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SEEDING SYSTEMS FOR USE WITH A LASER VELOCIMETER IN LARGE SCALE WIND TUNNELS

Joe W. Elliott
Rotorcraft Aerodynamics Office
Army Structures Lab, USARTL
NASA Langley Research Center
Hampton, Virginia

Cecil E. Nichols
NASA Langley Research Center
Hampton, Virginia

4- BY 7- METER TUNNEL

The Langley 4- by 7- Meter Tunnel which is shown in figures 1 and 2 is a closed circuit, atmospheric wind tunnel which may be operated with a closed or open test section. The test section ceiling and walls can be raised to provide the open configuration that is closed on the bottom. The test section, or the jet entrance in the open configuration, is 14.5 ft high, by 21.75 ft wide. In each case the test section is 50 ft long and is configured into two test bays each equipped with interchangeable model support mechanisms.

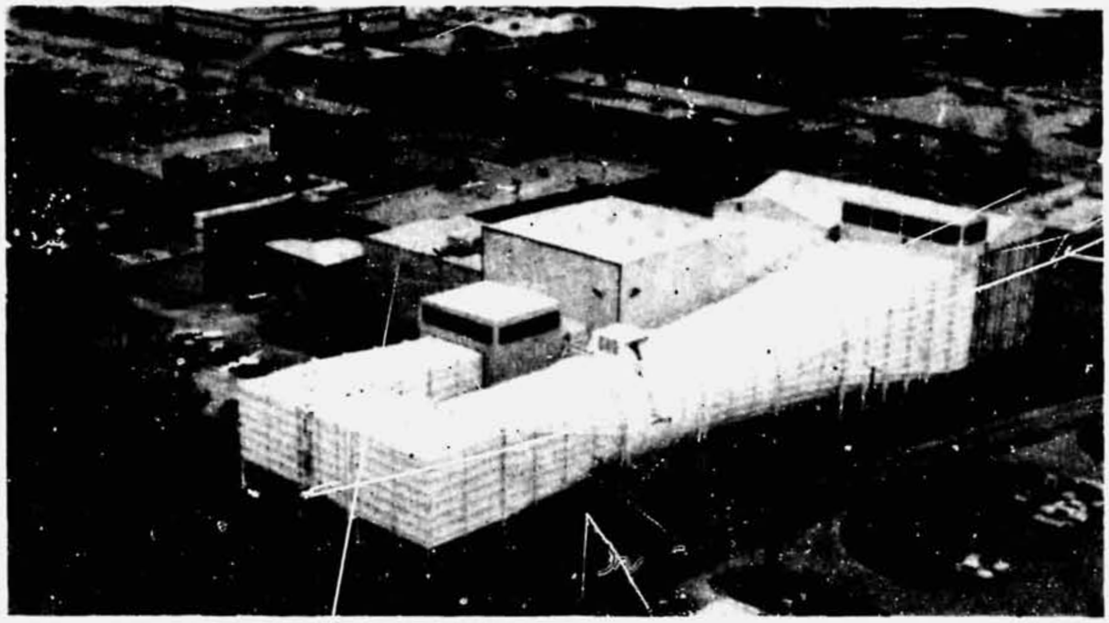


Figure 1

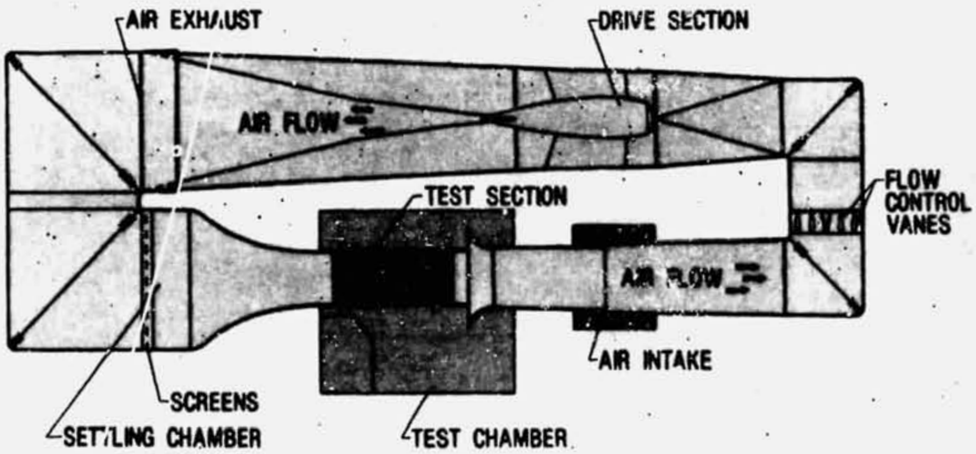


Figure 2

THE LASER VELOCIMETER

The laser velocimeter (LV) is configured to measure the instantaneous component of velocity in the horizontal (U component) and vertical (V component) directions (ref. 1). The system is comprised of three subsystems: optics, traverse, and data acquisition and control.

Optics

The optics subsystem which is shown schematically in figure 3 is operated in the backscatter mode and at high laser power (4 watts in all lines) in order to accommodate the long focal lengths required by the wide test section. The commercially available transmitting and receiving optics packages are augmented by a zoom lens system consisting of a 3 in. clear aperture negative lens and a 12 in. clear aperture positive lens. Bragg cells in each of the optical paths provide a directional measurement capability.

Traverse

The traverse subsystem uses a combination of mechanical and optical schemes to provide five degrees of freedom. Translation of the sample volume along the horizontal and vertical axes is accomplished by displacing the entire optics platform. Translation along the lateral axes is accomplished by translating the negative lens located in the zoom lens assembly thus refocusing the sample volume along the axis of optical transmission. The other two degrees of freedom, pan and tilt, are implemented by rotating the final mirror about its vertical and horizontal axis in order to change the direction of optical transmission. The total inclusive range of the traversing system is: Vertical: 7 ft; Streamwise: 6 ft; Lateral: 16.5 ft; Pan: 30°; Tilt: 30°

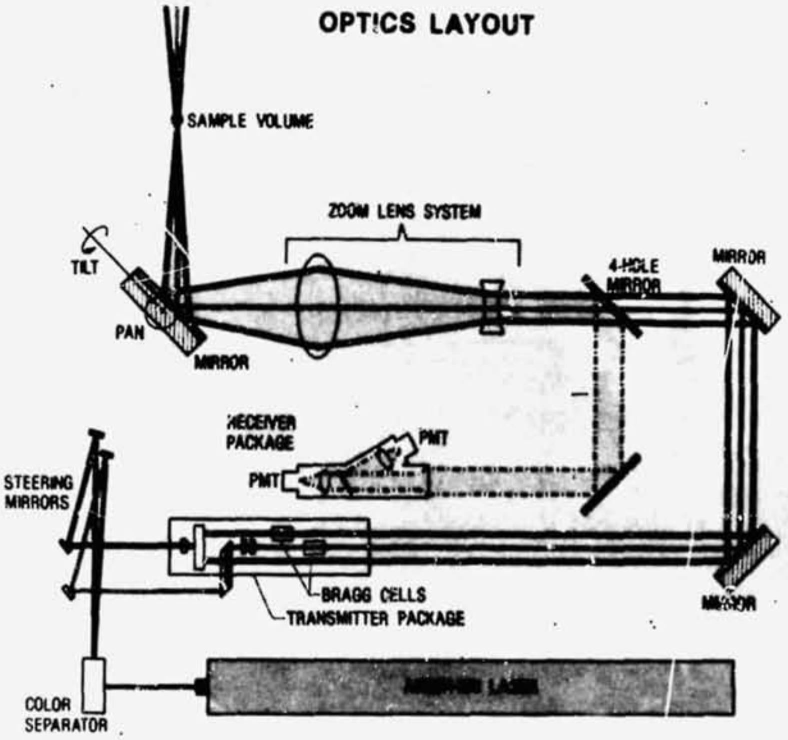


Figure 3

DATA ACQUISITION AND CONTROL

The data acquisition and control subsystem is shown schematically in figure 4 and performs the following functions:

1. Interfaces with the optical signal processing equipment to receive two channels of raw LV data and one channel of auxiliary data.

2. Converts that raw data to engineering units.

3. Statistically analyses the data and reports the results so that the test results can be evaluated on line.

4. Stores the test results on magnetic tape for subsequent analysis.

5. Interfaces with and controls the five degree of freedom scan system.

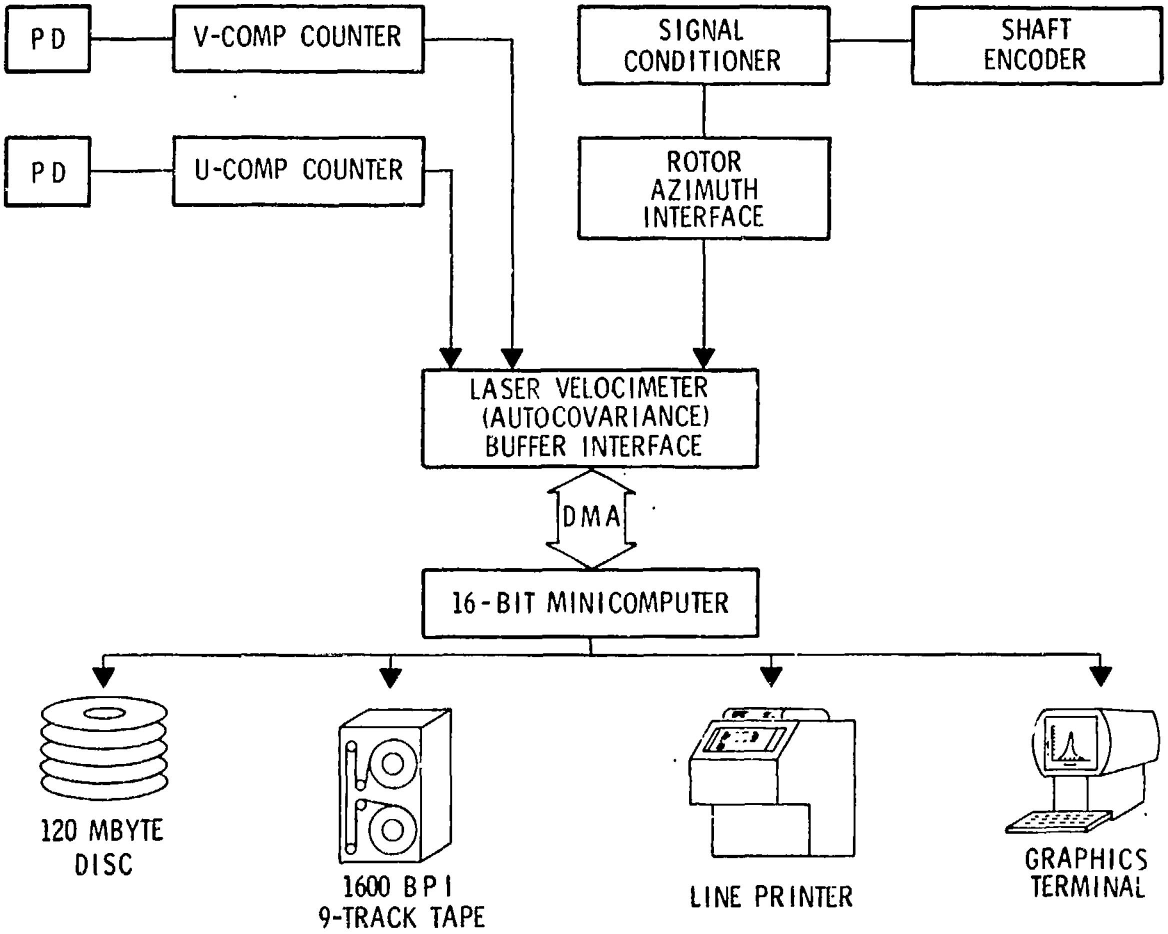
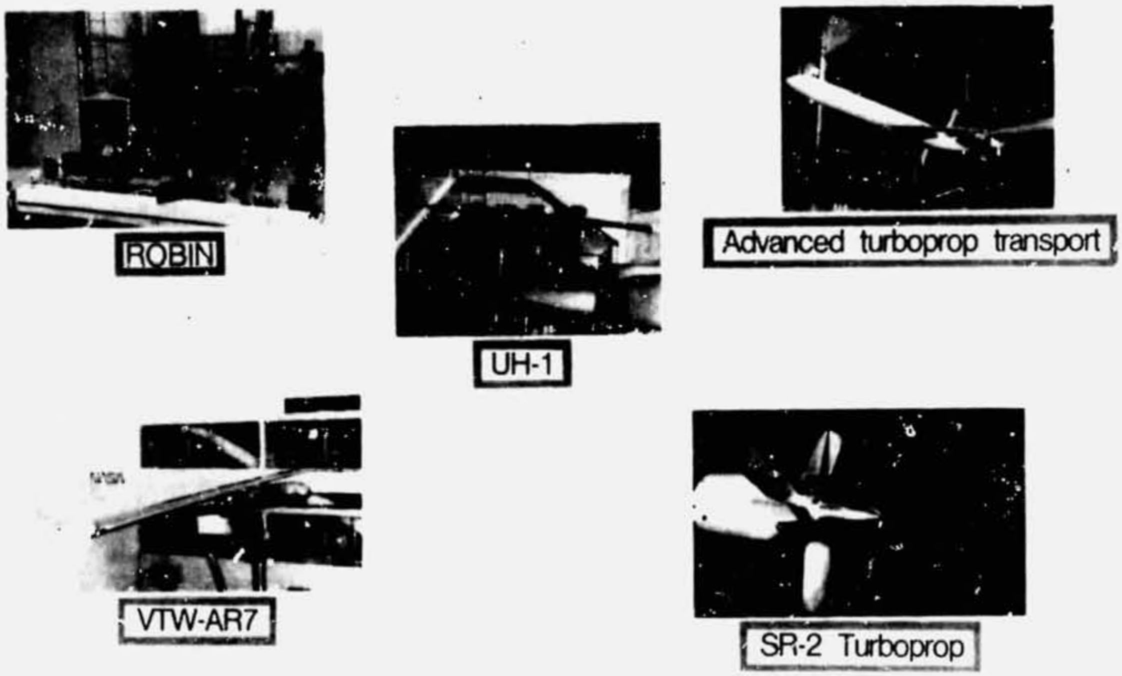


Figure 4

SEEDING REQUIREMENTS

The models shown in figure 5 are representative of those tested in the 4- by 7-Meter Tunnel. The areas that are to be seeded in support of such tests are on the order of 7 to 20 square feet. Each square foot of area requires 6.0×10^7 particles per minute to achieve a uniform data rate of 4000 samples per minute. The shapes of the seeded areas which are required to support such tests are vertical or horizontal rectangles, squares or circles.


ROBIN

UH-1

Advanced turboprop transport

VTW-AR7

SR-2 Turboprop

Figure 5

SEEDING TECHNIQUES

Three seeding techniques have been utilized thus far in the 4- by 7-Meter Tunnel: (1) kerosene smoke, (2) dry dispensing of solid particles and (3) liquid dispensing of solid particles. In all three cases seeding material was injected into the air stream in the settling chamber (fig. 1) because of the relatively low velocity, easy access, up-stream proximity to the test section and relatively safe environment that exists at that location during tunnel operations.

KEROSENE SMOKE SYSTEM

A schematic of the kerosene smoke seeding system is shown in figure 6. Pressure, applied to the storage tank, causes the kerosene to flow to the wand where it is heated and expelled through a nozzle that is sized to maximize the number of 2 micron particles. The output of this system is a single plume on the order of 18 in. in diameter which can be increased to 36 in. with the addition of a diffuser plate located downstream of the nozzle. The pressure that is applied to the storage tank and the voltage across the d.c. electric heater in the wand are the only control variables on this system. The position of the wand in the settling chamber and thus the location of the particle plume in the test section is changed by raising or lowering it on a system of cables that stretched from the floor to the ceiling. The size of the particles that are generated is dependent on the rate at which kerosene flows through the system and the temperature of the kerosene. Since temperature is critical, anything that causes a change in that temperature will cause the size of the particles to change. For example:

1. A local tunnel temperature increase during tunnel operation will increase the kerosene temperature and decrease the size of the particles.

2. A tunnel velocity increase will decrease the temperature of the kerosene and increase the size of the particles.

3. A kerosene tank pressure increase, in order to increase the number of particles, will decrease the temperature of the kerosene and increase the size of particles.

Thermocouples located in the wand provide the necessary inputs to control the temperature,and therefore the particle output, but the system still requires a great deal of operator skill and intervention.

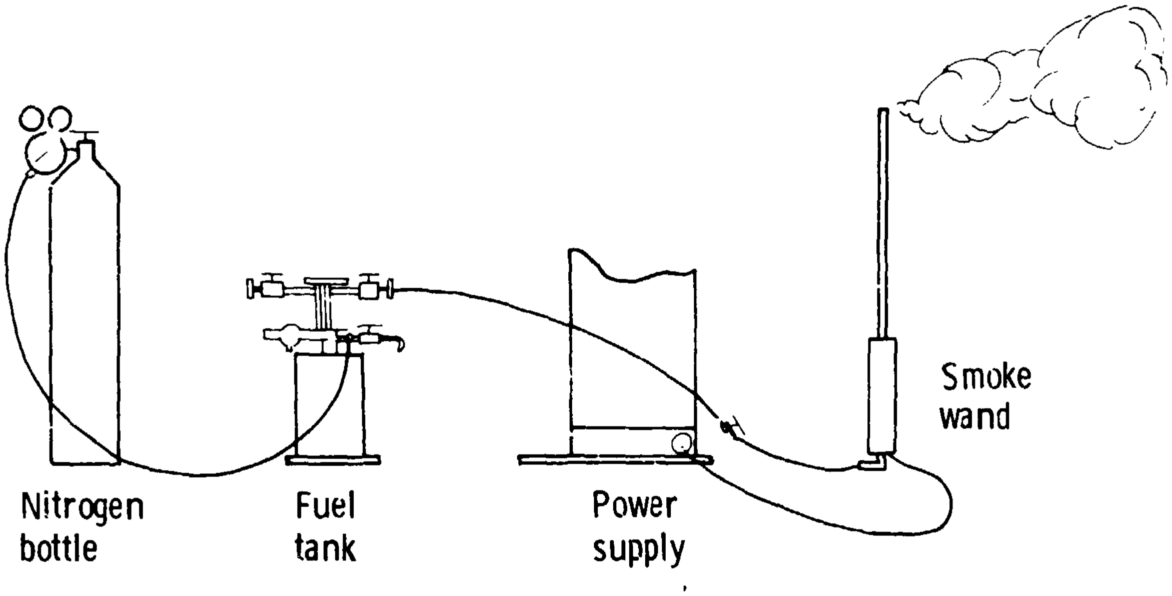


Figure 6

SOLID PARTICLE DRY DISPENSING SYSTEM

A schematic of the solid particle dry dispensing system is shown in figure 7. The dry particles which are contained in the hopper are deposited on the rotating toothed wheel, removed at the low pressure entrance to the nozzle and subsequently injected into the tunnel in a single plume which is on the order of 12 in. in diameter. The seeder is installed on the cable system in the settling chamber for dispersal of particles. Pressure applied to the hopper vibrator, pressure applied to the nozzle and voltage applied to the motor which drives the toothed wheel are the three control inputs to the system. The two major characteristics of the particles, size and quantity, are controlled by the selection of raw particles to be put in the hopper and the control of the speed of the toothed wheel. Two controls are provided to optimize the performance of the seeder:

1. The air supply to the hopper vibrator is used to vary the frequency of the vibrator. This insures that a continuous supply of particles will be available to the toothed wheel.

2. The air supply to the nozzle controls the effectiveness of the removal process and at higher settings acts to break up agglomerated masses of particles.

The system is fairly easy to set up and adjust,but does experience particle agglomeration. This condition occurs when clumps of the seeding material fail to break-up as they are removed from the toothed wheel. These clumps of seeding material,some estimated to be as large as 0.050 in., may not follow the flow and may change the model characterstics when they impact and adhere to the surface. Coating of the seeding material with particles of a sub-micron size reduces this problem and also improves the flow of the seeding material in the hopper (ref. 2).

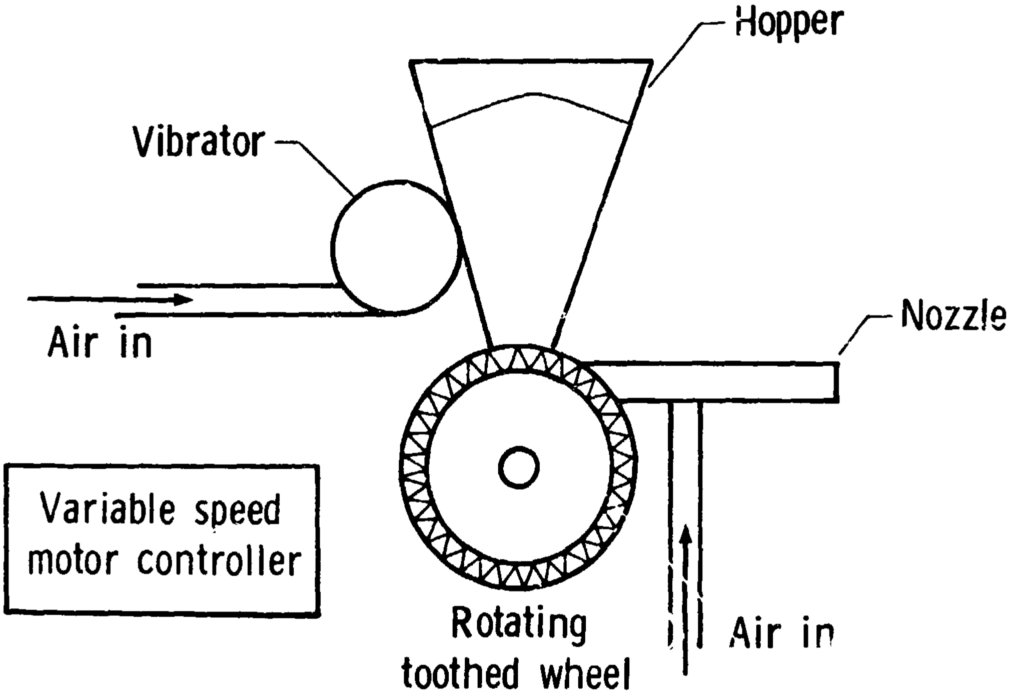


Figure 7

SOLID PARTICLE LIQUID DISPENSING SYSTEM

A schematic of the solid particle liquid seeding system is shown in figure 8. The storage tank is filled with up to 20 gallons of ethyl alcohol in which the particles to be dispensed have been mixed. The pump delivers the mixture under pressure to a series of nozzles where a source of compressed air acts to atomize the mixture. Up to 40 nozzles can be conveniently mounted on the frame that is 6 ft high and 8 ft wide and is then positioned with the same cable arrangement as the other systems. The pumping apparatus will support up to two arrays of nozzles which can be configured to meet the area and density requirements of the test in progress. Because of its low vapor pressure, alcohol evaporates as it travels from the settling chamber to the test section, a distance of approximately 85 ft. The particles that were contained in the droplets remain in the flow to be used in the velocity measurement. The array of nozzles which are connected in series on the liquid supply line is not capable of dispensing the amount of liquid which is supplied by the pump so the excess is returned to the storage tank where it circulates with the remaining fluid and acts to prevent the particles from settling out of the mixture. The active controls in the system are three pressure regulators:

1. Number 1 establishes the pressure of the air which will be supplied to the array of nozzles. This pressure is monitored at the array so that it can be accurately set.

2. Number 2 establishes the maximum pressure of the circulating alcohol particle mixture. The regulator also prevents damage to the pump which could be caused by excessive head pressure resulting from blocked or disconnected supply lines.

3. Number 3 establishes the pressure of the alcohol particle mixture that will be delivered to the array of nozzles. A pressure transducer is also used to monitor this pressure and is likewise mounted on the array housing to facilitate accurate settings.

Once the controls on this system have been set its output remains constant and requires no attention. The nozzles are commercially available units which dispense the atomized mixture in a wide angle round spray pattern approximately 12 in. in diameter. The volumetric flow rate of the liquid mixture is controlled by changing the ratio of air to liquid pressures,and the droplet size is controlled by changing both pressures. When the pressure of the alcohol mixture and the air are increased, the atomized droplets are smaller, vaporize faster and contain fewer particles. The droplets should be small so that they will completely evaporate by the time that they arrive at the test section and should contain only one particle.

LIQUID SOLID-PARTICLE SEEDING SYSTEM

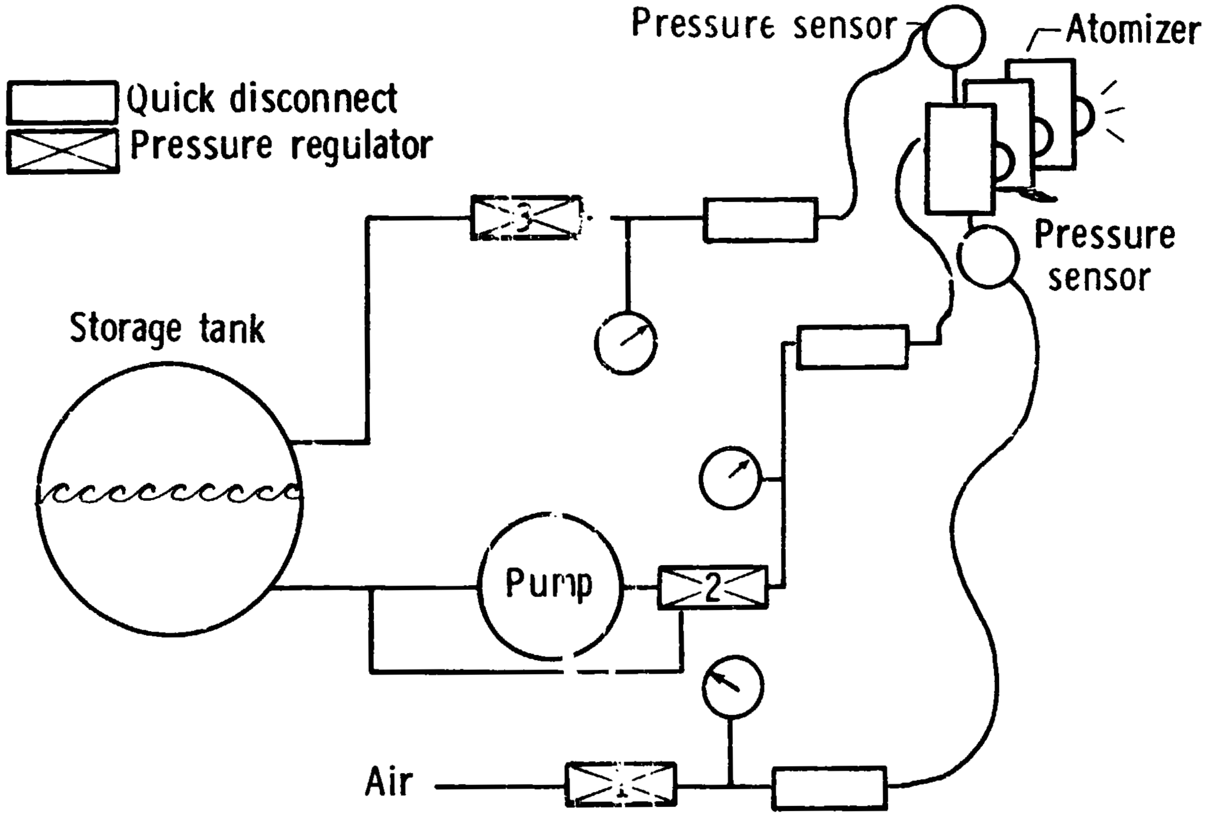


Figure 8

CONCLUSIONS

Three seeding systems have been used in the 4- by 7- Meter Tunnel: kerosene smoke, solid particle dry dispensing and solid particle liquid dispensing. It is anticipated that the liquid dispensing system will be used in all of the applications at this facility because:

1. It has a steady output.
2. It is easy to operate and reconfigure.
3. It delivers particles of near uniform size.

REFERENCES

1. Sellers, William L.; and Elliott, Joe W.: Applications of a Laser Velocimeter in the Langley 4- by 7-Meter Tunnel. NASA CP 2243, "Flow Visualization, and Laser Velocimetry for Wind Tunnels," pp. 283-294, 1982.

2. Nichols, Cecil E.: Experiments With Solid Particle Seeding: Wind Tunnel Seeding Systems for Laser Velocimeters. NASA CP-2393, 1985, pp 77-84.