I may remark in passing that VAN DER LEE's observations for water and phenol illustrate the case discussed here, and that through the existence of a maximum pressure the properties of the vapour-liquid binodal line give evidence either of the occurrence of the asymptote of the line $\frac{dp}{dx} = 0$ in the v,x-diagram, or of its lying not far to the left. So there are 4 plaitpoints after the appearance of this double plaitpoint. So two serve as plaitpoints of the plait which is detaching itself and they are both realisable according to our nomenclature and when detachment has taken place, both can actually be realised. They serve then as plaitpoints of what must properly be called a *longitudinal plait.* The two other plaitpoints, viz. the hidden plaitpoint which we placed in the neighbourhood of the points 2 and 3 above, and the lowest of the newly formed plaitpoints then form a couple of heterogeneous plaitpoints, which do not show themselves on the binodal curve of the vapour-liquid plait and will soon coincide and then disappear. From this moment the binodal lines of the two plaits are quite separated and behave independently of each other. The vapour-liquid plait is then simple and perfectly normal. But also the longitudinal plait may then be considered as a normal one.

(To be continued.)

Waterstaat. — "*Velocities of the current in an open Panama canal.*" By Dr. C. LELY.

(Communicated in the meeting of March 30, 1907).

§ 1. After an elaborate investigation the American Government has resolved on the execution of a project of a Panamacanal at high level, *viz.* at a height of 85 feet (25.9 M.) above the mean sea level. It will have three flights of locks.

Against this project of the minority of the Board of Consulting Engineers of 1905 there was a counterproject of the majority which favoured a canal at sea-level or rather a canal with one pair of locks. This canal would have been provided with one pair of locks in order to separate the Atlantic Ocean from the Pacific, but for the rest it would have been in open communication with these seas on both sides of the locks.

As a matter of fact this canal would not have been an open canal, therefore, like the Suez Canal, but a canal in which in most cases,

58*

if not in all, lockage would be necessary. A canal, therefore, which probably would have resembled more closely to the lockcanal proposed for Suez but not executed and strongly opposed, than to the present open Suez-Canal.

The question therefore presents itself whether the Panama-Canal, like the Suez-Canal might not have been made *open* and *without sluices.*

The technical commission of the International Congress of Paris in 1879 deemed a lock near the Panama-terminal an absolute necessity, because it was supposed that, without it the tidal motion of the Pacific would cause currents in the canal of a velocity of 2 to 2.50 M. per second [1]).

On the other hand the Board of Consulting Engineers of 1905 rightly judged that the necessity of such a lock was not established but, owing to lack of time, it was not able to investigate the matter [2]).

On page 56 of the report we find as follows:

"The question of the necessity of a tidal lock at the Panama end "of the canal has been raised by engineers of repute, but the limited "time available to the Board has not permitted the full consideration "of this question which is desirable. It is probable that in the "absence of a tidal lock the tidal currents during extreme spring "oscillations would reach five miles per hour. "(2.24 M. per second)" "While it might be possible to devise facilities which would permit "ships of large size to enter or leave the canal during the existence

[1]) This opinion clashed with that of the original projectors Messrs Wijse and Reclus. In a statement made by the latter at the meeting of the Technical Commission of May 19, 1879 he explains that the inclination of the high and low waterlines in the Panama-Canal will be about the same as on the Suez-Canal, as a consequence whereof velocities of the current might be expected in the Panama-Canal which would not exceed very appreciably those of the Suez-Canal. The latter, as far as they are due solely to the tides, usually do not exceed 0.90 M. per second; under the influence of wind they may increase to 1.30 or 1.35 M.

[2]) At the time of the meeting of the Consulting Board competent experts were still of opinion that a lock at the Pacific-terminal would be necessary. Such appears clearly from the letter of Mr. T. P. Shonts Chairman of the Isthmian Canal Commission received by the Board at the beginning of its labours. In this letter occur the following lines:

"A disadvantage which the two plans have in common is that the rapid develop-"ments of naval architecture make it difficult to determine the proper dimensions "of the lock chambers. It is to be considered, however, that up to the present "time such developments has not been greatly hampered by deficient depth in the "harbors of the world, and that development here after will have that obstruction "to contend with. Moreover, it is not possible to dispense with locks entirely. Even "with the sea-level canal a tide lock will be required at the Panama end".

"of such currents, the Board has considered it advisable to contem-
"plate and estimate for twin tidal locks located near Sosa Hill
'even though the period during which they would be needed would
"probably be confined to a part of each spring tide."

It would require a special investigation, however, to know whether in a canal provided with locks, those locks would have to be used only during part of the spring tides.

For, the oscillations of the sea above and below the mean level executed in a period of three hours are on an average $\pm$ 1.23 M. at neap tide and $\pm$ 2.53 M. at spring time. This being so it seems probable enough that, both in the interest of navigation and to prevent eventual damages which might be caused by the closing of the lockgates against a strong current, lockage of the ships would be preferred to passing the lock with gates open. For, assuming the total profile of the locks to be equal to the profile of the canal, observations made in the Suez-Canal justify us in evaluating the velocity of the current at 0.70 to 0.90 M. at mean neap tide and at 1.00 to 1.30 M. at mean spring tide.

At all events, each time after the gates having been closed the passing of the lock with gates open would not be possible before the sea had again reached its mean level. As a consequence, at each tide requiring the closing of the gates, the period during which passing of the lock with open gates would be possible, would be less than three of the six hours included between two returns of the sea to its mean level.

Howsoever this be and leaving out of consideration the question to what degree a lock in a sea level canal will be an obstacle to navigation, it appears at all events that the necessity af such a lock has remained an unsolved question when in 1905 the projects of a Panamacanal were examined. The cause thereof lies in the uncertainty about the velocity of the currents which will occur in an open canal, particularly as a consequence of the tidal motion of the Pacific.

In addition to the motion caused by the tides, great velocities of the current may occur in a sea level-canal, with or without tidal lock, at the time of high floods of the Chagres and other rivers, if the water of these rivers must be carried off by the canal. In contradistinction to the project of 1879 such would have been the case in the sea-level canal according to the project of the Board of Consulting Engineers.

The Board comes to the conclusion that in a sea level canal with tidal lock currents will thus be caused reaching a maximum velocity of 1.18 M. per second. (2.64 miles per hour). The Board is of opinion that such a velocity will be no hindrance to navigation.

These same velocities will occur in an open canal as well as in a sea-level canal with tidal lock, at least if in both cases the water of the rivers must be carried off by the canal. They occur very rarely however and need not necessarily lead to an increase of the maximum velocities caused by the tidal motion.

§ 2. The reasons which led the technical commission of the Congress of Paris in 1879 to expect currents with a velocity of 2—2,50 M. per second in an open canal, are twofold. In the first place, the commission gave some examples of currents with a velocity of 2—3,50 M. per second observed on the lower course of rivers where similar differences exist between high and low-water as on the Panama canal on the Side of the Pacific.[1])

In the second place the commission published a memorandum of Mr. KLEITZ, one of its members, containing some summary calculations in regard to the velocities which must be expected in an open canal.[2])

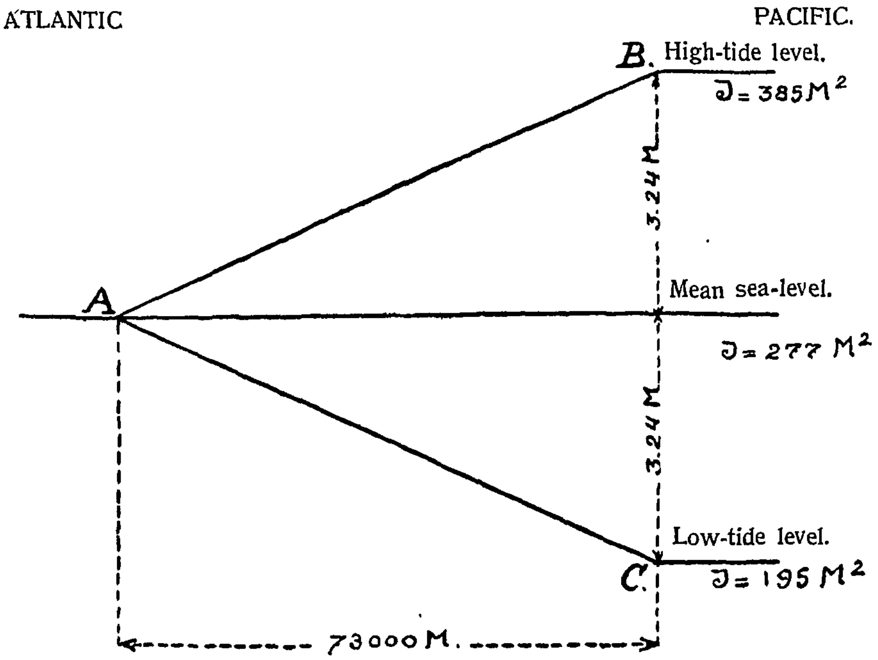
It is evident that on the lower end of a river with a great amplitude of the tide very considerable velocities of the current *may* occur; but it does not follow that equal velocities *will* occur in an open Panama-canal. This will be the case only if the remaining circumstances which have a decisive influence on the velocity are about the same in the two cases. Now it is evident that the velocity of the current caused by the tidal motion of the water will be no less dependent on the depth and in particular on the mean depth for the whole of the width, than on the amplitude of the tide and this irrespective of the question whether we have to do with a river or with an open canal of relatively great length. In other words the velocity of the current will depend as well on the proportion of the amplitude to the mean depth as on each of these quantities separately. Furthermore it is easily seen that in a river these velocities will depend in a great measure not only on the discharge but also on the changes of width and depth and on the inclination of the bottom near its mouth. In fact, the examples communicated by the commission show clearly that the velocity must be dependent in a high measure on other causes besides the amplitude of the tides. For among the examples of the commission we find the Rivière de l'Odet with an amplitude of the tides of 5 M. and

[1]) See: Congrès international d'études du canal interocéanique. Compte rendu des séances. Paris 1879 page 362.

[2]) Ib. p. 384 and Pl. IV fig. 6.

velocity of the high water flow of 3.50 M. and furthermore La Charente with an amplitude of the tides of 6.35 M. and a velocity of the high-water flow of 2 M.

As regards the calculation of Mr. KLEITZ, it is as follows:



According to the above figure the area of the wet section of the canal on the side of the Pacific was adopted to be 385 M.² at high-water and 195 M.² at low water.

The difference between the mass of water in the canal at high and low tide is then taken for the volume of the prism A B C.

$$\text{therefore} = 73000 \times \frac{385 - 195}{2} \text{ M}^3 = 6.935.000 \text{ M}^3.$$

As the interval between high and low tide is about six hours, the change of the mass of water per second is found to be 321 M³ on an average. The mean wet section of the canal on the side of the Pacific being $^1/_2$ (385 + 195) M², that is 290 M², Mr. KLEITZ derives for the velocity of the inflow during the whole period of high tide or for the outflow during the whole period of low tide

$$\frac{321}{290} = 1.11 \text{ M}$$

Furthermore, assuming that the most rapid change of the mass of the water will occur about at the time at which the sea-level is equal to the mean level and besides, that this most rapid change is equal to double the mean change, the maximum inflow is put at $2 \times 321 = 642$ M³.

As the wet section of the canal at the mean level is about 277 M², we find $\frac{642}{272} = 2.32$ M. per second for the maximum velocity.

It is easily seen that these calculations are valueless. For the fact has been wholly overlooked that a certain time must elapse before some rise or fall at the mouth of the canal on the Pacific will make itself felt over the whole length of the canal. If therefore, shortly after ebb, the level in the canal near its mouth begins to rise and, shortly afterwards, the first inflow takes place, the level of the canal further inland will still be falling and the water will there be flowing out as a consequence. Similarly when shortly after the moment of high tide on the sea, the level of the canal near its mouth begins to fall and shortly afterwards outflow sets in, the level further inland will still be rising and there the inflow will not yet have ceased.

Moreover the in- and outflow of the canal on the side of the Atlantic has been left wholly out of consideration. They will certainly not be small but will not take place at the same moments as the in- and outflow on the side of the Pacific. We may see that the difference in time, before mentioned, will not be insignificant but will have a great importance, by considering that, on the Suez-canal, the propagation of the high tide takes place with a velocity of about 10 M. p. second. Assuming the same velocity for the Panama-canal the propagation of the tidal motion over the whole of the length of the canal will require about 2 hours. As a consequence the currents near the two terminals of the canal will have different directions during a great part of the tide.

The incorrectness of the reasons for the conclusion of the congress of 1879, according to which a lock is to be considered an absolute necessity seems to have attracted little attention at that time, and consequently the canal was originally executed with the intention of building a sluice on the side of the Pacific.

Ferdinand de Lesseps, who always considered it a great advantage that the Suez-canal was executed without locks, probably never favoured this lock in the project of the Panama-canal. This led him in May 1886 to address himself to the French Academy of Sciences, requesting it to institute an investigation about the influence of the tidal motion of the Pacific and the Atlantic on the motion of the water in an open Panama-canal.

The commission charged with this investigation reported on the matter in the meeting of 31 May 1887. This commission consisted of the members of the section of Geography and Navigation and besides of the members DAUBRÉE, FAVÉ LALANNE, DE JONQUIÈRES and BOUSSINESQ and the reporter BOUQUET DE LA GRIJE.

This report, though short, contains the results of extensive computations, which led the commission to the following highly remarkable and important conclusion.

"*que, dans aucun cas, les courants dus à la dénivellation ne pour-*
"*ront depasser* $2\frac{1}{2}$ *noeud*" (±1.29 *M. par seconde,* "*et que cette vitesse,*
"*qui ne peut être atteinte tous les ans que pendant quelques heures,*
"*ne parait pas de nature à gêner la navigation des bateaux à vapeur*
"*dans le canal que l'on creuse actuellement à Panama*".

This conclusion was accepted by the Academy and the question concerning the possibility of an open Panama-canal without locks was placed in quite another light than that in which it appeared after the congress of 1879.

Owing to particular circumstances, this conclusion of the French Academy of Sciences has attracted comparatively little attention. For in the same year that this conclusion was reached, the original project of a sea-level canal with lock had to be given up and to be replaced by a canal with several locks. It was the beginning of the sufferings of the Panama-canal.

Since then the principal consideration has always been to limit the excavations to the utmost. For this purpose the hilly country required a canal at high level, consequently several locks.

§ 3. Therefore, if we wish to answer the question whether an open Panama-canal without sluices is possible, we have to inquire in the first place, whether the report of the French Academy of Sciences, of 1887 is based on sound foundations.

What were these foundations?

In accordance with observations at the tide-gauge at Panama the differences between high and low water, in other words, the amplitudes of the tides at the mouth of the Panama-canal were adopted to amount to:

at neap tide, on an average	2.46 M.
,, spring ,, ,, ,, ,,	5.06 M.
,, ,, ,, maximum in March or Sept.	6.76 M.

The commission now calculates the velocity of the current for this maximum difference in height of the tides on the Pacific of 6.76 M., neglecting the usually small tidal oscillation in the Atlantic and further starting from the following suppositions:

1. that experience shows that on a canal communicating on the one side with a sea of variable level, on the other side with a sea of constant level, the amplitude of the tidal curve diminishes uniformly from one sea to the other and further that the retardation of the tide is proportional to the distance, that therefore:

if $Y =$ half the amplitude of the tides of the Pacific,

$l =$ length of the canal,

$\omega =$ velocity of propagation of the tides,

the level y, with respect to the mean canal- or sea-level, at a distance x from the Pacific, will be:

$$y = - Y\left(1 - \frac{x}{l}\right) \cos.\left(2\,t - \frac{x}{\omega}\right)$$

2. that, in accordance with what has been observed on similar canals, particularly on the Suez-canal between Suez and the Bitter-Lakes, the velocity of propagation of the tide can be represented by the well known formula:

$$\omega = \sqrt{g\left(H + \frac{3}{2}y\right)} \pm Kv$$

where:

$H =$ depth of the canal below mean sea-level,

$v =$ velocity of the current,

$K =$ constant (0.4 at flood-time, 1.2 at ebb);

3. that, from the levels which have been derived by means of the suppositions 1. and 2. for any moment and for two mutually not too distant places, the velocity of the current for that moment may be computed by applying the formula:

$$v = 56{,}86\,\sqrt{R\,i} - 0.07.$$

By means of these suppositions the velocity of the currents have been computed for places at 9, 27, 45 and 63 K.M. from the Pacific, assuming a tide of the amplitude of 6.76 M. The results are as follows [1]:

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[1]) The length of the canal which according to the project made at that time, would amount to 72 K.M. has been put at 76 K.M. in the calculations to allow for the curves. The bottomwidth was put at 21 M, the depth at 11.50 M. below mean sea-level at Panama, and 9 M. at Colon, the slopes at 1 horizontal on 1 vertical.

Time elapsed since low tide on the Pacific.	Distances from the Pacific.			
	9 K.M.	27 K.M.	45 K.M.	63 K.M.
Moon-hours.	Velocities of the current in M. per second.			
0	— 0.95	— 1.00	— 0.77	— 0.60
½	— 0.81	— 0.90	— 0.93	— 0.72
1	— 0.60	— 0.84	— 0.87	— 0.83
1½	— 0.13	— 0.75	— 0.82	— 0.85
2	+ 0.35	— 0.59	— 0.75	— 0.86
2½	+ 0.67	— 0.34	— 0.63	— 0.81
3	+ 0.84	+ 0.35	— 0.42	— 0.73
3½	+ 0.93	+ 0.63	+ 0.08	— 0.61
4	+ 0.98	+ 0.78	+ 0.43	— 0.41
4½	+ 1.02	+ 0.93	+ 0.80	0
5	+ 1.17	+ 1.06	+ 0.82	+ 0.51
5½	+ 1.16	+ 1.11	+ 0.86	+ 0.66
6	+ 1.09	+ 1.06	+ 0.98	+ 0.76
6½	+ 0.97	+ 1.01	+ 0.97	+ 0.85

+ = current *from* the Pacific *towards* the Atlantic
— = „ „ „ Atlantic „ „ Pacific

From these computations follows that the maximum velocity in the canal on the side of the Pacific, due exclusively to the tidal motion, will amount to 1.17 M. Supposing that there might be some difference between the mean sea level of the Atlantic and the Pacific and that this difference might amount to 0.50 M., the commission concludes that the maximum velocity might then increase to 1.26 M. The commission thus finally arrives at the conclusion referred to above.

§ 4. The two first suppositions on which the computations are based will probably not seriously deviate from the truth. For they are, at least partially, confirmed by what is observed on the Suez-canal. The commission further points out, that the formula for the velocity of propagation of the tidal wave, which has been derived in the supposition that the amplitude of the tide is relatively small as compared with the depth of the water, leads to results which, for the Suez-canal, agree closely with the observations. For the formula leads to a velocity of propagation of 10.06 M., whereas we find 9.54 M. by observation.

Matters stand somewhat differently for the third supposition. The formula by which the velocities of the currents are computed is the well known formula for permanent uniform motion. It is in the nature of the thing that such a motion cannot occur in a canal where a strong tidal motion takes place. But the question on which every thing depends is not so much this, whether the use of this formula leads to sufficiently correct velocities for any moment, as the following, whether the computed maximum velocities are not too small.

In reference to this question we may remark that in general the formula will lead to too small a value of the velocity during the period that change in level is accompanied by decrease of inclination, to too great a value where the change is accompanied by an increase of inclination.

If, taking this into consideration, we examine the parts of the canal K.M. 0—9 and K.M. 9—27, during the period of $4^1/_2$ to 6 hours after low tide on the Pacific, we get as follows:

Time elapsed since low tide	Mean inclination K.M. 0—9	Mean inclination K.M. 9—27
4½ hours	0.000044	0.000040
5 "	0.000048	0.000046
5½ "	0.000048	0.000047
6 "	0.000044	0.000045

From these data it appears that, during the half hour preceding the epochs at which the velocities reach their maximum value at K.M. 9 and 27 the mean inclination for the part 0—9 as well as for the part 9—27 has been little variable but increasing.

From this it follows that by the application of the formula at these epochs we probably cannot have made any important error.

Meanwhile, in order to test the validity of the computations, we have still to inquire whether the computed velocities, taken in conjunction with the computed levels, satisfy the equation of continuity.

$$\frac{dI}{dt} = -I\frac{dv}{dx} - v\frac{dI}{dx}$$

where I represents the area, v the mean velocity of the wet section at the distance x from the Pacific, at the epoch t.

We can make out, approximately, in how far the computed levels and the velocities satisfy this condition by availing ourselves of the levels and velocities computed for each half hour and for the different distances from the Pacific. We thus find as follows:

A. For the differences in the discharge at 9 *and* 27 *K.M. distance from the Pacific.*

Moon-hours elapsed since low tide on the Pacific.	Area I		Velocity v		Discharge Iv		Per half hour in part 9—27		Excess of *in*flow over *out*flow in half an hour
	9	27	9	27	9	27	*in* flow	*out* flow	
	M².	M².	M.	M.	M³.	M³.	M³.	M³.	M³.
4½	450	388	1.02	0.93	459	361			
							914000	713000	+201000
5	475	407	1.17	1.06	556	431			
							1.013000	807000	+206000
5½	491	420	1.16	1.11	570	466			
							1.002000	828000	+174000
6	498	428	1.09	1 06	543	454			

B. For the change of the mass of water contained in part 9—27.

Moon-hours elapsed since low tide on the Pacific.	Area I		Change of area during half an hour.		Mean change for part 9—27.	Change of mass per half hour for part 9—27.
	9	27	9	27		
	M².	M².	M².	M².	M².	M³.
4½	450	388				
			+ 25	+ 19	+ 22	+ 396000
5	475	407				
			+ 16	+ 13	+ 14^5	+ 261000
5½	491	420				
			+ 7	+ 8	+ 7^5	+ 135000
6	498	428				

Comparing the last columns of the tables A and B we get the following differences for part 9—27:

from 4$^1/_2$ to 5 hours + 195000 M³, or on an average per sec. + 108 M³.
" 5 " 5$^1/_2$ " + 55000 " " " " " " " + 31 "
" 5$^1/_2$ " 6 " — 39000 " " " " " " " — 22 "

It appears from this comparison, that by the computed velocities, taken in conjunction with the computed levels, the condition of continuity is not fully satisfied.

Therefore, assuming the levels to be correct, the velocities need some correction.

Suppose these corrections for the consecutive half hours to be

for K.M. $9 = \delta_1, \delta_2, \delta_3, \delta_4,$

for K.M. $27 = \delta_1', \delta_2', \delta_3', \delta_4',$

we find for the values of the corrections:

$\delta_1 = +\ 0.15$ *M.*	$\delta_1' = -\ 0,13$ *M.*
$\delta_2 = +\ 0.12$,,	$\delta_2' = -\ 0,10$,,
$\delta_3 = -\ 0.04$,,	$\delta_3' = +\ 0,04$,,
$\delta_4 = -\ 0,01$,,	$\delta_4' = +\ 0,01$,,

Therefore, applying the corrections, for the velocities themselves:

	at K.M. 9	at K.M. 27
at $4^1/_2$ hours	1,17 M.	0,80 M.
,, 5 ,,	1,29 ,,	0,96 ,,
,, $5^1/_2$,,	1,12 ,,	1,15 ,,
,, 6 ,,	1,08 ,,	1,07 ,,

From these numbers it appears that we can satisfy the condition of continuity at least for the part 9—27, during the period between $4^1/_2$ and 6 hours after low tide, by relatively speaking slight modifications of the computed velocities.

It cannot be denied, however, that the circumstance of the condition of continuity not being necessarily satisfied in applying this method of computing the velocities, indicates that this method is uncertain to some extent; though it appears that the uncertainty, at least as regards the calculation of the maximum velocities, will be small.

Another reason of uncertainty in the computation of the velocities lies in the value assumed for the coefficient of the formula for uniform motion.

This value, 56,86, is not the result of a great number of observations made on rivers and canals of about the same inclination and depth as the Panama-canal, but of observations for rivers of considerably smaller depth.

We may of course test the validity of this coefficient, as well as, more generally, the validity of the formula itself, by comparing the velocities it yields for the Suez-canal with those really observed there. Of the observations which have been made about the velocities in that part of the canal which lies between the Bitter Lakes and Port-Thewfik, those of 23 July, and 8 en 22 August and 6 September 1892 have been published [1]).

These observations, however, are insufficient for a fair comparison.

[1]) See: The Suez-canal according to the posthumous papers of I. F. W. CONRAD arranged by R. A. VAN SANDICK. Tijdschrift Kon. Instituut van Ingenieurs 1902—1903, p. 89 and 90.

They have been made for two parts of the canal each 200 M. in length and separated by only 4.9 K.M. One part was included in that division of the canal which at that time had been widened to a bottomwidth of 37 M. while the other, having a bottomwidth of only 22 M., was situated a little beyond the point of transition to the not yet widened canal. As a consequence the motion of the water on the whole of this part of the canal, 4.9 K.M. in length, cannot have been uniform [1]).

Moreover these observations are only relative to the velocities in the middle of the current, observed by means of floats down to a depth of 6 M. below the surface, whereas the velocity given by the formula represents the average velocity for the whole of the wet section. Meanwhile a comparison of these observations with the results obtained by the formula might still give some idea about the reliability of the formula.

The comparison of the observations referred to above with the results yielded by the formula, putting the coefficient at 56.86, lead to the following results:

OBSERVATIONS ON THE SUEZ-CANAL IN 1892.

Day and hour of the observation		Direction of the current.	Distance between the places of observation.	Mean difference of level between the places of observation.	Observed velocities. Averages during an hour in the widened part	Observed velocities. Averages during an hour in the unwidened part	Computed mean velocity for the widened part.[2])
			K.M.	M.	M.	M.	M.
23 July	11—12 a.m.	flood	4.9	+ 0.12	+ 0.75	+ 0.97	+ 0 64
„ „	5—6 p.m.	ebb	4.9	— 0.14	— 0 84	— 1.11	— 0.58
8 Aug.	11—12 a.m.	flood	4 9	+ 0.09	+ 0.69	+ 0.87	+ 0.47
„ „	5—6 p.m.	ebb	4.9	— 0.11	— 0.80	— 0.93	— 0.57
22 „	6—7 a.m.	ebb	4.9	— 0.16	— 0.88	— 1.05	— 0 68
„ „	12—1 p.m.	flood	4.9	+ 0.07	+ 0.66	+ 0.82	+ 0.46
6 Sept.	11—12 a.m.	flood	4.9	+ 0.07	+ 0 66	+ 0 89	+ 0.47
„ „	5—6 p.m.	ebb	4.9	— 0.10	— 0.85	— 0.98	— 0.53

[1]) The first part was the widened part of the canal between K.M. 149 and 149.2; the other the not widened part between K.M. 144.1 and 144.3. The transition of the widened to the not widened part was situated at K M. 144.4.

[2]) As the part of the canal from K.M. 149 to 144.4 had been widened the observed difference of level is relative to the widened part.

From this table we derive for the proportion between the computed average velocity for the whole of the wet section to the velocities observed down to 6 M. in the middle of the widened part of the canal, the following values:

	at high water flow (from the Red Sea)	at ebb flow (towards the Red Sea)
	1.17	1.45
	1.47	1.40
	1.43	1.30
	1.40	1.61
Mean	1.37	1.44

The true value of this proportion for the case in which observation and computation agree, is unknown. But if we consider that the floats went down to only 6 M. below the surface, whereas the depth of the water at flood tide was over 8.50 M. and at ebb time over 7.50 M. and furthermore, that the canal had side slopes of 1 vertical on $2^1/_2$ horizontal, we conclude that at all events the velocity in the middle must have considerably exceeded the average velocity for the whole of the section. As far as can be ascertained therefore, the formula applied to the Suez-Canal leads to results which do not clash with the observation.

More conclusive information cannot be derived from a comparison of the computed velocities to the observed values. As long therefore as complete observations, made for the widened Suez canal, concerning the relation between the velocity of the current, the tidal motion and the dimentions of the section, have not furnished us with more reliable information about the value of the coefficient and about the question whether the formula applies fully to the case, we cannot avoid a relatively considerable uncertainty in the calculation of the maximum velocity.

§ 5. A closer examination is therefore required to decide in how far the velocity of the current in an open canal may cause a hindrance to navigation and whether this hindrance cannot be overcome.

In discussing this question we must consider, on the one hand that the computed velocities represent average velocities for the whole of the wet section and that therefore the absolute velocities in the middle of the canal will be more considerable; on the other hand, however, that the computed velocities are relative to the greatest possible differences in the height of the tide. The computed maximum velocities may occur therefore only on a couple of days every year. And on these days only during a few hours.

In how far a relatively rare velocity of the current offers difficulties to navigation is of course ascertained in the best way by a comparison to canals on which under similar conditions similar velocities occur. For such a comparison the Suez-canal offers the best conditions. For this canal several observations about the velocity of the current are known. Published observations, however, cannot lay claim to completeness, at least not for the present purpose. In the first place because they have not been frequent enough to justify the belief that among them will have occurred these rare cases which by an unfavourable coincidence of circumstances, must have given rise to exceptionally great velocities. In the second place because the measurements are, as a rule, relative to absolute velocities in the middle of the canal and not to the average velocity for the whole of the wet section.

Moreover, in comparing the Panama-canal to the Suez-canal we have to consider that the dimensions of the former will be much more considerable than those of the latter as originally executed. Consequently such velocities as have caused no difficulties for the Suez-canal will cause them still less for the Panama-canal.

For the Suez-canal between the Bitter Lakes and Suez originally had a bottomwidth of 22 M. and a depth of 8 M. below mean springtide low water, with which dimensions corresponds a cross section of 330 M^2. On the other hand the sea level Panama-canal would get a bottomwidth of about 45.7 M. (150 feet) and a depth of about 12.2 M. (40 feet) corresponding with a cross section of 855 M^2.

Observations, made during the period 1871—1876, have brought to light the following facts about the velocities of the current in the Suez-canal between the Bitter Lakes and Suez. [1])

"The maximum velocity of the high water flow, running North-"ward, amounts to 0.80 to 0.90 M. at the springtides of the months "of May and November, to 1.15—1.35 M. p. s. in the months of "January and February.

"The maximum velocity of the ebb flow running Southward amounts "to 0.75—0.80 M. at the springtides of the months of May and Novem-"ber, to 1.20—1.25 M. p. s. in the months of July and August.

"Along Port-Thewfik in the canal south of the main channel

[1]) *Vide* the paper of Mr. J. F. W. CONRAD pp. 89 and 90.

"towards Suez, bottomwidth 80 M., the velocity of the high water "flow at springtide is 0.60 to 0.70 M., at neaptide 0.45 to 0.50 M., "in the winter-season with strong South wind 1.00 to 1.20 M. p. s. "The velocity of the ebb flow at springtide is 0.55 to 0.60 M. In "the summer with strong North wind 0.90 M. p. s.

"Outside the mouth of the canal at Port-Thewfik no velocity of "the current has been observed."

The observations of 23 July 1892 made under circumstances which, as regards the flow, were certainly not unfavourable, led already to velocities which, at flood tide, ranged from 0.95—1.03 M. and were in the mean 0.97 M. at flood tide and 1.11 M. at ebb.

Mr. DAUZATS, chief engineer of the Suez-canal, speaking at the meetings of the Technical subcommission of the International Congress for the Panama canal in 1879, stated in regard to the sidings of the Suez-canal, as follows [1]:

"Dans les canaux où le courant est faible, et là où n'existe aucun courant, il suffit de faire les gares d'un seul côté; mais dès que la vitesse atteint 0.75 ou 1.50 M, il faut les établir des deux côtés et en face l'une de l'autre".

By this statement we are certainly justified in concluding that the said engineer, founding his opinion on his experience of the Suez-canal, deemed allowable velocities of the current of 1.50 M. The small original bottomwidth of the Suez-canal of 22 M., however, caused difficulties for the simultaneous navigation in both directions.

The following communications of Mr. E. QUELLENNEC, consulting engineer of the Suez-canal company, proves that these velocities of the current offer no difficulties even for the big ships which at present navigate the Suez-canal. These communications to the Board of Consulting Engineers of 1905 are as follows:

"In the Suez section the velocity of the current very often exceeds 0.60 meter per second, and reaches at times 1.35 Meters per second.

"In the latter case the ships do not steer very well with the "current running in; however the navigation is never interrupted "on account of the current. In the Port Said section ships can "moor with a current running in either direction; in the Suez "section they always moor with the current running out". [2])

The canal between the Bitter Lakes and the Red Sea has at present a width of about 37 M., but a widening of the cross section

[1]) See: Congrès international etc 1879, p. 361.

[2]) See: Report of the Board of Consulting Engineers for the Panama-canal, Washington 1906, p. 176.

to 45 M. width and 10.5 M. depth is being executed. After this widening, navigation will certainly experience still less difficulty than at present. Meanwhile, and this point deserves attention, the velocity of the current after the completion of the widening for the whole of the canal between Suez and the Bitter Lakes, will not be lessened but increased. For, owing to the surface of the two Bitter Lakes, which is about 23800 H.A., the widening will only cause insignificant modifications in the level of these Lakes. Consequently the fall of the water between the Red Sea and the Bitter Lakes will be nearly unaltered after the widening both at high — and low water. Under these circumstances the enlargement of the cross section will necessarily cause increased velocity of the current.

The mere consideration of the maximum velocity which may occur during a few hours every year, and even then only on the side of the Pacific, is evidently inadequate for reaching a true estimate about the question whether the velocities of the current in an open Panama-canal without lock will offer difficulties of any importance for navigation. We have to pay regard in the first place to the velocities which will regularly occur on the whole length of the canal at mean spring-tide and mean neaptide.

These velocities may be derived with some approximation from those found by the French Academy for a maximum difference in tide of 6.76 M.[1]), at least if we suppose that these velocities will not considerably deviate from the truth.

We thus find for the *maximum velocities*

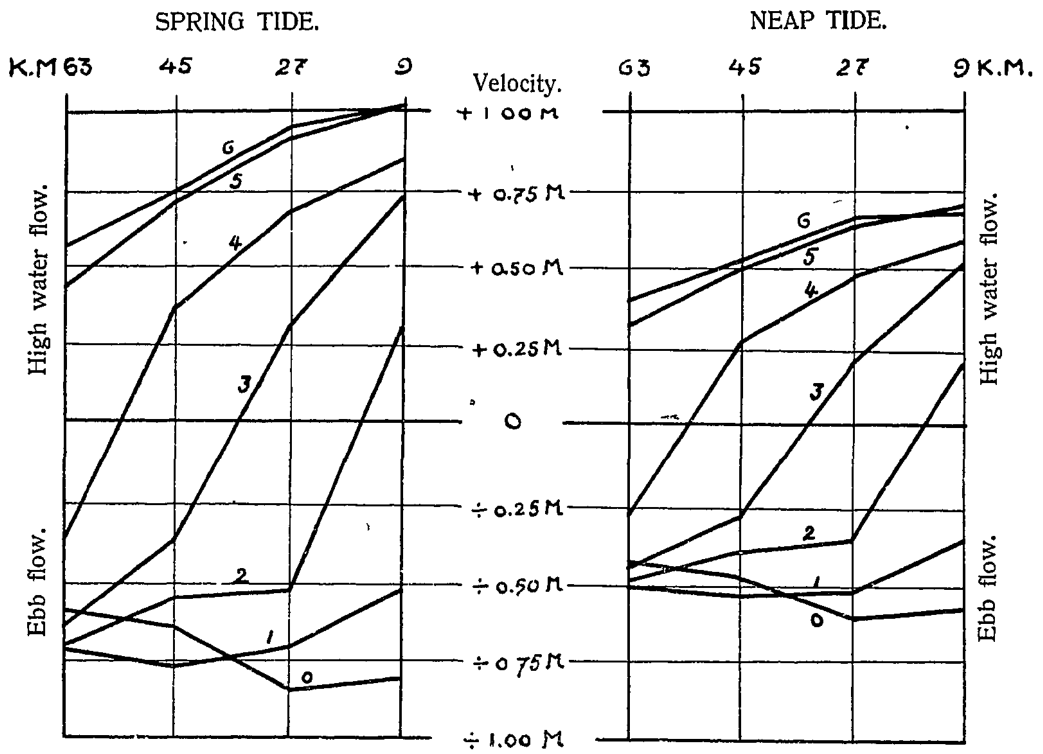
at K.M.	9	27	45	63
at mean neap tide:	0.70 M.	0.67 M.	0.59 M.	0.51 M.
„ „ spring „	1.01 „	0.96 „	0.85 „	0.74 „

The following diagrams show the velocities of the current, for the interval of from 9 to 63 K.M. distance to the Pacific, at mean spring tide and mean neap tide, 0 to 6 Moon-hours after ebb on the Pacific. They were derived from the calculations of the French Academy of Sciences.

1) The approximation neglects the differences of the velocities of propagation of the tide for different amplitudes We thus obtain for the velocity v', at an arbitrary place, the amplitude being y', the following value, which is expressed in terms of the velocity v for an amplitude y:

$$(v' + 0.07) = (v + 0.07)\sqrt{\frac{y'}{y}}$$

59*



The figures inscribed in the diagram represent the hours elapsed since low tide in the Pacific.
$+$ = current *from* the Pacific towards the Atlantic
$\div$ = " " " Atlantic " " Pacific.

§ 6. From the preceding considerations we may conclude that, as far as we can judge by direct computation of the velocities, to be expected in an open Panama canal, there is reason to think that these velocities will indeed be *somewhat,* but not considerably greater than those on the Suez-canal between the Bitter Lakes and the Red Sea.

Meanwhile we ought not to forget, that both in these computations and in our knowledge about the velocities which occur on the Suez-canal there remains some or rather considerable uncertainty. This uncertainty might only be diminished by more complete observations than have been published as yet concerning the relation between velocity of the current, tidal motion and dimensions of the cross-section of the Suez-canal.

We shall be enabled to get at a just estimate therefore about the question whether an open Panama-canal without lock is possible, only by following a way different from that of a comparison of the computed velocities with those observed on the Suez-canal. This way may consist in trying to get at a direct knowledge of the *differences* of the velocities on the two canals by a comparison of the circumstances which will occur on the two. Afterwards the circumstance that, on the Suez-canal the velocity of the current offers no difficulty, in conjunction with the probable value of the velocity of this canal, will help us in deciding whether these differences are of such a nature as to producé undoubted difficulties on the Panama-canal.

In making this comparison it will be permissible to assume that the violent winds occurring in the Suez-canal, which cause velocities of the current 0.30 to 0.50 M. in excess of those due to the tidal motions, are not to be expected on the Panama-canal near the Pacific.

First, however, we have to inquire whether an open canal cannot be executed in such a way that for that part where the current will be greatest the difficulties caused by such great velocities can be removed. It is evident that this would be possible only by giving a very great width to the canal. This is practically impossible for that part of the canal which intersects mountainous country, but it is well feasible for that part of the canal which extends from the Pacific to the Culebra mountain, that is to near Pedro-Miguel, a part which for the greater part intersects low country.

If to this part of the canal, where just the greatest velocities will occur, a bottomwidth is given of for instance 500 feet (about 150 M.) instead of 150 feet (45.7 M.) no difficulties will be experienced from any presumable velocity of the current.

Such a widening of the canal on the side of the Pacific would however increase the inclination and the velocity of the current in the remaining part, at least if no particular measures are taken to prevent such increase.

These measures would necessarily consist in making a reservoir or lake in open communication with the widened part of the canal. This reservoir or lake would have to be of such an area that it would be capable of retaining the water which, during the rise of the level, it would receive from the widened part in excess of what would be discharged by the unwidened part. During the fall of the level it would restore this surplus to the widened part.

From the nature of the thing this arrangement is theoretically possible. Whether it be practically possible depends on the surface which a determinate widening would entail.

A lake of somewhat over 800 H.A., such as is represented on Plate I, is feasible in the low country bordering on the canal near its mouth on the Pacific.

Starting from this area it is possible to determine the degree of widening which may be given to the part near the Pacific in such a way that, under given circumstances, for instance at spring tide, no change will occur in the gradient of the high and low water lines, nor in the velocity of the current in the remaining part of the canal.

As soon as the amplitude of the tides exceeds that of springtide the inclination and the velocity of the current will be somewhat increased for the wider part, somewhat diminished for the remaining part, as compared with what they would be without the widening of the first part and without the addition of a lake. In the case of a smaller amplitude of the tides the reverse will occur.

Owing to the situation of the ground the junction of the widened canal with the lake must be made at a distance of about 12 K.M. from the Pacific terminal of the canal. Not before 3 K.M. farther however, that is not before 15 K.M. from the sea, the surface of the lake reaches a considerable breadth. Therefore if the inclination of the high and low water lines remains nearly unchanged and if, according to the most recent project, the length of the canal is fixed at about 80 K.M., the amplitude of the tide in the lake may reach $(5.06 - 15 \times 0.0632)$ M. $= \pm$ **4.10** M.

With such an amplitude a mass of water may be received, in the interval between high and low water, of $800 \times 10.000 \times 4.10$ M^3. $= 32,800,000$ M^3.

Assuming, as an approximation, that this mass is received within a period of six hours, we find that *on an average* 1500 M^3. will be received per second.

The surplus width of the part of the canal near the Pacific must be determined in such a way, therefore, that *on an average* 1500 M^3. may be displaced — without increase of the velocity of the current — in excess of what might be displaced if the width remained normal.

It is not well possible, without elaborate computation, to fix accurately the surplus width necessary for the purpose. But it is easily seen that this *surplus* width must be about 100 M. so that a bottomwidth of 150 M. might be given to the widened part extending from the entrance of the canal to the junction with the lake. Corresponding therewith the width at the spring tide level would be about 250 M. At K.M. 64 this width might gradually be reduced to the normal width.

It will be possible therefore to remove eventual difficulties offered by considerable velocity of the current on the part of the canal nearest the Pacific, by increasing the bottomwidth of this part. (16 K. M. in length).

Now let us consider how the case stands for the remaining part of the canal, 64 K. M. in length.

On this part the inclination of the high and low water lines will amount to 3.16 cM. at mean springtide and to 1.52 cM. at mean neaptide.

On the Suez-canal the inclination of the high and low water lines between the Bitter Lakes and the Red Sea amounts to 2.52 cM. per. K. M. at mean spring tide and to 1.48 cM. at mean neaptide.

Under the influence of the direction and force of the wind, the height of the tides on the Suez-canal may be increased or diminished by about 0.25—0,33 M.

As a consequence the inclination of the high and low water lines may be increased by about 1 cM. per K. M.

As the distance of the Bitter Lakes to the Red Sea is about 28 K.M., this already enables us to conclude that the velocities of the current in an open Panama-canal, for the first 28 K. M. on the side of the Atlantic, cannot greatly differ from those which occur on the Suez-canal (See Plate II).

If therefore — leaving out of consideration the absolute value of the velocities — we may assume that the velocity of the current will offer no difficulties on the Suez-canal even when it will have been widened, then it follows that on an open Panama-canal, for about the distance of 28 K. M. from the Atlantic, no difficulties will be met with on account of the velocity of the current.

Finally as to the middle part of the canal extending for about 36 K. M. between K. M. 28 and K. M. 64 from the Atlantic.

For this part the *differences* between the velocities of the current, occurring therein, with those occurring in the preceding 28 K. M., may be computed with sufficient accuracy by means of the equation of continuity.

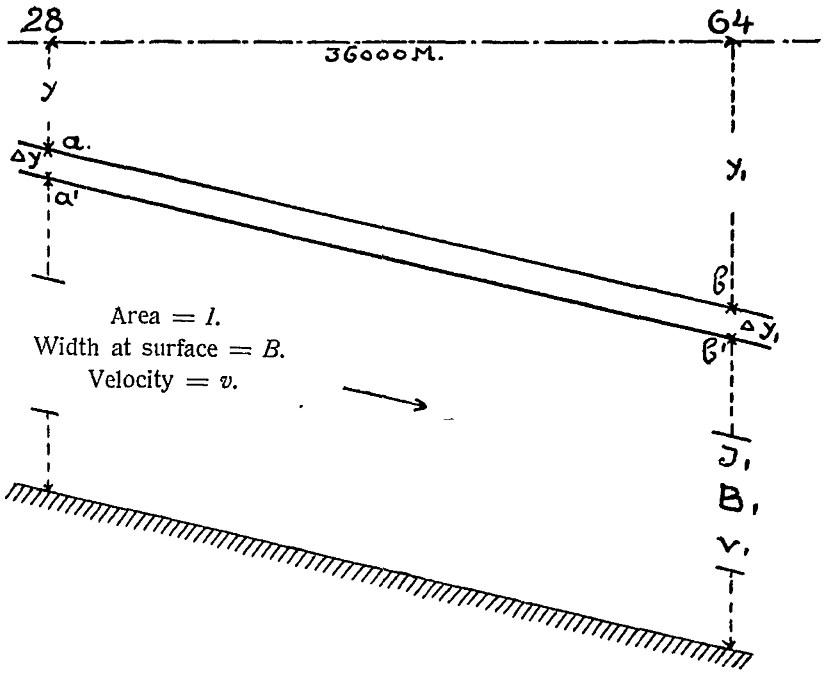
For, let ab be the canal's surface for this part, at the epoch t, a little before low water, at the distance of 64 K. M. from the Atlantic. Similarly let $a'b'$ be the canal's surface a second later, then necessarily

$$-\frac{(B+B_1)}{2} \times 36000 \times \frac{\Delta y + \Delta y_1}{2} = Iv - I_1 v_1$$

from which:

$$(v_1 - v) = \frac{36000\,(B+B_1)(\Delta y + \Delta y_1)}{4\,I_1} + v\,\frac{I - I_1}{I_1}$$

Now the quantities $I, I_1, B, B_1, \Delta y$ and Δy_1, are known for the epoch t, at least if we admit that — as is the case on the Suez-canal — the high- and lowwaterlines for the part 28—64 K.M. are



nearly straight lines, and further that the velocity of propagation of the tides is known with sufficient accuracy, likewise owing to observations made on the Suez-canal. Therefore we will be able to determine the difference of the velocities at 64 and 28 K.M. distance from the Atlantic, for the epochs at which $\frac{I-I_1}{I_1}$ is a small quantity. This will be the case near the moment of low water.

For the difference of the velocities v_1 and v, during the half hour preceding the moment of lowwater at K.M. 64, during which half hour the velocity of the current will be maximum at that point, we find as follows for spring-tide. We assume that between the distances 28 K.M. and 64 K.M. (from the Atlantic) there is a retardation of the tides of just one hour :

at $^1/_2$ hour before lowwater : $(v_1-v) = 0.32$ M. $+ 0.02\,v$

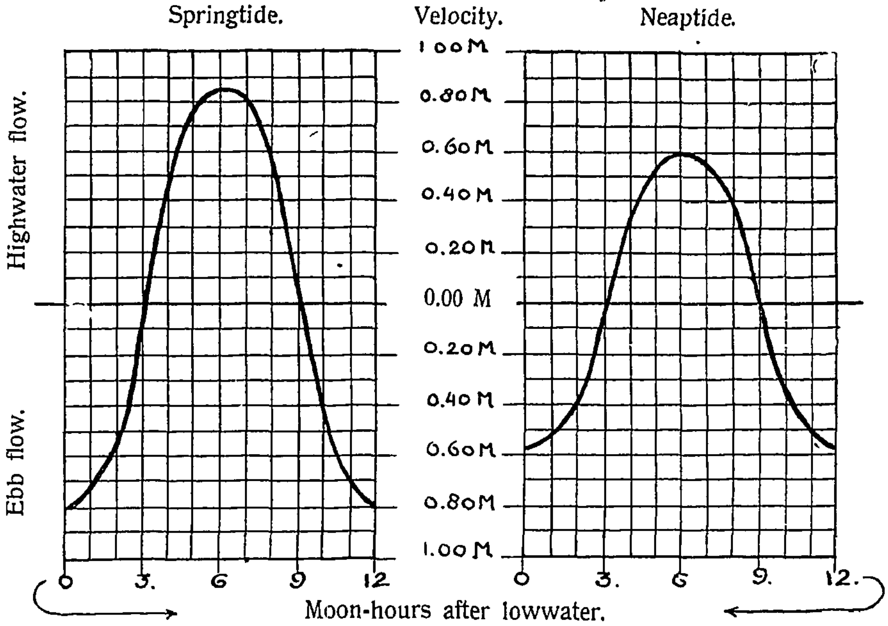
,, lowwater : $(v_1-v) = 0.12$ M. $+ 0.015\,v$.

From these figures it appears, that during the half hour before lowwater at K.M. 64 the *differences* of the velocities of the current are only to a small extent dependent on the value of the velocity v. These differences, therefore, may be determined with sufficient precision, even if the velocity v is only approximatively known.

By observations made on the Suez-canal during the period 1871—

1876 the velocity-curve for a place near the Red Sea is known both, for springtide and for neaptide. It has been represented in the following figures. [1])

Mean velocity-curves at the entrance of the Suez-canal.



The above velocity curves probably do not represent the mean velocities but the velocities in the middle of the canal. They have been derived from measurements made every hour partly by means of floats partly by means of the current meter of WOLTMANN.

It deserves attention, however, that at the time of these observations the Suez-canal had still only a depth of 8 M. below low water and a bottomwidth of 22 M. The section of the canal is now being increased to a bottomwidth of 45 M. and a depth of 10,5 M. below low water. The velocities in the widened canal may perhaps exceed by 20 percent those observed on the canal during the period 1871—1876.[2])

[1]) These curves are borrowed from the Etude du régime de la Marée dans le canal du Suez par M. BOURDELLES, in the Annales des Ponts et Chaussées of 1898. They occur originally in a Note sur le régime des eaux dans le canal maritime de Suez et à ses embouchures in 1881 by LEMASSON Chief Engineer of the canal-works.

[2]) For the original cross section of 8 M. depth below low water, 22 M. bottom-width and slopes of 1 vertical on 2 horizontal we have:

Area $I = 304$ M^2; wet circumference $O = 57.9$ M., consequently $R = 5.25$ M. For the future cross section of 10.5 M. depth, 45 M bottomwidth and slopes of 1 vertical on $2^1/_2$ horizontal, we will have: $I = 749$ M^2., $O = 101.5$ M. therefore $R = 7.37$ M. Now $\sqrt{\frac{7.37}{5.25}} = 1.20$.

If, in consideration of this fact, we substitute in the second member of the formula, for v the values observed in the period 1871—1876 increased by 20 percent, we finally find

$$\begin{array}{ll} {}^{1}/_{2} \text{ hour before low water} & (v_1 - v) = 0.33 \text{ M.} \\ \text{at} \quad ,, \quad ,, & (v_1 - v) = 0.13 \text{ M.} \end{array}$$

The differences 0.33 and 0.13 M. represent the differences of the simultaneous velocities, not those of the maximum velocities at the distances of 64 and 28 K.M. from the Atlantic.

At the moment that the velocity reaches its maximum at K.M. 64, the velocity at K M. 28, where the tides set in about an hour later, will still be below the maximum at that place. According to the observations on the Suez-canal we may assume that, at the epochs mentioned, the velocities of the current at K.M. 28 will at least be about 0.15 M. and 0.05 M. below the maximum of that place. Hence we may conclude that the maximum velocities at K.M. 64 and 28 will certainly not differ 0.18 M, and probably not much over 0.08 M. We are sufficiently justified therefore in assuming that the velocity at K.M. 64 may be about 0.15 M. in excess of that of K.M. 28.

As appears from what has been stated before the difference is inferior to the increase of the velocity of the current on the Suez-canal under the influence of the wind, which may amount to 0.30—0.50 M. It cannot, therefore, cause any serious difficulty.

§ 7. For an open Panama-canal executed as follows:

From the Atlantic to K. M. 64 having the same normal cross section as that of the project for the sea-level canal;

from K. M. 64 to K. M. 68, which is the place where the canal will be connected with a lake gradually widening;

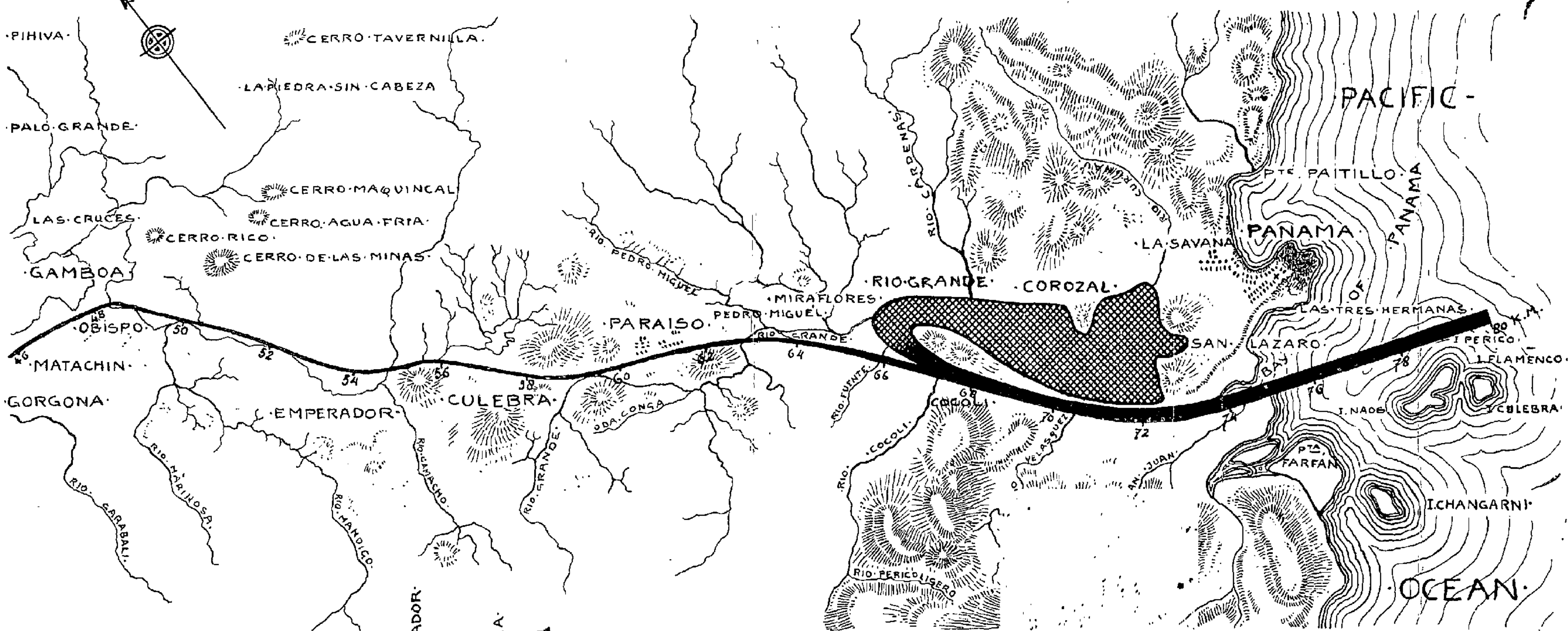
from K. M. 68 to the Pacific at K. M. 80 having bottomwidth of 400 to 500 feet;

the following conclusions in regard to the velocities of the current at springtide may be accepted:

On the first 28 K. M. of such an open canal, velocities of the current will occur at springtide which, on an average, will be about equal to those, which will take place at spring tide and with a moderate wind on the Suez-canal between the Bitter Lakes and the Red Sea as soon as the widening of this canal will be complete.

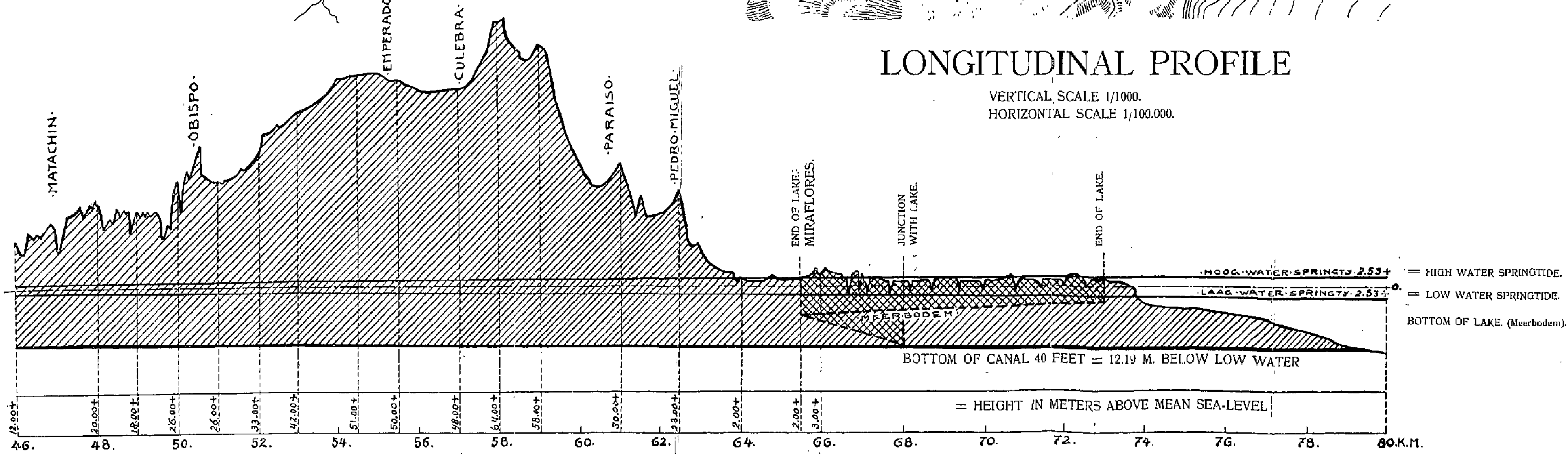
On the subsequent 36 K. M. of such an open canal the maximum velocities at springtide will exceed those on the preceding part by

SCALE 1/100.000.



LONGITUDINAL PROFILE

VERTICAL SCALE 1/1000.
HORIZONTAL SCALE 1/100.000.

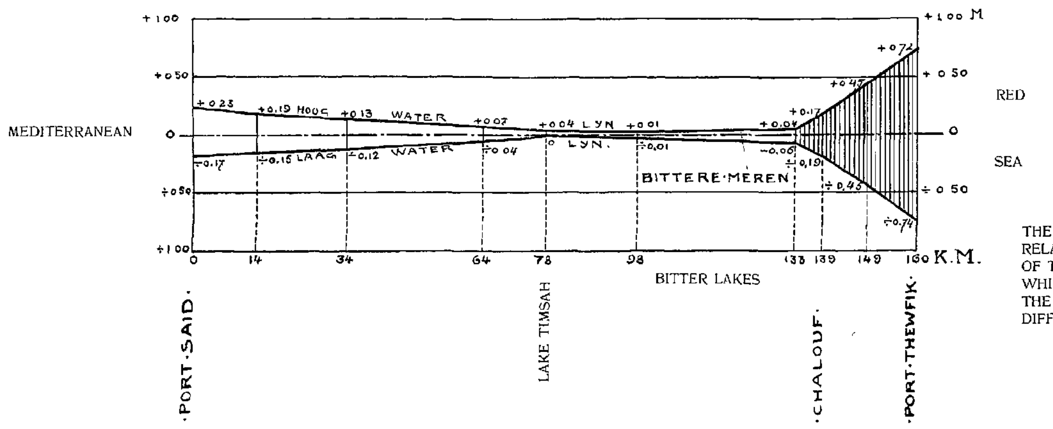


AT

SPRING TIDE.

SUEZ-CANAL

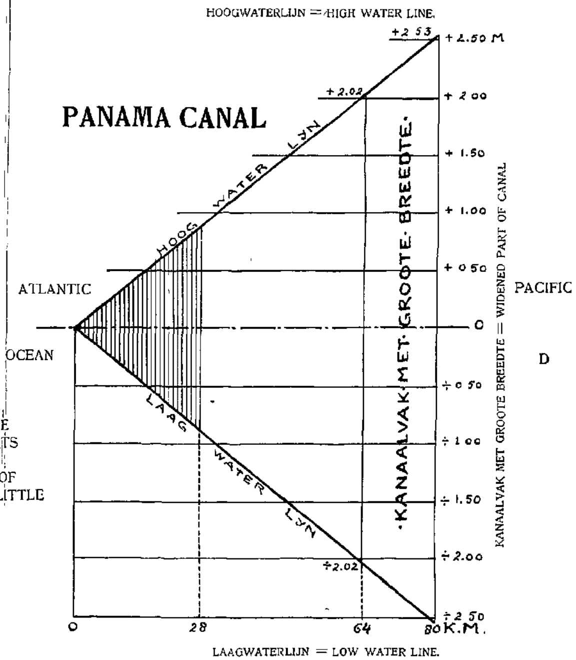
(1871—1876)



MEAN SEA-LEVEL

THE HATCHED AREAS ARE RELATIVE TO THOSE PARTS OF THE TWO CANALS IN WHICH THE VELOCITIES OF THE CURRENT WILL BE LITTLE DIFFERENT.

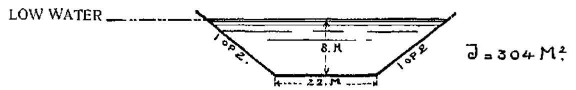
PANAMA CANAL



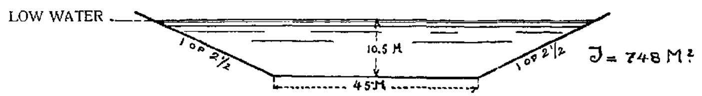
PROFILES

SUEZ-CANAL

A AS ORIGINALLY EXECUTED.



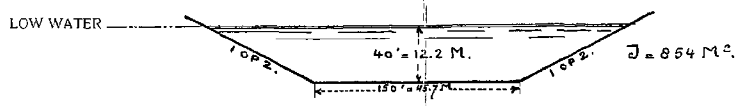
B IN EXECUTION.



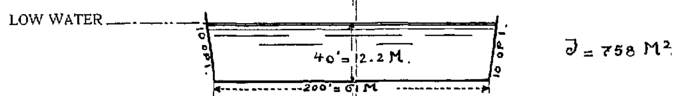
SCALE OF THE PROFILES 1/1000.

PANAMA-CANAL

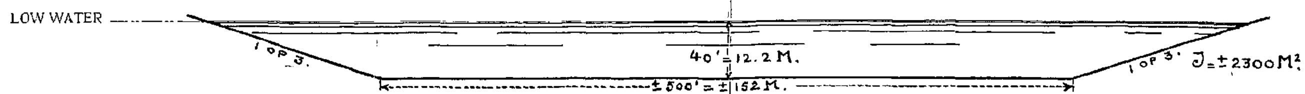
A. IN LOW COUNTRY



·B·IN·CULEBRA·



C. GREATLY WIDENED PART NEAR PACIFIC.



about 0.15 M. They will not exceed however those on the Suez-canal with a strong wind.

For the last 16 K. M. of such an open canal the maximum velocities at springtide may be somewhat more considerable. On account however of the great width, which may be given to this part they will cause no serious difficulty.

Therefore, if we assume, as we have good reason to do, that even at spring tide and with wind the velocities of the current on the Suez-canal offer no serious difficulty to navigation we may conclude that on a Panama-canal of the above description also navigation will experience no difficulties on account of the velocities of the current.

Therefore, *if we leave out of consideration* the question whether an open Panama-canal without tidal lock is to be preferred either to a sea-level canal with such a lock, as proposed by the Board of Consulting Engineers, or to a summit level canal with three locks, as is now in course of execution, we may conclude, in the main in conformity with the conclusion of the French Academy of Sciences of 1887, but for different reasons:

That the velocities of the current due to tidal motion in an open Panama-canal without tidal lock will be no obstruction to navigation.

Zoology. — "*On the formation of red blood-corpuscles in the placenta of the flying maki* (*Galeopithecus*). By Prof. A. A. W. Hubrecht.

(Communicated in the meeting of March 30, 1907).

At the meering of November 26, 1898, I made a communication on the formation of blood in the placenta of Tarsius and other mammals, which was later completed by a more extensive paper, containing many illustrations (Ueber die Entwicklung der Placenta von Tarsius und Tupaja, nebst Bemerkungen über deren Bedeutung als hämatopoietische Organe; Report 4th Intern. Congress of Zoology, Cambridge 1898). The facts observed by me and the interpretation founded on them, have not until now been generally accepted, and in a recent very extensive discussion of the position of the problem concerning the origin of the red blood-corpuscles in the 14th volume of the "Ergebnisse der Anatomie und Entwicklungsgeschichte" (Wiesbaden 1905), by F. Weidenreich, the author, when mentioning my views, emits the supposition that I mixed up phagocytic and haematopoietic processes.

This conclusion was not based on a renewed and critical examination of the material, studied by me. I have regretted this, since I have pointed out clearly and repeatedly that the numerous prepara-