ACVIO

Technical Executive Summary 24 August, 2007

1.0 Mission Statement

It is ACVIO´s goal to replace air-source heat pumps and air-conditioners invented in the 19th century. ACVIO´s LatentHeatPump

1) **reduces energy used in heating by half, concerning cooling even more,**
2) minimizes even eliminates energy used in ventilation,
3) lowers electricity peak load significantly,
4) contributes to lowering carbon release and green house effect,
5) improves indoor air quality,
6) can operate with renewables, and
7) is ideal for ESCO.

2.0 Executive Summary

A formidable opportunity has arisen from the combination of climate change, global warming, need to reduce green house gases according to the Kyoto draft, need to reduce urban heat island effect, demand on better indoor air quality and increasing of energy price.

By 2015, half of the global energy will be consumed by buildings, and the US department of Energy indicates the US residential buildings consume almost 40 percent of all energy for heating and cooling. Ventilation doubles cooling and heating demand.

Due to global warming and climate change more air-conditioning is required. Air-conditioning is the single leading cause of peak demand for electricity causing black-outs.

People need more energy-efficient products and use of recycling energy rather than new production of electricity.

The efficiency of existing air-conditioners is relatively low. Their Coefficient of Performance (COP) is average 3.0. LatentHeatPump´s COP is three times better 9.0.

LatentHeatPump can be applied to wide range of equipment such as heating, ventilation, air-conditioning, refrigeration (HVACR) for air, gas and liquid handing in buildings, vehicles, industry, computers, telecom etc.

It is ACVIO´s plan to market LatentHeatPump with existing strong and wide networks.

LatentHeatPump key-components will be made by ACVIO. Assembly is made locally.

3.0 ACVIO´s LatenHeatPump (LHP) is distinguished from its competitors in that:

- **Minimizing/eliminating ventilation load doubles COP.**
- In ACVIO´s LHP in a compressor used energy is not wasted in a condenser/expansion valve.
- Conventionally air humidity is a problem making heat transfer preventing insulation and creating an ideal breeding ground for unhealthy microbes that can infect the air.
- LHP gains humidity on energy and healthy point of view.
- It uniquely combines high efficient and patented enthalpy recovery ventilator (ERV) and phase change material (PCM).
- **Two PMCs uniquely guarantees permanent cooling/heating increasing COP**.
- It has automatic and free of charge evaporative cooling (swamp cooling). It uniquely has better performance in hot and high humid climate.
- It does not need circulating refrigerants, piping, compressor, evaporator, condenser, nor expansion valve.
- I does not use any harmful or toxic items.
- Electricity is needed only for fans.
- It is anti-frosting/freezing.
- Due to it is anti-bacteria and self-cleaning life-cycle cost is lower.
- Payback period is shorter.
- It is more reliable and more silent.
- It is globally patentable.

3.1 Technical Background

The use of energy and in particularly electricity for various needs is increased globally. Even for developed countries more measures are being taken for efficient power generation and utilisation, developing countries will face industrial, utilities and population growth in near future, which also raise demand for power and likely worsen GHG emissions situation. Security of energy supply puts additional demands for power availability and conditioning along with Kyoto requirements. Despite political and fiscal measures, one of the key solutions is in improvement of the heat/cold and power generation and condition efficiency, as well as new business opportunities in this sector.

It is known that strengthening of the rational energy utilisation is one of the main factors in combating GHG emissions. Although in many countries emissions trading did not yet affected long-term electricity and district heat prices, the situation is likely to change in future in spite of several political, economical and technological factors. New markets are opening for efficient power generation, power conditioning and adjacent service concepts, which are very attractive for many companies.

LHP´s focus was put on **novel, modular device concepts that give a significant advances in heat and power conditioning efficiency** in industry (construction), services (energy consulting, automation, etc.), consumer environment (living rooms, public rooms, recreation facilities). The **new concept is foreseen to provide significant value-added solutions such as drastic improvement in indoor air quality**, combating air-spreading diseases, providing customers' satisfaction yet with lower investment costs, lower running costs, minimal balance of plant and maintenance. By adding optional components, the modular nature of novel devices can gain new market areas (in particularly South-East Asia), new customer sectors (e.g. climate-controlled rooms, clean rooms, hospitals, houses for elderly people and children, resorts) and new solution possibilities (e.g. carbon dioxide capture, air and gas purification, all-the-year-round non-freezing ventilation, etc.).

3.2 General objectives

The general objectives of LHP were development and tailoring on the innovative waste heat and power recovery device concept, which is capable of recovering heat, cold and moisture and substantially drop GHG emissions (including indirect), aiming at the same time to improve indoor air quality (IAQ), health-safety-environment (HSE) issues and to globally access new markets and new application fields in different sectors.

The problem will be addressed using novel, recently patented solutions known as enthalpy recovery ventilators (ERV) and also as latent heat pumps (LHP), although this name is not technically exact.

3.3 LHP objectives and goals

- To carry out a synergetic analysis of the novel recovery device concepts, including:
    - enthalpy recovery (heat and moisture) in a traditional unit (a benchmark unit),
    - thermodynamics and kinetics of enthalpy recovery in a novel unit,
    - improvement in recovery capacity with novel solutions
    - possibility of application of added-value options CO_2 filtering
- To perform experimental tests of some of the devices and their efficiency analysis in a controlled environment over different time spans and seasons

- To develop and to demonstrate a concept of the "smart device" which would be not only able to recover enthalpy but also capable of minimise O&M costs and to provide necessary environment in a controlled and desired manner (this might be fitted to optimal solution at customers` conditions), including necessary automatics (the solutions related to automation and control are on the customer's side).

3.4 LHP initial issues

Many different systems and concepts are known in the world for waste heat recovery (in industry) and for power/environment conditioning (in living rooms). Industrial applications are rather well developed and documented, but in general they are still suffer from inability to utilise properly low-grade heat, condition secondary power through the seasons and to maintain device operations in industrial processes with aggressive gases and dust.
In living rooms (including public houses) and non-inhabitant dwellings three major air supply methods are used:

- natural ventilation-convection (limited use, very inefficient),
- normal ventilation – forced convection (air blowing, low efficiency) and
- air conditioning (forced compressive cooling + ventilation on demand, a very energy-consuming method).

For newly constructed buildings, the target for "low energy housing" is <20-25 kWh/m^3/year. Finnish D2 norms prescribe that at least 30% of the ventilation heat losses must be recovered. For example:

- In summer fresh air of 30℃ and RH of 90% is typical for Mediterranean and Asian weather conditions. In a living environment, one expects to have air of 22℃ and RH of 55% providing an optimal comfort.
- Allowing for 200-300 Pa pressure drop during ventilation, in this case about 17 g of water vapour has to be removed for every cubic meter of fresh air due to condensation and air density changes.
- Together with necessary work for cooling of air, this results in thermal energy of 50 kJ/m^3 air to be taken off.
- For fresh air rate of ~0.3 m^3/s that is equivalent to ~15 kW$_{th}$ cooling power, where direct air cooling takes only 20% of total power. This demonstrates how important is to take over heat due to water condensation – this heat is lost during traditional air conditioning.

More advanced devices such as rotary wheel regenerators also **have their drawbacks** like freezing, high-cross flow contamination (= lower efficiency!), limited possibilities for control and regulation, failures in bearings due to heavy load, difficult heat recovery. This is of a particular importance for dwellings with extensive use of water and utilities – **an average family of 4 persons releases from 6 to 20 kg water vapour a day** (including respiration, cooking, washing, drying, etc.). Removal of such water amounts with a conventional system presents a challenge in winter (freezing) and in summer (in the case of high outside humidity). Additionally, sensible heat of water vapour (about 2.5 MJ/kg) is lost:

	Small family house	Average family flat
Total annual power losses, MWh Of which, %:	25-45	15-35
• Windows • Doors	15-18 1-2	14-16 <1
• Outer walls • Roof • Basement • Central sewage drain	15-20 10-12 8-12 -	16-18 5-7 3-5 20-22
• **Ventilation**	**38-42**	**35-40**

In the present proposal, the novel enthalpy recovery ventilator (ERV) device (protected by several patents) is being considered as a basis for the modular recovery system, Fig. 1.

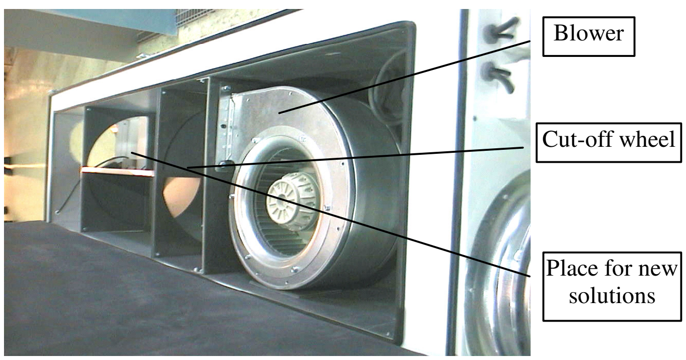


Fig. 1. An open view of the ERV device (0.3 m^3/s).

The recent ERV device has theoretical heat takeover capacity of **110-120 kJ** per one blowing cycle (approximately 30 s). Using LHP solutions, this capacity might be raised to **500-600 kJ** with a minimal compromise for the device costs. With solutions of combined LHP, such capacity might be theoretically increased yet to level of **1000-1600 kJ** although at the expense of higher materials costs.

On the other hand, a high heat capacity will allow to make a device smaller (within the limit of allowable air pressure drop) or to operate it less time (thus saving O&M costs and energy).

The heat recovery efficiency of the ERV for a house application was recently demonstrated by VTT at Oulu Housing Fair in Finland (2005) as high as 76% in comparison with typical values of order 25-60% for competitive products. This means at least a double heat recovery values versus conventional technology which satisfies "low energy housing" criteria. It was also shown by tests that the potential of ERV system might be yet improved (in terms both O&M as well as physical values) when above mentioned solutions would be applied separately or jointly.

Assuming the annual heat recovery efficiency will be the same (70-75%), novel solutions could be applied in more demanding areas like North or South where temperature and humidity are either extremely low or high, or varying through the year significantly (and where parallel installations of two separate systems for heating (winter) and cooling (summer) is costs prohibitive). Although somewhat obvious, added-value options need to be tested and proved at customer's sites or under properly specified conditions (for ventilation duct systems EUROVENT C or better), This concerns both living rooms and industrial sectors.

The summary of the novel ERV/LHP solutions are shown in the table below:

Novel techniques	Novel applications	New markets and business
• Using new materials • Using new heat exchangers • Using new materials combinations • Optional recuperative or enthalpy split modules • CO_2 level decrease and control in dwellings	• "Smart air" in the living rooms around-the-year • Substantial energy savings and emissions decrease with new technology • Possibility of tailoring of enthalpy + moisture recovery and IAQ just by combining different options and upscaling • Substantial reduction of costs (BoP, O&M, recycling)	• Climate rooms (normally air-conditioned) – electronics, computers and network equipment*, clean facilities, drying etc. • Hospitals, houses for elderly people, well-being and public places (airports, shopping malls) • Kitchens, bakeries, other food processing facilities • Recreation facilities (resorts, swimming pools, restaurants, hotels, etc.) • Industrial applications (power generation and recovery) • Adjacent services for the above

* For example, North American markets require indoors environments to be complied with the NEBS standards. Specifications beyond GR-3109 and GR-63-CORE/2 for central offices, mobile switching and data centres set operation conditions as 18…22℃ and RH 5…85% with venting cooling capabilities above 1.8…2 kW/m^2.

In different countries there are different regulations and procedures for new installations, and retrofitting of the older systems might not be always possible. Thus industrial partners might establish a consortium to implement the project results commercially after the project.

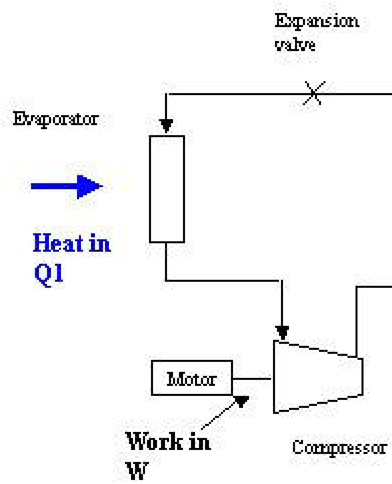
It is foreseen that the commercial interest of consumers about the application of novel systems will increase in near future when home electronic appliances will consume more and more power. For a typical flat with annual electrical energy demand of 2 MWh, computers, flat TVs, digital boxes etc. already take more that 20% of the energy supply. Although yet far from the commercial telecom rooms, heat power densities are rising in living rooms continuously which causes worsening of IAQ, increases dust circulations and demand yet more power for additional ventilation or air conditioning.

It is also known that too extensive air conditioning or ventilation would cause increasing rate of sickness of people due to wider temperature variations and shocks between outside and inside air. Thus, a wide implementation of novel systems would provide great social and environmental benefits.

3.5 Conventional heat pump technology

Coefficient of performance (COP)

In the air-conditioner, refrigerator or heat pump, a refrigerant, typically ammonia or freon, is pumped around a loop. The refrigerant gas condenses to a liquid in the condenser, giving out heat. The liquid passes through an expansion valve and drops in pressure. The liquid boils to a gas in the evaporator, absorbing heat. The compressor compresses the gas.



Energy is conserved so:

Q2 = Q1 + W

The coefficient of performance as a refrigerator is defined as:

COP = Q1/W

For example, at a COP of 3, one watt of motor power in will produce 3 watts of cooling at the evaporator and 4 watts of heating at the condensor.

The COP depends primarily on the temperatures of the evaporator and the condenser, the closer the two temperatures are, the higher the COP. COP also depends on the refrigerant gas and the model of compressor used.

In the table below, typical COP is given for a screw compressor operating on an ammonia refrigerant.

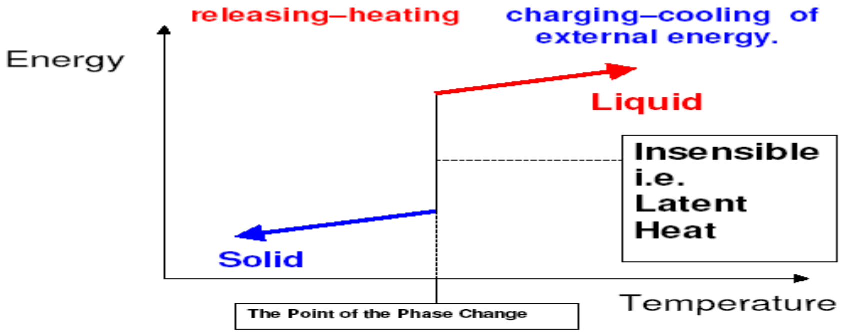
3.6 LatentHeatPump Summary

1. Latent Heat
   - All phase changes …
     - take place at a specific temperature.
     - take place without a change in temperature. (There is no temperature change during a phase change.)
     - involve changes in internal potential energy.
     - release or absorb latent heat.
       - Endothermic phase changes absorb heat from the environment. (They are cooling processes.)
       - Exothermic phase changes release heat to the environment. (They are warming processes.)
   - The specific latent heat (*L*) of a material …
     - is a measure of the heat energy (*Q*) per mass (*m*) released or absorbed during a phase change.
     - is defined through the formula $Q = mL$.
     - is often just called the "latent heat" of the material.
     - uses the SI unit joule per kilogram [J/kg].
   - There are three basic types of latent heat each associated with a different pair of phases.

	solid-liquid	**liquid-gas**	**solid-gas**
latent heat of …	fusion	vaporization	sublimation
endothermic phase changes	melting, liquefaction*	boiling, evaporation, vaporization	sublimation
exothermic phase changes	crystallization, freezing, fusion, solidification	condensation, liquefaction*	deposition
temperature	melting point, freezing point	boiling point, dew point	sublimation point, frost point

* Use of the word liquefaction should be avoided since the starting phase is ambiguous.

Energy of the Phase Change



The LatentHeatPump operates
- on the countercurrent principle,
- cyclically, and
- optimally

on the both sides of the point of the phase change.

Unique:
1) Permanent cooling/heating.
2) The highest efficiency.

The LatentHeatPump is patentable.

2. Conventional electric (absorption also) air-source heat pumps take advantage of latent heat of vaporization of refrigerant through piping. Evaporation takes place in an evaporator (indoor unit) # 3 and condensation in a condenser #1 (outdoor unit). Additional energy is used in a compressor #4. The indoor air circulates through evaporator and cools without ventilation, and the outdoor air circulates through condenser. An average COP is 3.0.

This drawing shows that refrigerant warms up when flowing through evaporator. Then it further warms up in a compressor by electricity (or by heat in an absorption heat pump). It cools downs in a condenser and in an expansion valve #2.

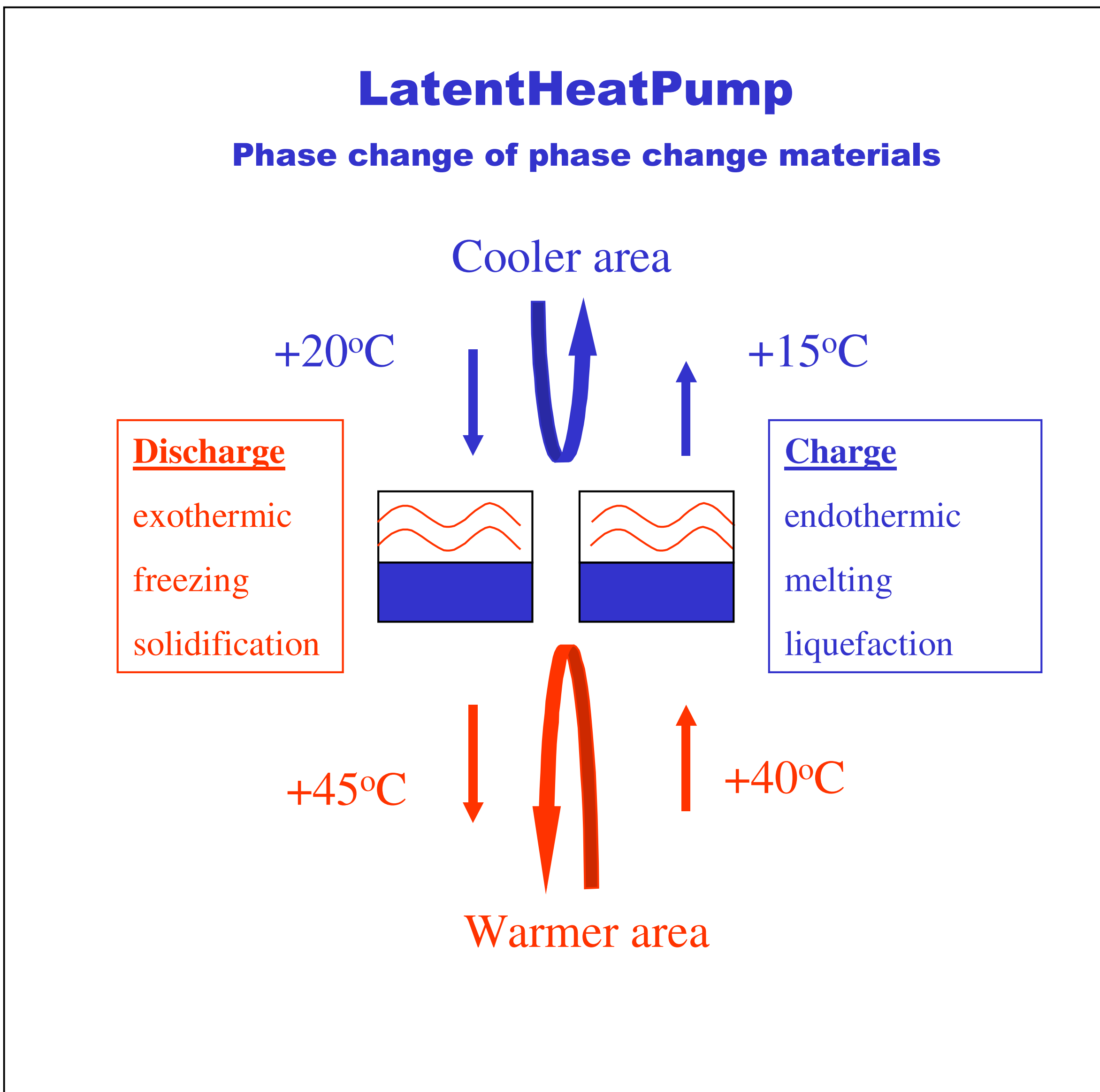
Energy used in a compressor is wasted in a condenser and in a valve.

3. LHP takes advantage of latent heat of fusion. Solidification of Phase Change Material (PCM) takes place by indoor air while it is heated when flowing out of the space. ***During the second cycle melting (liquefaction) of PCM takes place by FREE outdoor air while it is cooled when flowing in***. No compressor, refrigerant or piping is needed. LHP uses minimum two PCMs when the other one is charging simultaneously the other PCM is discharging. LHP is an economizer type with enthalpy (or “total heat”) control consisting of both sensible heat (temperature) and latent heat (humidity) control including *unique free evaporative cooling in high temperature and high humid climates. Its COP is the best in very warm and high humid climate. On PCM´s point of view a unique issue is a permanent process. Its average COP is 9.0.*

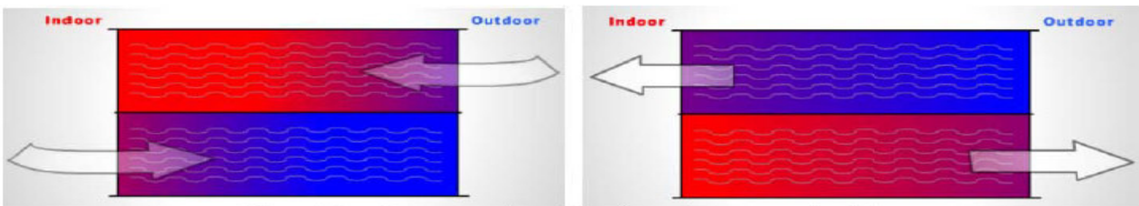
Instead of electricity or combustion LHP uniquely gains high amount of energy consisting enthalpy (heat and humidity) of ambient air. LHP operates independently and it can replace any air-conditioner.

LHP does not circulate any harmful or toxic liquids, it does not have compressor.

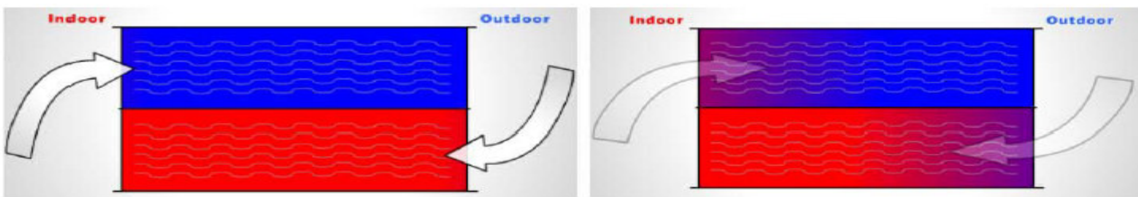
Energy is not wasted. Conventionally humidity is a problem, LHP gains it.



Ventilation doubles heating and cooling demand. That is minimized and even eliminated in hot and humid climate by ERV. Only due to this fact LHP´s COP is twice better than conventionally.



Warm air from the room vents out, heating up the regenerator plates



When cooler air enters onto the Heat Exchanger (HE), humidity evaporates on the warmer surface. Air takes energy out of HE cooling it and becoming warmer itself.

During the second cycle warmer air enters onto the HE. Due to dew point humidity condensates on the surface as a condensation film, not water. At the same time air gives heat energy to HE warming it up and cooling itself. That is free of charge evaporative/swamp cooling. Then the first cycle continues process.

Impurities follow humidity and do not permanently fix on the HE´s surface. The process is self-cleaning and anti-bacteria due to the HE is not permanently warm and wet enough for breed microbes.

Air flow of 500 m^3 in 24 h saves energy 84 kWh by cyclical condensation and evaporation. Conventional technology wastes that free energy.

	Conventional air-con	LatentHeatPump
Connection power requirement	2 kW	0,3 kW
Coefficient of Performance	3.0	9.0+
Efficiency in the winter	0 to low	High
Compressor	Yes	No
Outdoor unit (evaporator)	Yes	No
Toxic refrigerant	Yes	No
Piping	Yes	No
Ventilation heat recovery	No	Yes
Patenting	No	Patentable
Moving parts	A lot	Few