most successful method is that used by Messrs. Cenfield and Urbutt, which is described in their thesis for the degree of Bachelor of Science in 1909. This method, by which repeated trials gave substantially the same results, is to fill the testing receptacle with thoroughly dry sand by allowing it to flow through a tube maintained at a constant height above the sand surface in the receptacle. Water is added through a pipe connected to the bottom of the apparatus from the outside. This method of filing the voids drives out the air as the water rises. A difference of two per cent. by weight was found in the amount of sand necessary to fill the apparatus in various determinations by packing the sand in any other way than by the tube method. This method has a disadvantage in that the tanks used in the flow experiments are not packed in the same way and the consequence is that the correct value for porosity to use in the computation of results is not known.

Probably the most satisfactory way would be to measure the void space in the sand when in place in the flow apparatus. This would be open to criticism, since the value obtained could not be checked, and in case the determination was incorrect, the results would be unreliable.

The larger the size of the separate pores, the greater will be the flow through the porous material. The value of this factor depends upon the "effective size" of the soil grain in the sample The flow through the interstices of an ordinary sand bed is similar to the flow through capillary tubes and is proportional to the first power of the head causing the flow. When the grains become about three millimeters or larger in diameter, the condition for free flow obtains and the flow varies in accordance with $\sqrt{2gh}$.

The method of determining the effective size will be briefly taken up in a discussion of Hazen's Formula.

The rate of flow varies directly with the temperature. This is because of the effect of temperature on the viscosity of water. An idea of the effect of change in temperature on the flow may be had from the fact that a change from 50 degrees to 60 degrees Fahrenheit will produce a change of about sixteen per cent. in the flow.

It has been found that the shape of soil particles is an influencing factor, though it is impossible to express it in the flow formulas. It is plain that sand grains that are round, flat, rough or smooth will have varying effects on the results even though the effective size is the same for each kind. Cleanliness, chemical composition and distribution of sizes in the sample also have greater or less effects upon the flow, but are exceedingly difficult to express. The distribution of sizes is shown by the "uniformity coefficient" used in selecting the value for C in Hazen's formula.

There are two accepted formulas for the flow of water through soil, one by Allen Hazen, resulting from his work at the Lawrence Experiment Station, and one by Prof. Slichter, resulting from his investigations of the flow of underground water.

The former is generally used by American engineers in their designs and has become standard. This formula is

$$V^2 = c\,d\,\frac{h}{L}\,(0.70 + 0.03t)$$

V is velocity of flow in meters per day.

C is a constant depending for its value upon the shape, cleanliness, chemical composition and distribution of sizes of grain. In practice its value is assumed by comparison of the results of mechanical analysis of the given sand with those of a sand which has been tested.

d is the effective size of soil grain. It is the diameter in millimeters of a sphere whose volume is equal to the volume of that soil grain of such size that 10 per cent. of the grains in the sample are smaller. The size of grain is found by thoroughly shaking the sample through a set of sieves and finding that size which just will not pass each sieve. The results are platted and the effective size taken from the diagram. The size than which 60 per cent. of the sample is smaller divided by the effective size is termed the "uniformity coefficient," the comparative value of which is considered in selecting the proper value for C.

h is the loss of head or the head causing the flow measured between points just inside the ends of the soil column.

L is the length of sand column through which the water passes in losing the head h.

t is the temperature in degrees Centigrade. It may be noted that when t is 10° the last term of the equation becomes unity. The equivalent temperature, 50° Fahrenheit, is taken as the standard in Slichter's formula.

Prof. Slichter expressed his conclusions by the formula:—

$$Q = 0.2012\,\frac{h\,d^2\,a}{L\,w\,k}$$

Q is the volume flow in cubic feet per minute.

$\frac{h}{L}$ is the hydraulic gradient and has the same value as is used in Hazen's formula.

d is the mean size of soil grain and is defined as that size such that if all the grains were the same, the flow would be what it actually is. This term takes care of the size of voids, the cleanliness, chemical composition, shape and distribution of sizes in the sample.

W is a number called the viscocity coefficient which depends upon the temperature for its value. It is defined as that force necessary to maintain unit difference in velocity between two strata of water unit distances apart.

K is a constant depending upon the porosity for its value. Tables of values of both K and W are given in the water supply paper previously mentioned.

Experiments which have been made show the necessity for observing certain principles in conducting investigations of the flow through sand.

Water used in the tests should be treated with some agent such as formaldehyde to prevent the growth of organic life, and should be filtered through charcoal before using. It has been found that water treated in this manner answers the purpose about as well as distilled water. The water should not be used in the tests a second time. In passing through the sand the water may dissolve material which affects its viscosity.

The temperature of the influent water should not be different than that of the effluent by more than one-half degree. In varying the temperature, the experiments should not be conducted at a temperature much above about 65° F. until a satisfactory amount of data has been taken at the lower temperatures. The reason for this is that the heated water seems to cause an entirely new arrangement of the material. The increase in temperature of runs should be made in small increments to discover the critical temperature if such exists.

SHIP-RAISING AT SARNIA.

The Steel Trust is using a novel method to raise the Joliet at Sarnia. It was found impossible for the divers to work on account of the current, so another boat will be sunk directly in front of the Joliet, which will break the current and enable the damage on the Joliet to be repaired. It is expected the scheme will be successful and the boat removed in a short time.