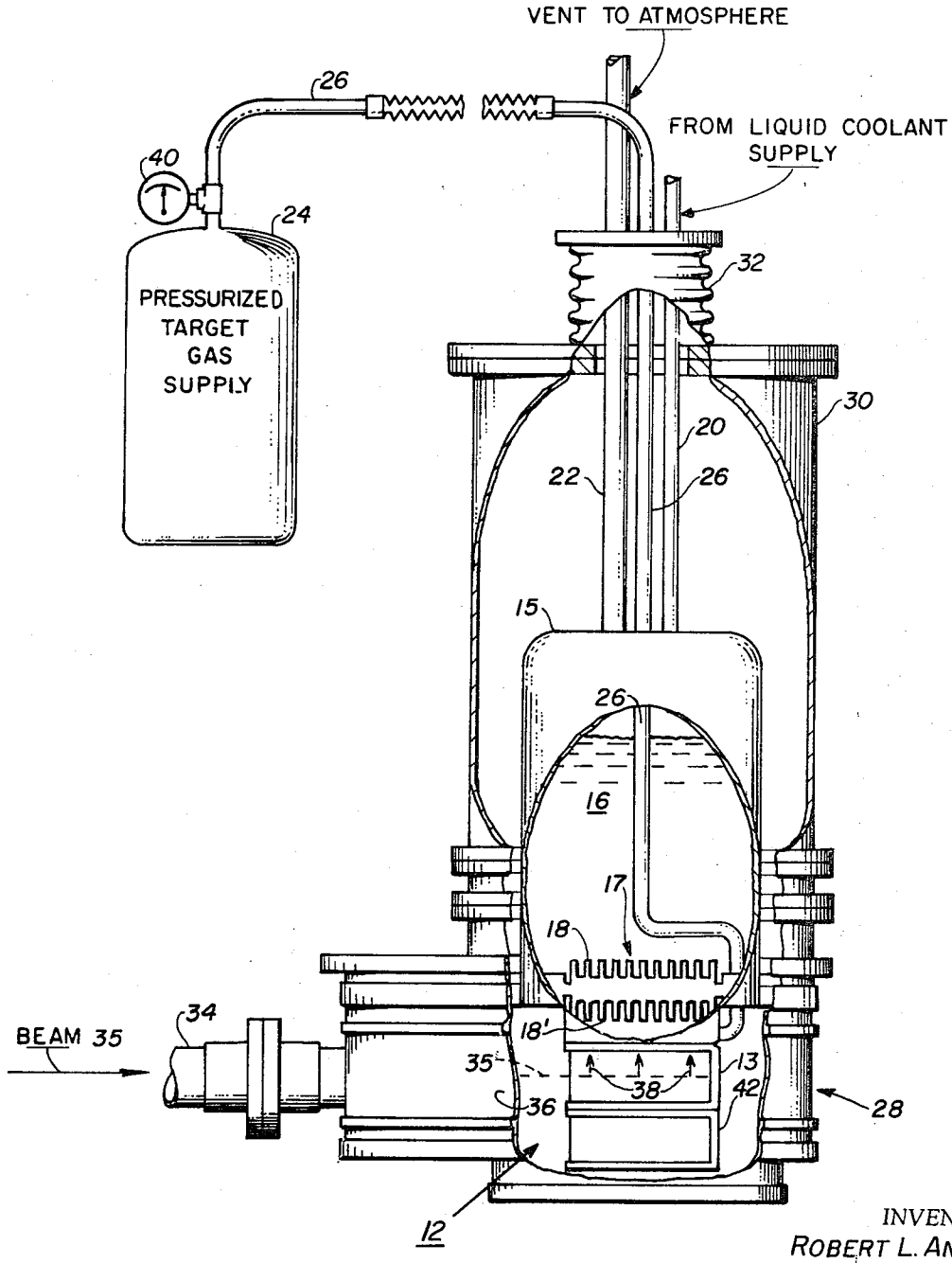
Aug. 25, 1970 R. L. ANDERSON 3,525,228

NONBOILING LIQUID TARGET FOR A HIGH-ENERGY PARTICLE BEAM

Filed Feb. 4, 1969



INVENTOR.
ROBERT L. ANDERSON

BY

Robert L. Anderson

ATTORNEY

United States Patent Office 3,525,228 Patented Aug. 25, 1970

3,525,228

NONBOILING LIQUID TARGET FOR A HIGH-ENERGY PARTICLE BEAM

Robert L. Anderson, Palo Alto, Calif., assignor to the United States of America as represented by the United States Atomic Energy Commission

Filed Feb. 4, 1969, Ser. No. 796,350
Int. Cl. F17c 13/00; F25b 19/00
U.S. Cl. 62—54 6 Claims

ABSTRACT OF THE DISCLOSURE

A differentially pressurized target system in which heat in a pressurized liquid hydrogen target is transferred by rapid convection currents to one side of a heat exchanger for dissipation on the other side in a liquid hydrogen reservoir that is maintained at atmospheric pressure. The rapid convection currents and the difference in pressures in the target and reservoir permits cooling of the target by the liquid hydrogen in the reservoir to a temperature below the boiling point of the liquid target, thus inhibiting boiling of the target liquid upon impingement of a particle beam.

The invention disclosed herein was made under, or in, the course of Contract No. AT(04-3)-400 with the United States Atomic Energy Commission.

BACKGROUND OF THE INVENTION

The present invention relates to nonboiling liquid targets for high-energy particle beams, and more particularly, it relates to a convectively cooled liquid target that is pressurized to raise its boiling temperature significantly above its operating temperature.

It is found desirable in high-energy physics research that is carried out in connection with high-energy particle accelerators, to bombard liquid targets with an accelerator beam to produce subatomic particles. The advantage of a liquid target is that it results in a greater number of interesting events than is obtained with the same target substance in a gaseous state. This is due to the greater density of a substance in its liquid state over its density in its gaseous state. It is necessary, however, for correct interpretation of detected actions of subatomic particles, to know the precise amount of target substance that the beam traverses. Thus, when using a liquid target, should the target boil, the amount of target liquid traversed by the beam is difficult to determine. For accurate interpretation of results, it is necessary, therefore, to maintain a liquid target in a nonboiling state in order to preserve the known density of the liquid. This is preferably accomplished without resort to complex and expensive cooling arrangements.

SUMMARY OF THE INVENTION

In brief, the present invention pertains to a liquid target that may be positioned in the path of a high-energy particle beam of predetermined energy and intensity without boiling the target liquid. The target is comprised of a target cell filled with a target liquid maintained under pressure to raise its boiling point. The cell is shaped to contain a large total volume of target liquid, relative to the volume traversed by the beam, to provide sufficient space for the creation of temperature differentials that

will sustain convection currents upon heating the target liquid with the beam. A heat exchanger is exposed to the convection currents for transferring heat from the cell to a reservoir of coolant. The coolant is maintained at a pressure such that it boils at a temperature less than the boiling point of the target liquid, thereby maintaining the target liquid in a nonboiling state.

It is an object of the invention to simply, effectively, and economically inhibit boiling of a liquid target for a high-energy particle beam.

Another object is to dissipate beam energy deposited in a liquid target by pressurizing the target to raise its boiling point to a temperature level that is significantly above that of a coolant that is permitted to boil to dissipate the energy.

Another object is to transfer heat from a liquid target for a high-energy particle beam to a heat exchanger by means of convection currents.

Another object is to detect the liquid level of a liquid target for a high-energy particle beam with a constant volume source of pressurized gas.

Other objects and advantageous features of the invention will be apparent in a description of a specific embodiment thereof, given by way of example only, to enable one skilled in the art to readily practice the invention, and described hereinafter with reference to the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The figure is a diagram with portions broken away of a liquid target for a high-energy particle beam and a target cooling system, according to the invention.

DESCRIPTION OF AN EMBODIMENT

Referring to the figure there is shown a target system including a target **12** comprised of a cell **13** filled with a target liquid such as liquid hydrogen. Hydrogen is often used as a target because it has a relatively simple nucleus that yields easily interpreted results. The cell **13** is suitably attached to one end of a reservoir **15** that is partially filled with a coolant **16** such as liquid hydrogen. A heat exchanger **17** is mounted between the reservoir **15** and the target **12** with fins **18** exposed to the coolant **16** and fins **18'** exposed to the target liquid. The reservoir **15** may be filled with liquid coolant through a line **20** connected to a coolant supply (not shown). The coolant in the reservoir **15** may conveniently be held at atmospheric pressure through a vent line **22** to atmosphere. The target liquid in the cell **13** is held under pressure by means of a pressurized target gas supply **24** connected to the cell **13** over a line **26** which is passed through the coolant **16** for precooling the gas.

The target **12** and reservoir **15** are enclosed in a vacuum environment for thermal isolation by means of a scattering chamber **28** and a tank **30**. The target **12** and the reservoir **15** may be moved relative to the tank **30** and scattering chamber **28** by means of a bellows **32** through which the lines **20**, **22** and **26** extend; these lines may be flexibly connected by conventional means to their sources to permit movement of the target and reservoir.

In operation, the target system may be connected to the end of an accelerator **34** in which a high-energy particle beam **35** is developed. The target **12** may be centrally located in the path of the beam to enable collisions between the beam particles and the particles of the target

liquid for development of subatomic particles which then pass through a thin window **36** in the scattering chamber for detection with a particle detector (not shown) such as a Geiger counter, spectrometer, bubble chamber or spark chamber.

Impingement of the beam **35** in the target **12** generates a large amount of heat in the liquid in the path of the particle beam. The cell **13** is arranged to have a relatively large total volume as compared to the volume of the target liquid traversed by the beam **35**, typically 60 to 1 with the heat exchanger spaced on the order of four beam diameters from the beam path. This permits a substantial temperature gradient to be set up between the heated volume in the beam path and cooler outer regions of the cell. In particular, the target liquid in the region of the fins **18'** is held substantially at the temperature of the coolant **16** by means of the heat exchanger **17**. Convection currents **38** are generated thereby to carry heat from the region of the particle beam **35** to the fins **18'** for transfer through the exchanger **17** to the fins **18** for dissipation in the coolant **16**. Since the coolant **16** is held at atmospheric pressure, the added heat causes the coolant to boil to dissipate the heat. The vaporized liquid hydrogen is vented to atmosphere through the vent line **22**, while additional liquid coolant may be automatically supplied through line **20** under control of conventional liquid level sensing means (not shown).

It has been found in practice that spreading the beam horizontally results in more effective target cooling and permits a substantial increase in maximum beam intensity; for example, an increase in the width of the beam by a factor of 2.2 permits the beam energy to be increased by a factor of ten.

The cell **13** may be filled with target liquid directly from the pressurized target gas supply **24** whereby the gas in the cell immediately condenses on the fins **18'** upon entering the cell **13**. Alternatively, the cell **13** could be filled by temporarily switching the line **26** to a liquid hydrogen supply to avoid delay in cooling the target.

When the cell **13** is filled from the gas supply **24**, completion of filling may be detected with a pressure gauge **40**. Since the volume of the cell **13** and the mass of gas in the supply **24** are easily determined, the drop in pressure due to the gas condensation necessary to fill the target may be calculated and the drop observed on the gauge **40**. Additionally, should the energy deposited by the beam in the target liquid rise above the capacity of the system to dissipate the energy and thereby cause the target liquid to boil, this condition will cause a rise in pressure in the gas supply that will be indicated on the gauge **40**. Similarly, when the cell **13** is filled from a liquid supply and the gas supply **24** is subsequently switched to the line **26** to maintain the target liquid under pressure, any rise in pressure due to boiling of the target liquid also will be indicated on the gauge **40**.

A dummy cell **42** may be suitably mounted on the lower end of the cell **13** and may be selectively raised into the path of the beam **35**. A vacuum is provided within the cell **42** so that when it is in the beam path, the effect of the beam on the cell walls may be determined with particle detectors and taken into account when interpreting the results obtained with the cell **13** in the path of the beam.

Alternatively, the dummy cell **42** may be used as a second target cell and filled with hydrogen or deuterium, using the target liquid in the cell **13** as a coolant to condense gas supplied to the cell **42**. Such an arrangement would be useful in an experiment requiring two different shaped target cells or for an experiment requiring a comparison between hydrogen and deuterium.

A system exemplifying the invention was constructed in which the volume of the reservoir **15** was approximately 50 liters, the coolant **16** was liquid hydrogen at a temperature of 20.4° K. at standard pressure, the target liquid was liquid hydrogen held at 15 p.s.i. above atmospheric by the supply **24** so that its boiling point was 23° K. This system was successfully operated in conjunction with an electron beam having a maximum average intensity of about 15 microamps and a cross-sectional area of 0.1 cm.^{2}. The beam was estimated to deposit approximately 120 watts in the target liquid. The beam had a maximum repetition rate of 360 p.p.s. The heat exchanger **17** was made of solid copper. A variety of target cells were made of 2 mil thick aluminum or nickel plated stainless steel, ranging up to 40 inches long for a horizontal rectangular cell and up to 12 inches in diameter for a large vertical cell. Convection currents on the order of 10 to 20 cm./sec. were generated with a beam having a horizontal dimension of 1 cm.

With beam currents of 15 microamps and a horizontal dimension of 1 cm., calculations show that the change in the target liquid density is of the order of less than one percent.

While an embodiment of the invention has been shown and described, further embodiments or combinations of those described herein will be apparent to those skilled in the art without departing from the spirit of the invention or from the scope of the appended claims.

I claim:

1. In a nonboiling liquid target system in combination with a high-energy particle beam generating device, the combination of:

a target cell filled with a target liquid for positioning in the path of said beam said cell having a large total volume relative to the volume of liquid traversed by said beam to permit the occurrence of temperature differentials that will sustain convection currents;

means for applying a predetermined pressure to said target liquid for control of the temperature at which said target liquid boils;

a reservoir containing a liquid coolant for cooling said target liquid;

heat transfer means for receiving heat from said convection currents for transfer from said target liquid to said coolant; and

means for maintaining said coolant at a pressure that permits boiling of the coolant at a temperature that is less than the boiling point of said target liquid for dissipating the energy deposited by said beam in said target liquid.

2. The combination of claim **1** wherein said target liquid and said coolant have the same chemical composition, said coolant is maintained at atmospheric pressure, and said target liquid is maintained at a pressure higher than atmospheric pressure.

3. The combination of claim **1** wherein said predetermined pressure applying means includes a constant closed volume supply reservoir for supplying the gaseous form of said target liquid to said target cell, and means responsive to the pressure in said supply reservoir for indicating the predetermined pressure at which said cell is filled with said target liquid.

4. The combination of claim **1** wherein said heat transfer means is comprised of a first heat conduction surface extending into contact with said target liquid, and a second heat conduction surface thermally connected to said first surface and extending into contact with said coolant.

5. The combination of claim **1** wherein said coolant is liquid hydrogen and said target liquid is liquid hydrogen.

6. The combination of claim **1** further including means for thermally isolating said target system to permit heat transfer from said target liquid to said coolant only through said heat transfer means.

(References on following page)

5

References Cited

UNITED STATES PATENTS

2,453,946	11/1948	Sulfrian	62—54
2,504,585	5/1950	Reid	313—330 X
2,576,600	11/1951	Hanson	250—83.6
2,821,650	1/1958	Zunick et al.	313—330
2,858,444	10/1958	Leisegang	250—49.5
2,868,987	1/1959	Salsig et al.	250—43
2,929,933	3/1960	Ela et al.	250—84.5
3,350,229	10/1967	Justi	62—48 X

6

OTHER REFERENCES

Chaplin, R. L.: Apparatus for Electron Irradiation Studies at Low Temperatures. In Review of Scientific Instruments 37(8), pp. 1014–1018, August 1966.

ROBERT A. O'LEARY, Primary Examiner

A. W. DAVIS, JR., Assistant Examiner

U.S. Cl. X.R.

62—514; 250—49.5, 84.5; 313—330