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A METHOD TO DETERMINE THE VECTORS OF THE AVERAGE VELOCITY FIELD IN UNIFORM FLOW

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SYNOPSIS

In order to determine the direction and magnitude of the average velocity vectors in stationary water flow by means of hot-film anemometry, anemometer voltages in various positions of the hot-film are measured for each vector. By varying the magnitude and direction variables, the mathematical magnitude and direction functions corresponding to the least square error are obtained for the measurements. It is shown that by using certain types of probes, it is possible to determine three-dimensional velocity vectors by rotating the hot film about only one axis. Experiments show that the total function may be expressed as the product of a direction function and a magnitude function. An accuracy of $\pm$ 0,7° for the direction and $\pm$ 2% for the velocity has been achieved.

INTRODUCTION

By the experimental determination of the building up and decay of secondary flows in channel-bends, it is necessary to measure the direction of the velocity vectors extremely accurate, with the least possible disturbance of the flow. With the help of the small probes of hot-film anemometry, the dependance of the heat transfer on the geometrical position of the hot-film relative to the flow direction is exploited. As only one variable is measured, it is necessary to measure its value at various positions of the hot film in order to determine several resulting variables (magnitude and direction). In the case of stationary flow, by measuring the time average of the velocity vectors, it is possible to carry out the measurements one after the other using a single probe.

The evaluation of such multiple measurements was based till now on the results of Hinze. The heat transfer or the anemometer output voltage in the equation of King:

$$a^2 = b_0 + b_1 w^n \qquad (1a)$$

depends not on the actual incident velocity w(o) but on the (smaller) effective velocity.

$$a^2 = w_x^2 + w_y^2 + w_z^2$$
$$= w(0)\{\cos^2(\varphi)\cdot\sin^2(\vartheta) + k_1\cdot\sin^2(\varphi)\cdot\sin(\vartheta) + k_2\cdot\cos^2(\vartheta)\} \qquad (2)$$

The k-factors show, however, an additional dependance on the incident direction (Jórgensen). Satisfactory accuracy may be obtained with these results only by assuming these factors to be dependant also on the direction.

In recent work, one tends to leave the method of effective velocity and takes account of the direction dependance in the velocity equation (Hoffmeister).

$$\bar{a}^2 = \bar{a}_0^2 + B(\varphi)\cdot w^n \qquad (1b)$$

One may determine the directions and the magnitude on hand only three measurements by solving a set of completely defined simultaneous equations. To achieve the highest accuracy the positions must be chosen so that the measurements fall within the range of the most favourable slope of the direction characteristic by the determination of the magnitude (e.g. $\partial a/\partial\varphi = min$). If the calculation of the corresponding directions is to be avoided, one has to carry out a sufficiently large number of experiments with different positions which lie close together, so that three of these correspond to the accuracy requirements. Instead of using only three measurements to compute three unknowns, one may also use all the measurements and compute the three unknowns from the set of undetermined simultaneous equations. The method of least squares due to Gauss and Legendre is well suited for this purpose. This method has been dealt with exhaustively in the literature concerning statistical data analysis and will not be handled here.

THE VELOCITY-DIRECTION FUNCTION OF WEDGE-SHAPE PROBES

To apply the method, it is necessary to formulate the relationship between the anemometer voltages and the direction and magnitude of the incident velocity mathematically. Fig. 1 shows the directional characteristic of the probe (DISA 55A81). Independent of any special mathematical expressions, one can conjecture on hand the directional characteristics of the wedge-shaped probe 55A81 that these characteristics are linearly dependent on the angles of the direction.

$$\bar{u} = f_1(w, \varphi) \cdot f_2(w, \vartheta) \qquad (3a)$$

For calculation of the magnitude and the directions, some three of the j equations

$$\bar{u}_j = f_1(w, \varphi - \varphi_j) \cdot f_2(w, \vartheta - \vartheta_j) \qquad (3b)$$

which connect the measured anemometer voltages with the positions φ_j, ϑ_j must be linearly independent of one another. This independance is assured if the functional determinant

$$D\left(\frac{\bar{u}_1, \bar{u}_2, \bar{u}_3}{w, \varphi, \vartheta}\right) = \begin{vmatrix} \partial\bar{u}_1/\partial w & \partial\bar{u}_2/\partial\varphi & \partial\bar{u}_1/\partial\vartheta \\ \partial\bar{u}_2/\partial w & \partial u_2/\partial\varphi & \partial\bar{u}_2/\partial\vartheta \\ \partial\bar{u}_3/\partial w & \partial\bar{u}_3/\partial\varphi & \partial\bar{u}_3/\partial\vartheta \end{vmatrix} \qquad (4)$$

is not identically equal to 0. As can be shown by a simple calculation, this condition is satisfied for the case of the wedge-shaped probe only if the probe is set along two different axes in space. Because of separation of the flow and manufacturing tolerances the directional behaviour of the probes with respect to the angle ϑ (Fig. 1) is so unfavourable that it cannot be described mathematically. For the determination of the magnitude the velocity vector must lie in the plane of section of the wedge, so that by unknown directions one angle must first be calculated (Fig. 3a). Only then one can set the axis of rotation in such a way that the vector lies in the plane which bisects the wedge. In a subsequent series of measurements and evaluation one can then use the relationship $\partial\bar{u}/\partial\vartheta = 0$ to obtain the magnitude and second the direction. (Fig. 3b).

This method is time consuming and subject to additional error sources. However, as the flow in the experiments for which the method was developed was largely two-dimensional, the probe could be employed also here by virtue of its superior mechanical stability.

To set up the total function, i.e. the relationship between the anemometer voltage and the direction and magnitude, it is assumed that the function $\bar{u}(w,\varphi)$ can be split up into two functions, one of which depends only upon the direction and the other only upon the magnitude

$$\bar{u}(w,\varphi) = A(\varphi)\cdot B(w) \qquad (5)$$

As opposed to Hoffmeister, the formal representation of the transition from the forced to the free convection is not included in the direction and velocity functions. The general exponential law describes the voltage - velocity relationship in a given region of error down to a certain minimum velocity. As, however, the measured velocities were above this minimum velocity (of about 6 cm/s), a zero-voltage $\bar{u}_o$ was not fixed. Both the coefficients in equ. (1) were allowed to be dependent on direction, thereby ensuring a better agreement between the measured calibration curve and the function.

$$\bar{u}^2(w,\varphi) = b_0(\varphi) + b_1(\varphi)\cdot w^n \qquad (6)$$

Taking equ. (5) into account, the directional behaviour of this type of probe is taken to be given by the Fourier series:

$$\bar{u} = f(w)\cdot\{a_0 + \sum a_\nu \cdot \cos(\nu\cdot\varphi)\} \qquad (7a)$$

The fit of this function with the directional characteristic measured by constant incident velocities revealed that the coefficients a_ν for $\nu \leqslant 1$ are negligibly small compared with the coefficient of the first order. Thus the dependance on the incident direction may be given by the simple expression:

$$\bar{u}(w,\varphi) = f(w)\cdot\{a_0 + a_1 \cos\varphi\} \qquad (7b)$$

$$\bar{u}(w,\varphi) = f(w)\cdot(a_0+a_1)\{a_0/(a_0+a_1) + (a_1/(a_0+a_1))\cdot\cos\varphi\} \qquad (7c)$$

These results have been checked experimentally at our Institute by taking directional characteristics for various velocities. The angle of position was $\varphi_j = 0^\circ, \pm 25^\circ, \pm 45^\circ, \pm 65^\circ$ and $\pm 90^\circ$. Due to the asymmetry of flow caused by the hot film, which juts in the one case inwards and in the other outwards, both the values of voltages corresponding to a certain value of the magnitude were averaged. The nine sets of values $\bar{u}_j, \varphi_j$ per directional characteristic were sufficient to fit the three variables a_o, a_1 and $f(w)$. The splitting up is permissible if the quotient of the two coefficients is independent of velocity, i.e. if a_1/a_0 is a constant. Table 1 shows the results of the calculations to carry out the fit and the averaging and also the quotient

Table 1: Direction function: Coefficients and their ratios

w [cm/s]	90°	65°	40°	20°	0°	a_0	a_1	a_1/a_0	$\frac{\Delta a_1/\Delta a_0}{a_1/a_0}$
14.49	4.76	5.38	5.98	6.25	6.28	4.744	1.598	0.338	0.003
16.12	4.84	5.49	6.11	6.36	6.40	4.834	1.611	0.333	0.014
17.75	4.92	5.60	6.23	6.47	6.58	4.913	1.671	0.340	0.007
19.39	5.01	5.68	6.34	6.57	6.62	5.003	1.671	0.334	0.013
21.02	5.09	5.77	6.44	6.68	6.79	5.075	1.723	0.340	0.005
22.66	5.15	5.86	6.52	6.78	6.88	5. 42	1.751	0.341	0.008
24.29	5.22	5.93	6.61	6.86	6.95	5.120	1.781	0.342	0.018
25.92	5.29	6.02	6.68	6.98	7.05	5.281	1.798	0.341	0.008
27.56	5.37	6.10	6.76	7.02	7.14	5.361	1.783	0.333	0.015

The fit of the magnitude function yields the coefficients of the function $f(w) = b_0' + b_1' w^n$ and the exponent n.

$$b_0(\varphi) = b_0' \cdot A(\varphi) \qquad (8a)$$

$$b_1(\varphi) = b_1' \cdot A(\varphi) \qquad (8b)$$

The results showed, in accordance with the work of Perry and Morrison, the exponent is varying from one probe to the other in the range of n = 0,30 ..., 0,5. To perform the fit a numerical procedure was employed in which the derivatives were simulated. The convergence was hereby poor with oscillation of the solutions. By the final computation of the calibration function the exponent was assumed to be fixed. This constituted an input parameter for the program. The computation was repeated for various values of n. The optimal value was obtained by comparing the various fits. Table 2 shows the tabulated voltage velocity function for various exponents, each with the best values of b_o and b_1.

Table 2: Coefficients of velocity functions with different values of n

calibration velocity	$n =$	0.305	0.315	0.325	0.335	0.345
	$b_o =$	0.307	0.307	0.685	1.850	2.385
	$b_1 =$	9.647	9.381	8.876	8.406	7.967
	$\chi^2 =$	1.903	1.845	1.784	1.798	1.886
w_{cal} [cm/s]	$\bar{u}$ [V]	computed velocity w [cm/s]				
3.05	3.74	3.04	3.03	3.01	2.99	2.97
4.68	4.00	4.74	4.74	4.74	4.73	4.73
6.31	4.17	6.24	6.24	6.25	6.26	6.26
7.95	4.33	8.00	8.01	8.02	8.04	8.05
9.58	4.47	9.86	9.87	9.89	9.92	9.94
11.29	4.56	11.24	11.25	11.28	11.30	11.33
11.85	4.65	12.78	12.79	12.82	12.85	12.87
14.49	4.73	14.29	14.31	14.33	14.36	14.38
16.12	4.82	16.17	16.18	16.21	16.23	16.25
17.75	4.88	17.54	17.55	17.56	17.58	17.60
19.39	4.94	19.00	19.01	19.02	19.03	19.04
21.02	5.00	20.56	20.57	20.57	20.57	20.58
22.66	5.07	22.52	22.52	22.51	22.50	22.49
24.29	5.13	24.33	24.31	24.29	24.26	24.24
25.92	5.19	26.25	26.33	26.18	26.14	26.11
27.56	5.24	27.95	27.92	27.86	27.80	27.75

THE VELOCITY DIRECTION FUNCTION OF FIBRE WIRE PROBES

Fig. 2 shows three directional characteristics of a fibre wire probe. First the probe was placed with its longitudinal axis in such a way that the velocity vector was perpendicular to it in the plane of rotation of the wire (Fig. 4.1). The second directional characteristic was obtained by rotating the probe perdendicular to its longitudinal axis and the wire axis with the velocity vector also in the plane of rotation (Fig. 4.2). The third directional characteristic was obtained by rotating the probe about the wire axis and with the velocity vector perpendicular to the axis of the wire (Fig. 4.3).

The directional dependance in the last mentioned position is clearly due to the disturbances caused by the mounting, viz. a single wire should exhibit a constant heat transfer.

For measurements near the wall, the first possibility of the position is most suitable because of the small space requirement and smooth directional characteristic. To determine two dimensional vectors, the longitudinal axis of the probe is thus set perpendicular to the plane of rotation of the vector, such that this plane is identical with the plane of rotation of the wire.

The fibre wire probe has a certain speciality compared with the hot film probe, which makes it possible to be used for the determination of three-dimensional vectors with positions about only one axis of rotation.

If the probe is rotated about its longitudinal axis, the greater the inclination of the velocity vector to the plane of rotation, the weaker is the dependance on the direction. In order to describe this behaviour, the first directional characteristic is at first represented as a mathematical function. Because of its symmetry , this must be contrary to the case of wedge-shaped probe, periodic in π. By using the expression

$$a(w,\varphi) = f(w)\cdot\{a_0 + a_1|\cos\varphi| + a_2\cos(2\varphi)\} \qquad (9)$$

and assuming that the magnitude and direction functions may be split up, accuracies comparable with those of wedge shaped probe could be achieved by two-dimensional measurements. The magnitude function in equ. (7) was used again. The fit of the velocity calibration by flow transvers to the wire and the longitudinal axis of the probe yielded exponents which were about 0.1 less than those by wedge-shaped probes, n = 0.25 - 0.35 (Fig. 5).

To take into account the independance of direction, by which the heat transfer is a maximum in every position, the direction function is modified as follows:

$$a(w,\varphi) = f(w)\cdot\{a_0 + a_{max} - a_{max}[1-R(\varphi)]\} \qquad (10a)$$

$$R(\varphi) = (a_1/a_{max}) \cdot |\cos\varphi| + (a_2/a_{max}) \cdot \cos(2\varphi) \qquad (10b)$$
$$a_{max} = a_1 + a_2$$

The new direction function R (φ) is normalized ($0 \leq R(\varphi) \leq 1$). This direction component cannot have any effect if ϑ = o (flow direction along the axis of the probe). If one introduces the total function $O(\varphi,\vartheta)$ instead of R (φ)

$$\bar{u}(w,\varphi,\vartheta) = f(w)\{a_0 + a_{max} - a_{max} \cdot O(\varphi,\vartheta)\}$$

then $O(\varphi,\vartheta)$ must satisfy the following conditions:

I	$O(\varphi,\pi/2) = 1 - R(\varphi)$
II	$O(\varphi,0) = 0$
III	$O(\pi/2,\vartheta) = S(\pi/2,\vartheta)$
IV	$O(0,\vartheta) = 0$

The new direction function which is obtained due to condition II corresponds to the second directional characteristic in Fig. 2, if the wire is rotated about a transverse axis perpendicular to both the probe and the wire axis. Because of the symmetry about the angle $\vartheta = 0^\circ$, this relation may also be expressed as a trigonometric series.

$$\bar{u}(w,\pi/2,\vartheta) = f(w) \cdot \{a_0 + F'(\cos\vartheta)\} \qquad (11a)$$

This function can also be re-written in a different and normalized form.

$$\bar{u}(w,\pi/2,\vartheta) = f(w) \cdot \{a_0 + a_{max} - a_{max}[1 - F(\cos\vartheta)]\} \qquad (11b)$$

By comparison one obtains: $S(\pi/2,\vartheta) = 1 - F(\cos\vartheta)$ (12)

The effect of the mounting being negligible, both the characteristics have equal maxima. Further, if it is assumed that the new functions are linear with respect to the angles, the total function can be expressed as:

$$\bar{u}(w,\varphi,\vartheta) = f(w)\{a_0 + a_{max} \cdot [1 - (1 - R(\cos\varphi)) \cdot (1 - F(\cos\vartheta))]\} \qquad (13)$$

This function has its maximum at $\varphi = 0^\circ$ independent of the magnitude of the angle ϑ and at $\vartheta = 0^\circ$ independent of the magnitude of the angle φ. To introduce the additional dependance of the maximum on the second angle ϑ, the third directional characteristic is also represented by means of a trigonometric series:

$$\bar{u}(w,0,\vartheta) = f(w)\{a_0 + G(\cos\vartheta)\} \qquad (14)$$

The constant a_{max} is then replaced by the direction function $G(\cos\vartheta)$

$$\bar{u}(w,\varphi,\vartheta) = f(w)\{a_0 + G(\cos\vartheta)[1-(1-R(\cos\varphi))(1-F(\cos\vartheta))]\} \quad (15)$$

The linear independance of this function, which gives the anemometer voltage, must be checked for three different positions. Let the probe be set at various angles ϑ. The functional determinant of the three equations (j = 1, 2, 3) is then:

$$Det \left| \frac{\bar{u}_1(w,\varphi,\vartheta)}{w} \quad \frac{\bar{u}_2(w,\varphi,\vartheta)}{\vartheta\ \varphi} \quad \frac{\bar{u}_3(w,\varphi,\vartheta)}{\vartheta} \right| \quad (16)$$

It may be seen that none of the conditions which are necessary for the determinant to be identically equal to zero is fulfilled. The fibre wire probe can indeed be utilized to determine three-dimensional velocity vectors by setting the wire in only one plane. For application of the method of least squares at least nine positions are required because of the condition $n^2 \leq m$.

THE EVALUATION OF TWO-DIMENSIONAL MEASUREMENTS

As the magnitude and the direction functions can be split up, the total function is completely determined by taking 2 calibration curves, one for the direction and one for the magnitude.

$$\bar{u}(w_e,\varphi) = a_0(w_e) + a_1(w_e)\cos\varphi \quad (17a)$$
$$\bar{u}(w,\varphi_e) = b_0(\varphi_e) + b_1(\varphi_e)\,w^n \quad (17b)$$

In the first stage of evaluation the velocity function, dealt with as a total variable, and the angle φ of the direction are computed by fitting the pairs of values u_j, φ_j with the function

$$\bar{u}_j(w,\varphi) = c_w\{a_0(w_e) + a_1(w_e)\cos(\varphi-\varphi_j)\} \quad (17c)$$

Due to $\partial u/\partial\varphi$ = min, the velocity calibration curve was taken as usual by transverse incident velocity $\varphi = 0^\circ$. The maximum anemometer voltage

$$\bar{u}_{max} = c_w\{a_0(w_e) + a_1(w_e)\} \quad (17d)$$

thus obtained by taking the fit is corrected for temperature. The magnitude is computed by a simple Newtons iteration of the equation:

$$\{b_0(\varphi_e) + b_1(\varphi_e)\,w^n\}^{1/2} = c_w\{a_0(w_e) + a_1(w_e)\cos\varphi_e\} \quad (17e)$$

To illustrate the quality of the measuring technique two velocity- (magnitude-) and angle- (direction-) distributions are shown as a function of the relative depth z/d of the test channel in Fig. 6. The distributions are obtained from measurements in the middle of the channel taken along the straight part of the test channel. The calculation of the mean deviation of from the well known formula

$$\sigma(\varphi) = \left(\sum_{k=1}^{m} \frac{(\varphi_k - \bar{\varphi})^2}{m-1}\right)^{1/2} \qquad (18)$$

yielded an accuracy in the angle of $\pm$ 0,7°. The deviation of the measured anemometer voltage was $\sigma(\bar{u}) = 0{,}02$ V. The accuracy of the maximum velocity is estimated by drawing a curve through the measured points and calculating the differences between this curve and a mean velocity. A value of $\pm$ 2% was obtained by a magnitude of the mean velocity of about 20 cm/s.

By the application of this method at the Theodor-Rehbock Laboratory for River Improvement, both the calculation of the coefficients using the direction and velocity functions and the actual evaluation have been performed with the aid of the UNIVAC 1108 computer of the University. The fit is obtained using a method due to Powell, which is available as a procedure in the library of the Nuclear Research Center Karlsruhe.

TEMPERATURE CORRECTION AND DIRT PROBLEM

The anemometer voltages obtained by fitting the directional characteristics have been corrected for temperature. From the general formula for the heat transfer

$$Q = I^2 \cdot R_c = f'(w, \varphi) \cdot (R_c - R_k) \qquad (19a)$$

it follows that the current through the hot film is independent of the temperature, as

$$\frac{R_c - R_k}{R_c} = \frac{\ddot{u} - 1}{\ddot{u}} = const. \qquad (19b)$$

holds. The resistance ratio can then be held constant only by changing the temperature difference of the reference resistance R_c. Further as a resistance R_s lies in series with the hot film, the voltage fed to the bridge used as a measured value is not independent of temperature:

$$\bar{u}_A = I_0 \cdot (R_s + R_c) = I_0 \cdot (R_s + \ddot{u} \cdot R_k(T)) \qquad (20)$$

The output voltage corresponding to the temperature of the calibrating apparature is obtained from that, corresponding to the water temperature by means of the simple formula:

$$\bar{u}_e = \bar{u}_m \cdot \frac{\ddot{u} \cdot R_k(T_e) + R_s)}{\ddot{u} \cdot R_k(T_{mo} + R_s)} \qquad (21)$$

A further correction eliminates effects of temperature changes of the water during the experiment, thus avoiding the necessity of adjusting the reference resistance. If the water temperature at the beginning of the experiment is T_o and if it changes after some time from T_o to $T_o + \Delta T$, one can calculate the anemometer voltage corresponding to T_o if the reference resistance $R_K(T_o)$ is held constant, from the formula

$$\bar{u}_A(T_{mo}) = \bar{u}_A(T_m) \cdot \left\{ \frac{R_c - R_k(T_{mo})}{R_c - R_k(T_m)} \right\}^{1/2} \qquad (22)$$

For the calibration runs the water could be filtered to such a degree, that the necessity of cleaning the probes during the entire calibration process was eliminated. The actual experimental set up is, however, fed by a central reservoir, so that the measurement at several coordinate points without consideration of the dirt led to errors. However, if the first position is chosen to be 0^o, and the subsequent positions symmetrical with respect to 0^o, the accuracy of the measurements obtained by cleaning once before the first measurement is approximately the same as that obtained by cleaning the probe before every measurement.

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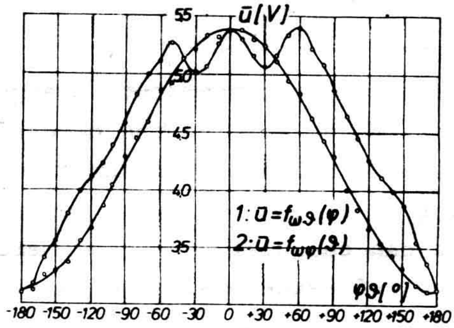

Fig. 1: wedge shape probe DISA 55A81 direction sensitivities

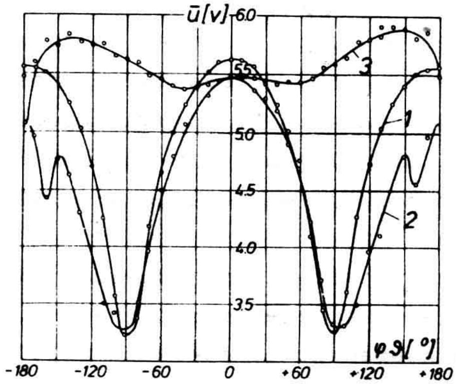

Fig. 2: fiber film probe DISA 55 A81 direction sensitivities

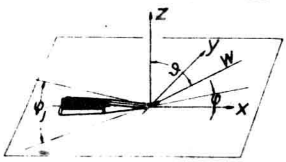

Fig. 3.1: wedge shape probe orientation for Fig 2, curve 1

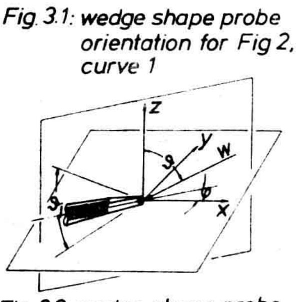

Fig. 3.2: wedge shape probe orientation for Fig 1, curve 2

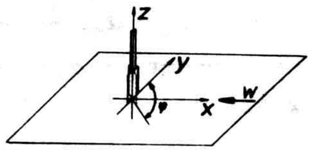

Fig. 4.1: fiber film probe orientation for Fig. 2, curve 1

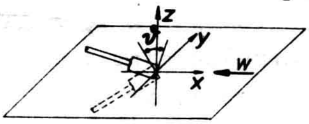

Fig. 4.2: fiber film probe orientation for Fig. 2, curve 2

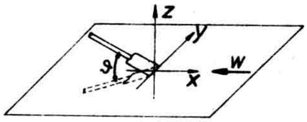

Fig. 4.3: fiber film probe orientation for Fig. 2, curve 3

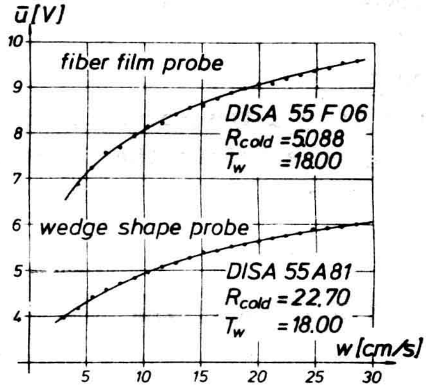

Fig. 5: variation of voltage with mean velocity

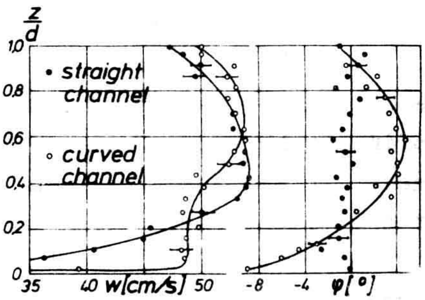

Fig. 6: velocity-and angular distribution

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METHODS OF MEASURING AND COMPUTING FLOOD DISCHARGES

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SUMMARY

River discharge is commonly measured by current meter. The usual procedures must be modified for measuring floods because of high velocities, floating debris, multiple channels, and rapid changes in discharge. Other measuring methods such as the moving-boat method, the use of floats, and rate of filling of a reservoir are suitable at some sites. After the flood has passed, the flood peak can be computed indirectly from a survey of high-water marks and channel characteristics. The various methods are explained, their advantages and weaknesses described, and suitable references given.

INTRODUCTION

Stream discharge is the product of cross-sectional area and mean velocity. Most discharge measurements are made by the current-meter method in which the mean velocity and cross-sectional area are measured in each of 20 or more subsections of the stream cross section. Although the method is simple in theory, specialized equipment and training are required, especially during floods when high velocities make accurate positioning of the meter difficult; floating debris limits the time that the meter may be left in the water, or prevents its use entirely; and suspended debris collects on the sounding line and on the meter.

Flood measurements entail other difficulties such as getting to the site with the proper equipment while the flood is in progress; at such times bridges and roads often are destroyed or become impassable. Forecasts may be needed to insure arrival at a site in time to measure on or near the flood peak. Some floods crest during the night when it is generally not practicable nor safe to measure floods on large streams.

When a current-meter measurement cannot be made, it is sometimes possible to estimate velocity by timing floating drift; the cross-sectional area can be surveyed later. Another possibility is to compute the flood peak inflow to a reservoir from a record of reservoir stage, the reservoir stage-capacity relation, and a record of spill from the dam.

During widespread flooding it is rarely possible to measure all streams at or near the peak discharge but indirect methods of computing peak discharge may be used after the flood recedes. Indirect methods are based on high-water marks along a channel reach, channel cross sections, and estimates of channel roughness. Given favorable conditions, the discharge corresponding to a flood mark at one point in a channel can be computed.

Brief descriptions of the various methods of measuring and computing flood discharges are given in this paper. The reader should study the references before attempting to apply these methods.

CONVENTIONAL MEASUREMENT BY CURRENT METER

The procedure consists of (1) measuring the width, depth, and velocity of flow in each of several parts of a stream cross section, (2) computing the discharge in each part as the product of area and mean velocity, and (3) summing the partial discharges to obtain the total. Referring to figure 1, the depth at each of the selected verticals is measured by sounding and the width of each subsection is computed from the spacing of the verticals. At each vertical the mean velocity is obtained from one or more velocity observations by current meter. Many studies have demonstrated that the mean of velocities at 0.2 and 0.8 of the depth from the water surface is virtually the mean velocity in the vertical. Likewise, the velocity at 0.6 depth very nearly equals the mean in the vertical. Velocity observations are usually made at 0.2 and at 0.8 of the depth in each vertical where depths are adequate. See Buchanan and Somers (1969) for a comprehensive description of methods for gaging streams.

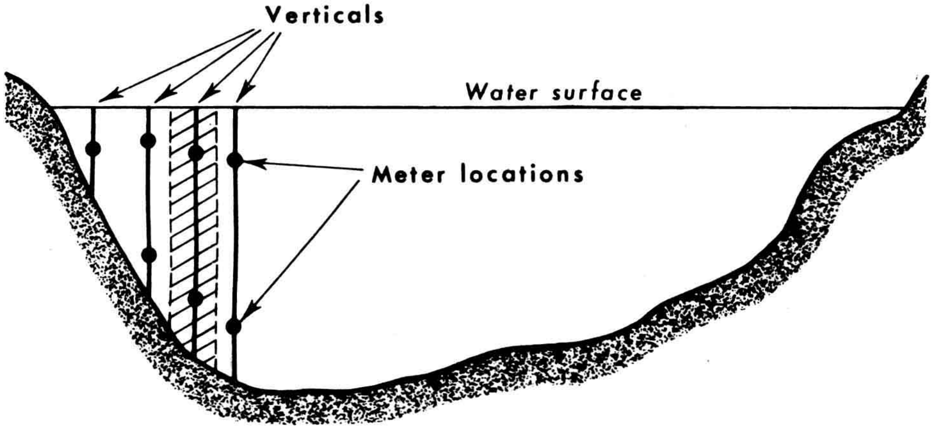

Figure 1.-Measuring section showing one subsection (Hatched).

Desirable characteristics of a measuring section include (1) location in a reach of channel having uniform size, shape, and depth, (2) flow perpendicular to section, (3) moderate velocities, (4) accessibility, and (5) absence of river traffic.

The basic equipment needed for measuring floods consists of a current meter, a device for indicating the revolutions of the meter, a stopwatch, a sounding weight, a reel and sounding line, and some support for this equipment over each vertical in the cross section.

Both vertical-axis and horizontal-axis current meters are used for discharge measurements. The Price meter, a vertical-axis meter used by the U.S. Geological Survey, is well adapted to flood measurements because it operates well in silty water and can be repaired in the field without affecting its rating. In use, the number of revolutions of the meter rotor is obtained by an electrical circuit which produces clicks in an earphone or registers on a counting device. Elapsed time is measured by a stopwatch. These data are translated to velocity through the rating table.

The sounding weight is used for depth measurement and to hold the current meter at the correct position in the vertical for velocity observations. The size of the sounding weight needed depends on the depth and velocity at the cross section. For large streams, weights of from 45 to 180 kilograms are used.