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Liquid Level Sensor[1]

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Abstract. There exists a serious need for a continuous liquid level sensing device for use in cryogenic liquids. An optical probe that will emit an amount of light directly proportional to the height of liquid in a Dewar is described. The optical output signal of the probe will be changed to an electrical signal by means of a photocell or a phototransistor.

The object of this project was to design and construct a working model of a continuous optical liquid level sensor. This sensor would be used to measure the height of liquid in a Dewar. Upon introducing a constant amount of light into the sensor the liquid level would be determined by the light output of the sensor. Preferably, the light output would vary linearly with the liquid level in the Dewar.

THEORY

According to Snell's law of refraction for a light ray striking the interface between two media,

$$\sin(a) = B/A \sin(b) \qquad (1)$$

where A is the refractive index of medium 1 and B is the refractive index of medium 2. (a) is the angle that an incident light ray makes with the normal to the interface between the two media measured within mdium 1 and (b) is the angle that the ray makes with the normal measured within medium 2. There exists for any two media of A greater than B a value of (a) such that (b) = 90°. This angle is called the critical angle for any two media. Let (c) represent the critical angle and, from (1), if (a) is greater than (c), then (b) must be greater than 90° (reflection). If (a) is less than (c) then (b) must be less than 90° (refraction).

POINT SENSOR

Consider that medium 1 is plexiglass and A equals 1.48. If medium 2 is air with B equal to 1.00, the critical angle for air will be, from (1), (a) = arcsin B/A = 42.5°. If medium 2 is water, where B equals 1.33 (at 25° C) then the critical angle for water is 64.2°. If we now wish to determine the presence or absence of water at a point on the surface of the plexiglass, all that is required is that a light ray pass through the plexiglass and strike the interface at an angle intermediate to the two

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critical angles calculated above. By suitably placing a light sensitive device such as a photocell which will be activated by the ray only if the ray is reflected, the absence of water can be established. This point sensor may be used to discriminate between air and any other liquid, provided that the critical angle of the liquid with reference to plexiglass is significantly greater than 42.5°.

Continuous Sensor

The concepts of a relatively new field in physics called fiber optics provide part of the theory for a proposed optical sensor. The remainder of the theory is based on two assumptions.

If a long bundle of coated glass fibers is fused into a circular cross section at one end and into a long thin rectangle at the other, collimated light may be introduced at the circular end of the bundle and obtained at the other end. The first of the assumptions mentioned above is that the light obtained will be constant over the length of the rectangular end. Secondly, it will be assumed that a light-sensitive device may be procured that will produce an electrical signal which varies directly with the intensity of the light striking it.

Light is introduced to the circular end of the above-mentioned bundle and the long rectangular end of the bundle is fitted with a long prism to receive the light and discriminate between air and liquid continuously over the entire length of the prism. Such a prism may be readily designed from Snell's Law and the foregoing description of a point sensor. This long prism would be placed in the container in which we wish to obtain a liquid level measurement. The optical output of the prism is then received by the rectangular end of a second bundle, which is identical to the first. The theoretical sensing device previously described would then be activated by the light emitting from the circular end of the second bundle, thus giving an electrical signal proportional to the liquid level.