A liquid level sensing system includes waveguides disposed in a liquid and distributed along a path with a gap between adjacent waveguides. A source introduces electromagnetic energy into the waveguides at a first end of the path. A portion of the electromagnetic energy exits the waveguides at a second end of the path. A detector measures the portion of the electromagnetic energy exiting the second end of the path.
LIQUID LEVEL SENSING SYSTEM

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and by an employee of the United States Government and is subject to the provisions of Public Law 96-517 (35 U.S.C. §202) and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefore. In accordance with 35 U.S.C. §202, the contractor elected not to retain title.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to liquid level sensing. More specifically, the invention is a liquid level sensing system using a form of electromagnetic energy such as optical energy.

2. Description of the Related Art

Typical liquid level sensing systems that measure the amount of cryogenic liquid in a tank use differential pressure measurement, capacitance measurements, or measurements made with a series of temperature or thermal resistance sensing devices in a rake or array configuration. Differential pressure measurements only work well in non-flowing conditions. Capacitance measurements do not work well when used in thermal gradients and dynamic flow conditions. Thermal measurement systems utilize the thermal change between a cryogenic liquid’s gas-to-liquid fluid phases, and are limited by thermal latency or the time it takes for the thermal sensing elements to respond to a temperature change. In addition, the surface boundary in cryogenic liquid storage (i.e., the village layer) transitions from liquid to saturated vapor or gas. The temperature of the saturated vapor layer is very close to that of the liquid layer. This makes it difficult for a temperature-based system to resolve the true liquid boundary in a tank. Still further, the accuracy of conventional level measurement systems are determined by the number of sensing elements. Since the number of sensing elements is typically tied to individual data channels, substantial data acquisition systems are usually required to achieve accurate results.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a liquid level sensing system.

Another object of the present invention is to provide a liquid level sensing system having a reduced number of sensing elements and data acquisition channels.

Still another object of the present invention is to provide a liquid level sensing system that does not rely on the use of pressure, capacitance or thermal sensing technology.

Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

In accordance with the present invention, a liquid level sensing system includes a plurality of waveguides distributed along a path with a gap between adjacent waveguides. The path has a first end and a second end. A source introduces electromagnetic energy into the waveguides at the first end of the path. A portion of the electromagnetic energy exits the waveguides at the second end of the path. A detector measures the portion of the electromagnetic energy exiting the second end of the path. The waveguides are disposed in a liquid whose level is to be measured.

BRIEF DESCRIPTION OF THE DRAWING(S)

Other objects, features and advantages of the present invention will become apparent upon reference to the following description of the preferred embodiments and to the drawings, wherein corresponding reference characters indicate corresponding parts throughout the several views of the drawings and wherein:

FIG. 1 is a top-level schematic view of a liquid level sensing system in accordance with the present invention;

FIG. 2 is a plan view of a waveguide segments sensor used in the present invention;

FIG. 3 is a plan view of a waveguide support with a plurality of waveguide segments mounted therein in accordance with an embodiment of the present invention; and

FIG. 4 is an end view of the waveguide support taken along line 4-4 in FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Referring now to the drawings and more particularly to FIG. 1, a liquid level sensing system in accordance with the present invention is shown and is referenced generally by numeral 10. System 10 is used to determine the level of a liquid 100 in a reservoir or tank 200. Liquid 100 can be a cryogenic or non-cryogenic liquid with the space 102 above the surface 100A of liquid 100 being non-liquid (i.e., a saturated vapor or gas). It is to be understood that liquid 100 and tank 200 are not limitations of the present invention.

Liquid level sensing system 10 includes an electromagnetic energy source 12 (e.g., an optical energy source such as a laser), a waveguide segments sensor 14, and an electromagnetic (e.g., optical) energy detector 16. Source 12 and detector 16 are tuned to the same wavelength(s) of operation. The particular wavelength(s) should be such that the electromagnetic (e.g., optical) energy will not be absorbed by the particular liquid 100 whose liquid is being sensed. In general, waveguide segments sensor 14 is disposed in liquid 100 along a path (e.g., straightline vertical path in the case of a tank/liquid subject to the forces of gravity) between source 12 and detector 16 such that sensor 14 will be sensitive to relevant levels of liquid 100 in tank 200.

Referring additionally now to FIG. 2, sensor 14 is illustrated in an isolated schematic view in order to explain the operating principles of the present invention. Sensor 14 includes a number of waveguides 140 separated from one another by gaps 142. Sensor 14 is configured such that gaps 142 fill with liquid 100, the non-liquid in space 102, or a combination of the two, depending on their position in tank 200 and the level of liquid 100 therein. Waveguides 140 and gaps 142 are distributed along a substantially straightline path designated by dashed line 144. In a normal gravity environment, sensor 14 is positioned such that straightline path 144 is in a substantially vertical orientation in tank 200 in order to measure the liquid level 100 in tank 200. However, it is to be understood that the orientation of sensor 14 can be changed to satisfy the needs of a particular application without departing from the scope of the present invention.

Each of waveguides 140 will generally by the same type of waveguide (e.g., rigid light pipe, flexible optical fiber, optical lens, or any other waveguide that can contain the electromagnetic energy produced by source 12) with known transmission properties. For processing simplicity, the length Lw of
each waveguide $140$ should be the same as should the length $L_G$ of each gap $142$, although $L_G$ does not need to equal $L_P$. Typically, $L_G$ is much smaller than $L_P$ and is dependent on the amount of energy loss caused thereby for the wavelength(s) of the electromagnetic energy. The resolution of sensor $14$ is defined by the length of waveguides $140$ and gaps $142$.

By way of example, operation of the present invention will be explained for the case where source $12$ is an optical energy source. A known amount of optical energy $120$ (of a wavelength that will not be absorbed by liquid $100$) is introduced at one end of sensor $14$. As optical energy $120$ propagates along path $144$, it passes through successive ones of waveguides $140$ and gaps $142$. When a gap $142$ resides in space $102$ above the surface $100A$ of liquid $100$, attenuation of optical energy $120$ will be different than when a gap $142$ is in liquid $100$. Accordingly, when the attenuated portion of optical energy $120$ exits sensor $14$ as optical energy $160$, such attenuated optical energy $160$ is indicative of the level of liquid $100$ in tank $200$ once sensor $14$ has been calibrated for a particular optical energy $120$ and liquid $100$. Methods of calibration would be readily understood by persons of ordinary skill in the art. Attenuated optical energy $160$ is provided to detector $16$ wherein said electromagnetic energy has a wavelength that is not absorbed by the liquid.

Sensor $14$ in its straightline orientation can be realized by a variety of embodiments without departing from the scope of the present invention. By way of example, such embodiment is illustrated in FIGS. 3 and 4 wherein said electromagnetic energy propagating through waveguides $140$ and gaps $142$, support body $180$ is adapted to be disposed in a liquid, and wherein said electromagnetic energy has a wavelength that is not absorbed by the liquid.

A liquid level sensing system as in claim 1, wherein said waveguides are adapted to be disposed in a liquid, and wherein said electromagnetic energy has a wavelength that is not absorbed by the liquid.

A liquid level sensing system, comprising:

**1. A liquid level sensing system, comprising:**

- a detector for measuring said portion of said optical energy.
- a rigid support; and
- at least three said waveguides distributed along a vertically-oriented straight optical path with a gap between adjacent ones of said waveguides, said path having a first end and a second end;
- a source for introducing electromagnetic energy into said waveguides at said first end of said path wherein a portion of said electromagnetic energy exits said waveguides at said second end of said path; and
- a detector for measuring said portion of said electromagnetic energy.

A liquid level sensing system as in claim 1, wherein each said gap is identically sized along said path.

A liquid level sensing system as in claim 1, wherein each of said waveguides is identically sized along said path.

A liquid level sensing system as in claim 1, wherein each of said waveguides is defined by a first length along said path and each said gap is defined by a second length along said path.

A liquid level sensing system as in claim 1, wherein said waveguides are adapted to be disposed in a liquid, and wherein said electromagnetic energy has a wavelength that is not absorbed by the liquid.

A liquid level sensing system as in claim 7, wherein said waveguides are selected from the group consisting of rigid light pipes, flexible optical fibers, and lenses.

A liquid level sensing system as in claim 7, wherein each said gap is identically sized along said path.

A liquid level sensing system as in claim 7, wherein each of said waveguides is identically sized along said path.

A liquid level sensing system as in claim 7, wherein each of said waveguides is defined by a first length along said path and each said gap is defined by a second length along said path.

A liquid level sensing system as in claim 7, wherein said waveguides are adapted to be disposed in a liquid, and wherein said electromagnetic energy has a wavelength that is not absorbed by the liquid.

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