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# CAPABILITY IN THE HYDRAULICS ENVIRONMENTAL ROOMS

by

J. Heidt, C.E.T.

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# TECHNICAL REPORT ON THE SNOWMAKING CAPABILITY IN THE HYDRAULICS ENVIRONMENTAL ROOMS

by

J. Heidt, C.E.T.

Technical Services Section
Hydraulics Division
Canada Centre for Inland Waters
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## 2. LIST OF FIGURES

FIGURE | PAGE NO.

## 3. SCOPE OF REPORT

3.1 The study of the snowmaking capability in the Hydraulics Environmental Rooms was undertaken at the request of C.N. DeZeeuw, Head, Technical Services Section, Hydraulics Division.

3.2 This report consists of how the study was conducted, how the data was gathered and to what use the information will be put. Negative data will not be discussed but will be mentioned in the chronology.

3.3 No attempt will be made to discuss the physics of snowmaking as it is beyond the scope of this report and the author.

3.4 S.I. units are used in this report. The pressure gauges are in English units and were subsequently converted to S.I. units. The numbers assigned to the nozzles are used for identification of the nozzles and are not necessarily their diameter. Appendix I lists the nozzles and their sizes.

## 4. PURPOSE

The snowmaking facility and equipment in the Hydraulics Division labouratory have never had a comprehensive examination to determine their full capabilities. The purpose of this study is to systematically gather data about snow type and quanity which can be displayed in tables and graphs for different cold room temperatures and air/water supply parameters. During the data collection, techniques will be learned that can be combined with the tables and graphs to form an operations manual. Therefore, simply stated, the purpose of this report is to contribute to the snowmaking operations manual and to provide documentation of how the techniques, tables and graphs in that manual were derived.

## 5. LIST OF EQUIPMENT

### 5.1 AIR COMPRESSING EQUIPMENT

5.1.1 Ingersoll-Rand, Type 30, Model 7T, air compressor and associated cooler and dryer.

5.1.2 Aro air line regulator, Model 27354-20S

5.1.3 Marsh pressure gauge, Model J2054

5.1.4 Marsh bi-metal thermometer, Model L3145

5.1.5 Ball shut-off valve

### 5.2 WATER PUMPING EQUIPMENT

5.2.1 Sherwood rotary gear pump, Model "V"

5.2.2 Watts by-pass relief valve, Model 5300A

5.2.3 Marsh pressure gauge, Model J2054

5.2.4 Marsh bi-metal thermometer, Model L3145

5.2.5 Ball shut-off valve

### 5.3 SNOW GUN

5.3.1 The snow gun is a fabricated piece of pipe in a "Y" shape with provision for nozzles, made from pipe plugs, to be screwed into the stem of the "Y". Each leg of the "Y" is threaded. The high pressure water is introduced into the side leg and the compressed air enters the straight leg.

5.3.2 Flexible hose is connected by means of quick disconnect couplings to the ball shut-off valves inside the cold room.

5.3.3 Marsh needle valves, Model N1514

5.3.4 Marsh pressure gauges, Model J2054

5.3.5 Apollo check valves, Model 1/2"

## 5.4 MEASURING EQUIPMENT

5.4.1 Hewlett-Packard temperature sensor,Model 2802A

5.4.2 Weather Measure humiditiy sensor, Model HM111 with coated probe.

5.4.3 Hewlitt-Packard strip chart recorder, Model 7100B

5.4.4 Precision balance

5.4.5 Collection pans 34cm * 24cm * 1.5cm

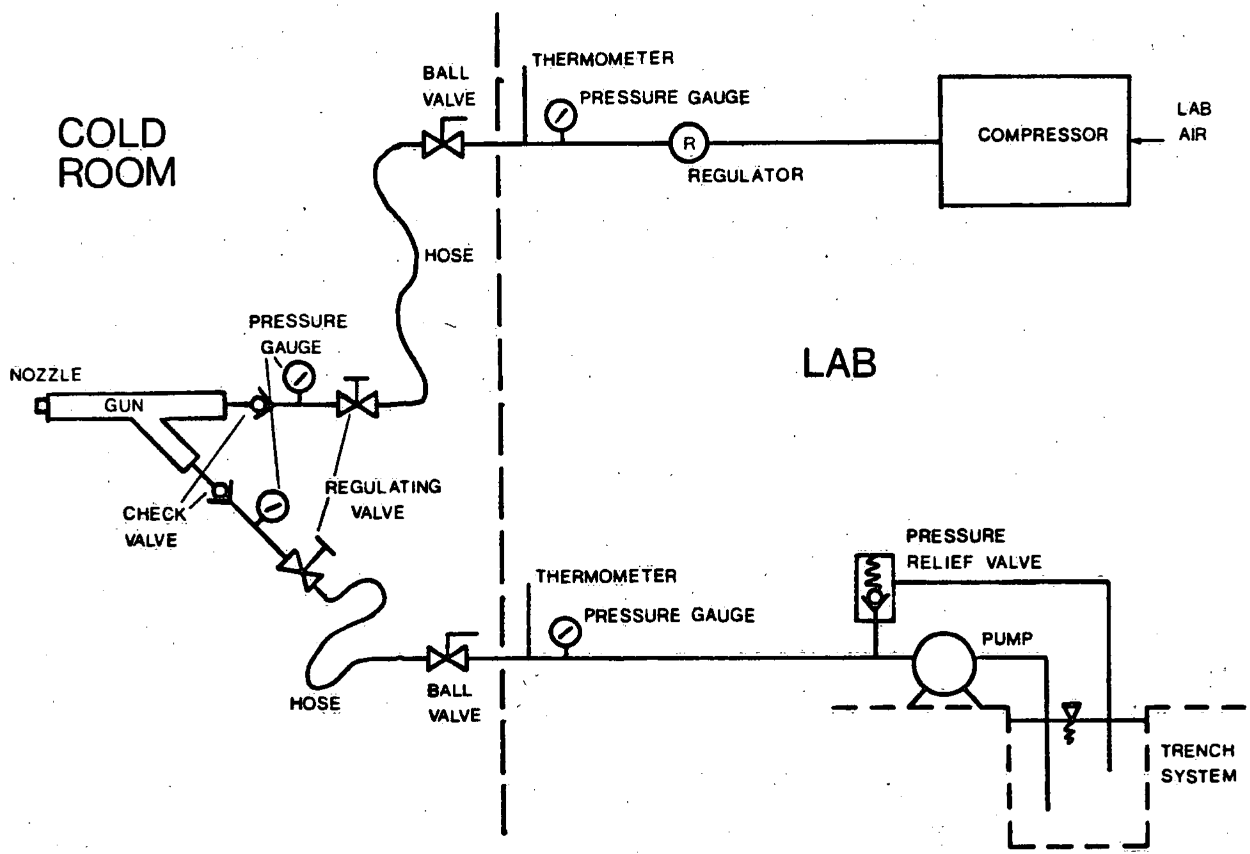


FIG.1 SCHEMATIC of SNOWMAKING EQUIPMENT

## 6. METHOD

### 6.1 STANDARD SNOWMAKING GUN

Figure 1 shows the schematic of the standard snowmaking equipment used in this study. The various nozzle types and sizes are screwed into the end of the snowmaking gun. The air pressure supplied to the gun is controlled by the pressure regulator (Fig. 2) located outside the cold room. The water pressure supplied to the gun is controlled by the pressure relief valve (fig. 3) attached next to the water pump. The pressure gauges (Fig. 2) outside the cold room are used to set these pressures. The temperature of the water and air is measured with the

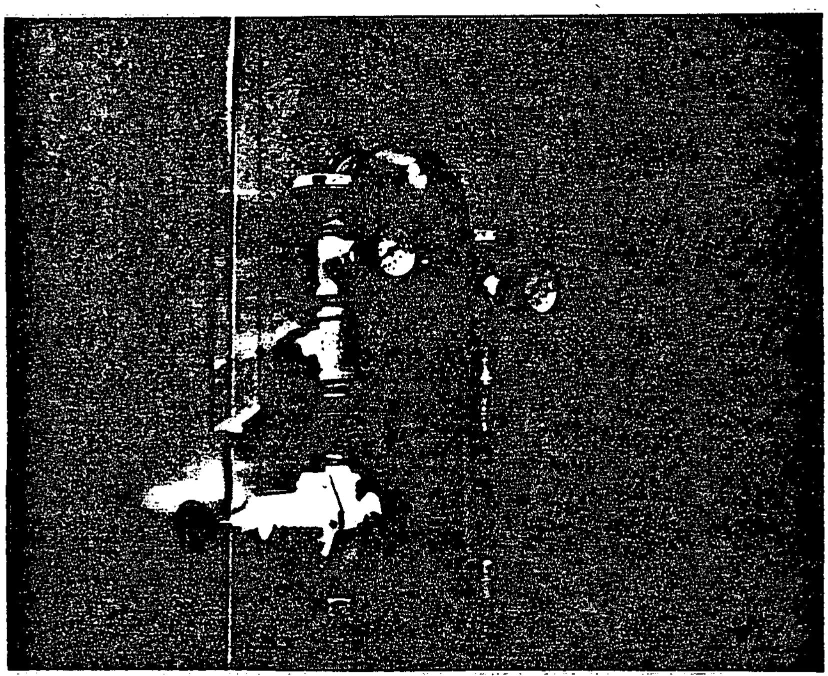

FIG. 2 GAUGES AND PRESSURE REGULATOR

thermometers (Fig. 2) located in the supply lines outside the cold room. The ball valves (Fig. 4) inside the cold room are merely for the convience of shutting off the flows. The flows are finely controlled by the regulating valves (Fig. 5) attached to the gun. Confirmation of the set supply pressures is read from the gauges (Fig. 5) attached to the gun. The check valves (Fig. 5) prevent back flow in the case of a compressor or pump break down.

6.2 SPRAY SNOWMAKING GUN

The only difference between the standard snowmaking gun equipment and the spray snowmaking gun equipment is the actual gun. The spray snowmaking gun (Fig. 6) consists of a spray painting mixing chamber and either an internal nozzle or an external nozzle. The gun is mounted on an aluminium plate to which is fastened a 500 Watt ring heater and thermostat. The 115 Volt heater prevents the nozzle from freezing.

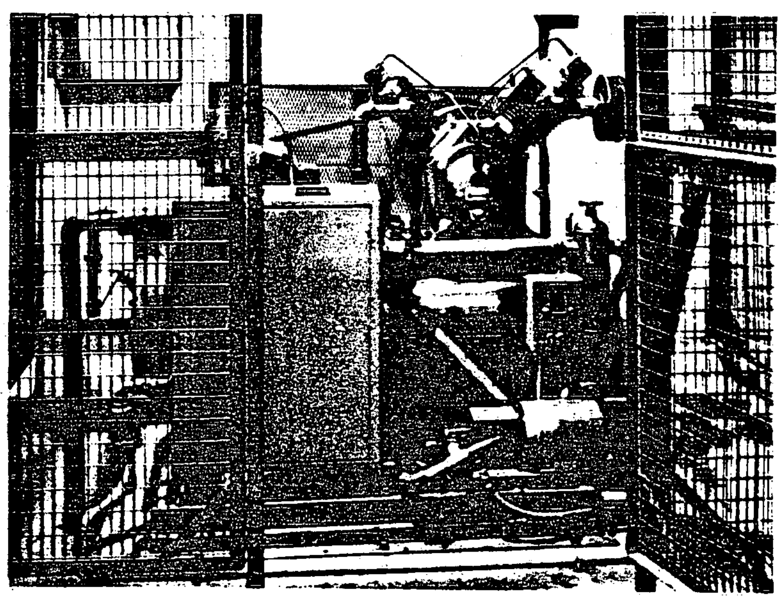

FIG. 3 COMPRESSOR AND WATER PUMP

FIG. 4 BALL VALVES

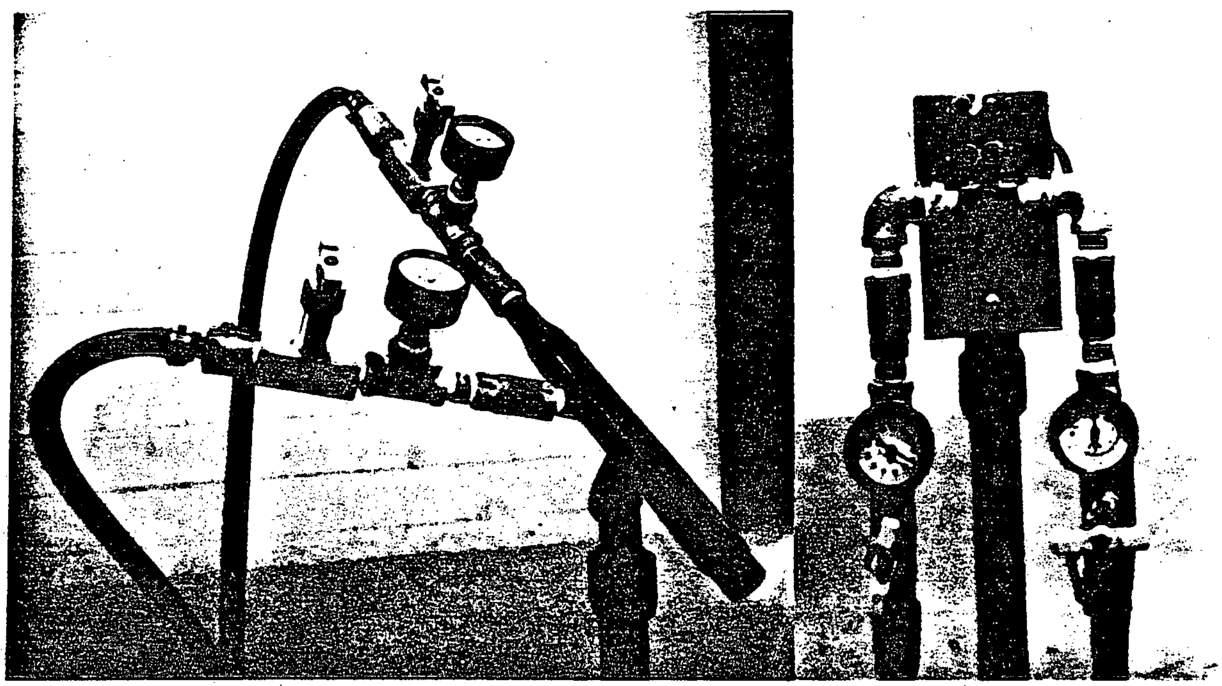

FIG. 5 GUN CONTROL EQUIPMENT

FIG. 6 SPRAY GUN

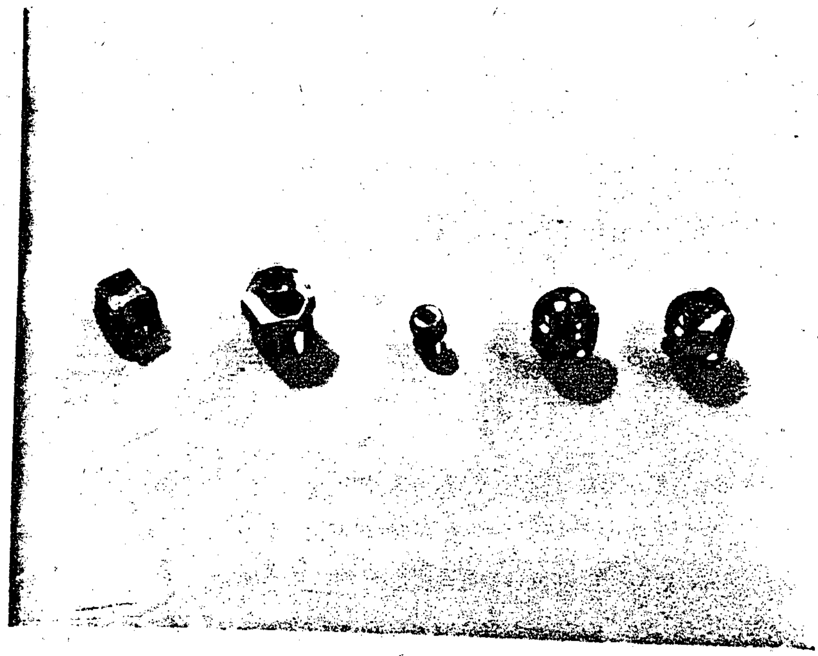

FIG. 7 NOZZLES

## 6.3 METHOD OF DATA COLLECTION

The cold room controller was set to the temperature required for the test to be performed. The temperature sensor, humidity sensor and the strip chart recorder were turned on to record the parameter changes as the room cooled. The air compressor and the water pump were switched on and allowed to warm up. The selected nozzle was installed in the gun.

When the cold room reached the required temperature the gun was mounted in the room and connected to the system. The valves on the gun were opened and the air and water supply pressures were set. The regulating valves on the gun were adjusted to a setting to make snow. The collection pans were arranged on the floor and the gun was aimed at the pans.

After a sufficient period of time had passed to allow the pans to fill with snow, the gun was aimed away from the pans and they were removed from the cold room. Very quickly the excess snow was scrapped from the top of the pans and they were weighed. From the known volume of the pans and the weight of the snow in them, the density of the snow was determined.

If another run was to be done the pans were emptied, dried and taken back into the cold room to cool off. The valve settings or supply pressures were changed and the pans arranged on the floor to catch the snow.

## 7. OBSERVATIONS

| RUN NUMBER | PRESSURE AIR kPa | PRESSURE WATER kPa | ROOM TEMP degC | NOZZLE NUMBER | SPECIFIC GRAVITY | REMARKS |
|---|---|---|---|---|---|---|
| 812-1 | 1000 | 517 | -10 | .125 | - | |
| -2 | 1000 | 862 | -10 | .125 | - | |
| -3 | 862 | 862 | -10 | .125 | - | Wet snow, pulsating |
| -4 | 862 | 862 | -10 | .125 | - | |
| 813-1 | 862 | 862 | +5 | .125 | - | Warm test, no pulsating |
| -2 | 862 | 862 | -5 | .125 | - | |
| -3 | 862 | 862 | -10 | .125 | - | Valves full open |
| | | | | .25 | - | All water |
| | | | | .187 | - | All water |
| -4 | 862 | 862 | -15 | .125 | - | Room temp rises to -3.5 |
| 814-1 | - | - | -16 | - | - | Portable high press. washer with #4009 tip All water |
| -2 | 862 | 862 | -15 | .125 | - | |
| | 517 | 517 | -15 | .125 | - | Temp. measurements |
| 816-1 | 517 | 517 | -10 | .080B | - | Pulsating |
| | 862 | 862 | -10 | .080B | - | Valves closed down |
| 8110-1 | 862 | 862 | -10 | .080B | - | Gun pointed slightly down. No pulsating |
| 8111-1 | 862 | 862 | -10 | .080B | - | Valves less than one turn open. |
| -2 | 862 | 862 | -10 | .080B | - | Testing pans |
| -3 | 862 | 862 | -10 | .080B | - | Testing pans |
| 8112-1 | 862 | 862 | -10 | .080B | - | Air open 1/2 turn Water open 1-11/2 |
| -2 | 862 | 862 | -10 | .080B | .15 | Air 1/2 turn Water 1/4 turn |
| -3 | 862 | 862 | -10 | .080B | .155 | |
| -4 | 862 | 862 | -15 | .080B | - | Nozzle froze |
| 8113-1 | 862 | 862 | -10 | .080B | .115 | Air 1/2 turn Water 1/4 turn |
| -2 | 862 | 862 | -10 | .080B | - | Pump quit |
| 8117-1 | 448 | 448 | -10 | .080B | - | Line pressure |
| | 448 | 448 | -10 | .062B | - | Valves at 1/4 turn, varying degrees of snow wettness |
| 8118-1 | 724 | 724 | -10 | .062B | .175 | |
| -2 | 724 | 724 | -10 | - | - | Air atomizing nozzle Almost water |
| | 862 | 862 | -10 | - | - | Almost water |
| 8119-1 | 517 | 517 | -10 | - | - | Air internal atomizing nozzle, line pressure, nozzle froze |
| | 517 | 517 | -10 | - | - | Air external atomizing nozzle, nozzle froze |

| RUN NUMBER | PRESSURE AIR kPa | WATER kPa | ROOM TEMP degC | NOZZLE NUMBER | SPECIFIC GRAVITY | REMARKS |
|---|---|---|---|---|---|---|
| 8120-1 | 862 | 862 | -10 | .125 | .195 | Valves 1/4 turn open |
| | 862 | 862 | -10 | .125 | .195 | " " |
| -2 | 690 | 690 | -10 | .125 | .24 | " " |
| | 690 | 690 | -10 | .125 | .25 | " " |
| -3 | 552 | 552 | -10 | .125 | .265 | " " |
| | 552 | 552 | -10 | .125 | .25 | " " |
| 8124-1 | 552 | 552 | -10 | .125 | .78 | Valves 1/2 turn open |
| -2 | 552 | 552 | -10 | .080B | .28 | " " |
| -3 | 552 | 552 | -10 | .080B | .22 | " " |
| 8125-1 | 552 | 552 | -10 | .062B | .14 | Valves 1/4 turn open |
| -2 | 690 | 690 | -10 | .062B | .17 | " " |
| 810319-1 | 827 | 827 | -10 | .062B | .12 | " " |
| -2 | 965 | 965 | -10 | .062B | .13 | " " |
| -3 | 690 | 690 | -10 | .080B | - | Bad reading |
| -4 | 690 | 690 | -10 | .080B | .145 | Valves 1/4 turn open |
| -5 | 827 | 827 | -10 | .080B | .11 | " " |
| -6 | 965 | 965 | -10 | .080B | .13 | " " |
| 810320-1 | 552 | 552 | -10 | .125 | .30 | " " |
| 810323-1 | 758 | 758 | -10 | .125 | .21 | " " |
| -2 | 827 | 827 | -10 | .125 | .14 | " " |
| -3 | 965 | 965 | -10 | .125 | .14 | " " |
| -4 | 965 | 965 | -10 | .125 | .15 | " " |
| 810324-1 | 827 | 827 | -10 | .125 | .195 | " " |
| -2 | 621 | 621 | -10 | .125 | .215 | " " |
| -3 | 896 | 896 | -10 | .125 | - | Bad reading |
| -4 | 896 | 896 | -10 | .125 | .11 | Air 1 turn open Water 1/4 turn open |
| 810602-1 | 345 | 345 | -10 | - | - | 1891125 Internal mix spray nozzle. Valves open 1/4 turn. Result was slush. |
| -2 | 345 | 345 | -10 | - | - | Small internal mix spray nozzle. Air valve open full. Water valve barely open. Fine powder snow. Low quantity. |
| -3 | 345 | 345 | -10 | - | - | Small external mix spray nozzle. Valves 1/4 open. Fine powder snow. Low quantity. |

## 8. CHRONOLOGY

What follows is a chronological listing of events that occurred during this study. The purpose of presenting this here is so that hopefully some logic will be seen in decisions which were made affect this report and snowmaking in general.

30 JAN 81: The temperature and humidity sensors and recorders were set up. The position in the cold room for the sensors was chosen so that a minimum of water or snow would accumulate on the humidity sensor. This position was within 15.2 cm of the ceiling and about 30.5 cm from either wall in the Southwest corner of cold room 1B. It was found that the room temperature controller had to be set to -11.25 $^{o}$C in order to reach an average temperature of -10 $^{o}$C. It was also noticed that the actual room temperature varied by as much as + or - 1.5 $^{o}$C about the average set for the room.

2 FEB 81: Attempts to make snow were thwarted on every occasion by a tendency for the water stream to pulsate. Many solutions to the problem were theorized and included heating the nozzle to stop freezing and possible installation of check valves to stop air or water from travelling up the wrong hose if a pressure imbalance occurred. It was not until a week later that it realized that the gun must be kept pointed at a slight down angle to eliminate the pulsing. When this practice was put into effect all pulsing problems stopped.

3 FEB 81: Good snow was made using the smallest supplied nozzle(.125B).

Making snow must have been mostly by accident as it had not yet been realized that the gun must be tipped down. The temperature rise in the room while making snow was quite dramatic. The temperature rose from -10 $^{\circ}$C to about -2.5 $^{\circ}$C and from -15 $^{\circ}$C to -3.5 $^{\circ}$C on two different occasions. The cold room return air grill was found to be clogged with snow particles. It was removed and no further trouble with air temperature rises were observed. Two larger size nozzles (.187 and .25 ) were tried but they produced only water or slightly slushy water. It was guessed that the cold room cooling capacity was too small and the supply pressures too low to make snow with these size nozzles.

4 FEB 81: The high pressure portable washer was set up to see if high pressure water would make snow. With the nozzle that was supplied with it, and at about 3500 kPa only freezing rain could be produced. The regular gun was set up with the .125B nozzle and it was found that the temperature of the stream was 0 $^{\circ}$C about 61 cm from the nozzle. The humidity sensor quit working. It was decided not to replace it since recordings had shown that the relative humidity rose to a high value when snow making was started. If the relative humidity had any affect on snow making there would be nothing that could be done about it in any case due to the limitations of the cold room.

6 FEB 81: A similar design of nozzle but with a 2.03 cm dia. bevelled hole was tried. The resulting snow seemed to be of a drier quality although the quantity was less than in previous runs. The air compressor started to give problems at this time. It

was decided to disconnect the intake line and draw the air for compressing from the lab and not the cold room. This method of operation has had no effect on snow making.

11 FEB 81: Testing was done to prove out the method of collecting the snow.

12 FEB 81: It was found that control valves openings of less than 1/2 turn caused the best snow to be formed.

13 FEB 81: The water supply gear pump failed.

17 FEB 81: While parts were being obtained to repair the pump, it was decided to try to make snow with just line water pressure. A smaller nozzle (1.57 cm dia.) was manufactured. Only the .062B and the .080B nozzles were used during this testing. While it is possible to make snow with line pressure, the quality of the snow varies in the room. This probably due to the fact that the line pressure varies due to the water usage in the building.

18-19 FEB 81: The pump was repaired. Various types of spray nozzles were at different pressures with mixed results. In most cases the nozzles froze up in a short period of time but while operating seemed to form dry snow. The quantities were small. It was decided that this type of nozzle was worth pursuing as it offered the advantage of making dry snow in a very localized area. Parts were ordered to heat the nozzles.

20-25 FEB 81: Data collection proceeded with few problems. However on 25 Feb the pump could not supply water at a pressure above 690 kPa. The pump was obviously about to break down again. Sampling was suspended and a new higher quality gear pump was ordered.

18 MAR 81: The new pump was installed with one important difference. The intake water was now drawn from the clean water pumping system trench instead of the building water supply. It had been noticed occasionally in the past that when other activities in the lab used a lot of building water the supply pressure would drop and affect the output pressure of the pump.

19-24 MAR 81: Data collection continued. On 24 Mar it was decided that this phase of the testing should be stopped. The reason for this will be discussed in the results section of this report.

1-2 JUN 81: The parts for heating the spray nozzle had been assembled and were ready for testing. The small internal mix and external mix nozzles performed well although the quantities of snow produced produced was too small to be measured in a reasonable length of time. The larger spray nozzles made a larger quantity of snow, it seemed to be very slushy.

## 9. CONCLUSIONS

The observations made during this study have proven that the Hydraulics Division snowmaking facility is indeed capable of making varied quantities and qualities of snow.

Wet snow is defined as a type that can be readily formed into a snowball and water can sometimes be squeezed out it. Dry snow is a little harder to form into a snowball and no water can be squeezed out of it. All the snow was of the granular powder type with no traditional flakes observed. Figures 7,8 and 9 show plots of air and water supply pressures versus specific gravity of snow. These graphs are based on meager data but do show the variations in specific gravity due to supply pressures. Specific gravities of snow between about 0.2 and 0.3 were judged to be wet snow. A specific gravity less than about 0.2 was judged to be dry snow.

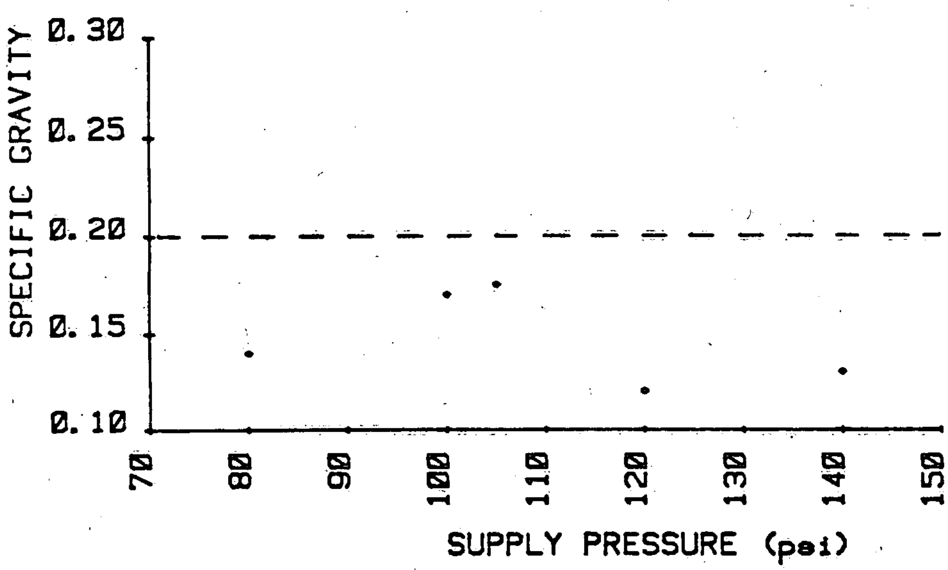


FIG. 7 .062B NOZZLE

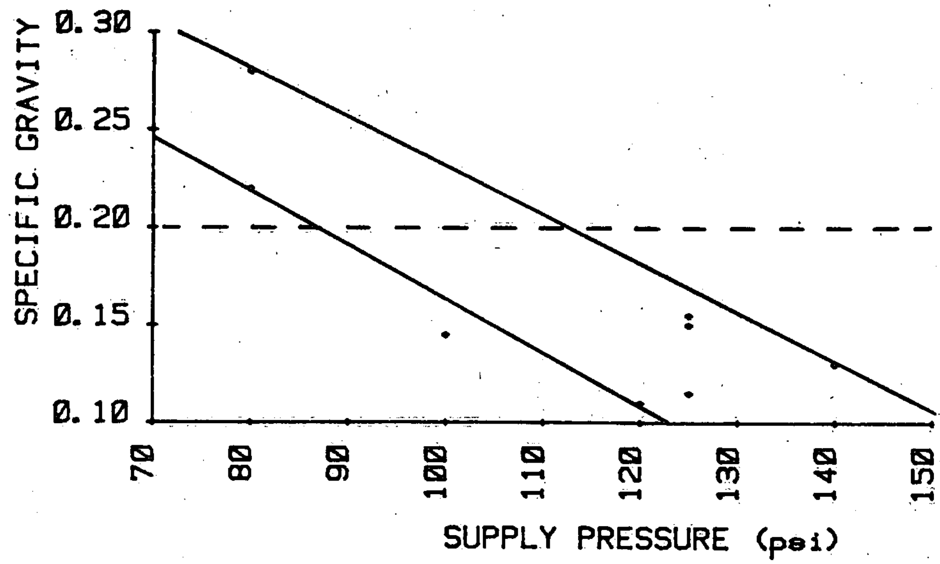


FIG. 8 .080B NOZZLE

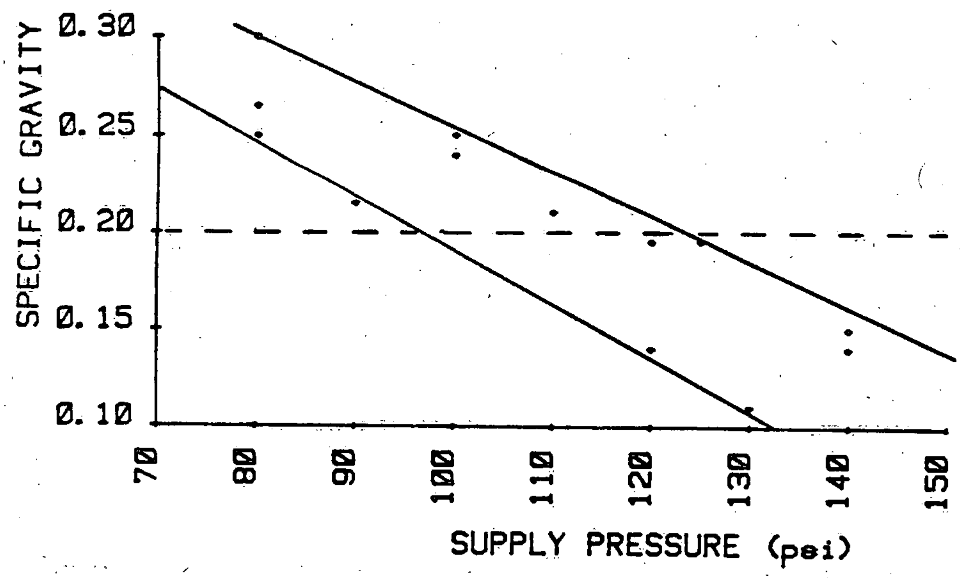


FIG. 9 .125 NOZZLE

The quantity of snow made in a given time (rate) is entirely dependent on the flow of water through the nozzle. No measurements were made during this study concerning rate of snow making since with the .125B nozzle large quantities are not a problem. By using a smaller nozzle or even a small internal mix spray nozzle the rate can be reduced to a small amount.

Figure 7 shows the range of specific gravities of snow made using the .062B nozzle. The graph indicates that snow made with this nozzle is in the dry snow range no matter what supply pressures are used. If a small quantity of snow is required in the dry range then the .062B nozzle is recommended.

The graphs for the .080B and the .125 nozzles in figures 8 and 9 respectively are quite similar with respect to the quality of snow that can be made. The range is from wet to dry. The only difference then between these nozzles is in the quantity of snow that is produced.

A great deal of information was learned in this study about how the Hydraulics Division snowmaking facility works. This information will be used to write an operating manual for snow-making. The following is a summation of pertinent facts learned about snowmaking:

9.1 A room temperature of $-10^{o}$ C is recommended for snow making. Colder temperatures cause problems with equipment freezing. Warmer temperatures mean wetter snow.

9.2 The water supply ball shut-off valve in the room must be heated with a thermostatically controlled heater at all times.

9.3 Hearing protection should be worn in the cold room when making snow because of the intense noise of the snowmaking gun.

9.4 The gun and hoses should be placed in the room immediately before snowmaking and removed to the warmth of the lab when snow making is finished.

9.5 The water supply should be turned on first when making snow. The warmth of the supply water will keep the hose and gun from freezing.

9.6 The gun must tipped down at a slight angle to prevent pulsing of the air-water stream.

9.7 The return grill in the ceiling of the cold room must be removed before making snow to prevent clogging and the resulting disfunctioning of the room.

9.8 The intake air for the compressor must come from the lab and not the cold room to prevent the filter from clogging and the ingestion of large amounts of water into the compressor.

9.9 The air and water supply pressures should be equal or nearly equal to make snow.

9.10 The regulating valves on the gun are usually opened less than 1/2 turn to make the driest snow.

9.11 The relative humidity in the room rises to almost 100% during snowmaking and seems to have no affect on the quality of snow produced.

9.12 The inlet temperatures of the air and water supply (which were noted on occasion to reach $20^{\circ}C$) have no effect on snow produced as the temperature of the air-water stream measured $0.0^{\circ}C$ at 0.6 m (2 ft) from the nozzle.

APPENDIX I NOZZLE SIZES

| NOZZLE NUMBER | DIA. mm | DIA. in | DESCRIPTION |
|---|---|---|---|
| .062B | 1.57 | .062 | 1/4 N.P.T. Pipe plug with bevel hole |
| .080B | 2.03 | .080 | 1/4 N.P.T. Pipe plug with bevel hole |
| .125 | 3.18 | .125 | 1/2 N.P.T. Pipe plug |
| .187 | 4.75 | .187 | Used only once |
| .218 | 5.56 | .218 | Not used |
| .25 | 6.35 | .25 | Used only once |
| 1891125 | 3.18 | .125 | Internal mix spray nozzle |
| 67147 | 1.19 | .047 | Internal mix spray nozzle |
| 62240-60 | - | - | External mix 60 deg. spray nozzle |
| 67228-45 | - | - | External mix 45 deg. spray nozzle |
| 1/4M 26 | 2.18 | .086 | Atomizing nozzle |
| 1/4M 12 | 1.97 | .076 | Atomizing nozzle |

## APPENDIX II S.I. CONVERSION UNITS

$$1\text{Pa} = 1.0*10^{-3}\ \text{kPa}$$

$$1\text{Pa} = 145.038*10^{-6}\ \text{psi}$$

$$1\text{kPa} = 145.038*10^{-3}\ \text{psi}$$

$$1\text{psi} = 6.895\ \text{kPa}$$

## APPENDIX III COLD ROOM TEMPERATURES

Over a period of several days the cold room temperature was measured at various controller set temperatures in the range of $-30^{\circ}$C to $+13^{\circ}$C. Figure 10 shows the plot of the set temperature versus the measured temperature. The equation of the line is:

ROOM TEMP. = 0.52 + 0.95 * SET TEMP.

CORR. COEF. = 0.999

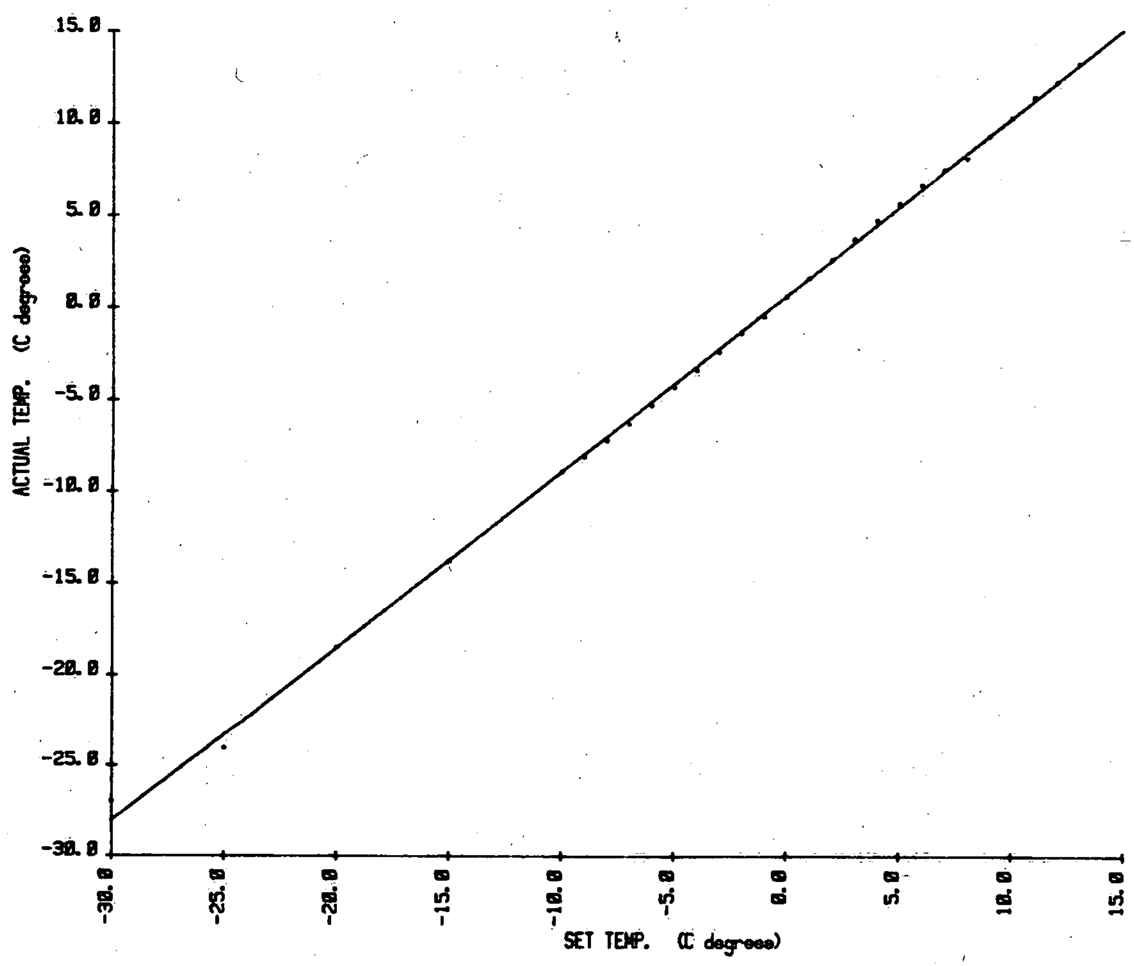


FIGURE 10