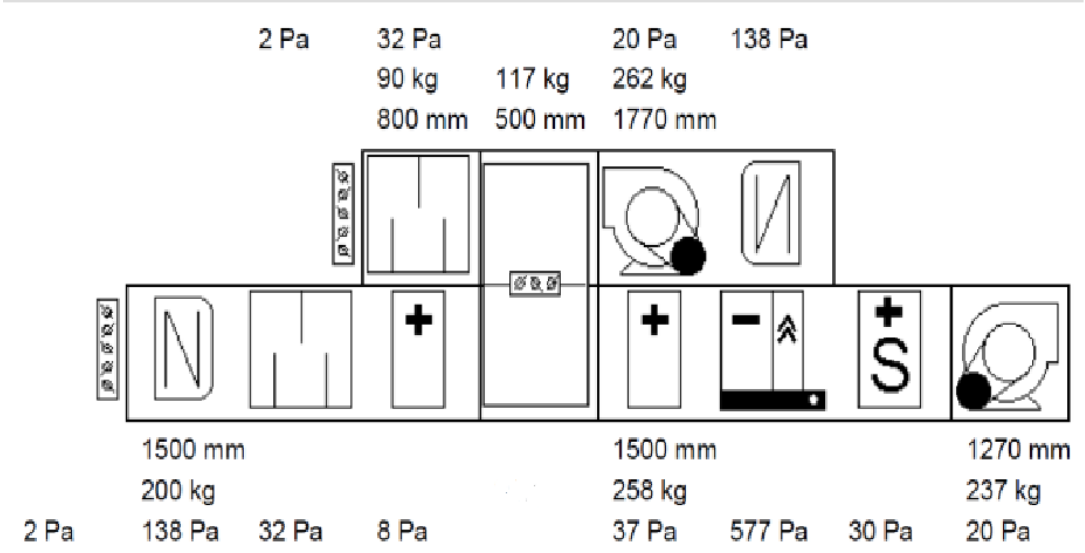

Figure 14. Equipment A-Clima

Exhaust equipment locates on the up part and consists of: flexible connector, sound attention section, mixture section, fan section and filter section.(From left to the right side).

Mechanical equipment locates on the down part and consists of: flexible connector, filter section, sound attention section, heating section, mixture section, heating section, cooling section, engine, fan section.(From left to the right side).

Mixture part considers with the air recirculation for the heat saving./7/

5 PRACTICAL PARTS

The practical part of this Bachelor's thesis divides into several steps:

1) Measurements of the air humidity and air temperature at the cinema hall with different customer loading
2) Calculations of the total heat and moisture emissions at the cinema hall with different customer loading
3) Questionnaire of the customers at the cinema hall. The main question is: How are the customers feeling themselves during the film sessions?

5.1 Measurements

Measurements of the air humidity and air temperature were undertaken on 24th of October at the study cinema hall with loading 5 customers and on 27th of October at the study cinema hall with loading 200 customers in 2 different points by Data logger device. The appearance of the cinema hall and also the location of the Data loggers in the cinema hall are shown on the Figure below.

Figure 15. Location of the Data loggers at the cinema hall

According to Russian requirement the acceptable value of the relative humidity at the cinema hall have to be in the range from 30%-60 % for winter time. Also according to Russian requirement the acceptable temperature value at the cinema hall have to be in the range from 19-23 degree Celsius for winter time.

a) In the case when there are 200 persons at the cinema hall

Film started at 5.30 pm on Saturday. So there were a lot of heat and moisture emissions from customers who visited this cinema hall on Saturday earlier.

Data logger 1

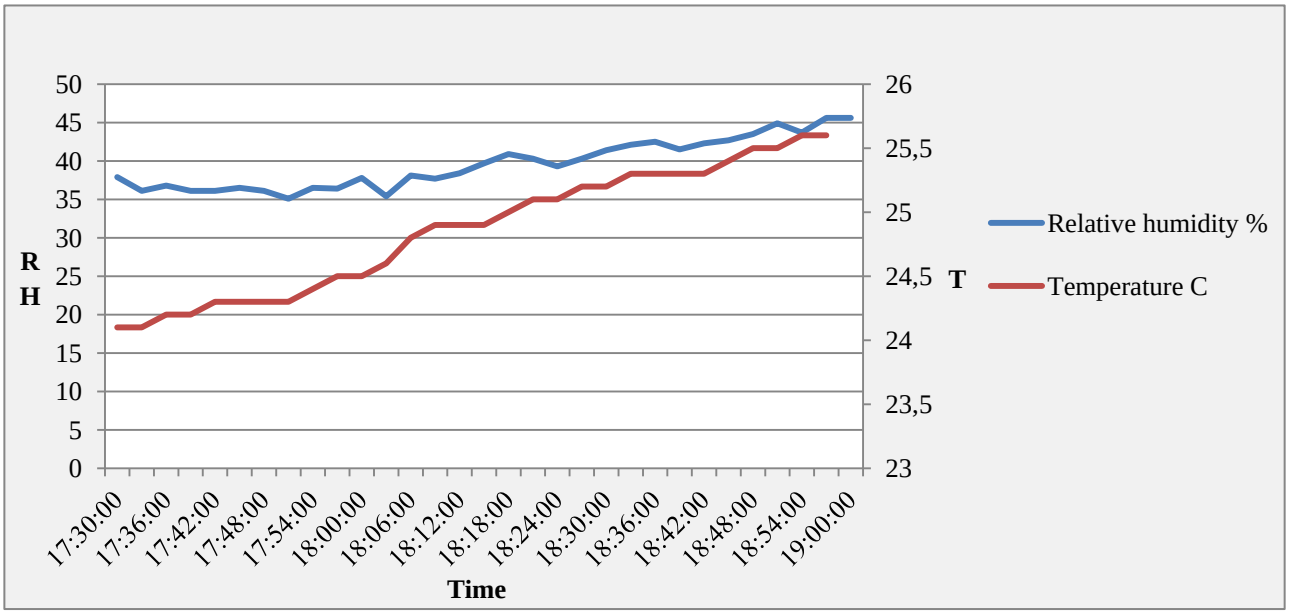

Figure 16. Measured values of the air temperature and relative humidity in the 1st point

According to measurements at the cinema hall with loading 200 persons, maximum value of the relative humidity was 45,9 % and maximum value of the air temperature was 25,7 degree Celsius. Minimum value of the relative humidity was 35,1 % and minimum value of air temperature was 24,1 degree Celsius. The average value of the relative humidity was 40,1 % and the average value of air temperature was 25,1 degree Celsius.

Data logger 2

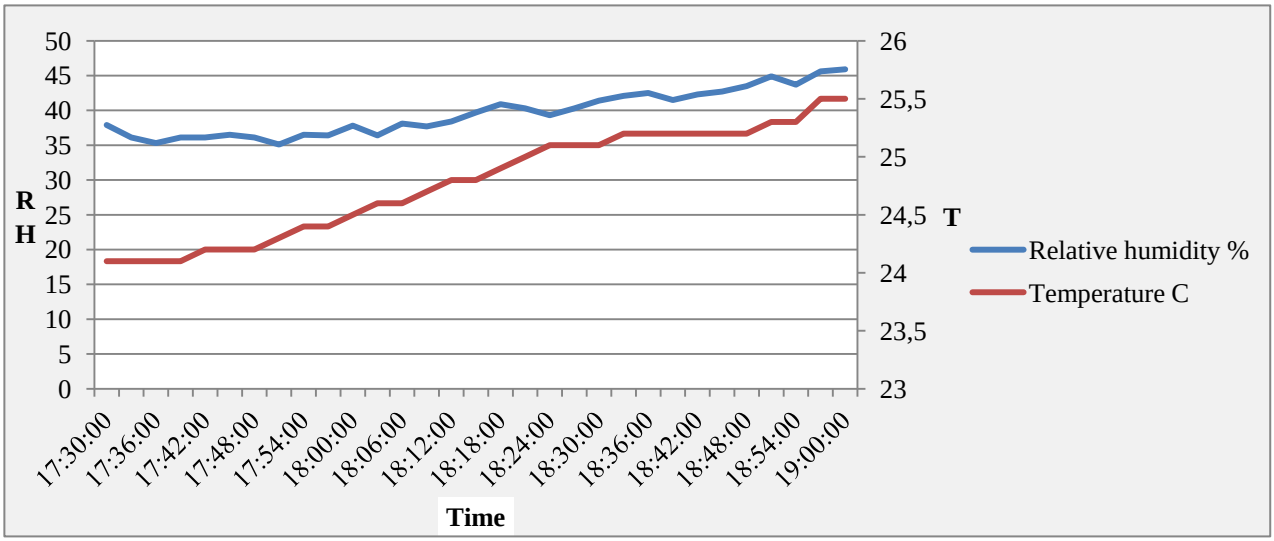

Figure 17. Measured values of the air temperature and relative humidity in the 2st point

According to measurements at the cinema hall with loading 200 persons the maximum value of the relative humidity was 45,9 % and the maximum value of the air temperature was 25,6 degree Celsius. Minimum value of the relative humidity was 35,1 % and minimum value of air temperature was 24,1 degree Celsius. The average value of the relative humidity was 39,8 % and the average value of air temperature was 25,0 degree Celsius.

According to the Figure the temperature and relative humidity levels were increasing during the film sessions because of the heat and moisture emissions from the customers in non-activity conditions. Comparing the results which are gotten by the Data logger 1 and Data logger 2 at the cinema hall with the values which are given by the Russian requirement it is obviously that microclimate at the cinema hall was inadequate.

b) In the case when there are 5 persons at the cinema hall

Film started at 10.55 am. It was the first film at the cinema hall according to the morning schedule of the cinema hall. So, heat and moisture emission from customers of the last night film session was diluted by ventilation system during the night.

Data logger 1

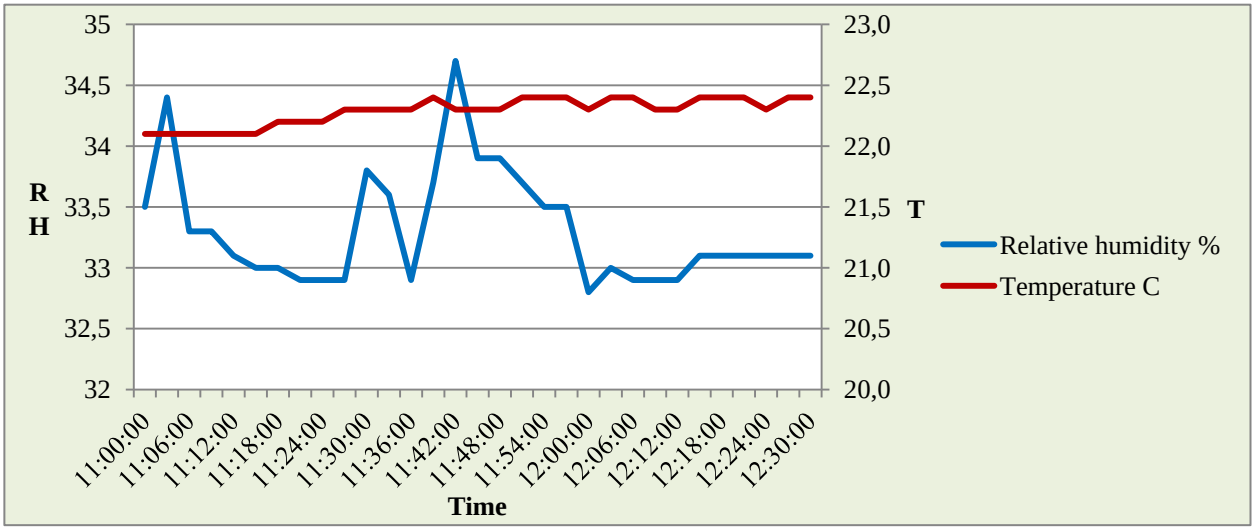

Figure 18. Measured values of the air temperature and relative humidity in the 1st point

According to measurements at the cinema hall with loading 5 persons the maximum value of the relative humidity was 34,7% and the maximum value of the air temperature was 22,4 degree Celsius. Minimum value of the relative humidity was 32,8 % and minimum value of air temperature was 22,1 degree Celsius. The average value of the relative humidity was 33,2 % and the average value of air temperature was 22,3 degree Celsius.

Data logger 2

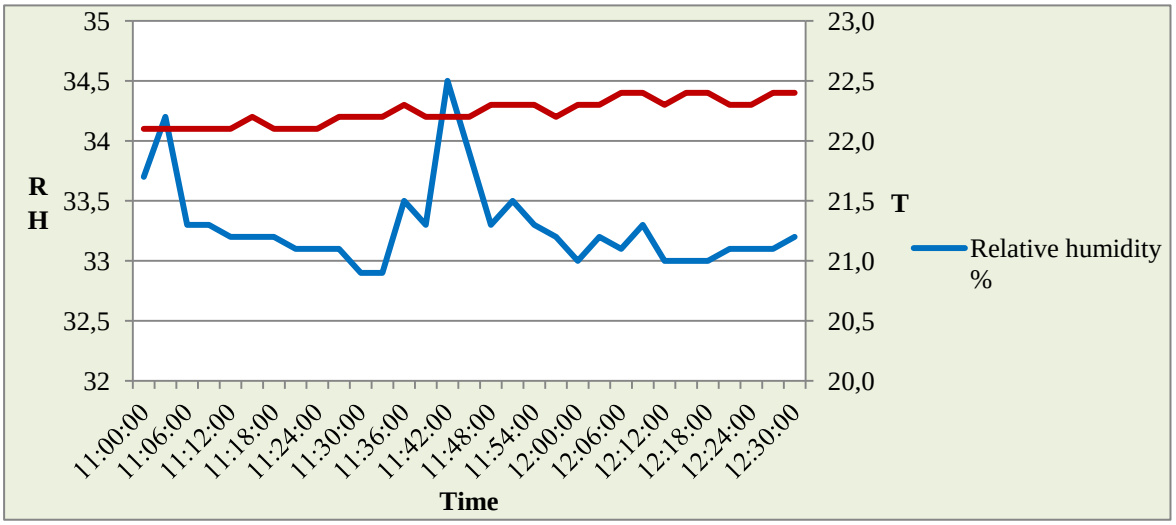

Figure 19. Measured values of the air temperature and relative humidity in the 2st point

According to measurements at the cinema hall with loading 5 persons the maximum value of the relative humidity was 34,5 % and the maximum value of the air temperature was 22,4 degree Celsius. Minimum value of the relative humidity was 32,9% and minimum value of air temperature was 22,1degree Celsius. The average value of the relative humidity was 33,3 % and the average value of air temperature was 22,2 degree Celsius.

The average value of air temperature at the cinema hall was quite high for the loading 5 viewers, but it was in the normative range from 19-23 degree Celsius for winter time according to the Russian requirements. The level of the relative humidity was in the normative range 30%-60% according to the Russian requirements.

5.2 Calculations of the heat, moisture and lighting emissions at the cinema hall with different customer loading

In this chapter there are calculations of the heat and moisture emissions at the cinema hall with different customer loading. In the first case there were 200 persons at the cinema hall.

In the second case there were 5 persons at the cinema hall. Results of these calculations facilitates to the assessment of the energy efficiency of the ventilation system at the cinema hall.

1) Calculations of heat emissions

Winter period

1) Quantity of the heat which emitted by viewers in non-activity condition

$Q_1 = n_1 * q_1$; (1)

Where:

Q1= quantity of the heat which emitted by viewers in non-activity condition, W

n_1= quantity of the viewers, person

q_1 = 120 W/person – heat emissions by person in non-activity condition. /9/

2) Heat emissions by the lighting

$Q_2 = E * F * q_{lighting} * \eta_{lighting}$; (2)

Where:

Q_2= Heat emissions by the lighting, W

E = is the lighting level for halls, lx . /10. Part 17/

F= is the square of the hall ,m^2

$q_{lighting}$ = specific heat emission by the lighting, W/$м^2$*lx. /10. Part 18/

$\eta_{lighting}$ = 0,15-heat emission share by the lamp

3) Calculations of moisture emissions

Quantity of the moisture emissions by visitors in non-activity condition:

$G_w = n_1 * q_w$; (3)

Where:

Gw= quantity of the moisture emissions by customer in non-activity condition, kg/h

n_1= quantity of the customers, person

q_w= moisture emissions by person in non-activity condition, g/h*person . /9. part 3. Table 2.2/

All calculating values are presented on the Figure below.

№	Calculating values	Customer loading	
		200 customers	5 customers
1	Heat emission	89900 kJ	5645 kJ
2	Lighting emission	967 W	967 W
3	Moisture emission	8 kg/hour	0,2 kg/hour

Figure 19. Calculating values of the heat, moisture and lighting emissions at the cinema hall with different customer loading

5.3 Questionnaire of the cinema hall customers

The main question is: How are the customers feeling themselves during the film sessions?

200 persons

In this case about 10 persons were examined. Eight persons from 10 told that it was really inadequate microclimate. They were sweated during the film session. The main complaint was about the temperature value at the cinema hall. Two persons from 10 responded that they were used to this situation with air temperature value in Saint-Petersburg buildings. According to the assessment of the customer opinions, microclimate at the cinema hall was inadequate.
The average value of the relative humidity was 40,1 % and the average value of air temperature was 25,1 degree Celsius with loading 200 persons.

5 persons

In this case 3 persons were examined. Everyone told that microclimate at the cinema hall during the film session was quite good. So, customers were satisfied with the microclimate at the cinema hall.
The average value of the relative humidity was 33,2 % and the average value of air temperature was 22,2 degree Celsius with loading 5 persons.

5.4 Comparison of the case study cinema hall with different customer loading

The comparison of different values of the cinema hall with different customer loading is presented in the Table. The values heat and moisture emission depends on the quantity of the customers during the film session. Different values of the temperature depend of the values of heat emissions by customers. Different relative humidity values according to

measurements depend of the different values of the moisture emissions. In the case when there were 200 persons, according to the questionnaire customers were dissatisfied with the microclimate. In the case when there were 5 persons, according to the questionnaire, customers were absolutely satisfied with microclimate during the film session. Table of comparison of the cinema hall with different customers loading is shown on the Figure below.

№	Values of comparison	Customer loading	
		200 customers	5 customers
1	Heat emission	89900 kJ	5645 kJ
2	Moisture emission	8 kg/hour	0,2 kg/hour
3	Relative humidity	40,1 %	33,2 %
4	Temperature	25,1 Degree Celsius	22,2 Degree Celsius
5	Questionnaire	Dissatisfied	Satisfied

Figure 20. Comparison of the cinema hall with different customers loading

This figure is presented that ventilation system of the cinema hall was working in one mode all time, independence of the hall loading. The temperature and relative humidity difference between two different loadings was occurred because of different amount of customers. Customers breathe and sweating during the film session, so heat and moisture emissions were increasing, so for that reason temperature and relative humidity level also increased.

6 DISCUSSION

In this Bachelor thesis I have considered the ventilation system at the cinema hall with different customer loading. In the first case there were 5 persons at the cinema hall. In this case ventilation system was created normal microclimate. All customers were satisfied with the quality of the indoor air. Temperature and relative humidity values were in the acceptable range according to Russian requirements. In the second case there were 200 persons at the cinema hall. In this case ventilation system worked inadequate. The average

temperature value in this case exceeded more than 2,1 degree Celsius the normative value according to the Russian requirements. Relative humidity was increasing during the film session. Customers were dissatisfied with quality of the indoor air.

The main question of this Bachelor thesis was to study the energy efficiency of the ventilation system with different customer loading through different instruments. First of all I have measured temperature and relative humidity at the cinema hall with different customers loading. Secondly I have calculated total heat and moisture emissions at the cinema hall with different customers loading. Then I asked customers the question about the indoor air quality.

Comparing the gotten results of the cinema hall with different customer loading it is obviously that ventilation system was working absolutely inefficient. Ventilation system worked out in one mode for two studying cases. The temperature and relative humidity difference between two different loadings was occurred because of different amount of customers. Customers were breathing and sweating during the film session, so heat and moisture emissions were increasing, so for that reason temperature and relative humidity level also increased in the case when there were 200 customers. Ventilation system was not diluting these emissions.

It is obviously that there was the wrong operation of the ventilation system at the cinema hall. The main mistake in the operation of the ventilation system is the absence at the cinema hall of the special temperature and humidity device. This device controls the value of the temperature and relative humidity at the cinema hall. In the case when the level of the air temperature or relative humidity exceeded the normative or settling value, this controlling device regulates the quantity of the supply air. It is the best way to control temperature and relative humidity level and to create the perfect microclimate. Also this device helps to reduce the energy consumption of the ventilation system.
Location of these devices is shown on the Appendix.

In the cases when there will be 300 customers at the cinema hall (100% loading) the values of heat and moisture emissions will desperately increase during the film session if we compare this case even with the case when there were 200 customers. For that reason values of the temperature and relative humidity won’t be in the normative level according to

the Russian requirements. The percentage share of dissatisfied customers in this case will also increase. The quality of the microclimate will be worse. In real life this case is almost unreal. It can be one or two times per year, but ventilation system even in this case have diluted all heat and moisture emissions from customers and created perfect microclimate condition at the cinema hall.

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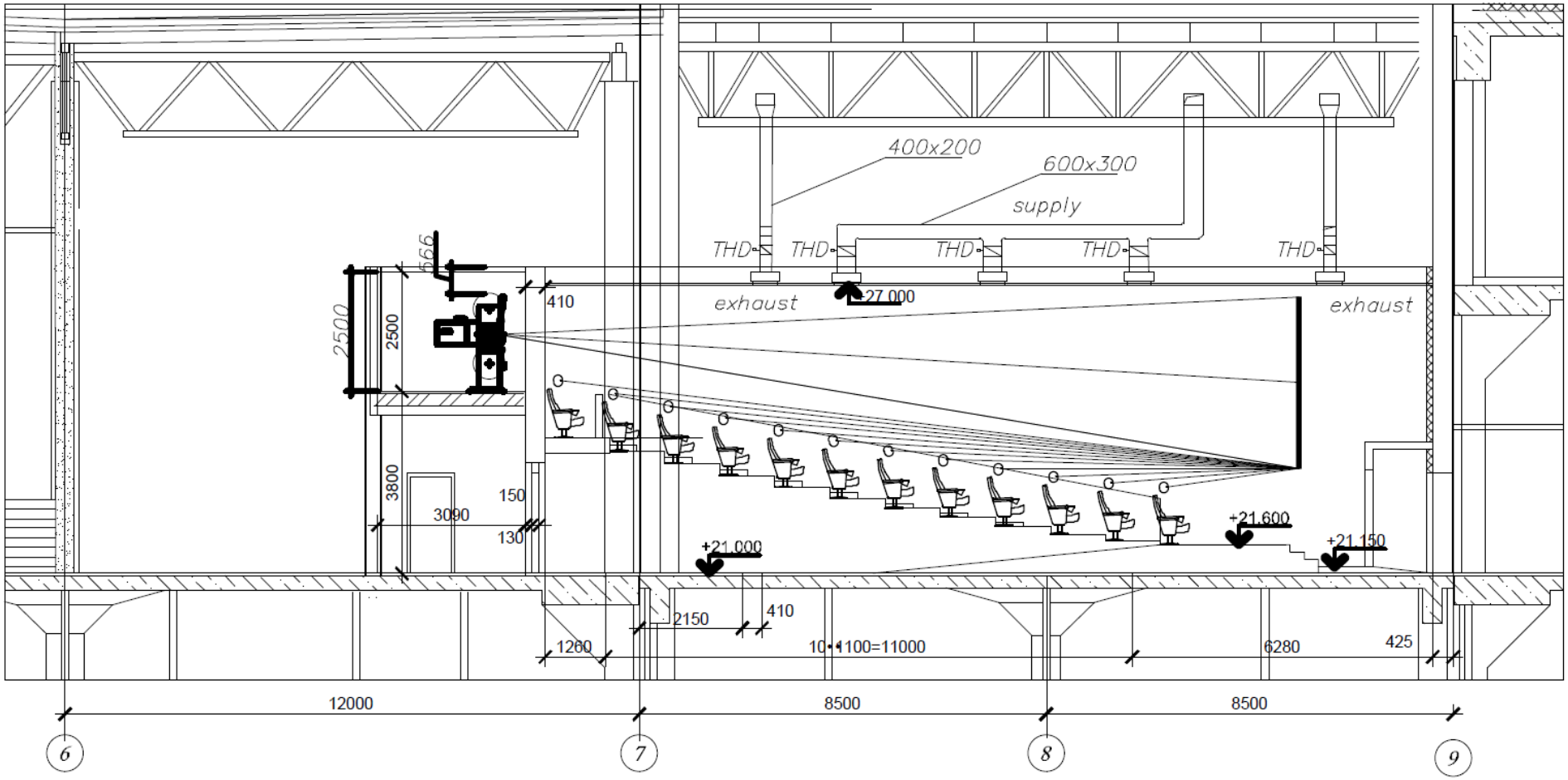
Appendix



Placement of the temperature and relative humidity devices (THD)