



# Chemical Injection Technologies

## Technical Bulletin

### Overfilled Chlorine Gas Cylinders Cautions, and Preventive Measures

#### WHAT IS THE PROBLEM?

Periodically, we see problems associated with chlorine gas cylinders which have been filled with liquid chlorine beyond their rated capacity. Usually the problems manifest themselves as liquid chlorine observed flowing through the chlorinator vacuum system, or ice forming either on the cylinder valve or on the chlorine gas flow meter.

There have been a few instances where overfilled cylinders have actually caused damage to the gas chlorinator vacuum regulator, due to extremely high pressures generated in the chlorinator inlet valve area. Luckily, these incidents have been extremely rare, although in recent years we have seen a marked increase in total problems caused by overfilled cylinders.

#### HOW MUCH CHLORINE SHOULD A FULL CYLINDER CONTAIN?

Although there are still some cylinders in use today that are designed to hold only 100 pounds of liquid chlorine, the standard cylinder is designed to hold a MAXIMUM of 150 pounds of liquid chlorine. At 72<sup>N</sup> F, 150 pounds of chlorine will occupy only 89% of the total volume of the cylinder. Under no circumstances should a chlorine packager fill a chlorine cylinder with more liquid chlorine than is specified by The Chlorine Institute and the U.S. Department of Transportation.

#### WHY IS IT DANGEROUS TO OVERFILL A CYLINDER?

The pressure of chlorine gas (Vapor Pressure) is a function of the temperature of the liquid chlorine in a cylinder. Figure 1 shows the vapor pressure of liquid chlorine at various temperatures. The curve assumes that there is sufficient space above the liquid for the vapor (gas) to exist. Notice that at normal ambient temperatures, the vapor pressure is relatively low (compared to liquid propane or oxygen, for example) and at 80<sup>N</sup> F the pressure would be approximately 100 PSIG. Even at 120<sup>N</sup> F, the vapor pressure is less than 200 PSIG.

These are the pressures that would normally be expected to exist in a gas chlorination system. All gas chlorinator manufacturers design their chlorine gas inlet valve assemblies to handle pressures many times that which would be expected. However, when a cylinder is overfilled, the values given in Figure 1 may no longer be valid.

Vapor Pressure of Liquid Chlorine

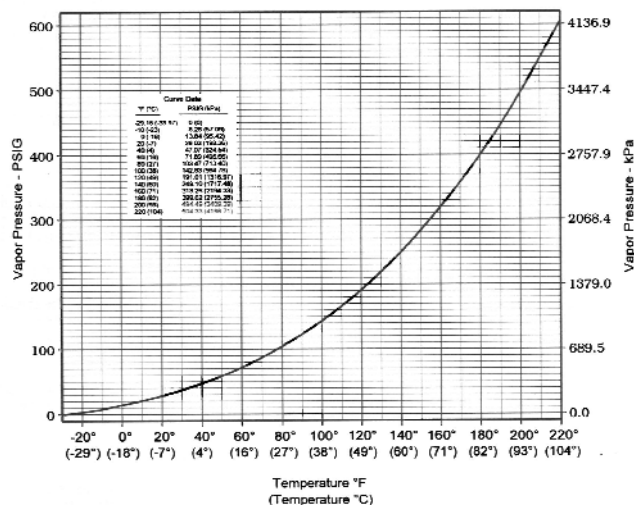


Figure 1

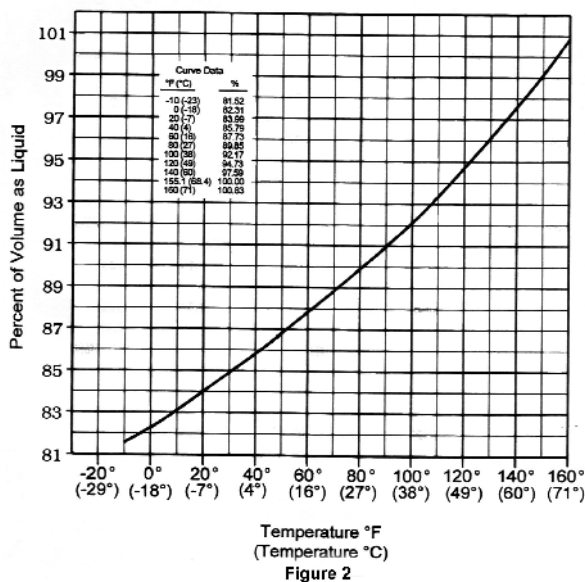
The reason is that liquid chlorine expands with an increase in temperature. That expansion is allowed for by only partially filling the cylinder, so the expanding liquid will have a place to go. Recognizing that the vapor pressure can build up very rapidly when the temperature gets higher, cylinder valves are equipped with a fusible metal relief device or fusible plug. Most valves have a threaded plug containing the fusible metal screwed into a tapped hole in the valve body, below the valve seat. The fusible metal is designed to yield or melt between 158<sup>N</sup> F and 165<sup>N</sup> F to relieve VAPOR pressure and prevent container rupture if exposed to fire or other high temperature. The relief device is only activated in the event of a temperature increase. It is not a pressure relief valve.

When a cylinder is filled beyond its intended capacity, increasing temperature will cause the liquid chlorine to expand. At some point the liquid may completely fill the cylinder (known as "skin-full") and instead of building gas vapor pressure, it starts to build HYDROSTATIC pressure. While gases are compressible, liquids are either incompressible or only slightly compressible. FIGURE 2 shows the relationship of chlorine liquid volume to temperature, in a container loaded to its authorized limit. Notice that the liquid volume becomes greater as temperature increases. If the cylinder was filled to its authorized limit, with enough gas area above the liquid to allow the liquid to expand and compress the gas, the volume of the liquid will increase.

At 72<sup>N</sup> F the liquid occupies 89% of the total volume of the cylinder, but at 120<sup>N</sup> F it occupies 95% of the volume. Under any normal operating condition, This is not a dangerous situation, and the pressures are well within the design range of all gas chlorinator vacuum regulators, by several orders of magnitude.

When the cylinder is overfilled, there is less room for this expansion to take place. In fact, it is quite possible for the liquid to expand and completely fill the cylinder when the temperature rises. Sunlight hitting the cylinder or increased ambient air temperature can then create a dangerous situation where the HYDROSTATIC pressure can reach VERY HIGH PRESSURES. Depending on the amount of overfilling and the temperature increases, pressures can go into the THOUSANDS of POUNDS PER SQUARE INCH.

Volume - Temperature Relation of Liquid Chlorine In A Container Loaded To Its Authorized Limit



This is a very different scenario than a cylinder which has been filled to its authorized limit, exposed to a large increase in temperature. In this case, only a very small increase in temperature can produce a very significant increase in pressure.

### HOW DOES OVERFILLING AFFECT GAS CHLORINATORS?

As mentioned earlier, all gas chlorinator manufacturers over design their equipment to handle cylinder pressures in excess of that which would be expected to be encountered using a cylinder loaded to its authorized limit. Overfilled cylinders, however, represent a situation which cannot be foreseen, and pressures that can vary from as little as a few hundred PSIG to over 2000 PSIG and more.

Such pressures could cause failure of threads or materials within the chlorine gas inlet area. Such failure can range from mild "venting" of gas past the inlet valve, to a rupture of the valve sealing area, allowing very high pressure chlorine

gas and liquid chlorine to enter the vacuum regulator. Since all modern gas chlorinators are constructed of engineering plastics to avoid corrosion and chemical attack, their ability to handle extremely high pressures in such a situation is very limited. The normal operating environment is usually less than atmospheric pressure, and such high pressures can cause rupture of the regulator body, releasing chlorine gas into the surrounding atmosphere.

The good news is that the chlorine release would be controlled by the cylinder valve orifice, in much the same way as the release through the fusible plug. As the gas and liquid expand into the atmosphere, the remaining liquid in the cylinder will rapidly cool, thereby slowing the release and quickly lowering the pressure. Overfilled cylinders always represent the potential danger of a cylinder wall rupturing, causing a very rapid chlorine release and the possibility of turning the cylinder into a flying projectile.

### WHAT PRECAUTIONS CAN USERS TAKE?

We recommend that all cylinders be weighed when received. The Tare weight (empty weight) of the cylinder is stamped on every chlorine cylinder. Deduct the tare weight from the total cylinder weight, and if it is more than a few pounds over 150 pounds, call the chlorine supplier and explain the situation so he can immediately retrieve the cylinder and safely evacuate the contents. In any case, the cylinder should be placed in a safe area and kept cool.

Unfortunately, many scales that are used to weigh the contents of chlorine cylinders today, are designed to "Dial out" the tare (empty) weight of the cylinders and thus read only the remaining pounds of chlorine. In such cases, we recommend using a small, inexpensive bathroom scale. Caution should be exercised when moving chlorine cylinders onto such a scale since the height of the weighing platform is usually higher than the scales used exclusively for weighing chlorine cylinders. A small ramp is often placed next to the scale to facilitate easy rolling of the cylinders on and off the scale. Placing the scale in a small scale "pit" is also a safer and more convenient method.

### RECENT EXPERIENCES

As mentioned above, we have seen more instances of overfilled cylinders in recent years. We are not in the chlorine packaging business, so we cannot give an accurate opinion on the cause for this apparent increase in incidents.

Our experience, however, has shown that most suppliers of chlorine cylinders are conscientious about following strict procedures in filling the cylinders.. Human error is always a possibility, even when a company takes extra measures to insure compliance.

We urge all users of chlorine gas to take the simple precautions outlined above, and to be aware of the potential for receiving an overfilled chlorine cylinder.