OPENING OF THE SUEZ CANAL.

(*From our Special Correspondent.*)

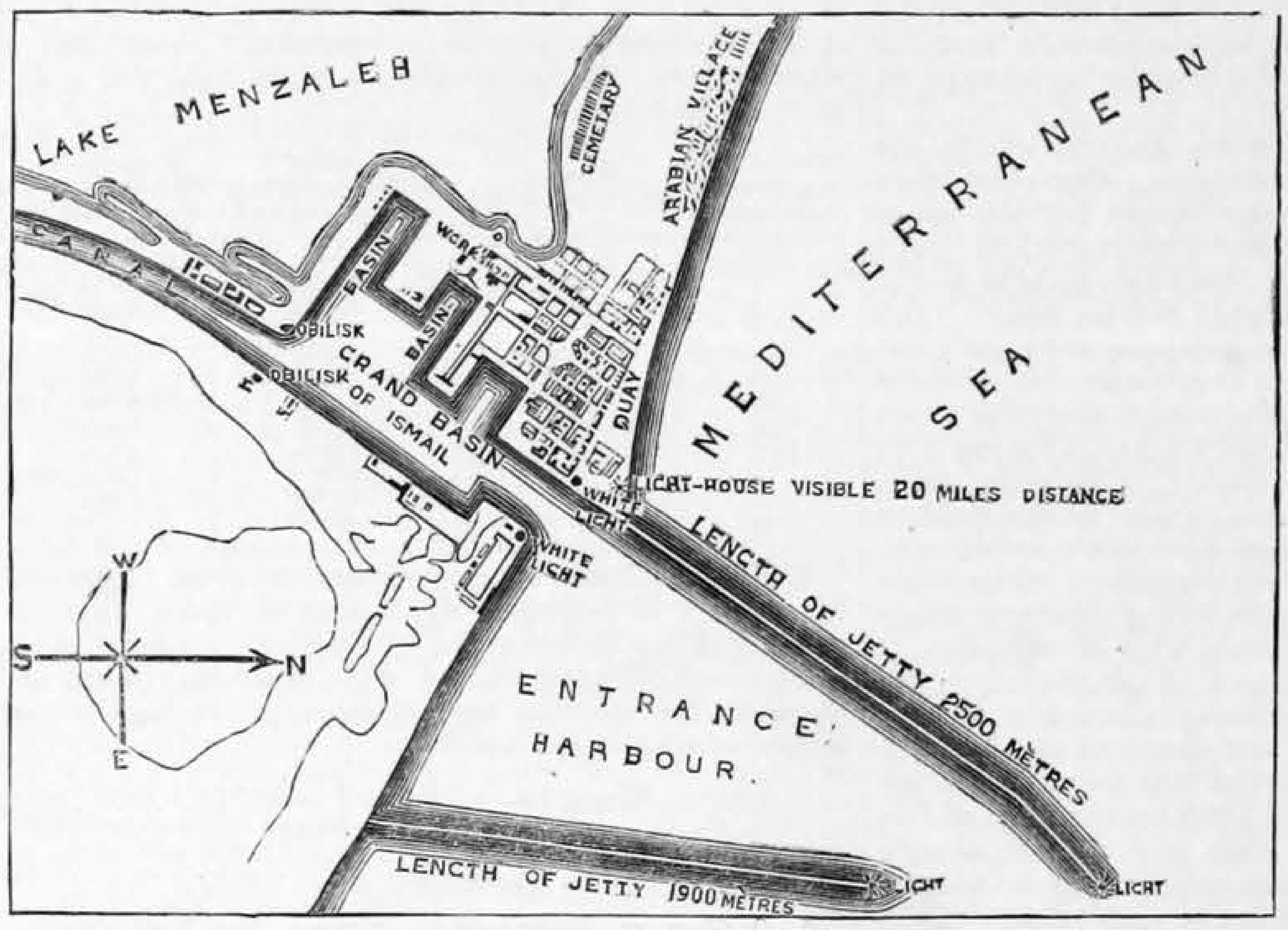
Ismailia, Nov. 18th.

The Suez Canal has been blessed; the Suez Canal has been opened; the Suez Canal is a constructive success. That is to say, a success with limitations, a success bearing to absolute and complete success the proportion of seventeen to twenty-four, or thereabouts; seventeen representing the number of feet of water drawn by the most deeply-laden ship for which it may be considered the canal is really available, and twenty-four the number of feet draught which the canal, if really complete, would accommodate. I well know that the first question I shall be called upon to answer by my readers at home is embodied in the sentence, "Is the canal a success?" I have answered it briefly above in almost the same words which I have employed many times since yesterday afternoon in replying to gentlemen who, however eminent in other respects, know nothing of engineering, and who, rightly or wrongly, believe themselves incompetent to say of their own knowledge—even now, after the passage from Port Said—how far M. de Lesseps has fulfilled the programme he laid down years ago when the Suez Canal was but a great prospect.

Having thus far unburthened myself, I shall proceed, as far as time will permit—for the post for this week's mail leaves this at eleven o'clock—to state what we have done and what we have not done during the last few days. I write now in quiet—that is to say, in comparative quiet. Notwithstanding the Babel around me, the shouting, the music, &c., I consider myself in perfect peace, compared with the uproar and excitement to which we have lately been subjected. I suppose more gunpowder has been burned within the last eight-and-forty hours than was ever burned before in salute-firing. Why this has been the case—involving, as it does, a history of royal arrivals, and meetings, and compliments, and religious services—I must leave to be explained by the gentlemen of the daily press, with several of whom I have spent several days of pleasant social intercourse, and whom I see now busily engaged in the preparation of ample reports. On my shoulders devolves a heavier task. As the only representative of an English scientific journal, I have to give my readers my impression of the canal, not as a picturesque study, but as an engineering work. I can only speak of it as far as I have got—that is to say, to about half its length. My next will deal with the other half of the canal, stretching from this place to Suez.

In the afternoon of Saturday, the 14th, I, with other of the Khedive's guests, arrived from Cairo at Alexandria, and immediately embarked on board the Fayoum for Port Said. The Fayoum is a fine paddle steamer of about 2000 tons burthen. She was built for the Peninsular and Oriental Company, intended to be the Carnatic,* but for some reason was not taken over by that company, but sold to the Viceroy. She has been used by him as a pleasure ship, especially devoted to the use of the ladies of the harem. We had a tremendously rough passage from Alexandria to Port Said. The Fayoum rolled and pitched till it became almost a miracle that she did not roll over altogether. Under ordinary circumstances the Fayoum is, I understand, a very well-behaved ship. The reason for her extreme liveliness on this occasion soon transpired, under the pressure of a little judicious questioning. The Fayoum was sent to Port Said almost without ballast, almost without coal, almost without anything which could bring her down an inch in the water. By judicious arrangement they succeeded in reducing the draught to less than 16ft. She was flying light; hence the rolling. I have said the Suez Canal was blessed—it was also something else'd! The blessing was done by Monseigneur Bauer, many Copts, and some others. The "something else" was done by the officers of the Fayoum and by Egyptian and Turkish gentlemen too numerous to mention, even if I had the ability to spell out their names. Our captain, who informed us that he had lived "ten months at Laird when she build ship," and that during that time his great anxiety was about the "four wife he left at Egypt," was particularly unreserved with his anathemas. It is certainly a remarkable fact that I have scarcely spoken to an intelligent native of this region who does not regard the Suez Canal and everything connected with it as an unmitigated nuisance. I shall not attempt to account for the fact. But it may, to some extent, be explained by the jealousy of the Alexandrines, who regard very unfavourably, and not without reason, the rise of a new port so near their own.

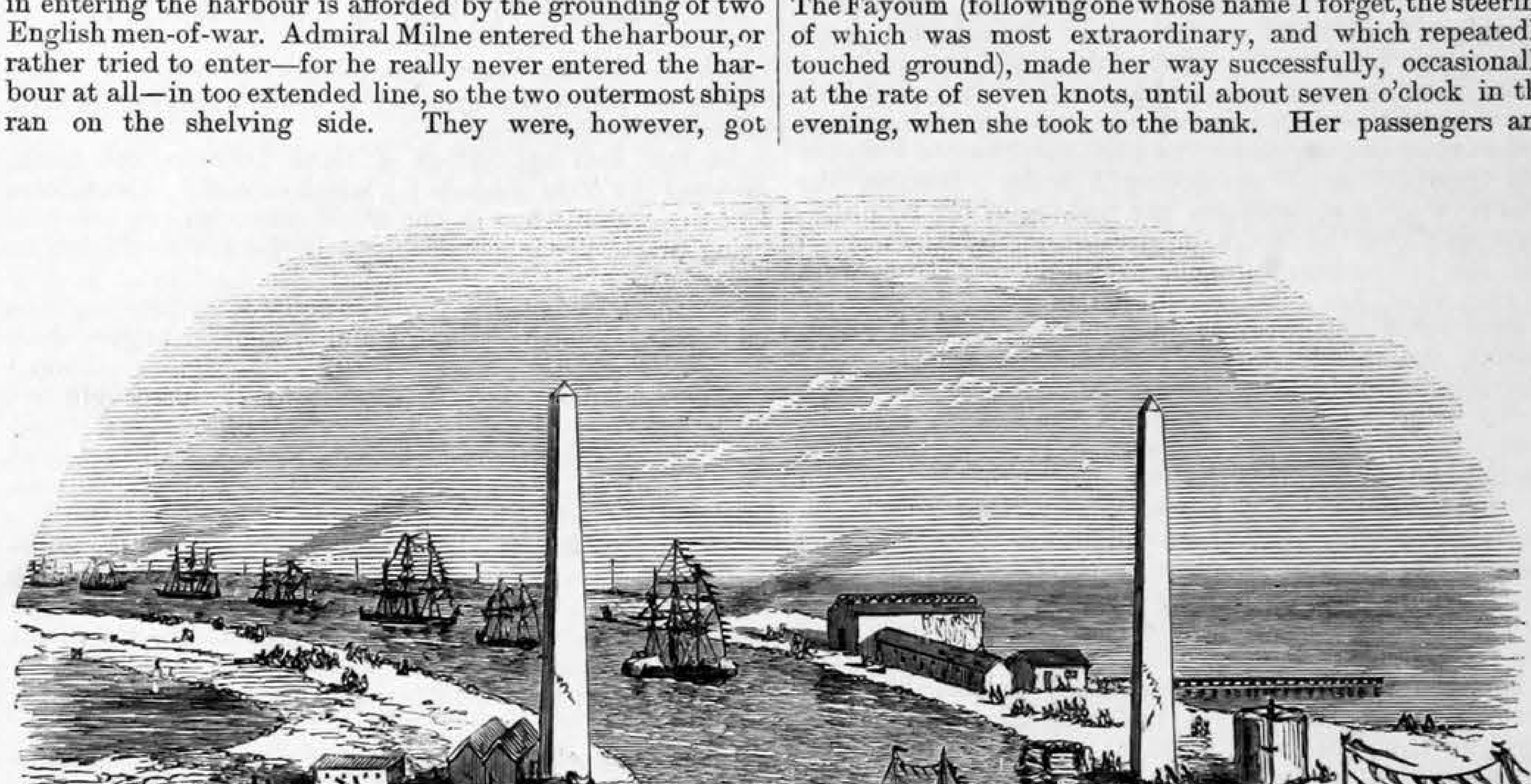
We reached Port Said on the morning of the 15th. It is long since I paid my last visit to this part of the Mediterranean, and, aware as I was, of the sinister rumours circulated in England regarding the qualifications of the harbour of Port Said, I took particular care to examine it thoroughly. To the eye it is a fine sheet of water, quite capable, as far as area is concerned, of holding a very large navy, and, in spite of anything said to the contrary, in moderate weather, and with moderate care, it seems very easy of access. I have heard deep forebodings expressed by men better able to form an opinion than I—seafaring men—who proclaim that with so low-lying a coast many disasters will occur in unfavourable weather. It may be that these prognostications will prove correct, though it is not easy for a landsman to understand that a well lighted harbour should be so extremely difficult to enter. The artificial moles run out to a distance of about two thousand yards. They are made, as you have perhaps informed your readers, of huge blocks of béton tumbled in anyhow. The béton consists of the sand of the place mixed with lime brought from Marseilles. No attempt has been made to fill up the interstices in the structure. It was the intention of M. de Lesseps that the natural drift of the sand should do this. He probably assumed that that solidification often noticed on our own coasts and elsewhere would ultimately bind the béton blocks and interstitial sand into a solid mass. No such action has, however, yet taken place. On the contrary, a vast quantity of sand finds its way through the breakwater into the bed of the harbour, and will do a great deal of mischief if not kept down by dredging. It would, doubtless, have been difficult, as it certainly would have been costly, to have laid the blocks with anything like studied closeness; but if rubble had been thrown in amongst the blocks, so as to lessen the interstitial space, much danger of silting would have been avoided, and the tendency to solidify



would have been largely increased. I took a boat shortly after my arrival, and proceeded to get as many soundings as I possibly could, but I confess it was no easy matter to carry out a scientific survey of this description in a harbour literally alive with craft of all sizes, and with steam launches by the hundred darting to and fro, and in all directions at once. The general results of my soundings were satisfactory. I got generally about 24ft. of water, and this without entering the deepest portion; excellent testimony, however, to the necessity which exists for care in entering the harbour is afforded by the grounding of two English men-of-war. Admiral Milne entered the harbour, or rather tried to enter—for he really never entered the harbour at all—in too extended line, so the two outermost ships ran on the shelving side. They were, however, got off without great difficulty. At the entrance to the harbour there is a lighthouse built of concrete—at first I thought it was iron. It is fitted with an electric light—I wish some one would tell me what the peculiar merits of an electric light are—worked by very indifferent apparatus. The imperfections did not matter, I was told by an intelligent Egyptian, so that the light worked till the 18th, a condition which doubtless will be satisfied. I send with this a tolerably accurate plan of Port Said, which may prove useful. My time was so fully occupied in examining the harbour, that I paid little attention to other matters which seemed to me of far less importance. That ships of all sizes and of all nations except ours* crowded the harbour, and by day were dressed with flags from truck to chains, and from jibboom to taffrail, and by night were illuminated by tens of thousands of lanterns; that bands of music were supported, or drowned [rather, by an incessant roar of broadsides of guns; that by night the heavens were taken by storm by rockets and bombshells; and the whole scene will be described and told you by my indefatigable friends who are writing so earnestly beside me, whose powers of delineation are much greater than mine.

On Tuesday evening came ominous rumours, rumours of evil import for all who wished well to the canal. It came to be doubtful if we should ever reach Ismailia excepting in tugboats or launches. All sorts of reports were current, but only one seemed certainly true—namely, that the Latif, which had sailed early in the afternoon, had taken the ground any distance from seven to twenty miles up the canal, and that unless she could be got off all hope of our getting through would vanish. The most illustrious of my *confrères* left the Fayoum for the Mehemit Ali as drawing less water, but it seemed to me that it was not so much a question of water as of way, and as I was being, and had been, particularly well treated on the Fayoum, I contented myself to remain. (I have found that my friend changed from the Mehemit Ali to a still smaller craft, and reached this last night). Then it was said the Khedive, with Nubar Pasha, had left his Imperial and Royal guests, and had gone himself to superintend the moving of the Latif. Yesterday, the great day, dawned anxiously. The ships were not dressed, the guns were silent, our captain, with a wicked smile on his face, informed us he was not to go up, and that, therefore, he should not get steam up. In spite of all this, however, we saw steamers, one after another, slowly enter the canal until far, far away to the horizon could we trace a long line of craft about half a mile apart slowly wending their way. I now made every endeavour to hire, at any cost, one of the steam launches which were so plentiful the day before, in which to get through the canal, or if not, to know the reason why. But no steam launch was to be had! All had gone in the night with hands to help get off the Latif. I returned to my ship somewhat disheartened, to find, however, that orders had come that we should start as soon as possible. This was joyful news for all of the guests, and at about two o'clock p.m. the thirty-second vessel, the Fayoum, passed between the two timber obelisks which mark the entrance to the Suez Canal.*

Six of the vessels before us ran aground in their progress. The Fayoum (following one whose name I forget, the steering of which was most extraordinary, and which repeatedly touched ground), made her way successfully, occasionally at the rate of seven knots, until about seven o'clock in the evening, when she took to the bank. Her passengers and



THE ENTRANCE TO THE CANAL AT PORT SAID.

crew were sent aft, guns were wheeled ditto, and some tons of water blown off before we were afloat again. At one time it seemed imminent that we should fix athwart the canal, a probability which led to many inquiries as to what would happen afterwards. The whole course of the canal is marked by posts, rendered necessary to indicate the greatest depth of water, which, owing to irregularities in the dredging, is not always exactly in mid-channel.

Once fairly in the canal, I devoted all my attention to the solution of three great questions which presented themselves to me. First, what was really the depth of water; Secondly, what was the effect of the water upon the banks; Thirdly, how far was the canal available for large ships—such, for example, as those of the Peninsular and Oriental Company. In order to solve the first question I sounded carefully, and frequently, perched as I was for the occasion on the top of one of the paddle boxes. Our captain afforded me every facility for doing this. He evidently believed I should find about 18ft. of water only. The result dissipated one rumour at least. The shallowest sounding gave us nearly 22ft. In

* I have just been informed of a curious coincidence. The Pera a few weeks ago, on entering Alexandria, struck on the bar and had a narrow escape of total wreck. She got off, and her passengers were presently transferred at Suez to the unfortunate Carnatic, many of them to be lost within a few hours on the reef of Shadwan.

* I believe the Peninsular and Oriental steamer Delta was then really the only British ship in Port Said. Later the Rapid and Newport arrived.

* I send you a hand sketch of the entrance to the canal. You will make out the narrow strips of land which form the banks, and the water of Lake Menzaleh on each side. The obelisks are apparently about 120ft. in height, and are to be replaced by structures of concrete of the same dimensions.

several places I got 24ft., and even a little more. Now, bearing in mind that the canal is but 70ft. wide at the bottom, that our ship measures 60ft. over the boxes, and that therefore I stood 30ft. from the centre, or within 10ft. of the point where the side begins to rise, the result is extremely satisfactory, for it cannot be possible that the bottom of the canal is a dead level. I feel confident, indeed, that could I have sounded in a line with the keel, I should have got a foot or two more depth on the average. On the other hand, however, there is no doubt but that, owing to our motion through the water—though it was slow when I took soundings—the line was drawn somewhat out of the perpendicular, and that, therefore, the apparent was not the real depth. The difference was not much probably; how much it is not possible to say. Still it may be assumed with confidence that the canal approximates pretty closely, thus far, at least, to its projected depth.

As regards the question of wash and its effects, the results are by no means so encouraging. Our ship drove a wave before, which ran high up; behind her the water was lowered, and here the sand and little stones and lumps of clay could be seen tumbling down the slope at a rate and in a quantity which threatened serious injury. The slopes are, beyond any question, vastly too steep. In the most favourable the banks stand, at an inclination of about 1 in 3, whereas I observed that the natural slope was about 1 in 5. It is true ours is a paddle ship, but then the run from her paddles is parallel with the banks; while screw ships, as is well known, throw their wake water to the right or left, according to the direction of the screw's revolutions. Before the canal can be considered permanent an immense amount of work must be done in flattening the slopes, either dry work or in dredging; and some kind of vegetation, if possible (the coral plant?), should be established on the banks to bind the loose material with its roots, or a breakwater of some description should be laid throughout the length of the canal. I have no doubt but that a line of floating timber booms at each side would break up the wave, and do much to save the banks. The boom might, for economy's sake, be built up of three planks arranged in a triangle. It could be laid in sections, secured to each other and the shore by chains. Such an expedient would be costly, no doubt, but less costly than the tremendous amount of excavation, or dredging, which will otherwise be indispensable.

And now as regards the last question—the availability of the canal for long ships. On this head I regret to say I can form only an unfavourable opinion. M. de Lesseps has succeeded in making the canal. So far it is a constructive success; but will it be a success in working? The fact that no fewer than six ships ran aground in a few hours is a bad omen. Now, it will be asked, how is it that ships drawing only 17ft. of water ran ashore in a canal 24ft. deep? The reply is very simple. If the ships could be kept in the centre of the canal there would be no grounding; but they cannot. At a moderate speed, say four miles an hour, it is absolutely impossible for the best steersman to keep the ship from falling off or yawing a little. Besides, the sides of a large steamer—to say nothing of her rigging—tower up above the banks for greater part of the way, so that they can be seen miles off. With no very strong wind blowing across the canal it will be practically impossible to keep a ship from obeying its influence. She will have lee-way, and this lee-way will set her to one side or the other, in accordance with the direction of the wind. If the helm is used to counteract the influence of the wind the ship will advance, not with her keel parallel with, but diagonal to the canal. If the ship be short this will not much matter, but if she be long her bow will, under such conditions, be in dangerous proximity to the shallow water on one side, and her stern on the other. The slower the speed the greater will be her angle with the line of the canal; and it appears that slow speed must be the rule, for at a velocity of four miles an hour the wash is small as compared with that at greater speeds. I see no remedy for this evil but in the use of guy lines from the bank, which is out of the question, or the employment of a small tug, drawing a very few, three or four feet, of water, to accompany each ship and keep her stern up to the wind. Tug and rudder together would keep the ship in the line of the canal. Without the aid of tugs I feel convinced that a moderate wind would render the canal impassable by such as the P. and O. boats.

The mail leaves so soon that I must bring this communication to a close. After I have reached Suez, and have examined the remainder of the canal, I shall probably be able to add something to my criticism, especially as to the best means in my opinion for improving the canal and rendering it what it ought to be. As I conclude this letter I am looking upon the waters of Lake Timseh, in the midst of the land of Goshen. It presents an extraordinary sight; a few months ago it was dry, now it forms a magnificent sheet of salt water—an inland sea in little. And on its calm bosom lie over forty ships, most of them of considerable size—forty ships in the midst of the desert—"in the barren and dry land where no water" was! Verily engineers can work wonders with this little earth of ours! Already the climate of Ismailia has changed, and rain has fallen more than once.

There is to be a grand ball to-night, and the preparations for it, for the illuminations, the fireworks, the Bedouin Arabs' fight, and other entertainments, are on an extraordinary scale. Indeed, from the moment I entered Egypt till now life has been a succession of *fêtes*, the princely hospitality of the Khedive having left unsatisfied no wish which his guests could express or even form.

P.S.—As to matters personal, several of the profession are here; among them, Mr. Hawkshaw, Mr. Falshaw of Edinburgh, Mr. Benjamin Haughton, Mr. Hadden, engineer to the Syrian Government, and I was agreeably astonished just now to find Mr. D. K. Clark sitting with a look of Mahometan contentedness at the entrance of the Arab tent which has been allotted to him. The Hawk, with the cable is here, Mr. Pender and fellow directors of the telegraph company being on board. The weather is most charming.

ON THE OUTFLOW OF STEAM.

By W. J. MACQUORN RANKINE, C.E., L.L.D., F.R.S.

(Continued from page 352).

The equations 4 and 5 were originally demonstrated with a view to their employment in calculating the work of steam in steam engines. Zeuner was the first (so far as I know) to apply them to the question of the outflow of steam, which he did in a paper entitled "Ueber den Ausfluss von Daempfen und hocherhitzten Fluessigkeiten aus Gefaessmuendungen," published in the "Civilingenieur" for 1864, vol. x. part 2. The following are examples of results calculated by him. The mass-velocities of outflow are given in kilogrammes per second per square metre of effective area of outlet; and I have added the corresponding values in pounds per second per square inch of effective area. The external pressure in each case is that of the atmosphere.

Internal absolute pressure. Atmospheres.	Velocity. Metres per second.	Mass-velocity. Kilogs. per square metre per second.	Mass-velocity. Pounds per square inch per second.
1	0	0	0
2	481·72	304·83	0·434
3	606·62	393·15	0·559
4	681·56	449·28	0·639
5	734·42	490·53	0·698
6	775·00	523·22	0·744
7	807·85	550·12	0·783
8	835·00	573·25	0·815
9	858·41	593·89	0·845
10	878·92	611·16	0·869
11	896·87	627·18	0·892
12	913·05	641·73	0·911

Within the limits of pressure that are usual in practice, the density of originally dry saturated steam when expanding in a non-conducting cylinder varies nearly as the ninth power of the tenth root of the absolute pressure, and therefore the following approximate formulæ may be used instead of equations 4 and 5:—

$$U = 10\, p_1\, v_1 \left\{ 1 - \left(\frac{p_2}{p_1}\right)^{\frac{1}{10}} \right\} \quad . \quad . \quad . \quad (6)$$

$$s_2 = s^1 \left(\frac{p_1}{p_2}\right)^{\frac{9}{10}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

9. *Outflow of Superheated Water.*—The following expressions for work done in driving a piston in a non-conducting cylinder by an unit of weight of water admitted into the cylinder while wholly in the liquid state, and for the volume to which that water ultimately expands by partial evaporation, were investigated independently by Clausius and myself, and first published in the two papers already referred to.

$$U' = J \left\{ t_1 - t_2 \left(1 + \text{hyp. log.} \frac{t_1}{t_2}\right) \right\} [+ l\,(p_1 - p_2)]. \quad (8)$$

$$s'_2 = \frac{d\,t_2}{dp_2} \left(J \text{ hyp. log.} \frac{t_1}{t_2} + \frac{H_1}{t_1} \right) [+ l] \quad . \quad . \quad (9)$$

in which l denotes the volume of unity of weight of liquid water, and the other symbols have the meanings already explained in article 8.

In my own application of these formulæ the terms enclosed in square brackets [ ], which depend on the volume l of the water when in the liquid state, are neglected, as being practically inappreciable. In Zeuner's calculations those terms are taken into account for the sake of greater precision. In fact, the terms in square brackets ought to be inserted in the equations 4 and 5, in order to give absolute precision.

The formulæ 8 and 9 (subject to the preceding explanations) were applied to the outflow of superheated water from a boiler by myself in the "Philosophical Magazine" for December, 1863, and by Zeuner in the paper already referred to, published in the "Civilingenieur" for 1864. The results of the calculations of both authors give for the mass-velocity of superheated water escaping into the atmosphere from a boiler in which the internal absolute pressure ranges from two to twelve atmospheres, values differing little from 1120 kilogrammes per second per square metre of effective area, or very nearly 1·6 lb. per second per square inch of effective area.

10. *Outflow of Mixed Water and Steam.*—Clausius was the first to combine the expressions 4 and 5 with the expressions 8 and 9, so as to obtain the values of the work done in a non-conducting cylinder, and of the final volume assumed, by a mixture of steam and liquid water in given proportions. In each unit of weight of the mixture let f be the fraction that is in the liquid state, and $1 - f$ the fraction that is in the vaporous state at the beginning of the expansion. Calculate U and s_2 as for steam, by equations 4 and 5, and U′ and s'_2 as for superheated water, by equations 8 and 9; then the mass-velocity is

$$m = \frac{\sqrt{2g} \,.\, \sqrt{\{(1-f)\,U + f\,U'\}}}{(1-f)s_2 + f s'_2} \quad . \quad . \quad (10)$$

11. *Outflow of Saturated Steam kept dry.*—If we suppose the steam to escape through a conducting nozzle, from which it receives just heat enough to prevent any liquefaction, the value to be taken for U is that of the work done by an unit of weight of dry saturated steam in a jacketed cylinder. The only original investigation of the exact value of that quantity of work with which I am acquainted is that contained in a paper of mine which was received by the Royal Society in December, 1858, and printed in the "Philosophical Transactions" for 1859, page 177. The formula is as follows:—

$$U = a \text{ hyp. log.} \frac{t_1}{t_2} - b\,(t_1 - t_2) \quad . \quad . \quad (11)$$

in which t_1 and t_2 are, as before, the absolute temperatures corresponding to the inside and outside pressure respectively; and a and b are the coefficients already given in the formula for the latent heat of steam; viz., a = 1109550ft. = 338191 metres; b = 540ft. per degree of Fah., or 297 metres per Centigrade degree.

The value of s_2 is simply the volume of unity of weight of dry saturated steam at the pressure p_2, that is to say

$$s_2 = \frac{d\,t_2}{dp_2}\left(\frac{a}{t_2} - b\right) \quad . \quad . \quad . \quad . \quad (12)$$

Tables and diagrams have been published, from which the values of U and of s_2 can easily be found.

In the paper just cited it was shown that within the limits of pressure which are usual in practice, the density of dry saturated steam varies nearly as the sixteenth power of the seventeenth root of the absolute pressure; hence the following approximate formulæ may be used:—

$$U = 17\, p_1\, v_1 \left\{ 1 - \left(\frac{p_2}{p_1}\right)^{\frac{1}{17}} \right\} \quad . \quad . \quad . \quad (13)$$

$$s_2 = s_1 \left(\frac{p_1}{p_2}\right)^{\frac{16}{17}} \quad . \quad . \quad . \quad . \quad . \quad (14)$$

The calculations already published in THE ENGINEER by Mr. Thomas Baldwin are examples of the results of these approximate formulæ.

12. *Mr. R. D. Napier's first Formula* gives results whose differences from those of Zeuner's calculations are immaterial in practice so long as the internal absolute pressure does not exceed twice the external absolute pressure. It has been shown by Weisbach (Civilingenieur, 1856) that a formula resembling that of Mr. Napier, though not quite identical with it, gives a value of the velocity of outflow of air about 2½ per cent. greater than that given by the exact thermodynamic formula when the external pressure is twice the external pressure. It is obvious that the simplicity of Mr. Napier's formula is a great advantage in calculations for practical purposes.

13. *Effective Area of Outlet.*—When the external pressure does not exceed about twice the internal pressure, it appears, from the experiments of Weisbach on air, and of Mr. R. D. Napier on steam, that the effective area of outlet is sensibly that of the contracted vein or throat; that is, for a tapering conoidal nozzle, an area very little less than that of the narrow end of the nozzle, and for a short cylindrical tube from ·9 to ·8 of the transverse area of the tube, according as the entrance to it is rounded or not at the inner end.

Zeuner, near the end of the paper already referred to, considers it probable that the effective area of the jet is in general *greater* than the actual transverse area of its throat or narrowest part, in a proportion depending partly on the form of the outlet and partly on the pressure. He makes no attempt to determine from theoretical principles what laws that proportion may follow, and states that those laws are to be ascertained by experiment only.

The experiments of Mr. R. D. Napier are to be considered as forming an important step towards the determination of those laws. The following table shows some examples of the calculation of the ratio of the effective area of the jet to that of its throat, or *coefficient of extension*, as it may be called, based on a comparison of the results of Mr. Napier's *second* formula (regarded as representing his experiments empirically) and those of Zeuner's calculations already referred to.

External pressure, 1 atmosphere.
Internal pressure, atmospheres,
2 3 4.
Mass-velocity in kilos. per square metre per second (Zeuner)
304 393 449.
Discharge in kilogrammes per second per square metre of throat of jet (Napier).
316 478 632.
Coefficient of extension,
1·04 1·22 1·41

Experiments on the outflow of steam should be made with nozzles of the form of the contracted vein, opening at once into large receivers, or into the atmosphere; for thus are obtained values of the coefficient of extension when freed from the effects of special forms of outlet. That the effects of such forms may be very great will at once appear when it is considered that in an outlet having a conoidal converging part at the inner end, a narrow throat, and a gradually diverging trumpet-shaped part at the outer end, the effective area (subject to certain limitations which it is unnecessary here to state in detail) is well known to be situated, not at the narrow throat, but at or near the wide mouth. This, in fact, is one of the essential principles of the action of jet pumps, injectors, and ejectors. Even when the widening towards the mouth takes place abruptly, as when a narrow cylindrical tube is followed by a wide one, the effective area is not that of the narrow tube, but is intermediate between the area of the narrow tube and that of the wide tube. Such appears to have been the construction of the apparatus employed by Mr. Napier in an experiment described in his letter which appeared in THE ENGINEER of the 1st of October, 1869. The mass-velocity, calculated theoretically from the pressures, is about 22 lb. per minute per square inch of effective area: the discharge per minute was 13 lb.; therefore the effective area was about 0·6 of a square inch. The transverse area of the narrow pipe was 0·246 of a square inch; that of the wider pipe, between 0·785 and 1·23 square inch. Hence it appears that the effective area of the jet was intermediate between those of the throat and of the mouth of the outlet tube.

14. *Maximum Mass-Velocity.* — Mr. Napier's second formula may be regarded as approximating to the results of the supposition, that when the outside pressure falls below that which corresponds to the maximum mass-velocity, the coefficient of extension adjusts itself in such a way that the pressure corresponding to the maximum mass-velocity is still maintained at the throat of the jet; a supposition not improbable in itself, and confirmed, at all events approximately, by Mr. Napier's experiments so far as they have gone.

In order to determine the consequences to which this theory leads when applied to the more exact formulæ for the work done by steam in expanding, it is to be observed that if the absolute pressure varies nearly in proportion to that power of the density whose index is n, the greatest mass-velocity is attained when the pressure at the throat, or narrowest part of the outlet, bears the ratio to the internal pressure which is expressed by the following fraction:

$$\left(\frac{n+1}{2}\right)^{\frac{-n}{n-1}}$$

The following are examples of the value of that fraction:

$n = 1$	$\frac{1}{16}$	$1\frac{1}{9}$	1·3	1·408
$\left(\frac{n+1}{2}\right)^{\frac{-n}{n-1}} = \frac{2}{3}$	0·5968	0·5823	0·5457	0·5269