# A Graphical Method for Sewage Pumping Problems—III.

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In the last article (Part II) we saw that the most economical arrangement for the conditions then set forth was given by two pumps running at 576 r.p.m. and discharging into a 14-in. rising main. We will now assume that the size of the rising main is definitely fixed at 14 in. and that it is desirable, if possible, to utilise this main for other stations along the route. The particular conditions to be met are as follows:—

At 4,540 ft. from the first station (hereafter called No. 1), a combined sewer crosses the route of the rising main. This sewer serves an area which is fully developed. The gauged maximum D.W.F. is 21,000 gal. per hr. and the average, 10,000 gal. per hr. It is anticipated that this flow will not increase. The top-sewage-level in the receiving-well is fixed at 12.00 and low-sewage-level may be anything down to 2.00 above the standard datum. This station will be called No. 2.

At 5,700 ft. from No. 1, the rising main crosses a bridge, the only means of access to the point of discharge. At this point it is possible to include the sewage from another sewer, 2,700 ft. distant. This sewer serves an extensive area which is developing rapidly. It is assumed that the flow from this area will increase at double the rate of growth of the whole city, or 34 per cent per decade, so that, the following minimum pumpages will have to be provided for:—

| | | |
|---|---|---|
| At present | 12,000 | gal. per hr. |
| 10 years ahead | 16,000 | „ „ |
| 20 „ „ | 22,000 | „ „ |
| 30 „ „ | 29,000 | „ „ |
| 40 „ „ | 39,000 | „ „ |

At the station to serve this sewer, T.S.L. is fixed at 12.00 and L.S.L. at 2.00 ft. above the standard datum. This station will be called No. 3.

A further problem presents itself here, "Is it desirable to lay such a main from this station as will provide for the next 40 years and install only such pumps as will meet immediate demands, adding additional units later, or will it be better to lay a rising main sufficient for the next 20 years, equipped with full capacity pumps, and duplicate this arrangement at later date?"

Considering the general problem of utilising the rising-main from No. 1 station for both Nos. 2 and 3, we have to provide for conditions of minimum discharge as well as for conditions of maximum discharge—a point that was overlooked on one occasion to the writer's knowledge, and by a presumably reputable firm of pump makers. The conditions of maximum discharge for all stations will be those which exist when all stations are operating at minimum lift, i.e., all receiving wells full. This can easily occur in times of storm. The conditions of minimum discharge for any station will occur when that station is operating alone at maximum lift, i.e., its receiving well empty. Let it be noted here, that the term "conditions of maximum discharge" and vice versa refer to rising-main conditions, not to pump conditions. Owing to the impossibility of synchronising sewage flow in different sewers, any condition may arise at any station, but it will be sufficient for us to investigate extreme conditions, for if we can obtain pumps which will satisfy the extremes, they will operate successfully at intermediate values.

No. 2 Station.—This will be placed quite close to the 14-in. rising main and a length of 30 ft. of 6-in. discharge pipe will be necessary to connect to the principal rising main. The rising main from this station will thus consist of 30 ft. of 6-in. and 1,760 ft. of 14-in. pipe. It will be wise to assume a higher value of Kutter's "n" than .012 for the smaller pipe as this will probably be cast iron and will include bends and enlarger, so that, we will take .013 as the value for this. We now compute the loss of head in this compound pipe for varying discharges, thus:—

| Discharge | Loss of Head | | |
|---|---|---|---|
| | In 6 in. | In 14 in. | Total |
| Gal. per hr. | Ft. | Ft. | Ft. |
| 10,000 | 0.3 | 0.1 | 0.4 |
| 20,000 | 1.0 | 0.4 | 1.4 |
| 30,000 | 2.3 | 1.0 | 3.3 |
| 40,000 | 4.0 | 1.7 | 5.7 |

We can now find the height of the hydraulic grade at No. 2 station, thus:—

| Discharge | Height of Hydraulic Grade at No. 2 |
|---|---|
| Gal. per hr. | Ft. above datum |
| 10,000 | 9.9 |
| 20,000 | 10.9 |
| 30,000 | 12.8 |
| 40,000 | 15.2 |

This enables us to find the total lift at No. 2 for conditions of receiving well full and empty, thus:—

| Discharge | Total Lift | |
|---|---|---|
| | Well Full | Well Empty |
| Gal. per hr. | Ft. | Ft. |
| 10,000 | −2.1 | 7.9 |
| 20,000 | −1.1 | 8.9 |
| 30,000 | 0.8 | 10.8 |
| 40,000 | 3.2 | 13.2 |

These are the rising main characteristics which we plot as shown on Fig. 1. On these, we superimpose the pump characteristics and find that the

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pump whose characteristics we have adopted will discharge 40,000 gal. per hr. under 3-ft. head. This pump will operate very inefficiently under these conditions (the worst it will experience), but provided that the impeller is of the non-overloading type, no great harm will result.

Let us now consider similar conditions for station No. 3. Here we have a rising main 2,700 ft. long discharging into another, 14 in. diameter and 600 ft. long. We will assume the first portion 9 in. diameter, and compute the loss of head for varying discharges, assuming "n" at .012.

| Discharge | | Loss of Head | | |
|---|---|---|---|---|
| | | In 9 in. | In 14 in. | Total |
| Gal. per hr. | | Ft. | Ft. | Ft. |
| 10,000 | .. | 1.9 | 0.0 | 1.9 |
| 20,000 | .. | 7.7 | 0.2 | 7.9 |
| 30,000 | .. | 17.3 | 0.3 | 17.6 |
| 40,000 | .. | 30.7 | 0.6 | 31.3 |

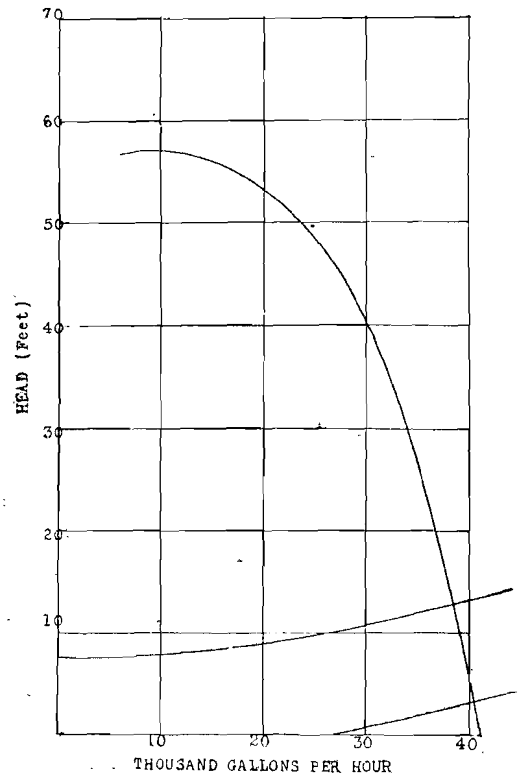


Fig. 1

We can now find the height of the hydraulic grade at No. 3.

| Discharge | | Height of Hydraulic Grade at No. 3 |
|---|---|---|
| Gal. per hr. | | Ft. above datum |
| 10,000 | .. | 11.4 |
| 20,000 | .. | 17.4 |
| 30,000 | .. | 27.1 |
| 40,000 | .. | 40.8 |

From which the total lifts for "Well Full" and "Well Empty" can be obtained:—

| Discharge | | Total Lift | |
|---|---|---|---|
| | | Well Full | Well Empty |
| Gal. per hr. | | Ft. | Ft. |
| 10,000 | .. | -0.6 | 9.4 |
| 20,000 | .. | 5.4 | 15.4 |
| 30,000 | .. | 15.1 | 25.1 |
| 40,000 | .. | 28.8 | 38.8 |

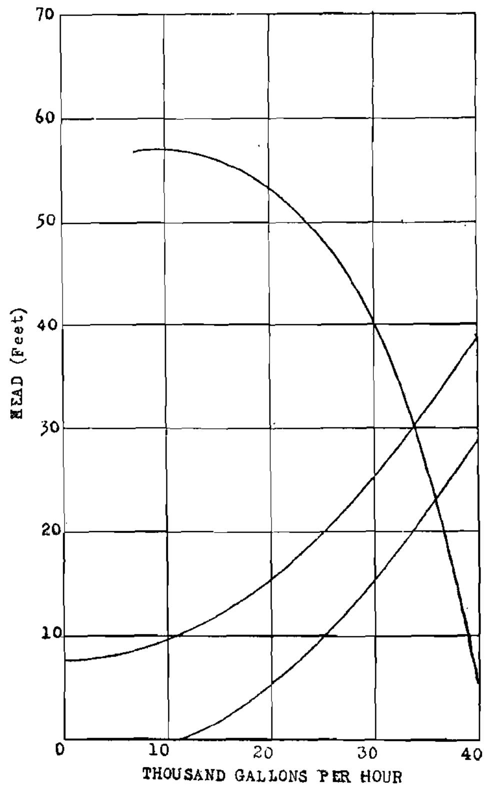


Fig. 2

Plotting these we obtain Fig. 2, and applying the pump characteristics we find that the same pump will deliver 36,000 gal. per hr. under 23-ft. head. This pump will operate fairly efficiently at this head.

What, now, are the conditions going to be when all these stations operate together? From the last article, we saw that two pumps at No. 1 station will lift 74,000 gal. per hr. under 19-ft. head. From this article, we have found the discharges from Nos. 2 and 3 when each station is operating singly. The method of approximations suggests itself. Let us see how it works out. Collecting the previous data we have:—

| | Gal. per hr. |
|---|---|
| No. 1 station .. .. .. .. .. .. .. .. | 74,000 |
| Nos. 1 and 2 .. .. .. .. .. .. .. .. | 114,000 |
| Nos. 1, 2 and 3 .. .. .. .. .. .. .. | 150,000 |

Computing the loss of head for these discharges we obtain:—

Loss of Head in 14-in. Rising Main

| | Ft. |
|---|---|
| Between junction of No. 3 and outfall .. .. | 8.2 |
| Between No. 2 and junction of No. 3 .. .. | 9.4 |
| Between No. 1 and No. 2 .. .. .. .. .. .. .. | 15.4 |

We can now determine the height of the hydraulic grade in the 14-in. rising main at the various points:—

Height of Hydraulic Grade at Stations

| | Ft. above datum |
|---|---|
| At junction of No. 3 .. .. .. .. .. .. .. | 17.7 |
| At No. 2 .. .. .. .. .. .. .. .. .. .. .. .. | 27.1 |
| At No. 1 .. .. .. .. .. .. .. .. .. .. .. .. | 42.5 |

Let us now compute the lifts at each station. No. 1 is arrived at at once, thus:—

Total Lift at Station No. 1

| | |
|---|---|
| Minimum lift .. .. .. .. | 42.5 — 12.0 = 30.5 ft. |
| Maximum lift .. .. .. .. | 42.5 — 2.0 = 40.5 ft. |

No. 2, strictly, has to consider the loss of head in the 30 ft. of 6-in. pipe, which works out at 4.0 ft. for a discharge of 40,000 gal. per hr., therefore,

Total Lift at Station No. 2

| | |
|---|---|
| Minimum lift .. .. | 27.1 + 4.0 — 12.0 = 19.1 ft. |
| Maximum lift .. .... | 27.1 + 4.0 — 2.0 = 29.1 ft. |

No. 3 station is not so simple owing to the effect of the 2,700 ft. of 9-in. rising main. As an assumption, let us consider the height of the hydraulic grade at the junction with the 14-in. rising main fixed at 17.1 ft. above datum, and proceed to correct the pump discharge by the graphical method:—

Height of Hydraulic Grade at No. 3 Station

| Discharge | Loss of Head in 9-in. | Height of Hydraulic Grade |
|---|---|---|
| Gal. per hr. | Ft. | Ft. |
| 10,000 | 1.9 | 19.6 |
| 20,000 | 7.7 | 25.4 |
| 30,000 | 17.3 | 33.0 |
| 40,000 | 30.7 | 48.4 |

We now compute the total lift at No. 3, thus:—

Total Lift at No. 3 Station

| Discharge | Total lift | |
|---|---|---|
| | Max. lift | Min. lift |
| Gal. per hr. | Ft. | Ft. |
| 10,000 | 27.6 | 17.6 |
| 20,000 | 33.4 | 23.4 |
| 30,000 | 43.0 | 33.0 |
| 40,000 | 56.4 | 46.4 |

Plotting these and applying the pump characteristics, we obtain Fig. 3, from which we obtain the discharge of No. 3 as 29,000 gal. per hr. under 42-ft. head, under the assumed conditions.

An inspection of the pump characteristic curve will give us the discharges from No. 2 as 33,000 gal. per hr. under 29-ft. head, and from No. 1 as 59,000 gal. per hr. under 40-ft. head. The corrected totals are now:—

| | Gal. per hr. |
|---|---|
| No. 1 station .. .. .. .. .. .. .. .. .. | 59,000 |
| Nos. 1 and 2 .. .. .. .. .. .. .. .. .. | 92,000 |
| Nos. 1, 2 and 3 .. .. .. .. .. .. .. .. | 121,000 |

These values are our second approximation. We proceed as before until we obtain the following:—

| | 1st | 2nd | 3rd | 4th | 5th Approximation | |
|---|---|---|---|---|---|---|
| No. 1 | 74,000 | 59,000 | 66.000 | 63,000 | 66,000 | gal. per hr. |
| No. 2 | 40,000 | 33,000 | 35,000 | 34,000 | 35,000 | „ „ |
| No. 3 | 36,000 | 28,000 | 32,000 | 32,000 | 33,000 | „ „ |

For the purposes of this article, it will be sufficient if we assume the following limiting conditions for each station:—

| | | |
|---|---|---|
| No. 1 station | 74,000 gal. per hr. under<br>66,000 | 19-ft. head<br>33 |
| No. 2 station | 40,000 gal. per hr. under<br>35,000 | 3-ft. head<br>27 |
| No. 3 station | 36,000 gal. per hr. under<br>33,000 | 22-ft. head<br>33 |

It will be obvious that No. 2 station is working under the worst conditions. If it is impossible to obtain a pump which will not operate at the low head of 3 ft. without overloading the motor, two courses seem to be indicated:—1, The provision of an ejector station in lieu of a pump; 2, the artificially raising of the hydraulic grade by providing additional frictional resistance between the pump and the 14-in. rising main. This could be done by a greater length of 6-in. rising main or the same length (30 ft.) of a smaller pipe.

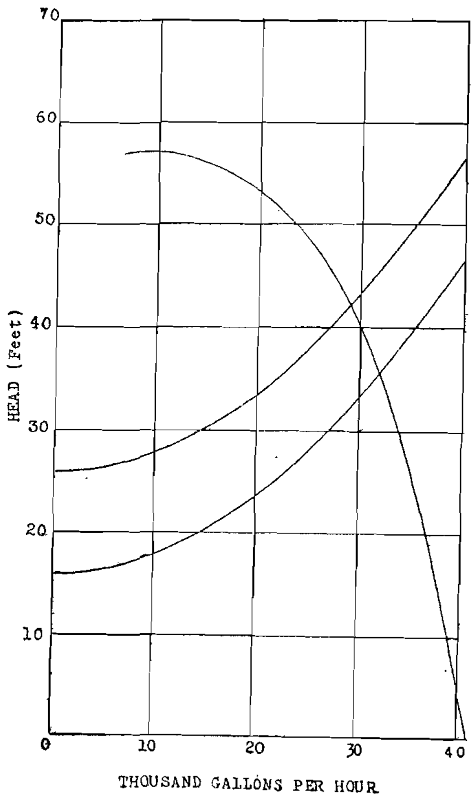


Fig. 3

If non-overloading type impellers can be obtained, the whole installation would lend itself to complete standardisation, all pumps and motors of the same size and power, running at the same speed, No. 1 station having three units (one spare) and the others two each (one spare in each).

Fig. 4 shows the graphical construction necessary to arrive at the correct solution for the size of rising main from No. 3 station. From it, we see that a 7-in. main will have an effective capacity life of over 20 years with one pump operating, but that the provision of another pump at that date will not be economical.

We see also that an 8-in. main will have a capacity life of over 30 years, but that the provision of an additional pump at the end of that period will not bring the capacity up to the requirements of 40 years ahead. The 9-in. main will have a capacity life of about 35 years with one pump and the provision of an additional unit will bring its capacity up to well over 40-year requirements. A knowledge of the costs of the respective items enables a correct economic solution to be obtained.

It is to be noted that in the whole of the above, and in the preceding parts, the loss of head due to acceleration of the velocity from a state of rest in the receiving wells to the final velocity in the rising mains has been neglected. This loss will be small and its effect will be to put a slightly greater lift on the pumps. In any case, in an analysis of this nature there are probable errors of greater magnitude than this item, for instance, the error from assuming a value of Kutter's "n" of .012.

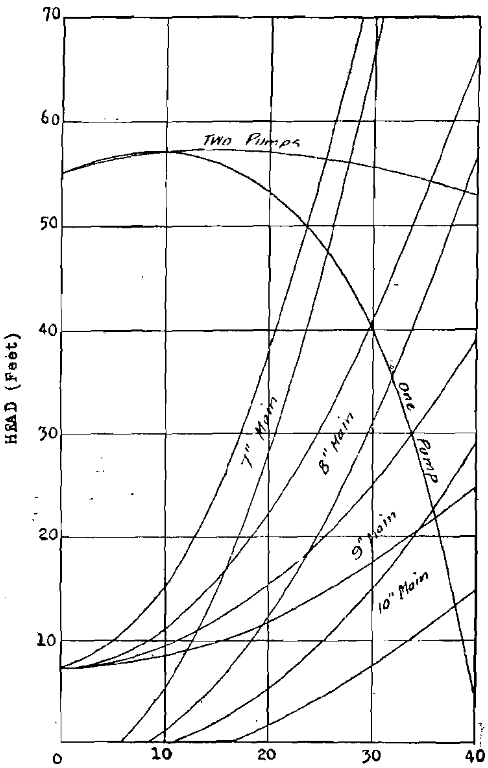

Fig. 4

(Concluded)

## WATER SUPPLY OF LAUNCESTON, TAS.

The report of the Launceston water supply department for the year ended June, 1926, contains some striking figures. It will be noted in the appended table that the per capita consumption during last summer, which was abnormally dry, rose to the high figure of 161 gal. per day, the average daily consumption for the year being 93 gal. These figures are doubtless affected by the fact that less than 25 per cent of the services are metered. During the year under review, 450 new meters were fitted, and the city engineer (Mr. G. D. Balsille) states that in the near future 50 per cent of the services will be metered.

Population supplied, approx., 28,000.
Average daily consumption, 2.6 m. gal.
Maximum daily consumption, Nov. 16/25, 4.5 m. gal.
Minimum daily consumption, June 28/26, 1.9 m. gal.
Maximum demand, Nov. 16/25, 200,000 gal. per hr.
Average daily consumption per capita, 93 gal.
Maximum daily consumption per capita, 161 gal.
Maximum monthly consumption per capita, 118 gal. per day.
No. of meters at end of year, 1,535.
Total metered registration, 172,516,000 gal.

The city of Launceston is fortunate an assured supply is available without any extensive headworks. The supply is obtained from St. Patrick's river, about 15 miles distant, at an elevation of 1,150 ft. It is diverted into Distillery creek and thence into the mains. A filter plant is in use, as follows:—

Type of filter plant, rapid sand, air scour and low velocity wash.
Capacity, 3 m.g.d. nominal.
No. of units, 4.
Output for year, 955 m. gal.
Sulphate of alumina, 70 t. 2 c. 0 q. 9 lb.
Carbonate of soda used, 29 t. 14 c. 3 q. 14 lb.
Average dose of "Alum," 16.6 p.p.m.
Average dose of soda, 7.0 p.p.m.
Average color of raw water, 41 p.p.m.
Average alkalinity of raw water, 15.6 p.p.m. (methyl red).
Average color of filtered water, 3.6 p.p.m.
Average alkalinity of filtered water, 15.7 p.p.m. (methyl red).
Percentage reduction in color, 91.
No. of beds washed, 1,460.
Quantity of washwater used, 26.3 m.g.
Percentage of washwater, 2.7.