Vacuum technology Troubleshooting

Csonka István
Frigyes Dávid

Failures in a vacuum system

Failures:

- vacuum
- other

Not always easy to distinguish

Troubleshooting is very similar in both cases:

- Failure localization
- Dis/reassembling the subsystem failed

Design: think through… check points: isolating valves, windows, gauges

Before starting… think

Important! There is usually one (max. 2) points of failure till we start (typical exception: arc)… after starting: who knows

Thus, only failed systems should be fixed. Do not fix something just for fun. One should understand the error.

But if we found something unexpected (e.g. contamination)… try to find the route cause

Before starting… preparation

- Much space, order, cleanliness (cleaned tables, large sheet clean papers, clean Petri dishes)
- Laboratory logbook, draws (+photos)
- Try to avoid working alone, ask for help
- Consider everything in advance. It takes time
- One should not start Friday in the evening

Useful tools

- gloves
- documentation
- Multimeter
  - Galvanic contact
  - U, I, R
- Hand tools (pliers, tweezers, wrenches, screwdrivers, files)
- Mirror (large, hand mirror), dental tools
- Vacuum gauges with acoustic signal

Useful tools

pliers

tweezers

wrenches

files

Cotton gloves

Diamond power files

Types of errors

- Pumps
- Vacuum elements: seals, valves, feedthroughs
- Vacuum gauges, electronics, contacts, cables
- (Virtual) leaks, outgassing
  - Air (is present everywhere)
  - Water: can cause troubles, hard to detect (silicon O-ring seals)
- Supplies (water (T, p), electricity (U, f, cosφ), gases, lN_2)

Pump failures 1. rotary vane pump

- Pump does not start
  - Plugged in?
  - Fuse
  - Capacitor
  - Motor
- Pump starts but does not pump
  - Loose belt
  - Broken belt (1/more)
  - hole
- “pump has stopped”
- High pressure
  - Oil contamination
    - Condensed water – gas ballast
    - Solvents, gases
    - Level window: level, color, opalescent
    - Let the whole down – black band; precipitate
    - Replace regularly (95%)

Other rotary pump failures

- Loose v-belt
  - Frazzle: replace immediately
  - More belts: replace all
- Direct drive: usually works well
  - clutch
- Loose hoses, clamps
- Open gas ballast
- Regular renewal

Rotary vane pump comments

- If a roughing pump is a fore vacuum stage of a diffusion pump, it is bad if the pump suddenly stops. Automatic protection can help (isolating valve closes immediately, diffusion heating off, emergency cooling on)
- For localizing the problem, close all valves, and use the gauges. Use the chamber or external gauge if necessary.

Pump failures 2. diffusion pump

- Pump does not start
  - Connector (terminal block), magnetic switch
  - Thermal trip (usually not accidental – causes? Cooling?)
  - Heating element – single element – discontinuity; more elements in parallel – resistance, current, power consumption
- Pressure jumps
  - Few oil
  - Failed o-rings
  - Roughing failure
- Small power
  - Clamp meter
- Oil backflow (e.g. window)
  - Roughing failure
  - Isolating valve opened to fast
  - Atmospheric jump
  - Cooling not satisfactory

More diffusion problems

- Bad pressure
  - Oil level
    - Level check (warm rather than hot)
    - refill
  - Properties of the oil
    - color (yellow good, brown bad)
    - odor (usually rotary pump)
  - Fast cooling (N_2, compressed air instead)
  - System contamination
- High fore pressure
  - Fill in/out
  - leak
  - Contaminated rotary oil
- High HV pressure
  - Leak
  - Isolation (chamber/pump)
  - Generally, not easy to find the leak
  - Leak detection

Pump failures – 3. ion pump

- Pump does not start
  - Leak detection
  - Contamination (e.g. molecular sieve)
  - Atmospheric pressure during operation
  - Age approaching lifetime
  - Sorption pump regeneration
  - Roughing leak
  - Sorption pump valve (stopper)
- Short circuit
  - Clean insulators (ceramics)
  - Check cable
  - Flakes (cleaning)
- Controller switches off
  - Strong leak
  - Arcing/shorting cable
- Leaking current
  - Field emission

Pump failures – 4. TSP

- Pressure does not approve after switching on
  - Base pressure high
  - TSP switches on too often
- Pressure jumps
  - Filament/Ti-source needs replacement

Pump failure – 5. cryo pump

- Compressor does not start
  - Supply voltage (plug)
  - He-fill
- Compressor works, expander does not
  - Connection ok?
  - Expander motor burned out?
  - Expander power supply ok?
- Pump does not cool down
  - Bad vacuum
    - Bad roughing pressure
    - leak
  - He-tubes seal well?
  - He-fill
  - Overheating?
  - Overheating trip?

Cryo failure 2.

- Slow pumping
  - Pump approaching capacity – regenerate
  - General contamination
  - Active carbon wore out (odor)
- Noise expander
  - Erroneous capacitor
  - He contamination (not serviceable)

Vacuum system failures

- Detailed logbook (dates) of basic performance indicators
  - Pressure (HV/roughing)
  - Temperatures
  - Sensitivity (e.g. MS – can be connected to vacuum system problems)
  - Pump down / pressure rise curves – t(p1→p2)
  - Background composition (RGA)
  - Look at the system (windows)

Sudden change needs to be inspected, slow change is an indicator for maintenance (schedule)

Useful tests for checking HV-valve

- Valve between the HV-pump and chamber closed → chamber vented → HV-gauge at the pump (or roughing gauge, if HV gauge not present) must not change at all (if it does: injured o-ring, clogged dirt)
- Chamber at fore vacuum (~1mbar), isolating valve closed → vacuum must not improve

Cleaning

- Metallic parts
  - Mild contamination: solvent (pure (!) acetone, chloroform(?)+ethanol)
  - Heavily dirty surface: polishing (powder rather than paste: Al_2O_3, SiC, diamond…, mesh, wet (EtOH, ^{i}PrOH), glass eraser, protect yourself! Mask!
- Ceramics, PTFE (Teflon^{TM})
  - Boiling in cc HNO_3, mechanical cleaning (file, diamond file)
- Elastomers (o-rings)
  - Thorough cleaning with ethanol (No acetone, chloroform)

Cleaning: what looking out for?

- O-rings should be wiped with alcohol (no chloroform, acetone); metallic parts with chloroform, acetone
- Vacuum grease (?) – not recommended, very thin layer
- Polishing powder must be removed completely

After cleaning

- First pumpdown after cleaning is always slower than general
  - Adsorbed water on surfaces
  - Traces of solvents
  - Human grease from hands (even at high level of precautions)
  - Oils in the system (from rotary, diffusion pumps) must desorb their solvent content
  - Seals (o-rings, PTFE-parts) may have injured (sometimes heating helps)

Some useful hints

- Opening of the system should be as short as possible (mainly water adsorption)
  - Preparation!
  - Vent with dry nitrogen instead of air
- Parts should be stored under dry nitrogen/vacuum
- Gloves (cotton or powderless elastomer)
- lN2 traps should always be filled while operating and taken away and cleaned after venting
- Check the compressed air system (if any); valves, filters
- Check cooling water (pressure, temperature, hardness) – closed circuit

Leak detection – leak types

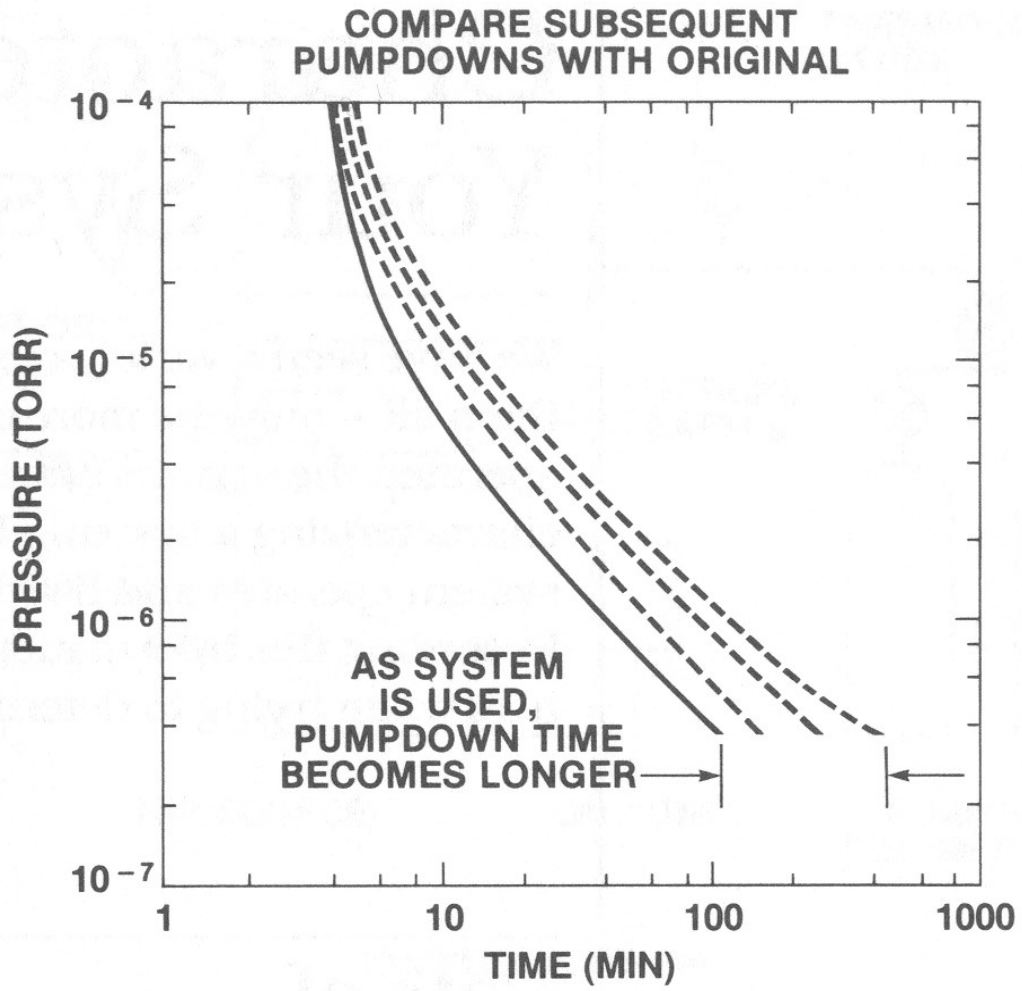
- Important – leaks are present everywhere

- Virtual leaks
  - Outgassing
  - Closed volumes (air under screws, double o-rings)
  - Permeation (e.g. o-rings)
  - Hole in the cooling water pipes (scale precipitation)
- Real leak
  - Permeable channel (generally microscopic)
  - Generally at material connections (tilted flanges, welds, soldering)
  - Rarely inside the material

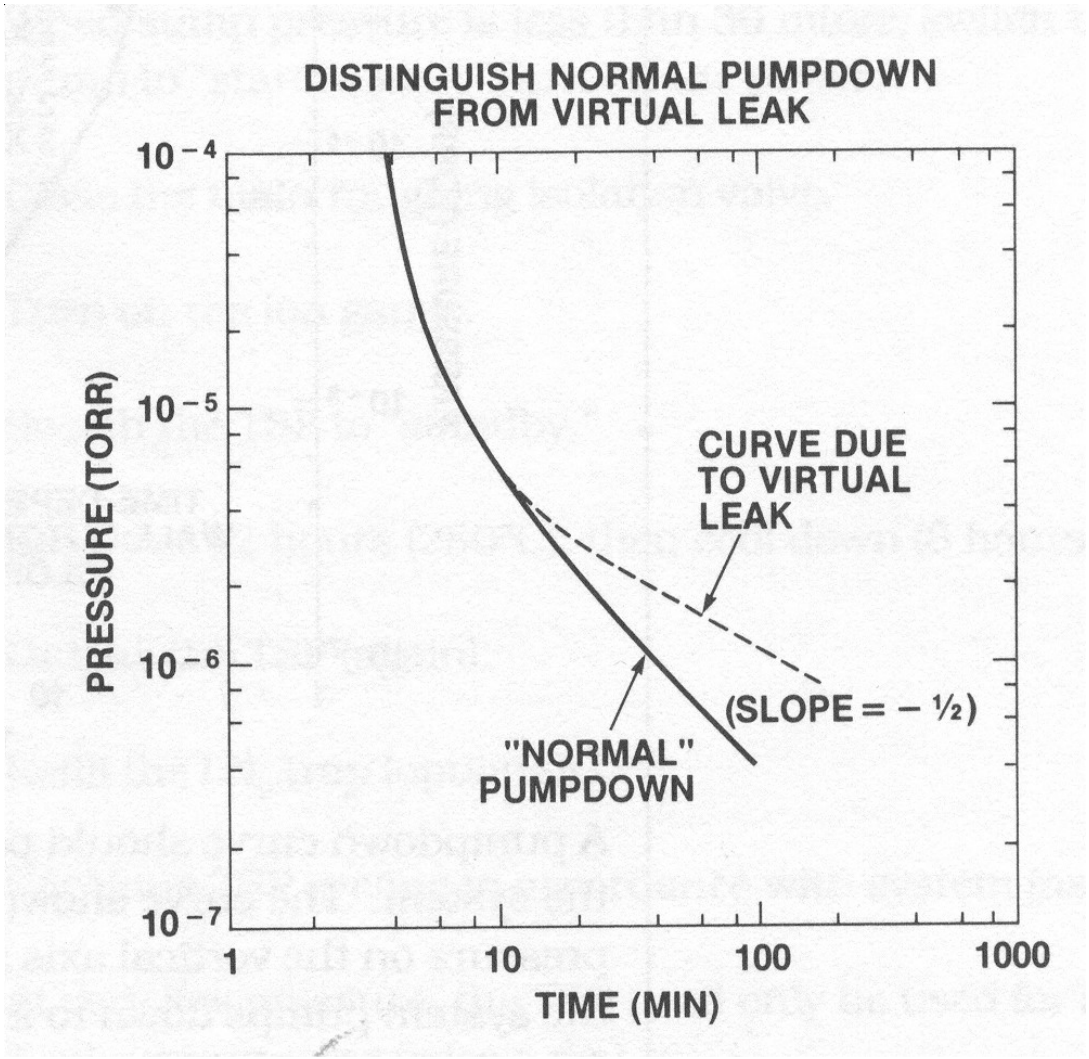
Distinguishing between dirt, leak, virtual leak

- Pump down curve: pressure-time log-log plot
  - If recorded regularly, there is reference
- Venting curve: the same in the opposite direction
- Time between pressures p1 and p2 twice (ore more times) one after another. Leak will give the same (close) time, in virtual leak the second will be much faster (even 3x, 5x)

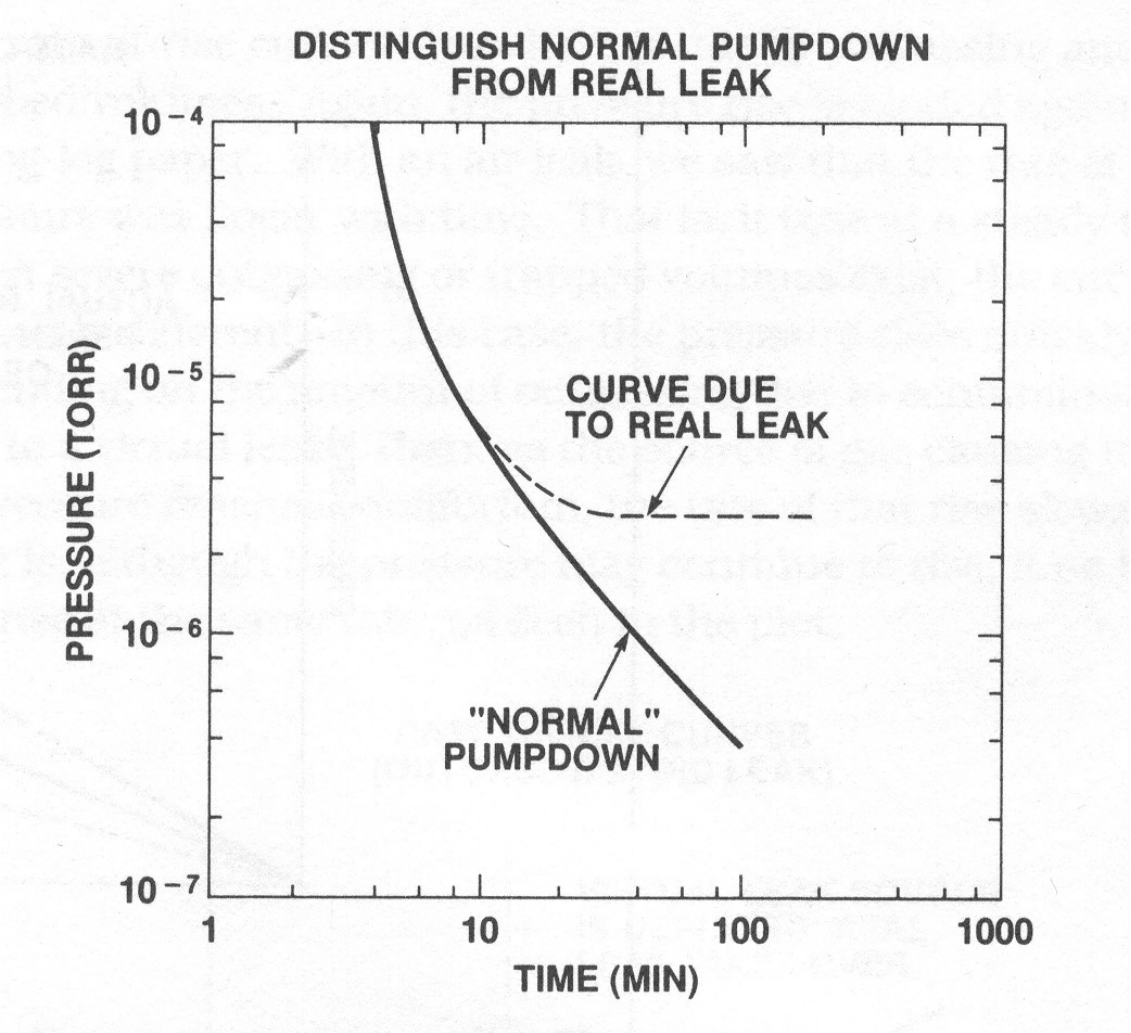
Pumpdown curve (normal case)



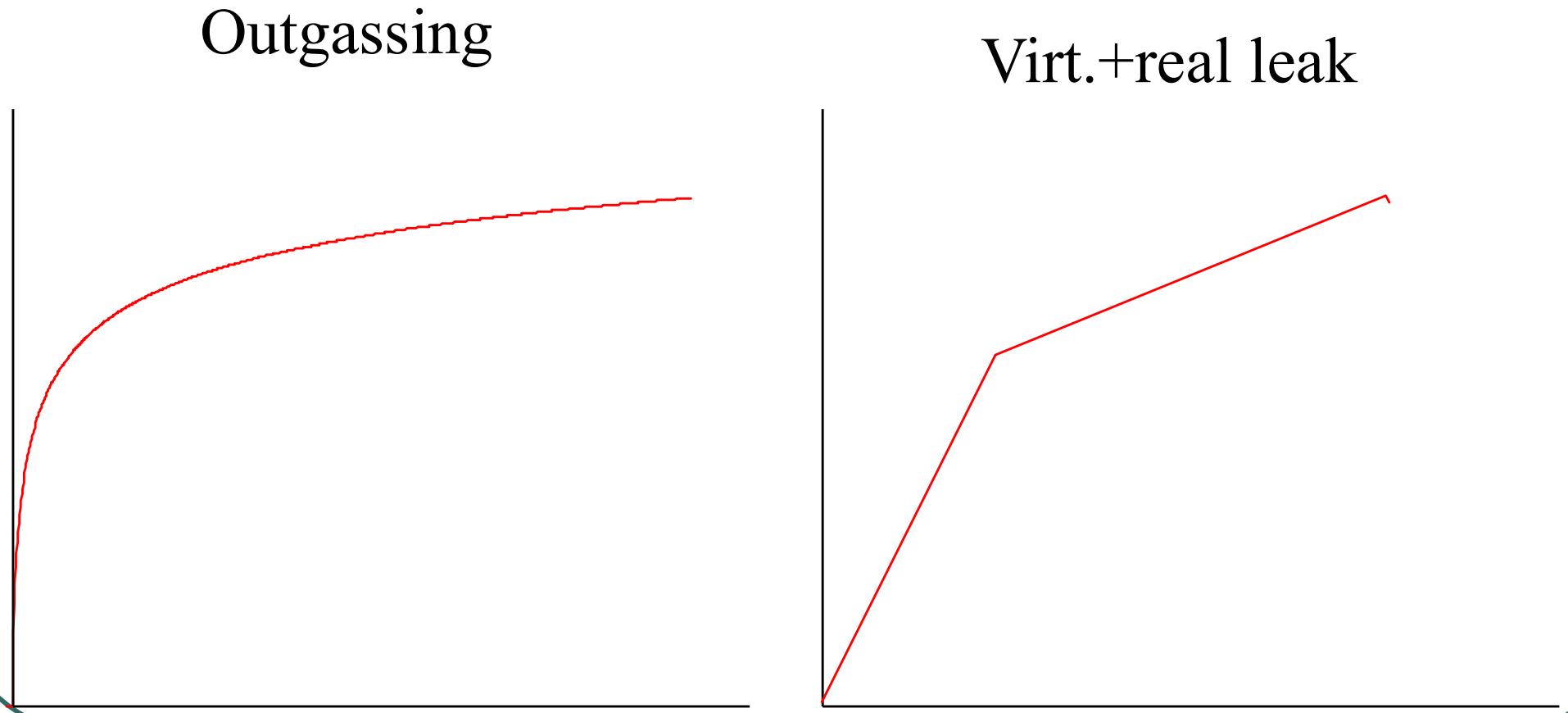
Pumpdown curve (virtual leak)



Pumpdown curve (real leak)



Pressure rise curve



Leak detection methods

- Tesla-coil
  - High frequency, high voltage power supply
  - Glow discharge
  - Applicaple only at insulators (e.g. glass)
  - Indicate the leaking place
  - Indicate the contamination (color)
  - Can hurt the glass
  - Can cause explosion
- Solvent (alcohol) method
  - Some ethanol is injected close to suspicious places – gauges are checked
  - Works both in fore and high vacuum

Leak detection 2: helium method

- Some helium is blown to the suspicious points
- He is detected mass spectrometrically
- Why helium
  - Light (high diffusion velocity)
  - Background is low (rare in air)
  - Selective (there is no other ion, m/z=4)
  - No harm (instrument, humans)