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# BRIEF COMMUNICATION

# AN ON-LINE HOLD UP OR QUALITY METER FOR TWO PHASE FLOW

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## 1. INTRODUCTION

In the operation of geothermal and petroleum fields it is highly desirable to have a detailed knowledge of the hold up conditions pertaining in the two phase pipe lines. Hold up can be determined in a number of ways and Chen (1979) in reviewing the subject has concluded that the most accurate method currently available is the quick acting valve technique. Some methods of less accuracy such as the $\gamma$-ray densitometer (see Isbin *et al.* 1957, Lapoli *et al.* 1973) and the electrical impedence technique (see Gregory & Mattar 1973) have the advantages that the measurement is performed without disturbance of the flow and the length of pipe over which the hold-up is measured is reduced closer to that of the ideal line cross-sectional value. Recent work by Spedding & Chen (1978) has shown that it is possible to measure holdup over a thin cross-section of pipe using a relatively simple device which does not cause disturbance of the flow of fluid in the conduit. In other words the technique combines the accuracy of the quick closing valve technique with the advantage of the $\gamma$-ray and electrical impedence method.

## 2. EXPERIMENTAL

The unit is shown schematically in figure 1 and consists of an enclosed concentric annulus piece set around the outside of the horizontal pipe conveying the two phase flowing stream. Connection between the pipe and the enclosing annulus is made by a series of 8 small holes of 3 mm diameter through which the fluid can freely exchange with that in the flowing stream. Observation shows that the liquid phase percolates freely through the connecting holes between the inside of the pipe and the outer enclosing annulus resulting in a definite level of liquid being formed in the annulus. The unit was tested on an apparatus similar to that used by Nguyen & Spedding (1977) for the measurement of holdup using quick acting valves. The steady state height $h$ of the liquid in the annular region of the unit as measured by a suitable height sensor is directly related to the actual holdup present in the pipe containing the flowing fluid. The datum for reference of the height of liquid $A$ is taken as the lowest point on the inside diameter of the horizontal pipe through which the liquid flows. In order to facilitate presentation of data a fictitious value of holdup $R_L{}^1$ was computed based on the height of liquid in the annulus using the formulae suggested by Burington (1973):

$$\bar{R}_L{}^1 = \frac{1}{\pi r^2}\left\{r^2 \cos^{-1}\left(\frac{r-h}{h}\right) - (r-h)\sqrt{(2rh-h^2)}\right\} \quad [1]$$

$$\bar{R}_G{}^1 + \bar{R}_L{}^1 = 1.0 \quad [2]$$

where $r$ is the inside pipe radius of the two phase flow tube which in the experimental rig was 2.275 cm. The value of the fictitious holdup $\bar{R}_L{}^1$ is merely the fraction of the flow tube cross-sectional area occupied by the liquid assuming that stratification occurs in the flow tube with a liquid level of $h$.

Equation [1] is valid for all values of $h$ ranging from 0 to $2r$. The data are presented in figure

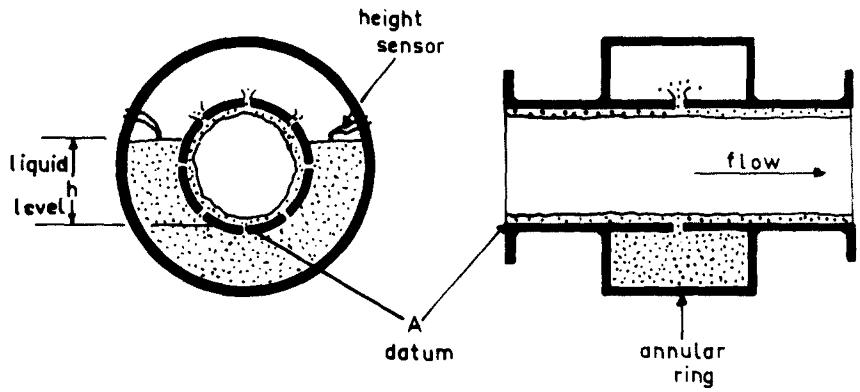


Figure 1. Schematic diagram of the holdup meter.

2 as a plot of $\bar{R}_G{}^1$ against $\bar{R}_G$, the actual measured holdup, and follow the relation

$$\bar{R}_G = 0.324 + 1.489\,\bar{R}_G{}^{11} - 1.080\,\bar{R}_G{}^{12} + 0.27\,\bar{R}_G{}^{13}. \qquad [3]$$

## 3. DISCUSSION

In developing the relation of figure 2 and [3] the data were collected for the annular, the film plus droplet and the droplet regimes with a few data being included for the annuluar froth regime, these being shown as crosses in figure 2. There are two basic reasons for including these and only these regimes in the correlation. Firstly these are the major regimes encountered in the field situation and are therefore those of practical interest. Secondly the other regimes are all characterised by some fluctuations by their very nature and as such present difficulties of interpretation. Actually the operation of the unit in the stratified and intermittent regimes is of a similar nature to that already presented here but because of certain limitations of the actual measurement technique and other factors the exact relationship giving $\bar{R}_G$ has not yet been formulated with sufficient certainty to warrent inclusion here. However, certain aspects of this area are clear and warrent discussion. The work of Spedding & Chen (1979) has highlighted the fact that certain limitations exist in the apparatus used by Nguyen & Spedding (1977) to measure holdup. The limitations apply to intermittent flow regimes such as slug flow regimes and certain types of stratified flow regimes. With these regimes the line cross-sectional holdup varies with time as the various characteristics of the flow pass along the pipe. With the slug flow regime the variation is from $\bar{R}_L \simeq 1.0$ when the pipe is almost completely filled with liquid to an appreciable value of $\bar{R}_G$ when the main body of the gas bubble is passing. For certain cases of stratified flow the average height of the liquid in the pipe cross-section alters with time since the interface is not truely horizontal but slopes somewhat. Thus the holdup registered by quick closing valves will be an average over the length of pipe enclosed by the two valves. It has become apparent that the measurement length used by Nguyen & Spedding (1977) was not sufficient to always enclose at least three slugs in the intermittent regime and the holdup data obtained show the expected wide scatter. To be fair the apparatus design was governed by the design requirement that it had to swing through 90° from the horizontal to the vertical position and therefore the length had to be necessarily limited. Even if the apparatus was of sufficient length to average out the fluctuations successfully the problem arises that the current holdup measuring unit tends to register the instantaneous line cross-sectional holdup while the quick closing valves used for calibration gives average holdup data. Thus there exists a problem in attempting to correlate the reading given by the holdup meter for fluctuating flow regimes with the averaging calibration method of measurement used. It is apparent that in order to obtain a meaningful correlation under these conditions a holdup measurement technique will have to be used for calibration which will give a holdup reading close to the instantaneous line cross-

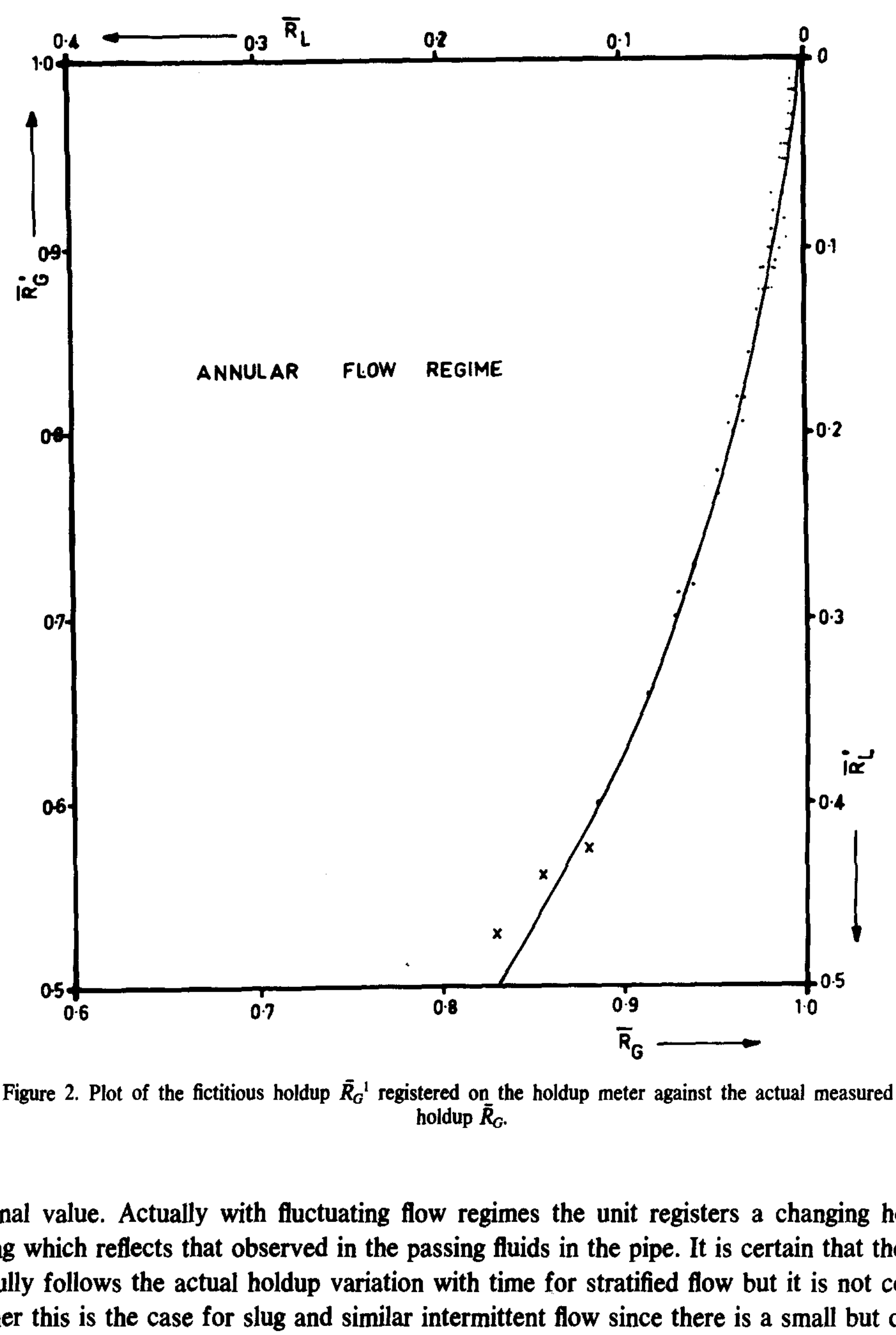


Figure 2. Plot of the fictitious holdup $\bar{R}_G{}^1$ registered on the holdup meter against the actual measured holdup $\bar{R}_G$.

sectional value. Actually with fluctuating flow regimes the unit registers a changing holdup reading which reflects that observed in the passing fluids in the pipe. It is certain that the unit faithfully follows the actual holdup variation with time for stratified flow but it is not certain whether this is the case for slug and similar intermittent flow since there is a small but definit reponse time taken for the liquid height to equilibrate to the new condition in the pipe. However, work is in hand to attempt to answer these questions.

Returning to the actual correlations presented in figure 2 and [3] for annular type flows. The data employed in the correlation were collected over a wide range of liquid flow rates of between 6.0 and 6100 kg/h while a suitable range of air flow between 90 and 475 kg/h were used to give the annular type flow regimes. A large number of readings were taken and the order of accuracy was determined as being in the region of 1 per cent or better. The effect of upstream and downstream disturbances on the unit are significant and care should be exercised to ensure that suitable calming lengths are employed before and after the unit. In this work a calming length of 110 pipe diameters was used upstream and a trailing length of 33 pipe diameters after the unit. No perceptible effect was noticed if the calming length was reduced to 45 pipe diameters.

The effect on the operation of the unit by other variables such as pressure and pipe diameter appear to be negligible. The actual correlation was obtained for a pressure range of between 0.95 and 1.25 atmospheres absolute and a pipe diameter of 4.55 cm but other work has indicated that there is no effect of these variables up to a pressure of 10 atmospheres absolute and a pipe diameter of 25 cm. Indeed there appears to be no intuitive reason why any effect should be obtained since the unit is calibrated by measurement performed under identical conditions. However, the accuracy of holdup measurement should rise with an increase in pipe diameter since the actual magnitude of the liquid height in the annuluar will increase correspondingly with pipe diameter. The error of measurement is directly dependent on the inherent accuracy of the technique of height of liquid measurement as well as being inversely proportional to the flow pipe diameter. The liquid height $h$ can be measured readily using available technology for height sensing and differential transmitters appear to offer the best accuracy.

The physical dimensions of the holdup unit such as the number and size of connecting holes, the external annulus diameter and annulus thickness could conceivably play a part in the operation of the unit and this aspect is being checked out at the present stage.

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