The basics of snowmaking

First, a fundamental: machine made snow is REAL snow. There's nothing artificial about it. Snow crystals - however they're produced - are simply minute crystals of frozen water.

In nature, evaporation of water from the ground, lakes, rivers and the oceans creates moisture in the atmosphere. Under the proper conditions, this moisture condenses - and when the weight of the moisture exceeds the capacity of the air to keep it aloft, it falls to the ground. If the air above the ground is cold enough, it falls as snow. Often the crystals pick up more moisture as they fall, resulting in the myriad shapes for which snow crystals are famous.

Machine snow shortcuts the process. There's no evaporation phase; the water is pumped as a liquid from a pond, reservoir or river. The water is forced into a specialized nozzle or "gun," where it collides with highly pressurized air. The compressed air shatters the stream of water into minute particles and launches them into the atmosphere.

From here, the process is similar to nature's: the droplet of water freezes and falls to the ground. The only difference is that the water doesn't have as much time to freeze before it hits the ground. Because of this, snowmaking systems must be carefully designed and operated in order to produce great snow.

▶ *So just what IS great machine made snow?*

It depends. Dry snow is certainly the most fun to ski. But it isn't always optimal, depending on what a ski area is trying to do. At resorts with sophisticated snowmaking control systems, crews will sometimes make wet snow deliberately. This is generally done when a trail is first made for the season, or when a thaw cycle has greatly reduced base depth. Wetter snow frequently has greater volume per gallon of water than does dry snow, which means the trail can be covered more quickly. This enables the trail to be opened with fewer hours of snowmaking. A second benefit is that wet snow sets up into a dense, durable layer that serves as a sturdy base to subsequent layers of snow made on top of it.

◈ *The Water Factor:*

Certainly, it sounds impressive that a good-sized ski area can claim to cover 80 or more percent of its terrain with machine-made snow. But far more relevant to skiers is the amount of snow a ski area can make at one time. This is the only true measure of how fast a ski area can open terrain early in the season, or refresh surfaces during the course of the season.

▶ *Physics lesson: What makes water freeze?*

In terms of pure physics, there is no such thing as cold. There is only heat - more heat, and less. Heat always tries to reach equilibrium - so it will flow from an area of more heat ("warmer") to less heat ("colder").

The speed with which a droplet of water radiates heat into the atmosphere and becomes snow is affected by relative humidity in exactly the same way.

As a result, modern snowmakers have less interest in the dry bulb temperature than the *wet bulb* temperature, which is a mathematical function of dry bulb temperature and relative humidity. When the atmosphere is saturated and cannot hold anymore moisture, the dry bulb and wet bulb temperatures are exactly the same. This is also known as the *dew-point*. But when humidity is extremely low, the wet bulb temperature may be subfreezing - less than 32 degrees Fahrenheit - when the dry bulb temperature is as high as 40 degrees. This makes it possible to make snow at temperatures well above "freezing."

◈ *The Air Factor*

Compressed air is the primary motive force for snowmaking. In the precisely engineered inner chambers of a modern snow gun, the compressed air breaks the stream of water into droplets properly sized to become snow crystals. The air's stream leaving the gun starts the freezing process and also pushes the water droplets up into the atmosphere - where the rapidly-cooling water droplets finish freezing and fall as snow.

Before one can fully understand how air capacity in a snowmaking system really works, it's important to understand a bit about the physics of compressed air. It's the most complex aspect of snowmaking.

▶ *Physics lesson: What occurs when air is compressed?*

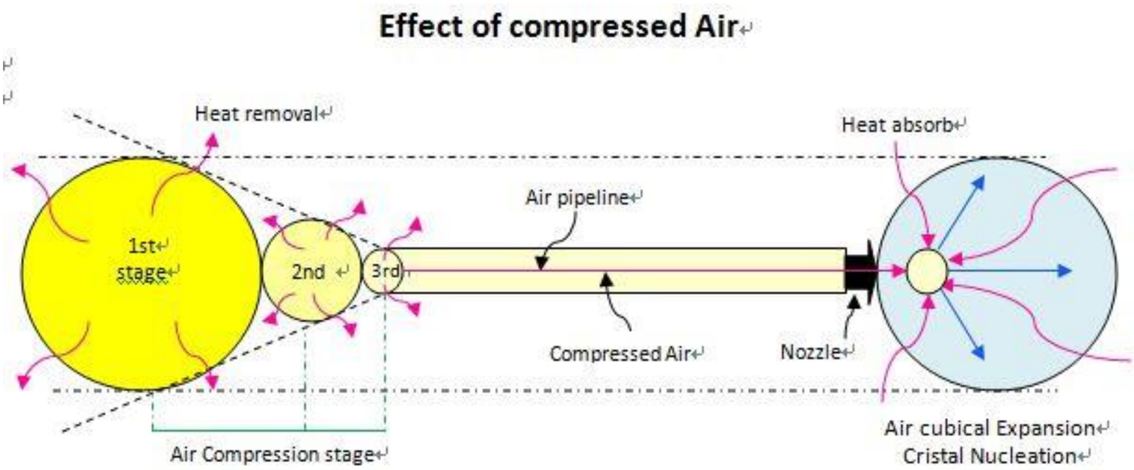
Air is a gas - or more accurately, a mix of gases. Unlike liquids, gases are compressible; a given volume of air can be contained in a much smaller space. In order to fill that smaller space, however, the gas will exist at a higher pressure. A basic law of physics tells us that the pressure of a gas and its volume are related to its temperature; when pressure goes up, so does the temperature. But the temperature doesn't necessarily *stay* high - it can be decreased.

When a compressed gas is released and goes back to its original pressure, a great deal of mechanical energy is released. At the same time, a great deal of heat is *absorbed*. It is these last two characteristics that makes compressed air such an important factor in snowmaking. The mechanical energy released by the air disrupts the stream of water in tiny droplets, then propels them into the atmosphere. And as it escapes the gun, it *absorbs* heat - in other words, cools.

▶ *System capacity*

There are two factors used in determining air capacity of a snowmaking system. The first is **volume** of air compressed, as measured by the number of cubic feet per minute entering the compressors. The second factor is the **pressure** to which that air is compressed.

The compressors at Skiing Company resorts are state of the art, oil-free machines that work by accelerating the air in chambers similar to turbines. The air goes through stages of compression. In the first, the ambient air goes from ambient - about 14 pounds of pressure per square inch - to approximately 30 psi. In the second, it goes from 30 to 80 psi. At Skiing Company resorts using high-pressure, a third stage takes the air pressure to 150 psi. In the process, the volume of the air is reduced to less than 1/8th its original volume.



Most conventional air/water snowmaking systems create pressures of roughly 80 to 100 psi. The smaller the volume to which the air is compressed, however, the greater amount of mechanical energy is released when it returns to normal atmospheric pressure -and the more heat is absorbed upon release of pressure.

As a result, when very high pressure air is used in snowmaking, there is a significant increase in snow production efficiency at warmer temperatures. And that's when ski areas are most likely to need to make snow: early in the season, when resorts are opening trails, or mid-season after a thaw. The more compressed air available, the more snow the resort can make when it needs it most.

Resorts without high - pressure systems can compensate by simply adding more compressors.

▶ *Getting the maximum benefit of that air*

It's costly to compress that much air. Permanent compressors cost upwards of $250,000 each (installed), and the resorts each spend well over a million dollars a year to operate them. So it's understandable that the company doesn't want to waste a single cubic foot.

Given the physics of air compression, the temperature of the air increases dramatically with each stage of compression. The first stages are cooled by circulating water. Final stages of compression happen so fast it's impossible to cool it in the compressor; air leaves the compressor at roughly 230 degrees Fahrenheit.

If the air remained at that temperature, the heat loss on expansion would be far smaller - essentially, taking the air back to ambient temperature. So the air is cooled again after it leaves the compressors, by means of large machines called *after-coolers*.

There's a second important reason for doing this. Air also contains moisture - liquid - and liquids don't compress. The amount of moisture in a cubic foot of compressed air can be significant. When air and the moisture it carries goes directly into the compressed air feed lines on the mountain, the moisture gradually condenses and creates rime ice on the interior walls of the pipes, hoses, and guns.

Since snowmaking systems are designed to work with specific volumes and pressures, any narrowing of the paths taken by the air results in less air escaping from each gun. Less air relative to the amount of water means that the water droplets won't freeze properly - resulting in wet or even icy surfaces. So in addition to creating greater efficiency by cooling the air, the after-coolers help create better snow - because moisture is condensed and removed as a stream of pure water.

▶ *What's the result of a good air system?*

The sheer volume of its air capacity and the skill with which the American Skiing Company handles its compressed air has several benefits for skiers. First, it helps keep operating costs down - enabling the resort to make more snow without passing along greater costs. Secondly, it allows the resorts to make more snow.

And perhaps most importantly, it provides skiers with high quality snow that is, above all, *consistent.* At many resorts, fresh machine made snow can vary markedly in consistency between the top and bottom of a trail - in some cases, it can vary markedly from gun to gun. At American Skiing Company resorts, however, the snow texture is generally consistent from the top to the bottom.

◈ *The Gun Factor*

At the simplest level, snow guns are simply nozzles in which air and water meet. The water, of course, is the raw material from which snow is made. The air has two purposes: to shatter the stream of water into tiny droplets, and - along with water pressure - propel those droplets into the atmosphere.

To accomplish this task, there are two basic types of snow guns: "airless" and "air/water."

▶ *How "airless" guns work*

Airless guns often resemble large oil drums, and are generally mounted on permanent towers or on sleds towed behind a snow cat.

Airless guns spray water out of small nozzles not unlike the spray valves homeowners attach to garden hoses. The nozzles ring a large, electrically - or gasoline - powered fan in the center of the "barrel". The fan disrupts the jets of water into small droplets, and propels them into the air.

Airless guns are cheaper to operate than air-water guns, given that no air compressor system is required. Additionally, rather than constructing a second pipe to transport compressed air, a ski area instead needs only to install a heavy-duty electrical line along the side of a trail.

There are some significant disadvantages, however. While airless guns can produce an impressive amount of snow, their size makes them very difficult to move around. And they're expensive, too - airless guns typically cost $10,000+ per copy, exclusive of the cost of the vehicle or tower.

▶ *How "air/water" guns work*

Air/water guns, the type favored by most large-scale snowmakers, are nozzles in which a stream of water is internally interrupted by a jet of compressed air. There are currently more than a dozen variants on the market.

Early air/water guns were ingeniously assembled from stock plumbing fixtures. By today's standards, they were inefficient - and could produce quality snow only in extremely cold conditions. In the mid '70s, as snowmaking became more common, guns became more carefully engineered. Still, they were a long way from today's guns in their efficiency, ease of operation and consistency in snow production.

Today's snow guns have markedly better performance characteristics than those available even as little as ten years ago. But there are still variations. Some can produce more snow than others; some work well at very cold temperatures, but poorly at warmer ones (during which time ski areas are most likely to need to make snow).

Since the performance characteristics of each type of snow gun varies, crews must learn to utilize different guns - often right next to each other. This often leads to inconsistent surface conditions An ideal gun is simple, with minimal chance for freeze-up; it throws snow a long distance, ensuring good coverage on wide trails; it works well over a wide range of temperatures and produces snow crystals of uniform size. It is energy efficient, requiring little compressed air (which also makes it quieter). Finally, an ideal gun is small, lightweight and easy for snowmakers to move, enabling crews to cover trails evenly.

Finally, it produces consistently - sized water particles, necessary to create consistent, powdery snow. The company is continuing its gun research, attempting to develop ways to increase snow depth by creating snow crystal structures more typical of natural crystals.

◈ *The Computer Factor*

Labor and energy costs are the most expensive components of snowmaking, and computers help resorts keep both costs to a minimum.

The Skiing Company is a pioneer in the use of computer control for snowmaking. Its system helps control energy costs, allows all of each resort's far-flung pumps and compressors to be controlled from one location, and helps ensure snow quality by determining optimal gun settings relative to weather conditions.

Energy costs are controlled in several ways. First, the operator can track the amount of energy being used, ensuring that the resort's electrical demand doesn't exceed limits set by the power company.

Secondly, readouts give control room operators a running tally on what apparatus is running and the system status. With the click of a mouse, the operator can tell exactly how much water is going to the hill (and what its pressure is). He or she can also determine how much compressed air is available. Since the crews keep the control room apprised of their whereabouts by radio, the operator also knows what the demands on air and water are likely to be in the near future.

Armed with this knowledge, the operator can start or stop compressors and pumps - also with the click of a mouse. This enables the operator to bring additional equipment on line at the moment it is needed - rather than wasting power by having excess capacity in the system.

▶ *Using computers to control snow quality*

One of the biggest challenges to producing consistent, high-quality snow lies in controlling exactly how much water goes into each cubic foot of snow - a critical factor in its weight and ski ability. Typically, ski areas rely on the "coat sleeve test -" in which a snowmaker walks out into the plume of snow and examines whether the crystals stick to his jacket (wet) or bounce off (dry).

Obviously, the subjective nature of this rather crude method affords tremendous variation in snow quality. Instead, Skiing Company's systems take current weather and system information fed from remote weather stations around the mountain and, using a computer to create the calculations, determine the optimal settings at each gun. In this manner, snowmakers can make very consistent snow with optimal energy efficiency.

The Skiing Company sees its snowmaking computers very simply: they are management tools, not a way to cut corners. Snowmaking is still tough, demanding, hands-on work - but the computers eliminate most of the guesswork, and make it easier to provide consistency and quality.