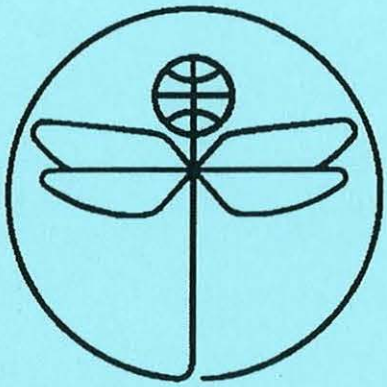
TWENTY FIRST EUROPEAN ROTORCRAFT FORUM



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ALEXEI M. CHERYOMUKHIN,

HELICOPTER CHIEF DESIGNER AND TEST PILOT

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This year would mark a centenary from the birth of Alexei Mikhailovich Cheryomukhin, one of the outstanding pioneers of Russian helicopter engineering. He was born to a family of teachers in Moscow on May 30, 1895. Having finished Moscow Gymnasium No. 5 with a gold medal in 1914, he entered the Saint Petersburg Polytechnical Institute. Soon after that World War I broke out, and the young student went to the front as a volunteer. At first, he was a mechanic and a driver in an aviation unit in Corps No. 13, and then he was sent to the aviation school of the Moscow Aeronautical Society where he was a student of the Theoretical Courses in Aviation headed by Professor N.E. Zhukovsky. Having finished that school in spring 1916, Cheryomukhin was given the rank of a warrant-officer and sent as a pilot to an aviation unit in Siberian Corps No. 4. From June 1916 to October 1917 he was a fighter pilot in the active army. He was awarded six Russian military orders and a French Military Cross. His service record contained the following references: "An outstanding pilot and officer. Accomplishes combat missions honestly, with remarkable presence of mind and intrepidity. Fond of aviation and is interested in it. An excellent companion in arms..".

In March 1918 after demobilization Cheryomukhin entered the Faculty of Mechanics in the Moscow Higher Technical School where he became a student of N.E. Zhukovsky, "the father of Russian aviation". Since December 1918 the student studied and at the same time worked in the Experimental Aerodynamics Department of the just founded Central Aerohydrodynamic Institute (TsAGI)where he was involved in wind tunnel studies, participated in designing and flight tests of the KOMTA heavy aeroplane and the AK-1, Soviet first passenger aircraft.

Cheryomukhin's graduation from the institute (he got a diploma of the aircraft mechanical engineer) coincided with the beginning of a large-scale construction of the TsAGI experimental facilities. The engineer was the author of the then largest wind tunnel, T-I-T-II. In 1923 he started to publish his works.

The head of the Experimental Aerodynamics Department in TsAGI was Boris N. Yuriev, one of the pioneers of Russian helicopter engineering. It was due to his persistence, that the first studies in this area in his department were made as far back as 1924-1925. However, systematic work in this field started only in the late 1926, when a special H ("helicopter") team under Cheryomukhin was organized. The team started its work by comprehensive studies of main rotor scale models on the test bench. Flying helicopter scale models were also investigated, wind tunnel tests were conducted. The team members thoroughly studied the experience gained in foreign countries.

In the mid-20s helicopters could fly for a short time only, the endurance being about 10 minutes, at an altitude of several meters with a speed of about 10 km/h covering distances of little more than 1 km. On the background of rapid advancement of aircraft engineering these figures were quite small, nonetheless, they convincingly proved that controlled flight by using the main rotor was possible.

In early 1926 Yuriev showed his colleagues helicopter configurations developed by him. After their thorough analysis, three configurations called "favorites" were chosen. The engineers did preliminary design , weight and aerodynamic analyses.

Yuriev considered the helicopter of the eight-rotor element configuration to be the most promising. By an element he meant a rotor-engine group comprising the engine, drive shafts and the main rotor. By comprehensive testing of one such group on the test bench, Yuriev planned to build helicopters of any payload capacity by combining the required number of the same elements. In late 1927 the first element was built. It consisted of the 120 hp Rhon engine and all-metal main rotor of 6 meter diameter. At the beginning of the next year Cheryomukhin erected a full-scale test facility in the TsAGI yard; the new facility allowed to investigate the performance of one element separately and two elements operating together. Bench tests lasted for about two years. The rotor thrust and power required were measured, the influence of ground effect was studied, the main rotor, drive shaft and engine system design was improved, a number of other problems were studied.

The second "favorite" chosen by the engineers of H group was a side-by-side rotor helicopter, and the third one, a single-rotor helicopter having tail rotors to counteract the main rotor torque. In contrast to the classical configuration developed by Yuriev in 1911, to ensure symmetry during takeoff, to reduce dependence on the control channels, the single-rotor "favorite" had four tail rotors instead of one: one pair of the tail rotors was installed in the nose section, while the other one, in the rear section. In the future the engineers planned to remove the nose section and return to the classical configuration. The swashplate was intended for cyclic pitch control. Fully aware of the sophistication of this design, Cheryomukhin insisted

that the swashplate of the single-rotor "favorite" should be tested on the full-scale test facility.

In late 1928 quite significant changes were made in the TsAGI helicopter group activities. The H group was given a new name, i.e. Section of Special Designs. Yuriev left the TsAgi. Since that time the responsibility for developing the helicopter programme was born by Cheruomukhin. He completely changed the orientation of the Section's activities. He curtailed work involved in the multirotor and side-by-side helicopters and all efforts and means were aimed at designing a single-rotor machine. Explaining his decision, Cheryomukhin pointed out the single-rotor configuration incorporating the tail rotor and the swashplate "was simple in principle, as if it were built by using the least work concept, i.e. it did not contain any excess member that could be removed from the aircraft design of this type." At present more than 90% of the built helicopters use this concept, but for the twenties, the selection of the configuration was quite a daring action.

In late 1928 Cheryomukhin headed design engineering of a new helicopter which later was designated TsAGI 1-EA (EA-meaning "Experimental Aircraft"). For the powerplant two Rhon engines of 120 hp each were chosen. They were rotary engines and needed no additional cooling devices. Special attention was paid to the main rotor, power train and control system design. The main rotor diameter was 11 meters. Its blades were rigidly attached to the hub. There was only a feathering hinge providing blade pitch changes. At first, the main rotor blades were all-metal, this design was replaced by a mixed one. An engine manufacturer was involved in designing the power train system. The swashplate design was developed by Cheryomukhin himself. Throughout the design stage tight weight control was exercised. To reduce weight, the fuselage had no skin. As Cheryomukhin recalled later, the designers sometimes "were on the brink of the strength limit." To counteract high vertical speeds the landing gear struts had a large stroke.

In June 1930 the TsAGI's experimetal facility finished assembling the TsAGI 1-EA experimental helicopter; after testing the structure parts, for reliable operation, the aircraft was carried to the Ukhtomsky aerodrome near Moscow. The empty and takeoff weights were 982 kg and 1,145 kg respectively. At first tethered tests were conducted on the aerodrome, lift developed by the main rotor was measured, forces applied to the control stick were trimmed. Cheryomukhin acquired the first skills in flying. At last, one night in September 1930 the first Soviet helicopter flown by Cheryomukhin made its maiden flight. According to the comments made by those participating in the tests, "the helicopter flew reliably, free of trouble; as for the usual matter such as transmission operation and behavior, main rotor operation, engine cooling there was no trouble at all."

During 1930-1934 the TsAGI 1-EA was used for conducting a comprehensive flight test programme during which the main rotor characteristics with the aircraft on the ground, engine power distribution, the influence of ground effect on the aircraft performance, required displacement of the control stick in different flight conditions were determined. The helicopter displayed all the propertied inherent in this type of aircraft: vertical takeoff and landing, hovering, turns in hovering, displacement in any direction in forward flight. That is why Academician Yuriev had every reason to state: "The first man in the world who started to fly helicopters in the full sense of the word was Zhukovsky's follower, Alexei Mikhailovich Cheryomukhin, engineer/pilot." The total number of free flights and hops made by the 1-EA was 39 and 15 respectively. In the course of testing, the required design changes were introduced.

During the whole period of the TsAGI 1-AA flight testing Cheryomukhin remained not only the chief designer, but virtually its permanent test pilot as well. His closest companion-in-arms in the field of developing the TsAGI rotorcraft, A. M. Izakson, called Cheryomukhin's flights "heroic deeds". Indeed, every flight in the unusual aircraft was highly risky and could become the last one. In addition to a fairy great amount of personal courage, excellent knowledge of the aircraft arrangement and features, the test pilots had to have broad flight experience. It was not an easy task to fly the TsAGI 1-EA. The helicopter is an unstable type of aircraft; what is more, it was the first experimental prototype encumbered with all the drawbacks inherent in the new structure, the control system in particular. As Cheryomukhin recalled later, "At first I always felt to be at the needle's point." But the experience of the former fighter pilot came to his rescue and soon "some habit was acquired ... and skills required to conduct flight tests were mastered."

In each new flight Cheryomukhin increased the altitude and endurance of the flight. Many foreign achievements were soon exceeded. On August 14, 1932 Cheryomukhin climbed to an altitude of 605 m thus exceeding the then existing official altitude record by 33 times. This achievement was beaten only in 1937 by the German Focke-Wulf 61 helicopter. When the TsAGI engineers reported the record-breaking flight to the leadership of the country, I.V. Stalin flatly refused to give any information about this achievement in the open press: he was afraid that the information would urge foreign governments to support developments of their helicopter companies.

The former chief engineer in TsAGI, and now the internationally known General Designer of fixed-wing aircraft A.N. Tupolev making a speech at the 70-th anniversary of Cheryomukhin birthday which was held at the height of the propaganda campaign related to the first flights of our cosmonauts in space, made the following evaluation of the record flight of the first Soviet helicopter: "And that flight, I think, was more

crucial and daring than the flights of our cosmonauts. Space flights are supported by the whole country, whereas the helicopter flight, by one maintenance engineer and a small TsAGI team. To perform such a flight, it was necessary to have an intrepid soul, strong will, keen desire so that our engineering could be always on move."

The altitude achieved was not a limit for the helicopter. The engine limited service life made Cheryomukhin reduce the time of the helicopter flight. Besides, some flight conditions were little known. Thus in power-on gliding after the record flight, the main rotor got into the vortex ring, and only the substantial flight experience of the test pilot allowed him to land the aircraft with minimum damage. Therefore the maximum time in flight did not exceed 14 minutes, and the distance covered, 3 km. The aft CG position and insufficient margin of control limited the airspeed to 21 km/h.

The leaders of Soviet industry and armed forces got interested in helicopter flights. In 1932 Tukhachevsky, Deputy Defence Minister even suggested that a small batch of experimental TsAGI 1-EA should be built. On December 22, 1933 Cheryomukhin was awarded the Order of the Red Star for outstanding achievements in developing rotorcraft. However, in late 1931 he was dismissed from the head of the TsAGI helicopter department despite all his outstanding services as designer and pilot in designing unique aircraft technology. At that time in TsAGI all department heads not belonging to the Communist Party were dismissed from their posts. A.M. Izakson became the new head of the Section of Special Designs which, a year later, was given the status of an independent Department of Special Designs. Cheryomukhin was appointed his deputy.

In 1933, based on the TsAGI 1-EA, the TsAGI 3-EA was built. Only tethered test were conducted, as it was soon decided to install an articulated main rotor of a radically new design instead of the four bladed rigid main rotor.

In those time many authoritative persons in helicopter industry stated that the swashplate would become inoperable with the articulated rotor installed. Loss of control when the aircraft got into the area of the vortex ring was of great concern. Therefore the TsAGI engineers working in the Department of Special designs made a decision to develop a special combined main rotor as if consisting of two "rotors" of different diameter to perform different functions. Three longer blades (of the 12-m diameter "rotor") were attached with the help of the flapping hinge and could change their collective pitch. Thus, they were intended to produce and control lift. Three shorter blades (of the 7.8-m diameter "rotor") had only a feathering hinge; they were connected with the swashplate and intended for fore-and-aft control of the helicopter. They were set at a small pitch to avoid stall.

This six-bladed main rotor was developed by Cheryomukhin follower I.P. Bratukhin who later became helicopter chief designer. The new rotor was installed in the TsAGI 3-EA which therefore got a new designation: TsAGI 5-EA. The empty and takeoff weights increased up to 1,047 kg and 1,210 kg respectively. The new helicopter was subjected to comprehensive testing, first of all to compare its performance with that of the TsAGI 1-EA having a rigid main rotor. Significant improvement of this performance was established. Blade flapping nature was studied in different flight conditions, helicopter control effectiveness, as well as loads applied to control levers were evaluated. Special attention in testing was paid to the problem of vibration.

In 1934 during one of the flights at an altitude of 10-12 one of the "lifting" blades was torn away. Cheryomukhin landed the aircraft with great difficulty. It was concluded that drag hinges should be introduced in the articulated rotor design to counteract moments produced by chordwise Coriolis forces. At the same time friction dampers and lead-lag flexible stops were installed.

The tests of the TsAGI 5-EA continued up to 1936. In total, 26 free flights and 8 hops were performed by Cheryomukhin. The insufficient engine service life and absence of spare parts limited the helicopter test time and performance. The altitude did not exceed 40 m, flight endurance, 13 minutes. The airspeed in this aircraft was equal to that of the old helicopter, i.e. 20 km/h.

Cheryomukhin made a great contribution not only in developing helicopters in the USSR, but also another type of aircraft, the so called autogiro. The head of the Section of Special Designs started to develop these aircraft as far back as 1929.
Young engineers I.P. Bratukhin and V.A. Kuznetsov under his guidance built the first autogiro designated TsAGI 2-3A during two years. It belonged to the class of winged autogiros; it was powered by the Gnome-Rhone Titan engine of 230 hp; it was equipped with a four-bladed articulated main rotor of 12-m diameter and a tail unit/deflector to deflect the propeller induced flow upward with the aim to speed up the rotor rpm during the start. The autogiro weight empty was 765 kg. When carrying two crewmembers and a payload, it increased up to 1,032 kg. After two years of comprehensive testing the autogiro was transferred to the Maxim Gorky propaganda squadron where it was in service up to 1934. Thus, under Cheryomukhin's guidance the first Soviet rotary-wing aircraft that found practical use was designed.

In early 1932 the Government made a decision to build a small batch of a more advanced autogiro (derived from the TsAGI 2-EA) to be powered by a home-made engine M-26 of 300 hp in order to study practical aspects of using this type of aircraft in the armed forces. Built in the same year in TsAGI under the general guidance of Cheryomukhin the A-4 winged autogiro differed from its predecessor not only by the engine but by an increased weight (empty and takeoff weights were 1,065 kg and 1,363 kg respectively)

greater diameter (13 m) and rotor mechanical drive (instead of normal aerodynamic speedup). In addition to the first prototype, a batch of 13 A-4 autogiros was put in production at the Kiev aircraft factory. The major part of these aircraft was sent to military units, and a few, to civil aviation. Flight tests of the prototype autogiros were conducted by test-pilot S.A. Korzinschikov, Cheryomukhin's student.

Building and testing of the first home production rotarywing aircraft enabled to acquire a wealth of experience in designing this new type of aircraft and putting it in quantity production. Development of radical new types of autogiros having direct rotor hub control started in the TsAGI with the active participation of Cheryomukhin. In 1934-1935 when he was on a business trip in Great Britain the engineer took a training course in the aviation school in Southampton to learn how to fly the Cierva autogiros.

During his activities in helicopter technology Cheryomukhin proved to be not only an outstanding designer, test-pilot and organizer, but the greates scientist/expert in aircraft strength. During the building of the TsAGI 2-EA he developed temporary standards for autogiro strength. Later, during 1936-1937 first official strength standards for rotarywing aircraft were developed under Cheryomukhin.

The designer was skeptical about excessive enthusiasm for autogiros in the TsAGI. He was always sure that the future would belong to the helicopter. However by mid-thirties all TsAGI activities in the field of this type of aviation equipment were practically stopped, and in December 1935 Cheryomukhin himself was transferred to the Big TsAGI under construction near Moscow where he was to build wind tunnels. The scientist brilliantly coped with his task. In early 1937 he was awarded a degree of Doctor of Science.

In late 1937 Cheryomukhin, like many other TsAGI members was groundlessly subject to repression. When in jail, he became the leader of the strength team in the Tupolev Design Bureau. His further labour activities were closely connected with this Design Bureau. "He nominally headed our strength department, but actually he was responsible for a wider sphere of our activity, i.e. the problem of strength as well as how to make an arrangement of the structure so that it was strong," recalled the famous General designer. "In all problems related to strength he was my right hand, a reliable, strong and very talented hand." As Tupolev recalled, his deputy never stopped to care for rotary-wing aircraft, and more than once he suggested that they should "get involved in helicopters". Unfortunately, the latter was beyond the plans of the Tupolev Design Bureau activities.

Cheryomukhin combined his career in aviation industry with his teaching activities: he was a professor of Moscow Avaiation Institute, heading there a number of chairs, and he founded the chair of "Aircraft Structural Mechanics and Strength".

For his fruitful activities in the field of aviation science and technology, Cheryomukhin was awarded the Lenin Prize, two Stalin Prizes and many other high government awards. The outstanding designer, pilot and teacher died on August 19, 1958. He made a great contribution to the progress of Russian fixed- and rotary-wing aircraft, structural and aerodynamical research, formation of higher aviation education in our country.

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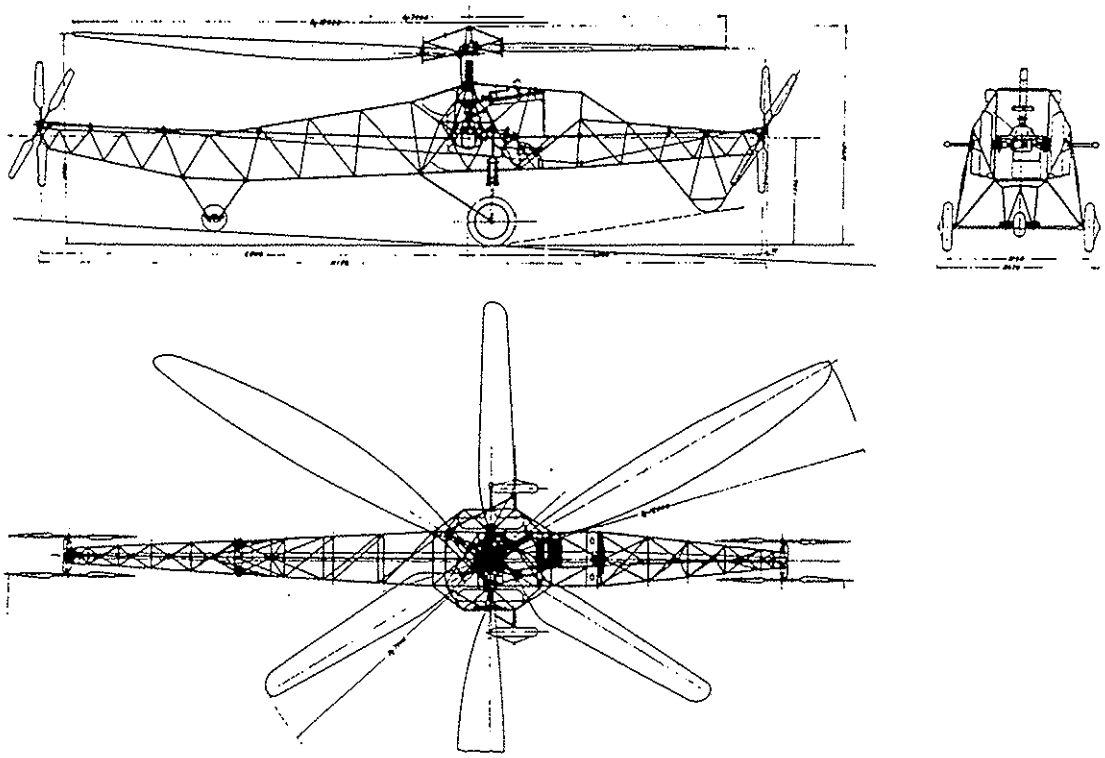
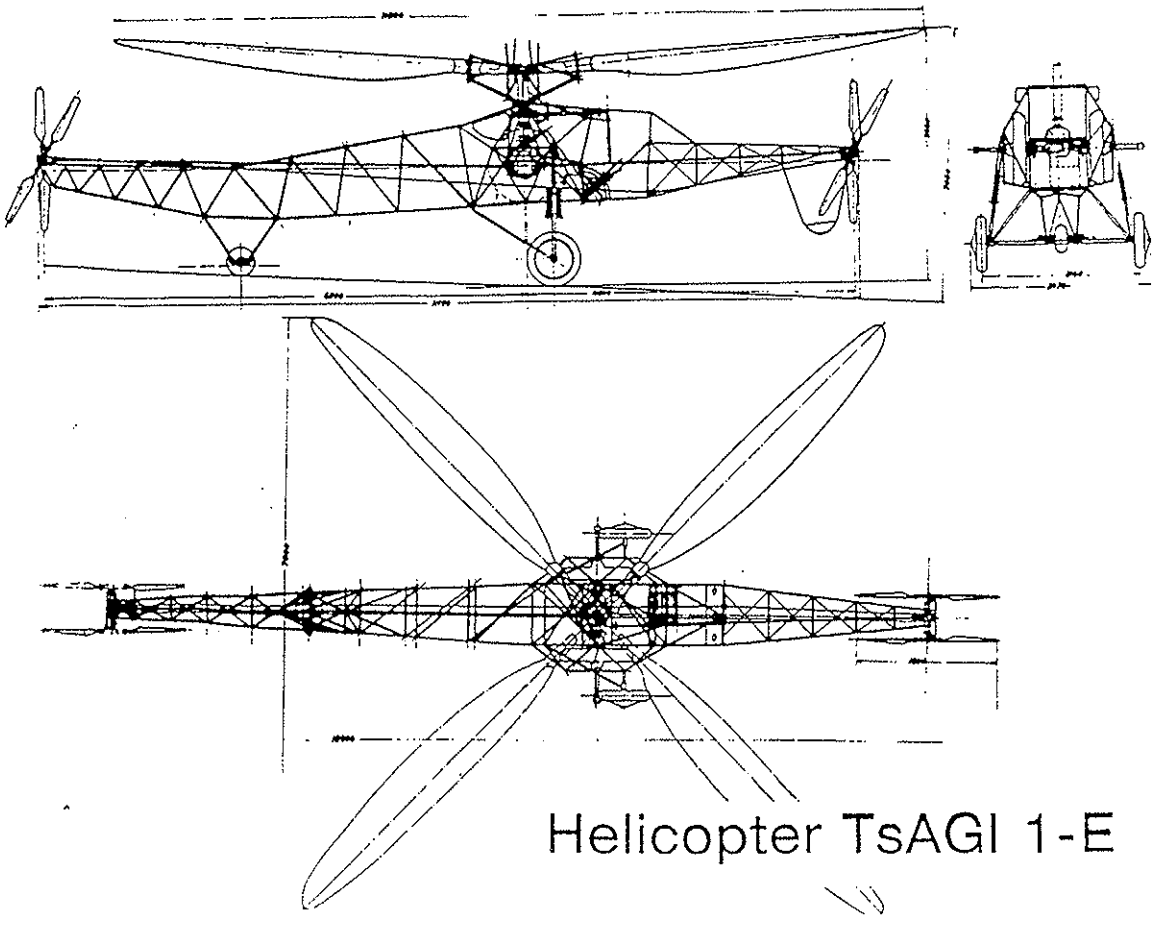
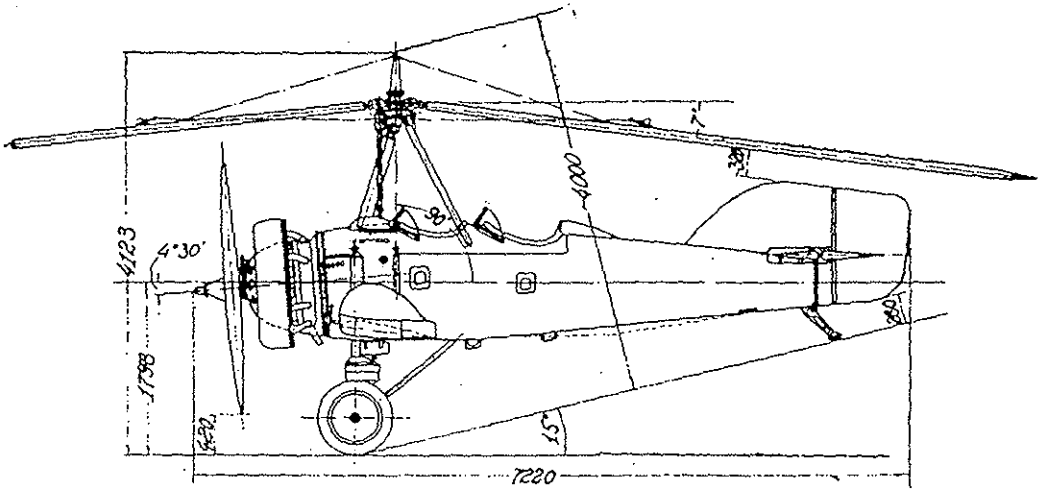
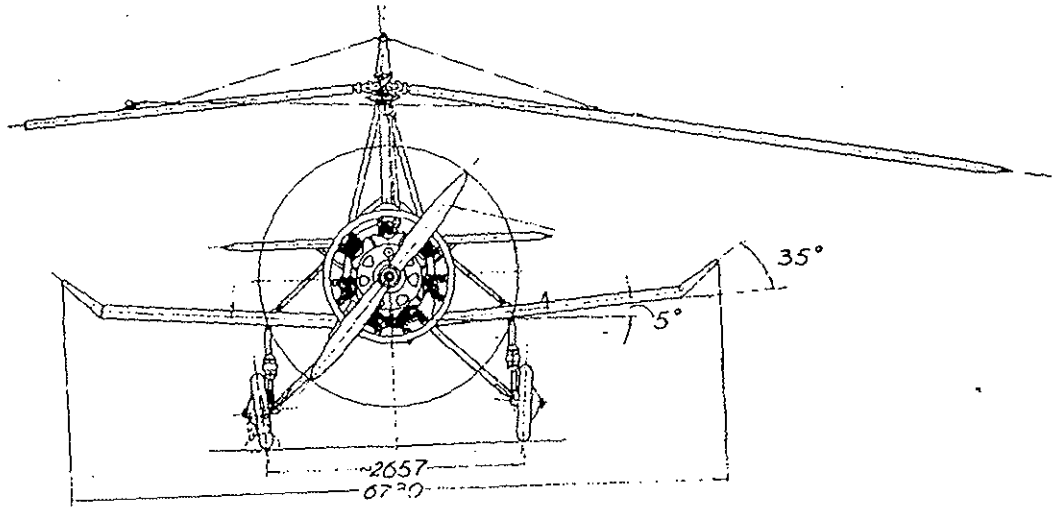


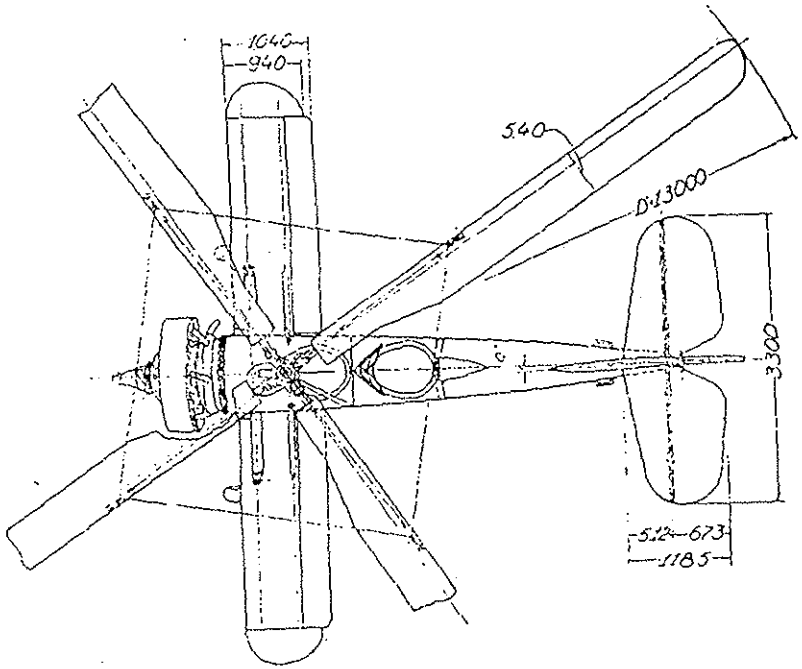
Helicopter TsAGI 5-E



Helicopter TsAGI 1-E







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Autogiro TsAGI A-4