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CROSSOVER PRESSURE AND CRYOPUMPING

When the term "crossover" is applied to vacuum pumping, it refers to the switching of one pump to another in the pumping process. In most cases, it would specifically refer to the transition from roughing pump to high vacuum pump to complete the pumpdown process. With capture pumps such as sputter-ion, getter, or cryo pumps, the crossover point is not only important but crucial. This is because the crossover point is where the capture pump must shoulder the entire pumping burden without overloading.

The Flywheel Effect

Assuming that the cryopump is already cold and valved off, as is the usual practice, two things happen when the cryopump's valve is opened to the chamber for crossover. Most importantly, the gas that is still in the chamber will begin to condense on the pump's cold arrays. As condensation occurs, the heat of condensation is released, and this latent heat must be absorbed by the pump without causing it to warm up and lose the capability to condense gas. Of secondary importance, the gas in the chamber will enter the pump and cause the thermal conductivity of the residual gas in the pump between the cold arrays and the warm pump wall to increase thermal flow, due to the additional molecules available for heat transfer. This is the same effect a thermocouple or Pirani gauge uses to determine pressure.

A good mental technique for understanding the effects of the sudden heat load can be to picture a mechanical analog in terms of a flywheel. A spinning flywheel can be tapped to release stored energy as long as the total energy load does not exceed an amount that would slow the flywheel to below some critical rotational speed. The cold pumping arrays in a cryopump can be looked at in much the same way, in that they can only absorb as much heat load as is allowed by the heat capacity of the arrays and the cooling power (energy removal) of the pump's refrigerator without raising the arrays' temperature beyond a critical point. In most cryopumps, that temperature is often cited at just above 20^{o}K for the second stage charcoal bed. Above this temperature, the charcoal bed will begin the release of previously pumped H_2, which will cause an increase in the thermal conductivity of the residual gas. This additional heat load will raise the temperature to an even higher point, cause further H_2 release, and so on, until the pump enters an uncontrollable and unintentional regeneration-type warm-up.

The Crossover Point

Prospective cryopump users will often search in vain through a manufacturer's data sheets for a maximum crossover pressure specification. Instead, they find a crossover specification given in torr liters. Initial confusion aside, there's no other way to define the crossover point. It's not the pressure that's important but the total amount of gas that the cryopump can handle without warming up. Since two chambers of differing volumes will contain differing amounts of gas at a given pressure, giving a crossover pressure to a particular pump would be useless at best. Just divide the torr liter specification by the chamber volume in liters to determine the maximum crossover pressure, in Torr, for the pump on that particular chamber. It can be clearly stated, then, that if a chamber is evacuated to the crossover point by a roughing pump, the roughing pump can be valved out and the cryopump valved in without fear of overloading the cryopump.

The roughing pump used to rough out a chamber prior to cryopumping is sometimes erroneously referred to as a backing pump. Backing pumps are required for momentum transfer pumps such as diffusion and turbomolecular pumps. The backing terminology is used because these pumps only operate within a reduced pressure envelope and require a support pump behind them. Hence, backing pump. Since capture pumps do not require a support pump to operate, the term "backing" is incorrect and confusing.

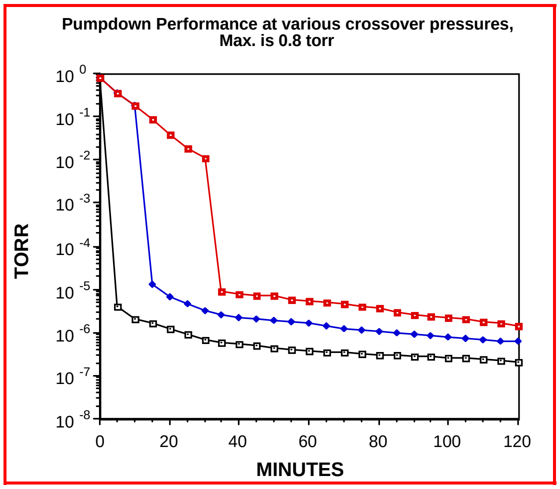
Choosing a Crossover Pressure

A certain amount of misunderstanding seems to focus around the choice of crossover pressure for a particular system or process. There is a tendency to assume that since a cryopump is a capture pump, it is best to cross over at the lowest possible pressure in order to limit the amount of gas that it must capture and hold. The thinking seems to be based on the erroneous assumption that the pump will "last longer" before it requires regeneration to release all that pumped gas. The truth of the matter is that a cryopump will pump a chamber down from the crossover point well over 3,000 times before becoming saturated by volume gas. Since, in the real world, this is seldom accomplished in a practical sense, some explanation is required.

Barring special applications, the usual need for regeneration is caused by H_2 buildup in the charcoal bed beyond the pump's capacity to sorb further H_2. The source of this H_2 is not from volume gas but from the H_2 in the residual gases that is constantly available when the chamber is at high vacuum. The source of the H_2 is complex, but most is from cracked H_2O fragments and from surface/volume reactions on the chamber surface. Since a normal cryopump application will require extensive time at high vacuum, a 3,000+ number of cycles will seldom be obtained without regeneration being required. Rough pumping to pressures below the crossover pressure will gain nothing, but it will cost considerably.

The Cost of Low Crossover Pressure

The major cost of roughing to a pressure lower than required is time. In a commercial process situation where product throughput is important, total cycle time is important. Since most roughing pumps will lose pumping speed as the chamber's pressure is lowered, the elapsed time to reach a lower-than-required pressure will be extended. The figure shows the pumpdown performance of a chamber where the crossover is accomplished at various pressures: 12 torr (maximum pressure), 0.8 torr, and 0.01 torr. It can be easily seen that the extended time to crossover to achieve lower crossover pressures gains nothing and costs time since the time extension is spent entirely on roughing when the high speed of the cryopump will overcome the higher pressure crossovers gas loads.



Pumpdown Performance at 3 Crossover Pressures Showing Loss of Overall Performance at Lower Crossover

In cases where an oil-sealed mechanical pump is used for roughing, there is an even more important cost. The backstreaming of oil vapor will increase as the pressure is lowered. Oil vapor that enters the chamber can have a detrimental effect on most processes, but a more important fact is that oil will end up in the charcoal bed of the cryopump and sooner or later will require replacement of the charcoal array. Charcoal, saturated with oil-ice will no longer pump H_2. The cryopump manufacturer has carefully determined the maximum crossover, and they mean it. Go ahead and cross over to the cryopump at the maximum pressure.