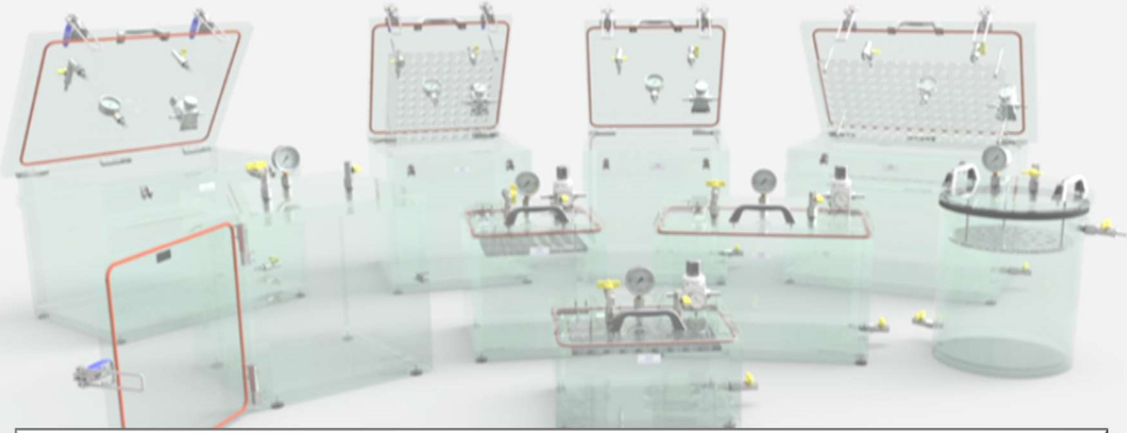

A Guide to AVE Vacuum Chamber Design & Suitability for Your Process

AVE

Applied Vacuum Engineering

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Celebrating 40 Years

1977 - 2017

Applied Vacuum Engineering

Technical Considerations to be Mindful of When Selecting and Configuring a Vacuum Chamber.

Allow us to apply our design expertise and experience to your application.

Introduction

AVE offer a vast array of vacuum chambers suitable for a wide range of processes; from acrylic package testing chambers and steel degassing pots, to fully automated bespoke vacuum systems.

It is important to make sure that the system you require meets the process requirements, therefore configuring the correct chamber to the correct application is an important process, and understanding your process and requirements helps us configure a chamber to match. An under-specified chamber can be inefficient and difficult to work with, whilst an over-specified chamber will be more costly and potentially unnecessary.

The purpose of this document is to assist you in your design considerations by discussing some important factors that need considering when designing a chamber or system.

Chamber Material

AVE use four main materials in the construction of our chambers, acrylic, aluminium, mild steel and stainless steel. Figure 1 shows three popular styles of vacuum chamber we sell.

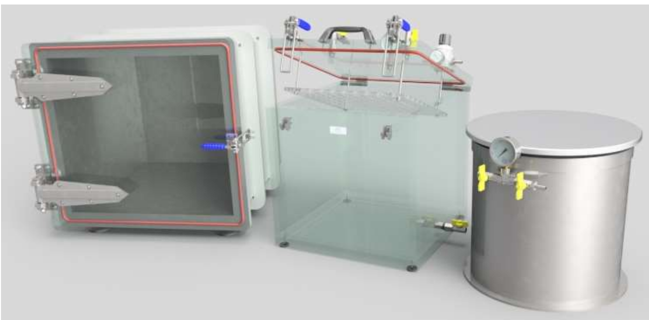

Figure 1: (From left to right) 125L Box chamber - Mild Steel Powder coated, ACB64PT - Acrylic Package Testing Chamber, DP42 Cylinder - Stainless Steel with Aluminium Lid.

Acrylic (PMMA)

Acrylic, or Polymethyl methacrylate (PMMA), is a transparent polymer (plastic) material with outstanding strength, stiffness, and optical clarity.

Acrylic sheet is easy to fabricate, bonds well with adhesives and It has superior weathering properties compared to many other transparent plastics. Acrylic sheet exhibits glass-like qualities: clarity, brilliance, and transparency, but at half the weight and many times the impact resistance of glass.[1]

Used mostly in our package testing systems and lids or doors for our chambers, it is a great option because you can see exactly what is happening inside the chamber at all times, the downside is that because of a relatively low outgassing rate the ultimate level of vacuum for acrylic is 1 x 10^{-3}mbar and we recommended that for any process lower than 1 x 10^{-2}mbar that aluminium or steel should be used instead.

Stainless Steel (SS)

The main requirement for stainless steels is that they should be corrosion resistant for a specified application or environment. The selection of a particular "type" and "grade" of SS must initially meet the corrosion resistance requirements. Additional mechanical or physical properties may also need to be considered to achieve the overall service performance requirements.[2]

SS is a popular choice for vacuum chambers because it is chemically inert, easily foldable and weldable, and compatible with a wide range of weldable flanges on the market for customisation. Our standard stainless chambers are constructed in 304 SS, but 316 SS is available for specific processes that need improved chemical resistance, but at a much higher cost.

[1] https://www.curbellplastics.com/Research-Solutions/Materials/Acrylic

[2] https://www.bssa.org.uk/about_stainless_steel.php

Mild Steel (MS)

For a more cost effective solution AVE offer a range of powder coated MS chambers suitable for many degassing applications.

MS is a type of low carbon steel that is easily machinable and weldable; while its Tensile strength (Ts) is relatively low it has a relatively good yield strength (Ys). The type we use for our chambers is S275 which has a Ys of 275MPa, hence the name S275, compared to 304L stainless at 210MPa, 6061 Aluminium at 240MPa and acrylic at 70MPa.

Due its susceptibility to corrosion we powder coat our MS chambers for longevity and aesthetics. Due to this high temperature applications should use the SS versions though.

Aluminium (AL)

AVE use aluminium in the construction of doors and lids for applications where acrylic is not an option; for example, where the processes require higher temperatures or pressures below 10^{-2}mbar, or where a chamber may have a door that is too large to be manufactured in acrylic.

We typically use EN6061 AL because of its relatively good machineability and workability, and it is much lighter than steel. It can then either be left with a natural machined or polished finish, or powder coated.

Surface Treatments

Surface finish and treatment becomes important when considering outgassing of water vapor during system operation. Water vapor molecules adhere to interior surfaces of a vacuum system while it is open to standard atmospheric conditions. The smoothness of interior surfaces affects not only how much vapor clings to those surfaces, but also how easily that vapor can be pumped off those surfaces and out of the system.[3] Essentially any surface defects will negatively affect pump down times, it's not just surface roughness, cleanliness and purging gasses will affect it as well.

The surface treatments we offer are: Flame polished for acrylic and then machined, garnet blasted, powder coated and electro-polished for metals, but almost any required treatment or coating can be applied if a specialist system requires it. Figure 2 shows the difference in surface treatments under a highly magnified microscope.

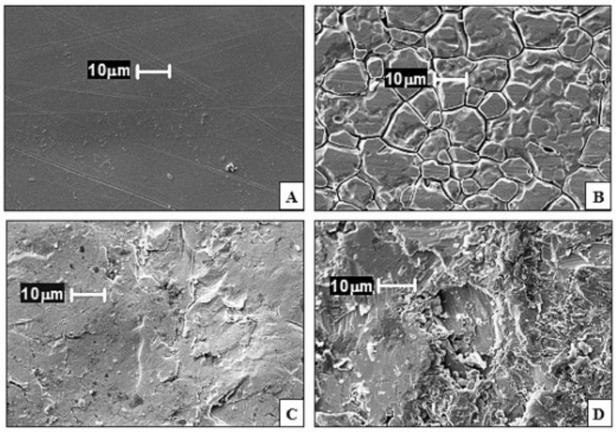

Figure 2: Scanning electron microscopy (SEM) images of clean stainless-steel surfaces at 2260× magnification: (a) electropolished finish; (b) mill finish; (c) bead blasted finish ; and (d) aluminium oxide treated finish.[4]

In reality, for rough vacuum and degassing processes surface finish bears little importance and the cost of electropolished SS versus powder coated MS far outweighs the negligible pumping down time saved. For super clean and High vacuum processes electropolished SS is applicable, standardly we will powder coat MS and Garnet blast SS for a natural looking finish.

Chamber Geometry

Chambers can be constructed in an abundance of shapes and sizes to meet the needs of a process.

Spherical

Commonly used in focal point applications such as laser deposition and surface sciences where all ports point to the same location, can be difficult to work with and only used if absolutely necessary.

[3]Dorothy M. Hoffman, Bawa Singh, John H. Thomas, III, (1998) Handbook of Vacuum Science and Technology (pp 566). San Diego, CA: Academic Press,

[4]https://www.researchgate.net/figure/Scanning-electron-microscopy-SEM-images-of-clean-stainless-steel-surfaces-at-2260_fig1_227675415

Cylindrical

Can be constructed relatively straightforwardly with 'OTS' tubes and flanges and simply assembled. They can prove challenging to mount and internally fixture, and more expensive if custom sizes are required.

Box Chambers (or Cube)

Provide high volume for their size with easy access with fully opening front or top mounted doors or lids, simple to mount and easily fitted with sliding trays and shelves.

Chamber Seals

Major factors in selecting the proper rubber for an elastomer seal include temperature, chemical resistiveness, permeability, and cost. While many elastomers are used for sealing applications AVE typically use Nitrile (Buna) or Viton 'L' gaskets and 'O' rings dependent on a customer's requirements, sometimes silicon is a useful sealing material too.

Viton and Buna are two of the most used elastomers for sealing applications and for good reason, both rubbers serve as great general purpose sealing options. These seals offer excellent compression set resistance, and both options are designed to resist most oils and lubricants, especially petroleum based lubricants.

Additionally, moderate temperature applications between -15°C and 120°C are served by both seals, making either seal a perfect choice for general industrial use. However, for more specific applications the decision becomes much more important. See "Viton vs. Nitrile (Buna)" for an in depth look at the two.

For chemical specific compatibilities and permeability rate, the manufacturers datasheets should be consulted.

Chamber Pressure

The desired ultimate level of vacuum for your system should factor into decisions made on chamber selection and configuration. Table 1 is a table outlining the pressure ranges in vacuum technology.

Pressure Range	Pascal	mbar
Atmospheric Pressure	101325	1013.25
Low Vacuum (LV)	30000 - 100	300 - 1
Medium Vacuum (MV)	$100 - 10^{-1}$	$1 – 10^{-3}$
High Vacuum (HV)	$10^{-1} - 10^{-5}$	$10^{-3} – 10^{-7}$
Ultra-high Vacuum (UHV)	$10^{-5} - 10^{-10}$	$10^{-7} – 10^{-12}$
Extremely High Vacuum (XHV)	$<10^{-10}$	$<10^{-12}$

Table 1: Pressure ranges in vacuum technology in Pascal and millibar.

Our chamber ranges are typically designed to work in the ranges of LV up to HV, UHV and above require special design considerations with low outgassing materials, super high cleanliness, extremely smooth surfaces and special seals, typically using Conflat™ metallic types over elastomers.

HV is significantly easier to obtain than UHV, while good clean practices and smooth surfaces are still important, elastomer seals and connections can be freely used.

LV-MV or 'rough vacuum' chambers present fewer challenges, a well built and maintained chamber with adequate pumping should be able to achieve the desired pressure.

Pressure Testing and FEA (Finite Element Analysis)

Vacuum chamber are designed and manufactured to withstand large pressure loads when under vacuum. For example, when a chamber is pumped down to vacuum every surface is subjected to 101kPa which is the equivalent to just over 1kg pressing down on every cm^2, or 250kg across a $500mm^2$ door!

All of this force is trying to buckle the chamber inwards and therefore the chamber wall thickness and addition of stiffeners, in some cases, are required to stop the chamber failing and keep its shape allowing for good seals, especially around the door seal area. Figures 4 and 5 show some typical FEA analysis AVE would perform on a chamber panel and door.

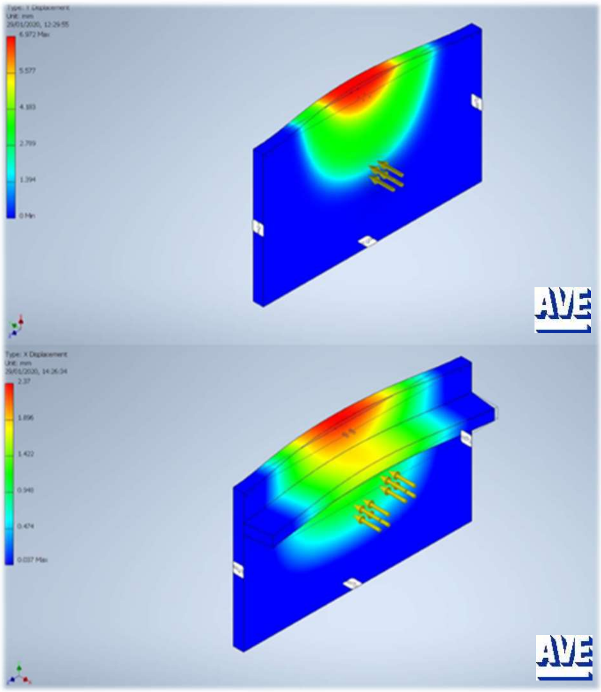

Figure 3: Front/rear panel of an ACB96 acrylic chamber with and without stiffener, subjected to vacuum conditions inside and atmospheric outside.

Figure 4 shows the buckling effect that the atmospheric pressure would have on the chamber under a vacuum. Without a stiffener the top would deform by nearly 7mm at the centre, but with the stiffener it would deform by only 2mm, and because this surface is the lid seal you can clearly see how much of an effect it would have if left untreated.

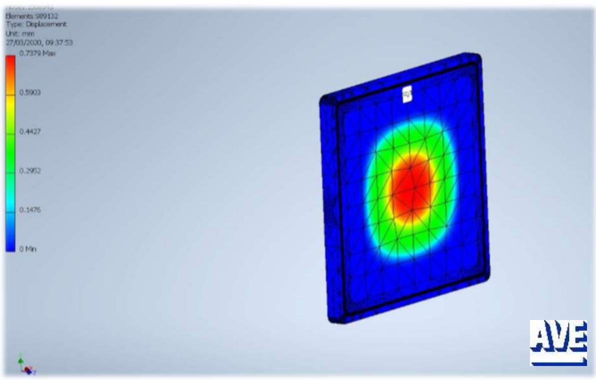

Figure 4: Acrylic door 500x500x40mm subjected to the same conditions as in figure 4.

Figure 5 shows how an acrylic door would behave under vacuum conditions, the deflection at the centre of this panel is only 0.7mm and would not have any effect on the chamber's sealing face, if this was to be made thinner, or from a different material the same analysis would have to be completed in order to check that the maximum deflection isn't too large, or that the maximum yield stress point isn't reached and risk causing permanent damage to the chamber.

Flange Configurations

With the vast array of connecting ports and flanges available, configuring your chamber to the specific needs of any given application is straight forward. However, it is prudent to consider not just the all of the connections required to run your system but consider: What will be needed to run the chamber? What might be needed in the future?

The standard port types AVE offers in chambers include: KF (NW), ISO, CF, NPT and Thru-Holes (straight or threaded). Matching the right connection types and sizes to chamber peripherals can reduce how many adapters and reducers may be needed in the future.

It can be useful to make a list of gauges, feedthroughs, pumps, and other accessories that will be used with the chamber. For example, most chambers will need the following:

- Pumping Ports
- Vacuum Gauges
- Feedthroughs
- Load Lock Mechanisms
- System Vents
- Viewports

Some systems may want full automation with solenoid valves etc. It's also a good idea to have a few spare ports open on a chamber to handle unforeseen changes on a system. Extra ports can easily be blanked off when not in use.

Conclusion

In conclusion, determining the appropriate vacuum chamber for your application requires considering the factors outlined above, although some requirements will be obviously apparent and governed by things such as size, pressure, and port configuration, due to the purpose of the vacuum chamber.

You know that you need to fit an object of a certain size into a chamber of a certain volume, this needs to be pumped down to a particular pressure, perhaps within a certain timeframe, and it needs to have compatible flanges, holes and feedthroughs to connect to your pumps and accessories.

In some cases, process requirements will influence other decisions, such as selecting the appropriate seal or chamber materials; either for a specific temperature environment, or if you are using corrosive chemicals.

Finally, other considerations such as mounting and surface finish may strongly influence how you use your chamber. With this in mind you can weigh these requirements against the timeline and budget of your project to determine which chamber is most appropriate for you and your application, not just for now, but in the future too.

Figure 5: Acrylic Chamber range.

Figure 6: Degassing Pot range.

Figure 7: A range of box chambers and custom projects.

Sales and further information

For further information please don't hesitate to call us or send an email to:

Tel +(44)1454 413561
sales@appliedvacuum.co.uk

More information can be found on our websites below, or make an enquiry straight from the website:

www.appliedvacuum.co.uk – For general enquires/sales/service/spares

www.vacuum-degassing.com – For degassing chambers enquiries/sales/information

www.acrylic-vacuum-chambers.com – For acrylic box chamber enquiries/sales/information