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Pioneering Russian wind tunnels and first experimental investigations, 1871–1915

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ABSTRACT

A review of foreign and Russian sources is given mentioning the pioneering wind tunnels built in Russia at the turn of 19th and 20th centuries. The first wind tunnel in Russia was constructed by V.A. Pashkevich at the Mikhailovsky Artillery Academy in St. Petersburg in 1871. In total from 1871 through 1915, 18 wind tunnels were constructed in Russia: 11 in Moscow, 5 in St. Petersburg and 2 in Kaluga. An overview of the pioneering Russian wind tunnels built by V.A. Pashkevich, K.E. Tsiolkovsky, prof. N.E. Zhukovsky, D.P. Ryabushinsky and prof. K.P. Boklevsky is given. Schemes, photographs, formulas, description of the research and test results taken from the original papers published by the wind tunnel designers are given. Photographs from the N.E. Zhukovsky Scientific and Memorial Museum and the Archive of the Russian Academy of Sciences are used in the article. Methods of flow visualization and results of their application are presented. The Russian scientists and researchers' contribution to the development of techniques and methods of aerodynamic experiment is shown, including one of the most important aspects - the wall interference problem.

World history adorns the world with great memories for the mind, and the Russian one decorates the homeland where we live and feel.

N.M. Karamzin "History of the Russian State"

1. Introduction

Two factors served as the impetus for writing the article. Stephen Wolf from ONERA gave the first one for writing these historical notes during preparation of information about the first wind tunnels of Russia for the "Wind tunnels" exhibition in Paris in 2013. The second one is an analysis of the author's available foreign sources [1–5], which showed that they did not fully explain the history of the appearance of wind tunnels in Russia, with some omissions and errors.

The first Russian wind tunnels are mentioned in domestic publications, but apparently they did not reach foreign historians. The Russian sources only partially describe the technical parameters, types of research conducted and there are nearly no references to primary sources. The author hopes that the historical materials presented in this review will fill the existing gap. The article contains photographs, diagrams, graphs, tables and quotations from primary sources for increasing the reliability of the description of historical events.

On the NASA website [1] in the history of wind tunnels for students, a list of the most significant first wind tunnels of the world is given. The sample up to 1917 is shown in Table 1. In the list of wind tunnels there are two wind tunnels designed by the Russian scientists K.E. Tsiolkovsky and D.P. Ryabushinsky.

The most detailed information on the earliest wind tunnels built worldwide in the 19th century is given in Ref. [2]. For ease of comparison, the main parameters of the wind tunnels considered are presented as a matrix (Table 2). Outside Russia, the first wind tunnels were constructed by Francis H. Wenham, Horatio F. Phillips and Hiram S. Maxim in the United Kingdom; Ludwig Mach in Austria; Charles Renard and Etienne Marey in France; H.C. Vogt and Paul LaCour in Denmark; and Alfred J. Wells in the USA. Reference [2] mentions the Russian wind tunnel built by N.E. Zhukovsky at the Moscow Imperial University as well as that built at the Aerodynamic Institute in Kuchino.

In the review [3] of the aviation section of the Nancy International Aeronautical Congress in 1909, a brief list of the main aerodynamic laboratories operating in the world is given. The Kuchino Aerodynamic Institute which was founded in 1904 under the leadership of Professor Zhukovsky is among them. The paper also mentions that Mr.

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Table 1
A list of important wind tunnels [1].

No	Date	Description	Designer	Location
1	1871	First wind tunnel	Frank Wenham	Great Britain
2	1897	Russian tunnel	Konstantin Tsiolkovsky	Russia
3	1901	16- by 16-inch tunnel	Wright Brothers	Dayton, OH
4	1901	6- by 6-foot tunnel	Albert Zahm	Catholic University
5	1904	Russian tunnel	Dimitri Riabouchsinsky	Moscow
6	1909	First closed-loop tunnel	Ludwig Prandtl	University of Gottingen
7	1912	Twin tunnels	Gustav Eiffel	Paris, France

Ryabushinsky and Kuznetsov collected valuable experimental documents on air drag and stability of axisymmetric bodies, on helicopters and kites design, as well as on aviation photography and, finally, on the investigation of high atmospheric layers.

A brief review of the research carried out at the Kuchino Aerodynamic Institute is given in Ref. [4] based on the Institute's publications in French. In paper [5], activities of aerodynamic laboratories of the world are analyzed, including the Kuchino Aerodynamic Institute.

Unfortunately, despite the fact that only a little more than 100 years have passed since the first wind tunnels appeared in Russia, most of the work on their history already belongs, according the definition given by N.M. Karamzin [6], to its third type: *There are three kinds of History: the first one is modern, for example, that by Thucydides, where an obvious witness talks about incidents; the second one, like that by Tacitus, is based on contemporary verbal traditions in the time close to the described actions; the third one is extracted only from monuments, like ours until the XVIII century*.

The first type should include works [7,8], describing the activities of the Kuchino Aerodynamic Institute on the basis of D.P. Ryabushinsky's articles.

The historical source related to the second typeis the work [9] devoted to the history of the foundation of the Moscow Imperial Technical School aerodynamic laboratory: *At this time and abroad they realized building special aerodynamic laboratories. The most famous ones - Prandtl's aerodynamic laboratories in Göttingen, those of Eiffel in Paris and the English National Physical Laboratory - were started in 1909 and put into operation in 1910. Because of this, the Aeronautic Club decided to create such a laboratory at the Imperial Technical School. The Board of the School met, as it had always done later, the students halfway and allowed them to use the workshops of the School and occupy a half the fifth-year course drawing room to install the equipment. In the school workshops it was decided to install two wind tunnels - one circular 1 m in diameter and the other, according to a N.E. Zhukovsky and P.P. Sokolov's idea, rectangular with the dimensions of the test section cross-section equal to 1.5 × 0.3 m. Design and supervision of the construction of these wind tunnels was assigned to a student A.N. Tupolev who accomplished this work quite successfully … Soon (in 1910) the lack of* funds *forced the Aeronautic Club to sell the constructed wind tunnels to the Technical School which continued the further organization of the laboratory at the expense of* funding *received from the Society named after Kh.S. Ledentsov. From that moment began the actual work of the Moscow Technical School Aerodynamic Laboratory*.

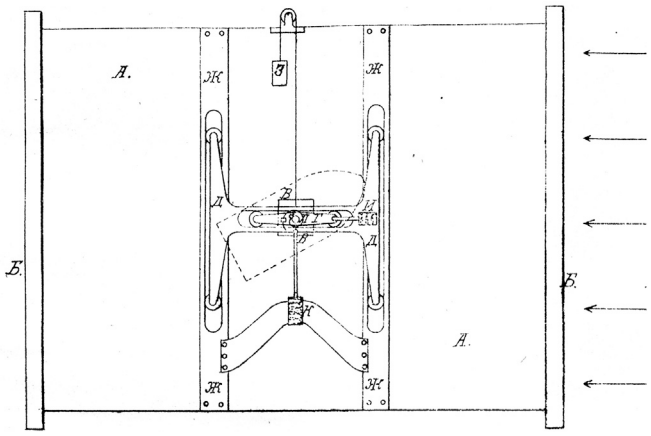

Fig. 1. General view of the test section and three component balance [11].

All subsequent historical works, which are referred to in this article, rely mainly on primary sources (“monuments” as defined by N.M. Karamzin) and refer, like this article, to the third type of historical research. The author gives only a brief list of works concerning the history of the first wind tunnels in Russia.

In the collection [10] materials are published relating to the development of the Russian air fleet in the period up to 1907. In particular, it presented a shortened version of the article by the creator of the first wind tunnel in Russia, V.A. Pashkevich, with a description of the facility and the results of the studies carried out in it [11].

The history of the creation by K.E. Tsiolkovsky of aerodynamic devices including two wind tunnels (1896 and 1899 approximately) is uncovered using archival sources in Refs. [12–15]. A brief description of the wind tunnels and balances for measuring drag is given. There is also a

Table 2
The main parameters of the wind tunnels built worldwide in the 19th century [2].

No	Built in	Designer	State, location	Dimensions	Flow velocity	Drive system
1	1871	Francis H. Wenham (designer) and John Browning (constructor)	England, Greenwich	Length 10 feet (3.05 m) Crosscut: a square with 18 inches side (0.457 m)	Up to 40 mph (17.9 m/s)	Forcing fan
2	1884	Horatio F. Phillips	England	Length 12 feet (3.66 m) Crosscut: a square with 17 inches side (0.432 m)	Up to 41 mph (18.3 m/s)	Steam ejector
3	1891	Nikolai Zhukowsky	Russia, Moscow University			
4	1893	Ludwig Mach	Austria, Vienna	7 x 9-3/4 inches (0.178x0.248 m)	22 mph (9.8 m/s)	Suction axial fan and explosion engine
5	1894	H.C. Vogt	Denmark, Copenhagen	Length 40 inches (1.016 m) 4.5 x 9 inches (0.114 × 0.229 m)	34 mph (15.2 m/s)	Exhaust duct draught
6	1896	Charles Renard	France, Etablissement Militaire de Chalais Meudon	Length 12 feet (3.66 m) Diameter 31 inches (0.79 m)	31 mph (13.8 m/s)	Forcing fan
7	1896	Hiram S. Maxim		Crosscut: 3 x3 feet (0.915x0.915 m)	49 mph (21.9 m/s)	100 hp steamer and co-axial fan
8	1896	Alfred J. Wells	USA, Massachusetts Institute of Technology (MIT)	30 x 30 inches (0.76x0.76 m)	15 mph (6.7 m/s)	Ventilation system air
9	1897	Paul LaCour	Denmark, Askov (2 WTs)	Diameter: 19.5 & 39 inches (0.5 & 0.99 m)	22 mph (9.8 m/s)	4-bladed fan and electromotor
10	Before 1899	Etienne Marey	France, Paris	8 × 12 inches (0.2x0.3 m)		