

ATMOSPHERIC EFFECTS: CO2 Fog

Technique:

Creating low-hanging fog effect using dry ice (solid carbon dioxide).

Background & Theory:

Carbon dioxide, under atmospheric pressure and temperatures, is a harmless gas which is a very small portion of the natural atmosphere. Under cold temperatures and high pressures, it can be made to freeze. Solid CO₂ brought to atmospheric pressure sublimates: it goes directly from a solid to a gas at -79 degrees C (-109 degrees F) without becoming a liquid in between; this property earns it the nickname "dry ice." As dry ice sublimates, the very-cold-but-now-gaseous CO₂ vapor is invisible, but is plenty cold enough to condense water in the air. It is the condensed water vapor which is visible above a block of dry ice as "fog."

Heating dry ice increases the amount of "fog" created per time, because faster heat exchange means faster sublimation, creating more cold CO₂ to condense water per time. A convenient and effect way to heat the dry ice rapidly is to throw it in water. The hotter the water, the greater the effect. The amount of fog produced also depends on the humidity -- if it's a really dry winter day there's a lower concentration of water in the air and so less vapor is condensed, producing thinner fog; conversely a humid August day in St. Louis will create thicker fog. Conveniently for the dry days, if you're throwing the dry ice into water there will naturally be water vapor hanging out over it.

Heat considerations:

For a small, short-term effect this technique is great because nothing needs to be plugged in to create the fog. Water in a cup, cauldron, etc. is sufficient to make the desired "fumes" when dry ice is added. Props such as beakers can be carried by actors while overflowing with white "smoke." Use hot water to start with for a stronger effect.

For sustained fog on a larger scale, however, the water needs to be heated. If you throw solid carbon dioxide into water, the water is giving up heat to the CO₂ to turn it into a gas and is therefore getting colder, even freezing around chunks of dry ice. Therefore to keep the effect going a heater is needed to continuously dump heat in the system and keep the water warm or at least from freezing. Dry ice would have to be added over time to keep up the fog rate as well.

Fog movement:

Dry ice fog is created as the really cold carbon dioxide gas condenses air. This fog is much colder than the ambient air and therefore denser, so this type of fog sinks (the CO₂ is also denser than air anyway). This makes a nice graveyard haze. It can be directed out of its container with a hose, and blown around on stage with a (quiet!) fan. It will swirl nicely around the actors' feet.

Safety!

Three safety issues to think about: the solid dry ice, the gas it becomes, and the water vapor it condenses.

Dry ice is really, really cold. Remember the big number below zero? Naturally solid carbon dioxide requires some special care in handling. You shouldn't hold on to chunks of it with your bare hands for much time, but something like oven mitts are sufficient for most handling that you might need to do. It should be stored in its original container or some type of container which is not sealed tightly, because as the dry ice sublimates it expands to many times its solid volume and can pop off lids or crack containers with explosive force if not properly vented.

Carbon dioxide itself is relatively inert (unreactive) and harmless (non-poisonous), but since it takes up volume in the air (or your lungs) it displaces oxygen and so can be an asphyxiation hazard where there is inadequate ventilation (which shouldn't be the case in a theater anyway). As mentioned, CO₂ is denser than air and so no one should be hiding in wells in the floor where it could gather.

The whole point of using dry ice is the condensed water vapor in the air which looks like fog. On a related note, anything that's cold enough

dry ice or the cold CO₂ gas may begin collecting water on it and becoming wet and slippery. Near the CO₂ source ice can form. And be sure that valves, tubing, and containers used with the dry ice can withstand the cold.

Comparison with other techniques:

By comparison with other techniques to create fog, dry ice has a few distinct advantages:

- dry ice can be used on a small scale without electricity
- dry ice fog is non-allergenic, and since there's no oily stuff involved none is inhaled or deposited in the theater
- the fog is naturally low-hanging (an advantage if that's what you need)
- dry ice is safer and easier to work with than liquid nitrogen
- dry ice is relatively cheap
- the mechanism in which the fog is made can be built; no special equipment (commercial fog machine) is required
- dry ice fog is nice and thick

Naturally it has some disadvantages as well:

- dry ice fog sinks (a disadvantage if you need it in the air, such as to catch light beams)
- dry ice needs to be purchased within a day or so of when you need it
- large volumes of dry ice are needed for a large effect

References:

The City Theatrical Dry Ice FAQ: <http://www.citytheatrical.com/fogfaq.htm>

Handbook of Chemistry and Physics (CRC), 84th Edition.
(plus intro level chemistry class)