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EVROPSKÁ UNIE  
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INVESTICE DO VAŠÍ BUDOUCNOSTI



Název projektu / Project

Mezinárodní výzkumné laserové centrum ELI

New chiller in SO03 machinery room and AHU modification

Stupeň Dokumentace / Stage

Jednostupňová dokumentace  
JDS | One-stage design

Fáze / Phase

Profese / Discipline:

Zařízení pro ochlazování budov  
A.3.2 | Cooling system

Zpracovatel části / Consultants



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1	INTRODUCTION .....	2
1.1	Project identification data .....	2
1.2	Initial information .....	2
1.3	Outdoor design temperatures .....	2
2	EXISTING .....	3
3	NEW PROPOSED SOLUTION.....	3
3.1	New chiller in the SO03 technical room.....	3
3.2	Operation modes .....	4
3.3	Modifications of cooling hydronic circuit.....	5
3.4	Modification of air-handling units 17AB, 18AB a 19AB – additional cooling coils installation .....	6
3.5	Phasing of the works.....	6
3.6	Machinery regular and emergency ventilation.....	7
3.7	Thermal insulation .....	7
3.8	Noice .....	7
3.9	Fire safety measures .....	7
4	ASSOCIATED WORKS .....	7
4.1	Architectural, coordination.....	7
4.2	Electrical.....	8
4.3	Plumbing .....	8
4.4	BMS .....	8
5	TESTING AND HANDING OVER .....	9

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## 1 INTRODUCTION

The project deals with the addition of one chiller of cooling capacity of approx. 1MW to the existing cooling technical room SO03 which is a part of the back-of-house area of the laser research centre ELI Beamlines Dolní Břežany. The newly installed chiller will ensure the production of chiller water of low temperature needed for air dehumidification in major air-conditioning units 17AB, 18AB and 19AB, which ensure the fresh air supply to the research laser halls and ensure the required positive in the clean rooms. The installation of a new chiller involves modifications of the hydronic system in the technical room SO03, modifications to the above-mentioned air conditioning units and modifications to the electrical installation in SO03. The newly proposed chiller will be powered from a normal, non-backup network.

The installation of the newly proposed chiller and the associated works will be split into two phases denominated as the preparatory and the main phase. The preparatory phase must be completed during the annual summer shutdown of the eli centre scheduled for summer season, the main phase can then continue even after the end of the summer shutdown during regular operation of the eli centre.

### 1.1 Project identification data

Project name:	ELI – NEW CHILLER IN TECHNICAL ROOM SO03 AND MODIFICATIONS OF AIR-HANDLING UNITS 17AB, 18AB AND 19AB
Location:	Dolní Břežany u Prahy
Investor:	ELI Beamlines Za radnicí 835 252 41 Dolní Břežany
Design detail:	One-stage design
M&E discipline:	Cooling
Designer of the cooling disciplinei:	Stantec s.r.o. Thámova 137/16, 186 00 Praha 8, IČO: 26429306 DIČ: CZ 26429306 Responsible person: Ing. Jan Bureš Mobile: 266 090 030 email: Prague.Office@stantec.com

### 1.2 Initial information

The basis for the design has been the as-built design documentation of M&E disciplines, the 3D Revit model of the building installations, the climatic conditions at the site, the user requirements, the study *Study of air dehumidification solutions for the laser hall at Eli Beamlines* dated 15.4. 2023 by Ing. Pavláček, site visits, verbal and written information provide by facility staff and provisions of applicable technical standards and regulations.

### 1.3 Outdoor design temperatures

Following data have been used for the design according to the code ČSN 73 0548:1985:

Parameter	(Dolní Břežany)	Zima	Léto
Dry bulb temperature		-15°C	32°C
Wet bulb temperature		-17°C	21°C
Air enthalpy		-8,9 kJ.kg <sup>-1</sup>	64 kJ.kg <sup>-1</sup> (for air pressure 100kPa)
Relative air humidity		96%	40%

## 2 EXISTING

The ELI facility is currently supplied with cold from a chiller technical room located outside the research part of the ELI facility, in the central machine room SO 03 - Management of technical gases and ELI cooling technology. The currently installed chillers produce chilled of the temperature gradient 8/14°C.

There are two water-cooled chillers with turbo compressors of a total cooling capacity 4.6 MW. A pair of closed cooling towers dissipate the waste heat from the chillers' condensers.

At an outside temperature below approx. +5°C, the heat load can be covered by free cooling operation mode ensure by one existing dry cooler with cooling capacity up to 510 kW. In addition to the dry cooler, one cooling tower with an further 500 kW cooling capacity can be used for free cooling operation mode.

The chiller water is brought to the cooling / heating distribution room on the 3rd floor of the laboratory building via an underground pipe route, where a DN 400 pipe distributor / collector is installed, on which the system is divided into individual circuits.

The existing chillers are not connected to back-up generator, so the chilled water production stops in the case of the public grid blackout.

For a limited time, the cold accumulated in the cooling hydronic system can be used to back up cooling of critical appliances. In order to achieve this, the power supply to some of the circulation pumps is backed up.

## 3 NEW PROPOSED SOLUTION

### 3.1 New chiller in the SO03 technical room

Stávající zdroj chladu bude rozšířen o jeden nový chladicí stroj o chladicím výkonu 1.015kW při teplotním spádu vyráběné chladící vody 4/10°C. Z praktických důvodů je nový zdroj chladu konfigurován tak, aby na kondenzátorové straně mohl pracovat s teplotou věžové vody 29/35°C, na kterou jsou konfigurovány i stávající chladicí jednotky i samotné stávající chladicí věže (požadovaný chladicí výkon nové chladicí jednotky byl zadán investorem na základě zkušeností z více než sedmiletém provozování zařízení tak, aby byl chlad vyráběn s co nejpříznivějším koeficientem COP, tedy s co nejvyšší účinností). Chladicí stroj bude navržen na výstupní teplotu chlazené vody +4°C tj. teplotu o 1°C nižší než na kterou jsou počítány nové chladiče čerstvovzdušných VZT jednotek 17AB, 18AB a 19AB, avšak po většinu času bude chladicí stroj vyrábět chladící vodu o teplotě +8 °C. Na výrobu chlazené vody o teplotě +4°C bude stroj přepnut v případě, že odvlhčování na chladících výměnících VZT jednotek 17AB, 18AB a 19AB nebude dostatečné. Tento stav zaznamená systém MaR a přepnutí set pointu stroje z +8°C na +4°C automaticky provede. Nový chladicí stroj bude osazen do stávající strojovny chlazení, kde je připravená prostorová rezerva včetně antivibrační izolovaného základu a včetně základů pod cirkulační čerpadla z doby výstavby ELI. Navržen je dvoukruhový chladicí stroj se dvěma šroubovými kompresory s plynulou regulací prostřednictvím frekvenčních měničů. Navrhovaný chladicí stroj bude pracovat s chladivem R134a. Výkon chladicího stroje bude možno plynule regulovat v rozsahu 15 až 100% jmenovitého výkonu, což umožní optimální provozování až do odběru chladu pouze cca 150kW, což je pro některé provozní stavby ELI optimální (v chladném ročním období v době, kdy probíhá minimum vědeckých experimentů nebo případně žádný).

Rozměry navrhované chladicí jednotky jsou 4.731x1.165x1.997 (délka x šířka x výška), hmotnost 6.668kg, hmotnost náplně chladiva R134a 240kg. Jedná se o rozměry referenční jednotky, odchylky jsou možné.

Na kondenzátorové straně budou nová chladicí jednotka napojena na stávající okruhy věžové vody, na kterém nebude nutno provádět žádné podstatné fyzické úpravy, pouze bude nutno osadit 6 ks motoricky ovládaných uzavíracích klapek a okruh hydraulicky zaregulovat.

Na straně chlazené vody bude nově navrhovaná chladicí jednotka napojena na stávající rozvody chlazené vody. Cirkulaci vody bude zajišťovat dvojice čerpadel (100% automatický záskok). V dalších částech rozvodů chladu již budou fyzicky provedeny jen drobné úpravy pospané dále v text v kapitole Úpravy hydraulických okruhů chladu (trojcestné ventily, připojení nově navrhovaných chladicích výměníků na VZT jednotkách 17AB, 18AB a 19AB, jejich protimrazová ochrana apod.).

Expanze, doplňování a zabezpečení hydraulické soustavy systému chlazení bude zajištěno napojením na stávající zařízení ve strojovně SO03.

Obě dvě stávající kompresorové jednotky ve strojovně zůstanou a budou nadále v určitých provozních režimech využívány. Bližší informace o provozních režimech výroby chladu jsou uvedeny v kapitole 3.2 dále v textu.

The existing cooling system will be expanded by one new chiller cooling capacity of 1,015 kW at temperature drop of the produced chiller water 4/10°C. For practical reasons, the new chiller is configured in a way the condenser side of the chiller can be connected to the existing cooling towers designed for temperature gradient of 29/35°C. If be switched to produce chilled water at a temperature of +4 °C if the dehumidification on the coolers exchangeable air conditioning units 17AB, 18AB and 19AB will not be sufficient. This condition will be recorded by the MaR system and the set point of the machine will be switched from +8°C to +4°C automatically. The new cooling machine will be installed in the existing cooling machine room, where a space reserve is prepared including anti-vibration isolated foundation and including foundations for circulation pumps from the time of ELI construction. A double-circuit refrigerating machine with two screw compressors with continuous regulation via frequency converters is designed. The proposed cooling machine will work with refrigerant R134a. The power of the cooling machine will be able to be smoothly regulated in the range of 15 to 100% of the nominal power, which will enable optimal operation up to the cooling consumption of only approx. 150 kW, which is optimal for some operating conditions of ELI (in the cold season when there is a minimum of scientific experiments or possibly none).

The dimensions of the proposed chiller are 4,731x1,165x1,997 (length x width x height), weight 6,668 kg, weight of R134a refrigerant charge 240 kg. These are the dimensions of the reference chiller, deviations are acceptable.

On the condenser side, the new chiller unit will be connected to the existing tower water circuits, on which no substantial physical modifications will be necessary, it will only be necessary to install 6 motorized shut-off valves and hydraulically regulate the circuit.

On the chilled water side, the newly proposed chiller will be connected to the existing chilled water distribution. Water circulation will be ensured by a pair of pumps (100% automatic backup). In other parts of the cooling hydronic system, only minor modifications will be physically carried out, described later in the text in the chapter Modification of hydraulic cooling circuits (three-way valves, connection of the newly proposed cooling exchangers on the air handling units 17AB, 18AB and 19AB, their anti-freeze protection, etc.).

The two existing compressor chillers in the engine room will remain and will continue to be used in certain operating modes. More detailed information on the operating modes of cold production is given in chapter 3.2 later in the text.

### 3.2 Operation modes

#### 1. Main operation mode:

- A new chiller is in operation
- The temperature of the water produced by the new chiller is +8°C (dehumidification on the air conditioning units 17AB, 18AB and 19AB is sufficient)
- Produced cooling capacity in the range of approx. 150 kW to 1,000 kW
- None of the existing chillers are in operation (but they are in stand-by mode)

This operating status will be in place during the winter and summer seasons and most of the time during the transitional seasons.

#### 2. Operation mode „enhanced air de-humidification“ on air-handling units No. 17AB, 18AB and 19AB“:

- A new chiller is in operation
- The temperature of the water produced by the new chiller is +4°C (dehumidification on the air conditioning units 17AB, 18AB and 19AB requires super cold water)
- Produced cooling capacity in the range of approx. 150 kW to 1,000 kW
- None of the existing chillers are in operation (but they are in stand-by mode)

This operating condition will be in operation during transitional periods of the year when conditions arise in which cooling water at a temperature of +8°C will not be sufficient for dehumidification on the HVAC units 17AB, 18AB and 19AB.

Criterion – the air humidity at the outlet of one of the air handling units 17AB, 18AB and 19AB units towards the building (humidity of the supplied air) is more than 5% higher than the required humidity for more than 15 minutes.

#### 3. Operation mode „temporary switching of the existing chillers“

- The new chiller is switched off
- The temperature of the produced water is +8°C (dehumidification on the air handling units 17AB, 18AB and 19AB is sufficient)
- Produced cooling capacity in the range of approx. 500 kW to 2,300 kW
- The other existing unit is in stand-by mode and after the specified time, the operation will be switched between existing unit 1 and existing unit 2

This operating state will only be triggered due to occasional rotation of the existing chillers' compressors, so that they do not deteriorate as a result of long-term inactivity. The estimated frequency of activation of this operation mode is 1x per month. The

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start-up conditions are that cooling water at a temperature of +4°C is not currently required for dehumidification on the air handling units 17AB, 18AB and 19AB. Criterion – time program + fulfillment of conditions.

#### **4. Operation mode „high cooling output is required“**

- The new chiller is switched off
- The temperature of the produced water is +8°C (dehumidification on the air handling units 17AB, 18AB and 19AB is sufficient or insufficient, it is not a criterion)
- Produced cooling capacity in the range of approx. 500 kW to 2,300 kW
- Cold production is provided by one of the existing chillers, the other existing unit is in stand-by mode

This operating state is triggered if the cooling capacity of the new chiller (approx. 1,000 kW) is not sufficient at a point of time. However, this situation is unlikely, according to statistical data from the last 3 years, the cooling capacity of 1,000 kW has been exceeded only exceptionally and for a short time. The criterion for triggering this operating state is the insufficient temperature of the cooling water at the outlet of the new chiller (+10°C instead of the required +8°C – to be specified)

#### **5. Operating mode „freecooling“**

- All chillers (new and both existing) are switched off
- Outside air temperature +2°C and lower
- The temperature of the produced water is approx. +8°C (dehumidification on the air handling units 17AB, 18AB and 19AB is sufficient at this temperature, or this operating condition only comes into consideration in the winter, when dehumidification on the air handling units is not needed)
- Produced cooling capacity in the range of approx. 100 – 1,000 kW (max. cooling power achievable when a dry cooler and one cooling tower are running in freecooling mode)
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#### **6. Operating mode „major failure of a chiller and cooling tower“**

- The new chiller is switched off
- The temperature of the produced water is +8°C
- Produced cooling capacity in the range of approx. 500 kW to 2,300 kW
- The second existing unit is in fault 1
- The cooling tower of the remaining chiller is faulty

In the event of a major failure of chiller 1 or 3 and a simultaneous failure of the cooling tower paired with the remaining chiller, it is possible to connect the functional chiller to the functional cooling tower by manipulating the motorized flaps and enable the operation of at least one of the 2.3MW chillers.

### **3.3 Modifications of cooling hydronic circuit**

#### Pumps

As part of the modification of the cooling source, new circulation pumps for the condenser and evaporator parts of the chiller will be added. In-line pumps with integrated frequency converters will be used, which will be mounted on the existing foundations prepared in the engine room of the cold source. A pair of identical pumps will be used for each circuit in 100% backup mode. The MaR system will ensure the monitoring of the real operation of the pump (sensing dp), automatic backup, regular rotation of the pumps according to the engine hours worked. In the event of prolonged inactivity, the MaR system will ensure regular rotation of the entire set of pumps and the chiller according to the set time program.

#### Motorized flaps

The connection of the existing system of chillers, cooling towers and a dry cooler will be modified. Closing, motor-operated flaps in front of each of the cooling towers and a dry free-cooling cooler will be added. The new wiring will make it possible to operate any of the chillers with any cooling tower, which will increase the flexibility and safety of the cooling source in the event of a combined failure of the cooling machine and cooling tower.

#### Conduit

New sections of steel pipes will be installed to connect the completed chiller. Preparatory work requiring the launch of the system will be carried out during the regular summer shutdown of the ELI complex. Due to the low load-bearing capacity of the roof, the pipes in the SO 03 building will be anchored to supporting steel structures resting on the floor. As part of the work, the existing support structures will also be modified, especially between the chillers, so that even after the installation of the third chiller, a sufficiently wide corridor remains for the transport of spare parts or of complete pumps for each of the circulation pumps in the building.

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All steel pipes will be provided with a double primer in two different color shades, pipes that will not be thermally insulated will also be provided with a covering enamel coating.

The color of the coatings will be solved in accordance with ČSN 13 00 74 and ČSN EN 12944-1a2.

All cooling water distributions, including circulation pumps and fittings, will be insulated, except for fittings where the insulation would prevent proper functioning.

The final thickness of the thermal insulation will be specified based on the choice of a specific manufacturer. It is necessary to meet the criteria of Decree 193/2007 Coll.

In accordance with Decree 193/2007 Coll., the thickness of the insulation was determined by an optimization calculation respecting economically effective energy savings, even in view of the limited spatial possibilities in the building. At the same time, the proposed thicknesses are suitable from the point of view of protecting the pipes from condensation of atmospheric moisture.

The resulting thicknesses of thermal insulation on the pipes of the heating system will be as follows:

### **3.4 Modification of air-handling units 17AB, 18AB a 19AB – additional cooling coils installation**

The newly added cooling exchangers will be connected to the cooling system via pressure-independent control valves. The regulation of the cooling performance will be quantitative, by throttling. According to the design of the HVAC designer, the cooling exchangers of the HVAC units are installed in an atypical position - in front of the heaters, therefore it is necessary to ensure their protection against freezing in winter. The protection of the coolers will be ensured by tempering them with the flow of heating water in the winter with regulation to the outlet temperature of the heating water <20°C. The heat exchanger temperature regulation will be qualitative, with a constant flow of min. 0.3m<sup>3</sup>/h, the mixing node for tempering the heat exchanger will have an injection connection with a pressure-independent valve.

Switching between tempering and cooling modes will be by means of motorized fittings on the supply and return at the point of connection to the heating and cooling system. Armatures will be controlled by the MaR system based on intake air temperature. When the intake air temperature drops below 5°C, the heat exchanger tempering system will be activated. The circulation pump will be equipped with an indication of real operation (dp sensing). The MaR system ensures the transition of the air handling unit to the anti-freeze mode (closing the damper at the inlet, switching to 100% circulation and opening the heat exchanger tempering valve to 100%) at the moment when the temperature of the heating water at the outlet of the exchanger drops to <10°C and when a malfunction is indicated pumps of the mixing node.

Although the heat exchanger tempering system is designed for year-round operation, in order to ensure economy of operation (maximum recuperation efficiency) we recommend that in periods when the outside temperature drops below +5°C for a long time, when additional dehumidification operation is no longer required, the dehumidification exchangers should be shut down and drained completely, while ensuring perfect drainage by blowing through with compressed air.

### **3.5 Phasing of the works**

#### Preparatory phase

After shutting down the cooling system, closing the shut-off fittings of all affected circuits and draining them, branches will be planted on the DN 200 and DN 250 pipes and the pipes will be installed to the nearest shut-off valve. A partial pressure test will be performed on the modified part of the circuit. Temporary thermal insulation will be installed to prevent condensation.

After the work is completed, the system will be flushed for a minimum of 4 hours. Then, after a break needed for the sludge to settle, the filters will be cleaned and the accumulation tank will be drained. Subsequently, a second flushing cycle will be carried out, and after checking the pollution of the filters and emptying the storage tank, a decision will be made on the next procedure (in case of impurities, the flushing will be repeated)

Branches on the heating and cooling water distribution equipped with shut-off fittings and blanking will also be installed in the VZT machine rooms at the place of installation of VZT 17AB, VZT 18AB and VZT 19AB.

Temporarily disconnected pipe ends will be blinded behind the nearest shut-off fitting and provided with temporary thermal insulation against condensation.

#### The main stage

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A new chiller will be installed, the circulation pumps will be connected to the connection points created during the preparatory phase. In the HVAC machine rooms, the newly added coolers will be connected to the heat and cold distribution systems. The device will be revived, tested and integrated into the existing MaR system.

After the work is completed, the system will be flushed for a minimum of 4 hours. Then, after a break needed for the sludge to settle, the filters of all affected circuits will be cleaned and the accumulation tank will be drained. Subsequently, a second flushing cycle will be carried out, and after checking the pollution of the filters and emptying the storage tank, a decision will be made on the next procedure (in case of impurities, the flushing will be repeated)

### 3.6 Machinery regular and emergency ventilation

The existing two chillers have a refrigerant charge of 623 kg each. The newly designed chiller will have a refrigerant charge of 240 kg. The refrigerant charge of the newly proposed unit is therefore smaller than the refrigerant charge of the existing unit. According to the ČSN EN 378-3 + A1 standard (for A1 refrigerants), the device with the largest refrigerant charge is always considered for emergency ventilation design. Thus, even after the installation of a new chiller, the existing chiller remains. The installation of the new unit does not affect the design of the size of the emergency ventilation - the existing emergency ventilation of the engine room, sized for the refrigerant charge in the existing chiller, is suitable even after the installation of the new chiller.

### 3.7 Thermal insulation

The proposed cold pipes will be equipped with Kaiflex rubber insulation thickness 19 mm. The distributor / collector will be insulated at the point of intervention with rubber insulation in the original specification - it is assumed that Kaiflex tl. 25 mm. In the outdoor environment, the insulation will be plated with AL sheet.

### 3.8 Noise

The newly designed chillers will be located in the interior - in the engine room SO03. The noise from these devices, like the noise from the existing chillers, will be damped by the perimeter casing and the roof of the engine room building.

### 3.9 Fire safety measures

Fire safety will be carried out in accordance with ČSN 73 0802 (2000) and ČSN 73 0872 (1996) and Decree No. 23/2008 Coll. On the technical conditions of fire protection of buildings.

In places of penetration through fire separation structures, the newly proposed pipeline will be sealed with a certified fire seal.

Penetrations of metal pipes, the surface of which is insulated at the point of penetration with a combustible foam material preventing the transmission of negative sound effects from pipes to building structures and vice versa, will be fireproofed with a combination of fireproof laminate and fireproof silicone sealant, whose constant flexibility will prevent the formation of sound bridges and fulfill the fireproof function ( INTUMEX S/L, PROMASEAL, etc.).

## 4 ASSOCIATED WORKS

### 4.1 Architectural, coordination

- ensure transport routes for all material
- Demolition of the masonry from the mounting hole measuring approx. 3 x 3 m in the southern facade and its re-walling, plastering and painting (on the outside, paint the facade with the same shade as the existing one)
- provision of space for installation of equipment.
- ensure a safe space for storing the components before assembly so that they are protected from the effects of the weather and are not mechanically damaged, soiled and stolen

#### 4.2 Electrical

- Ensure the connection of newly added equipment to the source of electrical energy - supplementing the equipment of the existing electrical switchgear in SO03

#### 4.3 Plumbing

- Ensure the connection of the newly proposed cooling exchangers of VZT units 17AB, 18AB and 19AB to drain condensate

#### 4.4 BMS

- Ensure the connection of the newly proposed devices to the building's measurement and regulation system.
- Power supply of the proposed actuators of closing flaps and control valves
- Sensing temperatures and pressures using field instrumentation elements. The location and quantity of field instrumentation elements must allow checking the efficiency of cold production, measuring the cold produced by the newly proposed chiller, the current consumption of the newly proposed chiller
- Ensure the setpoint switching of the chiller +4°C / +8°C. Switching will be provided according to the requirements for air dehumidification in units 17AB, 18AB and 19AB. The switching must take place with a certain degree of prediction, because the reaction time of the system (the time needed for the system to cool down) is around 2h. Switching will therefore take place according to the value of the humidity of the extracted air and the measured absolute humidity of the outdoor air. The values will be editable in the system for easy adjustment of parameters according to operational experience. At the same time, there will be a possibility of fixed manual setting of the desired setpoint.

##### PUMPS

For each pump, a switch with positions "AUT-0-MAN" will be placed on the MaR switchboard. The following states will be signaled to the MaR system:

- pump operation;
- local control of the pump (controller on the switchboard in the "AUT" position);
- real operation of the pump (sensing  $\Delta p$ )
- pump malfunction

For pumps with frequency converters, the frequency converter will be powered from the technological power switchboard and controlled and controlled from MaR. Using the panel on the inverter, it will be possible to control the inverter manually.

Double pumps will work with 100% backup, in the event of a failure of one, the other will automatically turn on. The switching order of the pumps will alternate regularly. The  $\Delta p$  control is part of the pump. MaR only controls on/off

All pumps that will not be switched on for a longer period of time (e.g. during the winter shutdown) will be periodically switched on for a trial period (about 10 minutes once a week) to test their functionality.

In the event of a lack of cooling capacity, MaR will ensure that the pumps are switched off (circuit shutdown) according to the order of priority so that the required cooling capacity for the laser halls is maintained.

- Pumps will be regulated to proportional pressure.

##### EMERGENCY CONDITIONS

- The newly proposed chiller in engine room SO03 will be equipped with its own running control system capable of communicating with the superior MaR system. The MaR profession will ensure the integration of the newly designed chiller.
- In the event of a power outage energy to ensure the start of the newly designed chiller and all pumps on the diesel network.
- MaR will provide power to the servo drives of the newly installed flaps.

##### ANTI-FREEZE PROTECTION OF THE PLATE EXCHANGER

- MaR will ensure frost protection of newly installed plate heat exchangers in HVAC units 17AB, 18AB and 19AB. Cooling water will flow as long as the temperature of the intake air is above +5°C. When the temperature drops below 5°C, the heat exchanger will be switched from the cooling system to the heating water supply by means of shut-off valves, and the tempering mode of the heat exchanger will start. In this mode, the performance of the exchanger will be regulated according to the temperature of the heating water at the outlet of the exchanger, which must not fall below +20°C. When the heating water at the outlet drops below +10°C, the HVAC unit goes into anti-freeze protection mode - this means closing the fresh air supply, 100% circulation and 100% opening of the control valve on the heating mixing unit. All fittings and pumps of the mixing circuits of the units must be connected from a backup network. For the pump of the heating mixing node, it will be monitored for the real operation of the pump (sensing  $\Delta p$ )

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## 5 TESTING AND HANDING OVER

when handing over the work, the supplier shall submit reports on:

- pressure tests, including partial ones
- running test (operational test)
- electrical revision
- regulation of performance parameters

Before starting the work, the contractor contacts the designer and initiates ongoing communication with him, including consultations, explanations, additions, throughout the execution of the work and always before starting the assembly of a sub-section in order to avoid possible additional work due to insufficient thought, especially coordination. Furthermore, the supplier will invite the designer to test the systems.

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