Final report

1. Project details

Project title	Airmaster Decentralized Heat, Ventilation and Air Condition Unit
File no.	64015-0048
Name of the funding scheme	Energieffektivitet
Project managing company / institution	Airmaster A/S
CVR number (central business register)	29527393
Project partners	
Submission date	24 September 2022

2. Summary

English summary

The objective of the project was to develop a compact integration of a decentralised duct-free heat recovery ventilation unit with a reversible air-air heat pump. The integrated, autonomous unit shall maintain both atmospheric and thermal comfort in a room by delivering fresh air, cooling, and heating according to demand, in an energy efficient manner, and with an intuitive and simple user interface. All objectives have been fulfilled. The primary technological result is a method to remove noise from the compressor, so it can be mounted in an indoor cabinet without increasing the low noise levels of the ventilation device. The method is filed as an international patent application. An important secondary result with perspectives beyond this type of unit is the capability to operate a counterflow heat exchanger in a "flat" configuration (low build height, suitable for mounting below the ceiling) in a reversible manner with both heating and cooling modes and remove condensate in an efficient manner in both situations. Another practical secondary result is a system for detecting and pumping said condensate from several alternative collection trays with only one pump and a minimum of tubing and cables. The unit has been demonstrated by fully operative prototypes in several field tests in office rooms in Denmark. This product has potential to expand Airmaster's geographical market far beyond the present, since it is suitable for very versatile climatic conditions. It can also expand Airmaster's market in terms of the technological challenges we can solve, since we take responsibility for more aspects of the indoor climate. The project has challenged Airmaster's existing capabilities in several ways and thus forced us to develop new methods and capabilities both in R&D and production, especially with regard to control systems, thermal testing, and production of heat pumps.

Dansk sammenfatning

Formålet med projektet var udvikling af en kompakt integrering af et decentralt, kanalfrit, varmegenvindings- og ventilationsanlæg med en reversibel luft-til-luft varmepumpe. Det integrerede, autonome anlæg skal opretholde både atmosfærisk og termisk komfort i et lokale ved forsyning af friskluft, køling, og opvarmning efter behov, på en energieffektiv måde, og med et intuitivt og simpelt brugerinterface. Alle formålene er indfriet. Det primære teknologiske resultat er en metode til at fjerne støj fra kompressoren, så denne kan monteres i et kabinet placeret indendørs uden at øge de lave lydniveauer fra ventilationsenheden. Metoden er indleveret som en international patentansøgning. Et vigtigt sekundært resultat med perspektiver, der rækker ud over denne type anlæg, er evnen til at drifte en modstrømsveksler i en ”flad” udførelse (lav byggehøjde egnet til loftsmontage) på en reversibel måde med enten varme- eller kølegenvinding, hvor der kan fjernes indvendig kondens på en effektiv måde i begge situationer. Et yderlig sekundært resultat af praktisk art er et system til detektering og fjernelse af kondens fra adskillige alternative kondensbakker med kun én pumpe og et minimum af slanger og ledninger. Anlægget er demonstreret ved fuldt operative prototyper ved flere feltforsøg i kontorer i Danmark. Produktet har potentiale til at udvide Airmasters geografiske marked langt ud over det nuværende, siden det er egnet til meget forskelligartede klimatiske vilkår. Det kan også udvide Airmaster marked med hensyn til de teknologiske udfordringer, vi kan løse, siden vi påtager os flere aspekter af indeklimaet. Projektet har udfordret Airmaster på flere måder og således tvunget os til at udvikle nye metoder og kompetencer både indenfor teknologisk udvikling og produktion, specielt med henblik på styresystem, termiske test, og produktion af varmepumper.

3. Project objectives

The objective of the project was to develop a compact integration of a decentralised heat recovery ventilation unit with a reversible air-air heat pump. By “compact” we mean that all parts of the solution are factory made within a single cabinet for easy installation inside the room to be climatized without any need for ducting and without need for handling of the coolant on-site, and thus without need for any kind of specialist involvement. The integrated, autonomous unit can maintain both atmospheric and thermal comfort in the room by delivering fresh air, cooling, and heating according to demand.

The main obstacle for making such a product is the integration into the indoor cabinet of that part of an air-air heat pump containing the compressor which in conventional technology is located outdoors due to noise issues.

By such an integrated solution, it becomes more attractive for building owners to use decentralised ventilation systems. These are significantly more energy efficient than centralised systems due to the lack of ducts which are a flow resistance, and which create heat losses. It also becomes more attractive to use heat pumps, since the issue with location of the outdoor terminal is removed, see also figure 1.

Another objective was to create a “one stop solution” for the user of the building, where it is easy for the user to understand how the indoor climate can be controlled. Since a single control system takes care of all actions, this can happen in a coordinated and energy efficient manner.

Figure 1: The well-known architectural problem and installation challenge we solve in this project.

Originally, it was an objective of this project to develop such systems for classrooms in school buildings. Another target was smaller rooms in especially modular buildings. Over the course of the project, we have had reason to re-evaluate these targets. Making in reality two products proved to be far beyond our capacity within the limits of the project. Furthermore, market research has led us to the conclusion that classroom sized systems of this type are less likely to find a market. For classrooms, it is much more likely to meet customer expectations for especially size and cost with passive cooling systems, such as natural ventilation for night cooling, which is now another R&D project of ours. Another economic and space-saving solution for warmer climates would be decentralized ventilation units with a centralized cooling and/or heating supply from e.g. a single large heat pump, or from other sources such as district heating or district cooling with naturally occurring cool water.

The smaller sized unit for modular buildings is on the other hand attractive for a much wider range of practical applications than the original scope, and for this reason, we have focused on one size, meant for smaller rooms.

It has been demonstrated that it is possible to locate the outdoor part of an air-air heat pump in an indoor cabinet with acceptable noise level, thus making it easier to install this solution in an architecturally pleasing manner and easily installable without need for certified personnel, thus removing obstacles to the use of air-air heat pumps.

Furthermore, the control of fresh air ventilation, cooling and heating is coordinated in an energy efficient manner in a single control system with a simple and intuitive user interface, so separate systems and/or the user do not take contra productive actions.

Some typical examples of contra productive actions that happen with competing separate systems:

- Heating system delivers a high room temperature, and ventilation or air conditioning system delivers colder air due to mismatch of setpoints between systems.
- Ventilation system delivers fresh air with heat recovery, but user opens windows all day due to unawareness of ventilation system
- User feels momentary discomfort and manipulates systems inappropriately and forgets or is unable to readjust later.
  - Set point on heating system is too low, User tries unsuccessfully to manipulate ventilation system to solve problem. Ventilation system now malfunctions.
  - Set point on heating system is too low, user over reacts and changes set point in an extreme manner not understanding an automatic thermostatic valve. Ventilation or aircon system tries to counteract excessive heating by cooling.

4. Project implementation

From the outset of the project, it was believed that the most central technological problem - the noise issue related to the compressor - would be solved by using an advanced technology that Airmaster already has experience with, namely Active Noise Control. This was already adapted by Airmaster to solve issues with low frequency noise transmitted through air from B-wheel fans. The thought was that the compressor noise would be suitable for treatment by similar means, under the assumption that vibration and flange transmission of noise is handled by the usual vibration dampers on the compressor, and that the main component of noise transmission would be through air supply and extract passages in the cabinet.

As this central part of the project evolved, it became apparent to us that compressor noise is not at all transmitted exclusively through air passages, which makes the Active Noise Control technology unsuitable for the purpose. As a result, we started looking into other noise cancellation techniques, the most promising being containment and vibration dampening.

This was the main focus during the initial stages of the project, since a failure to solve the noise issue would render the product worthless.

As it turned out, traditional methods for vibration dampening of the compressor proved to be insufficient, and we developed a novel approach, which is described in an international patent application.

Another important goal for the project was to have a user interface for the new product that is intuitive for the end user, since we have seen so many examples of end users interfering with the optimal operating conditions for the technical systems, resulting in energy waste and less than optimal comfort.

Creating an intuitive user interface is made difficult from the facts that most end users have already too many technical devices in their life, and that they really do not wish to learn more about technical systems. We have spent far more resources than the planned budget on this issue. We have a solution in the form of an app for smartphone or tablet/ipad, but we are still not sure we have reached the perfect solution. An important lesson has been that an intuitive user interface is probably the singular most important quality of a product, seen from the point of view of the end user. It is easy to underestimate this task, and those of us with an engineering degree are prone to do just that.

The control system and strategy were very important parts of the project. We came from a situation where the control system for our traditional products was delivered by a subcontractor according to our functional requirements but depending to a large degree on the subcontractor's expertise with electronics. Initially, we imagined that we could simply expand the existing system and have the subcontractor deliver it. In the course of the project, we became aware that operation of the new, more complex system demanded that we could perform more experiments with quicker iterations of alternative solutions than we are used to. This turned out to be too slow and with too many communication problems when everything had to go through an external supplier not close to the problem. For this reason, we decided to make our own hard-ware and software for the project. This has been successful in the sense that we have succeeded in producing functional prototypes for field tests for the project. In has also turned out to be a challenge to create a new control system that can meet all demands to a production ready system, and the development of such far exceeds the scope and limits of this project. For this reason, development of a new control system has continued in a project of its own.

There were certain risks for the successful outcome of the project. The main risk of this project was the uncertain outcome of the central technical issue: noise dampening of the compressor. If this is not fully successful, the whole project falls. Luckily, we were able to find an untraditional solution and solve the issue.

During the timeframe of this project, phaseout of HCFC gases has been agreed on internationally for environmental purposes (global warming effect). This has been another important risk for this project due to a limited supply of components for natural coolants in relevant sizes. The industry has known for many years that this phaseout will come sooner or later, but for reasons unknown to us, alternative solutions are not at all mainstream yet, at least not in compressor types matching our need. This means that for a large part of the project, there was considerable uncertainty regarding the choice of coolant and compressor, and extra resources had to be allocated for search and test of components.

As it turned out, we have been able to find components designed for traditional coolants where we could determine compatibility with natural coolants, and our solution is based on such. This means that our product is robust for future developments in this field, since we use a natural coolant (R290, propane), and have possibility for using an alternative natural coolant (R600a, isobutane).

Another risk derived from this choice is that natural coolants are in principle explosive. Part of the project was focused on a risk assessment to be sure that this risk can be handled safely, legally, and acceptable to the supply chain, also in the case of repair and maintenance. The solution is based on a combination of delivering a closed system that is factory tested with a modular design, where the cooling circuit can be dismounted and sent to factory for repair.

Regarding the startup of the project, it turned out that it is difficult for a small to medium sized enterprise such as Airmaster to allow employees to focus attention on one project without interferences from other tasks and suddenly evolving practical problems. On a number of occasions, key employees had to take care of other issues, and this delayed the project considerably. We also had a key employee who suddenly took sick leave for several weeks for a critical operation in the very beginning of the project, and we were not able to replace him. Another initial delay was caused by the fact that we were not able to free up employees to make them available for the project from the outset. Our previous experience from other applications were that chances for a grant are slim, so we were somewhat surprised that the project was granted at all. Another time, we will have an official start date which is delayed a few months, so we can make sure the necessary manpower is actually available from the start.

During the project, we made two full rounds of dimensioning and building Proof-of-concept models. From the beginning, we had mainly an engineering approach to dimensioning, meaning that we took into account all situations the commercial branch had expressed an interest for, and made a unit that could handle all situations in terms of capacity. As it turned out, this ended up in a physically rather large and unwieldy device. We used this for testing as proof-of-concept, so the effort was not worthless. However, when confronting salespeople and potential customers with the size, we had to reconsider our specifications, and went into a second round of dimensioning where size and architectural acceptability took first place, and capacity dimensioning became a question of making the most of a given space with a compact design, rather than making it “big enough”. This had the added benefit of forcing the design team into making a more clever and simpler internal structure. The product in its present incarnation has more narrow limitations for use than originally planned. The commercial solution in the future will be to have several sizes to choose from in a family of similar products.

An important part of the project was the demonstration in field tests in real buildings. Airmaster did not initially have much experience with field tests, and we made some mistakes which also delayed the project. The worst mistake was probably to let premature marketing ambitions interfere with the technical execution of the field tests, in that the field tests were seen as a way of showing off to potential customers. It is much better to let choice of appropriate field test be determined by project needs only, since these are complicated enough already.

For a technology project with an immature product, which is bound to have many technical problems in the beginning, it is in fact rather risky to show unfinished business to very attractive customers, since they are perhaps not understanding of the problems involved. It is better to find less high-profile hosts for the test. In our case, we ended up with one field test determined by such an important potential customer, where the end users were both completely uninformed and also rather uninterested in participating, and with a building use that was not particulary well suited for the purpose. This made for lots of frustration on several sides and communication problems leading to delays.

There is a lesson for the future in this, not to be forgotten or underestimated: It is really important to have end users for a field test that will buy into the project and who see a self-interest in helping to develop the product. It is equally important to inform the end users carefully and make sure they understand the circumstances. It may take quite a long time and many resources to prepare for this. Get started early. We can draw one more important lesson out of the first field tests of an immature product: Make sure they are not far away, geographically. You are going to make more trips than you think.

It proved much more difficult than expected to extract useful data and experiences from field tests. For instance, our previous knowledge of customer expectations to noise level and noise quality in office-type rooms, based mainly on building regulation requirements, proved inadequate. End user expectations can be much more restrictive than both building codes and customer requirements. The customer (building owner) is most often not the end user, and the customer is mainly focused on compliance. The end users in our first two field tests were not satisfied with noise according to building codes. The result was that they would often simply unplug the units, rendering the test useless – except for the insight that we must have a much better acoustic performance than expected.

Another issue with field test is that end users are preoccupied with their jobs. It is not urgent for them to make observations of the building systems, and it can be quite difficult to extract useful observations from them. Yet another issue is that measurements that are delivered online can be difficult to interpret, since the reasons for deviations are not necessarily obvious. For this reason, field test early in the development phase should be located close to the developers, so they can physically visit the product often. This was what Airmaster did in a second, additional round of field tests – these were performed in our own offices.

Figure 2: AMHVAC prototype installed at field test (office in temporary modular building, Rønde Efterskole).

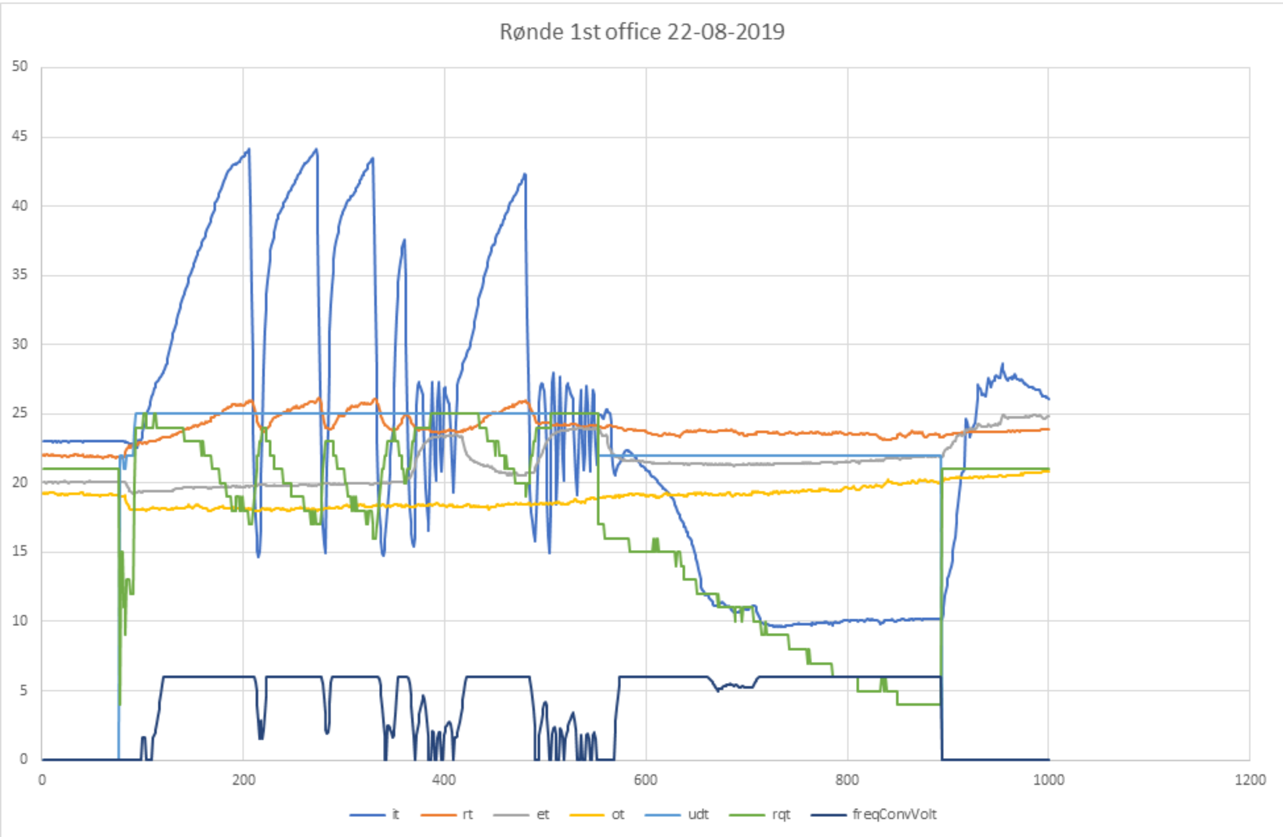


Figure 3: Example of results gathered online from the unit in figure 2.

5. Project results

The main objectives of the project were fulfilled. We have demonstrated that it is possible to make an integrated device as imagined, and that this device will fulfil expectations to noise levels, energy efficiency, and simplicity of installation and operation, much in the same way as Airmaster's exiting products.

The conventional approach to vibration dampening of a compressor is to place it on "shoes" in the form of a set of springs or rubber mounts which will absorb vibrations while transforming kinetic energy to heat. As we determined during the project, it is practically impossible to absorb all vibrations in this manner. As a result, some vibrations will be transmitted from the compressor to the external cabinet, where the vibrations create external noise. Another route for vibrations is through the fluid circuit, with similar end results.

The most important insight was that vibration transmission is paramount for the resulting noise level outside of the cabinet, but it is not necessary to absorb all vibrations made by the compressor, only to make sure that no vibrations are transmitted to the cabinet. Traditional methods proved insufficient, which has led us to develop an innovative approach, described in a European patent application.

The type of compressor used in this project is the most common type in the relevant size range, a rotational compressor. We determined by observation that such a compressor will move on its own accord in a certain pattern, where the top and bottom part show large movements, while the centre part moves relatively little. It follows that it is really a bad idea to try to dampen the vibrations at the bottom part, which is the conventional solution. If the compressor is suspended at the centre, much smaller vibrations need to be absorbed. Furthermore, if the compressor is suspended vertically, only vertical forces and vibrations need to be sustained and absorbed. Horizontal movements are of no consequence and need not be absorbed, as long as the surrounding fluid system is able to adjust to the movements, as explained in the following.

Our solution is to suspend the compressor from three vertical springs placed in a horizontal plane through the centre of gravity of the compressor, see figure 4. This makes it possible to dimension the springs to absorb the very small remaining vertical vibrations very effectively.

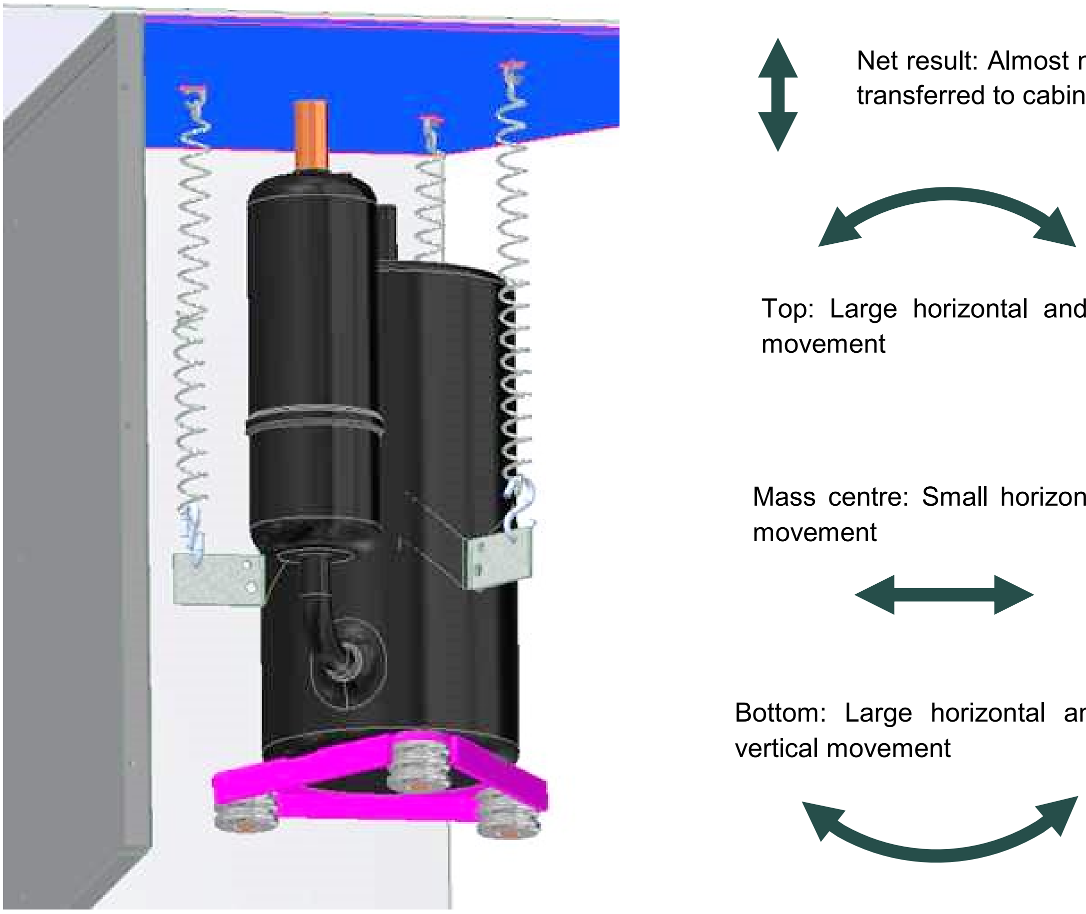


Figure 4: Suspension of compressor for vibration dampening. Magenta coloured part in bottom shows location of traditional dampening parts.

The other transmission path – through the fluid circuit – was removed by using flexible tubes that will absorb vibrations by themselves by nature of the materials, and also allow to make loops or bends similar to arrangements for absorbing thermal expansion.

Some air-transmitted noise still remains. This is effectively cut off by containing the compressor in a metal box, with the flexible tubes placed in a rubber gasket, so vibrations are not transmitted from tubes to casing. See figure 5.

The net result of these arrangements is that practically no vibration or noise is transmitted out of the unit and allows the entire fluid system to be placed directly in the room to be conditioned.

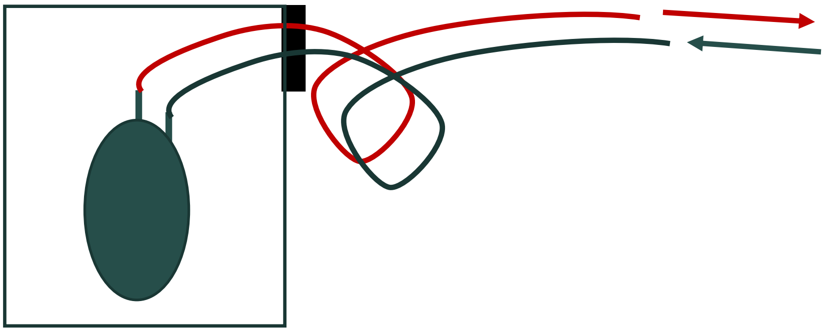


Figure 5: Principles of flexible connections through a flexible gasket placed in a containment.

Capacities for airflow, heating and cooling are shown in table below at respective sound pressure levels:

Sound pressure	dB(A)	30	35	+40
Fresh air flow	m^3/h	150	200	300
Heating capacity*	kW	0,9	1,2	1,5
Cooling capacity	kW	1,0	1,4	1,7

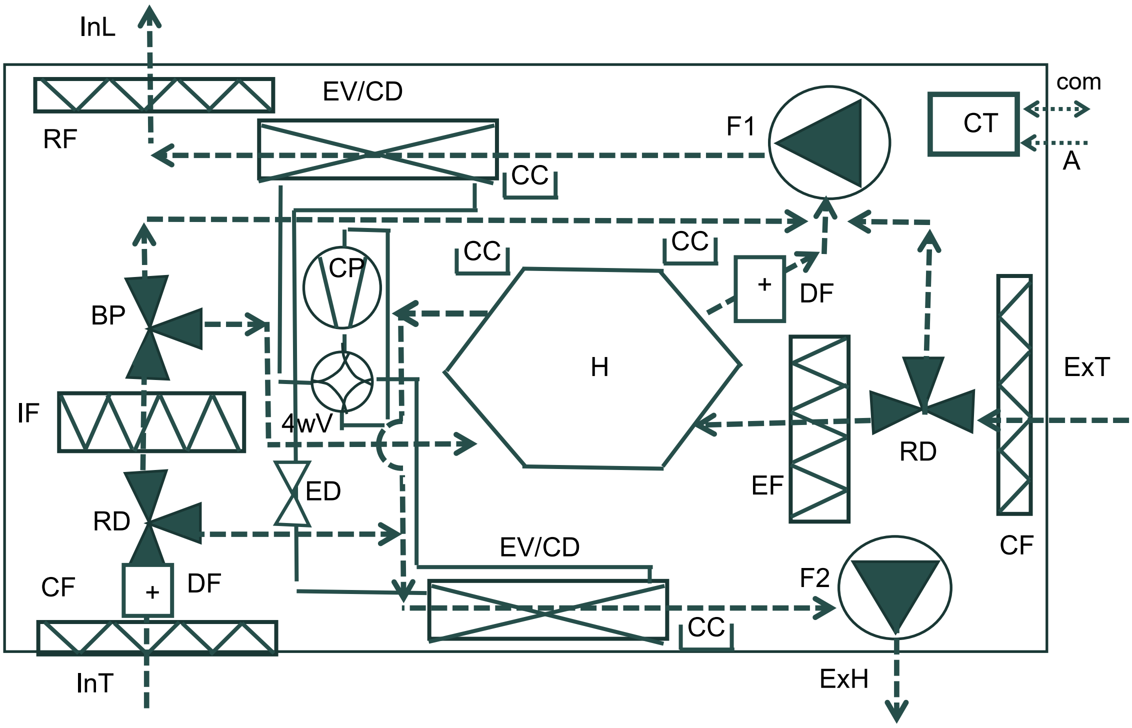
*additional 1,5 kW from electric heater optional (cold climate solution)

The heat pump has following energy performances depending on air flow rates, which are all well above regulation demands (EU Ecodesign directive):

	Efficiency COP/EER		Nominal test conditions	
	minimum	maximum	Indoor	Outdoor
Cooling	3,5	4,1	27°C, 50 %RH	35°C 40%RH
Heating	4,5	6,0	22°C, 30%RH	7°C, 80%RH

Figure 6: Climatic laboratory, built for COP/EER tests inside a container

The entire system is described by functional diagrams in figure 7 and the following explanations.



	Air system (dotted line)			Fluid system (full line)
F1	Inlet fan		CP	Compressor
F2	Extract fan		4wV	Four way valve
CF	Coarse particle filter		ED	Expansion device
IF	Inlet filter (medium/fine)		EV	Evaporator
EF	Extract filter (medium/fine)		CD	Condensor
RF	Return filter (active coal, optional)		CT	**Control system**
RD	Recirkulation damper, 3-way			(separate description)
BP	Bypass Damper, 3-way			
InT	Intake (outdoor air)		CC	Condensate collector
InL	Inlet (to room)			
ExT	Extract (from room)			
ExH	Exhaust (to outdoor)			
HE	Heat Exchanger			
DF	Defrost heater (electric)			

Figure 7: Functional diagrams for air and fluid systems

The control system will choose to focus first on maintaining temperature, and will use full capacity in recirculating indoor and outdoor mode, arriving as quickly as possible to a comfortable level. Then it will change to demand controlled ventilation with exchange of fresh air with heating or cooling recovery, if prompted to do so by sensors, otherwise it will simply maintain temperatures with recirculation mode at lowest possible capacity according to climatic conditions.

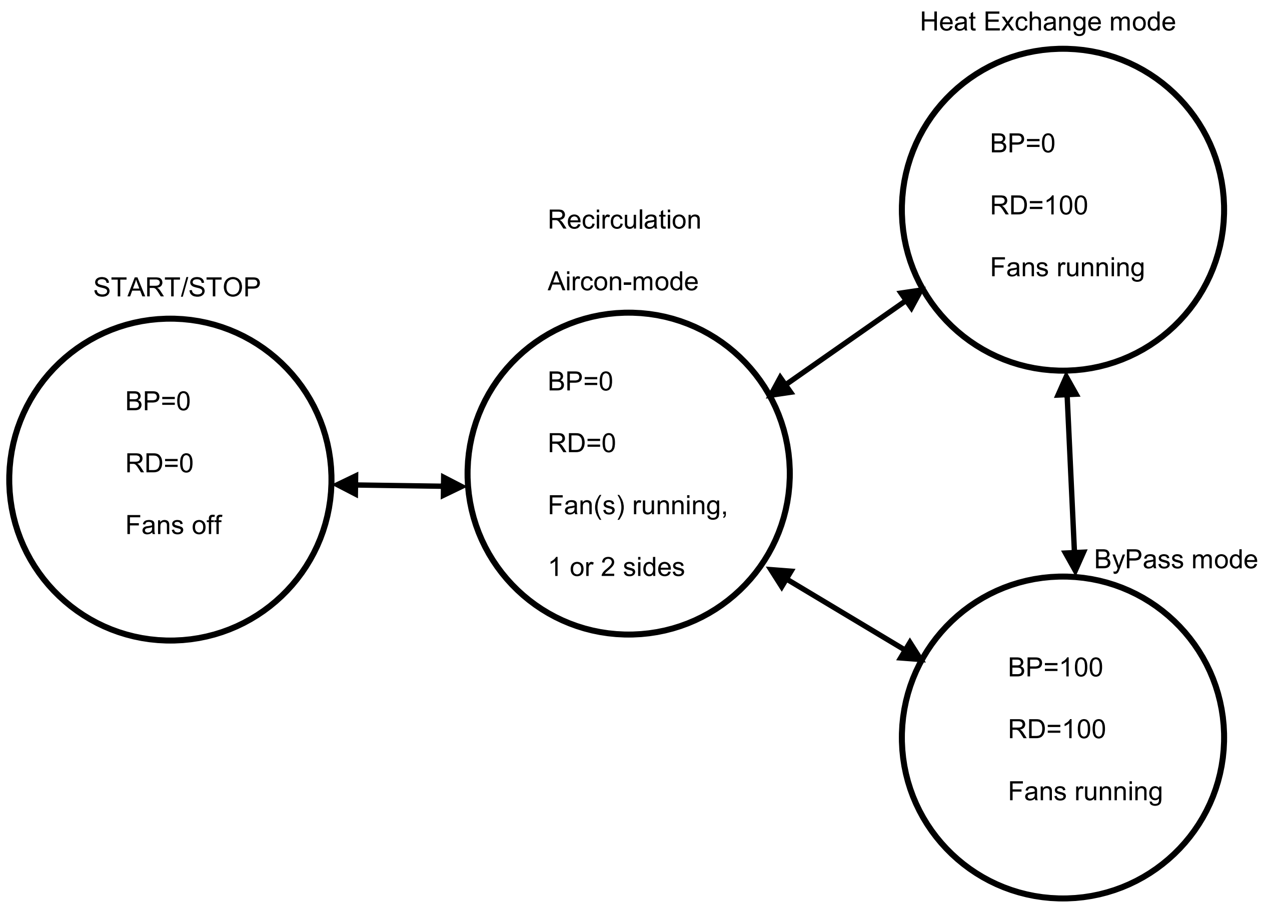


Figure 8: Basic program modes, as determined by damper positions and fan operation.

Within these fundamentally different operative modes, the unit can perform a large array of “jobs”.

Ventilation with Heat recovery

- Default
  - The unit supplies and extracts equal amounts of air through a heat exchanger, both air streams are passed through particle filters.
- Heating by heat pump
  - In this operation mode, the heat pump can supply additional heating from the exhaust air
- Cooling by heat pump
  - Do. for heat pump with cooling. Surplus heat is delivered to the exhaust flow.
- Defrost
  - The heat exchanger as well as both heating coils (when used as the evaporator) are in danger of ice formation and must be protected from this. This is done in part by an additional electric heater used in combination with the bypass mode, in part by running the system in recirculation mode for a short period.
- Bypass
  - To make use of so-called “free cooling” with fresh air, the unit has a bypass of the heat exchanger by the fresh air stream. This function is mandatory for mechanical ventilation units in EU countries.
- Comfort heater
  - The defrost heater can also function as a comfort heater, to help maintain temperature levels in the room, or to avoid cool air dropping from the ceiling, or to increase the possible “throw” of the inlet jet.

Cooling recovery

- This is a new feature of the present invention, that the same unit can function without modifications in thermally reverse mode and supply “cooling recovery”, such that colder indoor air is heated by fresh outdoor air, which can in turn be delivered to the room just a few degrees warmer than indoor air. This makes the unit ideal for maintaining cool indoor environment in warm climates, while at the same time supplying ample amounts of fresh air to maintain air quality.

Heat pump with recirculation

- Cooling
  - The air system is controlled by the three dampers to work in recirculation mode both indoor and outdoor airstream. The liquid system is controlled by the four-way valve to supply warm compressor gas to the outdoor heating coil. The indoor coil is the evaporator.
- Heating
  - Do, but the four-way valve turns 90 deg and now supplies warm gas to the indoor coil.
- Defrost
  - See above
- Dehumidification (possible, but not implemented in this project)
  - The heat pump can be used in recirculation mode in connection with the electric heater to simply dehumidify the indoor air without changing the temperature, if so needed.
  -

One-sided recirculation

- Indoor air cleaner (possible, but not implemented in this project)
  - As an optional feature, the unit may be fitted with a gas filter in the form of active carbon filter or similar. As an optional feature, the coarse extract filter can be changed to a finer grade. In one-

sided recirculation mode on the indoor side, the unit will work as an indoor air cleaner. It could even be fitted with e.g. a UV light for anti-bacterial effects or an electrostatic filter, the unit is versatile in a modular way.

- Heat conservation mode
    - In extreme frost conditions, if other options fail, the unit will go to one-sided recirculation with use of the electric heater to keep up indoor temperature.

Closed

- The unit is placed in recirculation mode, and all motors and actuators are powered off. Since the recirculation mode acts as a separation of indoor and outdoor air circuits, the recirculation three-way dampers are also effectively main shut-off dampers.

Other systems

- Electronic, electrical, and mechanical systems are not portrayed in the diagrams.
- Condensate system
    - Since the unit can operate in several modes, condensate can form in four different parts, making necessary a condensate removal function at each of the heating coils and on each side of the heat exchanger. The condensate system is described in the following diagram, see figure 11. The layout of the system makes sure, due to the small diameter of the condensate tubing and the (single) serial connection, that there is very little leakage between fresh air and indoor air. Also, the system enables a single pump to pump from individual condensate trays while others are dry, without running dry itself, which is detrimental to a water pump.

User interface

Significant resources were aimed at developing an intuitive and effective user interface in the form of an app for smartphones or tablets. There are two “parts” of the app, one for ordinary users and another for the more technically minded such are service personnel. Design and subsequent user tests were performed by company design-people of Aarhus, Denmark.

For “ordinary” users the input was kept at a minimum and requires no technical understanding.

Rather, the user is mainly faced with two questions and allowed to give input in a graphically easily understandable way, see figure 9.

1. Is the room temperature OK? Turn up or down
2. Is the fan speed OK (for reasons of Air Quality and/or noise)? Turn up or down

Apart from this, the user is offered some help in case of connection or other problems and can turn off the unit.

Technical personnel is offered a quick overview of operation status (figure 10) and can change or update certain parameters.

Figure 9: User interface by smartphone app. Left: easy to understand choices for modifying automatic settings, if wanted. Right: Status window, for the technically interested.

Figure 10: User tests of App (by professional industrial designers)

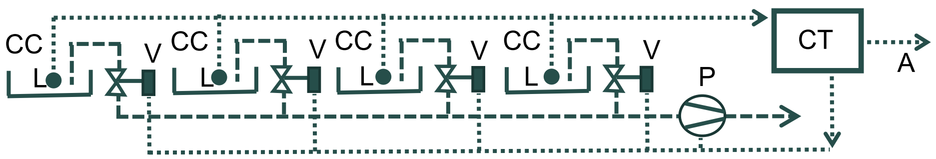
For a system that can work in several climatic conditions and modes, the formation of condensate becomes a larger challenge than in a traditional air handling system, which will usually just have a single condensate tray with an optional pump. In the AMHVAC system, four condensate trays are necessary, since condensate can form on the exhaust side of the heat exchanger (winter), the supply side (summer), evaporator indoor air (summer), evaporator outdoor air (winter). It is necessary to use a pump in each case, since large openings for gravity drains will create significant leakage between compartments, rendering the system inefficient.

As it turned out when we built the first prototype, these four separate condensate systems proved to be a mess of pumps, float switches, tubes, and wires all over the place. (Normally not a great issue with our traditional products with only one tray, so underestimated). All of this making necessary a large number of holes in compartment walls, creating more work and risk for leakage, and all of it taking up rather too much space.

The solution was to develop an innovative condensate removal system, which has been included as a subset of claims in the patent application. The idea is to have only one pump for all trays, and to have a serial collection system that requires as few holes in compartment divisions as possible. See figure 11.

The simplicity of system depends on a water level sensor of our own design that can deliver several types of signals: start pump, stop pump, stop compressor and fans (alarm).

The condensate removal system was designed as an autonomous system requiring no input from the main control system. This makes it easy to modify or expand or to use in other systems.



CC	Condensate collector
P	Pump
V	Valve, motor controlled
L	Level control sensor
A	External alarm signal
CTC	Control for condensate

Figure 11: Condensate system, autonomous. Water: large dots. Signal: Small dots.

Figure 12: Early model experiment, observing two-way removal of condensate from counterflow heat exchanger through glass panel in bottom.

We have not launched the product yet. It has turned out to be a greater challenge than expected to have the product ready for production. Development of sufficiently efficient production facilities and methods is an on-going project at Airmaster in its own right. The product continues to be of great interest to potential customers, and we expect the commercial launch in second half of 2021.

The product has received attention from southern European countries, and we have now installed a “version 2” field test at a potential customer (whole sale distributer and installer) in Valencia, Spain. The corona virus pandemic has increased attention in these countries on the importance of fresh air. To our great surprise, the heating function in wintertime is just as important at this location as it is in e.g. Denmark, maybe even more so. Of course, the climate is much warmer. However, buildings in Spain are simply not insulated at all, it seems. That means if outdoor temperature is 10°C which is perfectly normal in winter, heating is highly needed. The possibility of having a single intelligent system to monitor and take care of the indoor climate in an energy efficient manner is appealing to the potential customer.

This insight opens for another perspective. One of the results from this project is the capability to have a “reversible” counterflow heat exchanger for fresh air. This technology can be transferred to our existing portfolio of decentralised ventilation units. As southern Europeans become more aware of both air quality and energy conservation, this could open for a large potential market, also for our products without heat pump. This also goes for similar overseas climates.

Producers of modular buildings have been an inspiration for the project and were the original target group, since these have on their own initiative explained us that they have an interest in such a product as the AM-HVAC. The value for the modular buildings is that a single unit can take care of all climatization in a building module without extra installation cost once the module has arrived on-site. It is a benefit that the product is autonomous and needs no visits by service personnel for balancing, connecting interfaces between modules for e.g. airflow through ducts, coolant flow between outdoor and indoor units, communication, or anything else. Everything is installed from factory and needs only a 230V electricity supply, which is necessary in any case also for other purposes.

During the project, we have become aware that there is a growing interest in society in general for the health aspects of indoor air quality. The corona virus pandemic has boosted this general interest significantly. There is also a growing interest for replacing fuel-based heating solutions with heat pumps. This means that there is a very large target group consisting of owners of existing buildings with e.g. offices or similar rooms, who can have an interest in refurbishing their buildings with heat pump solution, who could at the same time take care to install balanced mechanical ventilation. Our solution with easy installation for refurbishment is obvious as a solution for them.

The project has not yet been disseminated apart from patent applications, and at one presentation at trade fair/ conference “Building Green” in Copenhagen in October 2020. We have prepared a presentation for an upcoming newsletter, which is sent to subscribers, and which will be publicly available on our company homepage. The newsletter will contain a link to this report.

6. Utilisation of project results.

Airmaster will use the technological results both in a new line of products containing heat pumps, and also for improving existing products. We assume that this will inspire competitors to develop similar solutions.

We anticipate that the new product line has the potential to generate the same turnover as all of our present products, within a short span of years.

We anticipate that our present product program can capture larger market shares with improved technology. Especially we expect to capture market shares outside of our present geographical area.

There is no competition in the market with directly comparable solutions and market segments. Our main competitors use different technological solutions or aim for other markets.

The competitors can be divided in different ways, for instance: Companies that are providing centralised or decentralised solutions, targeting the professional market or the household market, offering only ventilation or combined solutions with heating or heat pumps/cooling in different ways.

The market leading centralised HVAC manufacturers are YORK (USA) and TROX Technik (DE). Both companies specialize in larger systems that can produce heating, ventilation and air condition for commercial and residential buildings. Both YORK and TROX have years of experience in the Industry. TROX continuously launch some of the most efficient and flexible range of air distribution and comfort conditioning systems in today’s market. TROX has a decentralized ventilation line, but no heating/cooling on the decentralized range. We do not expect York to switch to manufacture decentralized units as it is a rather different technology and the whole production line would have to be shifted, but TROX could be a relevant competitor in the future. Other central unit competitors are Swedish Systemair, who are solely manufacturing ventilation systems. Wolf is a German manufacturer of both AC; ventilation and heating systems, but they do not have a combined unit. Meltem and Lunos are German ventilation manufacturer, with combined heat and ventilation unit. These focus solely on households. Danish Nilan produces combines ventilation and heat pump solutions, but these are air-to-water heat pumps for households. Other competitors are Exhausto, a Danish ventilation company, who has centralised HVAC lines and a decentralised ventilation line. Exhausto has previously copied one of our products, but we expect that the AMHVAC will be so difficult to copy that we have a head start in the market

A product that combines several solutions and solves several problems is initially more expensive than existing products with a narrower scope. It is probably a barrier that our product will be more expensive than for instance a stand-alone air-to-air heat pump. We will have to explain carefully and in a very concrete and easily understandable way why our solution is a benefit from a total economic perspective and in the long run, also we will have to emphasize the indirect benefits for the customer in the form of the simplicity of having a “one stop solution”.

It is a benefit for us that we target professional markets, since these are already more aware of indirect and long term costs of having several overlapping and/or incompatible solutions. In many cases, the customers will have professional personnel with technical understanding, which is usually not the case for households.

It is a policy objective to increase the use of heat pumps. By removing barriers for implementation of heat pumps, the present project is in line with the general policy in this field.

Roughly speaking, decentralised ventilation uses about half the energy for transportation of air as does centralised ventilation. This project has produced results that has the potential of increasing the use of decentralised ventilation.

7. Project conclusion and perspective

The main conclusion is that the main assumptions of the project are valid. It is possible to have both a decentralised ventilation system with heat recovery and a reversible air-to-air heat pump inside a single unit placed indoor in the room that needs climatization. The main obstacle was the noise level, but it is possible to solve this problem with the method developed in this project. It is possible and also attractive to have full control of the indoor climate gathered in one system with a single, intuitive user interface.

With regard to capacity and energy efficiency, the product is very suitable for climates that are typical of the most densely populated areas of Europe; Atlantic, Mediterranean, and Central Europe, as well as Southern Scandinavia. It is less suitable for areas with very cold winters, but luckily, these are not the most populated anyway. The present dimensioning of the product is not meant for very hot environments, but it would be possible to make that, and probably a god idea to do so.

It will be possible to produce this combined unit at a reasonable price, but this demands that Airmaster A/S improves production technology compared to now in certain fields where the new product is more demanding than the existing product portfolio.

We have developed a solution that is suitable for relatively small rooms in moderate climates. It is obvious to start considering other sizes and other climates in a family of similar products.

Considering future R&D, the project has already inspired us to start a related project with focus on development of decision methods for the control system. Since the product is intended to maintain all manner of indoor climate, it must ideally be able to optimize indoor climate based on evaluation criteria for multiple indoor environmental variables. It is not obvious how this should be accomplished, and Airmaster cooperates with Aalborg University on this subject. Some time in the future, the solution probably involves artificial intelligence due to the complexity of the input.

8. Annex

To better understand the concept, challenges, and benefits of a decentralized air handling unit, the following pages are useful.

https://www.airmaster-as.com/en/ventilation-and-indoor-climate/

https://www.airmaster-as.com/en/ventilation-planning/

Airmaster has commissioned an LCA of comparable centralized and decentralized ventilation solutions, carried out by consulting engineers MOE. The results give a good insight to the energy related environmental concerns related to the choice of system:

https://www.airmaster-as.com/en/news/co2-and-ventilation/