

Outgassing ...

... from the walls of a vacuum vessel and strategies for reducing it

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Vacuum System “Performance”

Vacuum Equation

$$P = \frac{Q}{S}$$

Where

P is the base pressure in the system

Q is the gas load in the system

S is the pumping speed available in the system

Why are we worried about outgassing?

- It may limit the performance of vacuum systems
- We cannot predict it
- It is difficult to measure
- We do not know the detail of the processes
- It costs money
- It affects processes and products

On the other hand

With experience, we can have a fair idea what to expect

We know the sorts of things to avoid in our vacuum systems

By baking long and hard, we can get rid of it

..... Or can we?

Limits to pressure

For UHV and XHV systems, outgassing of hydrogen will be the limiting factor in achieving low pressures

We will first of all look at the process of outgassing in a simple minded fashion

Then at what is found to affect this outgassing

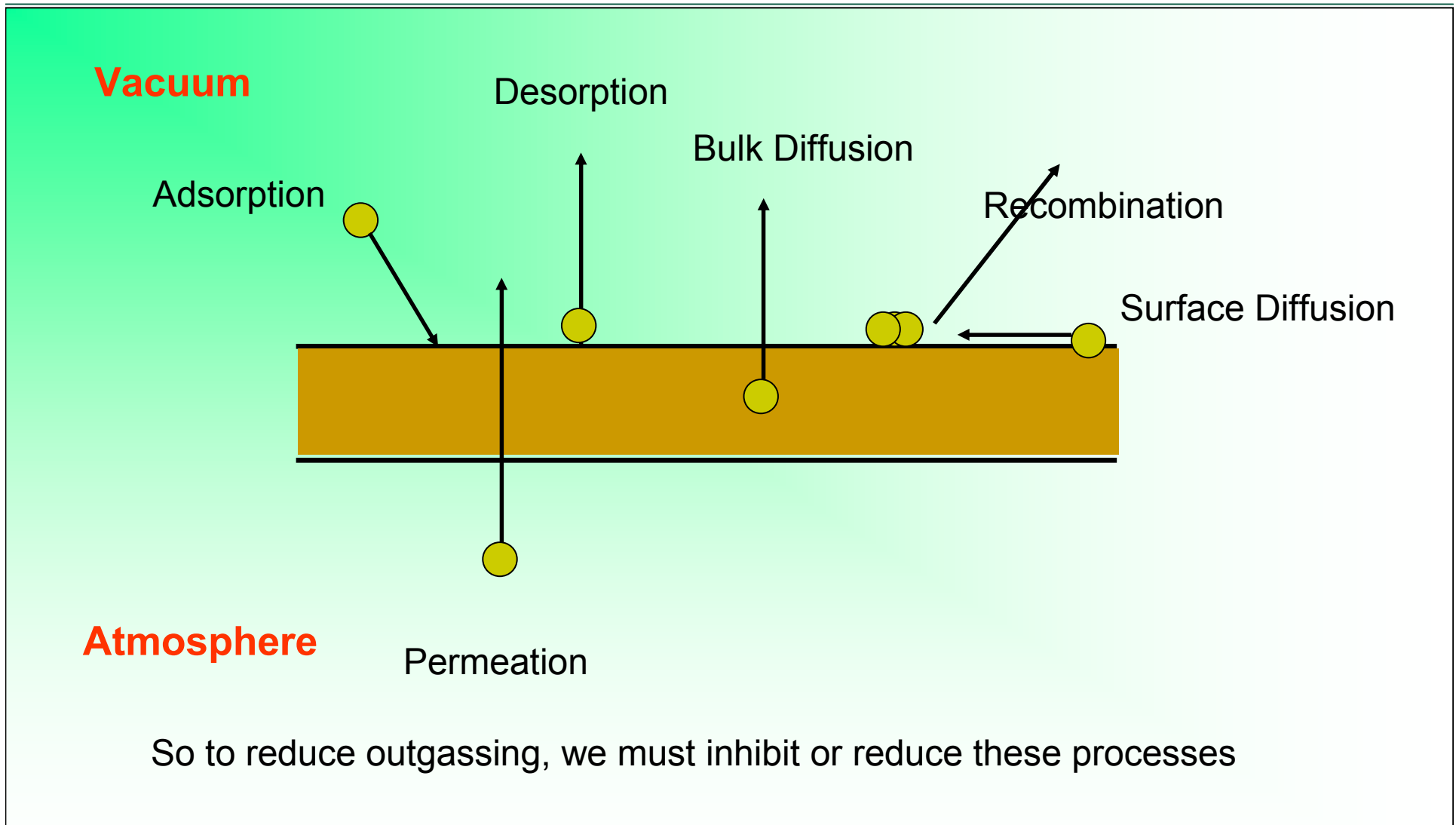
Mechanisms Contributing to Outgassing

Vacuum



Atmosphere

Mechanisms Contributing to Outgassing

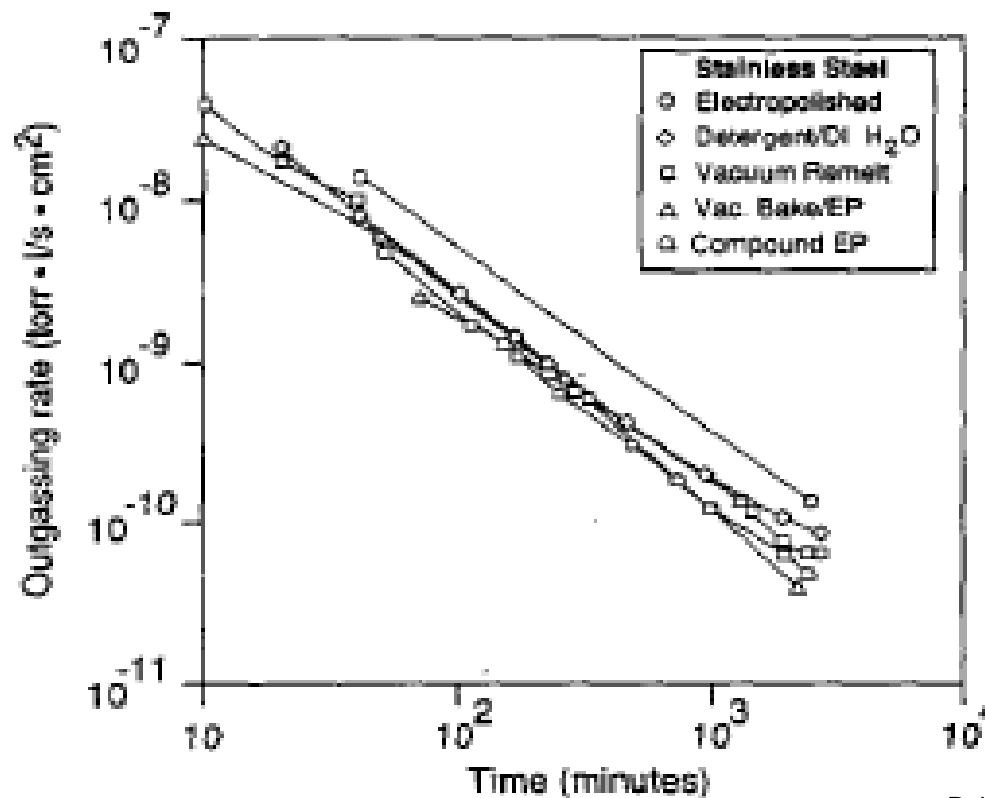


Reducing outgassing

- Permeation : barrier layer on surface (internal or external)
- Bulk diffusion : reduce dissolved hydrogen, induce trapping states (bulk or surface)
reduce or increase grain boundary density
- Desorption : reduce surface concentration
- Adsorption : reduce or fill surface binding sites
- Recombination : reduce surface mobility by introducing surface trapping sites

What affects Hydrogen Outgassing from Stainless Steel

- Conventional surface treatments (e.g. detergents, solvents, glow discharge) have only a small effect



Dylla, J Vac Sci Tech A11 (1993) 2623

Hydrogen Outgassing from Stainless Steel

- Conventional surface treatments (e.g. detergents, solvents, glow discharge) have only a small effect
- For technological surfaces, surface roughness has little effect
- Baking at moderate temperatures reduces the outgassing rate
- Successive bakes reduce the rate further
- Baking in air reduces the rate considerably
- High temperature vacuum firing reduces the rate considerably
- Thin wall vacuum vessels have lower outgassing rates than thick wall vessels

What do we know?

- The outgassing of hydrogen from stainless steel is complex
- Several different processes are involved – both diffusion and recombination have a part to play
- Fundamental properties, e.g. diffusion rates, not known to sufficient accuracy
- Better controlled, systematic studies are required, especially with regard to the thickness of the samples

What can be achieved?

Experience shows that an outgassing rate of the order of
 10^{-11} mbar l s⁻¹ cm⁻²
Is readily obtainable

An outgassing rate of
 10^{-13} mbar l s⁻¹ cm⁻²
is achievable with conventional techniques

Rates lower than
 10^{-14} mbar l s⁻¹ cm⁻²
are achievable with care, particularly in thin walled
vessels

Published values of outgassing rates

If we now consider outgassing from various materials, and not limit the species to hydrogen

- There is a great deal of data available in the literature
- Few systematic compilations
- One can almost select a value for a particular system of whatever one wants
- Certainly great spread in data and it is inconsistent
- Measurement conditions not standardised
- Measurement technique not standardised
- Pretreatments often not stated
- Materials often not well characterised

Published values of outgassing rates

- So is this a council of despair?
- Clearly, absolute values not well founded
- Number of valuable studies looking at *trends*
- *Folklore* can be of considerable use
- However, design work often based on unreliable and/or extrapolated data
- Designs tend to be conservative and therefore not optimised.

Strategies for Reducing Outgassing

- Thorough clean and bake – remove contamination
- Vacuum fire - depletion
- Air bake – oxide film – barrier layer or depletion
- Film such as TiN - barrier layer
- Getter film – barrier? trap?

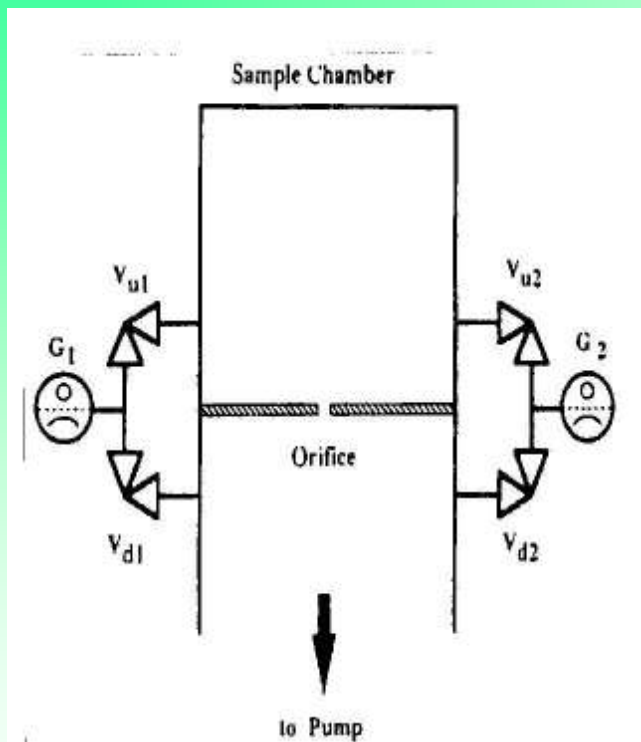
Methods of measuring outgassing

Two basic techniques

- Throughput
- Rate-of-rise (gas accumulation)

Methods of measuring outgassing

Throughput Method



$$Q = (P_1 - P_2) \cdot \frac{C}{A}$$

Conductance Modulation

$$Q = \frac{p_1 - p_2}{A \left(\frac{1}{C_1} - \frac{1}{C_2} \right)}$$

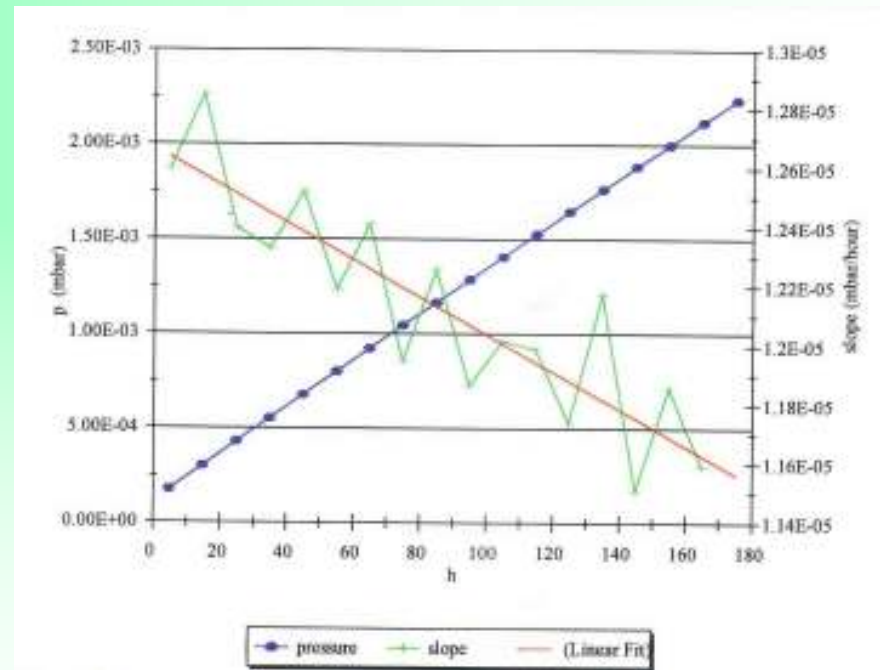
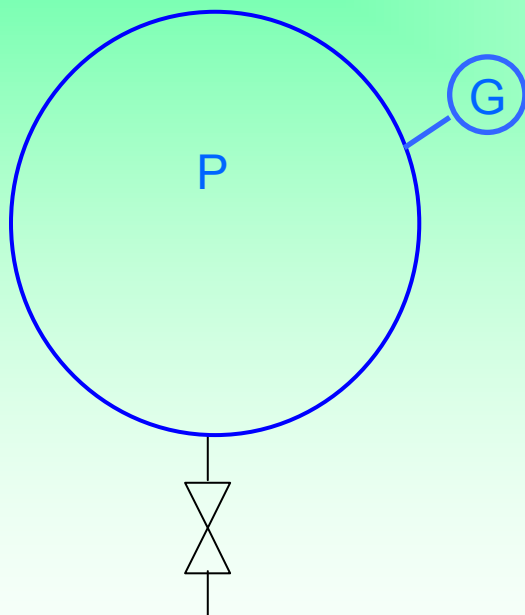
Jousten in Lafferty, *Foundations of Vacuum Science and Technology*, 1998

Methods of measuring outgassing

Rate of Rise (gas accumulation)

In a sealed chamber,

$$Q = \frac{dP}{dt} \bigg|_{t=0} \cdot \frac{V}{A}$$



Nemanic & Setina

Acknowledgements

Thanks to ASTeC Colleagues

- Joe Herbert
- Oleg Malyshev
- Keith Middleman

Colleagues at other laboratories

- CERN
- Diamond
- ESRF
- Others to numerous to mention