will be the most economical pipe for a particular loss of head. The new interpretation of formulas (1) and (2) (and all other formulas of the same nature) is therefore the general interpretation, and these formulas as an expression of Adams' Rule become a special case.

The economical size of a penstock or pipe may now be determined in a manner analogous to that suggested for pipes of constant diameter throughout. If, for instance, the percentage return on the original investment shall be a specified amount, we may proceed as follows:—

For each of several assumed values for b determine the pipe and calculate or approximate the percentage return p. With b as abscissa and p as ordinate a curve may be drawn. From this curve that value for b may be obtained for which the percentage return is the specified amount.

Illustrative Problem

A hydro-electric plant is to be designed so that the gross percentage return on original investment shall be a specified amount. The pipe is to be riveted steel. Besides the data given in the figure, let $q=50$ cu. ft. per sec.

$S=10{,}000$ lbs. per sq. in.
$t'=\frac{1}{4}$ in. as a minimum value
$c=\$.05$
$i=\$.12$

Since the pipe is homogeneous, the pipe of least annual cost is also the pipe of least amount of metal. We may if we choose, let $c=i=$unity (or we may let $\frac{b}{ci}$ be the constant) and design for minimum amount of metal. The final results will not be affected. We will design therefore for least annual cost.

As a first trial let $b=50$.

To eliminate the unknown coefficient of friction, f, use formulas (5) and (6). From (6)

$$d_1=0.1356\sqrt[6.25]{\frac{b\ q^3}{t'\ ci}}=4.35 \text{ ft.}$$

Run this section (low head) down to $h_1=220$ ft.

Divide the rest of the pipe line into three sections as indicated in figure. From (5)

$$d_2=0.1423\sqrt[7.25]{\frac{b\ q^3S}{ci\ h_2}}=3.70 \text{ ft.}$$

$d_3=3.50$ ft.
$d_4=3.35$ ft.

For the pipe thus determined, the total investment may be calculated, and the total annual income approximated. If the percentage return is the amount specified, the problem is

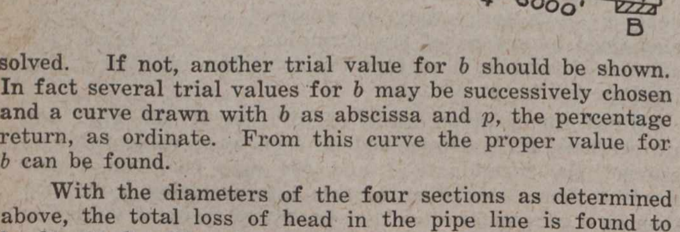

FIG. 2

solved. If not, another trial value for b should be shown. In fact several trial values for b may be successively chosen and a curve drawn with b as abscissa and p, the percentage return, as ordinate. From this curve the proper value for b can be found.

With the diameters of the four sections as determined above, the total loss of head in the pipe line is found to be $h'=49$ ft. The above pipe then for $h'=49$ ft., and for the particular mode of division assumed, is the most economical pipe that can be constructed.

It may be of interest to add the following: If the above pipe of four sections had been designed for a constant diameter throughout but variable thickness of shell, this pipe for $h'=49$ ft., would require 3.5% more metal. If the part AB, the part under high head and consisting of three sections, had been designed for a constant diameter throughout but variable thickness of shell, only 0.8% additional metal would be required. It seems advisable therefore to make the part AB have the same diameter throughout but to change the thickness of shell several times.

If the pipe had been considerably larger, the last statement would not hold. In such a case the saving in the amount of metal required if the pipe under high head is designed for several sections of different diameters and thickness of shell over that required if these sections are designed for the same diameter but different thicknesses of shell may be appreciable. In many cases, however, this saving is not enough to justify the expense of reducers.

The question therefore arises: What is the formula for a pipe or part of a pipe that shall consist of a certain number of sections all of the same diameter but different thicknesses of shell? This question can be readily answered. Referring to Fig. 1, assume that the three sections shall have the same diameter but different thicknesses of shell. Then [see equations (11), (9), (10), and (15)]

$$L=Ad^2\,(h_1\,l_1+h_2\,l_2+h_3\,l_3)+\frac{bq\,C}{8.8\,d^5}\,(l_1+l_2+l_3)$$

This must be a minimum. That is,

$$\frac{d\,L}{d\,(d)}=2Ad\,(h_1\,l_1+h_2\,l_2+h_3\,l_3)-\frac{5\,bq\,C}{8.8\,d^6}\,(l_1+l_2+l_3)=0.$$

Now let

$$(18)\quad h_c=\frac{h_1\,l_1+h_2\,l_2+h_3\,l_3}{l_1+l_2+l_3}$$

and solve for d, and we obtain, for high head,

$$(19)\quad d=0.2153\sqrt[7]{\frac{fbq^3S}{cih_c}}$$

as the required diameter of a pipe (or part of a pipe) that shall have the same diameter throughout but shall consist of a given number of sections of different thicknesses of shell. Formula (19) is the same as formula (1) except that h of (1) must be replaced by h_c as defined by (18). So far as the writer knows, formula (19) is here given for the first time.

Suppose that the part AB of the problem given above shall consist of three sections as shown and that these sections shall have the same diameters but different thicknesses of shell. From (18),

$$h_c=\frac{(3{,}000 \times 480)+(3{,}000 \times 720)+(8{,}000 \times 1{,}000)}{3{,}000+3{,}000+8{,}000}=828 \text{ ft.}$$

Formula (1) or (5) may now be used if h is taken as 828 ft., and the resulting value for d will be the economical diameter of the part AB consisting of three sections of the same diameter but of different thicknesses of shell.

The Corrugated Bar Co., Inc., of New York, announces that it has taken over the entire assets and liabilities of the Corrugated Bar Co., a Missouri corporation, and is continuing the business of the latter company, which is in process of dissolution. This means the retirement by purchase of the Garrison interests, which held the majority of the stock of the Missouri corporation from its inception, in 1891, until the recent reorganization. The control now passes to A. L. Johnson, who has been connected with the company since 1895, and who is now its president.

An information service is being organized by the Associated General Contractors of America, who have established a general office at 111 West Washington St., Chicago, Ill. It is planned to have the manager of the service keep in touch with all the technical and trade papers, and to issue a special bulletin to contractors at least once a month, calling their attention to the best articles on all topics which will be of interest to them. This bulletin will be sent to all of the chief general contractors and construction engineers in the United States, whether members of the association or not, in the hope of stimulating the interest of all general contractors in problems of mutual interest and also in the work of the association.