Date: 15 November 2007
To: Sophomore Engineering Clinic II Faculty
From: Jill
Subject: White Paper on an Engineering Problem

Abstract

Many ski resorts today rely heavily on a good system of snow makers to enable them to open earlier in the season, or even just tweak the conditions of their trails. The machines today require the correct weather conditions in order to produce snow. Ice particles are made by combining pressurized air and water inside the body of the machine, and once the particles hit the air, they freeze into snow. Installing a cooling system somewhere inside the body of the snow maker could allow the particles to form snow before hitting the air. This device could allow for snow to be made, even under weather conditions that aren't necessarily best for snow making.

Introduction

Recently, the amount of people interested in skiing and snowboarding has increased. However, the number of operating mountain resorts has been declining over the past twenty years. One of the main reasons for this decline is the lack of ideal weather conditions [1]. The national average temperature has been rising over the past few years, with this past winter being the fifth warmest on record [2]. Many resorts have installed snow making machines, which enable them to make snow even when nature cannot provide it. Snow makers rely heavily on the weather conditions, requiring them to be below freezing with relatively low humidity levels in order to make good quality, dry snow.

Snow makers have been in existence since around 1950, and have since been able to help mountain resorts achieve a longer season, or at least tweak the conditions of their trails. The original snow maker was just a nozzle with compressed air and water coming into it. Once the

air hit the water, it spread it apart into many small particles, which were expelled into the atmosphere, and as long as the temperature was cold enough, they froze into snowflakes [3]. This was then improved upon a few yeas later when the fan snow maker was developed [4]. Not only was this machine quieter than its predecessor, but it did not demand quite as much energy. However the fan snow maker encountered a little trouble with freezing, as the water and air mixture would disperse inside the machine, forming sheets of ice around the interior. A new version of the snow maker was then developed, called the Boyne Snowmaker, which eliminated freezing by isolating nucleator nozzles to the outer rim of the body. A nucleator is a small substance, such as a dust particle or bacterium in the atmosphere that help ice crystals to form by providing a crystal nucleus of some sort for the ice nuclei to form around. They help attract water molecules and therefore encourage the formation of ice. Having the nucleator nozzles on the outside helped keep water particles from freezing to the fan or other parts inside the body of the snow maker [5]. Once the snow particles hit the air, they are super cooled by the low temperatures, and some moisture evaporates to produce nice dry snow.

Snow makers only work, however, if the weather conditions cooperate. The temperature must be low enough for natural snow to form, and the humidity must also be low enough. If not, the concentration of moisture in the air will be too high for any moisture to evaporate from the snow particle, resulting in either rain or slush [6]. Producing rain or slush would degrade the conditions of the trails and the snow making could actually be hurting the resort.

Definition of the Problem

On average, the national temperature during winter has been increasing, which can directly result in a decrease in natural snow fall in parts of the country. It also poses a problem for snow making machines, which rely on the temperature of the air to be cold enough before snow can be made successfully. Because of the difference in temperature now, as compared to the 1980s, the number of operating mountain resorts has declined dramatically.

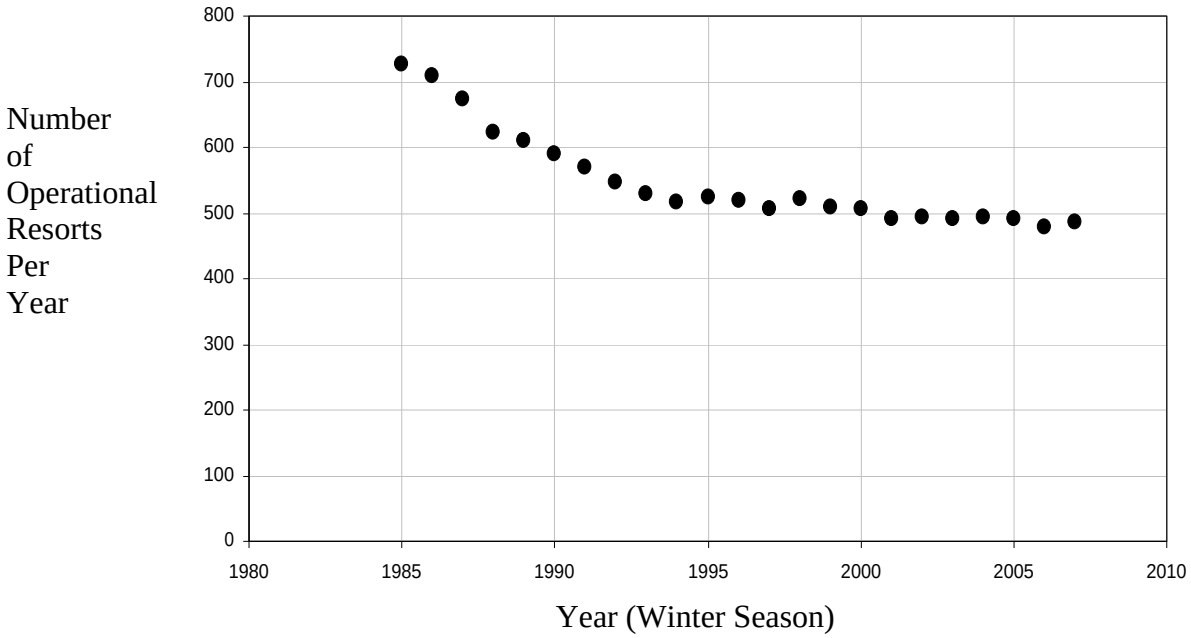

Figure 1. Number of Ski Resorts per Year
-This graph shows the decline in operational ski resorts across the nation over the past 20 years. The number almost halves, going from 727 operational resorts in 1985 to 458 resorts in 2006 [1].

Because the national average temperature this past winter, being the fifth warmest winter on record, was actually 1.2°F warmer than past averages, snow fall was less apparent in most places. This hurt the ski resort industry, which then turned to snow makers to bring in patrons.

However, since snow makers do not function correctly or efficiently above freezing temperatures or at high humidity levels, they could not completely make up for the lack of natural snowfall.

Although the number of resorts has declined, the number of participants in skiing and snowboarding combined has, in fact, increased. This could be due in part to the introduction of snowboarding around 1990, which drew a lot of attention to the winter sports.

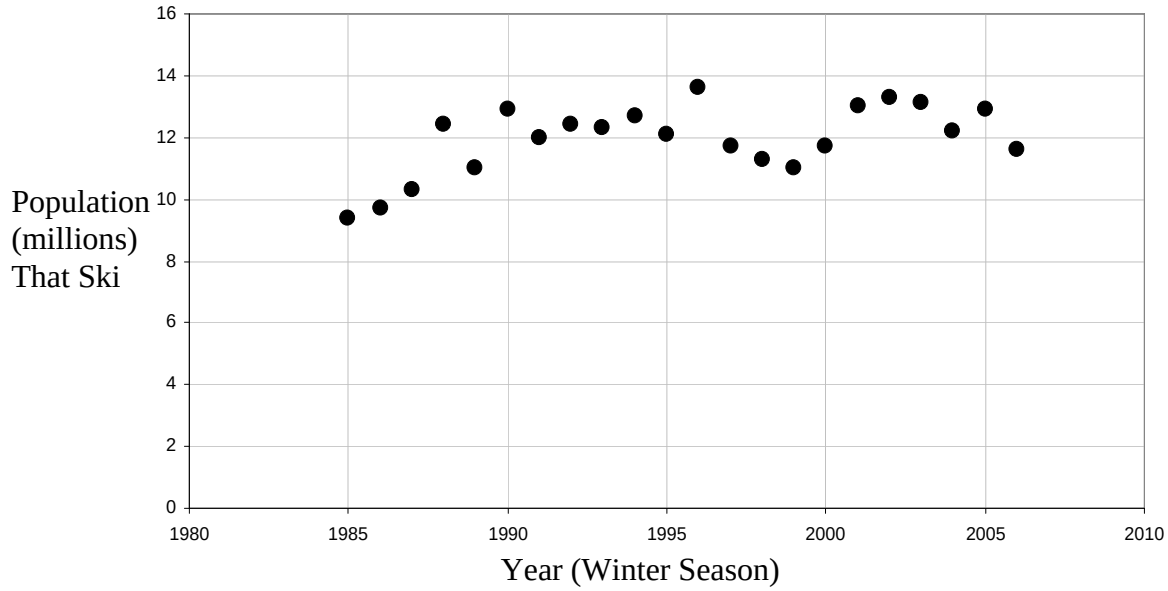

Figure 2. Population (in millions) of Skiers and Snowboarders Combined
-This figure shows the amount of people, in millions, who either ski or snowboard. The numbers have leveled off at around 12 million people per season.

In order for resorts to keep these numbers high, they need to be able to provide a sufficient amount of snow. Most resorts in the United States have a system of snow makers already, however only about 15% of them actually have a large enough system to make enough snow to open earlier in the fall. This is where the idea of developing a new kind of snow maker manifests itself. To develop a snow machine that could produce snow at temperatures above freezing would revolutionize the snow making industry.

Potential Solution

When snow machines make snow, the water particles are expelled into the air to super cool and form into snowflakes. For this reason, the temperature has to be at or below 32°F for snow to be formed successfully. In order for snow to be made at slightly warmer temperatures, a cooling system needs to be added to the body of the snow maker so that the snow has a chance to super cool before hitting the outside air. Ideal temperatures for snow making are around 15 and 16° F, so that the snowflakes easily freeze into snow. Snow can be made at around 30° F, but is generally not as dry. A snow maker with an internal cooling device could possibly make snow at temperatures up to 35 or 36° F. The temperature outside must still be cold enough for snow to exist, however it need not be as cold in order for it to form correctly. In this case, snow would be leaving the machine, instead of water particles that have yet to turn into snow.

A mini refrigeration system could serve the purpose. The body of the snow maker may have to be elongated slightly to allow for the nucleator nozzles to be located further inside the body. They are currently located on the outer rim of the machine so the particles can nucleate as they leave and form into snow upon hitting the atmosphere.

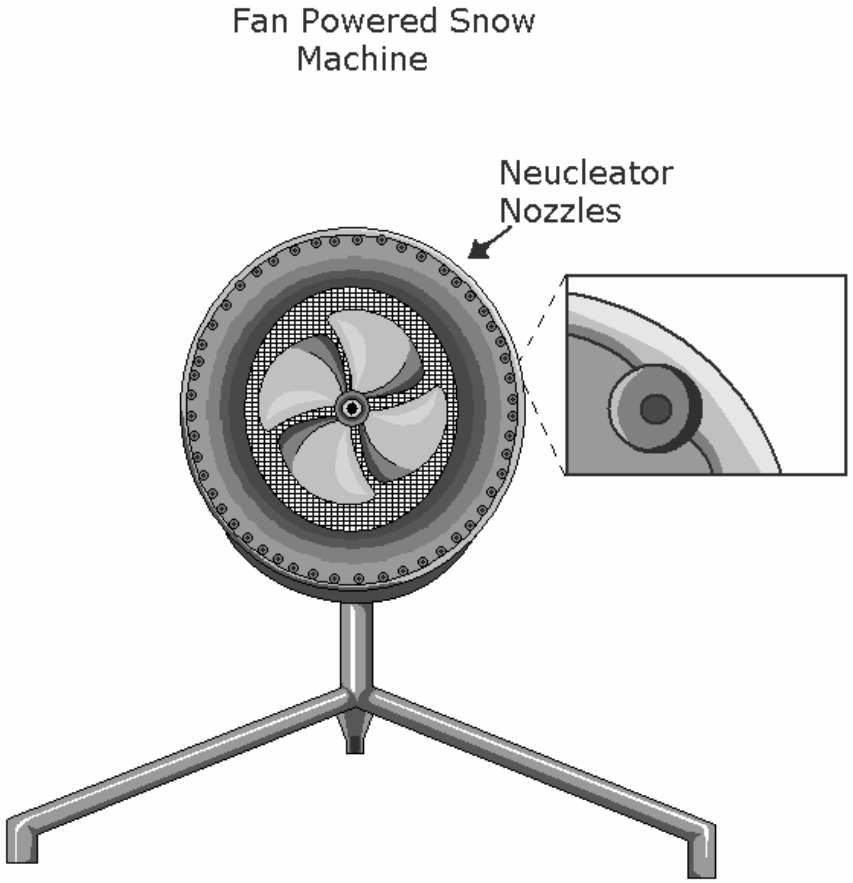

Figure 3. Diagram of the Snow Machine Looking in From the Front
-This figure shows the nucleator nozzles on the outer rim of the machine body, and a section is blown up for more detail. The model drawn is a fan snow maker.

In order to have an air-conditioning system incorporated into the design, the nucleator nozzles need to be moved back slightly. Nozzles blowing out very cold air will be lining the rim, and will allow the particles to super cool, meaning they will freeze quickly, and do so before hitting the atmosphere.

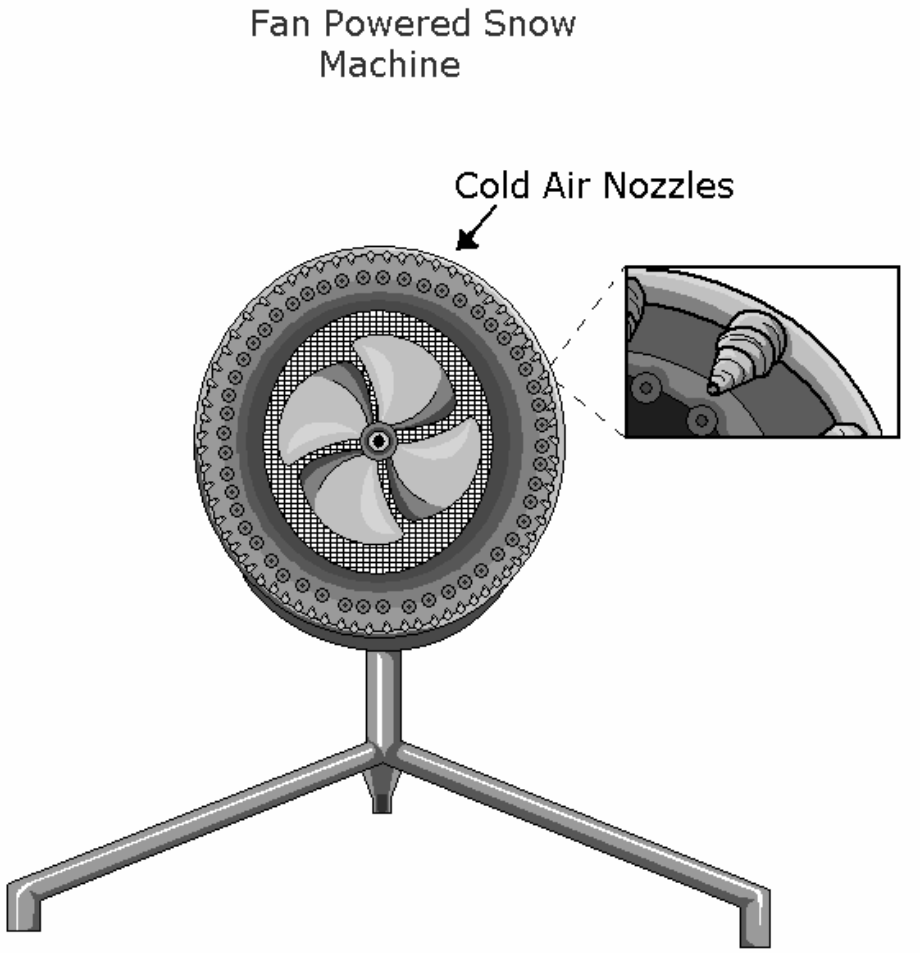

Figure 4. New Design for Snow Maker
-This figure shows the outer rim of cold air nozzles, along with a close up image. The nozzles will be angled outward and slightly down.

With the nucleator nozzles moved back slightly, the water particles can nucleate and form snow flakes while being cooled down by the air coming out of the cold air nozzles. The air coming out of the nozzles could be cooled down to as much as 10° F in order to ensure the product exiting the machine is snow.

Snow can survive in temperatures at or a little above freezing, yet it can not be made at these conditions. Having a snow maker with a refrigeration device could help to cool the water particles down enough so that they form snow just before leaving the body of the machine. Once

they hit the atmosphere they will continue to cool further because of the decrease in pressure. Therefore, even at temperatures slightly higher than freeing, snow could still successfully be made.

Conclusion

Snow makers are very expensive pieces of equipment to run, and if the volume of business is not high enough, some resorts cannot afford to have enough snow making power to sufficiently make enough snow to open earlier in the fall. Also, the warmer fall temperatures do not allow for modern snow makers to even operate correctly. The development of a snow maker with a ring of nozzles expelling cold air around the outer rim of the machine body could be the solution resorts have been waiting for.

To employ such a device on the rim of the snow maker would allow the particles to cool down before completely leaving the system. As a result, the particles would be leaving the snow maker as snow, as opposed to forming into snow only after they leave the body of the machine.

Only about 15% of ski resorts in America have the ability and snow making power to produce enough machine made snow to open a lot earlier in the fall, although almost all resorts have some sort of system of snow makers. It takes a rather long time to build up the trails enough for people to ski or snowboard on. And because of the volume of people attracted to these resorts, the owners need to rely on the mountain for vigorous use. The base is usually made out of heavier, wetter snow so that it packs nicely and will not get torn up when millions of people start ripping around the trails. Then, after the base is thick enough, a layer of light powdery snow is made. This gives the trail a good quality top layer for expert handling and control while skiing or riding.

Overall, to have a snow maker that can produce snow at warmer temperatures can allow for either mountain resorts to make a large volume of snow earlier in the fall, or just tweak the conditions of the trails as needed. This way, the weather does not always have to be perfect conditions, which gives resort owners the freedom of making adjustments to their trails even when the weather is not technically cold enough.

References

[1] T. Hawks, “National Ski Areas Association: Industry Stats.” [Online document] July 2007, [2007 July 30], Available at HTTP: http://www.nsaa.org/nsaa/press/operating- ski-areas.asp

[2] J. Leslie, “U.S. Winter Much Warmer than Average.” [Online document] March 2006, [2006 Mar. 09], Available at HTTP: http://www.publicaffairs.noaa.gov/releases2006/mar06/noaa06-027.html

[3] W.M. Pierce, Jr, “United States Patent and Trademark Office: Method for Making and Distributing Snow.” [Online document] Dec. 1950, [1954 April 27], Available at HTTP: http://patimg2.uspto.gov/.piw?docid=US002676471&PageNum=2&IDKey=26422CEADE53&HomeUrl=http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1%2526Sect2=HITOFF%2526d=PALL%2526p=1%2526u=%25252Fnetahtml%25252FPTO%25252Fsrchnum.htm%2526r=1%2526f=G%2526l=50%2526s1=2676471.PN.%2526OS=PN/2676471%2526RS=PN/2676471

[4] A.W. Hanson, “United States Patent and Trademark Office: Method of Generating Snow.” [Online document] Feb. 1958, [1961 Jan. 17], Available at HTTP: http://patimg2.uspto.gov/.piw?Docid=02968164&homeurl=http%3A%2F%2Fpatft.uspto.gov%2Fnetacgi%2Fnph-Parser%3FSect1%3DPTO1%2526Sect2%3DHITOFF%2526d%3DPALL%2526p%3D1%2526u%3D%25252Fnetahtml%25252FPTO%25252Fsrchnum.htm%2526r%3D1%2526f%3DG%2526l%3D50%2526s1%3D2,968,164.PN.%2526OS%3DPN%2F2,968,164%2526RS%3DPN%2F2,968,164&PageNum=&Rtype=&SectionNum=&idkey=NONE&Input=View+first+page

[5] M. Bellis, “Who Invented the Snow Making Machine?” [Online document] Available at HTTP: http://inventors.about.com/library/inventors/blsnow.htm

[6] T. Harris, “How Snow Makers Work.” [Online document] Available at HTTP: http://travel.howstuffworks.com/snow-maker.htm