TWENTY FIRST EUROPEAN ROTORCRAFT FORUM

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SUMMARY

This paper gives a review of the two helicopters designed in the Netherlands.
The Von Baumhauer helicopter from the 1920's featured for the first time in history a single main rotor for lift, a tail rotor for countering the main rotor torque and collective and cyclic blade pitch for height, pitch and roll control of the helicopter. These principles had been patented in various European countries. It seemed that da la Cierva had adopted this rotor control principle for his autogiros, and from thereon it had been applied in almost all modern helicopters. Also the now commonly used main-rotor/tail-rotor concept stems from Von Baumhauer's patent.
The 2-seat "Kolibrie" (Hummingbird) from the 1950's was a tip-driven ramjet helicopter with a maximum all-up weight of 700 kg. The helicopter featured a 9.95 m diameter 2-bladed main rotor and a 0.92 m diameter single-bladed tail rotor. The machine had excellent flying qualities, was safe (no dead man's curve), transportable on a trailer, easy to produce, a dream to maintain, rugged and inexpensive. On the negative side were the considerable noise, which it produced and the high fuel consumption.
The main application of this small helicopter was spraying and crop dusting. About 20 machines had been produced, of which about 12 ones have flown in 8 countries merely for agricultural purposes. The last one in Israël untill in the 1980's with full satisfaction.
Unfortunately, both projects ended due to financial reasons. In the Kolibrie case the sales were lacking far behind the expectations.

ACRONYMS

HTS	Haarlem Polytechnic, Department of Aeronautical Engineering
KNVvL	Royal Dutch Aeronautical Society
NHI	Netherlands Helicopter Industry
NIV	Netherlands Institute for Aircraft Development (later Aerospace)
NLL	National Aeronautical Laboratory (later NLR)
NLR	National Aerospace Laboratory NLR
PTT	Postal Services in the Netherlands
RSL	Government Service for Aeronautical Studies (predecessor of the NLL)
SOBEH	Foundation for the development and construction of an experimental helicopter in the Netherlands
TUD	Delft University of Technology

1. INTRODUCTION

In the Netherlands two helicopters have been designed and built. It seems that the first one still has an influence on modern machines. The Von Baumhauer helicopter from the 1920's used for the first time in history the single main rotor / tail rotor concept and collective and cyclic rotor blade pitch control.
The second one is the Kolibrie tip-driven ramjet helicopter from the 1950's. This helicopter featured the first all-bonded metal rotor blades, at a time when the majority of blades were of a wooden or fabric construction.

The helicopter of Von Baumhauer and his colleagues is recalled in five publications in Dutch (refs. 1, 2, 3, 4 and 5). All these references have used the documentation that is still available in the archives at the NLR and KNVvL.
The Kolibrie helicopter during its development in the 1950's is covered in many documents in Dutch and fortunately three publications in English (Refs. 10, 11 and 12). Afterwards, in 1985 and 1992 references 13 and 14 appeared in English. Especially reference 14 is of interest, as it gives the Kolibrie story comprehensively described by W.A. Kuipers, a member of the design team. All these publications about the Kolibrie helicopter had a limited distribution and their availability must be questionable, except reference 14 which can be obtained directly from the author.

This European Rotorcraft Forum creates a good opportunity to present some more information for a larger audience on the design and development of the only two helicopters designed in the Netherlands. Unfortunately, this presentation cannot be exhaustive as many retraced sources have not been fully used in the short time frame available. For a more balanced picture further literature research on helicopter developments elsewhere also would be required, this in order to investigate whether or where Von Baumhauer's inventions have been adopted by other helicopter designers.

After stating commonalities and differences of these projects, topics of both helicopters will be recalled in more detail. A short diversion to windturbines completes this overview.

2. COMMONALITIES AND DIFFERENCES OF THE TWO HELICOPTERS

Commonalities

* Rotorcraft design activities in the Netherlands can be characterized by the absense of military incentives and autogiro excursions. This is in contradiction to many other countries where helicopter development is stimulated by military needs.
* Both the Von Baumhauer helicopter and the Kolibrie project were of remarkable design and had their roots in Dutch patents. For the Kolibrie this patent was the self-adjusting blade pitch concept aiming at automatic autorotation when the engines stop running, improved stability and control and regularization of the induced velocity.
* A curious commonality was the two-bladed single-rotor design, at least exceptional for the oldest one at its time.
* Finally, common to both projects was their fate; financial problems, and in the Kolibrie case also the sales staying far behind the expectations, ended their existence. Maybe, these programmes were ahead of their time.

Some differences

* Von Baumhauer had a great interest in the aerodynamics and dynamics of wind mills and rotating wings and did many wind tunnels tests on these subjects. Note that Max Munk in the U.S., Lock and Bateman among others in England did comparable tests. And not to forget

Juan de la Cierva's Quatro Vientos (at Madrid) wind tunnel experiments. The Von Baumhauer project was based on the scientific knowledge and driving power of one man and started as a rival in a price-winning contest.

* The development of the Kolibrie helicopter was based on the general feeling in the Netherlands after the second World War, to join the developments in the world that they had been deprived of for five long years. In this view the helicopter, which had shown its capabilities during the period of the second World War (Focke, Flettner, Sikorsky), seemed to be the ideal aircraft for many applications in our country. For example, agricultural purposes like seeding reed in the new "polders" (reclaimed land from the sea) and crop spraying and dusting on stretched-out fields.
* What seems to be the main difference in the design and development, is the extent of the use of dynamically scaled models. The Kolibrie design was literally embedded in model experiments - rotor flow in various flight conditions, flutter, control and stability, blade flap frequencies, ground resonance (electric analogon) - roughly between 1947 and 1950. It remains to be checked if this was exceptional at the time.

3. THE VON BAUMHAUER HELICOPTER

3.1 The man behind the helicopter

When people think of the start of aviation in the Netherlands, they think about Anthony Fokker, but do not think about Albert Gilles Von Baumhauer. This Dutchman, born 10 October 1891 in Heerenveen, was the brain behind the aircraft that seems to be the forerunner of nearly all modern helicopters.
After his study at the Universities of Technology in Delft and Zürich, at the age of 30 years he joined in 1921 the RSL (predecessor of the National Aerospace Laboratory NLR) as assistant director of the institute.

Von Baumhauer had a many-sided interest in aerodynamic and dynamic subjects. Many scientific reports and lectures have been published of which a number are still in the library of NLR, for example references 6 and 7 about airfoils and flutter of airplane wings. Another interest of him was the aerodynamics and dynamics of windmills, on which subject he performed many experiments in the wind tunnel of the RSL. For example, reference 9 gives the results of an experimental study on the performance improvement of existing windmill blades.
Among the many committees of which he was a member, he also was the Netherlands' representative in the Guggenheim Fund.

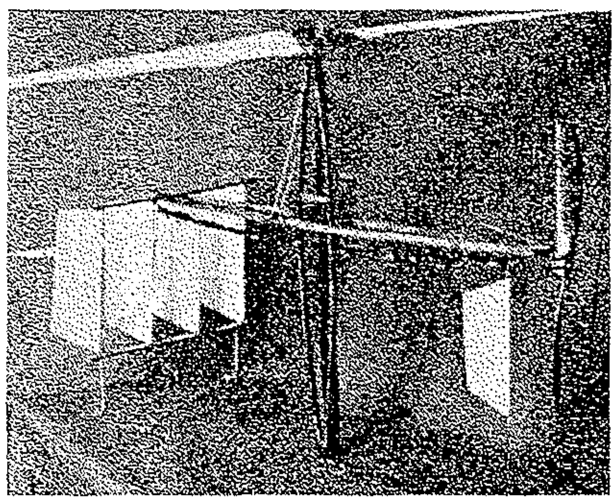

Fig.1 Von Baumhauer's model helicopter

Already in his first years at the university he became very enthousiastic about rotary wing machines. Of course he followed very anxiously the experiments of rotary wing pioniers abroad. He got in contact with Von Karmann, whos teethered helicopter had already reached a height of 50 meters but was still stabilized with chains to the ground. He studied the aircraft of Pescara with two counter-rotating rotors, which exhibited a poor stability. Oemichen already had built a machine equipped with 4 rotors which had flown a 1 km distance at a height of 5 meters and the de Bothezat helicopter lifted off the ground with a payload of four man.

Around 1912 he experimented with model helicopters equipped with more rotors, like everyone else, considering it as the only feasible solution for sufficient control and stability. From his experiments he learned that two counter-rotating rotors where not so stable. Stability could be improved by using one single rotor. A model helicopter of Von Baumhauer is shown in figure 1. Some parts of it, the fuselage, rotor blades and two tail surfaces are still kept at the NLR.
But solved one problem, he got two more problems in return; first the main rotor torque on the fuselage and secondly the control of the helicopter in pitch and roll.

For countering the main rotor torque he saw two solutions. A propeller in the nose of the aircraft blowing on guide vanes at the tail, which would deflect the airstream to the side. The modern NOTAR helicopter uses this principle.
The second idea was a more direct solution by mounting a tail rotor in a lateral sense which provided the necessary compensating torque. He patented this solution in 1920 in England and the Netherlands (Fig. 2).

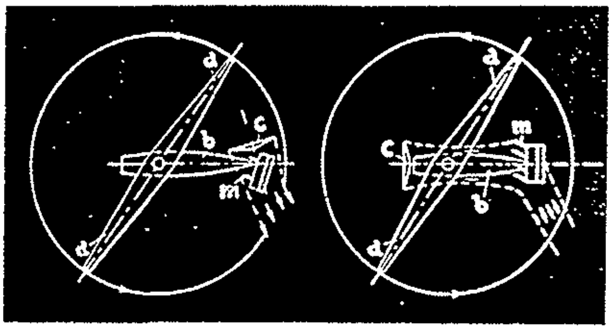

Fig. 2. Sketch in patent for main rotor torque compensation

For solving the controllability problem of a single rotor helicopter in pitch and roll he invented the differential lift on the rotor blades by controlling cyclically the blade angle-of-attack during its revolution around the rotor axis by using a swashplate. He patented this solution in 1912/1913 in France and England, and in 1920 also in the Netherlands (Fig. 5).
As already mentioned, Von Baumhauer had a scientific attitude. His designs always were based on numerous calculations and model and wind tunnel experiments. For example he investigated theoretically and experimentally the performance and stability of a rotor in ground effect (RSL reports A-120 and A-127) and the forward flight with an inclined rotor (RSL report V-513).
Another example is his presentation of a paper on the theoretical basis of helicopter flight in Innsbruck in 1922. Based on calculations he showed that the helicopter has the capability to perform a glide like a fixed-wing airplane when the engine stops running. There is one wind tunnel test mentioned in the archives directly in connection with the power-off descent of helicopters (Ref. 8). In 1923 and 1924 de la Cierva proved his thesis in reality.

After the end of the helicopter project Von Baumhauer devoted his attention to the safety of aviation by means of research and testing of existing and new airplanes and systems. On the 18th of March 1939 he perished during a test flight with a Boeing 307 Stratoliner.

3.2 The helicopter

3.2.1 Configuration

Around 1920 the first preliminary design sketches were made of a two bladed single rotor helicopter, based on numerous performance and stability calculations and model experiments in and outside the wind tunnel. For control of the helicopter in pitch and roll and of the rotor thrust Von Baumhauer invented the cyclic and collective blade pitch control.
For a good weight balance he decided to put the engine in the nose of the aircraft together with the fuel tank, in the middle the main gearbox and rotor, behind it the pilot and at the tail of the

aircraft a separate engine with tail rotor and guide vanes. A first empty weight estimation gave 600 kg. During the development of the helicopter the weight increased to 1100 kg at the beginning of the construction, and further to 1185 kg at the start of the flight tests.

3.2.2 Organization, construction and flight tests

Organisation

In 1924 Von Baumhauer got a unique chance to realize his dream, to build an own designed helicopter.

In that particular year the British Air Ministry announced a contest on the construction of a helicopter that had to show a number of rather severe flight performances.

1. A vertical take-off up to 2000 ft.
2. Hover out of ground effect for a certain time period.
3. Flying a closed circuit with a flight speed of about 60 kt.
4. Performing a glide and a safe landing with a stopped engine, and a safe vertical landing from a height of 500 ft.

The prize of £ 50,000.- (in 1924) was not bad at all. The final date was May 1st, 1925 which was later extended for one year.

In order to realize the development and construction of the helicopter, the First Dutch Helicopter Association "De Eerste Nederlandsche Helicoptère" was established in which a number of organisations in the Netherlands participated and took a design responsibility.

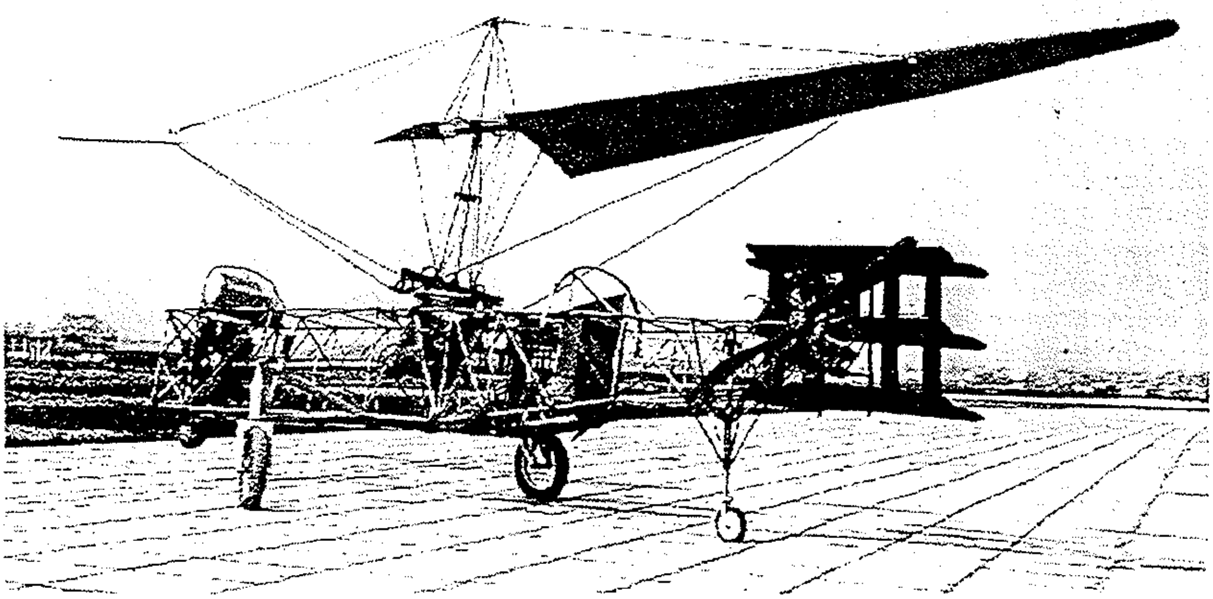

Fig. 3. The Von Baumhauer helicopter

Von Baumhauer was not a member of the board. Officially he was the scientific and technical advisor, but in fact he was the driving power and general manager of the project.
The government did not want that Von Baumhauer, being a governmental official, would bring his patents into operation on his own name and therefore the patents were taken out with the government's consent and put under the name of the First Dutch Helicopter Association.

Construction and tests

The construction of the helicopter started in the autumn of 1924 and ground tests began already in mid 1925 (Fig. 3). From these tests still a number of RSL reports or parts of it is available. In RSL report V.101 of 5 June 1925 it was stated "The fast rotation of the huge main rotor is an impressive scene".
On September 1925 the helicopter with an AUW of 1195 kg got 0.5 m into the air although tied with cables to the ground, and at the end of October with a pilot and 50 kg payload on board. At this time the first problems arose, very aggressive vibrations and broken tubes in the main rotor control system. During flight tests vibration measurements were carried out and rotor blade behaviour and tuft position on the blades were recorded by a film camera on top of the rotor.
Flight tests and construction modifications interchanged with each other until in the spring of 1926 Flight Capt. van Heyst flew continuously for 5 minutes. During one of the ground tests a steel wire, with which the helicopter was tied to the ground, got loose and hit the pilot's helmet. For safety reasons it was replaced by a rubber band.
In October 1926 the activities moved to Schiphol where the flight tests were continued with ir.J.C.G. Grasé from Fokker as the test pilot and later Jonkheer Peter J. Six. In fact Mr. Six was not at all a pilot. But this was considered to be a real benefit since piloting a helicopter was experienced as being quite different from flying an airplane.
Although the aircraft got into the air many times, it had never flown completely free from the ground. For stability reasons it always trailed four about 5 meter long iron chains over the ground hanging from the two ends of the fuselage and a cross placed outrigger. Their function was to grant extra weight to the side of the helicopter that was most elevated. According to Mr. Six, with this system a flight all over the Old-Schiphol area was possible in 1930, but in an indetermined direction and he had to continuously watch around in order not to fall into one of the ditches which traversed the airfield.
During a demonstration flight for a congress on the 29th of August, 1930, the helicopter crashed. An examination of the remnants revealed a fatigue crack in the attachment of the main rotor blades.
The lack of sufficient financial support and the world economical crisis gave a halt to the project. Moreover, Von Baumhauer realized that the British take-off and landing requirements of the contest were too severe for the state-of-the-art, and the development of a rotary wing machine would be more succesfull by doing it step by step.

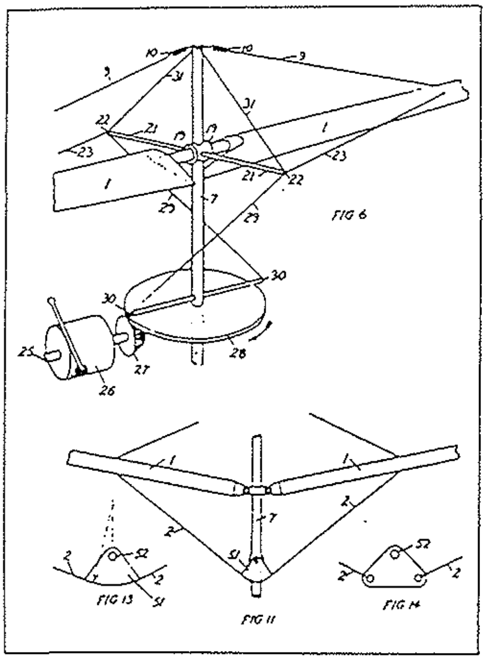

Fig.4 Rotor drive and blade flapping freedom in patent application

3.2.3 Technical details of the helicopter

Main rotor

Calculations showed that in view of the limited engine power available at that time a large rotor diameter was necessary for the hover and vertical landing

requirements of the contest. The diameter originally was 20 meters but in a later stage it was reduced to 15 m due to the use of a more powerful engine. The rotor speed of 100 rpm was remarkably low and gave a tip speed of around 100 m/s.
The 2-bladed rotor had a blade chord of 1.2 m at the root, which tapered to 0.28 m at the tip. This gave a 4.5% rotor solidity which is quite normal nowadays. The blades had a built-in twist of -10° to the rotor tip. The blade airfoil was cambered and had a flat bottom surface.
The blades were designed like wings of an airplane, 4 wooden longerons with ribs and covered by plywood. The blade weight was 27 kg each.
The blades were mounted to the rotor hub with thin blade arms and moored to the rotor shaft by steel wires, where the lower wires took up the rotor thrust. The mooring wires also provided some flapping freedom of the blades. For this reason the upper wires were connected to the shaft by springs, and the lower wires were aligned along vertically swinging plates as can be seen in his application for a patent.
The thin rotor shaft was supported by two slanted rods, going from the rotating part of the gearbox to the rotor hub.

Engine and transmission

The engine power was delivered by a 160 hp rotating OberUrsel engine, mounted in the nose of the fuselage and at a later stage replaced by the stronger 200 hp Bently Rotary II. A rotating engine was chosen in order to simplify engine cooling.
The engine power was transmitted by a long shaft to the main gearbox via a Rolls Royce automobile clutch, that was controlled by a handle in the cockpit. This clutch had to be manipulated very carefully during spin-up of the heavy main rotor.
The reduction of the engine rpm to rotor speed was 11:1 . At first an available Rolls Royce planetary gearbox would be installed, but the complicated construction made it necessary to develop an own gearbox with a worm wheel reduction based on a design of Von Baumhauer.
Due to the thin rotor shaft, the power from the gearbox was transmitted by cross wires from the rotating drum of the main gearbox to the blades and a cross bar at the rotor hub (Figs. 3, 4).

Collective and cyclic pitch blade control

As already mentioned, for the pitch and roll control Von Baumhauer applied the swashplate principle as can be seen in the drawing for his patent application (Fig. 5).

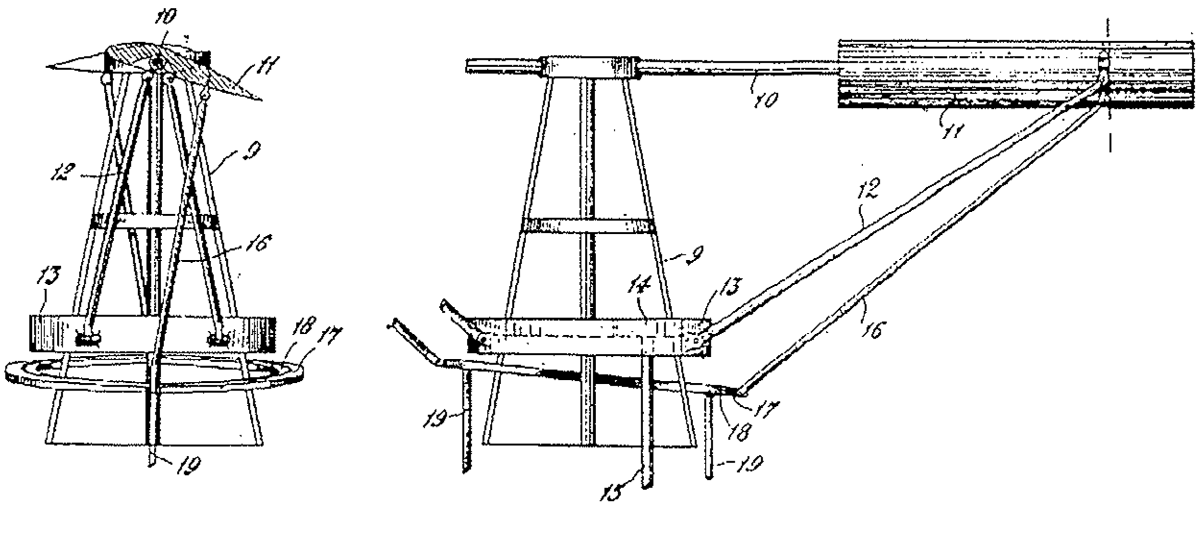

Fig.5 Von Baumhauer patent for collective and cyclic blade pitch control

Below the rotor two concentric rings were mounted which were connected to each other with bearings.
The non-rotating inner ring (18) was mounted on gimbals which allowed it to tilt and to move along the shaft, and was connected with the longitudinal and lateral cyclic and collective controls (19) from the cockpit. The outer ring (17) rotated with the rotor and adjusted the collective and cyclic blade pitch angle via rods (16).
In his patent, the non-adjusting ring (13) rotated with the rotor and served as support for the rotor blades. In the actual helicopter the supporting rods (12) were replaced by wires aligned along swinging plates on ring (13) in order to provide the blades with some flapping freedom.

Tail rotor
The tail rotor was a fixed-pitch propeller, driven by and mounted on an independent engine. Control of the independent engine with a propeller was much easier then collective control of a tail rotor coupled to the main transmission.
The tail rotor power was provided by a 40 hp Anzani engine, which later-on was replaced by the 80 hp Thulin rotating engine.
In the slipstream of the tail rotor a set of controllable horizontal and vertical planes were installed according to his patent. The exact purpose of this system could not be found, but it seemed to be used for augmentation of the yaw and pitch control of the helicopter.

Each engine had its own fuel tank, of which the position could be varied in order to control the centre of gravity.

Cockpit
The collective and cyclic blade pitch control of the pilot were combined in a conventional control stick with a horizontal wheel on top of it. Fore-aft and sideward motion of the stick controlled the cyclic blade pitch and turning the wheel controlled the collective pitch.
The pedals were used to control the vertical planes in the tail rotor downwash, the horizontal planes were controlled by turning a vertical wheel on the right hand side of the pilot.
The main rotor and the tail rotor engine power were controlled by two gas throttles. The necessary engine and flight instruments were placed in a instrument panel in front of the pilot.
The pilot was protected by a brace above his head and armour plates in the back, this for the unhappy case of tail rotor desintegration.

3.3 The inheritance of the Von Baumhauer helicopter

After the end of the project in 1930 the two patents, on the single main rotor concept and on the cyclic/collective blade pitch control, were no longer prolonged. So the way was free now to make use of the inventions of Von Baumhauer, and it seems that De La Cierva and Sikorsky had adopted these systems in their machines.
Interesting are the words of the test pilot of the Von Bauhauer helicopter Jonkheer P.J. Six in reference 2 when he told his story in 1978: "When De La Cierva came to Rotterdam in 1937 he had just installed for the first time the cyclic blade control system on his autogyro with the most excellent results for the conduct of the autogyro. We told him that he had been infringing on our patents but that we would not bring him into difficulties because we thought that what he had done was in the interest of the development of aviation."
Another interesting quotation of Mr. Six's story from the same reference is the following paragraph: "It is interesting to mention that shortly after the second world war I remember to have seen a publication by Mr. Sikorsky in which he mentioned that during the war the American Government had employed two pilots, who before the war had been flying the autogyros of De La Cierva for the Postal Authorities, on assignment with the task to speed the development of helicopters able to control the activities of German submarines. These pilots advised Mr. Sikorsky

to try to find a solution of his problems by means of using one rotor only with a control of our patents mentioned above. I do not remember whether the tail rotor also was mentioned in this publication, but anyway I am proud to say that our activities have been useful to the development of the modern aviation by helicopter. I may say that I feel privileged to be able to tell this helicopter story of fifty years ago."

4. POST-WAR PERIOD

An indication of the growing interest in helicopters after the 2nd world war in the Netherlands was the formation of the Study Committee Helicopters around 1946. One of the actions was the aquisition of a Sikorsky S-51 in order to explore the capabilities of the helicopter. As a result of the favourable first flight experiments a more extensive form of cooperation between several interesting organizations was established in May 1947 as the Foundation for Helicopters. The goals were gathering knowledge on technical and operational matters by theoretical and experimental research and by flight tests.
From the many flights that were carried out with the sole S-51 it was concluded that the helicopter offered particular advantages in cases where geographical obstacles had to be crossed, even in a flat and well developed country like the Netherlands. Particular in agriculture the helicopter seemed to offer promising applications for seeding, spraying and dusting crops for large areas or when the operation with ground machines was hampered by the soil conditions.
Many test flights were carried out and various measurements were taken, among others with a movie camera recording the instrument panel. During one of these flights, the engine suddenly stopped running without any warning to the pilot during a stabilized hover at 1800 ft altitude. Thanks to the alertness of the pilot and the flight test engineer J. Meyer Drees (known as Jan M. Drees in the USA) the instruments were filmed during the whole autorotation including transition from the hover, descent, flare and landing. This resulted in the world's first recording of a real engine failure and subsequent autorotational landing (Ref. 15).

On the aerodynamic side, the rotor flow was a subject of strong interest. The longitudinal and lateral non-uniform induced flow distribution in the rotor plane was analyzed by J. Meyer Drees, for which he received the Cierva Memorial Price 1949 (Ref. 16). The formulae were applied to the S-51 helicopter, leading to a gratifying agreement with flight tests. A second theoretical contribution to rotor aerodynamic knowledge came from R.Timman, who analyzed the unsteady lift on rotor blades in particular as affected by the free vortices shed by the blades (Ref. 17).
Also experimental research on rotor flow is worth mentioning, such as flow visualization in the wind tunnel during various helicopter flight conditions including the vortex-ring state as shown in figure 6 from reference 18. Another study of rotor flow was devoted to the transition into the autorotation and the pull-up or flare before landing (Ref. 19). Furthermore two other investigations are worth mentioning, analysis of the performance in turns and in turbulent air.

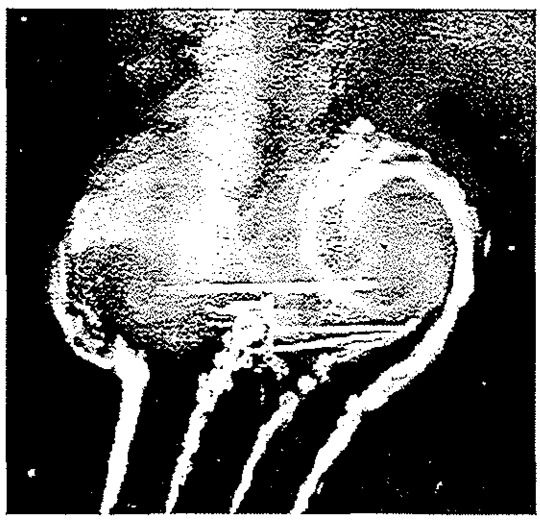

Fig. 6 Rotor flow in the vortex-ring state

It was remarkable to see how the helicopter enthousiasts found their way in our country. Another subject was the invention by H.G. Verhage of the self-adjusting rotor blade pitch when the engine

stopped running and the helicopter had to go into an autorotation (Ref. 20). It is noted that performing a succesful autorotation was high on the priority list at that time, due to the unreliable piston engines in the single-engine helicopters. Figure 7 shows a dynamically scaled model of this rotor system; and this was the first dynamically scaled model in the Netherlands.
The 1 meter diameter model proved the viability of Verhage's concept out and in the NLL wind tunnel in descent and forward flight up to advance ratio 0.63. Moreover, it revealed wake flutter, apart from the more familiar ones, and a low Reynolds number boundary layer instability; the latter was cured by trip wires (Ref. 17).

5. THE KOLIBRIE HELICOPTER

5.1 The development period

In December 1950 a team of helicopter experts came to the conclusion that the time was there for starting the development of an own designed helicopter.
This led to the establishment of the SOBEH foundation (Foundation for the development and construction of an experimental helicopter in the Netherlands); a remarkable decision at a time when a self creative aircraft industry and the acquirement of nescessary equipment, especially modern wind tunnels, were highly questioned. It would last until 1952 before the final governmental decision was reached on a new NLL high-speed transonic wind tunnel.

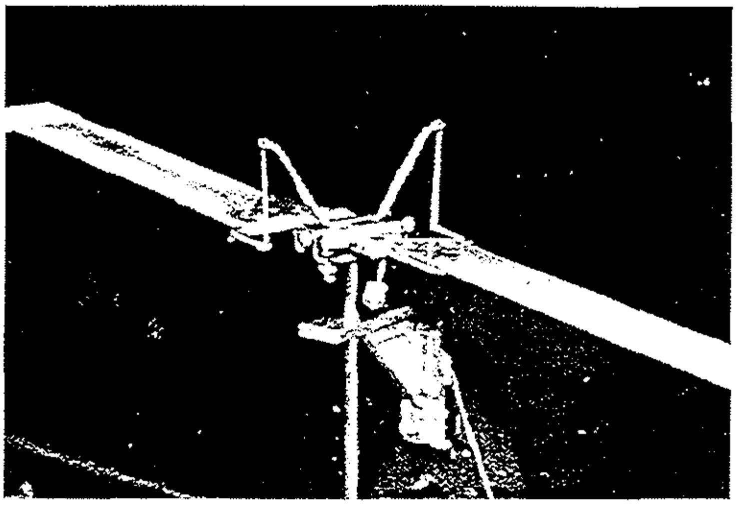

Fig.7 Verhage's self adjusting blade pitch device for autorotation

By selling its Sikorsky S-51 to the navy the old Foundation for Helicopters provided the starting capital for the SOBEH. Amongst others NIV, NLL,and PTT were to support the development directly and indirectly.
Because of military service obligations of some eventual design team members thê group was formed two years later, headed by J.Meyer Drees first and finally Will A. Kuipers. In this preamble period the decision for ramjet propulsion was made. As numerous references at that time show, amongst others by the McDonnell Little Henry(1947) and the Hiller Hornet(1950), this was not an exceptional decision. All tipdriven helicopter concepts were considered viable then. In view of the many short-haul missions, e.g. ambulance flights in the Korean war and in particular in agricultural uses (ground transportation with a trailer) the ramjet drive would now dominate the Kolibrie development for nearly a decade. The engine development demanded much creativity, a whirling arm test stand was built at the NLL. Emphasis was placed on how the ramjets affected design, instabilities and flying characteristics.

First prototype H1
Without striving for originality in the fuselage - Hiller Hornet like - the team produced the two bladed H1 in 1953 featuring:
* Automatic blade pitch reduction in autorotation (Verhage patent),
* Light metal Redux bonded main rotor blades (Fokker patent),
* No tail rotor (inclined rudder),

* Circular ramjets (so called TJ-3 model),
* Extremely powerful "smitsvonk" ignition (patent),
* Pitch-, flap- hinge order in the hub.

It is noted that Fokker produced these metal rotor blades when most helicopter companies were still making wooden and fabric rotor blades.
The last feature together with the weight of the ramjets caused a peculiar form of ground resonance during a hard landing in April 1954; the combined flap torsion motion displaced the rotor center of gravity in the lag sense. The problem was studied with the help of a PTT-designed and built electronic analogon (Ref. 12).

Second prototype H2

The necessity to redesign the rotor head - inversing the hinge order - and the need for more engine power resulted in the second prototype H2 in May 1955, featuring flat so-called elliptical ramjets (TJ-4 model), and an enlarged rotor diameter of 10 m. For the same tip speed the centrifugal force on the fuel droplets was reduced herewith. These ramjets with their irregular aerodynamic moment curve caused a limit cycle-like vertical vibration, turning into real flutter by a change of undercarriage stiffness. This led to extensive analog calculations by NLL including the second blade flapping mode, the vertical movement of the fuselage on its undercarriage and the influence of the ramjet thrust. Also blade sweep was considered and stiffening of the control rods. Practically the vibration problem was solved by the introduction of a stabilizer fin on the engine. In order to improve the helicopter flat plate drag some wind tunnel tests were carried out with a streamlined fuselage, in which the tail rotor was replaced by a Fenestron (Fig.8).

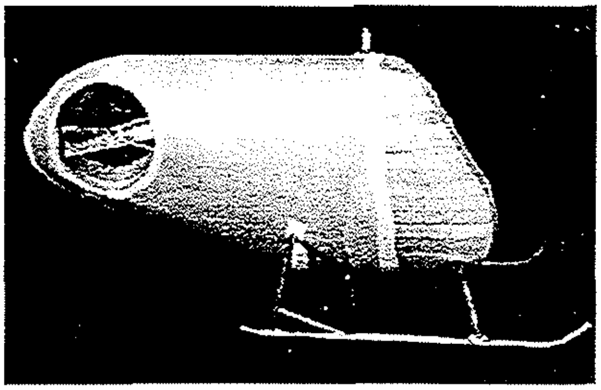

Fig.8 Kolibrie windtunnel model with Fenestron

The H2 prototype now became a very productive machine. It explored the tail rotor only for a better directional control, spraying booms and was the first ship attaining 1000 m altitude (1957). Fortunately this helicopter is conserved at the HTS in Haarlem.

Production type NHI H3

The time was now to develop a production type (Fig. 9). Therefore the SOBEH foundation was converted to the Netherlands Helicopter Industry NHI. The NHI H3 now boiled down to the design of a fuselage that could except litters, floats, cargo hook, sprayboom and a box with NLL measuring equipment. In its final version of the H3 helicopter the Verhage self-adjusting blade pitch concept was abandoned, the torsion stiff droop stops became control rods too. The ramjet weight and overdimensionized rotor diameter gave above-average flying characteristics. Also autorotation, certainly the one-engine-off descent, was quite acceptable and this helicopter in fact had no dead's man curve for all engines out.

In 1957, a 1000 hours ground endurance test was 300 hours under way when a ramjet tore off by a fatigue crack in the attachment lug. Many factors contributed to this accident of which one will be considered. Originally blade flap frequencies were drawn from a non-rotating dynamically scaled model, centrifugal forces being represented by small weights at nearly ten times the model blade length scale. In this model the ramjet was just weight scaled with its own scaled centrifugal force. After the accident the ramjet roll inertia was represented and the attachment stiffness varied. Especially the third elastic flap appeared sensitive to this variation in resonance with 6 p at

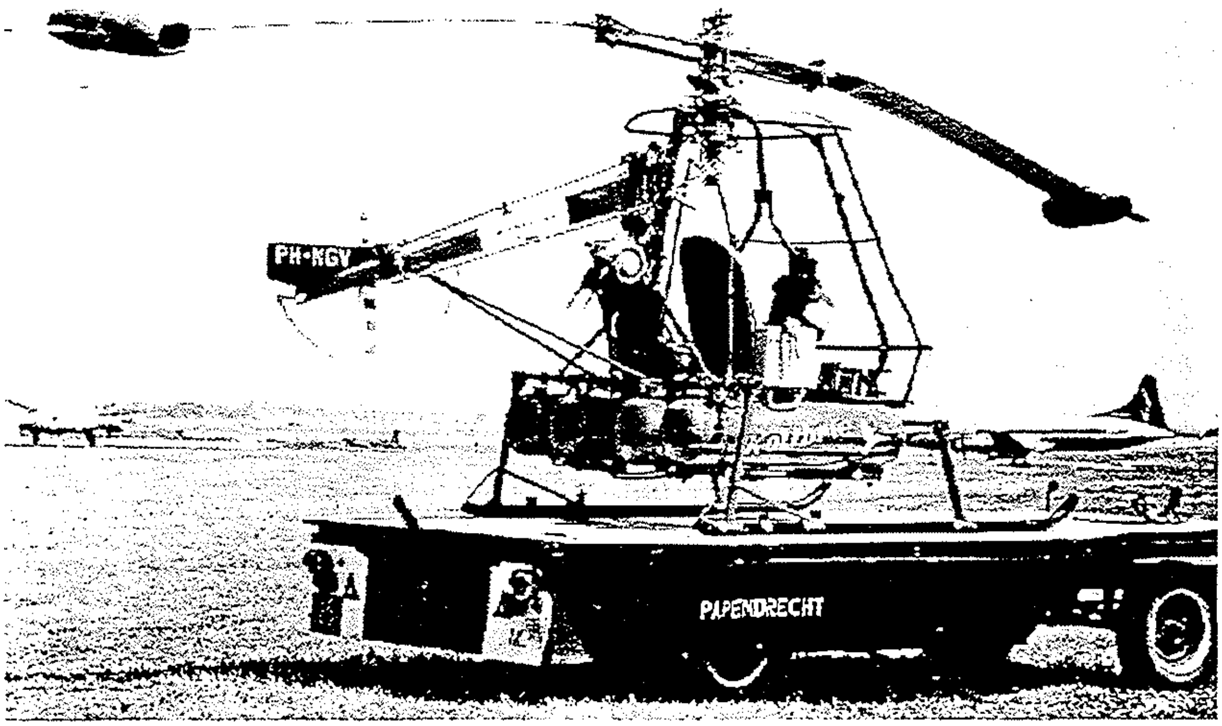

Fig. 9 Kolibrie helicopter on its trailer

operational rpm. So the main modification became a considerable stiffening of the engine attachment. To everyones relieve the adapted H3 helicopter of which a batch of ten helicopters was in production flew within a few weeks.

Also the certification of the ramjet TJ-5 model was under way in 1957. The variable thickness stainless steel shell of the engine, in and outside enamelled, suffered from high temperature fatigue. Not only the centrifugal load but the irregular combustion at a frequency of 70 Hz contributed to this fatigue problem. Although the 150 hrs test was successfully completed doubt arose about the capability of the team to treat the engine development. This became the beginning of the end of the Kolibrie three years later. Selling the helicopter, producing manuals, organizing demonstrations and especially the preparation for certification all came at once. The civil certification of the first and only ramjet helicopter in the world came in March 1958.
Despite this certification the golden years were over. Several improvements later-on were the not yet optimized high Machnumber swept ramjet fin (TJ-5A), rotor diameter 9,95 m, implying another collective control force reducing system by movable flyweights, a conventional stick, yaw controls by cables and an improved tail boom.

The helicopter had been used in Austria, Cuba, Great Britain, Germany, France, Sweden, Switserland, the Netherlands and in Israel into the 1980's, nearly all for agriculture purposes.
Totally, 20 machines have been produced of which 10 to 12 helicopters have been sold. Because the sales were lacking far behind the expectations the further development was stopped and the Kolibrie adventure was over by the end of 1960.

5.2 Technical details

A layout of the Kolibrie helicopter is shown in figure 10.
The production machine H3 is dimensionally characterized by a 2-bladed teethered main rotor The normal operating rotor speed range was 370 - 420 rpm, and a overspeed maximum of 460 rpm for autorotation.with a diameter of 9.95 m and a 1-bladed tail rotor with a diameter of 0.92 m. Blade section of the main rotor was a NACA 0012 modified airfoil.

The distance between tail rotor and main rotor axes was 1.42 m, and the total frame length was 4.32 m.
The height between skids and rotor hub was 2.75 m.
The final TJ-5A engines with swept fin had 62 equivalent hp each. The weight of one ramjet engine was 9.8 kg.
The helicopter empty weight was 250 kg, and maximum take-off weight 700kg.

Consumption
The high fuel consumption of the two ramjets is reflected in the following figures:
* endurance 400 ltrs/hr
* cruise 450 ltrs/hr
* spraying operation 500 ltrs/hr

For spraying and crop dusting operations, the high fuel consumption was not a real problem. The helicopter could be transported on a trailer behind a car. Moreover, it is noted that cheap household kerosene was used.

The Kolibrie was cheap as shown in some prices of 1960 US dollars:
* Purchase price of the complete helicopter $ 22000.-

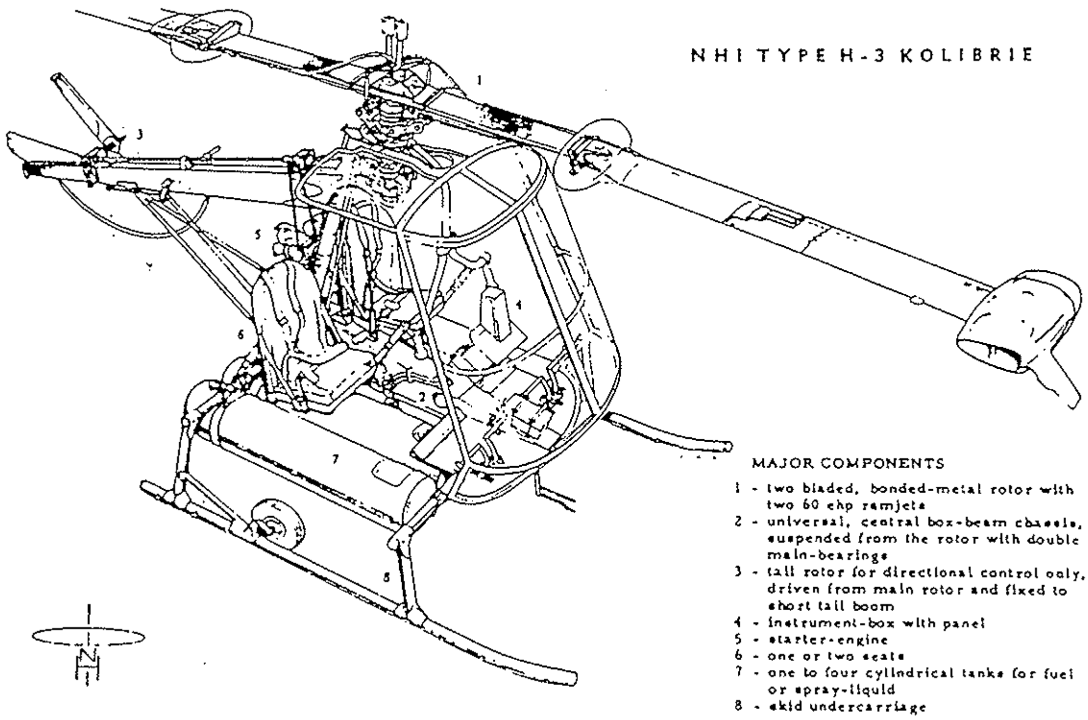

Fig. 10 Layout of the Kolibrie helicopter

* Two ramjets $ 2100,-
* One set of main rotor blades $ 2900.- (life time 600 hrs and 900 hrs applied for)
* Hourly operating cost was $ 70.- based on a 4 years depreciation and 500 flying hours/year. The hourly operating cost for crop spraying was $ 82.- . If 120 acres per flying hour could be sprayed, then the cost price per acre was $ 1.10 .

6. THE WINDMILL CONNECTION

From reference 21 it seems that Von Baumhauer's influence on windmill improvement was even larger and stretched even further after his untimely death. Apart from wind tunnel experiments in Amsterdam (RSL) and Delft (TUD) he also deviced a long used system to measure power output of the existing classical windmills. As early as 1918 he recommended the use of airscrew airfoils for windmill blades. In 1940 a tenfold enlarged copy was tested north of Delft of a Sabinin and Yurieff model from 1926 as described in reference 22. A hub camera was used, as on the Von Baumhauer helicopter and later for the Kolibrie, in order to monitor blade frequencies, ramjet behaviour, regions of stalled flow on the blades as indicated by tufts (Ref. 23).
Also, Jan M. Drees' study of the forward movement of the blade spar on classical windmills to the 1/4 chord point is well known (Ref. 24).

Finally the improved extended rotor of the Kolibrie H2 helicopter served later as a first testbed for an innovative windturbine project utilizing tipvanes (Refs. 25 and 26). This rotor is conserved at the Institute of Wind energy in Delft.

7. CONCLUDING REMARKS

Concerning the Von Baumhauer helicopter the concept was brilliant; the single main rotor and tailrotor, and the collective and cyclic blade pitch control. But the requirements of the British contest, with which the project started were excessively high and the time schedule was too tight for a succesfull completion. Afterwards Von Baumhauer recognized this and recommended a step by step approach. He never abandoned the idea of developing a helicopter. Unfortunately, his untimely death prevented him from realizing his dream.

The development of the Kolibrie helicopter and the novel and unusual power plant, were qualified technical successes. The machine flew and performed even better than predicted. This aircraft had excellent flying qualities, was safe (no dead man's curve), small, easy to produce, a dream to maintain, rugged and inexpensive.
But the sales were lacking far behind the expectations. So the production and a further development was ended.

REFERENCES

1. Six, P.J. : *Ir. A.G. von Baumhauer and his helicopter.* Lecture for the Dutch Aerospace Student Society "VSV Leonardo da Vinci", 1948 (in Dutch)

2. Six, P.J. : *Story about the Von Baumhauer helicopter told by the test pilot in 1978.* (in Dutch).

3. Lucassen, L.R. : *The Von Baumhauer helicopter.* De Ingenieur/ Jrg 84/ Nr.23/ 9 June 1972 (in Dutch)

4. de Groot, J. : *Von Baumhauer and his helicopter.* Avia-Vliegwereld 1953, Royal Dutch Aeronautical Society KNVvL (in Dutch)

5. Hubert, K. : *Rehabilitation for the first helicopter designed in the Netherlands.* Kijk, March 1981 (in Dutch)

6. Von Baumhauer, A.G., Koning, C. : *On the stability of oscillations of an aeroplane wing.* RSL report and RSL paper on International Air Congress, London, 1923

7. Von Baumhauer, A.G. : *Proposal for standardisation of the method of computing wing sections.* RSL report, April 1923

8. Von Baumhauer, A.G. : *Some notes on helicopters.* Proc. Intern. Congress for App. Mechanics, Delft, 1924

9. Von Baumhauer, A.G. : *A wind tunnel investigation on the performance of windmill blades.* RSL report A-258 and paper in De Ingenieur No.35, 1 September 1933

10. Verhage, G.F. : *The two-engined ramjet helicopter "Kolibrie".* Luchtvaarttechniek L.27, 1956

11. Lucassen, L.R. : *NHI ramjet helicopter "Kolibrie".* American Helicopter Soc. Newsl. Vol.4, No.4 , 1958

12. Lucassen, L.R. : *Helicopter ground resonance in theory and experiment.* NLL report V-1748 (in Dutch), 1954 and AGARD Paris 1954

13. Lucassen, L.R. : *A historical review of twenty post-war years helicopter research and development in the Netherlands.* 8th Blue Book of the Delft Student Aerospace Society "VSV Leonardo da Vinci" 1985, Delft University of Technology, Fac. of Aerospace Engineering

14. Kuipers, W.A. : *The Kolibrie Story.* Published by the author, 1992.
3960 Deep Valley Drive, Dallas, TX 75244-7229, USA

15. Lucassen, L.R., Meyer Drees, J., Senger, E.C. : *Emergency landing after power failure with a Sikorsky S-51 helicopter.* NLL Rep. V-1463 , 1948

16. Meyer Drees, J. : *The theory of airflow through rotors and its application to some helicopter problems.* NLL Rep. V-1497, 1949 and Journal of the Helicopter Association of Great Britain Vol. 3 N2, 1949

17. Timman, R., van der Vooren, A.I. : *Flutter of a helicopter rotor operating in its own wake.* Journal of the Aeronautical Sciences, September 1957

18. Meyer Drees, J., Lucassen, L.R., Hendal, W.R. : *Airflow through a rotor in vertical flight.* NLL Rep. V-1535, 1949

19. Meyer Drees, J., Lucassen, L.R. : *Transition into and pull-up from autorotation.* NLL Rep. V-1563 , 1951 (in Dutch)

20. Meyer Drees, J. : *Private communication.* July 1992

21. Prinsenmolen-Committee : *Research inspired by Dutch windmills.* Published by Veenman & Zonen, Wageningen 1959

22. Sabinin, G.H. : *Problems of utilizing of wind.* Transactions of the Central Aero-Hydrodynamic Institute No. 28, Moscow, 1926

23. Lucassen, L.R., Vodegel, H.J.G.C. : *An analysis of tuft position on a helicopter rotor blade and a comparison with experiments.* De Ingenieur, Jrg. 81/ No. 43/ 24 October 1969

24. Drees, J.M. (Meyer Drees, J.): *One thousend years of rotating wings.* 5th European Rotorcraft Forum, 1979

25. van Holten, Th. : *An analytical theory for tipvane performance and comparison with experimental research.* 8th European Rotorcraft Forum, 1982

26. Jessurun, K.P., Kuik, W., van Kuik, G.A.M. : *Design data of a tipvane rotor model for aeroelastic tests in the wind tunnel.* Technical Memorandum M-432, Dept. of Aerospace Engin., Delft University of Technology, 1982 (in Dutch)