Chemical Injection Technologies
Technical Bulletin

Chlorine Withdrawal Rates

Despite the fact that direct-cylinder mounted gas chlorinators have been available for over 50 years, there still remain many misconceptions and out-dated "rules of thumb" regarding the rates at which chlorine can be withdrawn from 100 or 150 pound (45 or 68 kg) cylinders, using direct-cylinder mounted gas chlorinators.

One of these out-dated ideas that people still believe to be a fact, is the "rule of thumb" that you can only withdraw 40 to 50 pounds of chlorine per 24 hours from a single chlorine cylinder. The actual basis for this idea goes back many years to the time when the only type of gas chlorinator available was either mounted on a wall or in a floor cabinet. These units were connected to either the chlorine cylinder or to a manifold by means of flexible connectors. Users of these gas chlorinators were told to connect one (1) 100-pound or 150-pound (45 or 68 kg) cylinder of chlorine to the chlorinator or chlorinator manifold for each 40 or 50 pounds per 24 hours of chlorinator (800 or 1000 gr/hr) feed rate capacity.

At that time, all manufacturers of gas chlorinators had the same problems. Liquid chlorine could and would be formed in the copper flexible connectors, and in the steel manifolds. There were already so many points of potential pressure leakage that it really didn't make much difference if one or more additional cylinders were hooked up. At the time when the concept of mounting the chlorinator directly onto the chlorine cylinder valve was introduced, maximum withdrawal rates suddenly became important. The idea that only 40 to 50 pounds per 24 hours (800 or 1000 gr/hr) could be continuously withdrawn from a single cylinder was pushed very strongly by gas chlorinator manufacturers. At that time, those other manufacturers did not have a direct-cylinder mounted gas chlorinator to offer. Users were told that when chlorine was withdrawn above these rates the chlorine would freeze; the valves would freeze up; the chlorinator would stop working; liquid would be formed in the chlorinator; etc. This issue was pushed very strongly in the 1960s and consequently remains in the minds of many people today.

The primary facts stressed at that time seemed to indicate that the Chlorine Institute clearly states that only the low withdrawal rates are possible. Many people today will still steadfastly maintain that the Chlorine Manual, published by the Chlorine Institute, contains a statement to this effect. In reality, the Chlorine Manual clearly spells out the findings of the Chlorine Institute with regard to chlorine withdrawal rates. It states, first, that the dependable continuous discharge rate of gas from a single 100 or 150 pound (45 or 68 kg) cylinder is about 1 3/4 pounds per hour, which is about 42 pounds per day (840 gr/hr). This, however, is stated to be under the conditions of 70° F (21° C) when discharged against a back pressure of 35 psi (2.4 Bar) and without the cylinder sweating on the outside. These findings also indicate that if sweating can be tolerated, these rates can be doubled. This takes us up to 84 pounds per day (1600 gr/hr). It makes little difference to anyone whether or not the outside of the cylinder has sweat or condensation on it, and it certainly has no effect on the operation of the chlorinator. The item that is most often overlooked is the fact that this data is given for discharging against a <u>35 psi back pressure (2.4 Bar).</u> With a vacuum operated, solution- feed gas chlorinator mounted directly onto the chlorine cylinder valve, the discharge is not against a positive pressure, but is actually against a <u>controlled negative pressure</u> of about 2 psi (0.14 Bar) below atmosphere.

To further verify this, data was obtained from tests made by one of the leading chlorine producers that showed a continuous withdrawal rate of above 125 pounds per day (2500 gr/hr). They were discharging against 0 (atmospheric) pressure. Additional tests were conducted during the winter and a 100-pound (40 kg) chlorine cylinder was placed out-of-doors at 20° F (-6.6° C) and left out-of-doors several days. At the time this test was conducted, the actual liquid chlorine temperature was 20°F (-6.6° C). A 100 PPD (2000 gr/hr) chlorinator was connected to the cylinder valve and operated at above 100 PPD (2000 gr/hr) continuously. Higher than maximum capacity was withdrawn until the liquid was almost exhausted, at which time the rate dropped to about 60 pounds per day (1200 gr/hr) for only a few minutes until the chlorine cylinder was empty.

Figure 1 illustrates the rate of chlorine discharge in pounds per day from a 150-pound (68 kg) cylinder, at 70° F (21° C). into the atmosphere (no back pressure) over a period of 20 hours. Curve "A" shows the rate of chlorine discharge over any given period of time when air is circulated by a fan blowing against the cylinder. Note that in this case maximum chlorine discharge rates are continuously maintained at over 200 pounds per day (4 kg/hr) and that the entire cylinder was exhausted in just 8 hours. However, more normal conditions are represented by Curve "B" where no air is circulated past the cylinder by a fan. Curve "B" illustrates that fact that at least 100 pounds per day (2000 gr/hr) of chlorine can be discharged continuously against atmospheric back pressure. In fact, the entire 150 pounds (68 kg) of chlorine contained in the cylinder would be exhausted in just 20 hours at 70° F (21° C).

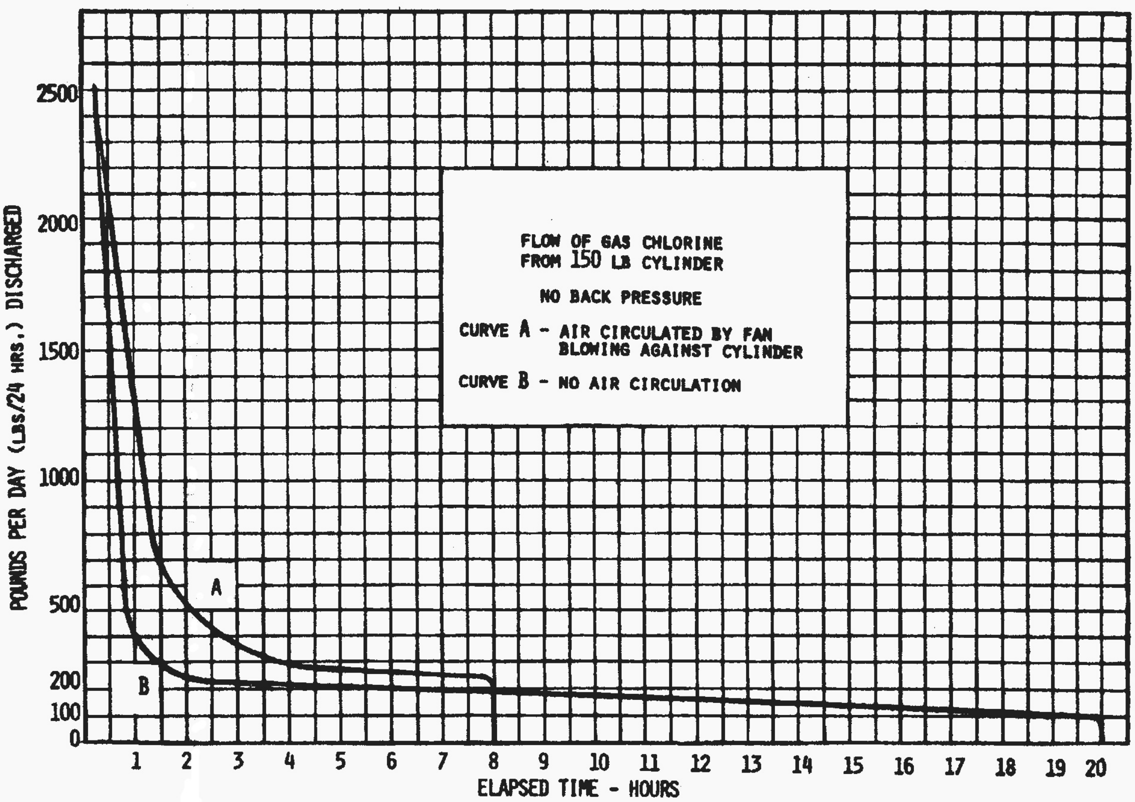
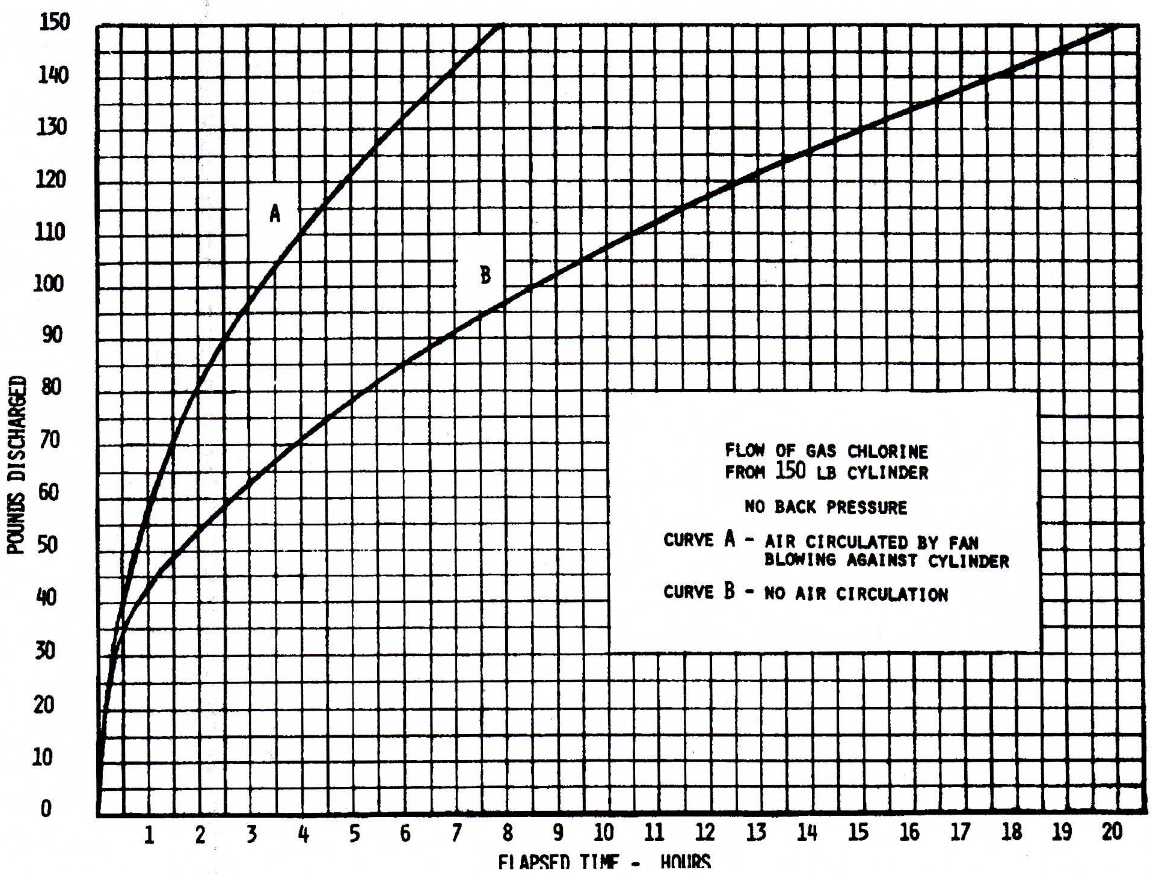


FIG. 1

Figure 2 illustrates the same data as above but it is expressed in terms of the total pounds of chlorine that are discharged over a given elapsed time, with the same conditions as stated for Figure 1. It should be noted that in the case where air is not circulated against the cylinder by a fan, as in Curve "B", 100 pounds (45 kg) of chlorine will be discharged in less than 9 hours.

Another misconception that has managed to survive after all of these years is the story that if chlorine is withdrawn at too high a rate from a single cylinder, the chlorine will freeze. This is impossible. Chlorine freezes at approximately

-150° F (-101° C). The pressure in the cylinder changes only with the temperature change and has nothing to do with the amount of liquid left in the cylinder. A certain lack of understanding on this point has led many people to believe that a chlorine pressure gauge installed in the system will somehow let them know how much chlorine remains in the cylinder. The vapor pressure presented in the Chlorine Manual shows that the cylinder pressure at 80° F (26° C) is 102 psi. (7 Bar). At 60° F (15.5° C) the pressure is 71 psi (4.9 Bar) and at -30° F (-34° C) the pressure in the cylinder finally drops to 0 psi (0 Bar).



A direct-cylinder mounted gas chlorinator will actually draw about a 2 psi (0.14 Bar) vacuum in the cylinder. As gas is taken out of the cylinder the pressure in the cylinder is reduced which causes the liquid in the cylinder to boil. This boiling obviously requires heat that is supplied by the temperature of the air around the cylinder. At high withdrawal rates the temperature of the outside of the cylinder adjacent to the chlorine liquid surface is lowered and this will eventually cause condensation of moisture to form on the outside of the cylinder. At very high withdrawal rates the temperature at this surface may drop below 32° F (0° C) and the condensation will freeze to form a frost layer. This is the same thing that can happen in valves, flexible connectors or manifolds where the chlorine gas has gone back to liquid state and is then rapidly re-evaporated. Obviously there is <u>no freezing</u> on the inside and the frost is merely an indication of the outside surface temperature and high humidity. This is no different than frost forming on refrigerator coils and certainly the refrigerant inside the coils is not frozen. An examination of the chlorine vapor pressure curve, shows that as the temperature of the liquid--and consequently, the pressure--becomes lower and lower you finally reach an equilibrium condition. At this point, the amount of gas that can be withdrawn from the cylinder is strictly a function of how much heat can be supplied from the atmosphere. Since the withdrawal rate is now limited, the cooling effect due to evaporation remains constant.

Let us examine for a minute the condition that exists when a gas chlorinator is hooked up to a cylinder by means of a flexible connector. The pressure inside the chlorine cylinder, the flexible connector, and in the gas manifold is constant since the cylinder valve is open and there are no points of pressure reduction. The cylinder itself is essentially a boiler with a very heavy steel wall. The flexible connector is comparable to a condenser tube with the surrounding air being the cooling medium. Since this system contains both liquid and gas phase, any decrease in temperature will cause some of the gas to go back to liquid. What often occurs is that a door or window is opened to cool off the room, or a thunderstorm or other change in weather causes the room to cool. Even sun through a window hitting the cylinder, but not hitting the flexible connector, can cause the connector to be at a lower temperature. Any slight differential in temperature that occurs will cause gas in the flexible connector and manifold to change to liquid. This liquid passing through the lines will actually tend to scrub the copper and steel so that when the liquid re-evaporates, dirt will be deposited. This remains the greatest single source of chlorinator failure and maintenance in non-cylinder mounted gas chlorinators. All chlorinator systems having flexible connectors and manifolds should either be in a temperature controlled room or have special heaters on the connectors and manifold to make sure that they are at all times at a higher temperature than the cylinder. A direct-cylinder mounted gas chlorinator is not susceptible to this problem since cylinder pressure is immediately reduced to a vacuum as the gas leaves the cylinder valve and enters the chlorinator, imparting what is known as "superheat" to the gas, making condensation of the gas back into a liquid a physical impossibility.

A WORD ABOUT CHLORINE TON CONTAINERS AND WITHDRAWAL RATES

All of the information discussed, above, regarding evaporation of chlorine, “Freezing”, etc., is equally applicable to Chlorine ton Containers. Since ton containers have a much larger exterior surface area, a larger volume of chlorine liquid is in contact with the heat exchanging surface. The same type of withdrawal testing has been done using direct Ton Container Mounting Adaptors which allow the chlorine vacuum regulator t o be mounted directly on the gas outlet valve. The continuous allowable chlorine gas withdrawal rate from a Ton Cylinder, at 70°F (21° C) is approximately 500 PPD (10 kg/hr), under all of the same conditions used in the chlorine cylinder withdrawal tests.

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