VLADIMIR SHUKHOV
PIPELINES AND WATER TOWERS

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Russia commemorated the 160th Anniversary of Vladimir Shukhov, a great engineer, architect, inventor and scientist, who made an outstanding contribution to the construction technologies of water towers, tanks and pipelines. He was the designer and technical project supervisor of Russia's first oil pipelines and facilities. Shukhov also used his development expertise in water supply projects in many Russian cities

Vladimir Shukhov was born on 28 August 1853 in Grayvoron near Belgorod. He graduated from Imperial Moscow Technical School (currently Bauman Moscow State Technical University) in 1876, and completed an internship in the USA. In 1878–1879 Shukhov designed and constructed Russia's first three 3-inch oil pipelines. These were 9 km to 12 km long and connected the Balakhany oil production site with oil refinery plants in the outskirts of Baku. Shukov also invented several types of oil pumps.

In 1878 Shukhov designed and constructed the first cylindrical reservoirs / oil storages for the Baku oil production sites. Before Shukhovs's reservoirs, oil was stored in drums and ponds and polluted the environment and soil. At the end of XIX, oil and oil products in the USA and Europe were stored in square tanks. The construction office of Alexander Bari, where Shukhov was a Chief Engineer and a business partner, had built over 20,000 cylindrical reservoirs. Nowadays there are hundreds of thousands of reservoirs built all over the world using Shukhov's design.

Shukhov was a designer of Russia's first main pipelines: Baku–Batumi (first project design – 883 km) and Grozniy–Tuapse (618 km).

Vladimir Shukhov developed a classical pipeline theory based on his practical achievements and some of the ideas are still relevant today. He gave exact mathematical formulae to describe oil, kerosene, residual oil and water flow in his "Oil pipelines" article (1884) and in the "Pipelines and their application in the oil industry" book published in 1895. This is the foundation of basic pipeline hydraulics.

The greatest invention of this engineering genius was the world's first industrial oil cracking plant (thermal cracking process, patent of Russian Empire No. 12926 dated 27 November 1891).

Shukhov's triumph was in 1896 at the largest pre-revolutionary All-Russia Exhibition of Industry and Art in Nizhny Novgorod. For this exhibition he built the world's first exquisite steel grid shell water tower in the shape of a single-cavity hyperboloid rotation.

Hyperboloid was a completely new and previously unused shape in architecture. After that first design, hyperboloidal designs were adopted by a number of famous architects including Antonio Gaudi, Le Corbusier and Oscar Niemeyer. Shukhov's design was also used for the construction of eight gigantic pavilions with arch-type steel shell roofs covering an area of 25,070 square metres. Similar structures appeared abroad only thirty years later and are still being used.

The same year, Shukhov was granted a patent for his original, highly efficient and safe vertical and horizontal steam boilers. In 1900 his steam boilers were awarded a gold medal at the World Exhibition in Paris. By the 1950s, these were being produced in Russia in the thousands.

In 1898, as a result of the development of the first science based project for the Moscow water network system, Russian universal methods for water piping calculations was created by V. Shukhov, E. Knorre and K. Lembke.

Shukhov designed over 30 marine mines during WWI, designed and built floating bateau portes, and created a mobile platform for long-range guns. All Vladimir Shukhov's military inventions were highly praised by marine and acting forces.

Vladimir Shukhov died on 2 February 1939 aged 86 and is buried at Novodevichy cemetery in Moscow. A monument commemorating this great engineer, architect and academic was unveiled on 2 December 2008 at Sretenskiy Bulvar in Moscow. This monument was a gift from LUKOIL to the city of Moscow.

Shukhov water towers

Vladimir Shukhov's part in the development of Russian water pipelines began the moment he created the hyperboloid steel grid-shell water tower. At the end of XX, the construction of water pipelines had begun in many cities of Russia and Shukhov had to find a way to radically improve existing water towers.

There is a legend that Shukhov was impressed with the durability of woven willow baskets. From 1895, after analysing the design of the basket, he calculated that the most optimal and durable vertical shape is a grid-like

The world's first hyperboloidal design Water tower. Nizhniy Novgorod, 1896

single-sheet hyperboloid formed by straight steel guide rods and connected by steel rings. He began testing a model water tower erected in the yard of the Bari plant in Moscow.

The model was used to work out the design parts and different methods of production and installation. The testing model did not exist for long – but as a result of testing, the first industrial sample hyperboloid water tower impressed home and foreign specialists at the All-Russia industrial and arts exhibition in Nizhniy Novgorod in 1896. The total height of the tower was 37 metres and the height of the support hyperboloid from the foundation to the bottom of the reservoir was 25 metres.

The world's first hyperboloid design was incredibly beautiful. The famous patron of art, Yuri Nechaev-Maltsov, who gave the Museum of Fine Art to Moscow (presently Pushkin State Museum of Art) bought the first hyperboloid after the Nizhniy Novgorod exhibition. The tower was dismantled and rebuilt by the palace of Nechaev-Maltsov in Polibino Village (presently Dankosvkiy District of Lipetsk Region) under Shukhov's supervision.

The tower has been standing near the palace of Nechaevs for over 114 years but now requires anticorrosion protection and partial restoration of the water reservoir and the basement. The hyperboloid's framework is still in a satisfactory condition.

Shukhov created a calculation method for grid-shell hyperboloid towers and a universal metal installation layout system, and found an easy and simple form of a graphic design which made drawings easier to read, not only by engineers but also by middle technical personnel. Shukhov widely used standardisation and standard designs for water towers.

In the beginning of the XX, Shukhov's grid water towers started to become more popular than previous standard tower designs. They were considered cheaper, more robust and more aesthetically pleasing. Even the most basic water towers from the first half of the XX were 1.5–3.5 times more expensive that Shukhov hyperboloid water towers.

"The hyperboloidal grid-shell designed by Engineer Shukhov currently presents such a perfect type of metal tower that their timely application for water supply, railways and cities would have saved an enormous construction capital..." said engineer D. Petrov in 1911 in his book "Metal water towers. Their significance, design and calculation".

Over 200 of Shukhov's hyperboloid water towers were built in Russia and USSR during his lifetime – a third of them with his involvement. The rest were installed by other companies using Shukhov's standard project plans sold by Bari's company.

The water towers for city water pipelines in Kolomna and Efremov (1902), Nikolaev (1906–1907), Kharkov (1912), Priluki (1914) and Voronezh (1915) were built under Shukhov's immediate supervision.

A great number of hyperboloid water towers were built by different companies all over the country including Lisichansk (1896), Yaroslavl (1904), Andizhan (1909), Kokand (1910), Khimki (1912), Kazan (1914), Tsaritsyn (1915), Lugansk (1915), Samara (1915), Shostka (1916) and Okhta (1916).

Over 40 Shukhov water towers were built for Russian railways. Vladimir Shukhov suggested a non-standard design for Yaroslavl station. The 9.5 metre tower consisted of two hyperboloids installed one on top of the other. These hyperboloids were connected by a single ring. Each

carried a reservoir: the top one was 200 м3 for fire purposes and the lower one was 120 м3 for the courier trains water supply. The total weight of the tower with both reservoirs was 66 tonnes. Built in 1911, this was the first multi-level hyperboloid tower. The experience was then used in Moscow in 1919–1922 during the installation of a multi-level 150 metre radio tower which consisted of six hyperboloids.

Shukhov's drawings, old pictures and calculations for hyperboloid water towers, reservoirs and water pipelines are archived at The Archive of the Russian Science Academy (fund 1508, ref. 1), Russian State Archive of Scientific Technical Documentation (RGANTD, Fund 166, ref. 1). RGANTD Fund stores unique full volumes of documentation on hyperboloid water towers in Ivanovo-Voznesensk (1924), Orekhovo-Zuevo (1924), Vologda (1930) and Evpatoria (1926) which show the exact design technology and construction of Shukhov water towers.

Only five of Shukhov's water towers have survived in Russia. These are the first hyperboloid tower (1896) in Polibino Village of Dankovskiy District of Lipetsk Region, and the Shukhov towers in Vologda, Ivanovo, Petushki and Lobnya (Lugovaya station). There are also towers without the tanks in Krasnodar and Vyksa. All these unique structures need anticorrosion protection and restoration. There are also a number of Shukhov towers still standing in other CIS countries.

Moscow water supply project

Construction of Moscow's first water supply system began at the end of XVIII by the order of Ekaterina the Great. Water was previously supplied by water carriers, however this was unacceptable for fire protection. The first Moscow gravity pipeline was built in 1804 and carried water from Mytischi district via the Rostokinskiy aqueduct. By the middle of XIX, its capacity was not enough to supply the city. There also was a need for fire pipelines able to supply water to the upper floor of buildings.

In December 1885, thanks to the initiative of Governor Nikolay Alekseyev, the City Duma took the decision to construct a new city water supply system. Initially they invited foreign specialists to help: British man Lindley and Belgian Verstraten, however their projects were rejected due to technical and economic reasons.

N. Alekseev then asked the Construction Office of Bari to design the Moscow water supply. Shukhov was the Chief Engineer and had experience in pumping and pipeline construction. By that time Shukhov had taken part in the design and construction of water supply systems in Kuznetsk, Syzran, Zhitomir (1883), Buzuluk,

The same Water tower in Polibino village. Lipetsk Region, 2014

Samara, Serpukhov, Odessa (1884), Kaluga, Nakhichevan and Tsaritsyn (1885). He was famous amongst the specialists owing to the Tambov water supply project (1883) which he designed in collaboration with N. Zimin upon the order of the head of local administration. The project supplied of 60,000 buckets of water per day.

Shukhov and his assistants, E. Knorre and K. Lembke, worked on the draft project for the Moscow water supply for about two months. According to the design, the water intake was planned in the Mytischi district near Moscow. N. Alekseev, Head City Administration, and the Moscow City Duma, approved the project as it was considered to be economically effective and in compliance with the Duma's technical requirements.

Shukhov and his employees conducted geological and hydrological research from August 1887 to March 1888. This showed that the area surrounding Mytischi was not

The water tower in Lugovaya village (Moscow Region)

able to supply even the half of the water required (3.5 million buckets per day). The decision was therefore taken to install an additional water intake in the upper reaches of the Yauza River near Bogorodsk.

As a result of his research and watershed data analysis, Shukhov developed a theory of groundwater for the Yauza basin. All survey works were completed by the end of March 1888. The final project for the Moscow water supply prepared by Shukhov, Knorre and Lembke was sent for approval in June. Calculations for the pipelines and reservoirs were conducted based on the optimal balance of structure durability and construction costs. During the design of the Moscow water supply, Shukhov applied the principles for pipeline construction and hydraulic systems he developed back in 1878–1879 for the construction of Russia's first oil pipelines in the Baku oil fields.

The project was approved by the Ministry of Transport in February 1889. However, the Temporary Moscow Water Pipeline Inspection Committee subsequently demanded a reduction in funds for the construction and cut the scope of work in June 1889.

The new project, designed by city engineers Zimin, Zabaev and Dunker was based on hydrological research and Shukhov, Knorre and Lembke's project and was approved for implementation.

The new Mytischi water supply system began operation in October 1892.

The approved project reduced capacity from 3.5 to 1.5 million buckets of water per day and the estimated cost was reduced by 857,800 rubles (4,957,800 from the Shukhov plan and 4,100,000 from Zimin's). Once the Mytischi water pipeline construction was complete, the need to increase the water supply to 3.5 million buckets of water per day soon arose – as already suggested by Shukhov, Knorre and Lembke. An additional 2,250,000 rubles was then spent to upgrade the water supply five years later.

Shukhov was needed again for the implementation of the corrected plan. His design was used by the Bari Construction company who worked as a contractor in Rublevskaya pumping station and supplied riveted tanks for the Krestovskie water towers.

Shukhov was awarded a gold badge for his part in the creation of the Moscow water supply system. He was also an active participant in the First Russian Water Congress held in March 1893 in Moscow.

The project and the supporting research undertaken by Shukhov, Knorre and Lembke created so much interest in technical circles that three years after their publication by Moscow city administration, the Bari Construction Company had to publish a new edition which also contained the theoretical articles developed by the authors. Shukhov's project for the Moscow water pipelines is archived by the Russian Academy of Science.

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