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VACUUM TECHNIQUES

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Our experience with ion pumps agrees with everything that Worstell had to say. We have a 25,000 liter system pumped entirely by ion pumps and I'm confident we would never have started these pumps at all if we hadn't had a roughing system that would rough the cavity down into the mid 10^{-5} scale. We do not believe we would have started any of those pumps at 1 micron, probably not even at 0.1 micron.

The linac vacuum system is really divided into two distinct systems, one of which has several 400 ℓ/sec pumps on it, and consists of all the beam pipes, and all the measuring equipment that is with them It is our experience with this system that makes me certain that an insufficient roughing system on the linac tank would have been unsatisfactory. The big pumps that are on the linac itself are basically no problem at all. The smaller system, which is pumped by 400 ℓ/sec pumps and has a tremendous number of organic O-rings in it plus many sliding and rotating seals, is tough to start. We're presently contemplating the addition of sublimation type pumps to the smaller pump systems to give us a high pumping speed during these starting periods when the ion pumps just won't take over. Once you get the pressure down low enough that they get out of the heating problem they'll hold the system well. The units that you take down to air most often are the units containing beam handling equipment, where changes are most frequently made. Presently it is not unusual to have to pump down a beam box, (i.e., a location where we place targets or TV screens or slit assemblies or toroids, etc.) several times a day. When we do this, we find that these pumps are a real problem to get going, because they'll start; then they'll heat and stall; and from there on, you're in trouble.

Reliability on the large pumps is excellent. Our average pump has had 16,000 hours of operation and in this time we have had only four problems that have required repair. Two of them were shorted feedthrough insulators. The other two occurred in a single pump at very close to the same time, when the cathode and anode shorted out. At the time this particular pump had had 550 days of operation. We took the elements out, examined them, measured the depth of the pits in the titanium cathodes and found that they were less than 10% of the way through the titanium. Now, if you can use the cathode until the titanium is halfway through this would mean something like 2500 days, or 8 years, of operation before you have to replace elements in a pump.

We have never observed what Grand suggested as being a potential problem, that is, swamping. However, I think that this is a very real problem, if one doesn't provide what might be considered at first look as an over-adequate pumping system. I think that you can make a real mistake by not being a little generous on pumping speed. If you cut yourself too close (and I'm not sure what the factors ought to be, but I lean in the direction of about a factor of two or more than what you really think you need), you may run into this problem because when you first bring the cavity rf on, you do get a rise in pressure.

I think that it's significant that we have never seen multipactoring in the ZGS linac. There are probably three reasons for this and I don't know exactly what the weighting factors are: the first is the very rapid rate of rise of the rf from the power amplifier, which goes up to about 90% of full power in about a microsecond. This means that the rate of rise in the cavity is fast enough to discourage multipactoring. I think that this should probably have the highest weighting factor. Second, is the fact that ours is a good, clean vacuum system. Third, I think that the OFHC copper probably has a beneficial effect.

On the rare gas problem that Grand mentioned, all I can say is that I believe that the fundamental philosophy should be that you must eliminate the problem before you have it, that is, you must get rid of your leaks.

I do believe that leak detection is an important reason for having a diffusion pump as part of the roughing system. The diffusion pump makes leak detection with a very high sensitivity possible when you sample from the foreline. We have tried the ion gauge type and the ion pump type leak detectors and if you're attempting leak detection when the pressure is stable and in the 10^{-7} range, they do have a very excellent sensitivity. But usually leak hunting must be done in pressure ranges much higher than this where these devices don't have very good sensitivity and are also very sluggish. Also, if you try to leak check directly into the tank with a spectrometer type leak detector, your pressure in the system is actually lower than your detector cares to operate at; and therefore, you have poor sensitivity in your analyzer. Consequently, I strongly recommend a roughing system that has a lot of capacity with a low base pressure. Our one diffusion pump has an effective pumping speed into the cavity of about 1000 ℓ/sec. We go on the diffusion pumps about 14 minutes after starting pumpdown, and on ion pumps in 50 minutes or when you're below 4×10^{-5} Torr. A recent pump-down curve is shown in Fig. 1. Turning the ion pumps on is a matter of just turning on the power and they start. The pressure in the tank does, in fact, immediately start down.

We haven't really tried the purging system Worstell suggested in the way he outlined it. However, we have experienced some of the effect. When we have had the tank down to air for a few days, we have pumped it down to the base pressure of the roughing system without the diffusion pump, which is 1 to 2×10^{-4} Torr using the blowers, and then let it go about half way up to atmospheric pressure with dry nitrogen. This makes a tremendous difference on the ability to start the ion pumps. If you've had the whole system down to air for several days, what I said about flipping switches is not necessarily true,

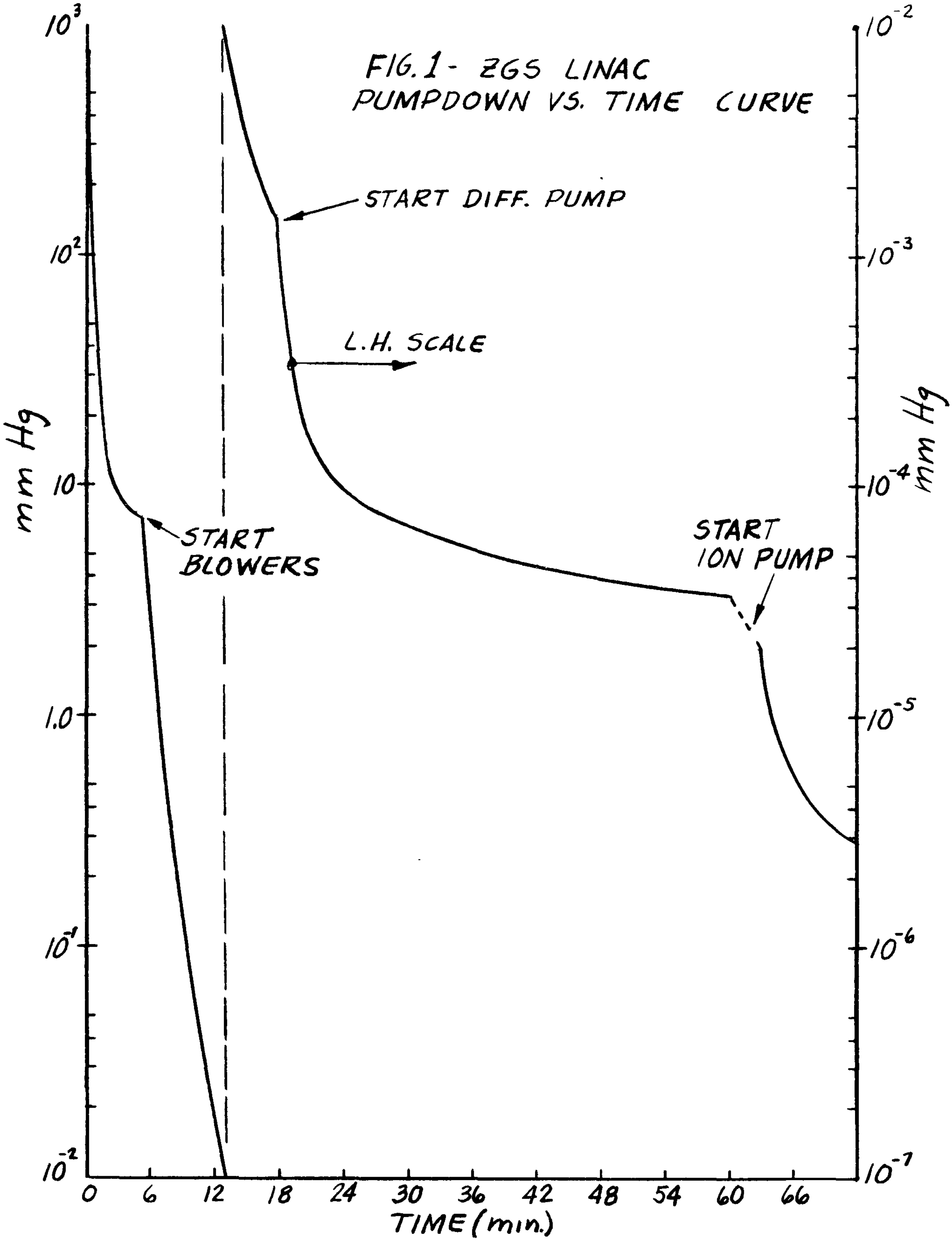
FIG. 1 - ZGS LINAC
PUMPDOWN VS. TIME CURVE
START DIFF. PUMP
L.H. SCALE
START BLOWERS
START ION PUMP
mm Hg
mm Hg
TIME (min.)
0
6
12
18
24
30
36
42
48
54
60
66
10^3
10^2
10
1.0
10^-1
10^-2
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7

it may take 20 minutes or more, but if you let the tank and the pumps up on dry nitrogen or you go through the purging process, it will take 5 minute or less.

Worstell said some things about low pressure that I feel are very significant. I think there's a fourth consideration in the multipactoring problem that may help, which wasn't mentioned earlier, and that is that our tank does run on the high 10^{-7} scale. There is a pressure gradient along the cavity that I believe is caused by the fact that in the low energy end there are a great many more gaskets. The pressure in the low energy end is usually about 8×10^{-7} Torr and it runs 3 to 4×10^{-7} Torr in the high energy end as read by ion gauges. We don't use the pumps to monitor the cavity pressure because they're only reading the pressure in the pump, and there is a rather high impedance between the pump and the tank. I believe that this low pressure contributes to the freedom from multipactoring.

QUESTION: What do the pumps think they are running at?

LIVDAHL: About 1×10^{-7} Torr.

GOULD: Originally you had a couple of 400 ℓ/sec vac-ions on your source. Are they still there?

LIVDAHL: Yes.

GOULD: I understood that once you had taken them off and put mercury diffusion pumps on.

LIVDAHL: No, the mercury pump has been on since the beginning. We use this when we're pumping hydrogen and shut off the 400 ℓ/sec vac-ion that's right above it.

GOULD: Is there any reason for doing that?

LIVDAHL: Yes, the Vacion won't take large amounts of hydrogen for a long period of time. In a period of about 8 to 10 hours at $2x10^{-5}$, the ion pump has had all the hydrogen it cares for, and it gives it all back with interest. I believe most of the interest is in the form of other rare gases that have previously been pumped.