

(*Paper No. 3853.*)

**“Hankow Waterworks.”**

By RICHARD ST. GEORGE MOORE, M. Inst. C.E.

(*Abstract.*)

IN August, 1905, the Author was retained by His Excellency Chan-Chih-Tung, then Viceroy of the Provinces of Hupeh and Hunan, to proceed to China and report on the feasibility and cost of a water-supply to the three cities, Wuchang, Hankow and Hanyang.

These three cities are on the River Yangtse (Fig. 1, Plate 5), 600 miles from its mouth, where the river is 4,800 feet wide, 40 to 50 feet deep in winter, and 80 to 90 feet deep in summer. The greatest recorded variation in the level of the water is -4 feet to + 50 feet 6 inches on the Custom House gauge, or a total of 54 feet 6 inches (Fig. 2). The River Yangtse here flows from south to north. The River Han enters on the west side and is, at its junction with the Yangtse, 600 feet wide.

Wuchang, the viceregal capital of the Provinces of Hupeh and Hunan, is an ancient walled city on the east bank of the Yangtse opposite the mouth of the River Han. The population is chiefly official and military, as it includes the Viceroy's staff of both provinces, the Governor of Wuchang and his staff, and the headquarters of the army with over 10,000 soldiers. The industrial buildings consist of two Government cotton-spinning mills, the mint, and a glass-cloth factory.

Hanyang is also an old walled city, now of no trade importance, but on a strip of land between the town and the Han River there are several important factories, viz.:—Hanyang Ironworks, where the blast-furnaces are capable of turning out 500 tons of pig-iron per day, and the steel-furnaces and rolling-mills can deal with 1,000 tons per day; the Government Arsenal, where a large number

of field-guns, rifles and other machinery, are manufactured; the Government powder-factory; and a screw- and nail-factory capable of an output of 10 tons per day.

Hankow is the tea mart and shipping port for the centre of China, being the highest point on the river served daily by the 2,000-ton river-steamers from Shanghai: large steamers from London and Liverpool and coasters also use the port. The upper-river traffic, to Changsha on the Sian River and Ichang on the Yangtse, is carried by smaller river-steamers varying between 600 tons and 1,000 tons.

The Author reported in November, 1905, that the two obvious sources of supply were the Rivers Yangtse and Han. Samples of water were forwarded to Dr. A. Stanley, the Medical Officer of Health at Shanghai, who reported that the water was a very pure sample of river water comparing favourably with that taken from the Thames, as may be seen from the following Table. The Author

RESULTS OF ANALYSES, SEPTEMBER, 1905.

All Unfiltered Waters.	Thames (Hampton).	Yangtse.	Han, High Water.	Han, Low Water.
Total solids . . . . .	29.75	19.2	15.6	31.6
Chlorine . . . . .	1.9	1.55	0.7	0.5
Albuminoid ammonia . . .	0.028	0.009	0.013	0.0106
Hardness . . . . .	21.5	13.00	12.00	22.00
Microbes per cubic centimetre	18,330.00	148.00	186.00	96.00

NOTE.—The sample of the Han at low water was taken in February, 1906.

also made investigations as to the possibility of obtaining underground water, but came to the conclusion that water thus found was in all probability river water. He therefore decided to recommend water pumped from the river above the town to be supplied: properly filtered, this would give a good supply.

The population of Hankow, according to official returns, was 173,379, but this return was considered very erroneous by foreign residents, who gave the population at 800,000. The Author based his estimate of the quantity of water required on a population of 250,000 at 10 gallons per head per diem, equal to 2,500,000 gallons daily.

The Author eventually selected site No. 1 upon the River Han, situated on the Hankow bank nearly opposite the Hei-Shan Temple, at which point the evidence appeared to show that the River

Han is never less than 250 feet wide, giving a minimum flow of 1,000 million gallons per day.

The Author recommended in his Report that the water should be treated on the same principle as that adopted at the works for the supply of London, Hamburg and Frankfort, with the additional aeration due to the water being raised from the river by an air-lift instead of an ordinary pump. The water is raised by the air-lift to a height from which it can flow into the settling-tanks, where it remains 20 hours. From the tanks it gravitates into the filter-beds and is filtered at the rate of 2 gallons per square foot per hour through 3 feet of sand, being delivered into a service reservoir, whence it is pumped through the town under the head of a balancing water-tower 5 miles distant.

In December, 1906, the Author received a cablegram asking whether he would act as Engineer for a waterworks capable of delivering 5,000,000 gallons (twice the size he recommended) in a working day of 16 hours for Hankow only, which offer he accepted. The preparation of the plans was commenced in his London office, but the Chinese were too impatient to commence work to allow of their being completed before starting. The Author arrived in Hankow at the end of April, 1907, and the first sod was turned in May, although the only plan in existence was a small general arrangement.

#### DESCRIPTION OF THE WORKS.

The works generally follow the lines of the original report, viz., air-lift from the reservoir, continuous-flow settling-tanks, sand-filters, covered reservoir, steam pumping-engines for delivering the water through the town to the balancing water-tower 5 miles distant.

*Foundations.*—The country round Hankow on the Hankow side of the rivers Yangtse and Han is flat for many miles. The nature of the ground is deceptive, the surface being a short clayey earth, apparently capable of carrying considerable weight, but this overlies a bed, estimated in places to be 70 feet deep, of fine water-bearing sand, similar to the sand of the Bagshot beds. No borings or sinkings exist to prove the extent of this sand bed, but it is known to extend from the site of the waterworks to the site of a well 200 feet deep made on the French Concession ("C" on Fig. 1, Plate 5). Some people are of the opinion that it is the old bed of the River Han, which theory the position of the old bed, where found, tends to confirm. The waterworks were the first sinkings which showed the conditions existing, but did not go deep enough to penetrate the

sand bed. The French municipal well since made gives the bottom of the sand at 120 feet below the ground, shingle to 183 feet, and under it red, white and black clay. The Author's supposition that the underground water was probably river water has proved to be correct. The water rises and falls in the sand bed as the river rises and falls, the weight of the overlying earth appearing to compress the sand when the water-level is lowered.

*The River-Wall.*—The river-wall was built prior to the Author's arrival, and was designed and carried out by Mr. Caw, the Chinese foreman of the works. About three-quarters of its length had a solid waterproof facing of 15 inches of lime and cement concrete, the remaining length being constructed of hand-pitched dry facing. The dry facing proved an expensive experiment. In the autumn when the water fell the whole of the dry facing and the liquefied earth behind slid into the river, followed by the superimposed wall, a catastrophe which had been anticipated by the Author. Being requested to advise on the reinstatement, the Author adopted the same form of construction as the portion that had stood, but increased the toe wall and concrete foundations under the superimposed wall, also returning the up-stream end well into the solid ground.

River-walls, under the conditions met with in the River Yangtse, are difficult to design, as for 6 months of the year they are retaining walls over 40 feet high, and should have good land-drainage, while for the other 6 months of the year they are dock walls and should be watertight, as the ground disintegrates freely when water is admitted.

*Intake Works.*—The construction of the intake works was difficult, the Chinese employed having no idea of timbering, either in sinking, tunnelling or trenching. For the first intake-well, a pit 14 feet by 20 feet was sunk from the surface of the ground (43 feet above Customs datum) to the level of the underside of the intake-pipe (+ 8 feet) a depth of 35 feet. While the pit was being sunk a tunnel was driven in the river-face of the wall to meet it, in which to lay the intake-pipe.

The cylinders were sunk from the bottom of this pit under air-pressure, which was found to be necessary. The compressor used had a steam-cylinder 12 inches by 24 inches and was found just large enough for the work, the maximum pressure used being 30 lbs. per square inch. The lock was formed by putting diaphragms, with doors in them, between two of the tubbing-sections. The cylinder in well No. 1 weighed about 65 tons and required an additional load of about 70 tons to sink it. When the cylinders

were down to their full depth, the bottom was still in water-logged sand, so that it had to be sealed under pressure. This was done by first inserting a 3-inch plank flooring extending well beyond the cutting edges of the cylinder. Three 8-inch by 4-inch rolled joists were cut to length and fitted under the flange 1 foot 6 inches above the cutting edge and held in place by packing from the plank flooring. Four feet of strong concrete was then put in and the pumps kept going for 4 days. When the pressure was taken off the bottom was found to be quite tight. The air-lock was removed and the bottom plate put in. The top sections were removed down to the level of the intake, the special section connecting the intake-pipe was put in and the cylinders were again built up to the top. Before the ground was filled in four 20-foot timbers, 14 inches square, were bolted on to the sides of the well and buried in the ground to prevent settlement.

The Chairman of the Company urged that the pit for the second well should be sunk in accordance with Chinese methods instead of timbering, making it 14 feet by 20 feet at the bottom with side slopes of from 1 to  $1\frac{1}{2}$ , that is, about 114 feet by 120 feet at the top. This construction, to which the Author reluctantly consented, nearly led to disaster, and eventually the cylinders had to be sunk by a method similar to that adopted in the first work.

*Intake and Air-Lift* (Fig. 3, Plate 5).—The main reason for adopting the air-lift was to overcome the suction difficulty caused by the great difference in the water-level in winter and summer. In the water there is a large amount of fine sand, which would render the upkeep of any form of pump very expensive. When the river is high it contains much silt, which, if not guarded against, would cover the intake and result in heavy deposits in the suction-well. The intakes, of which there are two, consist each of a cast-iron cylinder-well, 6 feet 6 inches in diameter, built up in rings, 3 feet 3 inches deep, bolted together. The bottom of the intake is -40 feet, that is, 40 feet below Custom House datum. The top is +62 feet, making a total depth of 102 feet. The inlet into the well is +10 feet, so that when the water falls below that level the intake-pipe will have to act as a siphon. The intake-pipe, 18 inches in diameter, runs horizontally at +10 feet until outside the river-wall, and then slopes down. The timber-work can, if necessity arises, be extended below zero. The inlet-rose is carried on wheels, and, by taking out or introducing lengths of pipe, can be raised or lowered for the purpose of keeping it above the mud deposited during high water. The Author anticipates that it will be eventually set at a level of +3 feet, and will be moved only in exceptional years.

The inlet-pipe was connected with the condensers to produce a vacuum in the event of its having to be used as a siphon. After the works were constructed, this was modified, and an air-pressure pipe was introduced, turning the inlet-pipe into an air-lift. The well-end of the inlet-pipe is fitted with a double-seated balanced valve worked by a spindle from the top of the well. In each well there are two 12-inch air-lifts with 3-inch air-pipes. These air-lifts deliver into a tank 29 feet 6 inches by 6 feet by 6 feet, fitted with baffle-plates and a weir. On the weir a signal-arm is fitted, indicating the exact amount of water passing the weir. The engine-driver can see this signal-arm from his office, and is thus enabled to control accurately the delivery of water to the settling-tanks, and to prevent any flooding of the filter-beds. By an arrangement of valves on the cover of the well, the whole well can be turned into an ejector, and the air-pressure used to clean out the well.

*Continuous-flow Settling-Tanks* (Fig. 4, Plate 1).—These tanks are fifty-three in number, 279 feet long, and 15 feet wide, with a mean depth of 5 feet 6 inches. There are seven baffle-walls across the tanks at various points to make the current rise, fall, and divide. At the inlet the stream coming from the valve is divided into fine jets to aerate it further, and to prevent disturbance of the water in the tank. At the outlet end the water flows under, and rises up through a broken-stone strainer, to remove the flocculent matter. A drain is provided for the purpose of cleaning out each tank, the process being completed by washing down with water from a high-pressure filtered-water service. At the outlet end all the settling-tanks discharge into a common channel from which the water can be delivered into any filter-bed. Fifty-two settling-tanks have a capacity of 7,500,000 gallons, and the velocity of the water during the 16 working-hours is  $\frac{1}{2\frac{1}{2}}$ -inch per second.

*Filter-Beds*.—These are of the ordinary sand-filter type, twenty-two in number, 203 feet long by 45 feet wide inside the walls. The water is delivered into the filter-beds in the form of rain, through small perforations in the bottom of a cast-iron trough, which extends from the inlet to half the length of the filter-bed. With all the beds at work the rate of filtration when filtering 5,000,000 gallons in 16 hours is 1.5 gallon per square foot per hour. The rate of filtration is controlled by a specially-designed automatic outlet-valve.

*Reservoir*.—This is an ordinary brick-and-concrete reservoir, with brick piers and brick arched roof. It is divided into two parts, each holding 2,500,000 gallons.

*Pumping-Engines and Boilers*.—The pumping-engines are three in

number, of improved Worthington type. Any two of the engines are together capable of pumping 312,000 gallons of water per hour against a head of 250 feet, with a steam-consumption not exceeding  $18\frac{1}{2}$  lbs. per P.H.P. per hour.

*Condensing-Plant.*—There are three sets of condensing-plant each with 1,000 feet of cooling-surface; with electrically-driven circulating pumps, each capable of delivering 750 gallons per minute against a head of 25 feet.

*Boilers.*—There are three Babcock-Wilcox boilers, each capable of evaporating 10,000 lbs. of water at a pressure of 160 lbs. per square inch. They are provided with superheaters, giving  $150^{\circ}$  F. of superheat, a Green economizer with 200 pipes in twenty sections, chain-grate stokers and induced-draught fan. The machinery is driven by electrical power with steam power in reserve for the stokers.

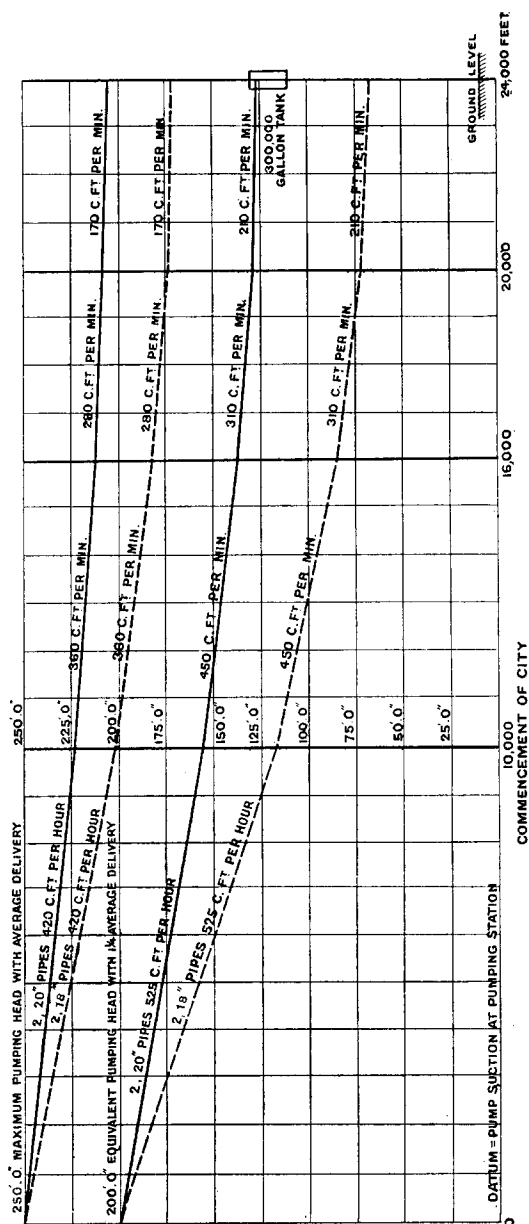
*Air-Compressing Engines.*—There are three of these engines, the specified capacity and efficiency of each engine being that it should compress 1,675 cubic feet of free air per minute to a pressure of 44 lbs. per square inch, with a steam-consumption of not more than 16 lbs. per I.H.P. at full head. The engines are of a compound horizontal type with an air-compressor behind the steam-cylinder, the air-inlet and outlet valves being of the Corliss type driven by an eccentric on the main shaft.

*Electrical Generating-Plant.*—The electrical plant for lighting the works and for driving the air- and circulating-pumps, stokers, fan, travelling-crane, lathe, drills, etc., consists of two vertical direct-coupled 150-kilowatt sets.

*Main Pipe-Line.*—The general arrangement of the supply-pipes is shown on Fig. 5, Plate 5. In deciding how to arrive at the correct size for the pipes the Author had considerable difficulty, which was overcome by dividing the city into squares and arranging to supply in direct proportion to the estimated density of each square. The two main supply-pipes were originally intended to be 18 inches in diameter, but this was increased to 20 inches at the request of the Directors. The friction-head is given in Fig. 6.

*Engine-House and Chimney.*—The engine-house gave no special difficulty, except that the concrete platform, 4 feet thick, upon which it was built showed a crack which it would have been impossible to account for but that its appearance coincided with the falling of the water in the river. This crack developed to a certain extent and then stopped, after which strengthening tie-rods were inserted in the wall and no further movement took place. Since the crack occurred the engine-foundations have been built and

Fig. 6.



FRICTION-HEAD IN PIPES.

COMMENCEMENT OF CITY

DATUM = PUMP SECTION AT PUMPING STATION

GROUND LEVEL

0

the engines erected, and therefore the weight is now evenly distributed over the whole area of the floor.

The chimney, 150 feet high, was built with outside scaffolding, hoop-iron being inserted into the brickwork at every fourth course to bind it together.

*Machinery.*—The three air-compressors, weighing about 97 tons, were erected complete by Chinese fitters, under the direction of the contractor's foreman, in less than 2 months, the time stipulated by the makers being 12 weeks. The main pumps and condenser plant, weighing about 120 tons, were erected on the same system in 2 months, the contract time being 18 weeks. The Author is informed by the representatives of the firms supplying the machinery that the above is a record rate of erection for this machinery.

The pumps and electrical generators and steam-piping were erected by the Chinese foreman fitter with such assistance and instructions as were necessary from the resident engineer.

*Pipe-Laying.*—The pipe-laying was carried out by special Chinese imported from Shanghai, Canton and Hong Kong, who knew the work thoroughly, the inspection and testing being done by a Cantonese foreman with assistance. The pipes were tested after laying by means of a small steam-pump. When under full working pressure only one 20-inch pipe, close to the engine-house, cracked, out of 10 miles of 20-inch pipes and 22 miles of smaller pipes, varying between 4 inches and 15 inches in diameter.

*The Water-Tower.*—This is an octagonal castellated building, carried out in red brick on a granite base, with a square turret projecting from one face to a height of 11 feet above the top of the rest of the tower, which enables the turret to be used as a fire-signal station, from which there is telephonic communication to the power-station. In the turret an alarm bell is hung, on which is signalled by the number of strokes the district in which a fire takes place.

The tank is circular, of wrought steel, 56 feet in diameter and 21 feet 4 inches in depth, entirely shielded by brickwork from the weather.

The tower is 35 feet higher than was originally intended. The increased height rendered it necessary to reduce the weight of the brickwork, which was effected by introducing sixteen cast-iron columns under the ends of the main and intermediate girders, instead of allowing them to rest on the brickwork as originally designed, the appearance of the building remaining the same. The structural ironwork supporting the tank consists of a central cast-iron column 3 feet in diameter on a cast-iron base extended to 12 feet 6 inches in diameter, and the sixteen columns above-

mentioned built into the brickwork. At intervals of 18 feet 6 inches up the central column there are radial horizontal tie-rods at each angle of the octagon tying the columns in the brickwork to the central column, the brickwork acting as struts and ties in the vertical plane between the outer columns. On the top of the column there are eight main radial plate girders, 32 feet long, 4 feet deep, weighing 5·35 tons each. At 13 feet 4½ inches from the centre there is a complete ring of cross-girders on which the inner ends of the intermediate girders rest. The floor on which the tank rests consists of rolled joists 1 foot 9 inches apart, varying between 5 inches by 3 inches and 8 inches by 5 inches according to their span. The total height of the tower to the top of the turret is 152 feet. The roof is carried on light lattice girders resting on an extension of the central column inside the tank. The roof is boarded and covered with "Maltoid" roofing. Ventilation is provided by a vertical light formed by a break in the roof 4 feet from the centre and 1 foot 6 inches deep, protected from the sun by the overhang of the upper portion of the roof and filled with fine wire-netting.

The weight of the tower is as follows :—

Water . . . . .	1,340 tons.
Steel and Ironwork . . . . .	280 "
Brickwork . . . . .	1,761 "
Concrete . . . . .	2,010 "
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Total weight . . . . .	5,391 "
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The foundations consist of a platform of concrete 3 feet thick, on which truncated concrete pyramids are built to take the central column and walls, the side slopes of these pyramids being at such an angle that the projecting concrete is strong enough to distribute the weight evenly over the whole surface of the platform. The area of the platform is 7,386 square feet; therefore the weight per square foot is 0·73 ton.

After the foundations had been excavated a load of 2 tons per square foot was placed upon the ground for 21 days, at the end of which time there was no settlement. The brickwork was carried up slowly and the height of the highest portion was never allowed to exceed that of the lowest portion by more than 5 feet.

After completion there was a total settlement of 8¾ inches, but as the tower had settled practically level, namely, at an inclination of 1 in 400, and without the slightest sign of a crack in the brickwork, the settlement was not considered serious.

The Directors of the Company are: Sung-wei-chen (Pink Button),  
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Chairman and Managing-Director; Wang-hai-fan, Vice Managing-Director; Whang-tat-foo (Taotai and Pink Button), and about four others, who did not take an active part. Mr. Tsung was works manager, and Mr. Caw, works foreman.

*Execution of the Works.*—In considering the execution of these works it must be borne in mind that they are the largest, or nearly the largest, carried out in China under such conditions. Engineering works of any magnitude, when not in the Concessions, are undertaken by the Government. The Hankow Waterworks and Electric Light Company is a purely commercial undertaking, financed by Chinese merchants who were granted the concession by the Viceroy subject to their carrying out the Author's scheme.

The work was executed by administration, small contracts and piecework. Piecework is carried to a fine art by the Chinese, payment by day wages being little employed by them. The main difficulty met with was that of getting the Directors to recognize the necessity of providing sufficient plant, more especially pumping-plant. No wheelbarrows or carts, either hand or horse, are used on works in China, everything being carried in two baskets slung from bamboos across the shoulders.

The settling-tanks, filter-beds and reservoir were all constructed by Chinese workmen under Chinese supervision. The Author was responsible for the design, advice as to the quality of the materials, machinery, etc., deciding in what order the works should be carried out, and inspecting them from time to time to see that the work was being done in a proper manner. The foreman set out the works from the drawings. At first the Author checked the setting out, but found this unnecessary, and therefore later only checked the important items.

From the commencement, in May 1907, until September 1908, the Author was the only European in China connected with the works, but on his appointment as Engineer-in-Chief of the Hupeh section of the Hankow-Canton Railway, Mr. C. A. St. George Moore, M.A., Assoc. M. Inst. C.E., who had been in charge of the preparation of the plans in the Author's London office and the inspection in England, came out to take the position of Resident Engineer, Mr. Arthur Verdon, Assoc. M. Inst. C.E., taking charge of the inspection.

The Paper is accompanied by eight drawings, from which Plate 5 and the Figure in the text have been prepared, and by a map and four photographs.

ARRANGEMENT  
OF SUPPLY-PIPES.

RISE AND FALL OF THE RIVER YANGTSE  
AT HANKOW 1899-1908.

R. ST. GEORGE MOORE

RIVER WALL, INTAKE AND AIR-LIFT.

Feet 10 5 0 10 20 30 Feet .  
 Feet 1000 500 0 1000 2000 3000 4000 Feet .

*Fig<sup>s</sup> 4.*

P L A N

Filtered-Wicker Main to Reservoir