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NEON TECHNIQUES

By Rusty Russo



Processing Dynamics

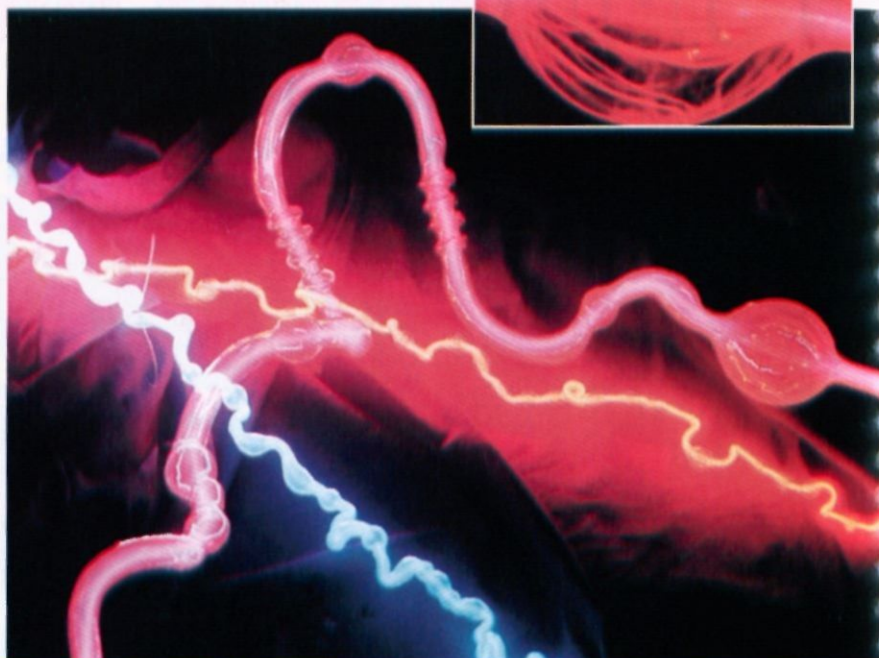
What's happening inside the tube affects the finished product

Many neon fabricators haven't the slightest interest in subjects like the nature of pressure, electron behavior, mean-free path and gas-molecule behavior. Of course, it's possible to learn the bombarding process without understanding the physical dynamics inside a neon tube. But it's equally true that those who understand the science behind neon production have a distinct advantage.

It's always necessary to adjust the standard bombarding process somewhat to accommodate the particular physical characteristics of each unit. Tube length, diameter, glass composition, phosphor coating (single or double), electrode size and relative humidity all affect physical reactions during processing. Thus, understanding the tube's internal dynamics helps you make appropriate adjustments. Paying close attention to visible and audible signals during bombardment, as well as monitoring instruments, plays a key role in achieving optimal results.

Ionization

First, let's examine how some frequently used terms relate to the bombarding process. One of the first steps in bombarding is opening the



Various glass diameters and fill pressures produce dramatically different results, including arc-stream matriculations in high-pressure neon fill (inset).

main stopcock to evacuate the tube. This creates a partial vacuum inside the tube, allowing the bombarder to strike an arc. This step also creates a condition where the number of gas molecules inside the tube is less than the number in the outside atmosphere. Reducing the tube's internal pressure also reduces its electrical

resistance, making it easier to light. This is true because, at lower pressure, fewer gas molecules are present inside the tube. Thus, resistance to an electrical discharge is also less.

What happens inside a neon tube when we strike an arc? Ionization (in this case, the process of creating positive ions) occurs when a gas mole-

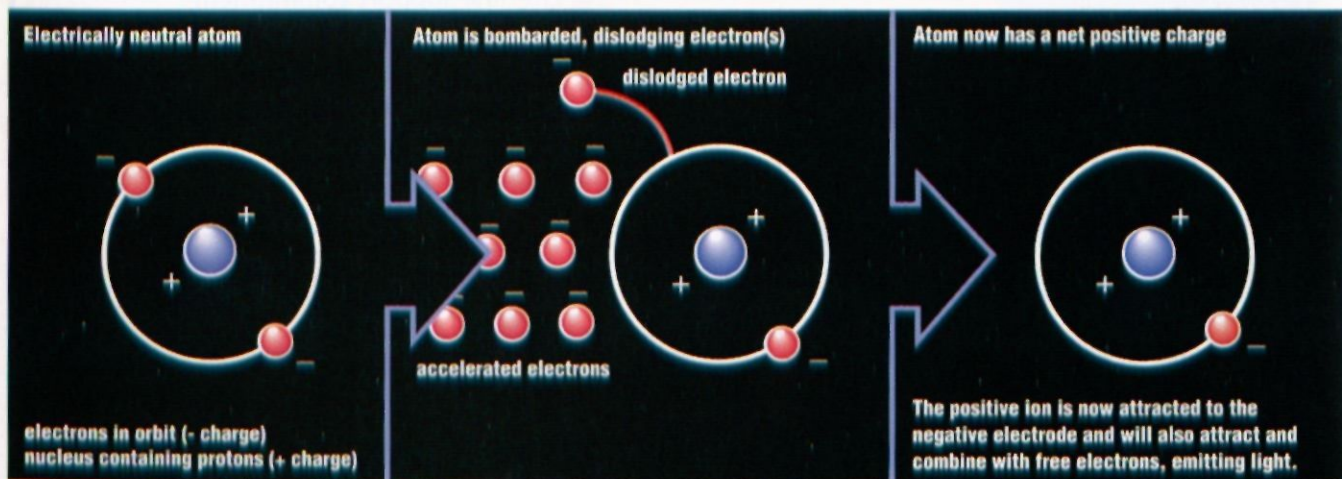


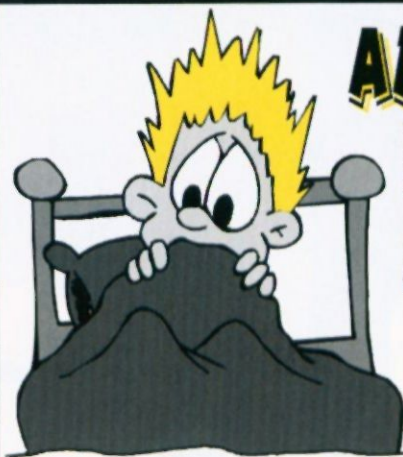
Fig. 1: Ionization of an atom

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correct tube pressure during bombarding. A sharp pressure rise on your Torr gauge or EZ-read gauge accompanied by erratic current readings and buzzing or tube flickering signals trouble. This indicates the electrical discharge inside the tube is preparing to become an electrical discharge *outside* the tube. The point of egress is usually through the tube's glass wall, while the point of ingress might be the processor's belt buckle (at which time we cancel the pizza and start again with a new unit or processor).

We previously examined the procedure to monitor bombarding pressure (see *Neon Techniques: "Manifold and Bombarding Procedures: Part 2," July 1999, page 22*), which is essential to avoid reaching this dangerous condition. Monitoring also confirms the pressure is sufficient to produce enough energy to break the molecular bonds of contaminants within the tube. Electron impact, UV impact and ion impact occur at different pressures. Pressures greater than 3 Torr effectively remove loosely bound surface molecules (mainly water), but pressures of 1-2 Torr are necessary to break the chemical surface bonds of oxygen (which binds very tightly to glass) and the bonds between water and carbon dioxide. This is also the pressure range specified by most manufacturers to properly activate the neon electrodes' emission coatings.

When "neonites" mention bombarding pressure, we refer to the force and frequency of gas molecules and particles as they collide with the walls of a neon tube and manifold. We measure pressure as a force per unit area, and bombarding pressure is usually expressed in millimeters of mercury (mmHg), which is a unit indicating the height of a column of mercury that a particular pressure level will support. In the vacuum technology field, however, pressure is always measured from zero or absolute pressure. Atmospheric pressure is equivalent to 760 mmHg.



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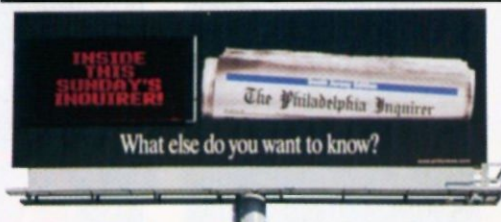
Viscous flow, molecular flow and mean free path

If fewer particles are available for collision in a tube under vacuum, why does a reduction in pressure during bombardment cause the electrodes to heat up? As I previously pointed out, when a neon tube is first connected to the manifold, its internal pressure is roughly the same as the outside atmosphere. If we try to strike an arc at this atmospheric pressure, not much happens. Hence, the operator must first evacuate the tube to reduce the number of gas molecules. When this is done, the average distance a gas particle must travel before it collides with another particle increases. This distance is also called the "mean free path."

How does mean free path relate to neon processing? At atmospheric pressure (760 mmHg), approximately 3×10^{19} molecules per cubic centimeter are present under standard conditions (i.e., 760 Torr @ 0 degrees C). That's equivalent to 30 million trillion. I certainly didn't count all these molecules personally, but some guys in lab coats with big foreheads and diesel calculators did. Furthermore, except for perhaps an obscure cult of Norwegian ice fishermen (who use bombardiers to keep warm and cook their fish), most people don't bombard at 0 degrees Celsius.

Regardless of these finer points, the mean free path is very short at atmospheric pressure (760 Torr). It equates to approximately 2 millionths of an inch (2×10^{-6} in.). This wide range of pressure above 1×10^{-2} Torr is called "viscous flow" because the densely packed molecules behave like a fluid and are easily removed by the vacuum pump. The molecules resemble a crowd of people rushing full speed through a tunnel because they tend to carry each other along (Fig. 2). When we reduce pressure by opening the main stopcock, however, we increase the mean free path by reducing the number of gas par-

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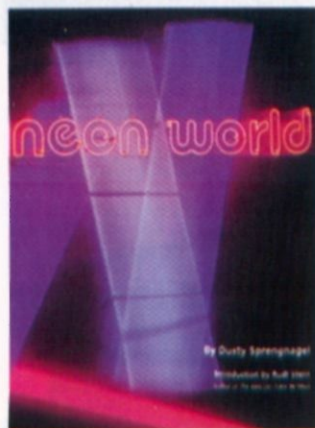
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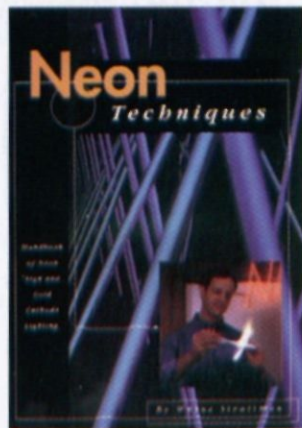


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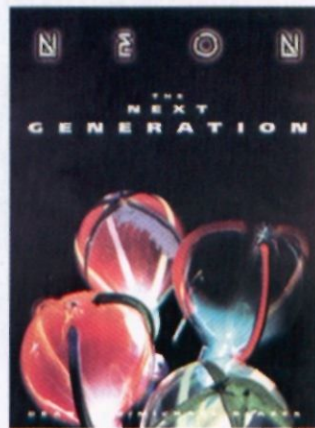


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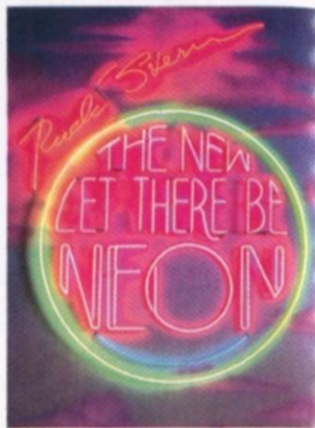


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ticles in the tube. As a result, the particles can develop greater velocity before colliding with other particles during bombarding.

Consequently, more frequent and violent collisions occur at the electrodes, transferring more mechanical energy to the shells. The electrodes heat up and, if we continue to reduce pressure, the collisions become so violent that bits of the metal shells are blasted away and deposited on the glass. This undesirable "sputtering" process can also occur at the end of a neon tube's life when the rare gas molecules have been "cleaned up" and the rare gas pressure has been reduced to almost nothing.

Virtually all bombardment takes place in the viscous flow range of 1-4 Torr. It's possible to reduce the pressure inside the tube to a point where so few particles are available that the electrical discharge is extinguished. Many old-timers checked the quality of a tube's final vacuum after bombardment by briefly engaging the bombarder. After pumpdown, absence of ignition or discharge was interpreted to mean all gaseous contaminants had been removed and the tube was ready to fill. This test was known as "flashing" (not to be confused with the kind you get arrested for).

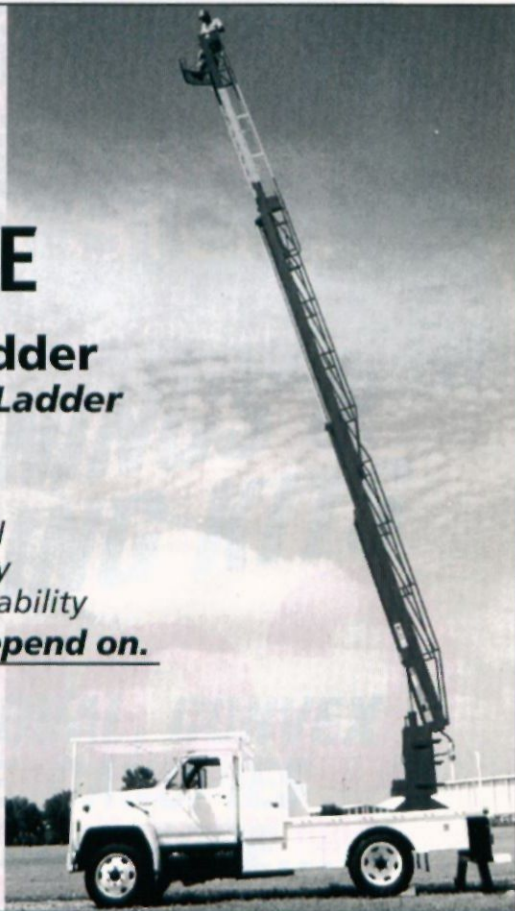
After bombarding, you must evacuate the dislodged gas molecules from the tube before it cools. If not, the molecules reattach themselves to the walls of the glass. This can interfere with the neon tube's longevity and aesthetic appeal. Depending on the efficiency of your system, as the final post-bombardment evacuation continues, either the manifold and, in some cases, the neon unit itself can approach what is known as the "molecular flow range." During this pumpdown, a transition occurs from viscous flow (where molecules have a direct effect on each other, pulling each other along on the way to the manifold and vacuum pump) to the molecular flow range (less than 1×10^{-3} Torr). At this vacuum level, the mole-

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cules are so few in number that they no longer pull each other along (Fig. 2). Their motion becomes random.

At this point, the operator should realize that, despite all the noise coming from under the workbench, nothing is actually being pulled out of the tube. Remember that, in the molecular flow range, gas molecules no longer behave like a liquid, but have minds of their own. The remaining molecules may or may not exit the tube, but you can slightly increase the probability of additional evacuation by using a shorter, larger-diameter tubulation. Also, a short, large-diameter manifold with a minimum of 90-degree bends increases the likelihood that randomly bouncing molecules will exit the system.

Molecular flow does not depend on pressure alone but also relates to the dimensions of the neon tube being processed and the manifold. A key factor is whether the mean free path is longer or shorter than the dimensions of the manifold and tube. But pressure has a dramatic effect on the length of the mean free path. For example, at a pressure of 1 micron (1×10^{-3} Torr), the mean free path of a molecule is 2 in. At 1×10^{-9} Torr, the mean free path distance becomes 30 miles!

While some may contend that most neon tubes never reach molecular flow during processing, many manifold systems available today are capable of pumping down to this range. With these systems, a short, large diameter, straight manifold ensures that most of the trash in a neon unit evacuates to the vacuum pump before you fill the tube with rare gas.

This raises a question about back-filling tubes. It seems logical that re-introducing millions of rare gas molecules back into the system will sweep any residual gas molecules (contaminants) in the manifold back into the tube. Could this be a problem? I will examine this question in my next article. ■

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