Undetectable “virtual” leaks

Thinking that vacuum systems in general depend mainly on the characteristics of the vacuum pumps would be a huge mistake. The vacuum-chamber as well as the vacuum lines and joints are as important if not more. The purpose of the present article is to inform vacuum systems designer from potential mistakes and assumptions that could result into poor performance of their systems.
Our recommendations will help engineers to optimize their pumping systems without the need of over-sizing them, saving money in the process.

Critical criteria:

- Vacuum lines: These elements are used to connect the pumping systems to the vacuum chambers. When vacuum is generated inside the vacuum chambers via these lines, if not sized properly, they will impact the performance of the pumping systems resulting in a significant over cost. Two possible scenario then. If under sized, bigger pumps may be required ($) to achieve the desired goal. If they are over sized, their manufacturing will add unnecessary cost to the project.

- Outgassing:
This phenomena also called « desorption » is generated from any material that « releases » some gas molecules that were “captured” during the « absorption » period. This absorption usually takes place when these materials are exposed to atmospheric pressure. The outgassing rate depends upon the surface finish of a material, its chemical composition and upon the time spent under vacuum. The longer a material is kept under vacuum, the lesser the outgassing. This is a complex phenomenon and we will not cover this subject in details, as this is not the purpose of this article.

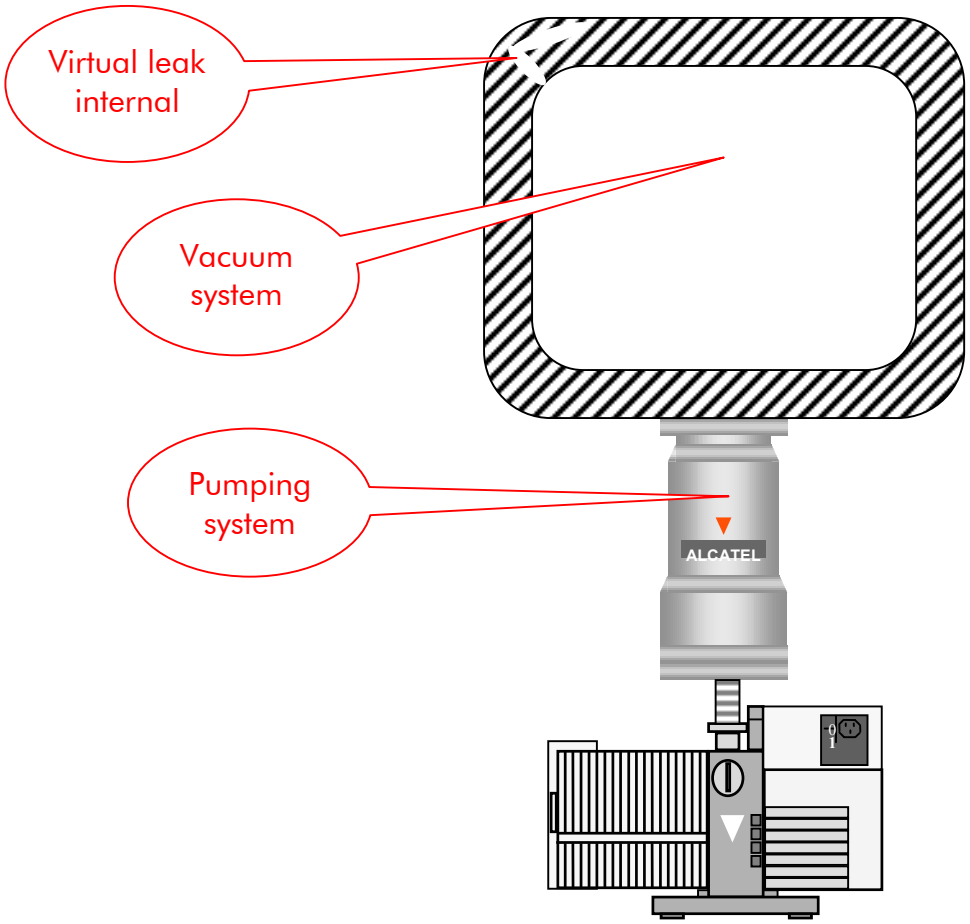
- External leaks:
External leaks are the results of poor welds or poor usage of seals that created path between the vacuum side and the outside of the system. Such leaks reduce the performance of the pumping system as they add some gas load forcing the designer to increase the size of the pumping system to compensate for it. These leaks are usually easily to detect using a helium leak detector. Since there is a path between the inside and outside of the system, a tracer gas such as helium is sprayed outside the system that is detected by the leak detector. This process also allows locating and measuring leaks.

- Virtual leaks :
The source of these leaks is usually a manufacturing defect within the material or a lack of complying with good vacuum practice. They are all kinds of virtual leaks. For instance, small volumes trapped that have a connection to the vacuum side, yet given the conductance restriction, these volumes cannot be pumped out easily.
A dual weld that has a leak on the vacuum side but no connection on the outside (see sketch below). Since there is no pathway from the inside and the outside, (the virtual leak is a dead end), there is no way to detect these leaks using a conventional leak detector. To make matters even worst, these leaks cannot be detected during the leak test right after the assembly sequence, they usually « appear » during the pump down test of the system. The desired base pressure is either never achieved or the time to achieve it is abnormally long.

ALCATEL

Alcatel Vacuum Technology France – 98 Avenue de Brogny – BP 2069 – 74009 Annecy – France
Tel : 33 (0) 4 50 65 77 77 - Fax : 33 (0) 4 50 65 77 89
Web site : www.adixen.com

What is a virtual leak ?



The virtual leak is also described as a gas load that comes out of the trapped volume during the pumping down phase.
The size of the path connecting the internal volume of the virtual leak to the vacuum system will determine the gas flow rate.
If the path were large enough, then there would not be any virtual leak any more as the internal volume will be pumped down as the same rate (speed) as the volume of the vacuum system.
If the path is very narrow then the internal volume will take a much longer time to get pumped down affecting the pump down time of the vacuum system. It will slow down the process.
If the path is very narrow and the vacuum system is frequently cycle back to atmosphere, then the pressure inside the internal volume will impact the pump down time at each cycle.

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Examples of virtual leaks

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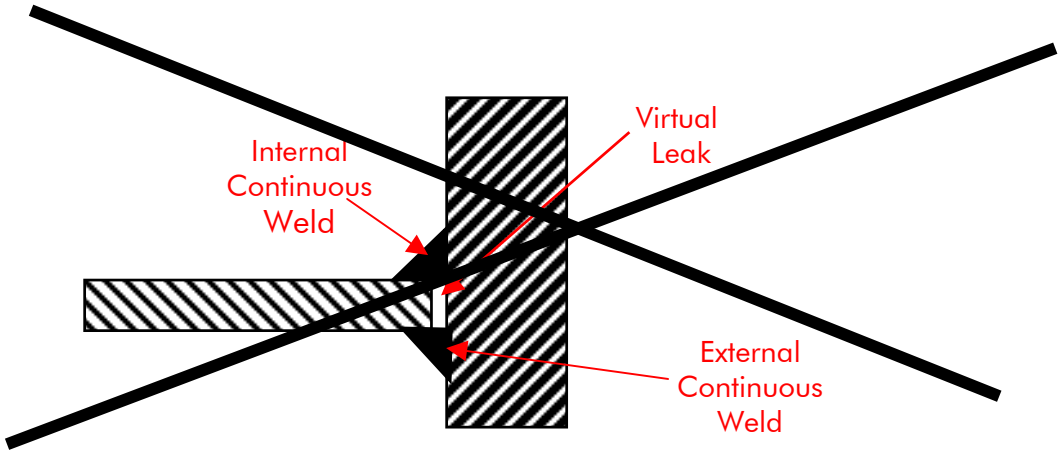
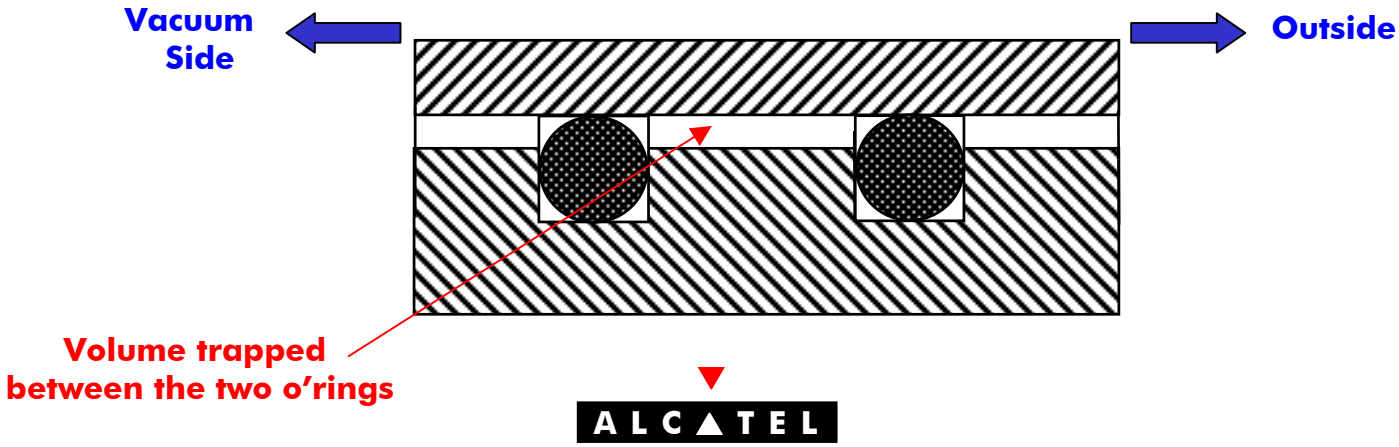
1. Welds that do not comply with vacuum welds requirements.



When two parts are welded together, there should be an internal continuous weld (on the vacuum side). There should be just a few welded spots on the outside for mechanical strength only. In the event both welds are continuous and a crack is present on the weld exposed to the vacuum side, the volume trapped between the two continuous welds will constitute a virtual leak.

2. Dual o'ring device (see below sketch) :
Dual o'rings are often used in vacuum systems. The volume trapped between the two o'rings may constitute a virtual if there is no access to that volume to evacuate it during the pump down of the system. In this case if the first o'ring (the one exposed to the vacuum side) had a leak across due to a scratch on the sealing surface, the o'ring is cracked or some dirt is present on that o'ring. Then we would have an undetectable virtual leak as the trapped volume between the two o'rings will not be accessible to get removed.



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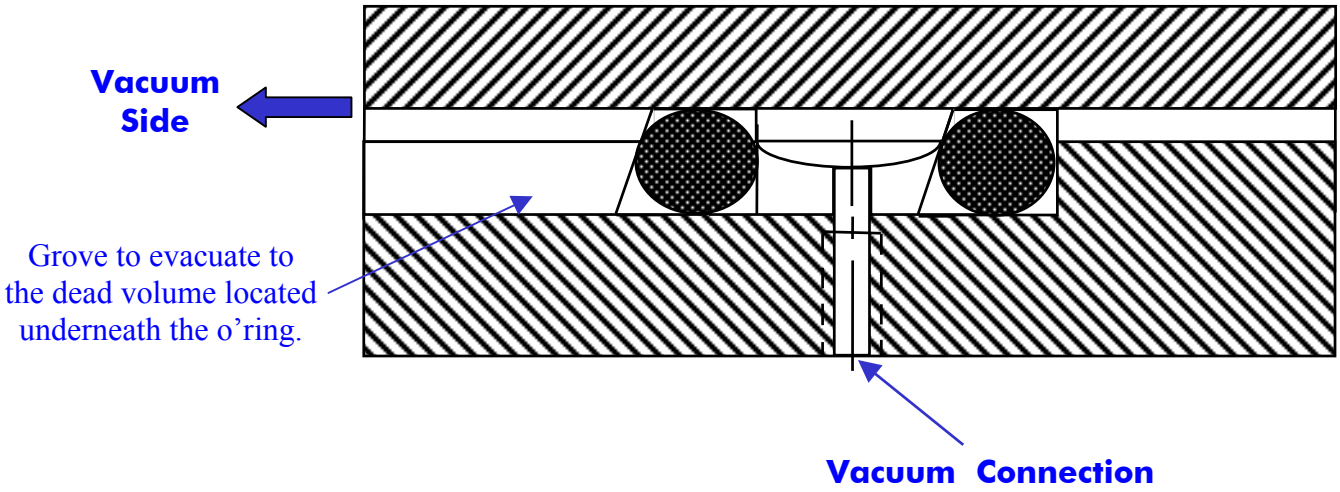
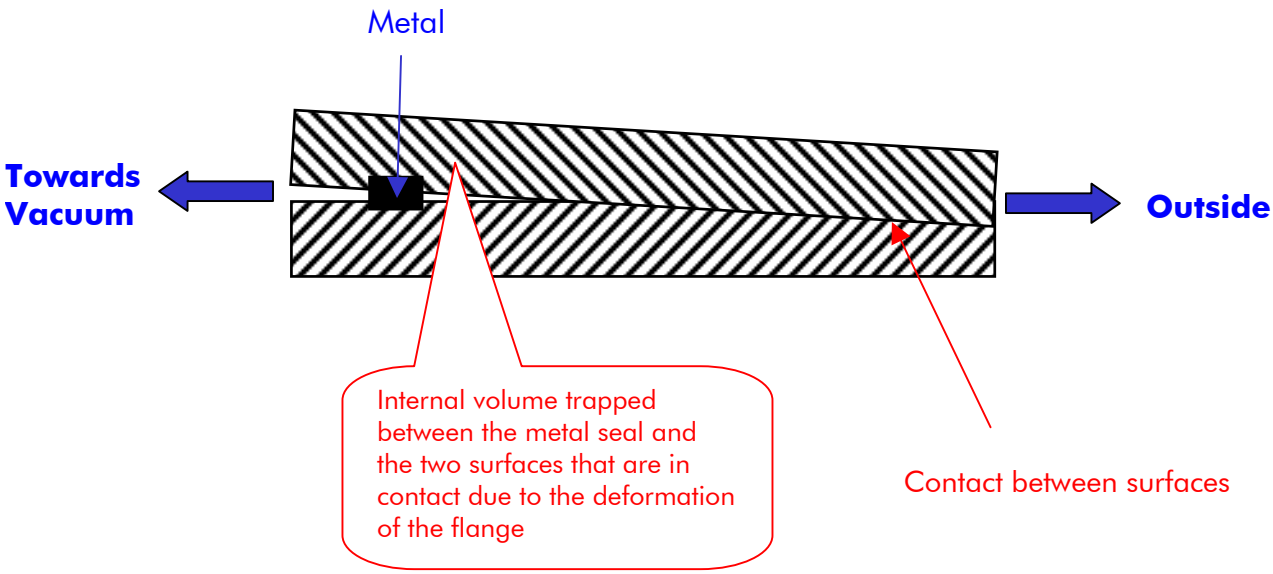
To avoid the above virtual leak, the correct way to design a dual o'ring concept is to have access to the trapped volume and evacuate it (at the same time vacuum is generated inside the chamber) with a vacuum pump. It is then easy to connect a helium leak detector and leak test each o'ring individually.



3. Metal seals flanges :
   When tightening the bolts of a metal seal, special attention should be taken to avoid trapping a dead volume (virtual leak) between the two metal flanges.



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To avoid virtual leaks from trapped volume between the two metal surfaces, (flanges to flanges) should have small groves to allow pumping any potential internal volume. These groves also allow performing a helium leak test.

Conclusion:

There are other types of virtual leaks that could be a source of aggravation for vacuum system engineers. Chances are, you may have experienced some of them already.
Our vacuum experts are available to help you during the design of your systems. Please feel free to contact us, we will be delighted to assist you.

Note: We welcome your inputs and comments. Please do not hesitate to contact us.
If you have a specific subject you would like us to write an article about, feel free to let us know, it will be our pleasure to oblige.

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