Lesker Tech "...vacuum science is our business."

Volume 3, Issue 2 **May, 2004**

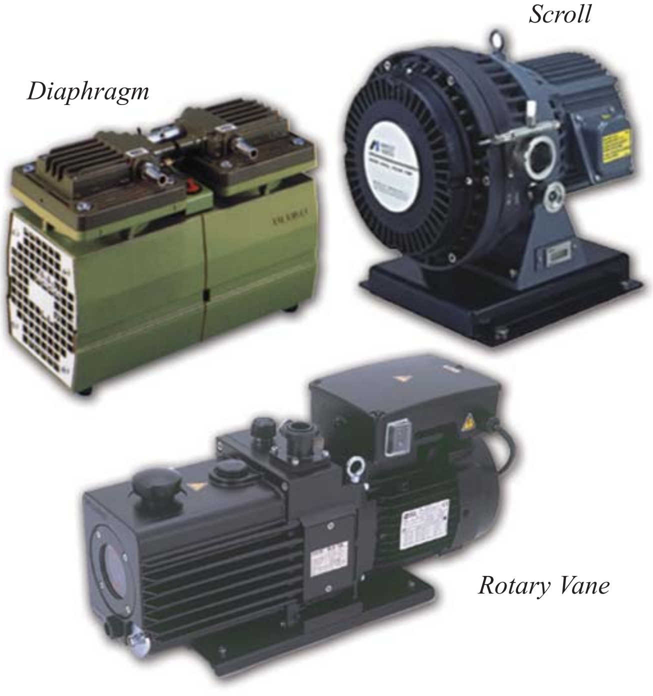
Pumping Up Your Applications

Part 2

Introduction

Recall from *Lesker Tech Vol 3 Issue 1*, that we started this journey towards ***Applications Classifications*** by classifying pumps in various ways that had some applications significance. In this issue, we are returning to Table 1 from the last issue and will examine in greater detail the applications implications of the named mechanisms.

In each pressure segment of Table 1 I'll summarize the overall capabilities of the various mechanisms. I'll also note (in a haphazard manner) any benefits and liabilities and add 'typical' applications for each pump type, where I know them. Please don't expect anything greater than an overview. If you really want to know all about a specific pump, hit the vacuum technology books. My first choice would be *Modern Vacuum Practice** by Nigel Harris. He writes in British English, but don't hold that against him. The technical detail on pumps is excellent.



ULVAC Rough Pumps

It's almost a given that I've left out a pump mechanism you feel constitutes a grave oversight. Well, tell me about it. Anything addressed to techinfo@lesker.com will find me. If your argument is valid and you add some appropriate applications for the mechanism, I'll make sure to squeeze it in somewhere and acknowledge you.

* To buy this book go to www.modernvacuumpractice.com or contact us.

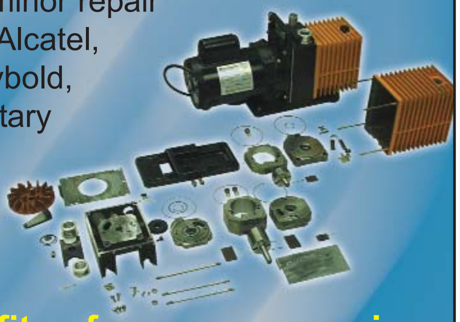


Table 1 — Pumping Mechanisms

Coarse (760 – 1 torr)	Rough (760 – 10^{-3} torr)	High Vacuum (10^{-4} – 10^{-8} torr)	UHV (10^{-9} – 10^{-12} torr)
Rotary vane (oil)	*Rotary vane (oil)*	*Diffusion (oil)*	*Ion (rdp)*
Liquid ring (water)	*Rotary vane (dp)*	*Turbo (ceramic bearing–dp)*	*Getter Evap (rdp)*
Screw (dp)	*Rotary piston (oil)*	*Turbo (mag.lev bearing–rdp)*	*Getter Non-Evap (rdp)*
Hook & claw (dp)	*Recip. Piston (rdp)*	*Cryogenic (rdp)*	*[Turbo (rdp)]*
Steam ejector (water)	*Scroll (rdp)*	*Molecular drag (dp)*	*[Cryogenic (rpd)]*
Venturi (air)	*Screw (dp)*	*Hybrid-Turbo/Drag (dp)*	
Diaphragm (rdp)	*Cryosorption (rdp)*	*Hybrid-Turbo/Drag (rdp)*	
Vapor booster (oil)	*Roots (dp)*		

Coarse Pumps

The need for a division labeled *coarse* is arguable. Don't these all fit under the *rough* heading? I agree with the few who answer—no. The *coarse* designation applies to pumps that can move scads of gas with inlet pressures as close to atmosphere as you wish, all day, every day—something few rough pumps do without protest.

Rotary Vane

In the *coarse* regime, **rotary vane** (oil-sealed) pumps are different animals from those listed in *rough* pumps. Here, the pumps have more vanes (to take smaller bites at the gas load apple?), many stages of exhaust filtering (to prevent oil mists being blown out), poorer ultimate pressures, and are generally able to accept 'rougher' operating conditions than *rough* regime rotary vane pumps. Particularly, they are better suited to handle higher water vapor loads.

These pumps show up in industrial applications: vacuum forming of plastics; central vacuum systems where the utility 'vacuum' is piped around the building; evacuation prior to oil impregnation for electrical transformers or chemical impregnation for lumber; and organic solvent extraction. For the last application, often OTO rotary vane pumps are used. OTO is *once-through-oil*, meaning the lubrication/sealing oil is discharged continuously to a sump and replaced with fresh oil from a reservoir.

Since 'gas hog' pumps are usually physically large, the oil volume to fill one is similarly large. This makes filling such a beast with inert fluid expensive. They are not used in corrosive processes where the gases will chemically attack hydrocarbon pump oils.

Liquid Ring

In **liquid ring** pumps, the gas sealing and compression is done with water (although some specialized operations run with silicone fluids or other liquids). Unlike the rotary vane, the **liquid ring** pump's impeller doesn't 'wipe' against any surface, it simply sloshes water around. This lack of contacting surfaces means these pumps keep on trucking no matter what you throw at their inlets. . . huge quantities of solvent vapor; slugs of liquid; dust; particles; fruits and vegetables; the occasional sub-compact car; it's all the same to a **liquid ring** pump.

They show up in: massive freeze dry operations; solvent extraction; vacuum distillation processes; and many food handling applications that need vacuum. One interesting side-issue—water flows continuously through the pump and is replaced either by fresh city-water or re-circulated chilled water. This means, despite gas compression and the inverse Joule-Thompson effect, these pumps run at room temperature, give or take a few degrees. For applications involving pumping blimp-loads of solvent vapor, the 'cold' water condenses the vapors, producing effective pumping speeds far in excess of rated speeds—a nifty bonus. On the down-side, these pumps use a river of water and their ultimate pressure is just this side of terrible.

Screw & Hook/Claw

The **screw** and the **hook/claw** mechanisms (and perhaps I should throw in the multi-stage **roots**) are quite different mechanical ways to compress gas with moving metal surfaces that don't quite touch. As you might expect, since the 'seal' is the dynamic interaction of gas and the moving bits, the ultimate pressure is only OK. But, with no oil or water seals, these *dry* mechanisms obviously avoid all the problems associated with vapor backstreaming or chemical attack on the pump's sealing liquid. They can also be built the size of a small truck with pumping speeds of ~1300 cfm (~2200 m^3/hr).

Added to this, the metal surfaces can be coated with films that resist attack from the corrosive skeletons found in any semiconductor processing closet. As you might expect, huge pumping speeds, close machining tolerances, and the ability to survive operating conditions—including dust ingestion—that instantly deep-sixes other pumps, mean you should lie down before asking for the price.

Steam Jet Ejectors

These are strange 'in-between' devices that might be listed in either coarse or rough regimes, or perhaps neither. Single-stage **ejectors** are such gas haulers and reach such poor ultimate pressures that they are true *coarse* pumps. Multi-stage steam ejectors reach pressures near the bottom of the rough regime. However, some 'embodiments' of this mechanism need backing pumps that vent to atmosphere. Can these models be called *coarse* pumps at all?

This mechanism's 'in-between-ness' aside, steam jet ejectors have four major assets: no moving parts; extreme reliability; an ability to ingest all sorts of gas, liquid, and solid rubbish including corrosives; all at unbelievably high pumping speeds. Search for '**steam ejectors**' on the web and among the umpteen hits, it's unlikely there is any mention of pumping speeds in units we know. These guys specify 'loads' as in—1000 kg/hr load. Do the math for water vapor and this looks roughly equivalent to 700,000 cfm at 1 torr!

We were once approached by a company that 'dries' orange juice for a single, big customer. (Can you say '*mil-i-tary*'?) They used **steam ejectors** and liquid ring pumps and were looking for alternatives. Their concern was the ecological effects of their water 'operating budget'—1 million gallons/day. The mind boggles!

Vapor Boosters, Eductors, & Venturi

I've lumped these together since they are really variants of the steam ejector mechanism. They are physically smaller, have lower pumping speeds, and use a 'motive medium' other than steam. The **vapor booster** pump uses oil vapor and is often made in multiple stages to reach lower pressures. They are applied as substitutes for diffusion pumps where high speed and crummy high vacuum levels are needed.

Eductors and **venturi** pumps overlap in design and application. Both are air-driven (although I've seen reference to water-driven **eductors**). The word **eductor** seems to imply a device that conveys pills, powders, pellets, parts, pieces, dust, dirt, sediments, slugs, slag, and maybe even slime. The **venturi** pump is much more refined—drawing air for aspiration, agitation, or filtration. If you did just one vacuum filtration in your high school chemistry lab life, you probably used a water-driven venturi pump.

Diaphragm

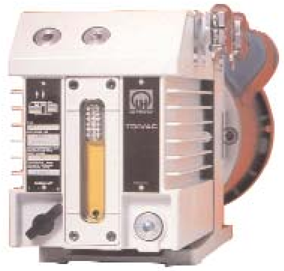
The lowly **diaphragm** mechanism hardly fits the 'scads of gas' description but the single-stage pump's operating pressure range puts it squarely under the coarse heading. But here's a heads-up about diaphragm pumps—there are two distinct types: air-operated and motor-driven. The former are big in all sorts of unmentionable applications like pumping semi-liquid sludges for oil well drilling, sewage treatment, and transporting smelly, liquidized scuzzies.

Yeah, let's stick with motor-driven **diaphragms** that pump gases. Their applications include vacuum filtering in chemistry labs and, in Teflon versions, handling low flows of highly corrosive gases. Some multi-stage **diaphragms** reach low enough pressures to back some types of turbo pumps and should, perhaps, appear in the *rough* regime.

Rough Pumps

Rough pumps are work horses. There are probably more of these in daily operation than all other pump types added together, and then some. Like coarse pumps, *rough* pumps (excluding the last two mechanisms listed) can have atmospheric pressure at the exhaust. However, most regular *rough* pumps, operated at continuous high inlet pressures (i.e. in the coarse range) will either over-heat or blow oil out the exhaust depending on the mechanism. To operate properly, they need to reach the lower end of their pressure range in a 'reasonable time'.

Rotary Vane (oil)



If *rough* pumps are work horses, **rotary vane** pumps are Clydesdales—you can depend on them to bring home the beer. Around the world at any instant, there must be a million of these operating in all sorts of appropriate and inappropriate applications. They are the 'universal' pumps for schools, universities, industrial and governmental R&D labs, and factory floors. Their applications as backing and roughing pumps range far and wide, covering fields as diverse as: scientific equipment such as electron microscopes; emptying gas cylinders at industrial compressor companies; removing air in powder metallurgy and ceramic processing; making neon signs; molding plastics; and all those you know about and are now wondering why I didn't mention.

Rotary vane pumps have one major disadvantage, they generate oil vapor that backstreams. But, their pluses are legion: maximum pumping speed bang-for-your-buck; good ultimate pressures in the *rough* regime range; high reliability; good range of pumping speeds; and broadness of application; to name but a few.

Rotary Vane (dry)

This pump's mechanism is identical to the rotary vane (oil) except there is no oil to lubricate or seal. And why doesn't it self-destruct in less time than a *Mission Impossible* tape? Well, the vanes are made of carbon (graphite?) and are, therefore, self-lubricating. However, the modest pumping speeds, poor vacuum levels, relatively short life-time, and terrible screech (at least the two I've operated), mean these pumps are found in only two niches. First, where users have lost all high frequency hearing, and second, for roughing chambers where oil vapor is absolutely forbidden and scroll pumps haven't been invented yet. If you know a valid application for these pumps, please tell me (techinfo@lesker.com).

Rotary Piston

Some of the higher pumping speed **rotary piston** pumps (now there's a pump mechanism I challenge anyone to describe!) may belong in the *coarse* regime. They are gas hogs. But most are simply *rough* pumps with large pumping capacity, according to my pressure criteria. I've seen them backing huge diffusion pumps in high gas load industrial processes such as: diffusion bonding of aluminum heat-exchanger parts; metal heat treating furnaces; degassing titanium bars; and casting superalloys into turbine blades.

As that list indicates, unless you are into huge vacuum systems, **rotary piston** pumps are probably way more pump than you need. And remember, they're oil sealed and that means. . . .?

Reciprocating Piston & Scroll

Reciprocating piston and **scroll** pump mechanisms are as different as chalk and cheese. But their reasonable pumping speeds, reasonable ultimate pressures, reasonable price, and *really dry* pumping mechanisms means they compete with (and are grabbing market share from) rotary vane pumps.

Over the last 15 years users have slowly awakened to the application problems caused by oil vapors in the chamber. As a result, these two dry pumps have become very popular in *clean* applications that require continuous or intermittent rough pumping.

There are three applications for which **reciprocating piston** or **scroll** pumps are unsuited. (1) With their limited pumping speeds they don't do well pumping large chambers or high gas loads. (2) If a diffusion pump is used for high vacuum, backing it with one of these is just plain silly. (3) Their acceptance of corrosive gases and dust is close to zero and they're not too swift with water vapor either.

While not the answer to every vacuum technology maiden's prayer, if *clean* and *really dry* are part of the application's description, look carefully at these pumps.

Cryosorption

The **cryosorption** pump has a single applications niche—as the rough pump for infrequently vented UHV systems. They require LN2 and all together too much 'hands-on' manipulation to make them wildly attractive for general *rough* pump use. But in their narrow niche they are tough to beat for simplicity, price and cleanliness.

Roots

This last *rough* pump is an odd-ball, but a useful odd-ball. The **roots**, also called a **booster**, **blower**, or **rotary lobe** pump, won't exhaust to atmosphere and, must be mounted with a normal rough pump behind it. A common combination, called a **booster pack** or **blower pack**, is a **roots** solidly mounted on top on a rotary vane.

The **roots**' dry mechanism greatly increases pumping speed at low pressures. Between 10^{-1} torr and 10^{-3} torr it might increase the gas throughput by a factor of 10 to 20, turning a modest *rough* pump into a gas hog. One company builds *roots* blowers big enough to host a ballroom dance contest. Maximum pumping capacities of 97,000 m^3/hr are quoted—that's roughly 57,000 cfm in American money!

However, you don't just switch on a blower at full speed and forget it. At atmospheric pressure, gas compression overheats the pump's and/or burns out the motor. At high pressures the **roots** mechanism is either automatically bypassed or has a variable speed drive (see sidebar).

I first used the **roots** mechanism in molecular beam applications where large gas loads must be removed from the initial, beam formation stage. But I've seen them increasing the capacity of rotary piston pumps that are either backing huge diffusion pumps or just roughing very large chambers. Look on a **booster pack** as a super rough pump below 40 torr and you'll get the idea.

Roots Variable Speed Drive

At the risk of boring even the most avid techie: a feedback loop monitors the power delivered to the pump's motor and keeps it constant at some pre-set level. At high inlet pressure this power setting causes the rotor to just flop around without much gas compression.

As the chamber pressure is pulled down by the rough pump, the reduced air resistance allows the rotors to speed up, still at the same power. At a chamber pressure of ~30 torr, the rotors are chomping along at full chat and delivering full pumping speed. The point of this background is to nail home the fact-you get no real benefit from any roots until the inlet pressure approaches 10 and 40 torr (depending on the design). But from there down to ~10^{-4} torr range, watch out.

High Vacuum Pumps

Diffusion

From ~1910 through the mid 60s, the **diffusion** pump was the only *high vacuum* pump mechanism worth noting and it was used for every high and ultrahigh vacuum application. (Oh yes, in an expert's hands, a trapped diff pump can generate UHV.) With two major exceptions, it is much less popular today. The exceptions are: (1) huge chambers with high gas load conditions such as diffusion bonding furnaces or NASA's space simulation chambers; and (2) final bake 'n seal step used by every (CRT) television tube manufacturer.

To flesh out these examples—I understand the operating pressures and materials for the recent Mars Lander air bags were tested in the "world's largest vacuum chamber" at NASA's Plum Brook facility in Ohio. This chamber is equipped with 32 **diffusion** pumps, each 48" diameter.

Photo found on NASA Plum Brooke's website

Every TV manufacturer has a separate assembly 'line' for each CRT size they make. Each line consists of 100 to 150 vacuum pumping carts chuntering round a track that passes through a long bake-out furnace. And on each cart is a diffusion pump. (Why did I nearly break into the chorus of "Old MacDonald..."?) Let's say the manufacturer builds five different CRT sizes, that means ~600 diffusion pumps (plus spares).

The problem with **diffusion** pumps for other applications is—yes, you've guessed it—oil vapor backstreaming. To my knowledge (and that company's credit) only Varian has measured and published backstreaming rates. The intermediate-sized VHS6 pump, for example, backstreams roughly 10mg/hr of oil.

Yes, LN2 traps will remove oil vapor, that's how UHV pressures are attained. But neglect trap maintenance and the best laid anti-oil plans will be royally screwed. Worse—you don't recover from a maintenance lapse by adding more LN2. . . Oh no, it's CLEAN UP time! And for the vacuum neophyte, an inattentive trap moment is almost a given. The only silver lining is, if the subsequent degreasing doesn't push you firmly into the dry pump camp, you may be destined for sainthood.

Turbo

Introduced in 1958, the **turbo** (actually turbomolecular) mechanism only slowly gained commercial acceptance. Early models were too prone to bearing craunching. Nowadays, with Formula 1 cars' *reciprocating* motions topping out at 18,000 rpm, the turbo's maximum *rotary* speeds (~60,000 rpm for small diameter and ~27,000 rpm for large diameter) are 'piece of cake' design/production issues. Turbo pumps are highly reliable and in demand for applications where: gas throughputs are high; quick start/stop characteristics are desirable; oil-free environments are required; good base pressures are needed; and when the process gas's hazardous nature suggests it should be exhausted to some abatement system, not stored in the pump.

There's also this niche. Turbo pumps are pretty much alone in providing low pumping speeds in the high vacuum range. So, for small, clean chambers designed for 10^{-7} torr to 10^{-8} torr, turbo pumps are the only sensible choice.

Early turbos used oil lubricated steel ball bearings. Mounting them inverted caused the oil to dribble out—need I say more? About 15 years ago, ceramic ball bearings entered service. The ball's lower mass, less likelihood of galling, and grease lubrication meant turbo pumps could be mounted in any orientation. Within the past ten years the introduction of magnetic levitation bearings, again with no mounting limitations, has divided turbos into two groups: *dry* (grease bearing) and *really dry* (mag-lev bearing) pumps.

Molecular Drag

The term **molecular drag** applies to three different mechanical designs. But who cares? Its abysmal pumping speed is only capped in ho-hum-ness by its rotten ultimate pressure. I might claim no-one buys a drag-pump, so why even mention it? Well, about 1980 some smart pump designers looked at the **turbo** pump's disadvantages:

- most designs do poorly at pressures above ~1 x 10^{-2} torr
- foreline pressure must be lower than 2 x 10^{-1} torr
- unspectacular compression ratios for H_2 and He

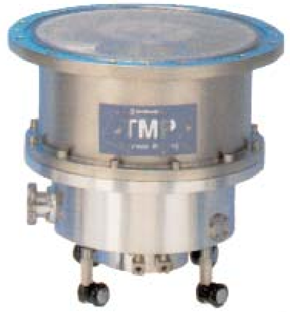
and recognized that adding a **drag** mechanism at the bottom of the **turbo's** drive shaft created a serendipitous synergy leading to . . . .

Hybrid-Turbo/Drag

Suddenly, the mediocre **drag** and the 'if-only' **turbo** turned into a **combination**, **hybrid**, or **turbo/drag** pump that accepts/has:

- inlet pressures ~1 torr
- foreline pressures in the 1 - 20 torr range
- ultimate pressure below 10^{-9} torr
- pumping speeds up to 3000 L/s

Added to which, the compression ratio for light gases jumps by one or two orders of magnitude making **turbos** effective pumps for H_2 and He. Now, here's a high vacuum transfer pump that finally cuts the mustard! Put mag-lev bearings on that puppy and you're cooking with gas! (Which only demonstrates my hopelessly outdated American 'street' vocabulary.)


Shimadzu 3000L/s Hybrid

Hybrid pumps are popular for many reasons, not least of which is—the high cross-over and foreline tolerance pressures mean that scroll, reciprocating piston, and multi-stage diaphragm pumps operate as roughing/backing pumps without straining the turbo. *Dry* and *really dry* pumping stacks are suddenly within the budget of many more facilities.

Typical applications for turbo/drag pumps run the same gamut as regular turbo pumps. Indeed, one manufacturer makes no attempt to identify their pumps as turbo-drag even though that's the only type of turbo they make. So, for applications that involve:

- Frequent shut down and start up (load-locks)
- Higher continuous pressures (sputter deposition, CVD)
- Higher cross-over pressures (batch coaters)
- Dry conditions demanding a *dry* foreline pump

Turbo/drag pumps are the answer.

Cryo(genic)

The two major designs of cryo pump, distinguished mainly by their operating temperatures, have very different pumping speeds and ultimate pressures. The **cryosorption** pump (described above) is cooled to 77 kelvin (with LN2) and goes from atmosphere to 10^{-4} torr with a modest pumping speed. The **cryogenic** (more typically called just **cryo**) pump operates with an adsorbent at 10 kelvin surrounded by a shroud held at 80 kelvin. This pump hits stride at ~1 torr and will zoom on down the road to 10^{-9} torr. Given a reasonable diameter inlet, it will muscle along that road at perhaps 5,000 L/s. The **cryo** provides really dry pumping needed in almost all oil-free applications. The exceptions are applications with high gas loads or those using H_2 and He in process quantities (see sidebar).

Pumping Hydrogen with a Cryo

The cryo pump's H_2/He hiccup is—the maximum quantity of gas a pump will absorb. It's the old "adsorption isotherm" genie popping its cork. As the total mass of absorbed H_2 approaches 0.2g to 2g (depending on the pump), its equilibrium vapor pressure rises to 5 x 10^{-6} torr, which is hardly a spectacular ultimate pressure for a high vacuum pump.

For perspective, 0.2g of H_2 represents ~2 liters at atmospheric pressure. If H_2 flows into your new cryo-pumped process at 100 sccm, after 20 minutes operation, regeneration is needed!

Ultrahigh Vacuum Pumps

Implicit in the idea of reaching UHV is very low gas loads. If the gas load isn't low, the effective pumping speed needed to reach UHV pressure is simply too high. There may not be enough physical space around the chamber to mount all the necessary pumps. So, reducing the outgassing rate is an important first step in any true UHV system.

Ion

Years ago, in Moscow, I saw huge **ion** pumps made from fifteen or so 500 L/sec modules surrounding a central tube. But the largest, readily available pump is probably Varian's 500 L/sec VacIon. Again with commendable honesty, Varian does not claim the high pumping speed available from a 'fresh' pump. Rather, it shows the practical pumping speed for one that's been working for a while. Its maximum N_2 speed of 500 L/sec occurs at an inlet pressure of 1 x 10^{-6} torr. By the time the pressure has reached high 10^{-11} torr range, its N_2 speed has dropped to 300 L/sec.

In a similarly sized **ion** pump, but differently arranged, the numbers for Ar are ~280 L/sec (at 1 x 10^{-7} torr) and 150 L/sec (high 10^{-11} torr). By *high vacuum* pump standards, those are pretty low numbers. But as already noted, UHV implies low gas loads so these pumping speeds will get a properly prepared chamber into the 10^{-11} torr range.

As in other pressure regimes, the concern is pumping all gases that appear in the chamber. When the ion pump's mechanism is examined in detail, it's really the sum of four 'sub-mechanisms'. Active gases (H_2, O_2, CO, CO_2, H_2O, and N_2) are pumped pretty well by the major sub-mechanism. Fringe components (He, Ne, Ar, CH_4, and other hydrocarbons) are pumped by a less direct sub-mechanism. Varian (and possibly other manufacturers) change the efficacy of the various sub-mechanisms by changing electrical potentials, construction details, and cathode materials. For example, Varian ion pump models are called different names to draw attention to different gas pumping capabilities:

- Diode VacIon (good for all 'active' gases)
- Noble Diode VacIon (reduced pumping speed for H_2 and active gases, but higher for He, Ne, Ar)
- StarCell® VacIon (a modified triode design that combines the diode's capacity for H_2, the noble diode's capacity for Ar and He, with good speed for CH_4)

While not disputing Varian's claims, I still get edgy thinking about ion pumping Ar and CH_4. When I was a lad (long before StarCell was even a twinkle in the firmament) ion pumps fed a too-rich diet of Ar, regurgitated it. And far from pumping CH_4, the claim was ion pumps **made** it by elemental re-arrangements of CO_2/CO and H_2.

Evaporation and Non-Evaporation Getter

Despite prior statements, when gas loads in UHV get a little large, an **evaporable getter**, such as a Ti-sublimation pump, is added. It's either integrated into the ion pump or housed in a separate shroud, with no line of sight to the chamber (remember my dirty capture pump story?) that is often LN2-cooled.

But a Ti-sub pump is always used as a secondary device backing up some primary device like an ion pump. I don't know of any example where it was the only high vacuum/UHV pump. Its application is to mop up all the active gases (O_2, N_2, H_2, CO_2, H_2O, etc) by chemical reaction with a fresh thin film of Ti.

Ti Sub Pump Tidbits

- It has no pumping speed for the inert gases or methane

- As the Ti filament (or ball) cools, it acts as a wonderful gas absorber. That is, when you switch on the evaporation supply at some later time to re-fresh the Ti film, the filament outgasses (typically H_2) and the pressure rises. Some power supplies, however, have a standby position that keeps the filament hot but at a temperature less than needed for evaporation.

- While a square centimeter of Ti film at room temperature has a reasonable pumping speed (2 to 9 L/sec depending on the gas), the equivalent film at LN2 temperature has a pumping speed between 10% and 700% greater (again, depending on the gas).

TV tubes and CRT monitors wouldn't exist without the lowly **evaporable getter**. After pumping and sealing, a small barium-filled boat mounted inside the tube is flash evaporated. Its purpose? To give a large area, reactive metal film to mop up water vapor outgassing from the glass. Does it work? Well, you're still watching *Baywatch* re-runs on your 10-year old TV, right?

In particle accelerator and beam line applications, **non-evaporable getters** (NEGs) based on heated zirconium alloys have made a considerable mark. Not only are they compatible with the 10^{-11} torr pressures needed in those vacuum systems, they act as distributed pumps. That is, rather than accept the poor conductance of long tubes to conventional ion pump stations, **NEG**s are built into 'rest stops' along the tube's length to mop up the locally desorbing gas, *e tutto è bene*. (Couldn't resist that NEG afficionados' in-joke).

Cryo & Turbo

I parenthetically included **cryo** & **turbo** pumps in the *UHV* pump mechanisms to suggest that for some applications these mechanisms might work in the UHV pressure regime.

The justification for the cryo is: providing the H_2, He, and Ne gas loads are exceptionally low or non-existent, the cryo's high pumping speed and their low adsorption isotherm pressures for other gases allow it to pull chambers into the high 10^{-10} torr range.

The justification for the turbo is: by putting two **turbos** in series, some Japanese researchers beefed up the compression ratio and reached chamber pressures in the 10^{-12} torr range. Of course, they had taken all the usual precautions for reducing the chamber's gas load—but when it comes to UHV, what else is new?

That's it! Two down and one (*Applications Classifications*) coming up.

StarCell® is a registered trademark of Varian Associates.

Lesker On The Road

Date	Event	Location	Booth
May 25-27	Soc for Info Display	Seattle, WA	Booth 317
June 13-16	CAP/COMP/CASCA	Winnipeg, MB, Canada	Booth 28
June 14	Prairie Chapt. AVS	Urbana, IL	
June 14-15	New Englad AVS	Burlington, MA	

LeskerTech@lesker.com
www.lesker.com/LeskerTech/subscribe.cfm

North American Headquarters
Ph: 412.233.4200
Fax: 412.233.4275
Sales (US):
1.800.245.1656
sales@lesker.com

West Coast Office
Ph: 925.449.0104
Fax: 925.449.5227
Sales (US):
1.800.245.1656
davidl@lesker.com

Canada Office
Ph: 905.770.8450
Fax: 905.770.3723
Sales (Canada):
1.800.465.2476
canada@lesker.com

Europe Headquarters
Ph: +44 1424-719101
Fax: +44 1424-421160
sales@leskerltd.com

Hungary Office
Ph: +36 1 383-5322
Fax: +36 1 383-4369
peters@hu.inter.net

If you believe a colleague would enjoy reading *Lesker Tech*, please feel free to forward this issue along with our compliments.

As always, your comments and suggestions are valued and welcomed.

Kurt J. Lesker Company