

[54] **DEVICE FOR SIMULATING REENTRY CONDITIONS IN A PARTICLE LADEN ATMOSPHERE**

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[51] Int. Cl. **G01m 9/00**

[58] Field of Search **73/147, 432 SD; 417/197**

[56] **References Cited**

UNITED STATES PATENTS

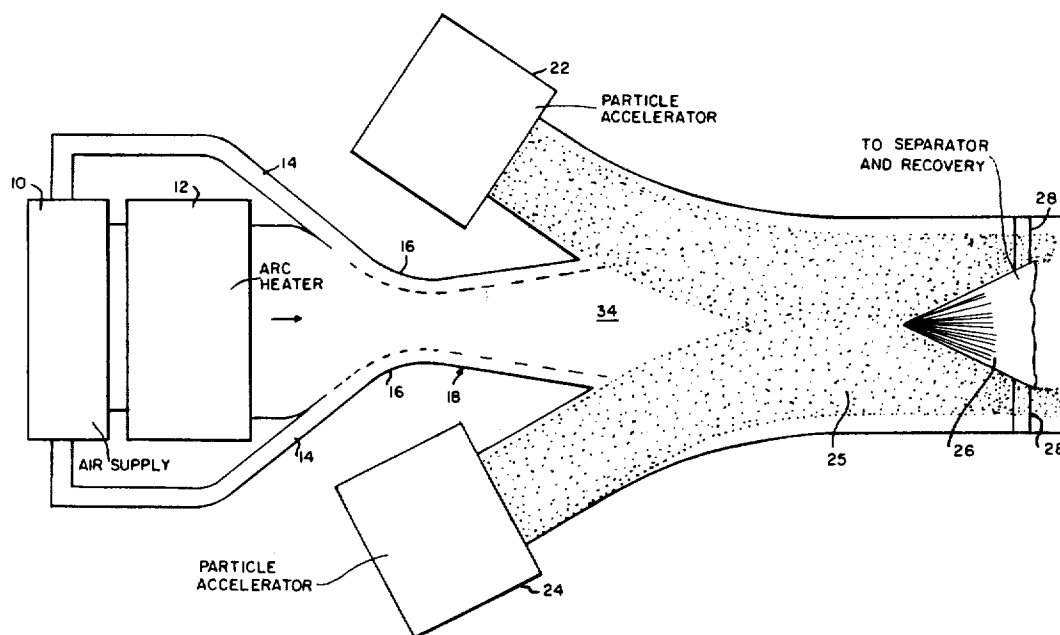
3,739,634 6/1973 Johnson et al. 73/147

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[57] **ABSTRACT**

A particle-laden atmosphere reentry-condition simulation system having arc heated air supplied to an expansion nozzle with high speed particles introduced into the air after the expansion of the air. The test device is positioned in the particle laden air stream near the position where the particles are introduced to limit the interaction time between the particles stream and the air stream.

2 Claims, 3 Drawing Figures



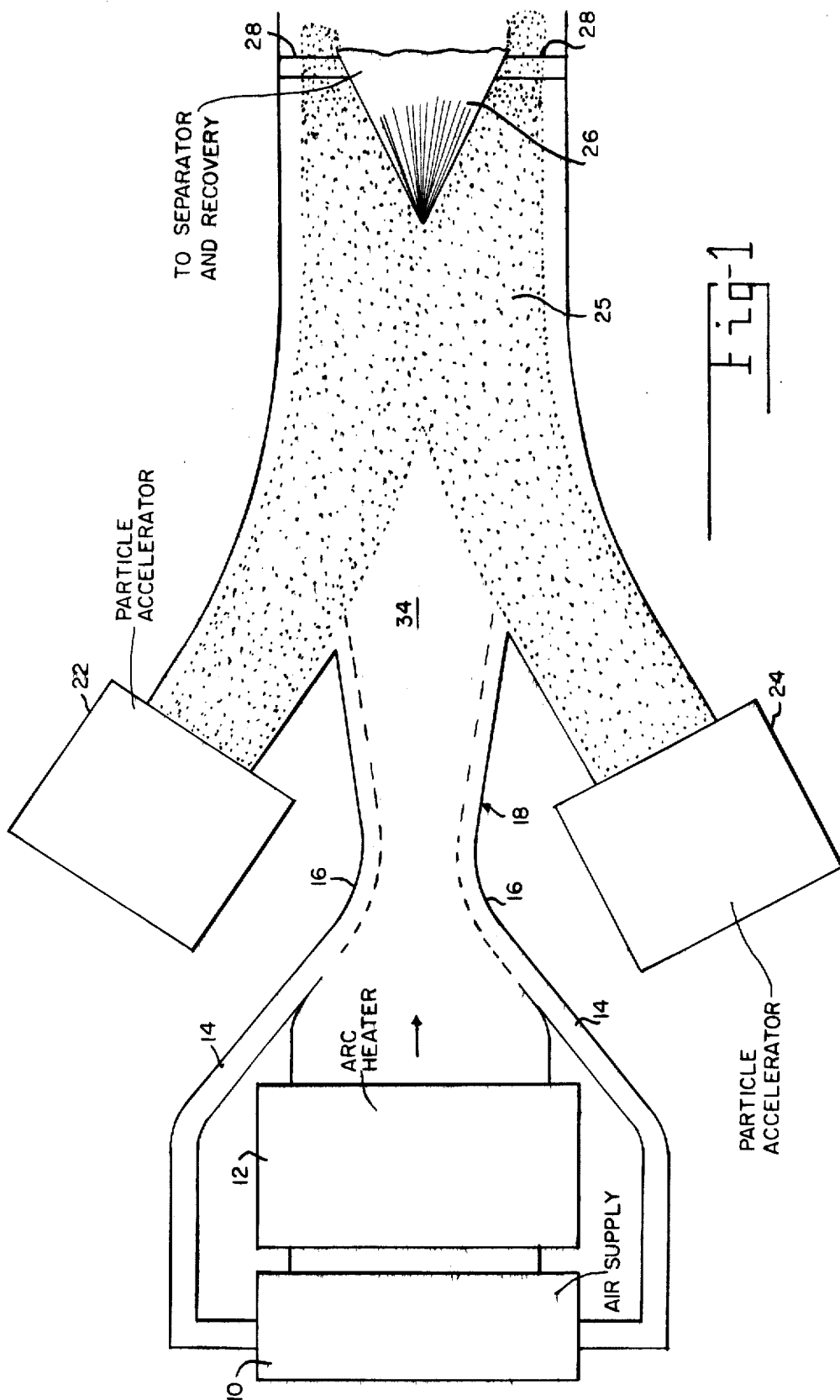
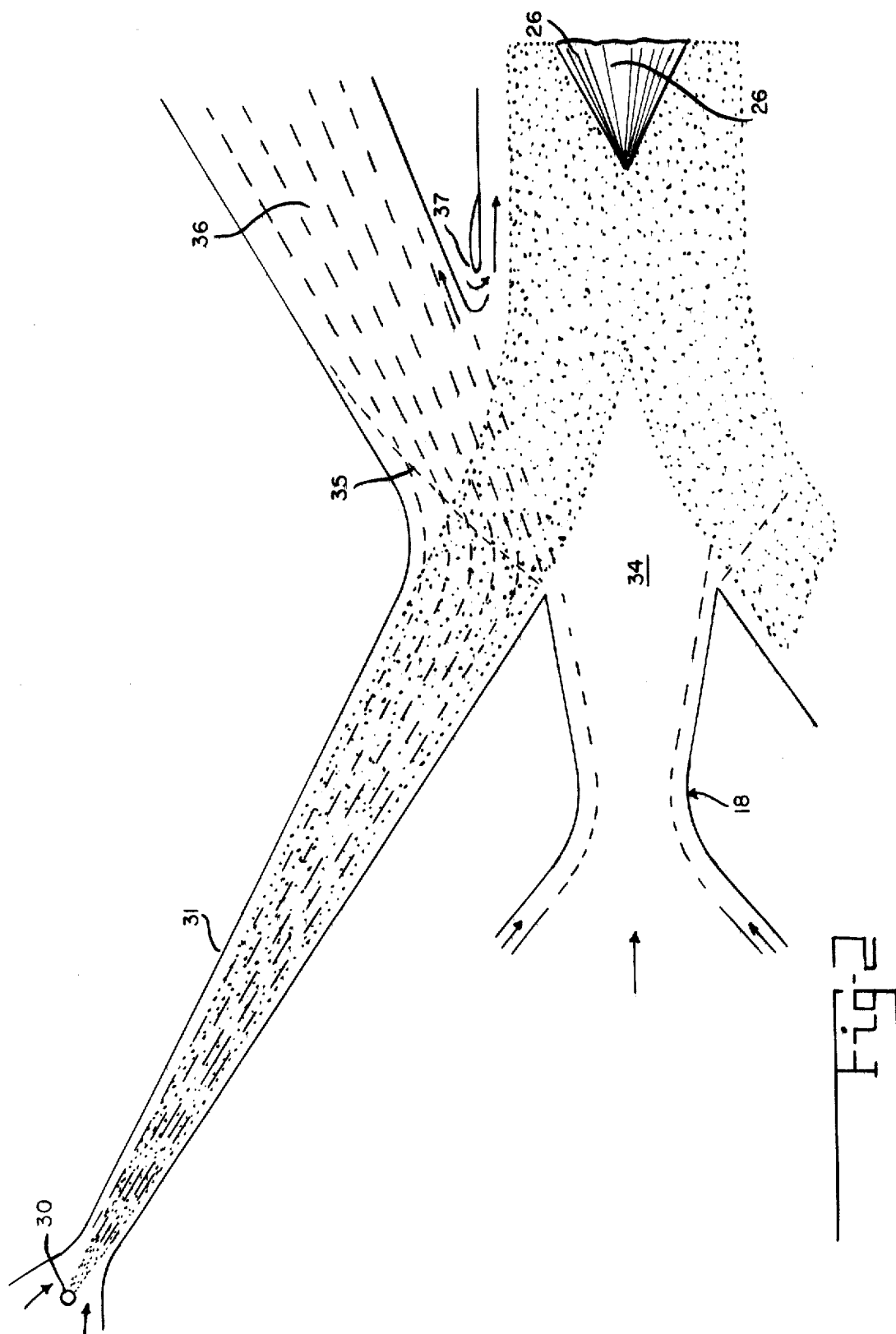


Fig. 1



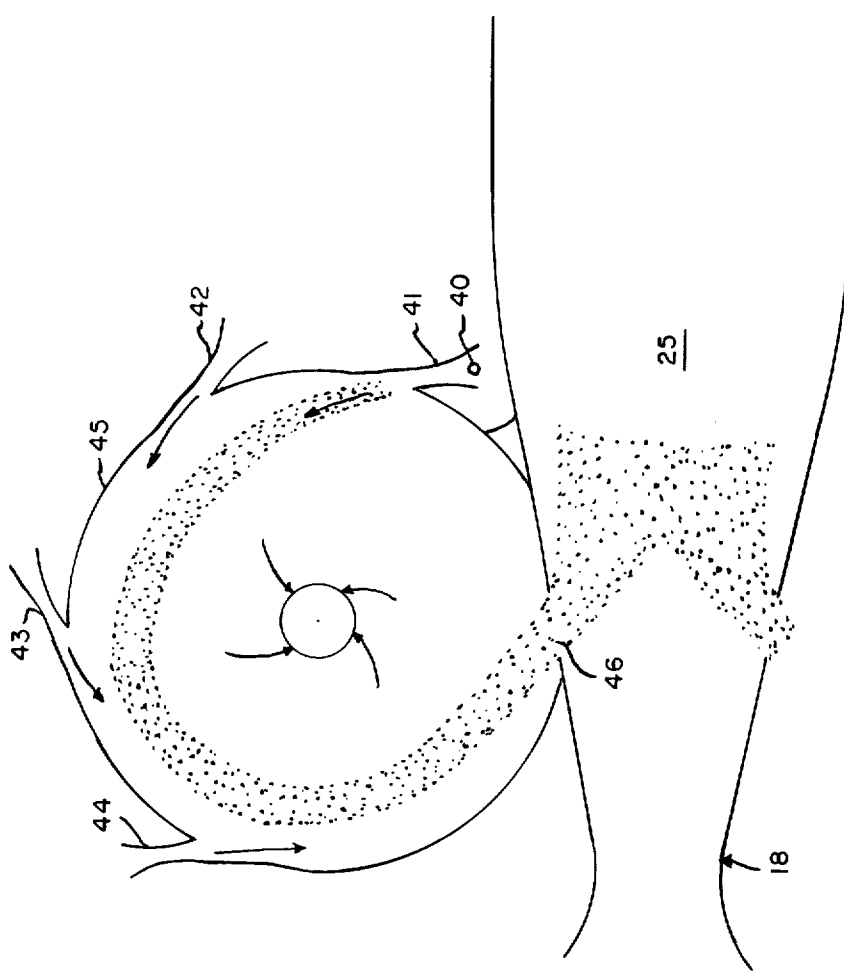


Fig-5

DEVICE FOR SIMULATING REENTRY CONDITIONS IN A PARTICLE LADEN ATMOSPHERE

RIGHTS OF THE GOVERNMENT

The invention described herein may be manufactured and used by or for the Government of the United States for all governmental purposes without the payment of any royalty.

BACKGROUND OF THE INVENTION

For years scientists and engineers have been striving for a ground testing capability which would duplicate the atmospheric conditions experienced by reentry ICBM's. Apparatus has been developed for generating ultra high total enthalpy gases, which may be supplied to test apparatus. One such system is described in the patent to Johnson et al., U.S. Pat. No. 3,739,634.

In recent years, particular attention has been placed on the environment containing snow, ice or dust that vehicles or nose cones traveling at hypersonic speeds encounter in the dirty atmosphere of the earth. A system, to provide ground testing capability, in apparatus that can simulate these dirty atmospheric conditions must be able to provide impact speeds as high as 20,000 ft/sec.

The current system for simulating reentry conditions in a particle laden atmosphere employs a process by which the particles are injected into arc heated air prior to expansion of the air through a nozzle. The particles are accelerated through the nozzle by viscous interaction with the expanding air. This causes a slip between the particles and the accelerating air. In order to limit particle-slip, to a reasonable value, extremely long expansion nozzles, which provide a gradual acceleration of the particles, are required. Long nozzles increase skin friction and heat transfer losses, which causes an enormous reduction in final velocity and enthalpy. In these facilities, the final velocity, of the particle laden air, is between 6000 ft/sec and 8000 ft/sec. This is far below the speed necessary for duplicating atmospheric conditions experienced by a reentry ICBM.

BRIEF SUMMARY OF THE INVENTION

According to this invention, the particles are accelerated, to a high velocity, external to the air expansion nozzle and then introduced into the air flow after the expansion in the expansion nozzle of the arc heated air or high enthalpy air produced by means other than an arc. Thus, the expansion nozzle for the arc heated air can be very short enabling a nearly isentropic adiabatic expansion. To protect the nozzle walls, particularly at the throat, a cold blanket of air is introduced near the walls of the nozzle in a conventional manner. The particles may be accelerated by means of an expanding low molecular weight gas or by other means such as an electrostatic accelerator or a centrifugal accelerator. The model is positioned close to the region of merging between the arc heated air and the particles so that the particles hit the model with little reduction in speed.

In the drawing:

FIG. 1 is a schematic block diagram of a reentry condition simulation system according to the invention.

FIG. 2 is a schematic diagram of one type of particle accelerator which may be used with the device of FIG. 1.

FIG. 3 is a schematic diagram of another particle accelerator which may be used with the device of FIG. 1.

DETAILED DESCRIPTION OF THE INVENTION

Reference is now made to FIG. 1 of the drawing which shows an air supply 10 which supplies cool air to arc heater 12 and to flow channels 14 for directing cool air along the wall 16 of expansion nozzle 18. Arc heated air from heater 12 flows through nozzle 18 and is expanded to a speed of between 10,000 ft/sec to 12,000 ft/sec. At present such heaters are available for handling supply pressures of the order of 600 atmospheres. Higher supply pressures could be used as arc heaters capable of handling higher pressures are developed. Particles are accelerated to speeds between 10,000 and 20,000 ft/sec in particles accelerators 22 and 24 and then introduced into the high velocity air in the output of expansion nozzle 18. The materials used for the particles will be determined by the particular test being made, for example, the material might be dust particles, ice particles or high refractory particles. Also, the size of the particles would be determined by the particular test. For some tests, the particles could be less than one micron and for other tests the particles could be as large as 1000 microns. Since the interaction region 25 between the air and particle stream is short, the particles are not slowed by the slower air stream any appreciable amount before they impact the test device 26 mounted on supports 28. After passing the test device, the particle and air stream may be directed to a conventional separator and particle recovery system, not shown.

One system that may be used for accelerating particles to a high speed is shown in FIG. 2. In this device, particles are introduced at 30 into the gas stream of a low molecular weight gas, such as hydrogen, in the subsonic inlet region of a long expansion nozzle 31. In nozzle 31, the slip between the particles and carrier gas is relatively large at the beginning of the expansion process and relatively small when the expansion process approaches completion. After expansion, the flow from nozzle 31 is merged with the flow in nozzle 18 in such a manner that mixing between the carrier gas and air is minimized. The static pressure in region 34 of nozzle 18 is higher than that of the carrier gas containing the particles. Consequently, a shock wave 35 is generated in the carrier gas, by which the flow direction of the carrier gas is drastically changed to cause the carrier gas to flow through channel 36 to a recovery system, not shown. Due to the inertia of the particles, the particles cannot follow the strong directional change of the carrier gas so that they enter the flow of air in the output of nozzle 18 to bombard the test device 26 as described above. A boundary layer control material material may be supplied at 37.

Another system which may be used for accelerating particles to a high speed is the conventional centrifugal accelerator, shown in FIG. 3. In this device, the particles are introduced at inlet 40 with a carrier gas, such as hydrogen, being introduced through expansion nozzles 41, 42, 43 and 44. This provides a vortex flow in the centrifugal accelerator 45 with the high speed particles being thrown to the outer wall to pass out through outlet 46 into interaction region 25 as described above. The hydrogen passes through the vortex exhaust duct 48 to a recovery system, not shown.

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There is thus provided a particle-laden atmosphere reentry-condition simulation system which more nearly duplicates atmospheric conditions experienced by reentry ICBM's.

We claim:

1. An apparatus for providing a particle laden air stream simulating the reentry conditions encountered by a ballistic missile, comprising: an expansion nozzle; means for providing an air stream at a speed of between 10,000 and 12,000 ft/sec; said means for providing an air stream at a speed of between 10,000 and 12,000 ft/sec. including an arc heater, means for supplying high pressure air to said arc heater and an expansion

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nozzle connected to the output of said arc heater; means for accelerating solid particles, of a predetermined material and size, to a velocity between 10,000 and 20,000 ft/sec; means for introducing said particles into said arc heated air near the output end of the expansion nozzle to thereby provide high speed particle laden air stream; means for supporting a test device in the particle laden air stream in close proximity to the position where the particles are introduced.

2. The device as recited in claim 1 including means for supplying a flow of cool air along the inner wall of said expansion nozzle.

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