THE

PHILADELPHIA WATER SUPPLY.

REPORT

OF THE

COMMISSION OF 1878,

SHOWING THAT THE FAIRMOUNT WORKS REALIZE LESS THAN THIRTY PER CENT. OF THEIR PROPER EFFECT—AND EVEN THIS AFTER THE MACHINERY HAD BEEN PUT IN REPAIR FOR THE EXPERIMENTS OF THE COMMISSION.

[PP. 94 AND 107.]

EDITED BY JAMES HAWORTH.

PHILADELPHIA, OCTOBER, 1880

PUBLISHED BY THE AUTHOR

1880.

Sent Post-paid on receipt of
PRICE, 50 CENTS

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PHILADELPHIA:
JOHN P. MURPHY, RAILROAD AND COMMERCIAL PRINTING HOUSE,
227 SOUTH FIFTH STREET.
1880.

ERRATA.

Page	Line top	from bottom	For	Read
42	7	—	Bryn Mawr	Bryn Mawr Avenue.
49	—	6	5,000,000	10,000,000
63	18	—	formula 2.	formula 4.
65	—	10	*Du.*	*Dn.*
67	—	6	lap	flap
75	5	—	25,000,000	30,000,000

The column 1878, page 17, should be filled up with the following data:

November........	2.89	2.19	2.63
December	4.87	3.19	1.37
Total.........	43.7	34.5	37.2

A NEW PLAN

FOR THE

PHILADELPHIA WATER SUPPLY.

As the offspring of the facts brought forth by the accompanying Report, the undersigned considers the following to be the most judicious mode of supplying Philadelphia with water:

The City of Philadelphia can be furnished with 100,000,000 gallons of pure water, every day in the year, by adding to the present volume of the Schuylkill an occasional supply from a large dam which could be constructed on the Perkiomen Creek.

This supply, whenever required, could be run down its natural channel to the Flat Rock Dam, and from thence to a point nearly opposite Fairmount by a canal on the west side of the river.

The combined head at this place of the two falls (Fairmount and Flat Rock) would be 36 feet, and the pumps would have 24 feet less lift into the basins than at present from Fairmount Dam. This head would be so powerful that the little 7 feet turbine wheel, No. 1, now at Fairmount, would give a power of 1200 horse, and a daily pumpage (after deducting one-third for friction, etc.,) of 40,000,000 gallons into the city basins. The present supply of Roxborough and Germantown from the Flat Rock Steam Works, which costs the City $60.00 per million gallons, could be derived from the Wissahickon, by water power, at $2.00 per million.

The aggregate cost of coal for the steam pumpage of 1879 was $65,000, which would pay the interest on the entire plant of the plan here recommended, while, at the same time, this plan would obviate the expense of the very costly sewer from Flat Rock to tide-water, which would be indispensable under the present system.

The cost of supplying water by the above plan, would only be about 50 cents per million gallons, as the works would require but a small amount of machinery, and but few hands.

At present there is over 191,000,000 gallons basin capacity, and yet it may be said that a little more than 100,000,000 gallons is ever stored.

As will be seen, there is 90,000,000 gallons storage capacity never used, and this does not look as if the city was short of basin room.

When there is need of more storage capacity, there can be a natural basin built on George's Run that would hold from 500,000,000 to 1,000,000,000 gallons at a cost not exceeding $30.000

Being interested in the welfare of the citizens and taxpayers of Philadelphia, we believe it is our duty to hereby inform them of the deplorable corruptions that are being continually perpetrated by the Water Department.

Having kept a close eye on this department for many years, we have come to the conclusion that the Fairmount Water-Works have not been supplying more than one-sixth of the water that they could have done, any day, whether the river was high or low, for the following reasons:

1. The pumps are only pumping one-third of the water that they register on account of their bad condition.

2. The turbine wheels are only run one-half of their proper speed, the department preferring to allow the water to run to waste over the Dam instead of through the wheels.

3. The wheels are systematically run at high tide, and stopped at low tide; when at high tide they have only 108 horse-power, and at low tide 250 horse-power per each wheel.

The above shou'd be no secret, for any intelligent man can ascertain these facts, at any time, by going to the works with his eyes open.

The Department have not at present any need of more basins, as those they have do not keep more than half full, on an average, as will be seen by referring to pages Nos. 35, 36 and 37 of the accompanying pamphlet.

JAMES HAWORTH.

PREFACE.

Oppressed with age and infirmity, the undersigned (through the accompanying Report) takes final leave of a subject which has engaged his attention for many years.

The grave and long continued errors which have pervaded the administration of the Philadelphia Water Department, have made him feel it to be a duty to impart to the public the facts here set forth. Amongst the reasons which most urgently induced him to assume the great expense and trouble attending this subject, may be mentioned the following.

1st. That the true condition of the Water Works would scarcely be revealed by any Commission or investigation authorized by a political party; for the reason that the integrity of such a report would naturally be questioned.

2d. That notwithstanding the expenditure of the City upon the Commission of Engineers of 1875, that Commission failed to bring to light the errors below detailed as urged and expressed before them by the undersigned; and even reported (p. 25) that the Fairmount Works utilized sixty per cent. of their power, and ought to utilize eighty; whilst in point of fact, some of the wheels utilized but from fourteen to twenty two per cent. and the others from twenty two to twenty eight per cent. only.

3d. That for years an enormous volume of water has been observed to enter the flumes to the Fairmount wheels; whilst scarcely a perceptible current was visible where their pumps discharged into the basins, a fact ignored by the Commission of 1875.

4th. That the Fairmount Water Works have pumped less water, since the introduction of the six largest pumps than before, their estimated capacity being 34,000,000 gallons, and their actual performance, less than 23,000,000 per day.

5th. That during the water famine of 1869, the water-level in the Fairmount Dam was drawn down three feet below its breast; thereby cutting off a supply of water from the pumps, and also stopping the navigation. Damages to the extent of a quarter of a million of dollars were thus entailed upon the City, together with the risk of a Chicago fire.

6th. That during this water famine, the wheels were continually run at high tide and stopped at low tide, thus enormously diminishing their power and efficiency.

7th. That the basins for long periods of time, were kept but half filled, and many citizens thus deprived of water; and as a consequence, muddy water had to be used after every storm.

8th. That neglecting to utilize the cheap water-power of the Schuylkill, expensive steam works were unnecessarily erected at Kensington, Frankford, Roxborough, &c.

9th. That for the ten years prior to 1874, the City not only received no revenue from the Water Department, but lost the sum of $400,000 over and above all its heavy appropriations during that period.

The undersigned has long been of opinion (as is hereinafter demonstrated) that the water-power of the Schuylkill River (with the aid of proper impounding dams) can for nearly a century to come, furnish the entire supply of Philadelphia, and at the same time endow its Treasury with an income of five hundred thousand dollars per annum. The pamphlet published early in this year (1878) entitled: "A discussion of the Economic Value and Engineering Mismanagement of the Fairmount Water-Works," will give his views more in detail on these points.

Under the existing system, the officials of the Water Department manifest no interest in the welfare of the City, nor does it appear in any way feasible to render their interests and those of the City identical, unless by consigning the Department to the control of a private company. Should the City thus be enabled to realize an abundant, cheap and permanent water-supply, the most cherished hopes of the undersigned in this connection, will have been accomplished.

JAMES HAWORTH.

Philadelphia, December, 1878.

REPORT TO JAMES HAWORTH, ESQ., ON THE WATER-SUPPLY OF PHILADELPHIA.

SIR:—The Commission appointed by you to investigate the Water-Supply of Philadelphia, has the honor to report that its labor is completed as far as the permission granted by the Water Committee of City Councils extended.

The interrogatories given in your letter of July 22, 1878, as well as your application to the Water Committee for permission to make experiments at Fairmount, did not include the steam water-works, which you afterwards desired to be investigated; and which, although commenced, was not completed, because the Chief Engineer of the Water Department did not consider himself authorized to allow it, as will be seen in the correspondence embodied in this Report.

This is to be regretted, because the investigation of the water-supply cannot be rendered complete without that of the steam works.

The water in the Schuylkill river has been very low during this whole summer, (1878,) which has occasioned delay in finishing the Report, as opportunity for experiment could be secured only from time to time according to the state of the river, when the works at Fairmount could be placed at the disposal of your Commission.

The General Superintendent of the works, Mr. Robert McFadden, as well as the Engineers, Messrs. Joseph Moyer and A. C. Bonsall, are entitled to the thanks of your Commission for their unvarying kindness and courtesy in giving every facility for the accomplishment of its task.

The Chief Engineer, Dr. McFadden, was requested to appoint an Assistant Engineer of the Water Department to join your Commission and witness the experiments, which was declined, and no one connected with the water-works appeared to take the slightest interest in the same. Your questions are printed in black italic, and the Commission's answers in Roman letters.

In the organization of your Commission, it was solemnly agreed, according to your request, that no policy or etiquette should impair the integrity of its Report, whatsoever interest it might affect.

In order to avoid confusion, it was further agreed, that in case of difference of opinion, each member of the Commission could append his individual ideas signed by himself. The few differences that have arisen, however, have finally been harmoniously reconciled, the result of which is, that the Commissioners have the pleasure and honor of submitting to you herewith their unanimous Report.

JOHN W. NYSTROM,
W. BARNET LE VAN, } *Commission.*
WILLIAM DENNISON,

To JAMES HAWORTH, ESQ.,

Philadelphia, Dec. 30, 1878.

INDEX.

REPORT

—ON THE—

WATER-SUPPLY OF PHILADELPHIA

RAINFALL AND QUANTITY OF WATER IN THE SCHUYLKILL BASIN.

§1 ***"What is the average, maximum and minimum daily flow of the Schuylkill River at Fairmount, in gallons, deduced from the area of its water-shed and from the annual rainfall?"***

It is difficult to give precision to this interrogatory, on account of insufficient records of rainfall in the Schuylkill basin.

The United States Signal Service has only three stations in Pennsylvania, namely, at Philadelphia, Pittsburg and Erie: neither of which is in the Schuylkill basin.

Mr. James F. Smith, Chief Engineer of the Schuylkill canal, has kindly furnished your Commission with some data of rainfall at Reading, Pa., from observations made by Dr. J. Heyl Raser, extending from July, 1869, to December, 1874; and others by Henry T. Kendall, City Engineer, from August, 1877, to the present time; which data are embodied in the table of rainfall below.

In his Report on the Schuylkill canal, to the P. & R. R. R. Co., dated December 16, 1874, page 87, Mr. Smith says: "The "area of the valley embraces about 1800 square miles, which, at "42 inches of rainfall annually, and utilization of 18 inches, which "is not excessive, will afford 75,271,680,000 cubic feet, equal "to 563,032,166,400 gallons per year, passing into tide-water at "Fairmount." This would be on an average 1,541,140,200 gallons per 24 hours, or 42.7 per cent. of the rainfall.

Mr. Henry P. M. Berkinbine, ex-chief of the Water Department, in his paper read before the Franklin Institute, February 20, 1878, says: "The drainage area of the Schuylkill above Fairmount dam is as follows:

Schuylkill	County	324	square	miles
Berks	"	841	"	"
Lebanon	"	43	"	"
Lehigh	"	73	"	"
Montgomery	"	376	"	"
Bucks	"	82	"	"
Chester	"	162	"	"
Philadelphia	"	22	"	"
Total		1943	"	"

Mr. Berkinbine assumes 50 per cent. of the rainfall to be available at Fairmount, and estimates the average flow of the Schuylkill thus,

Minimum daily average	200,000,000	gallons
Mean daily average	650,000,000	"
Maximum daily average	1,665,000,000	"

The percentage of rainfall available at Fairmount is not constant but differs with the seasons of the year. In summer, more water is absorbed by vegetation and evaporation than in winter, which causes the scarcity of water in the summer months, notwithstanding that the average rainfall is then greatest. In the Report of the Commission of Engineers of 1875, page

132, Mr. Wm. J. McAlpine estimates the percentage of rainfall available in each month of the year, as follows:

January,	90	July,	30
February,	80	August,	20
March,	70	September,	40
April,	60	October,	60
May,	50	November,	80
June,	40	December,	90

The average percentage for the year will accordingly be 59.2 per cent.

The quantity of water absorbed by vegetation and evaporation is probably nearly constant, for the respective months and seasons of the year, and is not a certain percentage of the rainfall. A very light rainfall in the summer may be all absorbed, whilst an exceedingly small portion of a heavy one would be taken up.

Your Commission is therefore inclined to believe, that it would be more correct to allow a certain number of inches of rainfall in each month of the year, for vegetation and evaporation, and the balance counted upon to be due at Fairmount. The question, then will further arise, how much is actually absorbed each month. This question cannot be satisfactorily answered, from the data in possession of your Commission; as even the records of the water in the Fairmount Dam, made by the Water Department, are very incomplete and even unreliable.

The flash-board at the Fairmount Dam is, generally, partially broken in the winter, by floating ice, &c., and no records are kept of the time or extent of this damage.

In the spring, generally in the month of May, when the water is sufficiently low for workmen to pass on the crib, the flash-board is replaced; but no account of that time appears in the W. D. Reports, and the Chief Engineer says, that no such records exist. This flash-board arrangement is but a specimen of make-shift engineering, and should be replaced by elevating the Comb of the Dam permanently to the same, or what would be better, to a greater height, and by providing a special outlet for flood-water.

The flash-board can be counted upon to be in position five months in the year, namely; in June, July, August, September, and October, for which time the daily average quantity of water passing into tide-water at Fairmount, is calculated for seven years, and is contained in the accompanying Table I, which also contains the total yearly rainfall, and the parts thereof available at Fairmount, as also the portion absorbed by vegetation and evaporation.

TABLE I.

PROPORTION OF PUMPAGE, WATERFLOW AND RAINFALL.

	Water nominally pumped per day by all the Schuylkill works Average.	Average daily flow through Schuylkill at Fairmount.	YEARLY RAINFALL. Schuylkill Watershed	Available at Fairmount	Absorbed by Vegetation, &c.	Percentage at Fairmount	Yearly mean temperature.
YEARS	GALLONS	GALLONS	INCHES	INS.	INS.	%	FAHR.
1867	29,762,798	2,411,800,000	61.19	26.0	35.2	42.6	59.60
1868	32,746,390	2,518,000,000	51.40	27.6	23.8	53.6	53.19
1869	34,013,020	1,539,800,000	48.86	16.7	32.1	34.1	52.59
1870	36,720,030	1,526,000,000	44.10	16.5	27.5	37.5	56.81
1871	36,981,916	2,151,750,000	47.32	23.6	23.7	50.0	55.14
1872	35,628,405	1,566,161,500	51.12	19.4	31.7	38.0	54.63
1873	38,967,667	1,720,885,636	58.28	18.6	39.7	32.0	51.40

This table was made up to the year 1877 inclusive, but afterwards it was considered that the data in the W. D. Report, since 1873, were so unreliable as to render it advisable to reject them from Table I.

The percentage available does not agree with the data of Mr. McAlpine, whose average, for the five months from June to October, is 34 per cent., whilst our table gives an average of 50.8 per cent. Your Commission therefore prefer to rearrange the monthly percentage of available rainfall, so as to make it conform with the calculation for Fairmount, namely as follows:

January,	90	July,	32
February,	87	August,	30
March,	79	September,	35
April,	66	October,	52
May,	52	November,	72
June,	40	December,	85

The average for the year, of these percentages of rainfall available at Fairmount, will be 60 per cent., which agrees nearly with the sum total.

It must evidently differ with the nature of the ground and temperature of the air, and can, therefore, not be constant for every water-shed. Naked Mountains and clay absorb less water than soil covered with vegetation.

The soil, vegetation and atmosphere are not the only agents of absorption, but a considerable portion of the rainfall percolates the ground, forming subterranean currents, which are found in mines and artesian wells.

The following table shows how much of the rain is realized in different localities in England.

Ashton,	40 inches,	38.4 per cent.
Belfast,	32 "	52.2 utilized.
Bolton,	50 "	61.9 "
Dublin,	45 "	50.0 "
Glasgow,	60 "	40.2 "
Greenock,	60 "	60.2 "
Huddersfields,	33 "	53.7 "
Liverpool,	55½ "	43.6 "
Macclesfield,	40 "	52.6 "
Manchester,	37 "	61.7 "
Oldham,	35 "	41.5 "
Paisley,	56½ "	54.8 "
Average,	45½ inches,	50.9 per cent.

It is, however, to be remarked, that all the water was not measured or collected, in some of these basins.

RAIN FALL.

Table II contains the rainfall as observed at the Pennsylvania Hospital, and at the U. S. Signal Service Station in Philadelphia, and also by Raser and Kendall, at Reading.

It will be observed that the Reports of the Penn. Hospital and Signal Service differ considerably, although the distance between the two rain-gauges in Philadelphia is only about 3000 feet. The greatest difference appears in 1877, when they were respectively 45.3 and 37.3, or 8 inches for the year. It will also be noticed that the rainfall in Philadelphia is not a relevant measure of that in the Schuylkill basin; which is particularly the case in the two months of July and August, this year, 1878, namely:

	Philadelphia.	*Reading.*
July, -	5.31 inches.	1.63 inches.
August, -	4.83 "	1.84 "
Total,	10.14 "	3.47 "

The rain in Philadelphia was nearly 3 times as much as in Reading, whilst the averages in 10 years is nearly the same, namely, 46.8 and 47.6 inches, vide Table II. The U. S. Signal Service give only 45.1 inches for the same time.

It may be considered doubtful if a rain-gauge is a correct measure of the average rain around any extended locality, for, as an illustration, we have often very heavy rain at Chestnut Hill, whilst not a drop falls in the centre of Philadelphia.

It can readily be observed that when a heavy shower falls between a clear sky and the observer, the rain is divided into streams or columns, the system of which passes over a narrow strip on the ground; now, if a rain-gauge should happen to be thereunder, it would indicate a very heavy rain for that locality, but, if the gauge were a few hundred feet from the rain strip, it would indicate, perhaps, no rain.

On account of local showers, it is probable that more rain falls than is generally indicated by the rain-gauge; and it will be noticed in the table that the rain was—

11.2 inches in July, 1872,
12.3 " " August, 1873,

whilst around those figures the rain is very small; whence, it may be assumed, that heavy showers happened to strike the gauge in these two cases, and thus increased the monthly average and yearly total.

Table II gives the monthly average for each gauge in 10 years; and also the monthly average of the three gauges in the same time. Their yearly average for 10 years is 46.5 inches.

The Chief Engineer of the Water Department, Dr. McFadden, from the Reports of the Penna. Hospital, assumes the average annual rain in Philadelphia to be 45 inches, and 3 per cent. more for every 100 feet elevation of the interior; that is, for an elevation of 500 feet the rainfall should be 45 (1 + 0.15) = 51.75 inches.

TABLE II.

Inches of Rainfall in Philadelphia and Reading, Pa.

Months	1869		1870		1871 Philadelphia			1872 Philadelphia			1873 Philadelphia			1874 Philadelphia		
	Philadelphia.	Reading	Philadelphia.	Reading.	Penna. Hospital.	Signal Service.	Reading.	Penna. Hospital.	Signal Service.	Reading.	Penna. Hospital.	Signal Service.	Reading.	Penna. Hospital.	Signal Service.	Reading.
January	4.28	—	4.07	3.97	3.46	2.57	2.79	1.27	0.95	1.96	6.05	5.84	4.03	4.22	5.58	3.19
February	4.76	—	2.53	5.88	3.09	3.12	5.83	1.18	1.12	1.29	5.61	4.75	5.23	2.82	2.46	4.56
March	5.30	—	4.06	4.61	5.81	5.81	6.25	3.78	3.67	2.86	2.24	2.04	2.29	1.59	2.16	4.00
April	2.12	—	5.60	6.46	1.83	1.83	1.93	2.50	2.60	3.66	4.19	3.51	5.12	7.51	9.76	4.29
May	4.23	—	6.28	3.91	3.38	3.38	4.10	2.81	2.15	2.86	4.78	5.83	5.58	2.70	2.75	4.11
June	5.59	—	2.89	5.69	3.77	3.77	6.24	4.22	4.29	3.45	0.89	0.90	0.61	2.66	3.02	4.19
July	2.88	2.20	3.95	3.74	6.81	6.81	5.13	11.2	9.20	4.43	5.55	5.00	8.32	2.76	2.25	3.96
August	1.28	1.02	5.11	5.58	5.97	5.92	5.12	8.32	7.81	6.30	12.3	11.5	7.05	6.53	5.65	5.14
September	3.25	4.83	1.71	2.38	1.77	1.77	2.34	3.82	3.66	4.00	4.04	3.58	6.65	3.99	6.01	4.04
October	6.32	9.49	3.89	3.00	4.86	4.86	1.62	5.36	5.20	3.07	5.89	5.20	7.00	1.65	2.81	4.84
November	3.72	1.82	2.10	2.90	4.29	4.09	3.94	3.38	3.40	4.05	5.00	5.10	5.09	2.23	2.32	3.56
December	5.12	5.44	1.89	2.39	2.26	1.57	9.08	3.66	2.74	3.31	1.76	1.38	1.52	2.25	2.18	2.73
Total	48.8	24.8	44.1	50.5	47.3	44.3	46.3	51.1	47.8	41.2	58.3	54.6	58.5	40.9	46.3	48.6

TABLE II.

Inches of Rainfall in Philadelphia and Reading, Pa.

Months.	1875 Philadelphia Penna. Hospital	1875 Philadelphia Signal Service.	1875 Reading.	1876 Philadelphia Penna. Hospital.	1876 Philadelphia Signal Service.	1876 Reading.	1877 Philadelphia Penna. Hospital	1877 Philadelphia Signal Service.	1877 Reading.	1878 Philadelphia Penna. Hospital.	1878 Philadelphia Signal Service.	1878 Reading	AVERAGE. Philadelphia Penna. Hospital.	AVERAGE. Philadelphia Signal Service.	AVERAGE. Reading.	Total Average.
January	2.36	2.83	—	2.02	1.52	—	2.89	2.62	—	4.67	3.94	5.01	3.53	3.17	3.49	3.39
February	3.28	3.20	—	3.68	5.03	—	1.55	0.84	—	2.17	1.64	2.43	3.07	2.77	4.20	3.35
March	3.93	3.03	—	5.60	6.71	—	5.10	3.40	—	3.64	2.89	3.44	4.11	3.71	3.91	3.91
April	1.36	2.80	—	2.00	2.16	—	2.96	2.66	—	2.54	2.55	2.75	3.26	3.48	4.03	3.59
May	1.57	1.36	—	5.19	4.45	—	1.22	1.10	—	4.33	3.29	3.48	3.65	3.04	4.01	3.57
June	2.26	4.13	—	2.21	2.29	—	5.56	5.22	—	4.75	3.66	2.73	3.48	3.41	3.78	3.56
July	4.17	3.63	—	6.22	6.71	—	6.20	5.53	—	5.31	4.35	1.63	5.50	5.31	4.20	5.00
August	6.58	6.42	—	1.21	0.98	—	1.03	0.66	2.15	4.83	3.83	1.84	5.32	5.55	4.28	5.05
September	3.03	2.53	—	7.78	8.77	—	3.88	2.74	4.34	1.12	0.96	3.18	3.70	4.15	4.08	3.97
October	1.83	1.42	—	1.21	1.06	—	6.96	6.52	7.16	2.30	2.04	3.74	3.88	3.87	5.17	4.31
November	5.54	5.40	—	9.03	7.31	—	6.51	5.14	5.77	—	—	—	4.64	4.68	3.88	4.40
December	2.92	3.37	—	3.17	1.40	—	1.36	0.83	1.46	—	—	—	2.71	1.93	2.55	2.39
Total	41.8	40.2		49.3	47.4		45.3	37.3	20.9				46.8	45.1	47.6	46.5

Professor Selden J. Coffin has observed the rainfall for five years, 1856 to 61, at Easton, Pa., which gave an average of 45.56 inches. At Nazareth, 7 miles N. W. of Easton, twenty-eight months' observation, gave 45.32 inches, annual average. At Gettysburg, Pa., 17 years' observations, 1839 to 55, gave an average of 38.78 inches.

The greatest monthly rainfalls known in the United States, are as follows:

Location.	*Year.*	*Month.*	*Inches.*
Charleston, S. C.	1841	August	16.9
Port Columbus, N. Y.	1843	August	15.26
Key West, Florida,	1853	June	18.53
Philadelphia, Pa.	1867	August	15.82

The average annual rainfall in Philadelphia has been gradually increasing from its minimum in 1819 of 23 inches, to its maximum 61.19 inches in 1867, and is now decreasing again.

RAINFALL PER SQUARE MILE.

One mile = 5280 feet, and one square mile = 5280^2 = 27,878,400 square feet × 144 = 4,014,489,600 square inches, which divided by 231 cubic inches, the contents of a gallon, gives 17,378,742.85 gallons per square mile, per inch of rainfall.

Mr. Henry P. M. Berkinbine, reports the Schuylkill water-shed, by actual measurement, to be 1942 square miles, which multiplied by 17,378,742.85, gives 33,749,518,628 gallons per inch of rainfall in the Schuylkill basin.

Assuming the average annual rainfall to be 46.5 inches, the total yearly quantity will be

33,749,518,628 × 46.5 = 1,569,352,616,224 gallons,

which divided by 365.25 days gives an average of 4,296,653,296 gallons per 24 hours.

WATER AVAILABLE AT FAIRMOUNT FROM THE RAIN IN THE SCHUYLKILL BASIN.

The average available percentage of the total rainfall in the Schuylkill basin may be assumed to be, at Fairmount, 60 per cent. in years of uniform weather, unmarked by floods or droughts; 60 per cent. of 46.5 gives 27.9, say 28, inches available at Fairmount.

The total quantity of water due at Fairmount will then be 33,749,518,628 × 28 = 944,986,521,584 gallons per year, or an average of 2,600,000,000 gallons per 24 hours. With the aid of impounding dams and adequate machinery at Fairmount and Flat Rock, for utilizing the power of all this water, it would pump 173,000,000 + 300,000,000 = 473,000,000 gallons, 100 feet high, per 24 hours.

The minimum daily flow in a dry season, like that in the year 1869, may be reduced to only 15 per cent. of the average or to 390,000,000 gallons.

To find the percentage of the rainfall in the Schuylkill Basin available at Fairmount.

G = monthly average gallons of water passing through at Fairmount per 24 hours.

r = inches of rain in the same month G is estimated.

% = percentage of rainfall available at Fairmount.

$$\text{Percentage, } \% = \frac{G}{11{,}088{,}110\ r}, \qquad 1$$

$$\text{Gallons, } G = \% \times 11{,}088{,}110\ r, \qquad 2$$

$$\text{Monthly rain, } r = \frac{G}{\% \times 11{,}088{,}110}, \qquad 3$$

Q = total number of gallons passed through at Fairmount in 1 year.

R = total inches of rainfall in the same year.

$$\text{Percentage, } \% = \frac{G}{337{,}495{,}186\ R}, \qquad 4$$

$$\text{Gallons, } G = \% \times 337{,}495{,}186\ R, \qquad 5$$

$$\text{Yearly rainfall, } R = \frac{G}{337{,}495{,}186 \times \%}, \qquad 6$$

The following Table III, shows the average hydrography of the Schuylkill water-shed, supposing that the monthly rainfall is as in the table, and no flood or drought interferes. It is not to be expected that such strict uniformity of weather will often occur, but the Table gives the maximum capability of the river at Fairmount, with the average flow of water. The percentages of available and absorbed water will not hold good when the monthly rainfall is irregular, as will be seen in Table II, is often the case, because the absorption takes out its share first, and whatever is left, if any, works its way to the river by gravitation. No allowance has been made for the time occupied by the rain-water from its fall to the time it reaches Fairmount; your Commission has no reliable data for that allowance.

TABLE III.

Average Hydrography of the Schuylkill Basin.

Months	Mean Temperature.	Yearly Rainfall.	Available. Percentage.	Available. Fairmount.	Absorbed. Percentage.	Absorbed. Vegetation, &c.	Average per 24 hours. Total in the Schuylkill Basin.	Average per 24 hours. Due at Fairmount.
	Fahr	Inch	%	Inch	–	Inch	Gallons.	Gallons.
January	30	3.	90	2.7	10	0.3	3,270,000,000	2,943,000,000
February	32	3.5	87	3.04	13	0.5	4,185,000,000	3,640,950,000
March	36	4.	79	3.16	21	0.84	4,350,000,000	3,436,500,000
April	50	4.3	66	2.84	34	1.46	4,840,000,000	3,194,400,000
May	63	4.5	52	2.34	48	2.16	4,900,000,000	2,548,000,000
June	73	4.6	40	1.84	60	2.76	5,180,000,000	2,072,000,000
July	76	4.7	32	1.50	68	3.2	5,120,000,000	1,638,400,000
August	71	4.8	30	1.44	70	3.36	5,230,000,000	1,569,000,000
Septemb'r	63	4.2	35	1.47	65	2.73	4,720,000,000	1,652,000,000
October	52	3.4	52	1.77	48	1.63	3,700,000,000	1,924,000,000
Novemb'r	39	3.	72	2.16	28	0.84	3,375,000,000	2,429,000,000
December	38	2.5	85	2.12	15	0.38	2,720,000,000	2,312,000,000
Average	54	3.87	60	2.32	40	1.55	4,285,000,000	2,571,000,000
Total,	—	46.5	—	27.9	18.6	—	————	————

MINIMUM FLOW OF THE SCHUYLKILL AT FAIRMOUNT.

The minimum flow at the Fairmount Dam, may be taken to be that in the months of August and September, 1869, when the dam was drawn down 3 feet below the comb, by which navigation on the Canal was stopped.

The height to which the water is pumped, into the Corinthian Reservoir, is 115 feet; and 90 feet into that of the Fairmount; the average of which is about 100 feet when the water is low in the basins.

The average height of fall when the dam was drawn down as above stated, was say 7 feet, and at the same time the wheels run at high tide, and stopped at low tide. The number of gallons required for pumping one into the reservoirs, must then have been 100 : 7 = 14 gallons theoretically and at least 80 per cent. more, say 25 gallons.

The minimum quantity of water pumped in August and September, 1869, was, according to W. D. Report, 16,447,000 gallons; average per 24 hours, say 16,000,000. From these data we have the minimum flow of the Schuylkill to be 400,000,000 per 24 hours.

Mr. Birkinbine has estimated the minimum flow of the Schuylkill to be 200,000,000 gallons per day.

Mr. James F. Smith, Chief Engineer of the Schuylkill Canal, in his report to President Gowen of the P. & R. R. R. Co., says 245,000,000 gallons is the minimum flow.

The Schuylkill Canal Company has several times measured the minimum flow at the lowest state of the river, namely :

In August 1816,	500,000,000.
1825,	440,000,000.
Later,	400,000,000.

The annual rainfall was gradually increasing during those years.

These minimum flows were measured by the cross-section and velocity of the water, in a regular portion of the Canal above Manayunk, when the river was lowest, and are probably the most correct measurements on record.

The minimum flow given by Mr. James F. Smith, was obtained by weir measurement at the different mills at Manayunk, and calculated by the Francis formula.

The Francis formula is, no doubt, very correct for a constant head over the weir, but when the head fluctuates, it will not be correct to take the mean head h, but the mean of $h\sqrt{h}$. The average of $h\sqrt{h}$ can be obtained only by an indicator diagram of h, or its equivalent, which Mr. Smith and the Commission of Engineers, 1875, did not use.

Your Commission inclines to believe, that the minimum flow of the Schuylkill at Fairmount, within the last 62 years, has not been much less than 400,000,000 gallons per 24 hours. There would be no difficulty in determining correctly the minimum flow of the Schuylkill, if proper and reliable records were kept by the Water Department.

FLOW OF THE RIVER SCHUYLKILL, BY THE CHIEF ENGINEER OF THE WATER DEPARTMENT.

§ 2. ***" In his Report for 1876, the Chief Engineer says on page 8, that he has given a table of the daily flow of the River Schuylkill and its volume. On what page is this table?"***

Your Commission finds the statement referred to on page 8, but cannot find the mentioned table in the Report, and we are convinced that the Chief Engineer cannot give such a table, for the reason that the records kept for that purpose in the Water Department, are inadequate. A table is given on page 122, giving the height of water over the comb, and also that over and under the flash-board, but there is nothing said about the time and extent of breaking down of the flash-board; other data bearing upon the same subject are also wanting.

In the Water Department Report for 1874, a table is given of the height of water over the weir at Fairmount, for the years 1867 to 1874, which is called *Average Monthly overflow at Fairmount Dam.* This table gives the average overflow for the months of August and September, 1869, at 3.11 and 5.93 inches whilst the fact is that not a drop of water flowed over the dam in those two months, but the average height of water was 3.11 and 5.93 inches *below* the comb.

INFLUENCE OF TIDE ON THE WATER-POWER AT FAIRMOUNT.

§ 3. ***"What is the relative effect of the Tides, Ebb and Flood, on the Water-Power at Fairmount?"***

The ebb and flood of tide-water is caused by the difference of attractions on opposite sides of the earth's surface of the sun and moon, the philosophy of which is not necessary to enter into here, except as far as regards its effect upon the water-power at Fairmount, where the average difference of tide is 6 feet, maximum, 8, and minimum, 5 feet. The variation of difference of tide is caused by the relative positions of the sun and moon in reference to the earth. This variation is also affected by the direction of winds, which may increase or diminish the maximum and minimum.

Although the sun's attraction on the earth is 195 times greater than that of the moon, but his difference of attraction, on opposite sides of the earth, is only one-half of that of the moon, and as it is these differences which cause the tide, we must calculate its effect by the motion of the moon only.

The moon passes the meridian at intervals of 24 hours, 48 minutes and 50 seconds, in which time there are two ebbs and two floods, of 12 h. 24 m. and 25 s. each; that is, 6 h. 12 m. and 12.5 s. of ebb or flood between the times of each mean-tide. The above are the average times; the actual times are rendered variable by the eccentricity of the moon's orbit.

The question before us bears directly upon the economy of running the wheels at Fairmount at high and low tides, in answer to which it is necessary to determine the average height of tide above and below the mean-tide.

v = double the difference of angle generated by the rotation of the earth and moon, around the earth's centre, omitting the earth's rotation around the sun.

t = time from that of mean-tide to the moment when the height or depth of water-surface, above or below mean-tide, is required.

T = time between mean-tide and high or low water. T and t, can be expressed by any unit of time, as hours, minutes, or seconds.

k = height or depth in feet of the water-surface, above or below mean-tide, at the time t.

h = height or depth in feet of water-surface, above or below mean-tide, at high or low water.

H = mean height of dam over mean-tide.

H' = actual head of fall at the time t.

Reference being had to the accompanying illustration, in which the letters correspond to these notations.

$$\text{Moon's angle, } v = \frac{90\,t}{T}, \qquad 1$$

$$\text{High,} \qquad k = h \sin.v, \qquad 2$$

$$\text{Height,} \qquad H' = H + h \sin.v, \qquad 3$$

The average head of fall between mean-tides, at low water, will be

$$\text{Head, } H' = H + \tfrac{2}{3}\,h, \qquad 4$$

The average head of fall between mean-tides, at high water, will be

$$\text{Head, } H' = H - \tfrac{2}{3}\,h, \qquad 5$$

In the application of these formulas to the operation at Fairmount, we have given the height of the flash-board 12.4 feet above mean-tide, and suppose the water in the dam to be kept, on an average, 4.8 inches below the plank, as has been done this summer, 1878, we have H = 12 feet, the height of fall above mean-tide.

Assuming the difference of tide at Fairmount to be 6 feet, we have $h = 3$ feet above and below mean-tide.

The average head of fall between mean-tides at low water will then be formula 4.

$$\text{Head, } H' = 12 + \tfrac{2}{3} \times 3 = 14 \text{ feet.}$$

The average head of fall between mean-tides at high water will be formula 5.

$$\text{Head, } H' = 12 - \tfrac{2}{3} \times 3 = 10 \text{ feet.}$$

Now, we have the proportion of economy in running the wheels at high and low tides to be as 14 : 10, which is 40 per cent. in favor of running the wheels at low tide. It is therefore evident that all the wheels should be running at low tide, and stopped at high tide, when it is necessary to economize the water-power; that is, when the supply of water is scarce.

The head of fall at low tide is 15 feet, and at high tide 9 feet, 15 : 9 = 1.66. The power for pumping at high tide is to that at low tide as 1 : 1.66, or 66 per cent. in favor of low tide; but this percentage is only momentary, and cannot be counted upon as an average.

The Commission of Engineers, 1875, says (page 20 in their report): "The depth of 16 inches over the area of the Fairmount dam, (480 acres,) becomes a storage reservoir, in which the water is retained, and permits the wheels to be stopped at and near high tide, when the power is least, and started at and near low tide, when the power is greatest. This is the proper manner of running the wheels at low stages of the water; by pursuing it, more water is pumped, than if the wheels are run constantly."

That Commission thus gives its opinion, that it is best to run the wheels at low tide and stop them at high tide, but gives no data or facts as to what is the value of the difference.

This is the doctrine you, (Mr. James Haworth,) have been advocating for the last nine years—the fruit of which begins to ripen at Fairmount.

The accompanying illustration represents the head of fall at Fairmount, at any time between mean-tides, during two convolutions of high and low tides, which occur in average periods of 12 hours 24 minutes and 25 seconds each.

This time, as represented by the illustration, is divided by ordinates into 4 equal parts, between mean-tide and high or low water, making 16 divisions for each convolution.

The time T, from mean-tide to high or low water, is at Fairmount, on an average, as follows:

From low tide to mean-tide,	$T = 2$ h. 36 m.
From mean-tide to high tide,	$T = 2$ h. 36 m.
From high to mean-tide,	$T = 3$ h. 36 m.
From mean-tide to low tide,	$T = 3$ h. 36 m.
When the tide is rising,	$T = 156$ m.
When the tide is setting,	$T = 216$ m.

The following illustration is constructed with ordinates, at intervals of 39 minutes, when the tide is rising, and 54 minutes when setting:

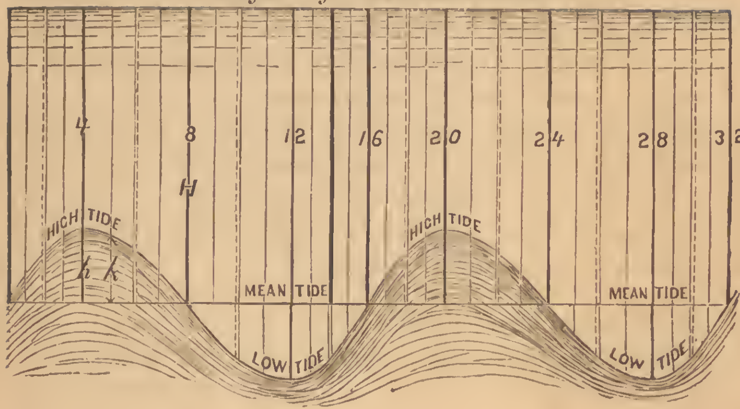
Example. Required, the height of water above mean-tide at 39 minutes after the time of mean-tide.

$$\text{Formula 2.} \quad v = \frac{90 \times 39}{156} = 22° \; 30'$$

Formula 2. $k = 3 \times \sin.22° \, 30' = 1.148$ feet, the height required.

At 39 minutes	after mean-tide,			$k = 1.148$ feet.
At 1 hour 18 minutes	"	"		$k = 2.121$ "
At 1 " 57 "	"	"		$k = 2.771$ "
At 2 " 36 "	"	"		$h = 3$ feet.

Surface of Fairmount Dam.



It is readily perceived at the first glance at the above illustration, that the water-wheels ought to run only at low tide, and stop at high tide, when water is scarce in the river, the result of which will be 40 per cent. more water pumped into the reservoirs, with an equal amount of water passing through the wheels.

The following Table IV, corresponding with the formulas and illustration, shows the height of tide and head of fall at each division or ordinate. The average head for high and low water is represented by the dotted lines in the illustration, which occur 25 minutes before or after mean-tide, when the tide is rising, and 18 minutes before or after mean-tide, when the tide is setting.

TABLE IV.

EFFECT OF TIDE WATER AT FAIRMOUNT.

Ordinates.	Time of Tides.		Angle.	Sine for Angle.	Heights, k and h.	Heights, H and H'	Remarks.
N	h	m	$v°$	Sin v	Feet.	Feet.	
0	0	0	00	0.000	0.000	12	Mean-tide rising.
1	0	39	22½	.3827	−1.148	10.85	
2	1	18	45	.7071	−2.121	9.88	Mean high tide.
3	1	57	67½	.9239	−2.772	9.23	
4	2	36	90	1.000	−3.000	9.000	High tide.
5	3	30	112½	.9239	−2.772	9.23	
6	4	24	135	.7071	−2.121	9.88	Mean high tide.
7	5	18	156½	.3827	−1.148	10.85	
8	6	12	180	0.000	0.000	12.00	Mean tide setting.
9	7	6	202½	.3827	+1.148	13.15	
10	8	0	225	.7071	+2.121	14.12	Mean low tide.
11	8	54	247½	.9239	+2.772	14.77	
12	9	48	270	1.000	+3.000	15.00	Low tide.
13	10	27	292½	.9239	+2.772	14.77	
14	11	6	315	.7071	+2.121	14.12	Mean low tide.
15	11	45	337½	.3827	+1.148	13.15	
16	12	24	360	0.000	0.000	12.00	Mean-tide rising.
17	1	3	22½	.3827	−1.148	10.85	
18	1	42	45	.7071	−2.121	9.88	Mean high tide.
19	2	21	57½	.9239	−2.772	9.23	
20	3	0	90	1.000	−3.000	9.00	High tide.
21	3	54	112½	.9239	−2.772	9.23	
22	4	48	135	.7071	−2.121	9.88	Mean high tide.
23	5	42	156½	.3827	−1.148	10.85	
24	6	36	180	0.000	0.000	12.00	Mean-tide setting.
25	7	30	202½	.3827	+1.148	13.15	
26	8	24	225	.7071	+2.121	14.12	Mean low tide.
27	9	18	247½	.9239	+2.772	14.77	
28	10	12	270	1.000	+3.000	15.00	Low tide.
29	10	51	292½	.9239	+2.772	14.77	
30	11	30	315	.7071	+2.121	14.12	Mean low tide.
31	12	10	337½	.3827	+1.148	13.15	
32	12	49	360	0.000	0.000	12.00	Mean-tide rising.

THEORETICAL AND PRACTICAL EFFECT OF PUMPING WATER.

§ 4. "***How many gallons of water are required (both practically and theoretically,) for pumping one gallon 105 feet high, both at Fairmount and Flat Rock Dams?***"

Divide the height to which the water is to be raised by the height of the waterfall, and the product will be the number of gallons required to lift one gallon the given height theoretically.

For example: The average fall of the Fairmount dam is 12 feet, which divided into the height, 105 feet, gives the theoretical amount of 8.75 gallons to pump one into the reservoir.

The waterfall at Flat Rock is about 24 feet, which divided into 105, gives, theoretically, 4.44 gallons for pumping one gallon to the same height.

The number of gallons practically required, depends upon the construction of the motor, which generally utilizes from 50 to 80 per cent. of the natural effect.

Assuming that 60 per cent. of the power is utilized, the practical results will be

$$\text{At Fairmount, } \frac{105}{12 \times 0.6} = 14.6 \text{ gallons.}$$

$$\text{At Flat Rock, } \frac{105}{24 \times 0.6} = 7.3 \text{ gallons.}$$

This does not include leakage of pump-pistons and valves, which further increases the number of gallons to an unlimited extent, depending upon the condition of the packing, &c., &c. Nor does it include the diameter and length of the main pipe and the angles through which it runs, which may double the amount.

WATER-POWER AT FLAT ROCK AND FAIRMOUNT.

§ 5. "*What is the water-power of the Schuylkill River at Flat Rock and Fairmount Dams? What portions of that power are consumed by the Canal and Mills at Manayunk? And how much of it is available for pumpage at both places?*

"*Also, to what extent can that power be increased, when necessary in the dry season, by impounding dams?*"

The water-power of the Schuylkill river varies with the seasons of the year, and the amount of rainfall.

In the summer months, water rarely flows over the dams at Flat Rock and Fairmount, but the water-surfaces are generally several inches below the flash-boards, and all the power of the Schuylkill is consumed by the mills and canal at Manayunk, and by the water-works and canal at Fairmount.

FAIRMOUNT WATER-WORKS.

The maximum pumping capacity of the present Fairmount water-works is 35,000,000 gallons per 24 hours; which require, at least, 700,000,000 gallons for motive power, or 1500 horses. About one-half of this supply, or 17,500,000 gallons pumped by 350,000,000 of 750 horse-power, may be relied upon at times of minimum flow of the river. Therefore, to accomplish the full operation of the Fairmount water-works in times of drought, 350,000,000 gallons must be supplied per day, from impounding dams, for, say 60 days. Hence, 21,000,000,000 gallons will be the required capacity of impounding dams; and in like proportion for a longer or shorter time of drought.

MANAYUNK MILLS.

In the year 1874, Mr. James F. Smith measured the water consumed by each mill in Manayunk during the period of extreme low water, from the 2d to the 16th of September, when it was necessary to stop some mills part of each 24 hours, in order to keep the water sufficiently high for navigation.

It is also customary at Manayunk, when the river is very low, to use the water only by day, and let it collect by night; thereby there is no water supply to the Fairmount dam at night, except from the Wissahickon and other streams, or the leakages of the canal and Flat Rock dam. The flash-board on the Flat Rock dam is for the purpose of collecting water at night.

The following is the consumption of the mills, as measured by Mr. Smith, in cubic feet, per 24 hours:—

		Cubic feet.
No. 1.	Dexter Mills,	624,720
2.	Economy Mills,	537,000
3.	Schuylkill Mills,	2,749,000
4.	Inquirer Paper Mills,	3,452,400
5.	Ripka Mills,	4,686,300
6.	Eagle Mills—not in operation.	
7.	Arcola Mills,	1,397,220
8.	Wabash Mills,	294,000
9.	Brown Roofing Paper Mills,	826,200
10.	Schofield Mills,	756,000
11.	Mount Vernon Flour Mills,	457,000
12.	Flat Rock Paper Mills,	6,167,340
13.	American Wood Pulp Works,	4,972,500
	Total,	26,919,880
	Cancel for 18 lockages,	875,460
	Lockage from Flat Rock and canal,	5,020,000
	Total minimum flow of the river,	32,815,340

These quantities converted into gallons of 7.48 per cubic foot will be as follows:—

For all the Mills in Manayunk,	201,360,692
For leakage in Canal,	4,548,440
Lockage,	67,549,600
Total gallons per 24 hours,	265,448,732

The only data attainable for finding the actual water-power of the Schuylkill at Fairmount, is by the amount of water pumped into the reservoir, and by the height of water flowing over the dam.

Allowing 15 gallons of water for pumping one into the reservoir, we obtain the volume of water passed through the works by multiplying the pumpage by 15.

Your Commission, however, had reason to believe that much more water passed through the works.

The gauge is placed in the forebay, which level differs from that in the dam, depending upon the number of turbines running.

The Chief Engineer of the Water Department informs your Commission that, "The tables in the Reports are made from the average of three daily readings of the gauge in the forebay, with no corrections."

For the last three years tables are given for the average height of water flowing over the dam for every day of the year, which is an important improvement; but, unfortunately, the explanation accompanying these tables makes their correctness doubtful.

In the table for 1875 the height of the dam is given above the new comb, and not by the gauge in the forebay. The new comb is 9 inches above the old comb; and the flash-board 11 inches above the new, and 20 inches above the old comb.

In the table for 1873, the height of the dam is given above the old comb, which is said to be 20 inches below the top of the flash-board.

In the table for 1877, the height of the dam is given above the old comb, which is the same as the reading of the gauge in the forebay; but it is stated that the flash-board is now 22 inches above the comb.

The flash-board is the same height over the comb now as it has been for many years.

The zero on the gauge in the forebay is on the level of the old comb.

Your Commission has observed the difference of height between the flash-board and zero of the gauge as follows: when the water stood 15½ inches on the gauge it was 3½ below the flash-board, making a difference of 19 inches; but the water-surface in the forebay is 1 inch lower than that of the dam, which makes the difference 20 inches and not 22, as stated in the Report for 1877, but it is only 19 inches as read from the gauge.

Table V is deduced from the Water Department Reports, and it will be observed that the flow over the Fairmount dam has been reduced in the Reports from 11.68 inches in 1870 to 2.82 in 1877, whilst the rainfalls for these two years are nearly alike, or a little more for the year 1877. The fact is that there is no such reduction in the flow of the Schuylkill, but the records of the Water Department are evidently wrong.

TABLE V.

Average Monthly and Yearly Height, in Inches, of Water Flowing Over the Flash-Board or Dam at Fairmount.

	1867	1868	1869	1870	1871	1872	1873	1874	1875	1876	1877
Jan.	—	8.54	17.50	19.56	6.37	4.68	6.72	11.69	0.64	5.00	3.40
Feb.	—	4.46	17.83	17.16	11.96	3.35	2.08	7.57	5.78	9.10	5.54
March	—	18.00	13.03	15.60	17.48	6.19	12.26	9.32	4.26	11.90	5.35
April	—	13.53	11.30	18.80	6.36	11.16	14.95	14.07	5.20	7.70	0.23
May	11.5	113.88	9.62	9.30	9.29	5.32	12.98	9.91	0.00	0.43	0.45
June	8.8	11.23	9.00	10.80	10.43	4 25	0.56	—	0.10	0.90	1.60
July	7.0	8.88	4.55	10.28	9.97	3.92	1.98	4.67	0.10	0.16	1.80
Aug.	18.8	7.50	—3.11	9.85	9.20	10.06	15.29	2.52	9.00	0.06	0.40
Sept.	8.6	13.42	—5.93	4.92	13.59	11.75	5.56	—	0.13	4.00	0.53
Oct.	12.1	11.73	19.00	7.35	10.37	9.96	14.39	3.32	0.45	1.10	3.50
Nov.	10.5	16.48	14.60	7.11	14.83	16.66	9.73	1.26	4.53	5.70	8.65
Dec.	8.7	11.93	19.68	9.41	7.19	4.42	9.50	9.01	6.55	1.26	2.40
Aver.	10.75	11.63	10.58	11.68	10.59	7.64	8.83	6.11	3 04	3.91	2.82
Rainfall	61.19	51.40	48.86	41.10	17 32	51.12	58.28	40.91	41.84	49.32	45.15
Temper.	59.60	53.19	52.59	56.81	55.14	54 63	51.40	50.26	50.91	52.70	50.26

Your Commission attempted to calculate from data in the W. D. Reports for 1875–76 and '77, the percentage of the rainfall in the Schuylkill basin available at Fairmount, which calculation gave the discouraging result of only 18 per cent. The average flow over the Fairmount Dam, in 1877, is the smallest on record, but the pumpage is the largest on record, and very near up to the theoretical capacity of the works.

WATER FLOWING OVER FAIRMOUNT DAM.

The quantity of water flowing over the dam, is determined as follows:

h = height of water in feet over the weir.

L = width of the weir in feet.

V = mean velocity in feet per second of the water over the weir.

Q = cubic feet of water passing over the weir per second.

a = area in square feet, of the cross-section of the water over the weir, measured under the level surface.

From the law of gravity, we have the velocity of a falling body to be

$$\text{Velocity, } V = 8\sqrt{h}. \qquad 1$$

$$\text{The area of cross-section, } a = L\,h. \qquad 2$$

$$\text{Differential area, } \partial a = L\,\partial h, \qquad 3$$

$$\text{Quantity of water, } Q = a\,V, \qquad 4$$

Insert the formulas 1 and 3 for V and a in formula 4, and the differential quantity of water will be

$$\partial Q = L\,\partial h\,8\sqrt{h} = 8\,L\,h^{\frac{1}{2}}\,\partial h, \qquad 5$$

$$\text{Quantity water, } Q = \int 8\,L\,h^{\frac{1}{2}}\,\partial h = \frac{8\,L\,h\sqrt{h}}{1.5}$$

This should be the quantity of water, in cubic feet, passing over the weir per second, if there was no contraction of the vein; but the overflow is contracted on at least two sides, namely: on the top and bottom, and it may also be contracted on the edges of the vein. The sinking of the upper surface over the weir, is caused by the lower strata having a greater velocity than the upper one, the result of which is, that the lower layer increases the velocity of the next upper one by cohesion, and there is not head enough at the upper part of the vein to supply water for the increased velocity.

The coefficient of contraction for an ordinary vein contracted on four sides is 0.64, or ten per cent. on each side; but a vein flowing over a weir is contracted on only three sides, for which the coefficient is 0.72, and the surface over the weir sinks 0.17 leaving the coefficient 0.72 — 0.17 = 0.55 for the overflow. Therefore, the true quantity of water, in cubic feet, flowing over the weir per second will be

$$Q = \frac{0.55 \times 8\ L\ h\sqrt{h},}{1.5} \qquad 7$$

$$\text{Quantity of water, } Q = 2.93\ L\ h\sqrt{h}, \qquad 8$$

This formula applied to the weir at Fairmount Dam, should be transformed to gallons (of 231 cubic inches) flowing over the weir per 24 hours, and the height h converted into inches.

$L = 1112$ feet, width of the weir at Fairmount.

Conversion $h\sqrt{h} = 12\sqrt{12} = 41.5692$.

$$\text{Coeffi't} = \frac{1112 \times 60 \times 60 \times 24 \times 1728 \times 2.98}{231 \times 41.5692} = 50{,}657{,}779.$$

This is the coefficient for $h\sqrt{h}$. It is a little smaller than that of Mr. Jos. B. Francis, of Lowell, Mass., who, by experiments, obtained 50,928,819, which is only one per cent. more. The coefficient derived from the formula of Box, which is preferred by the Water Department, is 51,305,011, or for English gallons 23 per cent. greater.

Your Commission has decided to use 50,000,000 as coefficient for the water flowing over the Fairmount Dam.

G = gallons of water passing over the Fairmount Dam per 24 hours.

h = height in inches of dam over the flash-board.

$$G = 50,000,000\, h\sqrt{h} \qquad 9$$

The formula for the water flowing over the old lock at the canal, is

$$g = 600,000\, h\sqrt{h}, \qquad 10$$

The value of $h\sqrt{h}$ is calculated in table VI for different heights, h in inches and tenths of an inch, which, multiplied by 50,000,000, gives the gallons of water flowing over Fairmount Dam per 24 hours.

The tabular number multiplied by $2.93L$, gives the cubic feet of water flowing over any weir of width L.

Table VII shows the number of millions of gallons flowing over the Fairmount dam per 24 hours, at different heights of water, in inches over the weir.

Example. Suppose the height h over the weir is 12.3 inches, for which the tabular number is 2157.2, which means 2,157,200,000 gallons flowing over the dam per 24 hours.

HYDRAULICS AT FAIRMOUNT.

The hydraulics of the Fairmount Dam and Water Works, are represented in Table VIII, for the year 1877. A similar table had been calculated for each year from 1867, or for eleven years, but on account of uncertainty of the data in the W. D. Report, these tables are not considered sufficiently correct for this report, for which reason only one of them, accompanies it as a sample.

The second column in table VIII, contains the average height in inches of water flowing over the dam, but not as given in the W. D. Report, but two inches has been added, and your Commission has even considered the propriety of adding 3 inches, allowing one inch difference of level of the dam and the forebay.

The next column contains the average gallons of water flowng over the dam per 24 hours, calculated for the average of h_1/h. It will be noticed, that the quantity of water does not correspond with that due to the height h table VII. For instance, in the months of August and September, the average height on the dam was one inch, which corresponds to 50,000,000 gallons, Table VII, but here is given 98,000,000 and 85,000,000 This difference is obtained by the average of h_1/h.

The column giving the total quantity of water passing through the Schuylkill at Fairmount includes:

1. The water flowing over the dam.
2. The water consumed for the pumpage, 20 gallons for each gallon pumped.
3. All the water pumped into the reservoirs by all the Works, except the Delaware.
4. The water consumed by lockage in the canal, averaging 6,000,000 gallons per day for 9 months..
5. Leakage of the dam and flow over the old lock, 6,000,000 gallons per day. With all this, only 65 per cent of the water flowing in the Schuylkill is accounted for; a great part of the remaining 35 per cent, no doubt flows through the water works, whilst the wheels are standing still, and the rest through the broken down flash-boards.

The percentage of rainfall available at Fairmount, as given in the next to the last column, is not expected to be correct, but it only demonstrates the incompleteness of the records in the W. D. Reports.

The horse-power column means the natural effect of the waterfall, and not that transmitted by the turbines.

TABLE VI.—VALUE OF $h\sqrt{h}$ FOR WEIR MEASUREMENTS.

h	Tenths of an inch of the Height h. 0	1	2	3	4	5	6	7	8	9
0	0.	0.0316	0.0894	0.1643	0.2530	0.3536	0.4647	0.5858	0.7155	0.8531
1	1.	1.1537	1.3145	1.4830	1.6565	1.8371	2.0238	2.2164	2.4149	2.6189
2	2.8284	3.0132	3.2631	3.4882	3.7180	3.9526	4.1927	4.4365	4.6868	4.9385
3	5.1961	5.4581	5.7213	5.9947	6.2692	6.5479	6.8305	7.1171	7.4071	7.7020
4	8.0000	8.3018	8.6074	8.9166	9.2285	9.5159	9.8658	10.189	10.516	10.846
5	11.180	11.520	11.858	12.196	12.550	12.897	13.258	13.610	13.975	14.331
6	14.697	15.065	15.437	15.812	16.192	16.575	16.955	17.343	17.734	18.120
7	18.522	18.921	19.324	19.721	20.133	20.540	20.950	21.367	21.875	22.210
8	22.621	23.056	23.488	23.910	24.350	24.781	25.222	25.663	26.156	26.558
9	27.000	27.455	27.910	28.361	28.820	29.282	29.747	30.211	30.678	31.151
10	31.623	32.111	32.570	33.060	33.538	34.027	34.513	35.000	35.495	35.985
11	36.483	36.985	37.483	37.999	38.494	39.000	39.500	40.018	40.548	41.040
12	41.569	42.090	42.610	43.145	43.675	44.192	44.725	45.255	45.800	46.333
13	46.872	47.418	47.958	48.506	49.055	49.600	49.934	50.707	51.266	51.824
14	52.383	52.944	53.508	54.075	54.644	55.219	55.786	56.368	56.936	57.514
15	58.094	58.676	59.262	59.846	60.439	61.022	61.611	62.206	62.803	63.400
16	64.000	64.600	65.200	65.809	66.413	67.021	67.632	68.245	68.853	69.473
17	70.092	70.714	71.333	71.954	72.584	73.210	73.835	74.463	75.095	75.730
18	76.367	77.005	77.643	78.284	78.930	79.570	80.216	80.865	81.514	82.169
19	82.819	83.172	84.130	84.789	85.450	86.110	86.772	87.440	87.970	88.771
20	89.442	90.114	90.790	91.463	92.140	92.819	93.496	94.180	94.862	95.548
21	96.234	96.922	97.614	98.303	99.000	99.690	100.39	101.09	101.79	102.49
22	103.19	103.89	104.60	105.30	106.00	106.70	107.41	108.15	108.85	109.59
23	110.30	111.01	111.73	112.48	113.19	113.90	114.63	115.38	116.12	116.80
24	117.57	118.35	119.06	119.79	120.51	121.25	122.00	122.75	123.50	124.25

TABLE VII.—NO. OF MILLIONS OF GALLONS FLOWING OVER FAIRMOUNT DAM.

h	Tenths of an inch of the Height h. 0	1	2	3	4	5	6	7	8	9
0	0.0000	1.5800	4.4700	8.2150	12.650	17.680	23.235	29.290	35.775	42.655
1	50.000	57.685	65.725	74.150	82.825	91.855	101.19	110.82	120.79	130.99
2	141.42	152.16	163.15	174.41	185.90	197.63	209.63	221.82	234.34	246.92
3	259.81	272.91	286.21	299.73	313.46	327.39	341.53	355.85	370.37	385.10
4	400.00	415.09	430.37	445.83	461.42	477.30	493.29	509.45	525.80	542.30
5	559.00	576.00	592.90	609.80	627.50	644.85	662.90	680.50	698.75	716.55
6	734.85	753.25	771.85	790.60	809.60	828.75	847.75	867.15	886.70	906.00
7	926.10	946.20	966.20	986.20	1006.6	1027.0	1047.5	1068.4	1093.7	1110.5
8	1131.2	1152.8	1174.4	1195.5	1217.5	1239.5	1261.1	1283.2	1307.8	1327.9
9	1350.0	1372.7	1395.5	1418.1	1441.0	1464.1	1487.3	1510.5	1533.9	1557.5
10	1581.2	1605.5	1628.5	1653.0	1676.9	1701.3	1725.6	1750.0	1774.7	1799.2
11	1821.2	1849.2	1874.2	1899.9	1924.7	1950.0	1975.0	2000.9	2027.4	2052.0
12	2078.1	2104.5	2130.5	2157.2	2183.7	2209.6	2236.2	2262.7	2290.0	2316.6
13	2343.6	2370.9	2397.9	2425.3	2452.7	2480.0	2496.7	2535.3	2563.3	2591.2
14	2619.1	2647.2	2675.4	2703.7	2732.2	2760.9	2789.3	2818.4	2846.8	2875.7
15	2904.7	2933.8	2963.1	2992.3	3021.9	3051.1	3080.7	3110.3	3140.1	3170.0
16	3200.0	3230.0	3260.0	3290.4	3320.6	3351.2	3381.6	3412.3	3442.6	3473.6
17	3504.6	3535.7	3566.6	3597.7	3629.2	3660.5	3691.7	3723.1	3754.7	3786.5
18	3818.3	3850.2	3882.1	3914.2	3946.5	3978.5	4010.8	4043.2	4075.7	4108.4
19	4140.8	4173.6	4206.5	4239.4	4272.5	4305.5	4338.6	4372.0	4398.5	4438.5
20	4472.1	4505.7	4539.5	4573.1	4607.0	4640.9	4674.8	4709.0	4743.1	4777.4
21	4811.7	4846.1	4880.7	4915.1	4950.0	4984.5	5001.9	5054.5	5089.5	5124.5
22	5150.5	5194.5	5230.0	5265.0	5300.0	5335.0	5370.5	5407.5	5447.5	5479.5
23	5515.0	5552.0	5586.5	5621.0	5659.5	5695.0	5731.5	5769.0	5806.0	5840.0
24	5878.5	5917.5	5953.0	5989.5	6025.5	6062.5	6100.0	6137.5	6175.0	6212.5

TABLE VIII.—Hydraulics of the Fairmount Dam and Water-Works.

Year 1877, and Months	Fairmount Dam. Height of Water over Dam.	Fairmount Dam. Average flow over Dam per 24 hours.	Fairmount Dam. Horse-Power of overflow	Fairmount Dam. Head of fall in feet.	Fairmount Dam. Water that could have been pumped by the over-flow.	Fairmount Water-Works. Water nominally pumped into the reservoir per 24 hours	Fairmount Water-Works. Horse-power utilized.	Fairmount Water-Works. Percentage of stoppage.	Fairmount Water-Works. Water consumed per 24 hours by the actual pumping.	Total at Fairmount. Water passing into tide-water per 24 hours.	Total at Fairmount. Horse-power of the Schuylkill.	Total at Fairmount. Percentage horse-power.	Pumpage per 24 hours. By all the water-works	Pumpage per 24 hours. Perc'tage steam pumping	Pumpage per 24 hours. By Steam alone.	Rainfall. Actual in Philadelphia.	Rainfall. Available at Fairmount.	Rainfall. Percentage available at Fairmount.	Mean temperature in Philadelphia.
	h	Gallons.	HP	H	Gallons.	Gallons.	HP	%	Gallons.	Gallons.	HP	%	Gallons.	%	Gallons.	Inch.	In.	%	Fahr
January	4.55	684,000,000	1540	12.7	34,200,000	25,099,480	1130	24	501,989,600	1,233,010,000	3000	37.7	41,017,940	38.8	15,918,460	2.89	1.1	38.2	28.61
February	6.72	1,216,868,000	2780	12.9	60,843,400	26,092,839	1212	23	521,856,780	1,786,454,600	4080	29.8	41,729,790	37.5	15,636,951	1.55	1.6	10.3	37.39
March	7.16	1,210,300,000	2760	12.9	60,515,000	26,398,251	1205	20	527,965,020	1,786,285,000	4080	29.5	42,017,135	37.1	15,618,884	6.00	1.6	26.7	39.94
April	0.6	58,361,000	128	12.4	2,918,000	28,484,122	1272	12	569,682,440	679,000,000	1510	74.3	44,912,621	36.6	16,428,499	2.96	0.6	20.3	51.77
May	1.1	102,602,000	220	12.1	5,130,100	25,954,103	1115	22	519,082,060	677,274,000	1450	77.0	49,589,585	47.6	23,635,482	1.21	0.59	49.0	62.81
June	2.63	365,000,000	808	12.5	18,250,000	28,029,731	1265	16	560,594,620	984,770,000	2180	58.0	53,174,665	47.3	25,144,934	5.55	0.87	15.7	74.13
July	3.00	404,305,000	904	12.6	20,215,000	23,261,246	1036	28	465,224,920	929,150,000	2070	50.0	53,618,117	56.6	30,356,871	6.19	0.82	13.3	78.86
August	1.00	98,789,000	217	12.4	4,939,400	19,972,951	876	29	399,459,020	560,285,000	1230	71.1	56,036,267	64.3	36,063,316	1.00	0.38	37.8	78.35
September	1.00	85,056,000	187	12.4	4,252,800	20,704,177	836	36	414,083,540	560,177,000	1230	68.0	55,037,169	62.4	34,332,992	3.88	0.52	13.3	69.76
October	4.32	857,460,000	1925	12.7	42,873,000	28,267,436	1271	11	565,348,720	1,481,948,000	3333	38.1	53,138,403	46.8	24,870,967	6.96	1.31	19.0	58.71
November	10.26	3,070,718,000	7175	13.2	153,500,000	30,030,682	1300	7	600,613,640	3,727,651,000	8320	15.6	50,318,939	40.3	20,288,257	6.50	3.34	51.4	47.05
December	3.45	489,015,000	1095	12.6	24,450,000	29,896,805	1335	7	597,936,100	939,635,000	2100	63.5	46,683,018	36.0	16,786,213	1.36	1.00	74.4	40.71
Average	3.06	720,706,000	1536	12.6	357,357,000	26,015,985	1155	20	520,178,000	1,280,000,000	2860	40.3	48,983,958	47	22,967,973	46.07	17.7	38.5	55.67

WATER-POWER AT THE FLAT ROCK DAM, OR MANAYUNK.

The surplus water flowing over Flat Rock Dam, above that consumed by the mills and canal, is about equal to the overflow at Fairmount, because the Water-Works consume about as much more water than the mills, as the supply from the Wissahickon; and the water-power at Flat Rock ought to be utilized for supplying the City with pure water.

All investigators of the water in the Fairmount Dam, in a sanitary point of view, agree, that the impurities thrown into the river at Manayunk, are very injurious. This serious evil can be avoided by pumping water from the Flat Rock Dam, for the City supply. There is an excellent location for Water-Works, between the canal and the river, a few hundred feet below the falls, or near the second lock.

If arrangement could be made between the City and the Reading Railroad Company, for a lease of that ground and water-power, it would make the best water-works in Philadelphia.

The head of fall at Flat Rock is about double that at Fairmount, and free from tide-water.

The dam between the guard lock and the second lock, would answer for the water-works, and could easily be enlarged, if necessary. In case all the water-power now used at Manayunk could be rented for these water-works, one or two mains of not less than five feet in diameter, should be laid along the river to any storage reservoir provided therefor.

The plan you have suggested, namely, to raise and widen the canal, from Flat Rock, and erect water-works at the lower part of Manayunk, deserves consideration.

Thus Flat Rock and Fairmount Water-Works would be sufficient to supply Philadelphia with plenty of water, for a great many years to come, without the aid of steam-pumping, as you have suggested.

RESERVOIR ON GEORGES RUN.

§ 6. *"Could not the Valley of Georges Run at some suitable point, be utilized for a storage reservoir?"*

Your Commission has examined the location referred to, and thinks it feasible to build a retaining wall or embankment across Georges Run, at some point near the crossing of the proposed N. 50th and Dauphin Streets, or above Bryn Mawr.

The ground appears to be favorable for retaining water, but your Commission has made no survey of the place, and can therefore not estimate the cost and capacity of such a reservoir.

Mr. James F. Smith, Chief Engineer of Schuylkill Canal, proposes to build Water-Works on the west side of the Schuylkill below Flat Rock Dam, and lead the water to some storage reservoir on the hills, so elevated as to permit the water to be carried to Belmont, or any other reservoir on the west side of the river.

This proposition is similar to that previously made by yourself, namely, to build a retaining bank over Georges Run, to form a natural basin for a storage reservoir.

There are several other locations on the west side of the river, where, as you have suggested, natural basins could be constructed high enough to supply Philadelphia with water, pumped by water-power either from Flat Rock, or from Fairmount Dam.

The plan you have suggested, namely, to raise the Delaware and Corinthian reservoirs, for supplying Frankford with Schuylkill water, by water-power, would, no doubt, answer.

Frankford could be supplied direct from the East Park reservoir, and, still better, from the proposed Cambria reservoir, which would be at least 20 feet higher.

The location of the proposed Cambria reservoir is marked with red ink, east of Laurel Hill, on the Distributing Map made by the Water Department, and presented to your Commission.

PERKIOMEN IMPOUNDING DAM.

§ 7 ***"To what extent could an impounding dam on the Perkiomen be relied upon for water-power at Flat Rock and Fairmount during the dry season?"***

The Commission of Engineers of 1875, estimated the capacity of an impounding dam on the Perkiomen, for the purpose of supplying Philadelphia with water by gravitation, and proposed to fix the water-rise at 70 feet, with 25 feet to be drawn out, which would furnish 10,000,000,000 gallons of available water, exclusive of two feet in depth allowed for evaporation.

The total capacity of this reservoir would probably be 20,000,000,000 gallons.

The water-shed of the Perkiomen is estimated at 220 square miles above the proposed dam, and the annual rainfall 48 inches at 60 per cent. will be 28 inches available, or 109,000,000,000 gallons per annum, which is a daily average of 300,000,000, gallons. The proposed dam is, therefore, much too small for its water-shed, but could be increased to, perhaps, double that capacity or more, by raising the dam sufficiently high to hold at least three-quarters of the annual rainfall, or say 80,000,000,000 gallons.

The height of 70 feet proposed by said Commission, was intended only for a dam to supply water direct by gravitation, to the East Park Reservoir, and not for water-power at Fairmount.

The maximum capacity of the present water-works at Fairmount is 35,000,000 gallons per day, with full water in the river; and the minimum capacity in the dry season is 16,000,000. Then, for the full capacity of said work in the dry season 35—16=19,000,000 gallons per day must be pumped by store-water from impounding dams. With the present extravagant waste of water-power at Fairmount, 37 gallons for pumping one, would require 37×19=703,000,000 gallons per day from impounding dams, and 80,000 : 703=113 days supply from the Perkiomen. With properly proportioned pumps and turbines at Fairmount, and with the aid of the Perkiomen dam, the City could be supplied with at least 80,000,000 gallons of water per day, the whole year round.

With adequate water-works at Flat Rock, this amount would again be more than doubled, or 180,000,000 gallons could be pumped per day, by water-power alone. In the Commissioners' Report, (1875,) pages 121 to 126, Mr. James F. Smith gives an account of existing and proposed impounding dams in the Schuylkill Basin, namely, as follows:

	Existing Reservoirs.		
Silver Creek,	320,000,000	gallons.	
No. 1, Tumbling Run,	191,000,000	"	
No. 2,	299,000,000	"	810,000,000
	Proposed Reservoirs.		
No. 3,	196,000,000	gallons.	
No. 4,	218,000,000	"	
No. 5,	525,000,000	"	939,000,000
Other dams proposed by Mr. Smith,			20,806,000,000
		Total,	21,745,000,000
Perkiomen proposed dam,			80,000,000,000
		Total,	101,745,000,000
Daily average through the year,			2,780,000,000

Your Commission believes, that the cheapest way of supplying Philadelphia with water in the future, would be to build water-works at Flat Rock, and an impounding dam on the Perkiomen, which, together with the present, would be sufficient until the end of this century. In the year 1900, mains from the Perkiomen to Philadelphia, will be required for supplying water by gravitation, 200,000,000 gallons daily.

COST OF PERKIOMEN DAM AND GRAVITATION SUPPLY.

§ 8 *"What will be the cost of building an impounding dam on the Perkiomen, and what will be the cost of laying mains therefrom, to supply the City with water by gravitation?"*

The Commission of Engineers of 1875, estimated the cost of an impounding dam on the Perkiomen, raised 70 feet, at $780,000. A dam to hold three-quarters of the annual rainfall would cost perhaps $1,000,000. It is, however, impossible to estimate the cost correctly, without making a survey of the same.

The same Commission estimated the cost of the gravitation plan at $10,000,000 for a daily supply of 100,000,000 gallons, and at $12,000,000, for 200,000,000 gallons daily.

COMMENTS BY JAMES F. SMITH ON NYSTROM'S CALCULATION OF WATER IN THE SCHUYLKILL.

§9 ***"In the Report on Water Supply, made by the Commission of Engineers, 1875, pages 127 & 128, it is stated, that " the calculation of the hydraulics of Fairmount Dam, made by J. W. Nystrom, for James Haworth, is wrong," or over-estimates the quantity of water. Can this be explained?"***

The calculations referred to were based upon data given in Water Department Reports; namely, the height of water flowing over the weir or dam at Fairmount. The formula used for these calculations rather under-estimates the quantity of water, as will be seen in the W. D. Reports for 1874, page 103, in which comparison is made from Nystrom's, Francis', and Box's formulas.

Mr. Nystrom says, that he purposely made the formula to under-estimate the quantity of water, so as to be on the safe side for water-power at Fairmount. Mr. Smith assumes the average yearly rainfall to be only 42 inches in the Schuylkill Basin, whilst the data of rainfall show an average of over 46½ inches in Philadelphia and Reading. Mr. Smith also assumes the area of the Schuylkill Basin to be only 1800 square miles, whilst Mr. Berkinbine, who has surveyed that basin, says it is 1942 square miles.

Mr. Smith estimates the average annual quantity of water passing through the Schuylkill at Fairmount, at 563,000,000,000 gallons, which will be a daily average of 1,550,000,000 gallons. From Nystrom's calculation, we obtain 1,905,000,000 gallons, which is 23 per cent. more than given by Mr. Smith.

Although the weir measurement of water is not very correct, it is evidently more correct than to guess at the percentage of rainfall available at Fairmount.

COST OF FAIRMOUNT WATER-WORKS AND DAM.

§ 10. "*What are the liabilities of the City, and to what extent in actual outlay, for the construction and maintenance of the Fairmount Dam, as also the aggregate cost of plant at Fairmount?*"

The building of the Fairmount Dam was commenced in the year 1817, by Messrs. Josiah White and Joseph Gillingham, and was finished in the year 1821, by Ariel Cooly. The Dam has since been twice rebuilt, namely, in 1843 and 1872.

COST OF BUILDING FAIRMOUNT DAM.

1818	To Messrs. White and Gillingham, for building dam, the City paid	$150,000
1821	To Captain Ariel Cooly, for building and completing the dam,	150,000
1824	To the Schuylkill Navigation Company, for the use (apparently) of the whole water-power at Fairmount,	26,000
1843	For rebuilding the dam,	56,000
1872	For rebuilding the dam,	195,640
	Expenses for repairing to date, about	50,000
	Total for the dam,	627,640

COST OF FAIRMOUNT WATER-WORKS.

Mr. Birkinbine says, that the interest on the cost of works and water-power at Fairmount, is $36,000, which is 6 per cent. interest on $600,000. (See W. D. Report for 1864.) Up to that time, the cost of the dam was $382,000, leaving $218,000 for the cost of the works.

AGREEMENT BETWEEN THE CITY OF PHILADELPHIA AND THE SCHUYLKILL NAVIGATION COMPANY, DATED JUNE 3, 1819.

It is hereby mutually understood and agreed, between the said parties: That the said President, Managers and Company of the Schuylkill Navigation Co. shall and may, at all times, draw off from the said dam as much water as they may deem necessary for the purpose of navigation, and that the said Mayor, Alderman and Citizens shall and may enjoy all the remainder of the said river for the purposes hereinafter mentioned: *Provided*, They do not at any time reduce the same, or keep the same reduced, below the level of the surface or top of said dam,* it being the design and meaning of the parties, that the said Mayor, Alderman and Citizens shall only have such use of the water as, with the use thereof by the said President, Managers and Company, will not reduce it below the said surface, or top of the dam,* or keep it so reduced.

And the said dam is to be kept up, and in good and sufficient repair, at all times and forever by the said Mayor, Alderman and Citizens of Philadelphia, and their successors, at their own proper expense and charges.

And it is further agreed between said parties, that a tail-race or canal, to accommodate the navigation of said river at the said dam, is to be completed and finished, in good order, by the Mayor, Alderman and Citizens of Philadelphia, and their successors, and, as soon as finished, delivered and secured to the said Navigation Company, and their successors forever.

* Top of the old comb, which is 4 feet 9 inches above City datum.

And the said Mayor, Alderman and Citizens of Philadelphia, and their successors, shall build one good and sufficient guard-lock, and two chamber-locks, each to be eighty feet long and seventeen feet wide, as required by the Act of Incorporation of the said Navigation Company, the said lock to be so deep as to admit the water of the said river, at the lowest time of the said water, to the depth of three feet on the ribbon of the gateways of the said lock or locks, so as to make a safe and convenient passage for boats, and other things which may pass through them.

RELATIVE COST OF STEAM AND WATER-POWER.

§11. "*What is the relative cost of Pumping the City Water Supply by Steam, (as now practised,) or by Water-Power, at Fairmount and Flat Rock; both with and without interest on plant?*"

The cost of raising 1,000,000 gallons 100 feet high, at Fairmount, was $1.74 by the old breast-wheels, and averages $2.00 by the turbines. With interest on plant, the cost will be $11.70 for the water-wheels, and about $14 for the turbines.

The cost of raising water by steam, depends much upon the construction of the engines and boilers, and particularly upon the grade of expansion of the steam. The cost varies between $6 and $21 per 1,000,000 gallons raised 100 feet high, for running expenses.

With interest on plant, the cost of steam-power varies between $15 and $30 per 1,000,000 gallons raised 100 feet high.

In comparing the cost of steam-power and water-power for pumping, it will not be correct to base the calculation on running expenses and on interest on plant alone, because a steam engine does not last as long as a water-wheel.

The Fairmount breast-wheels lasted from 1822 to 1862, or 40 years. In this time, many steam engines have broken down, were condemned, and new ones substituted; and there are now several steam engines standing idle, either unfit for use or too expensive to run.

In view of all these considerations, your Commission thinks that steam-power costs 10 times as much as water-power.

COST OF STEAM AND WATER-POWER; BY CHIEF ENGINEER DR. McFADDEN.

§ 12 ***"The Chief Engineer, Dr. McFadden, says, in his Report for the year 1876, 'That Steam-Power is cheaper than Water-Power.' On page 15, in the same Report, he says, 'Steam-Power costs nine times as much as Water-Power.' How does he arrive at such opposite statements?"***

The Chief Engineer has evidently arrived at these statements by adding the interest on plant in one case, and considering only the running expenses in the other. If all the expenses of the Fairmount Water-Works be added, from the year 1822 to 1876 inclusive, it will amount to $1,781,000; the interest on which will be $106,860, at 6 per cent.; and, if added to the running expenses of the water-power, it will appear very expensive pumping.

If the interest on only *the cost* of the steam engine is added to its running expenses, the steam-power may appear cheaper than water-power. If all the expenses of all the steam works be added from the time of the first steam pump to the same year, 1876, and the interest added to the steam running expenses, it will probably reverse the case again. Water-power is evidently the cheapest; and whilst the plant at Fairmount is already made, the addition of a few more wheels or turbines would cost less than an additional steam engine for the same pumping.

Mr. C. H. Gallagher, Chief Engineer of the Wilmington Water-Works, recommends water-power as being much cheaper than steam-power.

The Water Department has been particularly unfortunate this year, (1878,) in breaking down of steam pumping machinery.

The new 5,000,000 gallon engine at Frankford (Lardner's Point) broke down in July, after a short run, and is yet (Nov. 13) under repair.

The new 20,000,000 gallon engine, at the Schuylkill Works, met with the same fate, and is yet standing in the condition it was when it broke.

Only two of the four engines at the Schuylkill Works are in running order (Nov. 13, 1878).

Only one of the two engines at Roxborough is running. The Cornish engine there ran only 467 hours in 1865, and 726 hours in 1867; since which time it has pumped very little water.

One engine at the Delaware Works stopped running Nov. 13, and is under repair.

At the same time, several boilers at the Belmont Works are being scaled and cleaned; so that only one of its three engines is running, and supplies the east side of the river; whilst no water is pumped into the George's Hill basin.

The water in the reservoirs supplied by steam-power are all very low, and the Chief Engineer says: "The supply will be short," and he recommends economy in the use of water.

These inconveniences establish the fact that water-power is not only the cheapest, but also the most reliable for supplying the City with an abundance of water.

In calculating the expense of steam pumping, the interest on plant of all the steam works, whether running or not, should be included for a fair comparison with the expense of water-power.

ADDENDUM TO § 2, PAGE 23.

On page 24, W. D. Report for 1876, is given a statement under the head "Flow of the Schuylkill and Rainfall," which says the daily average flow for 45 days, was only 230,788,888 gallons, including the water used by the Canal. The average daily pumpage in the same time, was about 16,000,000 gallons. It requires at least 25 gallons to pump one into the reservoir, which would make the average daily flow of the Schuylkill at least 400,000,000 gallons, without the leakage, and that consumed by the Canal.

BAD WATER IN KENSINGTON.

§ 13. ***"The water in Kensington is pronounced unfit to drink, and injurious to health. Cannot the Schuylkill supply Kensington and Frankford from the Corinthian basin, and thus dispense with Steam Pumping on the Delaware?"***

The daily capacity of all the steam engines on the Schuylkill, is as follows:

Water-Works.	*Engines.*	*Gallons.*
Schuylkill,	Old Cornish,	5,287,680
	Side Lever,	7,598,880
	Com. H. G. Morris	10,132,416
	Comp'nd, Cramp's	20,000,000
Belmont	Three Worthingtons,	19,749,726
Roxborough	Two Engines,	6,863,673
Fairmount	Worthington,	2,364,249
Four Works	Ten Engines,	71,996,624

This capacity is more than the maximum pumpage of all the works; but it is only the Schuylkill Water-Works which pump directly into the Schuylkill and Corinthian basins, from which it must flow to the Delaware basin, in order to supply Kensington with water.

The capacity of the Schuylkill Works alone, is 43,018,976 gallons daily, but its actual maximum pumpage has been only 18,000,000 per day; leaving 25,000,000 that could be pumped for Kensington, which is over three times the maximum daily pumpage of the Delaware Works.

The present main connecting the Corinthian and Delaware basins is only 30 inches in diameter, and the head of fall only 6 feet, in a distance of nearly three miles between these basins, through which only 5,000,000 gallons can flow per 24 hours; but if a main of suitable size were laid, the requisite amount of water could be delivered by it.

INDIFFERENCE OF THE COMMISSION OF ENGINEERS, 1875.

§ 14. "***Can you assign a technical reason why the Commission of Engineers of 1875 should decline to consider my proposition, to show how a daily additional pumpage of 20,000,000 gallons could be effected at Fairmount, without any extra cost to the City?***"

Your Commission does not understand why such an important proposition was rejected by the Water Supply Commission of 1875; particularly, as it bore directly upon the subject those engineers were invited to investigate.

PUMPS AT FAIRMOUNT RUNNING WITHOUT PUMPING.

§ 15. "***The pumps of the wheels Nos. I and II had been running for years without pumping any water: which, when told the Commission of 1875, they asked, 'how I knew that?' I answered, that by examination and by absence of agitation on the surface of the basin. Is not that always occasioned by inflowing currents?***"

The influx from the pumps to the reservoir must be exceedingly weak, or amount to nothing, if no disturbance is observable on the surface of the water over the inlet. The influx from the stand-pipe creates much disturbance on the water-surface; and the same ought to be the case with that from the pumps mentioned.

One member of your Commission says, that he observed the leakage of the pump-piston of wheel II, some twelve years ago, by placing his ear close to the pump, the passage of water through the packing could thus be distinctly heard.

MODES OF MEASURING THE LEAKAGE OF THE PUMPS.

10. *"The Commission of 1875 asked me how I would measure the water lost by leakage. To which I replied, by noting the number of strokes made per minute of the pumps, without delivering water into the basin, whilst the pipe is kept full to nearly the overflow." How would that method answer compared with the weir measurement?*

Your Commission thinks that the method proposed by you is a very good one, and is, evidently, better and more correct than weir measurement.

Your method could be readily applied to those pumps from which the water is discharged near the surface of the basins, as is the case both at the Fairmount and Corinthian basins.

One member of your Commission happened to be present at the Corinthian basin when the weir experiments were made by the Commission, (1875,) and his conviction was that the result would give a very uncertain approximation to the truth, because the engineers were not provided with the necessary means for attaining accuracy.

The volume of water flowing over the weir was calculated by Francis' formula, which is no doubt very correct for a constant head, but when the head varies irregularly, as was the case at the Corinthian basin, a precaution must be taken for obtaining accuracy, which was omitted by the Commission, namely, to take the average of $h + h$, and not h only, as they did.

The Commission ought to have adopted the method proposed by you for measuring the leakage of the pumps.

THE COMMISSION COULD NOT MEASURE THE WATER.

§17. ***In their Report, the Commission declare their inability to measure the water. "Can not the water be measured as I proposed?"***

The declaration quoted is probably derived from a statement on page 23, as follows: "It was impossible to measure the actual quantity used by the wheels, on account of the tide and low archways of the tail-race, without a very considerable expenditure; but, from a consideration of their openings, the observations we could make, and the best data obtainable, we are satisfied that the wheels do not exceed the duty of 60 per cent."

The volume of water pumped into the reservoir can be measured by the method you proposed, but not the volume used by the wheels.

Your Commission is surprised to learn that engineers of so high standing, should declare it impossible to measure the actual quantity of water used by the wheels; which is indeed a very simple engineering problem, that can be solved with much greater precision than by weir experiments, and at an insignificant expense.

THE FAIRMOUNT DAM DRAWN DOWN AND NAVIGATION STOPPED.

§18. ***"Are there any engineering reasons to justify reducing the level of the Fairmount Dam 36 inches below its breast, in 1869, whereby the Navigation and the Water-Works were both arrested? Can a statement of the minimum performance of the pumps at that time be supplied?"***

The total rainfall in Philadelphia for the four months, June, July, August and September, 1869, was only 11.86 inches, which is the smallest rainfall, in the same months, since the dry year, 1819, excepting the year 1854, when the fall was only 10.054.

From the tables of rainfall, pages 16 and 17, it will be seen that it rained less in Reading than in Philadelphia, during the two months of July and August, 1869, namely:

1869.	*Philadelphia.*	*Reading.*
July, -	2.885	2.20
August, -	1.280	1.02
Total, -	4.165 in.	3.22 in.

The rainfall at Reading may be considered the average in the Schuylkill water-shed, and it was smallest about the time the navigation was stopped.

It appears, also, that, at the date mentioned, the dam was unnecessarily drawn down by running the wheels at high tide, and stopping them at low tide. If the dam had been kept full, and the wheels run only at low tide, much more water could have been pumped, without stopping the navigation, provided the diameter of the wheels and pumps are of such proportion, as to utilize the best effect at low tide. [This subject of propor proportion of the wheels and pumps, is treated in another chapter.]

The total rainfall during the year 1869, was 48.84 inches, which is up to, and rather above the average for the last 50 years. In the month of October, the same year, a heavy freshet raised the dam at Fairmount, 11 feet 5 inches above the comb.

Your Commission has no means of finding out the minimum performance of the pumps at Fairmount during the drought in 1869, except by the Water Department Report, which gives the average daily pumpage 16,447,743 gallons, in the month of August, which is the minimum for that year. This Report does not say that the pumps were arrested; but if the level of the dam was drawn down three feet below the comb, it was probably below the top of the suction pipe, and the pumps, consequently, pumped air instead of water.

The greatest difference of rainfall at Philadelphia and Reading, up to this time, is, perhaps, this summer, 1878, namely:

1878.		*Philadelphia.*	*Reading.*
June,	-	4.750	2.73
July,	-	5.313	1.63
August,	-	4.833	1.84
Total,	-	14.896 in.	6.20 in.

This accounts for the scarcity of water at Fairmount this summer, although there was plenty of rain in Philadelphia, but the dam has, nevertheless, been kept constantly full, to within a few inches of the top of the flash-board, by stopping some wheels during high tide; the probable result of your efforts in behalf of the interest of the Water Department.

Your plan of economizing the water-power at Fairmount, namely, to run all the wheels at low tide, and stop them during high tide, has not been fully carried out, as the wheels Nos. 3 and 4 have been running almost constantly during high tide. Much power has also been wasted by allowing the water to run freely through the turbines Nos. 8 and 9, whilst standing still.

On August 27, 1878, at 10 h. 15 m. A.M., your Commission was standing on the abutment at Fairmount Dam, and counted the number of wheels running, by noticing the strong current of water issuing from them, and your Commission thought that the wheels Nos. 3, 4, 8 and 9 were running: but, upon entering the new wheel-house, the wheels 8 and 9 were found standing still. Your Commission, satisfied that those wheels could not possibly have been stopped in so short a time, observed the current from the doorway between the wheels, and found it to be nearly as strong as when the turbines were running. This is a careless waste of water-power.

Your Commission can see no engineering reason for drawing down the dam in the manner stated, but conclusive reason for keeping it filled to the comb.

§ 19. ***"On the 17th of September, 1876, both the Spring Garden and Corinthian reservoirs were down 6 feet, whilst only one of the engines at the Schuylkill Steam Works was in operation. Is it not an extravagant waste of power to stop the wheels at low tide, the time when the power is greatest, and particularly when the water is low in the reservoirs?"***

To run the wheels at high tide, and stop them at low tide, is certainly a waste of power. There are, however, circumstances involved in all kinds of operations, which are not generally apparent to transient observers, one of which may be mentioned in regard to the Fairmount Water-Works.

In his address to the Franklin Institute, Mr. Berkinbine said, "that the pumps are run to full working speed when the tide is in, and, on account of defective arrangements of parts, the piston speed cannot be increased."

The machinery at Fairmount is, evidently, wrongly proportioned for the duty it is to perform.

The principal advantage of turbines over breast-wheels, at Fairmount, should be that the turbines utilize the whole head at different heights of tide, which the breast-wheels cannot do; but, under the actual circumstances, the turbines are worse than the breast-wheels. When the tide is low, the circular gate is let down, *to prevent the wheels from running too fast,* and thus the discharge is choked, so as to impair the full action of the water on the wheel.

REMARKS.

Example—Wheel No. I was stopped during the year 1875 *for* 6170 *hours, or over* 275 *days! Wheel No. II was stopped the same year* 8195 *hours, or over* 341 *days!*

Six other wheels mentioned were stopped, collectively, 8680 *hours, or over* 351 *days, or* 60 *days for each wheel. The reason assigned for the stoppage being, that the reservoirs were full.—(filled by steam-power, of course.)* J. H.

STOPPING THE WHEELS AT LOW TIDE.

§ 20. ***"I have visited Fairmount, the Corinthian and other Reservoirs, with the following results."***

In the Year 1870.

Sept. 3, *Corinthian Avenue basin down* 10 *feet*; 3 *wheels stopped at low tide.*

"	7,	*Fairmount*	*basin*	*down*	6	*feet;*	3	*wheels*	*running*	*at low tide.*	
"	8,	"	"	"	6	"	4	"	"	*at high tide.*	
"	9,	"	"	"	6	"	5	"	"	"	
"	10,	"	"	"	7	"	5	"	"	"	
"	11,	"	"	"	7	"	5	"	"	"	
"	12,	"	"	"	7	"	6	"	"	"	
"	13,	"	"	"	7	"	2	"	*stopped*	*at low tide.*	
"	15,	"	"	"	7	"	5	"	*running*	*at high tide.*	
"	18,	"	"	"	7	"	3	"	*stopped*	*at low tide.*	
"	21,	"	"	"	7	"	2	"	"	"	
"	22,	"	"	"	7	"	6	"	*running*	*at high tide.*	
"	24,	"	"	"	7	"	6	"	"	"	
"	27,	"	"	"	7	"	6	"	"	"	
"	28,	"	"	"	7	"	6	"	"	"	

I, also, further visited said basins and water-works in the year 1871, *with the result as stated in the following Table:*

Aug. 6, 3 *wheels stopped at low tide, the rest running at half speed.*

"	19,	2	"	"	"
"	22,	6	"	*running*	*at high tide.*
Sept.	4,	6	"	"	"
"	5,	5	"	"	"

It must be remembered that the water in the river was very low all this time, not running over the dam, thus showing that the wheels were running at high tide when the water had the least power, and stopping at low tide, when, if the pumps were in good condition, they had three times the power, but in proportion as they were out of condition, the power would decline.

Continuation of the above statements for the Years 1875 *and* 1876:

1875, *June*	14,	6	*wheels stopped at low tide.*
" "	27,	3	" " "
" *July*	8,	5	" " "
" "	9,	4	" " "
" "	13,	4	" " "
" "	15,	4	" " "
" "	19,	4	" " "
" *Aug.*	20,		*the water 3 feet deep over dam breast.*
" "	20,	2	*wheels stopped, steam engines running.*
" *Sept.*	24,	3	" " *at low tide.*
" "	28,	4	" " "
1876, *Mar.*	24,	2	" " "
1877, *Sept.*	2,	4	" " "
" "	28,	3	" " "

They always had pumping capacity enough to keep the basins full, if the pumping machinery at Fairmount was in even a moderate condition, or if they had pumped one-half of their full capacity.

Below is given the height of the water in the basins at the respective dates:

1875, *June*	24,	*Corinthian*	*basin*	*down*	10	*feet.*		
" *July*	11,	"	"	"	12	"		
" "	12,	*Kensington*	"	"	7	"		
" *Aug.*	18,	"	"	"	7	"		
" "	20,	*Corinthian*	"	"	10	"	4	*inches.*
" *Sept.*	17,	"	"	"	6	"	8	"
" "	30,	*Kensington*	"	"	6	"		
" *Oct.*	19,	*Corinthian*	"	"	12	"		
1876, *Mar.*	1,	"	"	"	5	"	3	"
" *April*	10,	"	"	"	6	"	6	"
" "	11,	*Kensington*	"	"	9	"		
" "	11,	*one-half of the pumps stopped.*						
" "	12,	*Corinthian*	*basin*	*down*	7	*feet.*		
" "	22,	"	"	"	5	"	6	*inches.*

1876, *May* 4, *Corinthian basin down* 5 *feet.*
1877, *Sept.* 2, 4 *wheels stopped at low tide.*
" " 22, 3 " " "

The above statements go to show that they could not have stopped the pumps while the muddy water passed down, as might have readily been done if the basins had been kept full, so as to contain a few days' supply.

Year 1878.	*No. of wheels stopped.*	*Corinthian Basin down.*
July 13,	2	$4\frac{1}{2}$ *feet.*
" 17,	–	4 "
" 21,	–	$5\frac{3}{4}$ "
" 24,	4	$6\frac{1}{2}$ "
" 29,	3	— "
Aug. 2,	2	$4\frac{1}{2}$ "
" 15,	2	$4\frac{1}{2}$ "
" 17,	2	5 "
" 20,	3	$6\frac{1}{2}$ "
" 22,	3	$5\frac{1}{2}$ "
" 27,	4	$5\frac{1}{3}$ "
" 29,	4	$6\frac{1}{4}$ "
Sept. 2,	4	$6\frac{1}{2}$ "
" 4,	3	6 "
" 9,	3	$4\frac{1}{2}$ "
" 14,	2	$5\frac{1}{2}$ "
" 18,	3	6 "
" 22,	2	$4\frac{1}{2}$ "
" 24,	6	6 "
" 26,	3	7 "

J. H.

Your Commission has already commented upon the error of running the wheels at high tide, and stopping them at low tide.

MUDDY DRINKING WATER.

§ 21 "***If the reservoirs should be kept full, and the wheels stopped when the river is muddy, could not the City be generally supplied with clear water?***"

The capacity of all the reservoirs (except the East Park) is 191,778,000 gallons, and, if the city require 50,000,000 registered gallons per day, which is, perhaps, not more than 36,000,000 actual gallons, the required number of days will be 191,778,000 : 36,000,000 = 5.3 days, in which time the muddy water might pass. This, however, implies that all the water should be drawn out from the basins, which is not advisable, but 3 days might be allowed for stopping the pumps. With the aid of the East Park reservoir of 750,000,000 gallons, added to the other reservoirs, there would be 941,778,000 gallons; which could supply the city with water for 10 days, without pumping.

TURBINES AND PUMPS.—PROPER PROPORTION OF DIAMETERS.

§ 22. "***Are the Pumps at Fairmount rightly proportioned to the wheels and head of fall?***"

This simple question, which the Commission answers in the negative, involves an important problem in hydraulics; namely, to prove mathematically: *First.* What is the proper velocity of the water-wheel, or turbine, for utilizing the greatest effect of a given head of fall? *Secondly.* What sized pumps will make the motor run with the most effectual velocity? In order to utilize the greatest possible effect of a waterfall, the velocity of the circle of percussion of the turbine, or water-wheel, must bear a definite proportion to the velocity due to the head of fall.

H = head of fall in feet.

V = velocity, in feet, per second, due to the head of fall.

v = velocity of the circle of percussion in the turbine.

D = diameter of the circle of percussion, in feet; this diameter will afterward be converted into the diameter of the turbine.

n = revolutions per minute of the turbine.

F = motive force in the circle of percussion.

P = power of the turbine in the circle of percussion.

The force acting on a body moving in water, or water moving against a body, is as the square of the velocity of motion. In the case of the water striking the buckets of a turbine-wheel, the velocity of impact is equal to the difference between the velocity V and velocity v, or $V-v$, and, consequently,

Force, $F = (V-v)^2$, 1

Power is the product of force and velocity, or

Power, $P = F v$, 2

Insert for F, its value, formula 1.

Power, $P = v (V-v)^2$, 3

Power, $P = v (V^2 - 2 V v + v^2)$

Power, $P = V^2 v - 2 V v^2 + v^3$, 4

MAXIMUM AND MINIMUM POWER OF TURBINES.

1st. Suppose the turbine to be allowed to spin around as fast as the water can drive it, without doing any work, the water will then flow freely through the wheel without any power being realized from it, and is, therefore, a minimum.

2d. Suppose the work of resistance to be so great, that the water cannot overcome it, but the turbine stands still, and the water run through it without any power being realized, we have another minimum of the wheel.

In both these cases the power of the waterfall is lost; but when the turbine runs with a moderate velocity, and overcomes resistance, power is realized, and there is evidently some action between the first and second case which is a maximum. The power of the turbine, formula 3, depends mainly upon the velocities V and v.

The problem before us is to find the proportion of V and v, when the power P is a maximum; that is, when $\partial P : \partial v = 0$. Differentiate the formula 2, and we have

$$\partial P = V^2 \partial v - 4 \, V v \, \partial v + 3 v^2 \partial v.$$

$$\partial P = \partial v \, (V^2 - 4 \, V v + 3 \, v^2).$$

$$\frac{\partial P}{\partial v} = V^2 - 4 \, V v + 3 v^2 = 0$$

$$3 v^2 - 4 \, V v = - V^2$$

$$v^2 - \frac{4}{3} \, V v = - \frac{V^2}{3}$$

$$v^2 - \frac{4}{3} \, V v + \frac{4}{9} V^2 = \frac{4}{9} V^2 - \frac{V^2}{3}$$

$$v - \frac{2}{3} \, V = \sqrt{\frac{4}{9} \, V^2 - \frac{V^2}{3}} = - \frac{V}{3}$$

Velocity, $$v = \frac{2}{3} V - \frac{V}{3} = \frac{V}{3}$$ 5

That is to say, the velocity of the circle of percussion, in the turbine, should be only one-third of the velocity due to the head of fall H.

Velocity of circle, perc. $$v = \frac{\pi D n}{60},$$ 6

Velocity due to fall, $$V = 8 \sqrt{H},$$ 7

$$\frac{\pi D n}{60} = \frac{8}{3} \sqrt{H}$$

$$D n = \frac{60 \times 8}{3 \times 3.1416} \sqrt{H} = 50.9296 \sqrt{H},$$ 8

This formula must be corrected for the angle of the guiding buckets, about 15° to the wheel.

$$\frac{50.9296}{\text{Cos.}^2\ 15°} = 54.58,$$

The width of the buckets in turbine-wheels, is generally made one-sixth of the diameter, and, if we call $D =$ diameter, in feet, of the wheel, measured over the outside of the buckets, the coefficient will be

$$54.58 \times 1\tfrac{1}{5} = 65.5$$

This coefficient, inserted in formula 8, should give the proper proportion of the revolutions of the turbine to the head of fall, or

$$D n = 65.5 \sqrt{H},$$ 9

This, however, implies that the turbine works only with impact, and without reaction, which is rarely the case; but the area of discharge in the wheel is made smaller than that in the guides. The turbine will then work with both impact and reaction, and the proper revolutions for utilizing the maximum duty will be higher, depending upon the proportion of these areas of discharge.

In the construction of the turbines at Fairmount, Mr. Geyelin has been consulted about these areas, but he could not give the required information, and your Commission is, therefore, unable to determine with precision the proper revolutions in proportion to the head of fall.

In carefully constructed turbines the proportions of these areas varies between 3 to 4, and 8 to 9. Assume the proportion to be as 35 to 45, in the wheels at Fairmount, the coefficient in formula 9 will then be increased 19 per cent., or $65.5 \times 1.19 = 77.945$, say 78. Then we have the proportions

$$D n = 78 \sqrt{H}, \qquad 10$$

Revolutions, $$n = \frac{78}{D} \sqrt{H}, \qquad 11$$

Diameter, $$D = \frac{78}{n} \sqrt{H}, \qquad 12$$

Head of fall, $$H = \left(\frac{D u}{78}\right)^2, \qquad 13$$

These formulas are expected to give a close approximation to the proper proportions of the diameter and revolution of turbines to the head of fall, for utilizing the maximum duty of the waterfall.

Observations were made, September 17, 1878, on the turbines Nos. 3 and 4, making $N = 24$ revolutions under a fall $H = 14$ feet. The diameter of the wheels are $D = 10.25$ feet. Required the proper revolutions.

Formula 11, revolutions, $n = \frac{78}{10.25} \sqrt{14} = 28.4$ per minute.

This is about four revolutions more than actually made; but the circular gate was partly down, so that the wheel did not run with the full head of pressure. With the gate wide open, the revolutions would probably have far exceeded 28 per minute, which indicates that the pumps are too small for these turbines.

The turbines in the new wheel-house, Nos. 7, 8 and 9, are 9 feet in diameter, and made 38 revolutions per minute, under a fall of 14 feet, with the circular gate partly closed. Required the proper revolutions per minute.

$$\text{Formula 11, revolutions, } n = \frac{78}{9}\sqrt{14} = 32.4 \text{ per minute,}$$

This is 6 revolutions less than actually made by the turbine with the gate partly closed, and your Commission is, therefore, convinced that the pumps are too small. This is probably one of the reasons why the present turbines at Fairmount do not pump more water than the old breast-wheels.

PERCENTAGE OF POWER LOST BY RUNNING TURBINES AT IMPROPER SPEEDS.

n = proper revolution of the turbine, calculated from formula 10; that is, for the maximum effect.

$N >$ or $< n$, or any number of revolutions of the turbine greater or less than n.

φ = the fraction of the maximum effect available with N revolutions per minute.

$\%$ = percentage of power lost by improper speed of the turbine.

$$\varphi = \frac{N}{4\,n^3}(3\,n - N)^2, \qquad 13$$

$$\% = 100\,(1 - \varphi), \qquad 14$$

Applying these formulas to the turbine No. 7, at Fairmount, we have given $n = 32.4$ revolutions, and suppose it to make $N = 60$ revolutions when the circular gate is wide open, and the head of fall is, say, 14 feet.

$$\varphi = \frac{60}{4 \times 32.4^3} (3 \times 32.4 - 60)^2 = 0.62$$

Loss of power, $\% = 100\ (1 - 0.62) = 38$ per cent.

This loss of power is not the percentage of the natural effect of the waterfall, but of the duty the turbine would make with the proper revolutions, say 60 per cent. Then, $60 \times 0.62 = 37.2$ per cent., the actual duty of the turbine under the assumed conditions.

Your Commission inclines to believe that the turbines at Fairmount do not exceed this duty.

When the circular gate is closed down to reduce the revolutions to 38, as is actually made, the loss of duty will be much greater than when run with full water.

The proportion of the turbine and pumps should be made right at first, for otherwise the power will be wasted by operating the circular gate.

Your Commission is of opinion that the pumps at the Fairmount Water-Works are much too small. The branch pipes leading from the pumps to the main are rather small, and the suction lap-valve ought to be made circular, like the delivery-valve.

The branch-pipe leading from each pump should be of the same diameter as that of the main; because when the two pumps are connected at right angles to one driving shaft, the velocity of one pump is greatest when the other stands still.

§ 23. DUPLEX ADJUSTABLE TURBINE.

Philadelphia, September 18, 1878.

Dear Sir:—

Enclosed is an article from the "Inquirer," embodying a proposal of Mr. Emil Geyelin to the Philadelphia Water Department, to introduce at Fairmount a Duplex Adjustable Turbine.

Will you have the goodness to call the attention of your Commission on Water Supply to this Duplex Turbine, for a criticism of the same in your Report now in progress?

I am, Yours Respectfully,

John W. Nystrom, Esq. *JAMES HAWORTH.*

[*The Philadelphia Inquirer, Wednesday September* 18, 1878.]

MORE WATER.

Improving the Fairmount Works.

A meeting of the sub-committee of the Committee on Finance and Water, of City Councils, was held yesterday afternoon.

The Chief presented and read the contract entered into with Mr. Emil Geyelin for certain improvements at the Fairmount Water-Works. It is as follows:

I hereby propose to construct and deliver at the Fairmount Water-Works, and erect an additional superstructure for wheel No. 5, as shown in plan, whereby the new work will be entirely disconnected from the wall of the building, and will sustain the gearing without vibration; also a movable and a guide wheel of the duplex pattern, of 10 feet diameter; also a short cylinder, to serve as a seat in the 10 feet diameter cylinder.

The wheel is to be provided with a hood and gate, which gate shall be fitted with automatic motion, secured partly in the upper part of the existing inlet chamber, so as to assist in the opening and closing of the said gate by the fall and rise of the tide. *First.* The ability to run the turbine so as to give twelve strokes to the pumps per minute when the tide is out, whereas now they run so as to give the pumps but eight strokes per minute. *Second.* That by means of the automatic gates acting upon the inner division of the duplex wheel, one-third of the issue of discharge will be retained. Whenever the tide is out, a consequent saving of water will result therefrom, which will become available for pumping purposes.

What I would, therefore, hereby guarantee, as the advantage to be desired by the City of Philadelphia, is an increased capacity for pumping at the Fairmount Works over the greatest amount pumped at present, equal to one and one-half million gallons per day, with the machine at full work, showing no vibrations. The cost of the alterations will be four thousand dollars, and the cost of the erection will be three hundred and sixty dollars. The contractor is to be paid one-fourth of the amount upon the delivery of the material, and one-half the total amount additional upon the starting of the wheels, and the remainder upon the satisfactory performance of the machine, in accordance with the guarantees, after being tested by the Chief Engineer, who is to be the sole judge, both as regards quality of the improvements and the performance of the machine.

The failure of the Chief to disapprove of any part of the machine prior to the test, is not to be considered as an acceptance of the same. The Chief Engineer is to be the sole judge in all cases of dispute. If after the test it is found that the guaranteed improvements have not been made, the contractor must place the machinery in its present condition, to the satisfaction of the Chief Engineer, and refund the money advanced.

On motion of General Wagner, the Committee decided that the alteration was a proper one to be made.

REMARKS UPON THE FOREGOING.

The Duplex Adjustable Turbine, invented and patented by Mr. Emil Geyelin, consists of two concentric wheels on one shaft, with separate guiding buckets to each wheel; so arranged with circular gates, that water is admitted to either one or both the wheels, for accommodating variable motive power, and power of resistance.

By this arrangement, three different powers can be transmitted by the turbine for each constant head of fall. For different heads, the power may be equalized or varied *ad libitum*, within certain limits.

The circular gates regulate the admittance of water to the guides, and are proposed to be operated automatically by rise and fall of the tide-water.

This duplex turbine will, no doubt, be very good for cases where the power of resistance is variable. At Fairmount the power of resistance is constant, or nearly so, for which this duplex turbine is of little utility, as far as regards economy of the water-power.

It is explained that the duplex turbine is suitable for variable head of fall, namely: for a high fall, or when the tide is out, only the inner wheel is used for motive power; for an average head of fall, that is, at mean-tide, the outer wheel is used; and for the minimum fall, that is, when the tide is in, both the wheels are used for motive power.

This will, no doubt, work well for maintaining a nearly uniform velocity of the wheel and pumps, without regard to economy of the water-power.

The second advantage claimed for the Duplex Adjustable Turbine is, "that by means of the automatic gates acting on the inner division of the duplex wheel, one-third of the issue of discharge will be retained. Whenever the tide is out, a consequent saving of water will result therefrom, which will become available for pumping purposes," when the tide is in, of course.

The philosophy of this, is as follows: To save the water at low tide, when it has the greatest power, so as to be able to spend more of it at high tide, when its power is smallest. This is the saving doctrine which has been in operation at Fairmount since the year 1860, of which you have been complaining for the last nine years.

It has been explained (formula 10, page 50) that in order to utilize the greatest percentage of a water-power, the turbines must run with a certain velocity, proportionate to the height of fall.

If the duplex turbine is so constructed as to utilize the best effect with full water on both wheels at high tide, then it will waste water when running at low tide, the time when the power ought to be best utilized. A turbine so constructed will be a repetition of the blunders of 1860 and 1870.

The Duplex Adjustable Turbine, with automatic motion of the circular gates, will answer very well at Fairmount when there is plenty of water in the river; but will not answer for economizing the water-power in the dry season.

The operation of gates for regulating the motion of turbines, is generally accompanied with a loss of power, and conspicuously so in the present case.

Your Commission believes that the best arrangement for utilizing the maximum power in the dry season, is to construct the turbines and pumps so as to run with its greatest effect at the time of mean low tide; that is, for a fall of 14 feet, with the gates wide open.

At Flat Rock dam, where the head of fall is nearly constant, there will be no trouble of constructing turbines for the maximum effect; and no need of the Duplex Adjustable Turbine.

§ 24. WATER-PRESSURE ENGINES.

Your Commission, however, believes that *water-pressure engines* would be much better at Flat Rock than turbines.

Water-pressure engines cost much less than turbines, are less liable to get out of order, simpler in construction, take up less room, less expensive to run, and utilize a much higher percentage of the natural effect of the waterfall.

§ 25. MINIMUM FALL ON TURBINES.

Philadelphia, October 1, 1878.

Mr. John W. Nystrom:

Dear Sir:—

I have read with interest that part of the Report of the Water Commission which treats of the proper velocity of turbines, and the criticism on Geyelin's Duplex Turbine; in which it appears that turbines for Fairmount Water-Works should be constructed for mean low tide, or 14 feet fall. How will a turbine so constructed run at high tide? And what head of fall will just balance the pumping resistance, so that the turbine-wheel will not turn whilst the water runs?

Respectfully Yours,

JAMES HAWORTH.

In answer to your letter of October 1, your Commission submits the following explanation:

H = head of fall for which the turbine is constructed.

V = velocity due to the head H.

h = head of fall at high tide, or when the turbine stops, or cannot run.

V' = velocity due to the head h.

v = proper velocity of the circle of percussion of the turbine, produced by the fall H.

v' = velocity of the circle of percussion, produced by the head of fall h.

F = motive force acting in the circle of percussion to turn the turbine.

The weight of the column of water elevated into the reservoir, is practically the same for different speeds of the turbine, for the small difference of head, caused by variable velocity, can, without detriment, be omitted in this particular case. The force F must balance this head of water.

From formula 1, § 22 we have:

$$F = (V - v)^2 = (V' - v')^2, \quad \text{or,} \quad V - v = V' - v'.$$

Formula 5, same paragraph, gives:

$$V = 3\,v, \text{ or, } v = \frac{V}{3}, \text{ then, } V - v = V - \frac{V}{3} = \tfrac{2}{3}\,V.$$

$$\tfrac{2}{3}\,V = V' - v', \qquad \text{and} \qquad v' = V' - \tfrac{2}{3}\,V. \qquad 1$$

$$\text{Velocity,} \qquad V = 8\sqrt{H}, \quad \text{and} \quad V' = 8\sqrt{h}.$$

$$\text{Velocity of Turbine,} \qquad v' = 8\,(\sqrt{h} - \tfrac{2}{3}\sqrt{H}.) \qquad 2$$

The formula 2 will answer your first question: "How will the turbines run at high tide?"

For high tide, the head of fall is, $h = 9$ feet.

For mean low tide, . . $H = 14$ "

Velocity, $v' = 8\,(\sqrt{9} - \tfrac{2}{3}\sqrt{14}) = 4.376$ feet per second.

$$v' = \frac{\pi\,D\,n}{60}. \qquad n = \frac{60\,v'}{\pi\,D}.$$

The diameter of the circle of percussion in the turbines Nos. 7, 8 and 9, is $D = 7.5$ feet.

Revolutions of turbine, $n = \dfrac{60 \times 4.376}{3.14 \times 7.5} = 11.15$ per min.

The second question will also be answered by formula 2, in which $v' = 0$.

$$8\sqrt{h} = \tfrac{2}{3} \times 8\sqrt{H}.$$

$$24\sqrt{h} = 16\sqrt{H}.$$

$$3\sqrt{h} = 2\sqrt{H}.$$

$$9\,h = 4\,H.$$

Head of fall, $h = \frac{4}{9}\,H.$ 3.

" $h = \frac{4}{9} \times 14 = 6.22$ feet.

That is to say, when the dam is drawn down so as to make the head of fall only 6.22 feet, the turbine will stop and the water run through it.

When the turbine is constructed to run with its greatest effect at high tide, or head of fall, $H = 9$ feet; it will stop running with a head $h = \frac{4}{9} \times 9 = 4$ feet.

§ 26. LOW WATER IN THE SCHUYLKILL

Philadelphia, October 5, 1878.

Mr. John W. Nystrom,

Chairman of Water Commission.

Sir:—The Chief Engineer of the Water Department has written a letter to Hon. Mayor Stokley, stating that the water is so low in the river that he can run only the small turbines half the time, for which extraordinary saving of water is required in the city.

I desire your Commission to examine this.

Respectfully,

JAMES HAWORTH.

The water was up to the top of, and even running over the flash-board, on the 5th of October. The true difficulty about supplying sufficient water is, that two of the largest new steam-pumping engines have broken down, and are, consequently, not working. The capacity of these two engines is over 25,000,000 gallons per 24 hours.

THE OLD BREAST-WHEELS PREFERRED.

§ 27 "*I approve of the breast-wheels in place of the turbines. I would put the wheels two feet lower, and make them smaller than the old wheels, with two pumps at right angles on each wheel. To run only 7 hours and stop 5 hours in each tide. A small water-motor for operating the gates. Would not this be expedient?*"

A breast-wheel, like the old ones at Fairmount, transmits about 60 per cent. of the natural effect of the waterfall.

A well-constructed turbine transmits about 70 per cent. of the natural effect.

At Fairmount the turbine has the advantage over the water-wheel, that it utilizes the whole head of the fall at different heights of the tide, which the breast-wheel does not.

However well a turbine may be constructed, if not properly proportioned to the height of the waterfall, and to the power of resistance, it may utilize a much smaller percentage of the natural effect than does a breast-wheel; which is actually the case at Fairmount, as has been heretofore explained.

The cost and repair of turbines, such as used at Fairmount, are about 30 per cent. greater than those of breast-wheels. One great disadvantage with the breast-wheels was their interruption by ice in the winter time; and the turbines were preferred for that express reason.

The water-works at Fairmount were built in 1820–22, by Frederick Graff, father of the late Chief Engineer Graff, and is yet a masterpiece of engineering skill; only one of the old breast-wheels remains, the others being replaced by turbines.

The old breast-wheels had each only one double-acting pump, of 16 inches in diameter, and 54 inches stroke, making about 14 revolutions per minute.

Two pumps coupled at right angles to each wheel, would have increased the pumpage about 41 per cent., with the same water-power.

When the water is low in the river, it is no doubt best to run the wheels about 7 hours during low tide, and stop them 5 hours during high tide.

A small water-motor, for operating the gates, would no doubt be very good. The present gates, operated by hand, require three men, for about half an hour, to open them.

COST OF STEAM PUMPING.

§ 28. ***"How much money has been expended on Steam Pumping up to this time, when water-power could have been employed without any cost?"***

The first steam engine erected on the Schuylkill, about the year 1800, cost $6000 per year in running expenses. The centre-square engine raised the annual expenses for steam pumping to $13,807; from which time the running expenses increased, on an average, $670 per year, until the year 1860, when the yearly running expenses were $40,550.96. The whole amount expended up to that time, was $1,448,950, for running expenses only. From the 1st of January, 1860, to the 1st of January, 1878, $1,618,634.23 has been spent in running the steam-power.

The 24th Ward Steam Pumping Works, started in 1855, and abandoned in 1870, cost $360,000.

TABLE IX.

Expenses for Steam and Water-Power.

	Cost of Steam Power.		Cost of Water-Power.	
For 18 years.	Yearly Running Expenses	Average Water Pumped per 24 hours.	Yearly running Expenses.	Average Water Pumped per 24 hours.
Years.	Dollars	Gallons.	Dollars.	Gallons.
1860	40,552.96	10,514,688	6,295.66	9,867,378
1861	41,712.07	10,587,099	6,207.98	10,224,070
1862	50,868.26	11,967,565	7,629.93	9,766,369
1863	57,103.47	10,717,980	9,079.18	15,306,060
1864	87,818.51	9,136,516	14,797.86	16,358,360
1865	94,846.04	10,878,228	16,669.65	19,402,791
1866	82,413.58	10,519,209	15,541.54	21,155,664
1867	57,999.05	11,847,595	17,572.82	21,951,694
1868	67,016.99	11,235,835	15,072.83	21,929,053
1869	92,017.40	13,648,596	16,487.56	20,519,482
1870	99,086.99	16,160,029	15,775.06	22,253,212
1871	88,609.87	13,433,097	12,229.96	24,195,782
1872	106,082.49	19,685,812	13,879.90	19,892,776
1873	102,933.79	16,199,155	17,543.91	24,077,029
1674	127,268.75	20,606,994	17,305.45	21,504,736
1875	139,224.09	26,628,017	15,981.05	21,013,724
1876	155,894.63	24,842,213	17,505.36	22,899,066
1877	127,784.29	22,967,973	26,234.90	26,015,985
18 yr.	1,618,634.23	271,574,581	261,880.60	348,353,211

Steam-power cost \$16.30, and water-power \$2.06 per million gallons pumped. Allowing for 55 per cent greater height pumped by the steam, the proportion will be \$10.50 : \$2.06 = 5.1, that is, steam-power cost 5.1 times as much as water-power.

The question before us, however, implies the cost of that much of steam pumping which could have been accomplished with the water-power at Fairmount utilized to its full capacity. It is not definitely known how many gallons are consumed at Fairmount for pumping one into the reservoir, but under the present condition of the pumps, 22½ gallons are probably required. With proper proportions of the pumps and wheels, 13 gallons ought to be sufficient.

The average height to which the steam-power pumps the water, is 55 per cent. greater than that at Fairmount. The full capacity of the Fairmount Water-Works is 35,000,000 gallons daily, and allowing for one turbine to be continually under repair, the maximum capacity may be set down at 30,000,000. In the W. D. Report for 1877, it appears that an average of 30,000,000 was pumped in October, and the average for the whole year is 26,000,000 gallons pumped per day. If this Report is correct, a very small portion of the steam pumping could have been accomplished with the present water-power at Fairmount. When the dam is low, the turbines should run only at low tide, for economizing the water, when only 66 per cent. of the maximum capacity can be relied upon. From Table VIII we find that the water-works are stopped about 20 per cent. of the time, and also that they are stopped during the times of plenty of water in the river, when the full water-power ought to have been used. The reason given for the stoppage is, "For high or low water, or full reservoir." It is not stated whether the "high or low water" means in the dam or of tide-water, but, in either case, the works should not stop for high water on the dam, nor for low tide-water, which are the circumstances under which the works are most powerful.

To stop the pumping by reason of the reservoir being full, would indicate that the works are too large for the demand; but there is a main, 30 inches diameter and 6 feet head, connecting the Corinthian and Delaware basins, through which Kensington could be supplied with purer water by the surplus power at Fairmount, and thus save much of the expensive steam pumping.

Table X shows the average daily pumpage, by water and steam, for each month in four years; and, it will be observed, that in the winter, when the river is full, the minimum quantity of water has been pumped by the Fairmount Water-Works; whilst in the summer, when the river is lowest, the maximum quantity has been pumped.

If the works had been run with their full capacity the whole year, it would have saved a great deal of money to the city, expended on unnecessary steam pumping.

In the last two years, 1876 and 77, the Fairmount Water-Works have been run with some better regard for economy.

Your Commission cannot ascertain, with correctness, the whole amount of money uselessly wasted on steam pumping.

TABLE X.

AVERAGE DAILY PUMPAGE BY WATER AND STEAM FOR EACH MONTH IN 4 YEARS

	1860.		1865.		1870.		1875.	
	WATER POWER.	STEAM POWER.	WATER POWER.	STEAM POWER.	WATER POWER.	STEAM POWER.	WATER POWER.	STEAM POWER.
	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
January	8,171,185	8,364,060	13,508,602	4,395,541	15,087,023	11,542,169	18,984,114	13,742,282
February	7,930,578	7,290,276	17.094,818	4,425,218	17,804,775	11,573,200	21,426,336	14,784,240
March	8,951,307	9,126,612	18,385,808	6,233,679	15,444,033	13,232,483	21,316,976	16,036,848
April	10,481,658	9,991,546	20,139,024	6,015,531	23,238,604	13,216,256	23,018,286	15,484,921
May	8,926,005	10,281,283	19,363,967	9,417,051	23,735,175	13,710,193	24,396,026	23,366,171
June	11,189,517	11,535,779	23,593,453	15,792,891	24,417,463	16,252,278	20,650,366	30,599,551
July	12,446,775	14,718,875	20,798,382	16,000,223	26,191,619	19,817,116	14,326,853	35,582,484
August	11,786,307	13,975,347	23,923,115	15,203,729	27,206,145	16,457,042	25,909,418	21,684,301
September	11,419,237	12,726,510	21,988,214	15,901,787	16,062,014	25,043,293	17,160,412	28,164,174
October	10,650,200	11,072,303	21,514,862	13,716,072	25,454,561	15,390,982	18,363,695	27,329,328
November	8,724,030	9,878,690	19,683,975	10,336,413	26,088,477	13,792,512	23,742,940	19,604,593
December	7,731,735	7,674,985	13,907,223	12,560,732	26,306,015	8,729,186	22,925,877	14,500,803
Average	9,867,378	10,514,688	19,402,791	10,892,741	22,253,242	14,996,143	21,013,724	26,626,017

EX-CHIEF ENGINEER BERKINBINE; AND HIS PAPER READ BEFORE THE FRANKLIN INSTITUTE.

§ 29. "*In a paper read before the Franklin Institute, May 15, 1878, by Henry P. M. Berkiubine, (late Chief Engineer of the Water Department,) it is stated that the minimum daily average flow of the Schuylkill river is nearly 1,665,000,000 gallons. This amount is nearly 1,000,000,000 less than the actual average flow.*

About the year 1865, Mr. Berkinbine, being then in office, made a survey of the Schuylkill water-shed, and found it contained 1942 square miles. The average rainfall for the last twenty years, has been found to be about 45 inches.

This rainfall would amount to, within a small fraction, 800,000,000 gallons on every square mile; of which 60 per cent. can be utilized. This amount of rainfall on 1942 square miles, would yield a daily average flow of the Schuylkill river, throughout the year, of 2,500,000,000 gallons, which could be utilized for water-power; and this amount, as above stated, is only 60 per cent. of the rainfall."

In his Report for the year 1865, Mr. Berkiubiue says:

"*In the old wheel-house there are eight double-acting pumps, sixteen inches in diameter, propelled by breast-wheels, and one by a turbine-wheel. In the new wheel-house there are six double-acting pumps, eighteen inches in diameter, propelled by turbines. The full capacity of both these works, at ordinary stages of the river, is 28,000,000 gallons per day.*"

In the table of Operation at Fairmount Works during 1865, we find the number of gallons (by register) pumped per day ran down to the amount of only 13,508,602 gallons in January; and to 13,907,223 in December, when the river was full.

Why did not Mr. Berkinbine pump the 28,000,000 gallons during the remaining eight months, when the river was full, instead of employing steam-power to pump 14,000,000 gallons, at a cost of $20 per 1,000,000 gallons, when it could have been pumped by water-power for nothing?"

Your Commission cannot answer that question; but by examining the W. D. Reports, it is found that steam-power is invariably employed, whilst water-power is wasted, at Fairmount.

The average daily pumpage by Mr. Berkinbine was about 15,000,000 gallons, with the three turbines in the new wheel-house, the old breast-wheels and the small turbine, the theoretical capacity of which was 28,636,000 gallons. The same has occurred both before and since, as appears by table X.

§ 30 ***Mr. Berkinbine says, "The arrangement of the machinery of 1870, is simply a repetition of the defects of the apparatus of 1860."***

"Was not the defective apparatus of 1860, approved by, and erected at Fairmount under the supervision and knowledge of Mr. Berkinbine?"

Yes, that appears to be the case, because he was Chief Engineer of the Water Department at that time. In the same address, Mr. Berkinbine says, "The turbine wheels and pumps, figs. 1 and 2, put in the works in 1860, were under my own supervision, but are not now satisfactory to me."

These are the turbines Nos. 7, 8 and 9 in the new wheel-house at Fairmount, and correspond to the illustrations given below.

§ 31. ***Mr. Berkinbine says, "With properly arranged and managed machinery, a daily average of 35,000,000 gallons could be pumped at Fairmount."***

"Why did he not pump that proportionate amount when he had the management of the machinery he had himself approved? How can he accomplish that pumping now?"

Mr. Berkinbine did not say in his address to the Franklin Institute, why he did not accomplish what he said could be done; nor did he give any data for elucidating or removing the alleged defects.

Your Commission believes that 35,000,000 gallons or more, can be pumped per day with the present turbines at Fairmount, if the pumps were made larger or the gearing redueed, so as to make the present pumps run faster in proportion to the wheels.

§ 32. ***Mr. Berkinbine says, " The wheels now in these works can absorb more than the average flow of the river. Little can, therefore, be gained by increasing the number of wheels." Can that be so?***

No. Mr. Berkinbine underestimates considerably the flow of the Schuylkill River.

Two new turbines for Nos. 2 and 6, and by altering the pumps in Nos. 3, 4, 5, 7, 8 and 9, would probably double the aetual pumping capacity at Fairmount.

INCREASE OF COST OF PUMPING WITH WATER-POWER.

§ 33. ***"In the W. D. Report for 1877, it appears that the pumpage at Fairmount has exceeded that of any other year, but the expense per million gallons is greater than that in any other year. Should not an increased pumpage cause a decrease in cost per million gallons pumped?"***

The cost per million gallons pumped at Fairmount should certainly deerease with the inerease of pumpage, and *vice versa,* when only the running expenses are considered.

SMALL PUMPAGE AT FAIRMOUNT.

§ 34. ***" The average pumpage per day at Fairmount in 1872, was only 19,898,776 gallons, the last three new wheels and six of the largest pumps having just been put in; and all at work in perfect order. Why was that pumpage so small?"***

Your Commission cannot answer that question.

COST OF STEAM AND WATER-POWER.

§ 35 ***Mr. Berkinbine says, "That steam-power is cheaper than water-power." Is that so?***

No; water-power is cheaper than steam-power, which is a well-known fact.

The Manufacturers at Manayunk who pay $43,100 rent for 1000 horse-power of water annually, find it cheaper than steam-power.

The less water pumped at Fairmount, the more expensive will it be per million gallons, because the interest on plant and running expenses are nearly the same, or independent of the quantity pumped. The extravagant misuse of the water-power at Fairmount more than doubles the expense of its pumpage.

TWENTY-FOURTH WARD STEAM PUMPING WORKS.

36. ***"What was the cost per million gallons pumped into the standpipe by the abandoned Twenty-fourth Ward Works, with and without interest on plant. How long were these works in operation?"***

The Twenty-fourth Ward Steam Works were first started in the year 1855, and abandoned in the year 1870.

When started, they cost $360,000, and, according to the W. D. Report of 1860, 283,646,000 gallons were pumped with $6,086.87 running expenses that year, which makes the cost of pumping $21.46 per million gallons. Six per cent. interest on $360,000 is $21,600; with which the cost of pumping will be $97.60 per million gallons.

These works had been in operation only fifteen years when abandoned.

Original cost of the Works, . .	$360,000
Six per cent. interest for fifteen years,	324,000
Running expenses " .	91,303
Total,	$775,303

During the fifteen years operation, these works pumped 4,254,791,000 gallons into the standpipe, which makes the cost $182.22 per million gallons pumped.

In calculating the expenses of supplying West Philadelphia with water, the cost of the first Twenty-fourth Ward Works should be added to that of the Belmont Works, in order to make a fair comparison with the cost of water-power at Fairmount.

§ 37. WATER FAMINE.

Philadelphia, Nov. 16, 1878.

John W. Nystrom, Esq.

Dear Sir:

Enclosed is an article cut from to-day's "Record," which indicates fears of a water famine.

I beg you to submit this article to the consideration of your Water Commission, for a criticism on the same in your Report now in progress.

I am, Yours Respectfully,

JAMES HAWORTH.

[*From the Public Record.*]

FEARS OF A WATER FAMINE.

TWO PUMPING ENGINES DISABLED, AND THE SCHUYLKILL VERY LOW.

Chief Engineer Dr. McFadden, of the Water Department, was not in his best humor yesterday. The cause of this was that there promises to be a scarcity of water next summer. The six million gallon Worthington engine at the Delaware works broke down on Tuesday, and on Thursday the ten million gallon Simpson engine at the Spring Garden works was disabled. Thus a pumping capacity of 16,000,000 gallons per day suddenly ceased in the course of one week. Added to this, the water in the Schuylkill has become unprecedentedly low.

"Lower, in fact," said Dr. McFadden, "than has ever been known at this season of the year. On Thursday I telegraphed to Mr. Smith, the consulting engineer of the Philadelphia and Reading Railroad, who has charge of the Schuylkill canal, asking him to open some of the locks and allow the water to come down the river, as we feared that our supply would run short. To-day I received his reply, which does not give much consolation:

"'We have no surplus in any of our dams. Our flash-boards were all displaced in October. Our trade is heavy, and we have hardly water enough to accommodate it. Our reservoir is only half full, and we are drawing on it to supply the upper river. The river at Flat Rock is not far from a double minimum flow. If I notice by our reports to-morrow that Fairmount is falling I will try to fill it up so far as I can with safety.'"

"Now, the trouble is just here," said Chief Engineer McFadden; "there has not been a soaking rain since the 15th of May, and consequently the river is running dry. We are just holding our own. I cannot tell when the engine at the Delaware River Works will be ready. For the present, the people in that section receive their supply from the Corinthian basin. The constant strain upon the machinery has resulted in its breaking down. We have not had time to clean or repair our machinery for a year. It is fortunate this did not occur in the summer. When I asked Councils for an extra appropriation for boilers at Belmont, the cry was raised, 'Job, job!' If an accident should occur there at the present time, the people would have it brought home to them that something else should have been done than to raise such a foolish cry."

REMARKS ON THE ABOVE.

Your Commission visited the Delaware and Schuylkill Water-Works to examine the extent of breakage of the pumping engines, and found that the Worthington engine at Kensington had not broken down, but, as we were informed, the slide-valve seat had worn so as to leak, and the engine stopped on that account. It is possible that the valve-seat had been thus injured for want of proper lubrication. The slide-valve was, however, soon made tight, and the engine started.

After concluding the experiment at Belmont, November 16, your Commission went to the Schuylkill or Spring Garden Works, to examine the supposed broken-down Simpson engine, and, to their surprise, found it working at full speed. They were informed the engine was stopped a few hours the day before, to tighten up a key, and started the same day at 5 o'clock P.M.

Your Commission can see no indication of a water famine.

ACTUAL PERFORMANCE AT FAIRMOUNT.

§ 38. "***What is the number of gallons actually employed at Fairmount by the old wheels, and by the present turbines, respectively, for pumping one gallon 105 feet high; also, the relative cost of plant and repairs?***"

For the solution of this problem, application was made to the Chief Engineer of the Water Department, for permission to measure the quantity of water consumed by the wheels, and pumped thereby into the reservoir, viz:

1010 Spruce Street,
Philadelphia, August 22, 1878.

Dr. William H. McFadden,
Chief Engineer Water Department.

Sir:—Mr. James Haworth has engaged two associates and myself to investigate the water-supply of Philadelphia, in view of its future improvement.

The Commission desires to make some measurements at the Fairmount Water-Works, for determining its actual efficiency, and ask your permission to do so without interfering with the operation of said works.

I would also ask if you will be kind enough to appoint one of your Assistant Engineers to join the Commission.

Yours Respectfully,

JOHN W. NYSTROM.

WATER DEPARTMENT,
PHILADELPHIA, September 4, 1878.

JOHN W. NYSTROM.

DEAR SIR:—It is customary for gentlemen seeking the courtesy of the Department to make the request in writing, and state the purpose and object.

If you, as the agent, will furnish the request, and the purpose of your authority, I will submit it to the Committee, and recommend their approval. While my Assistant at your request would accompany you, there would be a delicacy in receiving pay for such services. I have, however, consulted Mr. E. Geyelin, who will accompany and give all the facts which he, as the builder, constructor and engineer of the machinery, is fully capable of doing.

At our earliest convenience we will send you the map, and a copy of the Report for 1877.

Yours Respectfully,

W. H. McFADDEN.

PHILADELPHIA, September 5, 1878.

DR. WILLIAM H. McFADDEN,
Chief Engineer Water Department.

SIR:—Your favor of yesterday is received with thanks.

The object of the Commission appointed by Mr. James Haworth to examine the water-supply of Philadelphia, is to find out, if possible, if any improvements can be made therein. With that object in view, Mr. Haworth has propounded some questions, the most important of which is, "How many gallons of water are actually consumed at Fairmount for pumping one into the reservoirs?"

With your permission to make some measurements and experiments, without interfering with the operation of the waterworks, the Commission can answer that question correctly.

In case the required permission is granted, you are hereby respectfully requested to appoint an Assistant Engineer of the

Water Department to witness the measurements and experiments, on condition that said Engineer shall receive no pay therefor, or favor whatever, over his regular salary in the Water Department.

Your early answer, with the required permission, is earnestly craved.

Very Respectfully,

JOHN W. NYSTROM.

PHILADELPHIA, September 30, 1878.

DR. WILLIAM H. MCFADDEN,
Chief Engineer Water Department.

SIR:—Your attention is respectfully invited to the consideration of my letter to you, dated September 5, asking permission to make some measurements, &c., at Fairmount, which letter yet remains unanswered.

Very Respectfully,

JOHN W. NYSTROM.

WATER DEPARTMENT.
PHILADELPHIA, September 30, 1878.

JOHN W. NYSTROM.

MY DEAR SIR:—Yours of 30th to hand, and will be submitted to the Committee on to-morrow afternoon, at 3 o'clock, when I would be pleased to have your Committee present with a letter of request from your authority, Mr. Haworth, stating your object and purpose, as per my answer to yours of September 5, 1878.

Yours, Very Respectfully,

WM. H. MCFADDEN,
Chief Engineer Water Department.

The Committee on Water.—A meeting of the Committee on Water, of Councils, was held Tuesday, October 1, 1878; Mr. Charles Thompson Jones, chairman, presiding.

The following letter was read by the clerk:

Philadelphia, October 1, 1878.

To Dr. Wm. H. McFadden,
Chief Engineer:

Dear Sir:—The bearer of this, Mr. John W. Nystrom, is chairman of a Commission appointed by me for the purpose of investigating the water-supply of Philadelphia, the object of which has been explained in his application for permission to make some measurements and experiments at Fairmount. The Commission consists of John W. Nystrom, W. B. Le Van and William Dennison. I respectfully request that you will permit the necessary facilities to the Commission for the accomplishment of its important purpose.

Respectfully Yours,

JAMES HAWORTH.

Mr. Bardsley moved that the permission asked for be granted, under such restrictions as the Chief Engineer may deem proper.

Mr. Jones, Chairman, desired to know whether the proposed investigation would be made in the interest of an organization which are trying to obtain the passage of measures looking to a utilization of the water of the Schuylkill river above Fairmount dam.

Mr. Nystrom replied, that he knew nothing of such an organization; but the proposed investigation was simply scientific in its character.

Question.—What benefit would such an investigation be to the city, and to the Water Department?

Mr. Nystrom answered, that it would reveal the actual operation of the works, and that there has never been a thorough scientific and technical investigation made of the present water-works at Fairmount.

Mr. Jones asked: "How do you know that such an investigation has never been made?" To which Mr. Nystrom replied, that there is nothing of the kind on record in the W. D. Reports.

The Chief Engineer, McFadden, maintained that the Commission of Engineers of 1875 made an exhaustive investigation of the Fairmount works; and, after a long argument in relation to the different systems into which the water-supply of Philadelphia is divided, Mr. Bardsley's motion was finally agreed to.

The Chief Engineer then offered to give all facility and aid in his power to your Commission, and he gave orders to that effect to the Superintendent and Engineers at the Fairmount works; which orders were kindly and cheerfully complied with. All information required about the works was promptly and sincerely given.

THE LOG, FOR MEASURING THE WATER AND DUTY OF THE TURBINES.

This instrument is constructed upon the same principle as the *marine log*, only that the propeller is much larger in diameter, and the clock-work geared to indicate feet instead of miles.

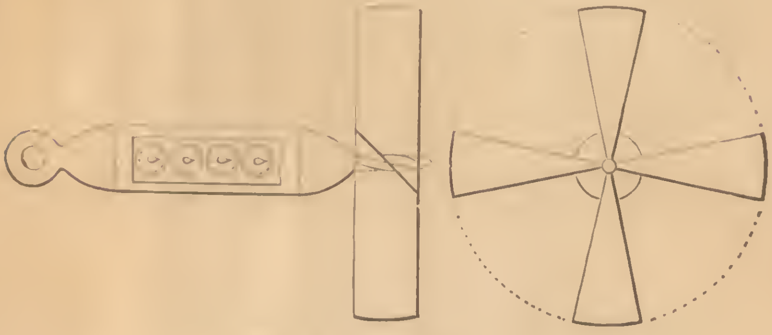
The accompanying illustration represents the log, consisting principally of a propeller, which is set in rotation by the current of water in which it is immersed.

An endless screw, on the end of the propeller shaft, sets the clock-work in motion in the casing, and the number of feet of current passing the propeller is indicated by hands on the dials.

The log has four dials, decimally divided, so that each division on the first dial from the propeller represents 10 feet, on the second 100, on the third 1000, and on the fourth 10,000 feet.

Thus, with the four dials, 100,000 feet can be indicated. A sleeve covers the dials when the log is operating, to prevent solid matter in the water from interfering with the hands and settling in the instrument.

Two of these instruments were constructed expressly for measuring the water at Fairmount, and other water-works, by your Commission.



Scale, 2 inches to the Foot.

The number read on the dials, multiplied by 1.14, is the space in feet, which multiplied by the area of cross-section in square feet of the current, gives the cubic feet of water that has passed the log. Both instruments have propellers of equal pitch, and the same proportion of gearing in the clock-works.

Both were tried in the same current of water, and the coefficient, 1.14, established by experiments.

JONVAL TURBINE AT FAIRMOUNT.

The following illustrations, figures 1 and 2, represent a side elevation and cross-section of the Jonval turbine, as constructed by Emil Geyelin, and erected in the new wheel-house at Fairmount.

The flume, leading from the forebay to the turbine, is made of wrought iron, and is elliptical, 7′ by 12′ 9″ diameters. For the larger turbine, in the old wheel-house, the cross-section of the flume is rectangular.

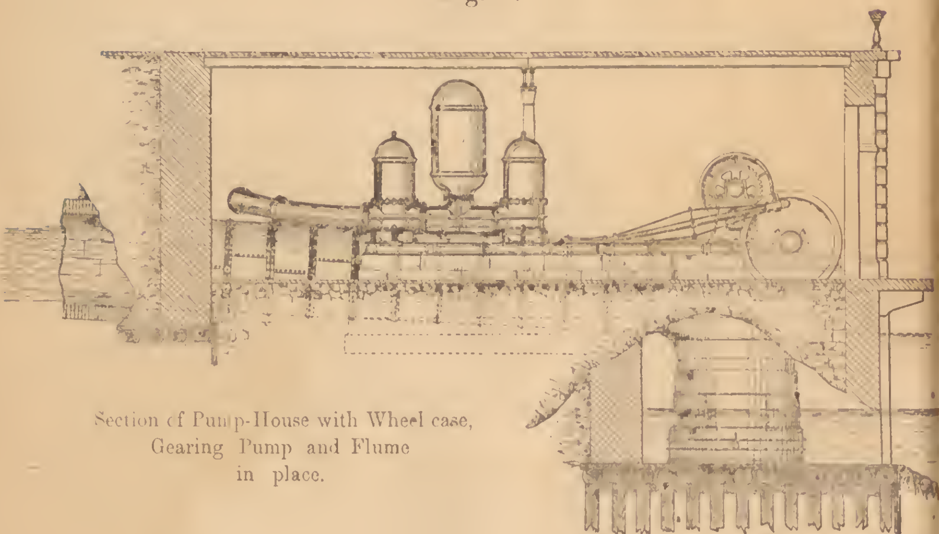
In the experiments made by your Commission on these turbines, the log was placed in the flume, a little on one side, and also above the middle, where the mean velocity of the current was expected to be.

In the years 1859 and 1860, experiments with different kinds of turbines were made by the Water Department, under the supervision of Mr. Berkinbine, then Chief Engineer.

The duty obtained by these experiments varied between 53 and 87 per cent.; the highest being given by the Jonval turbines, namely, the Geyelin Jonval 82, and Stevenson Jonval 87, and the lowest only 53 per cent., by the Monroe and Bartlett turbine.

Although the Geyelin turbine was the second best in duty, it was considered to have many practical advantages over the others, and was therefore adopted for the Fairmount Water-Works.

Fig. 1.



Section of Pump-House with Wheel case, Gearing Pump and Flume in place.

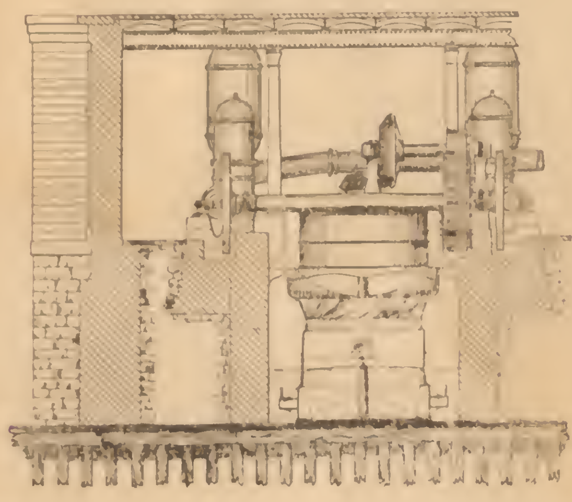
The illustrations are kindly furnished by Mr. Berkinbine.

The most important feature of a turbine is its duty percentage, but it appears that no such feature was required by the contract for building said turbines; nor was any experiment made to find out the same. Also, in his late proposition to the City Councils to furnish a duplex turbine, Mr. Geyelin does not bind himself to any percentage duty of the same.

PRELIMINARY DUTY EXPERIMENT.

The Commission met at Fairmount, October 17, 1878, at 9 o'clock A.M., fully prepared for making experiments on all the wheels; but the Chief Engineer of the Water Department would not allow the turbines in the old wheel-house to run, on account of scarcity of water in the dam. Only the two wheels Nos. 8 and 9, which are the most economical, were running; the wheels Nos. 3, 4 and 5 being too extravagant on water.

Fig. 2.



Transverse Section of Pump-House, with Turbine Gearing and Pumps. The lower part of Wheel Case shown in Section, exhibiting Guide-Cams, Wheel and Gate.

Experiments were made by the wheel No. 9, which was found to use 720,468 cubic feet of water per hour, and pumped 25,570 cubic feet, in the same time, into the Corinthian basin, 115 feet high, which is 28 to 1, or, in other words, it required 28 gallons to pump 1 into that reservoir.

In this experiment, the log was placed outside the grating in the archway leading from the forebay to the turbine, by which only the water used for motive-power was measured.

The pumpage was taken from the register, which showed a difference of 716 revolutions during the hour of experiment, and leakage assumed to be 20 per cent.

The pumps made 12 double strokes, and the turbine 33.3 revolutions per minute. The natural effect was 307, and the realized, 92.7 horse-power, or 30.3 per cent. of the natural effect.

The head of fall was 13.5 feet average, and the circular gate partly down to prevent the wheel running too fast.

N. B.—In the above calculation, it is assumed that the leakage was only 20 per cent.; but subsequent experiment proved it to be 25 per cent., as will appear hereafter.

DUTY EXPERIMENTS AT THE FAIRMOUNT WATER-WORKS, OCTOBER 24, 1878.

The first regular experiment was made with turbine No. 4, by placing one log in the flume leading to the turbine, where the section area was 82.58 square feet; and the other log in the outlet of the main into the basin, 3 feet in diameter, or 7.068 square feet section.

The wheel was started at 11 o'clock, and observations taken for every 10 minutes, as shown in the following Table XI.

Stopped at 12 o'clock, when the register showed a difference of 555 revolutions for one hour; the log in the basin showed 3395, and that in the flume 11,169. The proportion of water used by the turbine to that pumped into the basin, will then be

$$11{,}169 \times 82.58 : 3395 \times 7.068 = 38.6 : 1.$$

That is, the turbine requires 38.6 gallons for each gallon pumped into the reservoir 90 feet high, or 45 gallons to pump to a height of 105 feet, and utilizes 22.5 per cent of the natural effect.

For the second experiment, Table XII, the log in the basin gave 3135, and that in the flume 9911, from which the proportion will be

$$9911 \times 82.58 : 3135 \times 7.068 = 37 : 1.$$

That is, the turbine requires 37 gallons for each gallon pumped into the reservoir.

It will be noticed that it requires 38.6 gallons at high tide, and 37 at low tide, to pump one gallon into the reservoir. The head of fall at high and low tides is, respectively, 10.45 and 16.92 feet, and the lift into the reservoir is 90 feet. 90 : 10.42 = 8.6 gallons, and 90 : 16.92 = 5.3 gallons, the theoretical value of pumping one gallon into the reservoir.

The theoretical capacity of the two pumps, 22 inches diameter and 72 inches stroke, with 5 inch piston-rod, is 61.718 cubic feet for each double stroke or revolution, which is equal to 461.68 gallons.

When the pumps make 9.25 double strokes per minute, the leakage is 20 per cent., or 12.34 cubic feet for each revolution, or 114 cubic feet per minute. The pumps will then deliver 49.37 cubic feet of water into the reservoir for each revolution.

The duty realized by the turbine No. 4, is only 22.5 per cent. at high tide, and 14.2 per cent. at low tide, of the natural effect. The reason why the turbine gives the the smallest percentage at the highest head of fall, is that it is constructed to run with the greatest advantage at high tide.

At low tide, the discharge is contracted by the circular gate, to prevent the turbine from running too fast, and the water thus passes under the gate with a force and velocity many times greater than the power utilized by the turbine.

As regards economy of water-power, it makes very little difference if the turbines Nos. 3, 4 and 5, run at high or low tide.

DUTY EXPERIMENTS WITH TURBINE NO. 7, OCT. 26, 1878.

The turbine No. 7 is in the new wheel-house, and is smaller than those in the old house; its pumpage can be led either into the Fairmount or the Corinthian basin, with that of the turbines Nos. 5, 8 and 9, but cannot be led alone into them whilst the others are running. The delivery into the Corinthian basin could not, therefore, be measured by the log for one turbine separately, except by stopping the others, which your Commission then had no authority to do.

The water consumed by the turbine was measured by a log in the flume, which gave 14,491 × 78 square feet × 1.14 = 1,174,539.72 cubic feet, which pumped 30,446.64 cubic feet into the reservoirs, by 882 revolutions in two hours. This is a consumption of 38.6 gallons for pumping one into the reservoir.

It was expected that the water pumped by this experiment was to go into the Corinthian basin, and, after having run for half an hour, it was found that the revolution had suddenly increased, and by inquiring for the cause of the same, your Commission learned that the stop-valve to the Fairmount basin had been opened, which operation was not in the programme. It, however, turned out to the advantage of showing that the turbine gives a higher duty by pumping into the Corinthian basin, as seen in Table XIII.

The theoretical capacity of the two pumps, 18 inches diameter and 6 feet stroke, for one revolution is, .	43.15	cubic feet.
Pumpage for each revolution, . . .	34.52	"
Leakage, assumed to be 20 per cent., .	8.63	"

The programme of this experiment was to start at high tide, and observe how the revolutions increase with the fall of tide, and how the duty is affected thereby; the result of which reveals what has been anticipated, namely, that the turbines at Fairmount are very extravagent on motive-power.

The Commission of Engineers (1875) assumed the duty of the Fairmount turbines to be 60 per cent. of the natural effect, and says: "Under favorable circumstances 80 per cent. can be realized, and 75 per cent. ought to be obtained, when flash-boards can be used on the dam, and the wheels run only when the tide is below mean height."

The raising of the dam by flash-boards increases the water-power, and will pump more water, but decreases the duty percentage with the present turbines.

The same Commission recommended to alter the large turbines, so as to operate more economically; but do not say what alteration should be made.

Your Commission believes that, apart from the pumps being too small, the wheels and guides are not properly constructed or proportioned for economy, but cannot say positively what are the errors, if any, without examining the details when the turbines are taken apart.

A well-known law of hydraulics is, that *the higher the head of fall, the greater is the power* of equal quantities of water; which law is infringed upon by the present turbines at Fairmount. The complaints naturally made that the turbines have been run at high tide, and stopped at low tide, under these unwarranted circumstances, have not been wholly justified; but the engineers have not defended themselves, by exposing the true condition of the motors, as they ought to have done.

The exceedingly low percentage of duty given by the turbine, particularly in the second experiment, is not wholly due to faults of the turbine, but more by running it too slow.

Your Commission regulated the speed of the turbine to run the same as did the other two, Nos. 3 and 5, which were running at the same time.

The quantity of water running through the turbine is almost independent of the number of revolutions per minute; that is, nearly the same quantity of water will run through the turbine, if kept stationary, and the gates wide open, as when it ran faster or slower.

Mr. Berkinbine's statement, § 32, page 82, that "the wheels now in these works can absorb more than the average flow of the river," is not so much wrong after all; but if he had said that the power of the average flow at Fairmount is realized by the present turbines, he would have been very far from right. With the average flow, at least double the quantity of water could be pumped by properly constructed turbines.

TABLE XI.

EXPERIMENTS WITH TURBINE NO. 4, OCT. 24, 1878, ONE HOUR, FROM 11 TO 12 O'CLOCK, DURING HIGH TIDE.

Time of Observation.	Register of double Pump Strokes.	Revolutions per 10 Minutes.	Tide Gauge.	Forebay Gauge.	Head of Fall.	Cubic Feet of Water per 10 minutes. Used by Turbine.	Cubic Feet of Water per 10 minutes. Pumped into reservoir.	Cubic Feet required to pump one.	Rev. per minute of turbine.	horsepower Natural effect.	horsepower Realized.	Duty Per Cent.
h. m.			' "	' "						HP	HP	%
11 00	629,372		8 6	1 8	10.33							
11 10	629,460	88	8 7	1 8	10.25	171,439	4,335	39.6	25.5	332.5	73.5	22.1
11 20	629,550	90	8 7	1 8	10.25	171,441	4,435	38.8	26.0	332.5	75.3	22.7
11 30	629,645	91	8 6	1 8	10.33	171,443	4,482	38.4	26.3	335.5	76.1	22.6
11 40	629,734	92	8 5	1 8	10.42	171,445	4,531	38.0	26.6	338.0	77.0	22.8
11 50	629,829	95	8 3	1 8	10.58	171,447	4,692	36.6	27.5	343.0	79.7	23.3
12 00	629,928	99	8 0	1 8	10.58	171,448	4,880	35.2	28.7	343.0	83.0	24.2
1 h'r.	Diff.555	92.5	8.4	1.66	10.42	1,028,663	27,355	37.7	26.8	338.6	77.5	23.0

TABLE XII.

SAME TURBINE DURING LOW TIDE, OCT. 26, 1878.

Time of Observation.	Register of double Pump Strokes.	Revolutions per 10 Minutes.	Tide Gauge.	Forebay Gauge.	Head of Fall.	Used by Turbine.	Pumped into reservoir.	Cubic Feet required to pump one.	Rev. per minute of turbine.	Natural effect.	Realized.	Duty Per Cent.
8 10	650,164		2 3	1 10	16.75							
8 20	650,250	86	2 2	1 10	16.83	155,407	4,166	37.8	25.0	494	70.0	14.2
8 30	650,337	87	2 1	1 9½	16.92	155,419	4,163	37.4	25.2	496	70.7	14.3
8 40	650,425	88	2 0	1 9	17.00	155,432	4,210	37.0	25.5	499	71.5	14.3
8 50	650,514	89	1 11	1 9	17.08	155,446	4,251	36.6	25.8	501	72.2	14.4
9 00	650,604	90	2 0	1 9	17.00	155,459	4,310	36.1	26.1	499	73.2	14.7
9 10	650,692	88	2 3	1 10	16.75	155,470	4,210	37.0	25.5	491	71.5	14.6
1 h'r.	Diff. 528	88	2.11	1.79	16.92	933,033	25,260	37.0	25.5	497	71.6	14.4

NOTE TO TABLE XIII.

* The counter or register must evidently have slipped in the ten minutes between 2 h. 20 m. and 2 h. 30 m., making it read 10 too much. Mr. Le Van of your Commission says that he saw the counter slip on other occasions.

TABLE XIII.

EXPERIMENTS WITH TURBINE NO. 7, OCT. 26, 1878, TWO HOURS, FROM 1 TO 3 P.M, DURING HIGH TIDE.

Time of Observation	Register of double pump strokes.	Revolutions of pumps.	Tide Gauge.	Forebay Gauge.	Head of Fall.	Cubic Feet per 10 minutes. Consumed by turbine.	Pumped into reservoir.	Cubic feet required to pump one.	Revolutions of turbine.	horsepower Natural effect	Realized.	Duty per cent.
1 h. m	181 106		9′ 0″	1′ 9″	9.16					IP	IP	%
1 10	181,162	56	9 8½	1 9	9 21	94,120	1,935	48.8	15.6	163.5	42.0	25.7
1 20	181,218	56	9 8	1 9	9.25	94,670	1,943	48.8	15.6	165.0	42.1	25.5
1 30	181,281	63	9 7½	1 9	9.29	95,240	2,178	43 8	17.5	167.0	37.0	22.2
1 40	181,346	65	9 6½	1 8	9.29	95,840	2,243	42.8	18.1	168.0	38.0	22.7
1 50	181,412	66	9 6	1 8	9.33	96,480	2,285	42.3	18.4	170.0	38.7	22.8
2 00	181,480	68	9 5	1 8	9.42	97,130	2,348	41.5	18.9	172.6	39.8	23.0
2 10	181,550	70	9 3½	1 7½	9.50	97,850	2,420	40.5	19.5	175.6	41.0	23.5
2 20	181 622	72	9 1	1 7	9 66	98,480	2 480	39.8	20 0	179.5	42.0	23.5
2 30	181 707	85*	8 10½	1 7	9 87	99,360	2,935	34.0	23 0	185.1	49.8	27.0
2 40	181 795	88	8 6½	1 7	10.5	100 220	3,020	33.2	24.5	199.0	51.2	25.8
2 50	181,888	93	8 3½	1 7	10 6	102,030	3,205	32 0	25 8	204 6	54.4	26.6
3 00	181,988	100	7 11½	1 7	10 79	103,120	3,455	30.0	27.8	210 0	58.6	28.0
2 h'r	Diff 882	73.6	9 2	1 8	9.66	1,174,540	30 447	38.6	20.4	178.1	44.5	25.

The following Table gives the proper speed of the turbines and pumps for different heads of fall.

TABLE XIV.

Head of fall in feet.	TURBINES. Nos. 3, 4 and 5. Gearing 1 : 2.9 Double stroke of pumps.	Revolution of turbine per minute.	Nos. 7, 8 and 9. Gearing 1 : 2.78 Double stroke of pumps	Revolution of turbine per minute.
9	7.86	22.8	9.38	26.0
10	8.26	24.0	9.88	27.4
11	8.68	25.2	10.4	28.8
12	9.03	26.3	10.8	30.0
13	9.45	27.4	12.5	31.2
14	9.78	28.4	12.9	32.5
15	10.1	29.4	13.2	33.6
16	10.6	30.4	11.2	34.7
17	10.8	31.3	11.7	35.8
18	11.1	32.2	12.1	36.8
	Diam. 10.25 ft.		Diam. 9 feet.	

It is not to be understood by Table XIV, that the maximum duty will be realized simply by regulating the revolutions by the gate to suit the height of fall, for it means that the gate should be wide open; but then the turbines will make a great many more revolutions at low tide than required by the maximum duty.

It is, however, better to regulate the proper revolution by the gate than to run the turbines too slowly, as is generally done in the old wheel-house.

The turbines Nos. 7, 8 and 9 run too slowly at high tide, and much too fast at low tide, when the gates are wide open.

The turbines Nos. 3, 4 and 5 run just right, with the gate wide open, at high tide, that is, with a fall of 9 feet, but as the tide sets, they run much too fast, showing that the pumps are too small for that proportion of turbines and head of fall.

Your Commission asked permission to run the turbine No. 7 from the time of high tide, with the gate wide open, until its revolutions increased to the maximum it can run with safety, in order to find by that means the point at which the pumps are the proper size for the wheel and head of fall; but the engineer replied, that it is not allowed to run faster than 10 double strokes per minute, which it made in the experiment, Table XI.

It was remarked, that "there is nothing gained by running the turbines fast, because they will then soon get out of order, and must be stopped so much longer for repairs." This statement corresponds with the condition of the turbines Nos. 3, 4 and 5, in the old wheel-house, which appear to be more delicate in their movements; but the pumps No. 7, 8 and 9, in the new wheel-house, generally make 12 double strokes per minute, and often 13 or 14, and even run as high as 15, without any apparent inconvenience. In his address to the Franklin Institute, Mr. Berkinbine says, "At mean-tide, the pumps make 29 single strokes, and when the tide is out, they make 35 strokes per minute," which is 17½ double strokes. The faster the turbine runs, the more water will it pump; but the consumption of water driving the turbine will not be in the same proportion when the speed is regulated by the gate.

The higher the head of fall is, the greater will be the power of an equal quantity of falling water; but that law does not imply that the increased power is unconditionally utilized for pumping. The experiments made with turbine No. 4, and recorded by Tables XI and XII, show that a higher per cent. of duty was obtained with 10 feet than with 17 feet fall, the reason of which was that the turbine ran much too slowly, by not letting on sufficient water at low tide, and that the pumps are too small for that turbine and 17 feet fall.

§ 39. HORSE-POWER AND DUTY.

The natural effect of the waterfall and available duty thereof, are simply expressed in the following formulas, in which letters denote:

H = height of fall in feet.

C = cubic feet of water passing through the motor per minute.

h = height, in feet, to which the water is pumped.

c = cubic feet of water actually pumped and delivered into the reservoir per minute.

IP = horse-power of the waterfall, or natural effect.

IP′ = " realized by the pumpage.

% = duty percentage.

Natural effect, $$IP = \frac{H\,C}{530} \qquad 1$$

Realized effect, $$IP' = \frac{h\,c}{530} \qquad 2$$

Duty percentage, $$\% = \frac{100\,h\,c}{H\,C} \qquad 3$$

These are the formulas by which the horse-power is calculated in Tables XI, XII and XIII.

§ 40. CONSTRUCTION OF THE FAIRMOUNT TURBINES.

Philadelphia, November 12, 1878.

John W. Nystrom, Esq.

My Dear Sir:—In your pending Report on duty performance of the turbines at Fairmount, it is stated that the construction of the wheels cannot be examined without taking them apart.

The very small duty percentage obtained in your experiments, particularly with turbine No. 4, justifies strong efforts in ascertaining the construction of those wheels, so as to demonstrate any possible defects.

I am Yours Respectfully,

JAMES HAWORTH.

The turbine No. 4 is now (Nov. 25th) being taken apart for alteration to the duplex adjustable pattern, so that your Commission has an excellent opportunity to examine it, and produce the accompanying illustration, representing a cylindrical section through the centre of the buckets, laid out flat.

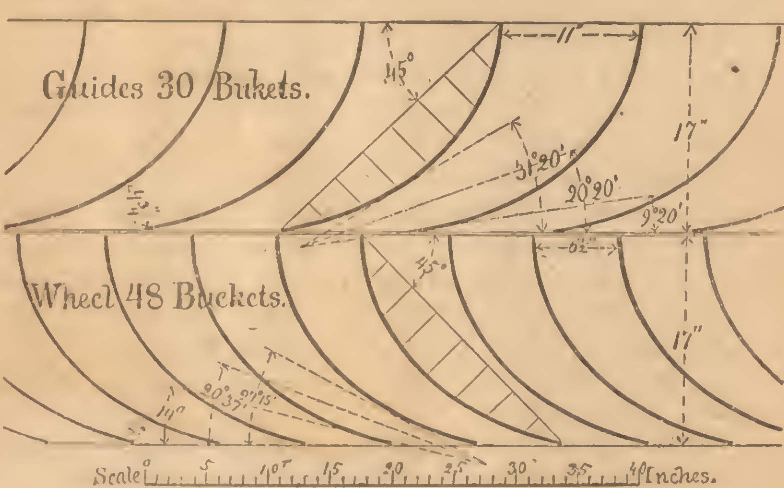
The illustration was first drawn on a large scale, from which it was reduced by photo-electrotype, so as to represent the true construction of the motive portion of the turbine.

The width of the buckets, both in the guides and wheel, is 20¾ inches in the direction of the radius; and the areas of discharge from the guides and wheels are 2116.5 and 2763.25 square inches, or in proportion as 32 : 42; which is the same proportion as that in the Stevenson's turbine, which gave the highest duty, 0.8777, in the competitive experiments at Fairmount, 1860. Geyelin's turbine, which then gave the next highest duty, 0.821, had the proportion of these areas as 37.7 : 44.6.

The principal reasons why the turbines Nos. 3, 4 and 5, now at Fairmount, give so very low duty are: *First,* That the wheels are much too deep, being 17 inches, or the same as the guides; *Secondly,* That the form of the buckets makes a very easy passage for the water to slip through without doing much duty, as can be readily perceived by a glance at the illustration.

The turbines Nos. 7, 8 and 9, in the new wheel-house are evidently better constructed, as proven by experiments made by your Commission. From notations by Mr. Berkinbine, of the construction of these wheels, it appears that the areas of discharge in the guides and wheels are both alike, or 2000 square inches.

In his paper, read before the Franklin Institute, Mr. Berkinbine said the area of discharge in the wheel is 1700 square inches.



In Mr. Geyelin's first experimental wheel, of 1860, these areas were nearly alike, or 42 and 42.6 square inches.

The velocity of discharge from wheel No. 4, in the experiment at high tide, October 24, 1878, by your Commission, was 19.5 feet per second, which corresponds with a head of fall 5.9 feet, whilst the actual head was 10.12 feet. The velocity of the circle of percussion was about 13.5 feet per second, which makes the actual velocity of discharge into the tail-water, about 19.5 — 13.5 = 6 feet per second.

In the second experiment with the same wheel, at low tide, October 26, the velocity of discharge was 17.7 feet per second, which corresponds to a head of fall 4.87 feet, whilst the actual fall was 16.92 feet.

FIRST EXPERIMENT ON LEAKAGE OF THE PUMPS.

§ 41. ***"What is the leakage of the Pumps at Fairmount, determined by the method I proposed to the Commission of 1875?"***

On Monday morning, October 28, the Fairmount basin was drawn down three feet, for the purpose of finding the leakage of the pumps by running the turbine No. 4 at so slow a speed that the leakage would be equal to the pumpage, that is, when the main is kept full, but no water enters the reservoir.

The turbine was run so slowly that it barely went over the centre, and it was found then to make one double stroke or revolution in 28 seconds, but some water still flowed from the main into the basin. The speed of 28 seconds for one revolution makes 2.15 revolutions per minute, which, divided by the regular speed 8, makes the leakage 26.9 per cent. Not being able to run the turbine any slower without stopping, the leakage was approximated to 20 per cent., which is the same as found by weir measurement, made by the Commission of 1875, for the pumps Nos. 7, 8 and 9.

With a speed of 9.25 double strokes per minute, as made in the experiment Oct. 24, (see Table XI,) the leakage will be only 23 per cent.

SECOND EXPERIMENT ON LEAKAGE OF THE PUMPS.

It has been supposed that the pumps for wheels Nos. 1 and 2 have leaked so badly as not to pump a drop of water for many years, (see § 15, page 52.)

On the 26th of October, the wheel No. 1 was running, and your Commission went up to the reservoir to see if any disturbance on the surface of the water over the outlet could be observed. The wind was perfectly calm, and the surface of the basin as smooth as a looking-glass, but not the slightest indication of disturbance could be seen over the outlet, which is in the middle basin. Your Commission then suspected the pump to leak so badly as to pump no water.

On Monday, the 28th of October, the front pump-head was taken off, and the leakages examined by letting on the full water pressure on the back side of the piston, but no leakage of much account could be seen, except through the delivery-valve, which leaked considerably. It was supposed that the back delivery-valve leaked sufficiently for admitting water pressure on the back of the piston, which it actually did. This examination was, however, not considered satisfactory, and on Thursday, Oct. 31, another inspection was made, as follows:

On account of the back head of the pump being cast solid, that side of the piston could not be examined like the front side. The stop-valve in the basin was closed, and the main emptied from below until filled with air; the stop-valve opened, and the main refilled with water by gravitation, forcing the air out into the basin, to indicate the exact spot of the discharge, which was before not definitely known. The turbine (No. 1) was started to run very fast, (12 revolutions per minute,) but no disturbance could be seen on the surface of the water over the discharge. It was then considered that the discharge, being 11 feet under the surface, and entering horizontally into the basin, would make very little disturbance, if any, on the surface. Light bodies, such as leaves and paper, were thrown on the water over the discharge, and found to move slowly in the direction of the discharge, about two feet per minute, which your Commission thought would indicate that water entered the basin from the main. Although the piston did not leak very much, the valves leaked considerably, and your Commission is, therefore, not satisfied that the pump works well.

In answer to the question, "By what means is the condition of the packing, or leakage of the piston, ascertained?" They said, by noticing the turbine running very fast, and also by the hemp of the packing stopping up the holes in the strainer of the pipe leading to the step (pivot). These two answers are of great importance, and deserve particular attention.

1st. The condition of the packing, or leakage of the piston, is ascertained by noticing the turbine running unusually fast, that is, when the leakage is so great as to nearly equalize the pressure on both sides of the piston, and when that happens, the pump may have run for months without pumping a drop of water, but merely balancing the column of water to the reservoir.

If the looseness of the piston was known, it would be easy to calculate the amount of leakage, but we may call

a = area in square inches of the leakage around the piston; to which must be added that of the valves, if any.

h = head of pressure in feet.

g = gallons of water leaked through the piston and valves per 24 hours. Then,

$$\text{Leakage,} \qquad g = 36{,}410\, a \sqrt{h}, \qquad 1$$

Example 1. Suppose the area of leakage is $a = 3$ square inches of the piston and valves, and the head $h = 90$ feet. Required the leakage per 24 hours.

$$\text{Leakage,} \qquad g = 36{,}410 \times 3 \times \sqrt{90} = 1{,}026{,}756 \text{ gallons.}$$

This leakage is one-half of the pumpage of turbine No. 1. A leakage of $a = 6$ square inches, which is equal to a circle of $2\frac{3}{4}$ inches diameter, would be equal to the pumpage, or 12 double strokes per minute, would just balance the column to the reservoir, without pumping any water. When the leakage is greater than 6 inches, the turbine will run faster, which must have been the case at Fairmount.

2d. The "pivot" is the most delicate part of the turbine, and if deprived of water, it may get ruined in a few minutes. The wearing out of the packing and the hemp, covering the strainer, may prevent the water from entering the pipe to the pivot.

Only the pistons for Nos. 1 and 2 are packed with hemp, the others are solid brass pistons, which appear to wear very well.

Arrangements could easily be made for measuring correctly the leakage of pistons and valves at any desired moment.

THIRD EXPERIMENT ON LEAKAGE, NOV. 29, 1878.

When preparing for duty experiments with turbine No. 7, October 26, the water in the flume was drawn out for inserting the log, and it was then found that the valves leaked considerably; that is, water entered from the main through the suction passage into the flume. After concluding the duty experiment, your Commission asked permission to make experiments on leakage of these pumps, which was declined, on the ground that the water was very low in the dam, and that all the power was required for supplying the city; but permission was promised as soon as the water in the dam permitted. Meantime, the engineer of the works found that the valves of other turbines also leaked, whereupon it was decided to repair all the valves before the leakage experiments should be made.

On the 29th of November, there were 27 inches of water on the dam, and the permission was then granted.

The turbines Nos. 5, 7, 8 and 9, pump water directly into the Corinthian basin through a 48 inch main, which discharges above the surface of the reservoir, where the flow could be correctly observed.

Four signal stations were established between the basin and the works, for regulating the speed of the pumps according to your method of measuring leakage, as before described.

The results of these leakage experiments are given in Table XV.

The proportionate leakage of the valves and piston could not be determined by these experiments. If the valves are tight, the whole leakage will be in the piston only when the pumps are working; but if the valves leak, they will do so whether the pumps are working or not; therefore, part of the leakage charged to each pump in operation, may have leaked through the valves of the pumps at rest, and, consequently, the total leakage of the four pumps, as given in Table XV, may be too high.

TABLE XV.

Experiments on Leakage, Nov. 29, 1878.

Numbers of Turbines.	Time of Observation.	Revo. per m.	Leakage per Minute.	Remarks on Flow at the Basin.
	H. M. S.		Gallons.	
No. 5...	12 30 00	8	. . . . .	Started, good flow.
	12 33 00	2	. . . . .	Flow nearly stopped.
	. . . .	$1\frac{7}{8}$	865	Leakage speed.
	12 35 10	$1\frac{3}{4}$	. . . . .	The water receded.
No. 7...	12 36 00	8	. . . . .	Started, good flow.
	12 40 00	3	. . . . .	Flow very slow.
	. . . .	$2\frac{3}{4}$	890.8	Leakage speed.
	12 43 15	$2\frac{1}{2}$	. . . . .	The water receded.
No. 8...	12 44 00	8	. . . . .	Started, good flow.
	. . . .	$3\frac{1}{8}$	1030.9	Leakage speed.
	12 48 10	3	. . . . .	The water receded.
No. 9...	12 49 00	9	. . . . .	Started, good flow.
	12 51 00	3	. . . . .	Flow hardly perceptible.
	. . . .	$2\frac{7}{8}$	937.8	Leakage speed.
	12 52 32	$2\frac{3}{4}$	. . . . .	The water receded.
Leakage of the 4 Turbines,			3724.5	Gallons per minute.
" " "			5,363,280	" per 24 hours.

If the valves were tight, as your Commission expected them to be, on account of having been lately repaired, all the leakage must evidently have been through the piston, as shown in the Table. This leakage is, on an average, 25 per cent.; but it must be remembered that the valves were prepared for the experiments, otherwise the leakage would probably have exceeded 30 per cent.

§ 41. FOURTH EXPERIMENT ON LEAKAGE OF THE PUMPS.

Philadelphia, Nov. 20, 1878.

John W. Nystrom, Esq.

My Dear Sir:—From the experiment made, Oct. 28, by your Commission on pumps No. 4, the leakage is assumed to be only 20 per cent. I have many times seen these pumps run very slowly at high tide, about 6 double strokes per minute, and not a drop of water entered from the main into the reservoir. Is your Commission aware that there is a connection between that main and the standpipe, through which water might have passed, and deceived your observations?

There is no water connection between the standpipe and main of No. 3 pumps, with which I expect your Commission to make experiment on leakage.

Respectfully Yours,

JAMES HAWORTH.

Your Commission was aware that there is a water connection between the standpipe and the main of No. 4 pumps, and was informed by the engineer and men of the works, that the valve of that connection had not been opened for years, and that it was closed during the experiment. It is possible, but not likely, that this valve was opened.

On December 4, experiment was made on leakage of No. 3 pumps, which were found to make one double stroke in 34 seconds, or 1.77 revolutions per minute when the flow stopped, which, at the regular speed of 8 revolutions, makes the leakage 22 per cent.

Leakage of No. 3,	816 gallons per minute, or 1,175,000 gallons per 24 hours.
Leakage of No. 4,	992 gallons per minute, or 1,325,000 gallons per 24 hours.
Leakage of No. 5,	865.5 gallons per minute, or 1,246,536 gallons per 24 hours.

§ 42. BELMONT WATER-WORKS AND GEORGES HILL RESERVOIR.

In obedience to your request to examine the Steam Works, on the 16th of November, an experiment was made with the pumpage of engine No. 1, Belmont, which was the only one pumping water into the Georges Hill reservoir.

The accompanying Table XVI shows the results of the experiment.

The log was placed in the low standpipe, from which the water enters into the reservoir, during one hour, and the revolutions and other data were taken from the engine, at the same time. The outlet at which the log was placed, is 30⅜ inches diameter, making the area of cross-section 5.028 square feet. The log showed 3157 in one hour's run, which made the delivery 136,405 gallons in the same time. The water displaced by the two double-acting plungers, during the same hour, was 224,187 gallons, which makes the delivery 61 per cent., and the leakage 39 per cent. of the pumpage.

This great amount of leakage surprised your Commission, as it was expected to find these pumps in good order. Without knowing the result of the experiment, the engineer in charge said that the engine had been running the whole summer, and on account of low water in the Schuylkill all the time, it could not be stopped long enough for examining the plungers and valves, which he expected would leak considerably.

The engineer also said, that at this season of the year, the pumps draw in leaves and other matter, which settles in the valves and makes them leak.

This experiment was made without any previous notice to any one in the Water Department, the object of which was, to find out the regular everyday operation of the works. Your Commission went first to the Georges Hill reservoir, and prepared for the insertion of the log, after which one of them went to the works at Belmont, to observe the running of the engines; which was the first information the engineer had of the experiment then in operation.

TABLE XVI.

Dynamics of Steam-Pump No. 1, at Belmont.

Time of Observation.	Register of double Strokes.	Double Strokes per 10 Minutes.	Pressure per Square Inch. Steam.	Pressure per Square Inch. Vacuum.	Operation per 10 Minutes. Pumpage at Belmont.	Operation per 10 Minutes. Delivery into Reservoir.	Operation per 10 Minutes. Leakage of Valves and Plungers.	Horse Power. Pumpage.	Horse Power. Delivery.
h. m	Number	No.	lbs	lbs	Gallons.	Gallons.	Galls.	HP	HP
10 00	923,201		38.50	13.92					
10 10	923,319	118	38.15	13.92	36,288	22,079	14,209	186	113
10 20	923,438	119	39.00	13.92	36,596	22,266	14,330	188	114
10 30	923,558	120	39.27	13.80	36,801	22,451	14,350	189	115
10 40	923,680	122	39.50	13.80	37,119	22,828	14,591	192	137
10 50	923,801	121	40.50	13.68	38,034	23,202	14,832	196	139
11 00	923,930	129	41.25	13.68	38,648	23,576	15,072	199	141
1 hour	Diff 729	121.5	39.63	13.64	224,189	136,405	87,781	191	133

The engineer, evidently anxious to have his engine perform well, got up higher steam, and the revolutions increased, as seen in the accompanying Table XVI.

The experts of 1872 found, by weir measurement, the leakage to be only 3.8 per cent., which is only one-tenth of that found by your Commission.

But it must be remembered that the engines and pumps were put in the best possible condition, and were run during these experiments by Worthington's own engineers.

The water-gauge showed a pressure of 84 pounds to the square inch, which corresponds to a column of water 194.12 feet high. The water in the reservoir was 16 feet 8 inches, which is 8 feet 4 inches less than when full.

The head of suction, from pump-well to centre of engine, was 17 feet 6 inches, and the total head, from well to the surface of discharge, was about 212 feet.

A report of experts and engineers upon the performance of engine No. 2 at Belmont, will be found in W. D. Report for the year 1872.

The engine No. 2 was not running, on account of some boilers being scaled and cleaned. The engineer remarked, that the water pumped into the boilers at Belmont forms a great deal of scale, and gives more trouble in cleaning than any other boilers in the Water Department.

The largest engine, No. 3, was running, and pumped water to the east side of the Schuylkill.

STEAM BOILERS AT BELMONT WATER-WORKS.

The boilers at the Belmont Works are of the French pattern, and known as elephant boilers.

According to the Report of the Commission of Experts of 1872, these boilers evaporated about 30 pounds of water per hour per horse-power, with a consumption of about four pounds of coal, and steam pressure 49 pounds to the square inch—working a compound engine, for which two pounds of coal per hour per horse-power ought to be sufficient.

The boilers are encased in brick work, so that but little more than one-half of the boiler-shell comes in contact with the products of combustion, which enters the chimney at a temperature of over 900 degrees Fahrenheit, against 297 degrees of temperature of the steam. Allowing 150 degrees difference in temperature of the steam and of the gases entering the chimney, we have 900 — (297 + 150) = 453 degrees lost by these boilers.

The manner in which the products of combustion are conducted under these boilers, makes the heating surface of the mud drums of very little utility for making steam.

By resetting these boilers, so as to return the products of combustion over their top, as is now generally done in factories, a saving of from 25 to 50 per cent. of fuel would be attained.

These boilers are used at all the Philadelphia steam water-works, and are very extravagant on fuel.

The accompanying illustration represents these boilers, which at Belmont are 14 in number, set two over each fire-grate, making 7 sets.

Dimensions of each Boiler.

Length of shell, ...	30.83 feet.
Diameter of shell, . . .	54 inches.
Length of mud drums, . . .	22 feet.
Diameter of mud drums, . . .	28 inches.
Number of " . . .	2
" of necks, . . .	10
Length of "	12 inches.
Heating surface of shell, . . .	254 square ft.
" of mud drums, . .	308 "
Total heating surface, . . .	562 "
Length of grate bars, . . .	60 inches.
Width of grate bars, . . .	52 "
Area of grate surface, . . .	22 square ft.
Ratio of heating surface to grate, . .	26 : 1

The horse-power developed by six of these boilers was 252, by indicator cards, of which 204 horse-power was realized by the pumpage, which makes the duty 81 per cent., as reported by the Commission of 1872.

§ 43. COMBUSTION OF COAL.

The size of coal used at the water-works is entirely too large for economical firing, as the fire must be kept so thick on the grate as to prevent perfect combustion. The thickness of the fire on the grate, as observed by your Commission, varied between 12 and 15 inches, whilst 9 or 10 inches would be sufficient, and more economical, even for that size of coal. Your Commission examined the boilers, coal and firing in different factories, in order to compare the same with those at the water-works, and found the boilers better set, small coal used, known as egg and chestnut, and the thickness of fire varying between 4 and 8 inches.

The philosophy of combustion of coal is better known than respected by engineers.

Combustion is the rapid combination of oxygen in the air with the carbon in the coal, or fire, which forms two distinct gases, namely, *carbonic acid* and *carbonic oxide.*

1. One pound of carbon, burned to carbonic acid, generates 14,500 units of heat.

2. One pound of carbon, burned to carbonic oxide, generates 4,500 units of heat.

In the first case, which is perfect combustion, the combination generates over three times as much heat as in the latter, which is imperfect combustion. When air enters from under the grate into the fire, carbonic acid is first formed, which, when rising through a thick layer of fire, another atom of carbon is taken up, by which carbonic oxide is formed.

The economy in combustion consists in burning all the carbon to carbonic acid, which is accomplished by having the fire so thin that the acid has no time or chance to take up another atom of carbon before it rises above the fire. The perfect combustion in a thin fire can be better accomplished and regulated by small than by large coal. All this is well known by engineers and firemen, and the principal reason why it is not more generally attended to is, that it requires more care and skill, but less work, in keeping the fire thin on the grate. The most economical firing in the Water Department, is at the Works of Chestnut Hill.

§ 44. SCHUYLKILL WORKS.

On the 13th of November, only two of the pumping engines at the Schuylkill Works were running, namely, the compound engine built by Henry G. Morris, and the side-lever engine built by Merrick & Sons.

The old Cornish engine built by I. P. Morris & Co., was undergoing repairs, and started November 15.

The 20,000,000 gallon compound engine built by Cramp & Sons, broke down on the 26th of September, and was still standing in that condition.

The pumpage delivered into the Schuylkill reservoir could not be measured by the log, on account of the mains entering at the bottom. Your Commission was at first informed that the main from the side-lever engine entered above the surface of the reservoir, whereupon experiments were started with the log in that main, but whilst in operation, one of the engineers came and stated that most of the pumpage of that engine went into the standpipe, and entered at the bottom of the reservoir. In half an hour's operation, the log showed a delivery of 2717 cubic feet, which would make only 975,511 gallons per 24 hours, instead of 5,140,000 gallons, which ought to have been the delivery.

Your Commission then asked the engineer to let all the pumpage of that engine go into the main entering the reservoir above the surface, which he declined to do, on account, he said, of "the plunger being single-acting, the water column would then rebound too severely, and likely start the joints of the main and pump to leaking." Your Commission accepted this objection, and considered it unsafe to try the experiment, as there is only a small air-vessel on the pump for taking the rebound of the column.

For the actual performance of the Schuylkill Works, your Commission has assumed 25 per cent. leakage of the pumps, the result of which is given in Table XVIII.

§ 45. CHESTNUT HILL WATER-WORKS.

These works consist of a horizontal steam engine and pump of a capacity of 374,400 gallons per 24 hours, and also a Knowles' Donkey pump which is kept in reserve. The water is pumped from an artesian well into a tower of very small capacity, from which Chestnut Hill is supplied; and the present demand being smaller than the capacity of the pumps, the engine is run only half the time or every other hour. The surplus power of this engine could be used for supplying that part of Mt. Airy which has as yet no water facilities.

In the dry season, when the artesian well gives out, water is supplied to it by a main from Mt. Airy reservoir.

§ 46. ROXBOROUGH WATER-WORKS.

On November 22 your Commission visited the Roxborough Steam Pumping Works, with the intention to inquire into the feasibility of making experiments on the actual pumpage and delivery into the reservoir; and also, in obedience to your instruction, to examine the steam boilers and their economy in fuel.

On explaining to the engineer of the works our object and desire, he replied that he knew that such investigations were going on at the different water-works, but had no official notice to that effect from the Chief. The engineer, evidently expecting our object to be sanctioned by the Chief, promised to let us make the experiment of the pumpage the next day.

Your Commission then made a preliminary examination of the boilers, which are of French pattern known as *Elephant boilers*, similar to those at Belmont, which are described and illustrated on page 113.

A pyrometer was inserted in the flue leading from the boilers to the chimney, and in less than one minute it rose to 900 degrees Fahrenheit, which was the highest reading on the scale, but evidently not high enough for the temperature in the flue. The steam pressure varied between 45 and 50 pounds to the square inch, which corresponds to a temperature of 292.58 degrees and

297.31 degrees, making at least 150 degrees lost through the chimney. As at Belmont, we found the fire much too thick on the grate, varying between 12 and 15 inches, and very large coal used.

The Worthington engine only was running, making 13 double strokes per minute, which makes the pumpage about 5,890,000 gallons per 24 hours without leakage.

The water pressure gauge showed 150 pounds to the square inch, which corresponds to a column of water 346.66 feet high.

According to previous agreement, your Commission, with men and instruments, arrived at the Roxborough Water-Works at 10 o'clock, November 23, and was informed by the engineer of the works, that he had received orders "not to allow any experiments to be made without special permission from the Chief." Your Commission thereupon returned with the next train to Philadelphia.

At noon the same day, one member of your Commission called on the Chief Engineer at the Water Department, to ask permission to make the experiment at Roxborough, which was declined.

Your Commission expected that the Chief had given orders at the different water-works in regard to their investigations, and after having made experiments at Belmont and Schuylkill Works, and preliminary examinations at the Delaware Works; one member of your Commission related the same to the Chief in his office at Fairmount, when he seemed pleased with our labor, and asked how we were treated at the different works. The answer was, that we had been treated with great kindness at all the works without exception. Your Commission then felt confident that the examination went on harmoniously with the Water Department, and therefore avoided troubling the Chief by asking special permission for each act. Now, your Commission suspects that it has committed an error, and owes apology to the Chief Engineer for not having asked permission in every instance.

§ 47. DELAWARE WATER-WORKS.

The Delaware Works and Reservoir were visited on the 15th of November, for preliminary examination and preparation for experiments on the pumpage, delivery and leakage.

The water was very low in the reservoir, and very little water entered from the 36 inch inlet. There are only two mains from the works to the reservoir, one 18 inch, which is tapped on the way for supplying the lower part of Kensington, and also Bridesburg. This main enters the reservoir, in two branches, at the bottom. The other is a 36 inch main, entering the reservoir through a standpipe projecting over the surface of the water. The delivery from this standpipe can be measured with great precision by the log.

On the 10th of December, one of the plunger heads of the Worthington engine at the Delaware Works broke, and disabled its working.

LETTER TO THE CHIEF ENGINEER.

PHILADELPHIA, Nov. 20, 1878.

DR. WM. H. McFADDEN,
Chief Engineer Water Department.

SIR :—I would respectfully ask permission to measure the pumpage of the Delaware Works into the reservoir, by placing a log in the inlet of the 36 inch main.

For this measurement, it would be necessary to let all the pumpage into the 36 inch main, and stop the 18 inch main at the standpipe.

The supply for distribution from the 18 inch main would then be taken from the reservoir, by opening the valves* at the upper stop-house.

The experiment will not last more than one hour, at any time convenient to you and for the operation of the works.

Awaiting your favorable reply, I remain

Yours Respectfully,

JOHN W. NYSTROM.

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* On the 23d of November, the Chief said that these valves are always open, but his assistant had previously declared they were closed.

REPLY FROM THE WATER DEPARTMENT

Received November 22.

Water Department.
Philadelphia, Nov. 22, 1878.

John W. Nystrom, C. E.

My Dear Sir:—Yours of the 20th inst. is at hand. The Chief directs me to say that your request can be complied with.

Yours, &c.,

CHARLES G. DARRACH,
Assistant Engineer W. D.

A SECOND THOUGHT.

Received Nov. 23.

Water Department.
Philadelphia, Nov. 22, 1878.

John W. Nystrom, C. E.

Dear Sir:—The request embraced in the communication presented by you to the Committee on Water-Works, Oct. 15, 1878, was to make some measurements and experiments at Fairmount.

If you desire to extend your experiments beyond that point, permission must first be obtained from the Committee.

Yours Truly,

L. T. HICKMAN,
Assistant Clerk.

§ 48. REMARKS.

Up to the time this notice was received, your Commission has made preliminary examinations of all the City Steam Works, except those at Frankford, where only a Worthington 2,000,000 gallon engine is working; the Cramp's 10,000,000 gallon engine being under repair.

Now your Commission will not be able to carry out your instruction about the steam pumping machinery, for want of permission from the Water Committee of City Councils.

The condition upon which the Chief Engineer requires an application for permission to be made is of such a nature, that the Water Committee could not be expected to grant the same.

PHILADELPHIA, Dec. 5, 1878.

DR. WILLIAM H. MCFADDEN,
Chief Engineer Water Department:

SIR:—The Commission appointed by James Haworth, Esq., which was authorized by the Water Committee of Councils, and yourself, to make measurements and experiments at the Fairmount Water-Works, has concluded the same, and returns to you and to the engineers at the Works, the most sincere thanks for the exceptional kindness realized in that connection.

In default of a like permission of the Water Committee, the City Steam Works have not been examined as desired.

Mr. Haworth is indisposed to make to the Committee such an application as you required, namely, to "assume all responsibility for injuries that might befall the machinery experimented upon," on the ground that it would undoubtedly impress the Committee with the erroneous idea that there would be some probable or possible risk.

The Water Committee would not be likely to grant the required permission upon an application couched in such terms.

Copies of the Report of our investigation shall be sent to you as soon as ready for distribution.

I have the honor to be,
Your Obedient Servant,
JOHN W. NYSTROM.

CAPACITY OF THE WATER-WORKS.

§ 49. ***"What is the theoretical and practical capacity of each and of all the Water-Works in Philadelphia?"***

The following two tables represent the theoretical and practical capacity of each and of all the Works.

The leakage of the pumps at Fairmount averages 25 per cent. at the regular speed of the turbines, which amount has been deducted from the theoretical capacity, and the remainder assumed to be the practical capacity of the pumps.

At Belmont, the leakage was found by the log to be 39 per cent.

At the other Works, the leakage has not been measured, but assumed to be 25 per cent.

Theoretical capacity of all the Works, 127,042,288 gallons per 24 hours.

Practical capacity " " 90,564,000 gallons per 24 hours.

ACTUAL CONSUMPTION OF WATER IN PHILADELPHIA.

§ 50. ***"What is the actual average daily consumption of Water in Philadelphia?"***

Deduct 30 per cent. from the average daily pumpage as given in the W. D. Report, and the remainder will be a close approximation to the actual consumption.

Table XIX, page 124, gives the average daily consumption of water in Philadelphia for every month in four years.

Assuming the population of Philadelphia to be 820,000, consuming, on an average, 34,300,000 gallons per day, will make 42 gallons, or one barrel per head.

TABLE XVII.—Fairmount Water-Works.

Number assigned to each wheel.	Kind & dimensions of wheels.				Dimensions of pumps.				Diameter of piston-rod.	Capacity of pumps per revolution.	Theoretical capacity.		Actual performance.	
		Diameter.	Width of buckets.	Area of discharge.	Diameter of piston.		Stroke of piston.	Area of piston.			Revolutions per minute.	Per 24 hours.	Revolutions per minute.	Per 24 hours.
No.		Feet.	In.	sq.in.	In.	In.	In.	Sq. In.	In	Gallons.	No.	Gallons.	No.	Gallons.
1	Turbine	7	.....	.....	16	....	72	201.06	$3\frac{5}{8}$	121.11	12	2,110,060	12	1,600,000
2	Breast	16	180	.....	16	....	54	201.06	$3\frac{1}{2}$	91.75	14	1,387,260	000	....
3	Turbine	10.25	$20\frac{3}{4}$	2116	22	22	72	380.13	5	461.68	8	5,318,553	8	4,000,000
4	Turbine	10.25	$20\frac{3}{4}$	2116	22	22	72	380.13	5	461.68	8	5,318,553	8	4,000,000
5	Turbine	10.25	$20\frac{3}{4}$	2116	22	22	72	380.13	5	461.68	8	5,318,553	8	4,000,000
6	Removed	....	....	....	....	....	....	......	...	......	...	....	...	....
7	Turbine	9	16	1700	$18\frac{7}{16}$	$18\frac{3}{8}$	72	266.08	4	323.90	11	5,130,576	12	4,200,000
8	Turbine	9	16	1700	$18\frac{5}{16}$	$18\frac{1}{2}$	72	266.08	4	323.90	11	5,130,576	12	4,200,000
9	Turbine	9	16	1700	$18\frac{9}{16}$	$18\frac{3}{8}$	72	267.90	4	326.19	11	5,166,690	12	4,200,000
												34,880,821		26,200,000

TABLE XVIII.—Steam Pumping Water-Works of Philadelphia.

Works	Engines	Manufacturers	Dimensions of Pumps: Number, Single acting	Number, Double acting	Diameter of Piston	Diameter of Plunger	Stroke of Piston	Diameter of Piston Rod	Capacity of pump per Revolution	Theoretical Capacity: Revo. per min.	Theoretical Capacity: per 24 hours	Actual Performance: Revo. per min.	Actual Performance: per 24 hours
			No	No	In.	In.	In.	In.	Gallons	No.	Gallons	No.	Gallons
Schuylkill	Old Cornish	I. P. Morris	1	.	. .	30	120	.	376.2	10	5,287,680	10½	4,170,000
	Side-Lever	Merrick	1	.	. .	36	120	.	528.7	10	7,598,880	9	5,140,000
	Compound	H. G. Morris	.	2	28½	.	182	.	502.6	14	10,132,416	10	5,440,000
	Compound	Cramp	.	2	. .	30	72	8	850	16	20,000,000	16	15,000,000
Belmont	No. 1. Comp.	Worthington	.	2	. .	22$\frac{1}{16}$	48	4	307.53	12	5,400,000	12	3,270,000
	" 2. "	"	.	2	. .	22½	48	4	325.67	12	5,620,147	12	3,270,000
	" 3. "	"	.	2	. .	28	48	4½	505.14	12	8,729,579	11	6,000,000
Delaware	Compound	Worthington	.	2	. .	24	48	3½	372.01	12	6,428,229	11	4,810,000
	Beam Eng.	Neaflie & Levy	.	1	19½	.	72	4½	181.2	.	4,696,807	14	3,520,000
	Horzt. Eng.	Brock & Andrew	.	1	18	.	72	4⅞	152.8	.	3,960,887	10	2,970,000
Roxboro'h	Cornish	Mathew & Moore	1	.	. .	20¼	120	.	167.3	10	2,409,120	. . .	1,800,000
	Compound	Worthington	.	2	. .	22	48	4½	309.25	10	4,454,553	13	3,336,000
Frankford	Compound	Cramp	.	2	. .	21	60	5½	350	20	10,000,000	. . .	7,500,000
	Compound	Worthington	.	2	. .	16	24	3	82.08	20	2,364,249	. . .	1,770,000
Chest. Hill	Donkey	Knowles	.	1	. .	. .	.	.	. . .	.	150,000	. . .	112,000
	Horzt. h. p.	. . . .	.	1	7	. . .	40	2	13	20	374,400	20	280,000
									Total,		97,586,947		68,128,000

TABLE XIX.

Actual Daily Average Consumption in Gallons.

Years.	1874	1875	1876	1877
January	25,000,000	23,000,000	25,750,000	28,700,000
February	24,900,000	25,300,000	25,400,000	29,200,000
March	24,600,000	26,200,000	26,250,000	30,000,000
April	26,500,000	27,000,000	30,250,000	31,500,000
May	31,200,000	33,500,000	34,700,000	34,700,000
June	35,250,000	36,000,000	39,000,000	37,300,000
July	38,000,000	35,000,000	40,000,000	37,600,000
August	33,750,000	35,400,000	40,090,000	39,200,000
September	32,200,000	31,700,000	39,000,000	38,500,000
October	29,200,000	32,000,000	38,000,000	37,200,000
November	28,000,000	30,700,000	34,000,000	35,200,000
December	25,200,000	28.200,000	29,000,000	32,700,000
Average	29,500,000	33,350,000	43,400,000	34,300,000

HYDROGRAPHY OF THE WISSAHICKON.

§ 51. ***"To what extent can the Wissahickon be depended upon for supplying Roxborough and Germantown with Water by Water-Power?"***

The Report of the Water Department for 1866, page 12, in the Appendix, says: that "Water for supplying the city could be obtained at sufficient elevation ten miles above the mouth of the creek, and thirteen miles north of Broad and Market Streets." "Above this point, the creek has a surface drainage of forty-four square miles."

The drainage area above Bischoff's mill, six miles from the Schuylkill, is about 55 square miles, and with an annual rainfall of 46.5 inches, which, at 60 per cent. available, say 28 inches, will make 26,873,259,600 gallons per annum, there would be a daily average of 73,766,000 gallons.

Suppose the Wissahickon to be dammed up to a 25 feet fall at Bischoff's mill, which is 114 feet above city datum, the dam would then be 131 feet above the water-works erected here for supplying Mount Airy and Roxborough reservoirs, which are, on an average, 364 feet above city datum, or 233 feet above the proposed dam; there would then be required, theoretically, 233 : 25 = 9.32 gallons of water to pump one into the reservoir; and suppose the duty of the water-works to be 52 per cent., then 18 gallons would pump one into the reservoir, practically.

Suppose the monthly percentage of available rainfall to be as given on page 13, the hydraulics at Bischoff's mill would be, on an average, as in the following Table.

TABLE XX.

Hydraulics of Wissahickon at Bischoff's Mill, with 25 Feet Fall.

Months	Average per 24 hours. Flow of the Creek.	Average per 24 hours. Pumpage into Reservoir	Horse-Power	Average daily pumpage at Roxbo. Works 1877.
	Gallons.	Gallons.	HP	Gallons.
January	111,000,000	6,160,000	521	2,205,312
February	107,000,000	5,930,000	503	2,240,790
March	97,000,000	5,390,000	457	2,095,053
April	81,000,000	4,500,000	382	2,091,914
May	64,000,000	3,550,000	302	2,474,669
June	49,100,000	3,725,080	231	3,128,848
July	39,390,000	2,185,000	185	2,488,376
August	36,900,000	2,050,000	173	3,131,805
September	43,000,000	2,390,000	202	3,222,196
October	64,000,000	3,555,000	302	2,961,925
November	88,400,000	4,890,000	417	2,830,132
December	104,500,000	5,780,000	493	2,905,096
Average	73,766,000	4,175,400	347	2,648,010

The above Table approximates the average hydraulics of the Wissahickon, without allowance for droughts, which would embarrass these works like those at Fairmount; but by the aid of impounding dams and a storage reservoir, their supply could be made more reliable.

The water pumped at the Roxborough Works, as given in the last column, also supplies Manayunk, which, if deducted from that column, will bring the power of the Wissahickon up to the requirements of Germantown and Roxborough in the summer months.

The plan suggested by you, namely, to build temporary water-works on the Wissahickon, above the pipe aqueduct, and connect them with the inverted syphon leading to Roxborough and Germantown, deserves consideration.

WISSAHICKON PIPE BRIDGE.

§ 52. ***"When the cost of Steam Pumping here is $48, and that of Water-Power only $2 per million gallons, would it not have been better to have constructed water-works on the Wissahickon with the money wasted on the Pipe Bridge?"***

"The cost of replacing the injured pipe at that bridge is estimated, by the Commission of 1875, at $40,000."

The pipe aqueduct across the Wissahickon was completed in the year 1870, and cost about $75,495.31, (see Report for 1870, pages 72 and 73,) and is not now used, but the water passes through an inverted syphon. The money expended on this pipe aqueduct would have paid the greatest portion of the cost of water-works on the Wissahickon.

REMARKS.

I have the authority of the late John Agnew, fire engine builder, Vine Street, Philadelphia, as to the method of supplying water to New Brunswick. That city is supplied by one water-wheel and pumps, which are attended by one man. It is self-lubricating, and only requires his brief attention in the morning and evening. I cite this as an example of what could be done on the Wissahickon and at Manayunk.

Whenever the city wishes to utilize all the water in the Wissahickon, these works should be removed to a point six miles above the mouth of the Wissahickon, and after supplying Germantown and Roxborough by water-power, the water used as power, after passing over the wheels, could be brought down to the city by gravitation. By these means the Wissahickon could supply 60,000,000 *gallons per day, which is about twice as much as the city is consuming at the present time* (1878). *J. H.*

GATES FOR ADMITTING WATER TO THE TURBINES.

§ 53. ***"These outside gates have been kept too low, and thus not admitted a full supply of water to the wheels. Does not this diminish the acting head of fall and, consequently, the motive power?"***

It makes very little difference if the speed of the turbines is regulated by the outside gates or by the circular gate under them. If these gates are left wide open, the wheels will run too fast, except at high tide.

The error is in the construction of the turbines and size of the pumps. It is true that much power is lost by not admitting the full head of fall on the wheels at all tides.

TRANSFERRING THE WATER DEPARTMENT TO A COMPANY.

§ 54. ***"Would it not be best to give the Water Department in charge of a Company?***

Your Commission cannot answer that question.

REMARKS.

By the general policy I have recommended, 300,000,000 gallons of water could be brought into the City per day, by the employment of water-power at $2 per million, including interest on future plant, and by a proper administration of the Department, 50,000,000 gallons per day could and should be used for flushing the gutters and sewers of the City, and promoting the public Health.

The surplus over the City's consumption could be rented for motive power, to the marked advantage of the City Treasury.

J. H.

METALLIC SPRING PACKING OF PUMP-PISTONS.

§ 55. ***"Solid brass pistons without packing, but simply fitted in the pumps, are now used at Fairmount, which must evidently wear on the under side by scraping in the mud, until they leak so badly as to pump no water. Would not a metallic spring packing be better, and keep the piston permanently tight?"***

A metallic spring packing may possibly be devised, that would keep the piston tighter than does the present solid one. In the Worthington pump, a long plunger is fitted in the pump-cylinder without any packing; it is not known, however, how tight that plunger is, but it must inevitably wear, and finally leak very much.

Your Commission believes that a metallic spring packing could be devised that would keep the piston practically tight, and which would be much preferable to the solid piston which can never be rendered so, even when it is first put in.

PISTON ROD OF HORIZONTAL PUMPS.

§ 56. ***"The piston in horizontal pumps, must evidently wear on the under side, by its own weight on the lower side of the pump. Would it not be advisable to run the piston rod through at both ends, so as to guide the piston concentrically with the pump."***

It is a very old idea to run the piston rod through both ends of horizontal pumps or cylinders, for the purpose you mention, but experience has proved it to be of little or no value. Horizontal blowing machines have been so constructed, and found to wear out the stuffing-box to greater inconvenience than the wearing of the piston.

The philosophy of the case is as follows:

The weight of the piston has a much greater surface to lay on in the cylinder than in the stuffing-box; and therefore, if depending upon the latter, it will sooner wear to leak. To overcome this difficulty, various arrangements have been made in the stuffing-box for bearing the weight of the piston and rod, and also, by constructing special guides for bearing the end of the projecting piston rod. Attempts have also been made to bear the piston by part of the pressure acting upon it, all of which have been abandoned, and they now depend upon the wearing of the piston in its cylinder.

The best method your Commission can suggest, for the present, is to make a hollow and tight plunger of equal weight to that of the water it displaces, and pack it in the middle of the pump by a metallic spring packing, which may be arranged so as to tighten it from the outside, whilst the pump is working.

FROM THE PHILADELPHIA PAPERS, OF DECEMBER 4, 1878.

OUR DEFECTIVE WATER-SUPPLY.

A PLAN UPON WHICH CHIEF McFADDEN SMILES APPROVINGLY.

The Council Committee on Water pricked up its ears yesterday when the clerk read the proposition of Mr. Joseph D. Thornton to furnish the city with a supply of fourteen millions of gallons of water per day, at a cost of $7.93 per million gallons for each one hundred feet high. Mr. Thornton proposes to erect a pumping engine at any of the water-works of the city, place in all the necessary machinery, and take a contract for six years. At the expiration of that time, the whole of his apparatus reverts to the city.

"The proposition is a fair one," said Chief Engineer McFadden, when his views were asked. "So far as the rate is concerned, it cost in 1876, at Belmont, which is our cheapest pumping station, $7.14 to raise water 100 feet high."

At this juncture, the doctor went into an elaborate explanation of the different systems into which the water-supply of the city is divided. He makes it a point, at each meeting of the Committee, to say something on this subject, fearing that some members might forget it. When the Chief drifted back to the matter before the Committee, it was learned that it now costs but $6.05 to pump 1,000,000 gallons 100 feet high at Belmont; but the average cost for pumping that amount of water the distance named, was $8.52. The subject was referred to a sub-committee, who, at Mr. Bardsley's suggestion, will ascertain whether Mr. Thornton's plan is meritorious or not, and make a speedy report.

Should the proposition be accepted by the city, it is proposed to utilize the machinery of Mr. Thornton for the purpose of supplying the north-western section of the city, including the Fifteenth, Twenty-ninth and Twenty-eighth Wards, where the residents suffer from a paucity of water.

On behalf of the residents of Mount Airy, Mr. Gowen asked for water facilities, which are now wanting in that locality, although they are compelled to pay for the maintenance of the system, and the interest on the water loans.

Chief McFadden stated, that for $10,000 he could erect the necessary pumping station and standpipe to supply that locality. The department would receive $2000 per year income, in the way of rents, which he considered a fair investment for the money. He was instructed to incorporate that item in his appropriation for 1879. The Committee then adjourned.

Philadelphia, December 4, 1878.

Gentlemen:

Herewith you will receive an article from the papers of to-day, reporting a proposition to Councils to enlarge the city water-supply by steam pumpage.

Be pleased to state in your Report now in progress:

1st. Whether the aggregate capacity of the steam works has not been estimated, both by the W. D. Reports and that of the Commission of 1875, at nearly 100,000,000 gallons per day?

2d. Whether one-half of that amount has ever been pumped by steam?

3d. Whether the habitual waste of coal at the steam works is not such as to enable a thrifty contractor to pump water much cheaper than at present, merely by the diminished consumption of coal?

4th. Whether the new 20,000,000 gallon engine now standing idle at the Schuylkill Works, will not answer as well as that proposed by Mr. Thornton? What are the particularities of this engine?

5th. Whether the control of the Register by the contractor, would not expose the City to imminent risk as to the estimated pumpage?

6th. Whether $7.93 per hundred feet of elevation does not mean $16 at Belmont, $9 at Schuylkill, and $29 at Roxborough, per million?

7th. Whether, if expedient to contract for a portion of the water-supply—it would not be far more so, to lease the whole City supply to a private Company?

I am, Yours Respectfully,

JAMES HAWORTH.

Messrs. Nystrom, etc.,
Water Commission.

§57. ANSWERS TO THE ABOVE QUESTIONS.

1st. In the W. D. Report for the year 1874, page 97, the theoretical capacity of all the steam works is estimated at 67,082,547 gallons per 24 hours. Since then, the two Cramp's engines, of 30,000,000 gallons, have been added, making 97,082,547 gallons, their present capacity. The Commission of 1875 made the same estimate, or copied that in the W. D. Report.

Your Commission also has estimated the theoretical capacity of the steam works at 97,607,047, and the practical at 68,128,000 gallons per 24 hours. (See Table XVIII, page 123.)

2d. Table IX, page 77, gives the average daily pumpage by steam-power for 18 years. Table X, page 79, gives the average daily pumpage by steam for every month in four years.

The maximum daily pumpage by all the steam works, as far as your Commission has been able to ascertain, was reached on one or two occasions in 1876, when it amounted to about 40,000,000 gallons, which is below one-half their estimate.

3d. Mr. Thornton is no doubt aware of the extravagant use of coal at the water-works, the saving of which would alone make his contract very profitable.

4th. There appears to be some mystery about this engine, not known outside of the Water Department. The Chief Engineer advocates increase of steam-power, and fears a water famine, whilst this new 20,000,000 gallon engine has been standing idle since it broke, in September last. From the outside of the engine no breakage can be seen, but it appears to be as sound as when first started, Dec. 20, 1876. The engineer of the works, who speaks well of the engine, says there is only a crack in the casting in the valve-chamber, and that he does not know why it is not repaired. This engine cost the Water Department about $90,000, and was to pump 20,000,000 gallons into the Schuylkill reservoir per 24 hours. The contract price for this engine was $67,000, and the foundation for it cost $20,000.

The dynamic duty of the engine was to be 75,000,000 foot-pounds of work per 100 pounds of coal consumed, provided the boilers evaporated at least 9½ pounds of water per pound of coal.

The perfect combustion of one pound of carbon generates 14,500 units of heat; and 772 (Joule) foot-pounds per unit of heat, would make 11,194,000 foot-pounds of work per pound of carbon consumed. Allowing 74 per cent. of carbon in the coal, the duty now required of the engine is only 9 per cent. of the natural effect of the coal consumed, according to Joule's equivalent.

A forty-eight hours' trial of this engine was made, commencing Dec. 20, 1876, the results of which are partly tabulated in the W. D. Report for that year, without giving the pumpage, or any detailed description of the experiment, nor signature of the experimenters, who are unknown to the public.

Their tabulated data indicate that the experiments must evidently have been made by inexperienced men.

Your Commission does not know what kind of engine Mr. Thornton proposes to introduce at the water-works, and can not therefore compare it with that of Mr. Cramp. There are various conflicting opinions given on the Cramp engine by parties who pretend to know, but none that could be accepted for this Report.

Your Commission has seen the engine in operation, and it appeared to work very well, but cannot give a definite opinion on the same without a thorough examination, which could not be made, for want of permission from the Water Department.

5th. The control of the Register (or Counter) by the contractor, would possibly, or probably, not protect the interest of the city. (See * page 98.)

6th. Mr. Thornton's proposition is very clear on this point, namely, $7.93 per million gallons pumped 100 feet high, which makes $16.81 at Belmont, $9.12 at Schuylkill, $29 at Roxborough, and $9.07 at the Delaware reservoirs.

7th. Mr. Thornton's proposition appears to be that he runs only the engine furnished by himself, whilst the other engines in the same works are run by the Water Department, which arrangement would undoubtedly open very serious objections; but if Mr. T. leases the whole works, it may be advantageous to the city, and so, also, the lease of all the water-works, to a private and responsible company.

RECOMMENDATIONS BY YOUR COMMISSION FOR IMPROVING THE FAIRMOUNT WATER-WORKS.

The examination of the Fairmount Water-Works, as described in this report, has made your Commission so conversant with its operations as to be able and justified in recommending the following improvements for increasing the capacity of the same.

First. To alter the form of the buckets in the guides and wheel of turbines Nos. 3 and 5, (No. 4 is now being altered to the Duplex Automatic Adjustable pattern,) so as to utilize the maximum effect of the water-fall at mean low tide.

Second. To enlarge the pumps to suit the alteration first recommended:

N. B. The first recommendation can be accomplished without the second, that is, the buckets in the guides and wheel can be so constructed as to utilize the best effect with the present pumps; but then it will take only half the quantity of water now used for the same pumpage; but as the demand for water is now increasing, it is better to enlarge the pumps, and construct the guides and wheel accordingly.

Third. To connect all the pumps, by mains, with both the Fairmount and Corinthian reservoirs, so as to throw all the pumpage into the higher level during low tide, and to the lower level at high tide.

Fourth. To construct such valves for leading the pumpage to the different reservoirs, that they could be opened or closed in a minute or less; which can easily be accomplished.

The present valves require about half an hour to open or close.

Fifth. To raise the Corinthian reservoir 12 feet, so as to make the proportion of lift into the two reservoirs equal to the proportion of head of fall at mean high and low tides.

Head of fall at mean high tide,	- -	10 feet.
" " " low "	- - -	14 "
Lift into the Fairmount reservoir,	- -	90 "

$$10 : 14 = 90 : x. \qquad x = 126 \text{ feet.}$$

The lift into the Corinthian reservoir should be 126 feet.

The raising of the Corinthian reservoir about 12 feet, would accomplish two important advantages, namely:

1. It would enable the Fairmount Works to utilize the maximume ffect of the water-fall at any height of tide, and thus increase its pumping capacity.

2. It would enable the Corinthian reservoir to distribute its water to that much higher levels, and to supply more water to Kensington, and even to Frankford.

The size of the pumps, and construction of the buckets, should be so proportioned as to utilize the maximum effect of the water-fall both at mean low and mean high tides.

Sixth. To erect a *Water-Pressure Engine* in the vacant space No. 6, connected so as to pump into the Corinthian at low tide, and into the Fairmount reservoir at high tide.

After the first water-pressure engine has proven a success, a second one should be erected for No. 2.

In case the above recommendations are carried out, it may be found expedient to alter also the wheels and pumps in the new wheel-house, and the capacity of the Fairmount Water-Works would thus be more than doubled, and the running expenses per million gallons pumped, would be decreased in the same proportion.

JOHN W. NYSTROM,
W. BARNET LE VAN,
WILLIAM DENNISON,

Philadelphia, Dec. 30, 1878.