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[54] **POWDER FED SHEARED DISPERSAL PARTICLE GENERATOR**

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[52] **U.S. Cl.** **406/155**; 239/568; 241/95

[58] **Field of Search** 406/142, 143, 155, 47, 406/49; 241/95, 39, 5; 239/568

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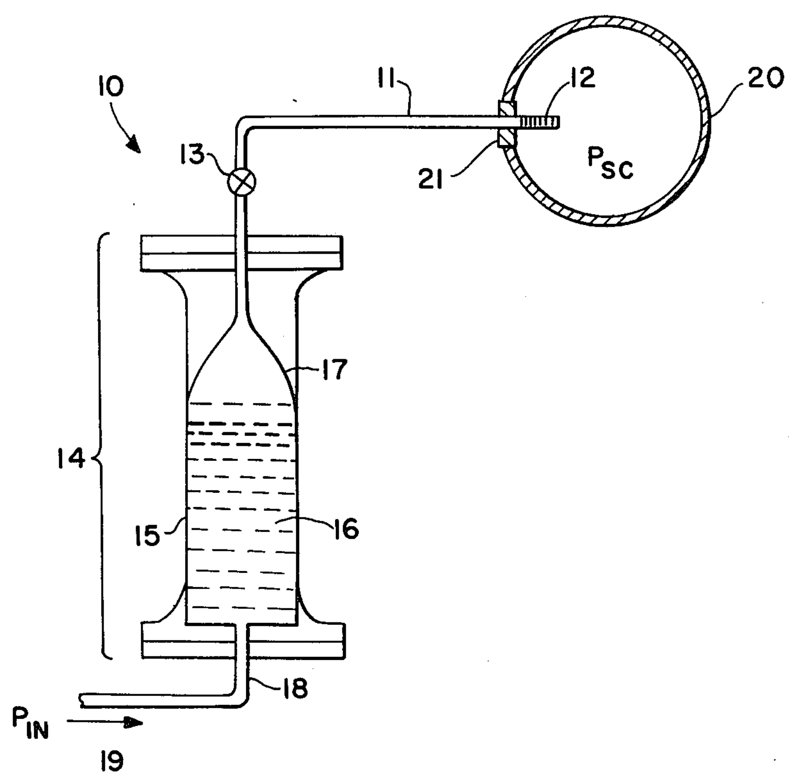
[57] **ABSTRACT**

The present invention discloses a particle generating system which is capable of breaking up agglomerations of particles and producing a cloud of uniform, submicron-sized particles at high pressure and high flow rates. This is achieved by utilizing a tubular structure **11** which has injection microslits **12** on its periphery to accept and disperse the desired particle feed **16.** By supplying a carrying fluid **19** at a pressure, P_{in}, of approximately twice the ambient pressure of the velocimeter's settling chamber 20, P_{sc}, the microslits 12 will operate at choked flow conditions. The shearing action of this choked flow is sufficient to overcome interparticle bonding forces, thereby breaking up the agglomerates of the particle feed **16** into individual particles.

10 Claims, 2 Drawing Figures



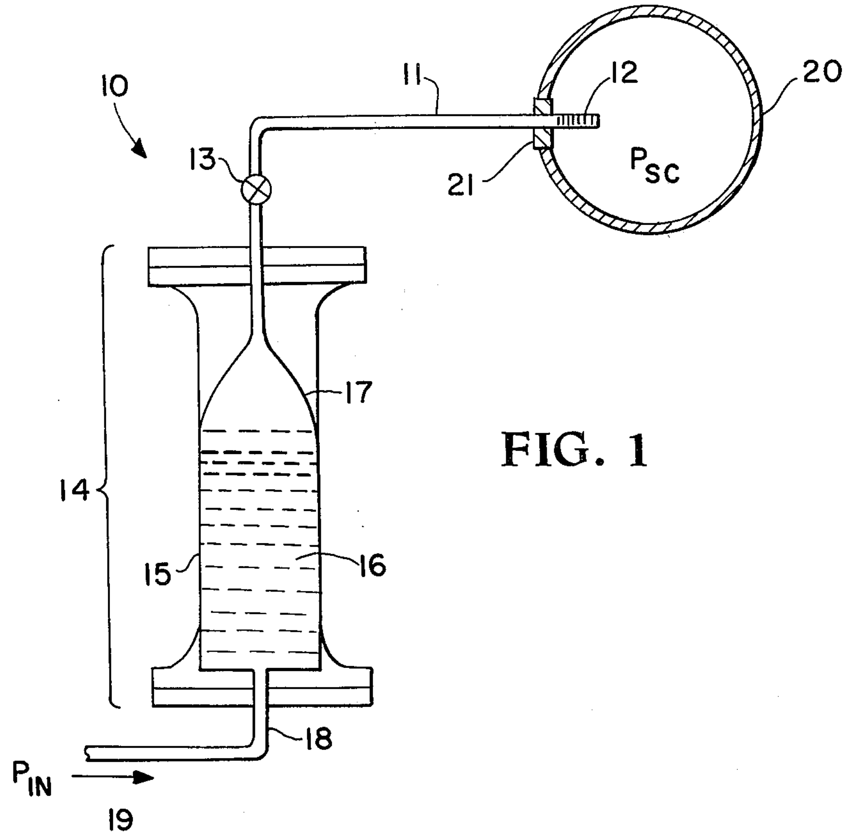


FIG. 1

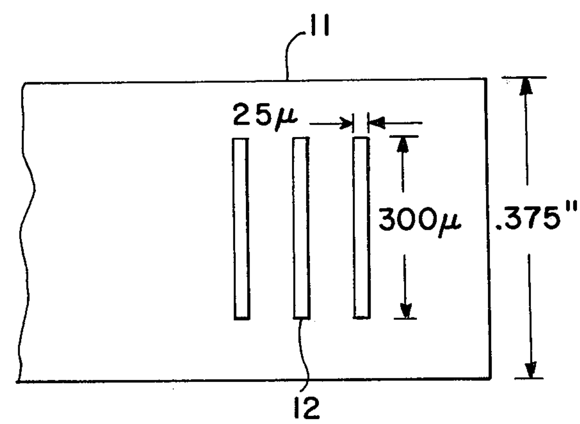


FIG. 2

POWDER FED SHEARED DISPERSAL PARTICLE GENERATOR

ORIGIN OF THE INVENTION

The invention described herein was made by employees of the U.S. Government and may be manufactured and used by or for the Government for government purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

Until recently, pitot, static and total temperature probes have been the primary means of obtaining flow information in high speed flows. These probes have proven to be inadequate, however, for obtaining detailed measurements of more complex flow fields such as three-dimensional flows. As research in this area has heightened, so has the need for a means of accurately evaluating these flows. This increased need has been the primary impetus behind the development of nonintrusive measuring techniques.

One such technique, known as laser velocimetry, is designed to measure static density, temperature and three components of velocity in the flow field. The velocimeter is actually a particle velocity measuring device which requires the use of seeding particles in the flow to act as light scatters. It, therefore, will measure the gas velocity only if the particle and gas velocities are the same. Consequently, the particle requirements of this system are an important factor in its successful operation. Initially, there must be a sufficient number of particles of uniform size to obtain a statistically reliable velocity average at a point. The particles must be small and low in density to follow the flow, but they must be large enough to scatter light sufficient for the receiving optics to measure. In addition, the particles should not combust or evaporate in the high temperature and pressure of the setting chamber, and they should be both nonabrasive and noncorrosive.

This invention relates to a particle generating system which is capable of breaking up agglomerations of particles and producing a cloud of uniform, submicron-sized particles at high pressure and high flow rates. Conventional particle generators are incapable of meeting the rigorous demands imposed by the laser velocimeter. Smoke generators, although commonly used in other settings, are nonfunctional at the high mass flow rates (higher densities) and high pressure of the velocimeter's hypersonic tunnel because of the resultant interference with the generator's evaporation and condensation processes. In addition, such systems are very sensitive to small changes in the stagnation pressure of the tunnel. Fluidized bed systems are also inadequate because of their tendency to produce only aggregates or agglomerates of particles rather than single particles. This invention was designed to overcome the deficiencies of these previously utilized systems.

Accordingly, it is an object of this invention to provide an apparatus which is capable of producing a cloud of uniform, submicron-sized particles at high pressure and high flow rates.

Another object of the invention is to provide a particle generating system which remains independent of external environmental conditions.

Another object of the invention is to provide an apparatus which will effectuate consistent and uniform separation of particle agglomerations.

SUMMARY OF THE INVENTION

The foregoing and other objects of the invention are achieved by providing a particle generating system which utilizes a convenient particle feeding system such as a fluidized bed. In this system, the desired particles are mixed with a chemical which acts as a hydrophobic agent and electrical charge neutralizer, and are stored in an upright cylindrical casing. A fluid source is introduced from beneath, thereby lifting the particle mixture through a fairing and into a tube with extremely small slits (25–50μ) on its periphery. By supplying a fluid at a pressure of approximately twice the ambient pressure of the velocimeter's settling chamber, the slits will operate at choked (sonic) flow conditions. The shearing action of this choked flow is sufficient to overcome inter-particle bonding forces, resulting in the generation of uniform, submicron-sized particles.

Other advantages and objects of the present invention will become apparent from the following explanation of an exemplary embodiment and accompanying drawings thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view of a particle generator in accordance with this invention; and

FIG. 2 is an enlarged sectional view of the tubular structure of FIG. 1.

In describing the preferred embodiment of the invention illustrated in the drawings, specific terminology will be resorted to for the sake of clarity. However, it is not intended to be limited to the specific terms so selected, and it is to be understood that each specific term includes all technical equivalents which operate in a similar manner to accomplish a similar purpose.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIGS. 1 and 2, there is seen an embodiment of the present invention, designated generally by the reference numeral 10. The particle generator 10 consists primarily of a tubular structure 11 which has injection microslits 12 on its periphery and is attached atop a particle feeding system 14.

The feeding system 14 comprises an upright cylindrical casing 15 which is used to store and supply the desired particle feed 16. The dimensions of the casing 15 are determined by the mass flow rate required for any particular application of the system. At the bottom of the casing 15 is an inlet structure 18 which is used to introduce the carrying fluid 19 to the particle feed 16. Although the fluid used in this embodiment is air, any other fluid which the velocimeter can tolerate may be used.

Because the particle generator 10 is designed to break up agglomerations, the experimentor will achieve the best results by utilizing particles which are manufactured in submicron size. In the disclosed embodiment, a submicron Teflon powder is used in the particle feed 16. There are, however, other commercially available dry powders, such as aluminum oxide, silicon carbide and talcum, which also may be used. Depending on the size of the injection microslits 12, the generator 10 will produce particles of a uniform size down to that of the smallest particle in the feed 16.

A difficult problem with developing a particle generator for operation at high back pressures is that the particles cannot be maintained for long periods of time. The natural inclination of small particles is agglomeration and deposition if a surface is near. To overcome that agglomeration problem, silicon dioxide, SiO_2, is added to the Teflon, coating the agglomerations and acting as a hydrophobic agent and electrical charge neutralizer. This ensures as easier and longer lasting primary particle dispersion and improves the fluidizing characteristics of the particle feed **16**. The SiO_2 may be added to any other particle feed **16** with the same result.

Immediately above the particle feed **16** is an exhaust fairing **17** which accepts and guides the flow from the particle feed **16**. The fairing's **17** primary function is to provide a smooth outline for the flow which will reduce drag and ensure a more laminar flow in the tubular structure **11**. Any acceleration through the fairing **17** is minimal and does not bear on the generator's **10** operation. The top of the exhaust fairing **17** exends from the upper portion of the casing **15** thereby providing a connection for the tubular structure **11**.

The tubular structure **11** is attached to the feeding system **14** by means of a ball valve **13**. This connection keeps the flow uniform and smooth as it enters the tubular structure **11** and prevents clogging or buildup of particles. Along the periphery of the tubular structure **11** are numerous injection microslits **12**. To minimize the agglomeration-deposition problem, the tubular structure **11** is placed in the velocimeter's settling chamber **20** so that the final particle generation is into the tunnel environment. This connection is achieved by a high pressure fitting **21** which ensures that uniform pressurization in the settling chamber **20** is maintained. Once generated, the particles may then be utilized quickly and effectively.

FIG. **2** presents an enlarged view of the tubular structure **11**, emphasizing the injection microslits **12** thereon. The tubular structure **11** in the disclosed embodiment has an outside diameter of 0.375" while the microslits **12** have a width of approximately 25–50μ and a length of approximately 300μ. Depending on the desired particle size and recognizing the limitations imposed by particle manufacture, the dimensions of the individual microslits **12** may be altered accordingly. In addition, the injection microslits **12** will operate as designed regardless of their position on the tubular structure **11**. Such positioning, therefore, is controlled only by experimental need.

OPERATION OF THE INVENTION

In operation, the carrying fluid **19** is introduced to the particle feed **16** via the inlet structure **18**. In the disclosed embodiment, air is supplied at a pressure, P_{in}, of 1000 psia, thereby lifting the particle feed **16** into the exhaust fairing **17** at a rate of 5 billion particles/sec, a velocity of 4×10^{-3} ft/sec, and a mass flow of 3×10^{-3} lbm/sec. Once guided through the fairing **17**, the particles **16** will enter the tubular structure **11** for injection into the velocimeter's settling chamber **20**.

The injection microslits **12** along the periphery of the tubular structure **11** are designed to provide a shearing effect on the agglomerated particles. The increase in the velocity gradient of the flow between the microslit **12** wall (velocity=0) and the center of the microslit **12** (sonic velocity) provides shear forces greater than interparticle bonding forces, thereby breaking up the agglomerates into individual particles.

In order for this generator **10** to operate as designed, the pressure of the inlet carrying fluid **19**, P_{in}, must be approximately twice the ambient pressure of the velocimeter's settling chamber **20**, P_{sc}, thereby ensuring sonic flow through the microslits **12**. Specifically, P_{in} for any gas is calculated by the following equation:

$$\frac{P_{sc}}{P_{in}} = \left(1 + \frac{\gamma}{2} - 1\, M^2\right)^{-\frac{\gamma}{\gamma-1}}$$

where,

M=Mach number of flow through microslits **12** (=1 for sonic flow)

γ=specific heat ratio of the gas

P_{sc}=ambient pressure of the settling chamber **20**

P_{in}=pressure of the inlet carrying fluid **19** and,

$$\gamma = \frac{C_p}{C_v} = \frac{\text{specific heat at constant pressure}}{\text{specific heat at constant volume}}.$$

Maintenance of this pressure ratio, which is approximately 1:2 for most gases, will ensure that the microslits **12** operate at choked (sonic) flow conditions.

Operation at choked flow means simply that the flow through the microslits **12** is not affected by the pressure of the settling chamber **20**, P_{sc}. The velocity of the particle flow in the tubular structure **11** increases steadily as the pressure of the inlet carrying fluid **19**, P_{in}, approaches twice the ambient pressure of the settling chamber **20**, P_{sc}. Near this point, as calculated by the above stated equation, sonic velocity is achieved in the microslits **12**. It is well known physical phenomenon that once this pressure ratio is attained, the velocity of a flow through an orifice will not exceed sonic velocity (Mach 1 flow). Consequently, to increase P_{in} further will result in an increased mass flow, but no change in the particle exit velocity. Because this choked (sonic) condition is a function of pressure ratio and not pressure level, the generator **10** is independent of small variations in P_{sc} and, thereby, capable of generating particles even at high ambient pressures.

The advantages of this invention are numerous and it is particularly adapted for laser velocimeter particle generation. Because the system is capable of producing a cloud of uniform, submicron-sized particles at high pressure and high flow rates, it can attain the rigorous particle requirements of the laser velocimeter.

Another advantage of this invention lies in its ability to generate submicron particles regardless of external environment conditions.

Still another advantage of this invention is its capability to effectuate consistent and uniform separation of particle agglomerations.

The specifications herein discussed are not meant as limitations on the scope of the invention and its underlying theory as described in connection with the disclosed embodiment. Various changes may be made without departing from the scope of the invention as defined in the following claims.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. An apparatus to supply a cloud of uniform, submicron-sized particles to a high pressure environment, comprising:

feeding system means for storing and supplying the desired particles;

conduit means for accepting said particles from said feeding system means, said conduit means having microslits on its periphery for separating and injecting said particles;

settling chamber means for receiving the injection of said particles from said conduit means; and

carrying fluid means for transporting said particles wherein said carrying fluid means is supplied at a pressure sufficient to cause said microslits to operate at choked flow.

2. An apparatus as in claim **1** wherein said feeding system means comprises a casing whose dimensions are determined by the required mass flow rate of said particles.

3. A casing as in claim **2** having an inlet for supplying said carrying fluid.

4. A casing as in claim **3** having fairing means for guiding both said particles and said carrying fluid into said conduit means and ensuring a laminar flow therein.

5. An apparatus as in claim **1** wherein said microslits have a width of approximately 25–50μ and a length of approximately 300μ.

6. An apparatus as in claim **1** wherein said carrying fluid is supplied at a pressure of approximately twice the ambient pressure of the velocimeter's settling chamber so that said microslits will operate at choked flow conditions thereby resulting in shearing forces adequate to overcome interparticle bonding forces.

7. An apparatus as in claim **1** wherein said particles are mixed with a chemical which acts as a hydrophobic agent thereby ensuring easier, longer lasting primary particle dispersion.

8. An apparatus as in claim **1** wherein said particles are mixed with a chemical which acts as an electrical charge neutralizer.

9. An apparatus as in claim **7** wherein said chemical is SiO_2.

10. An apparatus as in claim **1** wherein:

said feeding system means comprises an upright, cylindrical casing;

said casing has an inlet at its bottom for introduction of said carrying fluid means;

said carrying fluid means is air supplied at a pressure of approximately twice the ambient pressure of the velocimeter's settling chamber;

said particles are mixed with SiO_2;

said conduit means is attached to said feeding system means by means of a fairing at the top of said casing;

said conduit means is tubular in shape;

said conduit means has microslits measuring 25μ in width and 300μ in length on its downstream side;

said microslits operate at choked flow conditions thereby effectuating uniform particle separation; and

said conduit means is placed in the flow of the velocimeter's settling chamber injecting the separated particles therein.

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