ASSCON
Vapor Phase Technology

Statement in the public hearing on PFAS REACH - Restriction

Introduction

Relevance PFAS REACH restriction for vapor phase technology

The development of global electronics production in recent years shows an ever-increasing need for the technology of vapor phase soldering. Especially in modern and promising areas such as renewable energies, alternative drives, network and security technology, power modules and the semiconductor industry, automotive, electromobility, medical technology and aerospace technology, conventional processes for manufacturing electronics are reaching their process limits. Electronics manufacturers worldwide are increasingly unable to produce their innovative products with conventional process technologies if they do not want to avoid additional thermal damage potential, above-average reject rates, elaborate design and protection measures as well as cost-intensive process adjustment and set-up times.

In vapor phase soldering systems, a perfluoropolyether (trade name Galden®) is used as the operating fluid to transfer the heat required for soldering. The current initiative to completely ban PFAS would mean the "end" for this technology, which is becoming increasingly important in electronics.

In the following, we describe the technology of vapor phase soldering, the use cases of this technology and the impact of a ban on global electronics production.

As a **SUMMARY**, the following can be stated in advance:

Vapor phase technology is used as a soldering process in electronics production worldwide. Our company is the market leader in this field.

This soldering process is increasingly replacing conventional soldering processes, as the soldering technology requirements of the new product generations can no longer be met with conventional processes. Electronics for the energy sector (production of energy, storage, power electronics), automotive (electromobility, charging infrastructure), medical, aerospace and communication technology (5G, networks, data storage) are just a few examples. As a further effect, vapor phase soldering significantly increases the performance, reliability and durability of all products manufactured with it due to the particularly low temperature load.

The necessity and performance of this technology has already been proven very successfully during the conversion of electronics production to lead-free (RoHS).

Vapor phase technology stands for climate-friendly and sustainable electronics production. It can reduce electricity consumption in electronics production by up to 70%. Only considering the ASSCON vapor phase installation base a CO2 saving of approx. 75,000 t/year and a reduction in electricity consumption of 180 million kWh/year are currently achieved worldwide compared to conventional soldering processes. This compares with a consumption of operating material of 0.3% to 0.6% of the PFAS consumption assumed in the dossier.

This required operating material (heat transfer fluid) is currently covered by the planned PFAS regulation, which is already causing considerable uncertainty in the global electronics sector. However, it is not substitutable for vapor phase technology.

A ban on this resource means the "end" of vapor phase technology worldwide. All our customers who rely on vapor phase technology will have to stop their production as there are no alternatives to produce this type of electronics. Due to the lack of this type of highly engineered electronics, products such as electric vehicles, aircraft, power converters, satellites, renewable energy, and battery technology can no longer be manufactured.

However, vapor phase technology is one of the essential success factors for achieving and successfully implementing the goals of the EU Green Deal as well as the initiatives for environmentally friendly mobility and digitalization. If Europe does not want to jeopardize these goals and remain a leader in the development and production of future-proof electronics, vapor phase technology must be preserved for the future and especially for Europe, and **an indefinite exemption / derogation of vapor phase soldering from any restrictions must be made!**

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Content

1. Vapor phase / condensation soldering - The technology

1.1. Starting point & use case - electronics production with reflow soldering

“Reflow soldering” describes a common soldering process in electrical engineering for soldering SMD components.

In the first step of reflow soldering, the solder is applied in the form of solder paste to the circuit carrier/printed circuit board before assembly. This is the main difference to other soldering processes such as soldering iron soldering, dip soldering or wave soldering.

In the next step, the components are assembled. By using solder paste, the components adhere directly to the paste during assembly and do not have to be glued on.

The assembled PCB is heated strongly enough so that the solder contained in the solder paste melts. At the same time, the increased temperature activates the flux in the gel of the solder paste. With the final cooling of the assembly, the solder solidifies and connects the PCB and components mechanically and electrically.

1.2. Common reflow soldering methods

1.2.1. Contact soldering by means of hot plate

The carrier substrate equipped with components is placed on a heating plate and heated up. This process can be used with inorganic carrier substrates. Organic carriers (such as the widely used printed circuit boards) are not suitable for contact soldering due to their glass transition temperature (e.g. glass transition temperature for standard printed circuit board approx. 140 °C). Furthermore, only one-sided assembly is possible.

1.2.2. Heated moulded parts, stirrups and punches

A punch or bracket adapted to the shape of the housing of the component to be soldered is heated with a resistance heater. This then presses the component connections onto the solder joint and melts the solder. The heating is then switched off and the stamp is not lifted off until the solder has solidified. Usually only individual components are soldered one after the other in this way.

1.2.3. Infrared radiator

Here, the soldering material is moved by a conveyor belt through an oven that is equipped with infrared radiators. The soldering process can be controlled by the time spent in the different temperature zones. Usually there are four zones, one for heating the solder, the second for activating the flux, the third for soldering and the fourth for cooling. One of the disadvantages of this process is the strong absorption of radiation energy by black components (IC housings). Uneven heat distribution and damage due to local overheating are the result.

1.2.4. Full convection reflow soldering

The full convection reflow soldering systems are similar to the infrared radiator systems, but here air is heated and led to the soldering material via a nozzle system. This achieves a more even heat distribution than is possible with infrared radiators. This method is most frequently used in electronics production.

Each board that needs to be soldered passes through at least 4 chambers/zones - pre-heating, flux activation, peak zone and cooling. Large convection systems have up to 26 zones. The energy consumption is partly significant and measured in terms of the CO_2 footprint convection soldering is more and more being critically questioned.

One of the disadvantages of this process is that cold zones can appear in the shadows of large components, as these are not always 100 % enclosed by air during convection. With regard to setting a solder profile, shadow formation, longitudinal and transverse profile disturbances (different temperature distribution on the PCB and on the assembly), convection soldering is much more difficult to control. In some cases, aggressive fluxes or the use of N_2 or formic acid spray are necessary to displace oxidation-favouring oxygen and achieve sufficiently good soldering results.

1.2.5. Vapor phase soldering / Condensation soldering

Vapor phase soldering, also known as condensation soldering, uses the heat of condensation released during the phase change of a heat transfer medium from a gaseous to a liquid state to heat the assembly. Condensation takes place on the surface of the solder product until the entire assembly has reached the temperature of the vapor. If the liquid boils, a saturated, chemically inert vapor zone is created above it, the temperature of which is largely identical to the boiling point of the liquid, so that an optimum inert gas atmosphere is created and oxidation is excluded.

Perfluoropolyether (PFPE, commercially available for example under the brand name *Galden®*) is used as heat transfer medium.

The heat transfer is fast and largely independent of the geometry of the solder product. There are no cold zones in the shadow of large components. Due to the clearly defined soldering temperature and the uniform heating, overheating and the resulting damage to the components is physically impossible. This enables soldering with low activated fluxes, as almost no oxidation takes place during the completely oxygen-free soldering process.

High-performance inline systems allow almost the same throughput rates at about half the cost compared to the convection process. In terms of power consumption, the process is about 10 times more efficient than conventional convective manufacturing processes. The requirement for preheating zones is lower, making vapor phase soldering systems more compact than other ovens. Vapor phase soldering systems are used in all areas of the electronics industry.

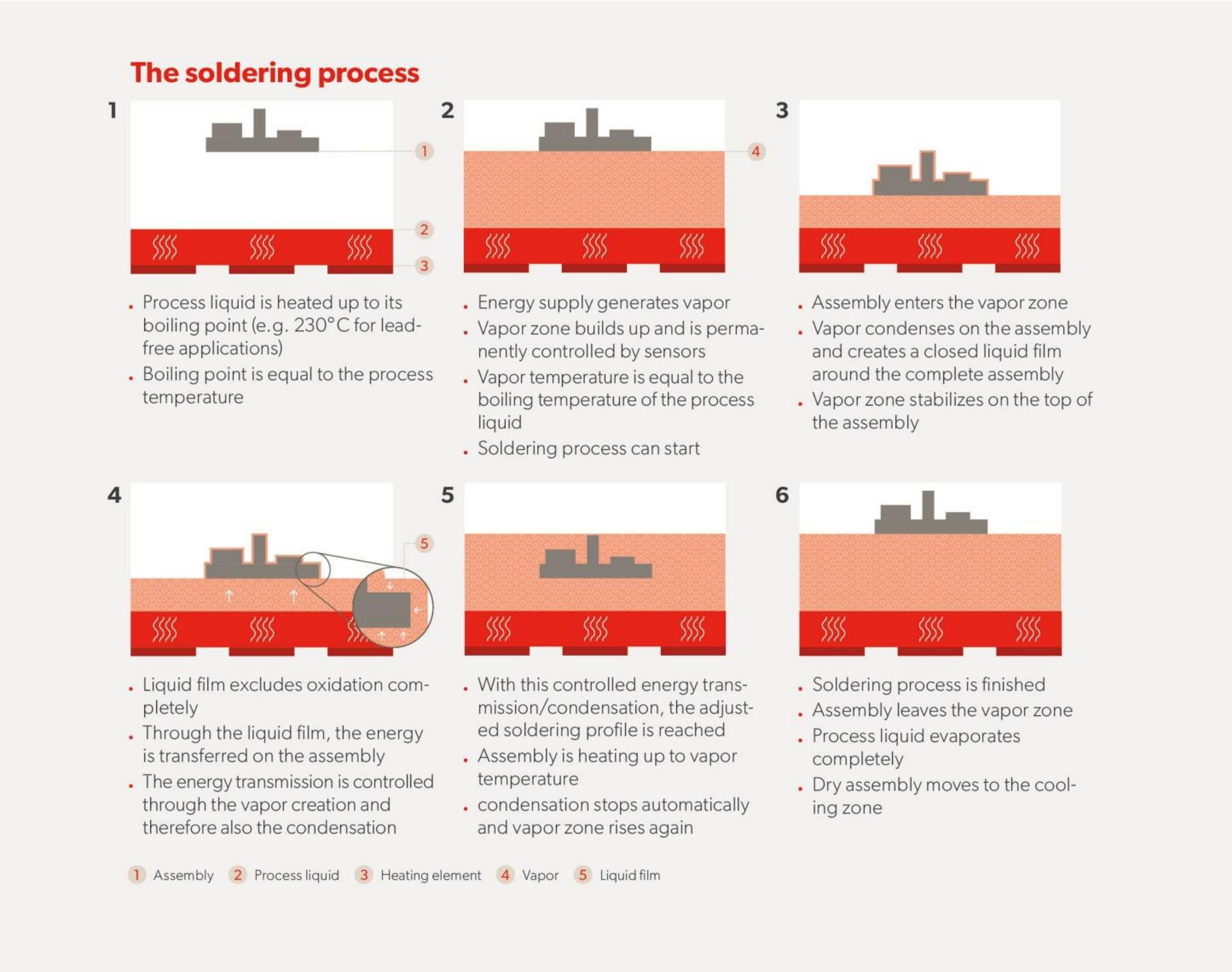
A special form of vapor phase soldering is vacuum vapor phase soldering. After the solder paste has completely melted, the air in the process chamber is sucked out. The vacuum ensures that gaseous inclusions (so called “voids”) in the solder joints are largely displaced to the outside and thus eliminated from the solder joint. The result is solder joints without air inclusions/voids. This technology is particularly advantageous when the solder joints are to dissipate heat or the solder joints should conduct high currents, because air inclusions/voids increase the thermal resistance and reduce the conductivity of the solder joint. In addition, the performance and life time of the assembly is significantly increased by the vacuum treatment.

1.2.6. Laser beam

In laser soldering, solder joints are heated with a laser beam that can transfer a great amount of energy with pinpoint accuracy. The solder joint is heated in a very limited time (soldering time approx. 0.2-0.4 s) and space. Due to the high costs, this process is only profitable in mass production for highly sensitive components.

2. Vapor phase soldering - the process sequence in detail

In vapor phase soldering, vapor is used to heat the assemblies. Vapor as an energy transfer medium is one of the most effective methods for heating assemblies. The efficiency is many times higher than, for example, heating by convection. By using a special liquid GALDEN®, an oxygen-free process atmosphere is created in which the entire pre-heating and soldering process takes place without oxidation. By controlling the amount of condensing vapor, each temperature profile (ramp/linear profile) can be variably adjusted.



Process control and technical equipment of the vapor phase soldering systems ensure that the process liquid largely remains in the system. Furthermore, this is also an important aspect of our past and future development activities.

3. Vapor phase soldering - the best and increasingly the only process for many new products

Vapor phase soldering already has general process advantages over the conventional soldering processes due to the mode of operation described above (see section 3.1. below). In addition, more and more products are appearing that can technically only be soldered using vapor phase technology, as other processes fail here (see section 3.2. below). One example where vapor phase soldering has already shown and proven its necessity and performance as an innovative soldering process was the conversion of electronics production to lead-free (RoHS) (see section 3.3. below).

3.1. Advantages over conventional soldering methods (especially convection soldering)

Vapor phase soldering offers significant advantages over other soldering methods. The main advantages are:

- No overheating or delamination, as the boiling point of the process liquid determines and limits the maximum achievable process temperature (= no elaborate protective measures by shielding etc. necessary).
- Homogeneous heating on the entire assembly, even with different components and masses (= significantly lower damage potential for the assembly, as there is no thermal stress inside the assembly).
- Oxidation-free soldering process without additional use of protective gases such as nitrogen (incl. infrastructure costs for tanks, pipes, maintenance etc.).
- Much more efficient use of energy than with the known soldering technologies such as convection or radiation. The heat transfer coefficient of the liquid used for heat transfer is significantly higher than with air (convection systems) (= up to 70% energy saving compared to conventional soldering systems).
- In combination with a vacuum process, almost void-free solder joints can be achieved (void rates < 1%). Manufacturers can thus increase the performance, reliability and longevity of their products. (= significant reduction of electronic waste).
- Product changeover without waiting times. Whereas convection systems often need several hours until the process conditions in the system are constantly adjusted to the new product, in the vapor phase soldering system only the required soldering programme needs to be called up due to the vapor blanket that is already provided. With inline systems, only the automatic mechanical adjustment of the transport width in the

system is required, which is completed within a few minutes in the case of a product change (= maximum up-time and significant reduction of set-up times).

- By using soldering pastes with a lower flux content, significantly less maintenance is required (= higher system availability).

3.2. Technically necessary soldering process for many soldering tasks / products

Due to the increasing demands of today's products on the soldering process, conventional systems are increasingly reaching their limits. The last few years confirm that more and more products are absolutely dependent on vapor phase soldering as a soldering process. They can technically not (any longer) be processed with alternative soldering processes, e.g. due to mass, shape or technically necessary product design. These increasing requirements can be easily met by vapor phase technology. This also applies in particular to the use of vacuum soldering processes.

Due to the technological advantages of the process, electronic assemblies in the following sectors can increasingly only be reasonably manufactured using vapor phase soldering:

- Power electronics (especially electromobility & renewable energies; e.g. power converters)
- Network technology
- Safety technology for all sectors of application
- LED / Lighting technology
- EMS (Electronic Manufacturing Services; with special requirements regarding "high mix - low volume")
- Automotive (both electromobility and conventional drive technology; onboard networks)
- Aerospace (aircraft and satellites)
- Medical technology
- Renewable energies
- Military
- 3D MID (three-dimensional assemblies, miniaturisation of electrical devices)
- Applications with high-mass and large-format electronic assemblies
- Battery technology

- Thermal treatment of mechanical components (hardening, tempering etc.)

The above-mentioned applications provide only an extract from possible sectors of application. Today, highly complex electronic components are used in a permanently increasing variety of products and applications. The increasing sectors of application in electromobility, in the distribution of regeneratively generated electricity, in aerospace, in medical technology and in all applications of power electronics and network technology show particularly well that the highest performance is demanded of the components used. Therefore, both mechanically and electrically, an optimal connection of the components to the PCB is important, which is optimally achieved by vapor phase soldering and additionally by the MultiVacuum process. In this way, manufacturers can significantly increase the reliability and durability of their products.

Example products:

Leading global manufacturers of hearing aids, pacemakers, ultrasonic scan devices, heating and charging systems for batteries, inverters for solar and wind energy systems, aircraft flight control systems, satellite antennas, production of piezo ceramics, radar systems for assisted driving, led lighting and signalling systems, produce them with vapor phase technology.

Vapor phase soldering remains the technology of the future - not only because of the energy savings.

3.3. Specific example of technical necessity - The introduction of lead-free soldering processes (RoHs)

Vapor phase soldering has also already proven its efficiency as a soldering process during the introduction of lead-free soldering processes. Vapor phase soldering ensured safe soldering even at the higher soldering temperatures and guaranteed that the maximum soldering temperature was not exceeded due to the physical properties of the heat transfer liquid. Damage to the assemblies due to the higher process temperatures was reliably excluded due to the process. Convection soldering systems were confronted with significantly higher process risks here and could only be converted for production in the higher temperature ranges with a great deal of effort - but for some products this has not been achieved until today.

3.4. Vapor phase soldering as a sustainable and climate-friendly soldering process - CO2 footprint, electricity consumption

The vapor phase soldering process is significantly more sustainable and climate-friendly than the alternative soldering processes. Climate change and the need to drastically reduce CO2 emissions are forcing governments and industry worldwide to act. In recent months, energy costs have risen massively due to the Ukraine conflict. In the future, energy costs will remain high in the long term, if not rise even further. In addition, companies have to determine their CO2 emissions. In some cases, they will also have to purchase CO2 certificates in order to be able to continue producing.

Vapor phase soldering systems have a significant advantage over conventional reflow soldering systems for future electronics production due to their very low power consumption and significantly smaller footprint.

A simple comparison

Convection		Condensation	
Heat transfer	**30 - 120 W/(m²·K)**	Heat transfer	**100 - 700 W/(m²·K)**
Connection power	**60 - 90 kW**	Connection power	**max. 25 kW**
Average power consumption	**15 - 22 kWh**	Average power consumption	**max. 7 kWh**
Profile change	**60 - 75 min**	Profile change	**max. 5 min**

Convection:

- ☆ **Product changes mean down time of the line**
- ☆ **Excellent soldering quality needs nitrogen**

Condensation:

- ☆ **Changeover times are reduced to a minimum**
- ☆ **Oxygen-free process eliminates need for nitrogen**
- ☆ **Gentle soldering process without temperature peaks**
- ☆ **Homogeneous heating with lowest Δt**
- ☆ **Reduce energy consumption by up to 75 %**

The following is a detailed example calculation of the operating cost comparison between vapor phase soldering and convection soldering:

Operating costs

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Comparison vapour phase vacuum /convection vacuum with nitrogen

Guideline for using the "Operating costs"
For a proper comparison it is necessary to use real values from the machines and production environment to compare.

Costs for exhaust are different in local countrys. In hot areas aircon costs are higher. In cold regions costs for exhaust are higher, because the incomming air has to be heated up. If machines are operated under clean room applications please ask for detailed values.
These Values are originaly calculated seriously from european EMS manufacturer

exhaust:	**0,0007**	**EUR /m³**
aircondition:	**0,2**	**EUR / kw cooling**

Values from ASSCON are real mearuesd values during operation at produduction site.
If possible please use measured value from the customer production site.

	VP7000-200		**Reflow Convection** (Model series known but here anonymized)
	Euro	**Operating time**	
Direct consumption			
costs for energy/kwh	0,25 €	hours/day	22
Costs for nitrogen/m³	0,25 €	days/year	250
costs for Galden/kg	143,50 €		
Indirect consumption			
costs for exhaust/m³	0,0007 €		
costs for aircondition /kw cooling	0,2000 €		

Please fill in the real consumption values				
Consumption	**VP7000-200**		**Reflow Convection**	
Average energy consumption	4,80	kW/h	15,00	customer information
Nitrogen	0,00	m³/h	18,00	customer information
Galden	0,03	kg/h	0	
Active cooling unit average consumption. If no values are available choose 50% of average energy consumption	1,92	kW/h	7,2	
Exhaust	200,00	m³/h	600	
Radiation of machine into productionarea. If no values are available choose 45 % of average energy consumption. Radiation creates aircond. costs.	1,92	kW/h	7,20	

Direct operating costs	**Vapour phase**		**Reflow Convection**
	Euro		Euro
	1,20 €	*Energy*	3,75 €
	0,00 €	*Nitrogen*	4,50 €
	3,59 €	*Galden*	0,00 €
Indirect operating costs			
	0,14 €	*Exhaust*	0,42 €
	0,38 €	*Aircondition*	1,44 €
	0,48 €	*Active cooling unit*	1,80 €
Overall operating costs			
per hour	5,79 €		11,91 €
per day	127,41 €		262,02 €
per year	31.853,25 €		65.505,00 €
in 5 years	159.266,25 €		327.525,00 €

Version: 4.0 Nov. 20th 2020
Name ASSCON Sales Dept AW

Nov 20th 2020 Operating costs VP7000-200 vs Reflow Convection
The reflow convection oven has the configration 7 Zone pre-heating, 3 Zones Peak and 4 Zones Cooling

CONCLUSION: vapor phase means > 50% cost saving

Calculation of additional CO2 consumption with PFAS ban (means vapor phase (VP) ban) 21.03.2023 CZ

			Number	Unit	Figure
Assumptions:	Number of machines considered:		2000	Pieces	A
	Average electricity consumption per machine in production: (equipment consumption plus cooling)		7	kw/h	B
	Convection: Average electricity consumption per plant in production: (plant consumption plus cooling)		22	kw/h	C
	Working days per year 3 shift (5 days week)		300	Days	D
	Working hours per day		20	h	E
	CO2 emission per kwh (2021 data from German Federal Environment Agency based on European electricity mix)		420	gr/kwh	F
	Comparisson: CO2 Emission heating oil		318	gr/kwh	
CO2 emission of ASSCON vapor phases units (to/anno)		.=A*B*D*E*(F/1000000)	**35.280**	Tons per year	
Total electricity consumption per year (kwh)			**84.000.000**	Kwh	
CO2 emission comparable convection (to/anno)		.=A*C*D*E*(F/1000000)	**110.880**	Tons per year	
Total electricity consumption per year (kwh)			**264.000.000**	Kwh	
Additional CO2 consumption per year with PFAS / VP ban:			**75.600**	Tons per year	
Additional consumption in KWH			**180.000.000**	kwh per Jahr	
Heating oil equivalent to additional CO2 consumption as calculated above (additional consumption in Kwh corresponds to the following quantity of heating oil)			**57.240**	Tons per year	
Plus on electricity consumption of households / year to additional CO2 consumption as calculated above (annual consumption 3,500 kWh)			**75.429**	Households	

CONCLUSION:

If, in the event of a complete PFAS ban, current global electronics production with ASSCON vapor phase systems were to be converted to convection, this would therefore result in an

- increase in CO2 consumption by 75,520 t/year,
- increase in CO2 consumption converted into heating oil equivalent of 57,000 t/year,
- increase in electricity consumption by 180,000,000 kWh/year,
- increase in electricity consumption calculated on households of 75,429 households/year.

3.5. Galden consumption

Vapor phase soldering systems operate as closed-loop systems. By far the largest proportion of the heat transfer liquid is kept in the system by closed system circulation. Only a very small part leaves the system, e.g. via the processed products or via the loading and unloading processes. Exemplary consumption data determined for the year 2020 in the course of a survey by the Federal Environment Agency (Bundesumweltamt – BUA), result in the following consumption values for the systems supplied by ASSCON:

Average consumption of all ASSCON VP systems operated in Germany (year 2020)	7,340 kg (= 7.3 to)
Average consumption of all ASSCON VP plants operated in Europe (except Germany) (year 2020)	8,590 kg (= 8.6 to)
Average consumption of all ASSCON VP plants operated outside Europe worldwide in 2020 (in 2020)	5,000 kg (= 5.0 to)

Based on an assumed annual PFAS consumption according to Annex XV Restriction Report PFAS - Table A.50 and Table A.51, the share of consumption of vapor phase soldering is as follows:

	Table A.50 / Table A.51	Vapor Phase	Share of VP (EEA) in the assumed total PFAS consumption
Total PFAS low	2,541 to	15.9 to	= 0,6%
Total PFAS high	6,304 to	15.9 to	= 0,25%
Total PFAS midpoint	4,423 to	15.9 to	= 0,35%

Based on our worldwide market observations, we assume that we are the market leader among the manufacturers of vapor phase soldering systems with at least 65% market share. Based on these basic data, the following currently valid figures (as of 2020) result for the consumption of vapor phase soldering calculated over the vapor phase soldering systems of all manufacturers of vapor phase soldering systems:

	Table A.50 / Table A.51	Vapor Phase	Share of VP (EEA) in the assumed total PFAS consumption
Total PFAS low	2,541 to	24.5 to	= 0,96%
Total PFAS high	6,304 to	24.5 to	= 0,38%
Total PFAS midpoint	4,423 to	24.5 to	= 0,55%

4. Need of using perfluoropolyether (product name Galden®) for vapor phase soldering – key properties

A liquid polymer is used as the heat transfer medium in vapor phase soldering. These liquid polymers are made up of carbon, fluorine and oxygen. The C-= and C-F bonds present in the molecule are extremely stable. Perfluoropolyethers are among the most stable bonds in carbon chemistry. The fluorine atoms on the outside shield the carbon chain. They thus protect the more sensitive C-C bonds from chemical and thermal effects.

Perfluoropolyethers have excellent heat transfer coefficients as well as good dielectric properties. Fluxes and other impurities do not change the physical properties. Galden® is a completely inert liquid and has no chemical activity due to the fully closed molecular grid. Galden® never needs to be changed.

The soldering result always remains constant and is not influenced by the degree of contamination of the machine. Vapor is a distillation product and always 100% purified.

The following key properties are offered by perfluoropolyethers as a heat transfer liquid

- Excellent heat transfer coefficient
- Clearly defined boiling point
- High thermal stability
- Excellent material compatibility, as no reaction with other chemicals or substances (inert)
- No flash point
- No danger of explosion
- Dielectric (complete electrical insulation, non-conductive)

- High vapor density
- Low surface tension, thus excellent wetting properties and high viscosity
- High purity manufacturing process (no potential for contamination of the solder product)
- Low carbon footprint
- No ozone damage potential
- Meet the OECD's most important internationally recognised safety criteria, which classify them as polymers of low concern.

5. No substitutability of perfluoropolyethers for vapor phase soldering

The aforementioned physical and chemical properties of the heat transfer liquid Galden® are essential for the process of vapor phase soldering. Only these properties make this process possible and applicable for the production of electronics. The properties required for the soldering process are immanent to perfluoropolyethers (FP), they are based on this chemical structure and are conditioned by it.

The properties of the heat transfer liquid required for vapor phase soldering can only be guaranteed by this FP. No other material offers the properties required for this process. If the production or composition of this heat transfer medium is changed, this soldering process no longer works. The FP cannot be substituted by any other material as a heat transfer liquid.

Since 1995 we have been permanently searching for alternative substances that are not based on FP and have the properties of FP as a heat transfer liquid. We have been in contact with the chemical industry, research and development and universities - the only result: there are no alternatives on the market and they are not even imaginable!

A ban on FP for use in vapor phase soldering systems therefore inevitably leads to the "end" for the technology of vapor phase soldering.

CONCLUSION

Vapor phase technology is one of the essential success factors to achieve and successfully implement the goals of the EU Green Deal as well as the initiatives for environmentally friendly mobility and digitalisation. If Europe does not want to jeopardise these goals, vapor phase technology must be preserved for the future and especially for Europe, and an indefinite exemption / derogation of vapor phase soldering from any restrictions must be made!