Original Romanian Research for a Rocket Engine with Multiple Combustion Chambers during 1940 - 1944

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Abstract: *The paper presents certain points of view regarding the history of Romanian rocket engines, during 1940-1944. Working independently of other scientists, during 1942 – 1944 the Romanian Nicolae Văideanu has invented and designed, independently of other researchers, a liquid fuel missile called UDOVILUL-V [3]. According to the design drawings, this missile was equipped with aerodynamically profiled propelling nozzles and was provided with a special alternator – distributor, the bypass valve adjusting the fuel components dosage in the two combustion chambers, in fuel tanks and pipes, while a special designed gas turbine was driving the centrifugal pumps and other mechanical equipment. Within his main patent the Romanian inventor has included the design of several components [2], [4], [5]. The technical solution of this outstanding design in rocketry development could provide 20kN thrust after 60 sec, enabling a speed of 3200 km/h [10].*

Key Words: *rocket engine, combustion chambers, liquid fuel rocket,*

1. LIVING IN THE PIONEERING AGE OF ROCKETRY

1928 – 1939 was one of the most prolific periods for rocket engine research. Research was conducted in Germany, Austria, US, Italy, France, Soviet Union, etc [1], [2], [3], [4], this research being supported by the efforts of "rocketry enthusiasts" such as Hermann Oberth, Louis Damblanc, George Edward Pendray, Robert Hutchins Goddard, Robert Esnault-Pelterie, Philip Ellaby Cleator, Eugen Sänger or Friedrich Zander[1]. This prestigious list should be completed with the name of the Romanian Nicolae Văideanu.

[1]Russian: Фридрих Артурович Цандер / Fridrikh Arturovich Tsander; Latvian: Frīdrihs Canders; German: Friedrich Zander

Nicolae Văideanu was born on March 3rd, 1911 in the village Pricaz near Orăştie[2], Hunedoara County, in a farm workers family with 6 children. His father fought in World War I and became a disabled veteran. Nicolae Văideanu attended elementary school courses in his home village, followed by high school education in Orăştie[3] and the graduation exam (Baccalaureate) in Deva[4]. He graduated as a lawyer at the University of Bucharest, in the middle of the fourth decade of the twentieth century.

Nicolae Văideanu (1911-1981) in his younger days

The work of Nicolae Văideanu in the exciting domain of flight started already during his high school education period, under the guidance of Professor Rodeanu, and materialized in several aircraft models. His unusual passion had an unexpected, but highly successful direction, when at the age of 19, he discovered the principle of action and reaction. It was the result of an awesome experience: during the school holidays, using an old boat on the river Mureş, the young Văideanu had the opportunity to experiment an application of this principle. This will bring him later very complex involvements and satisfaction. Looking forward to build a flying vehicle able to reach supersonic speed, Văideanu started calculations for a Romanian liquid fuel rocket already as a university student and devoted his entire life to this purpose. The most prolific was the decade 1934 - 1944. During these years, working independently of other inventors, and having little reference literature, Văideanu designed original solutions for his invention – the missile *Udovilul-V*[5] and its main components. The rocket engine was designed with all main systems, parts, equipment and components of modern rocket engines [4], including a gas turbine driving the liquid fuel components pumps [5], [6], [7], [8].

After getting proper approvals, Văideanu, who already designed the missile *Udovilul – V* and its main components, started the technological design and the manufacturing of the missile and the gas turbine at the "Central Workshop Petroşani (Atelierele Centrale din Petroşani)", continuing the activity until 1945.

[2]Orăştie is a Transylvanian city in the same geographical area where Hermann Julius Oberth [1894-1989, one of the astronautics founding fathers] and Conrad Rudolf Haas [1509-1579, imperial artillery officer, commander of the arsenal of the Sibiu Fortress, from 1556 to 1579, pioneer of multiple stage rockets] lived and created.
[3]Currently the National College "Aurel Vlaicu".
[4]Currently the National College "Decebal".
[5]"*Udovilul*" is best translated as "Water Arrow" in Latin.

After several meeting with US Embassy, the inventor could study many technical and scientific reference papers in rocketry and connected areas, such as thermodynamics, fluid mechanics and gas dynamics[6], as well as clear definitions of various chemical fuels for rocket engines, study devoted to the improvement of his inventions [rocket engines, missiles, flying discs, etc.].

Although in Orăștie, the inventor's home town, the documentary material concerning the design and testing of rocket engines was insufficient, Văideanu didn't ceased to work, and the results of this rigorous and persistent scientific work were the following:

- Technical project calculation and 6 scale models of a solid fuel missile;
- Technical project calculation, general assembly drawings and two scale models for the sounding rocket N-2[7], which was proposed by the inventor to the Romanian Meteorology and Hydrology Institute[8];
- Series of technical project calculations, assembly drawings and performance tables for many liquid fuel rocket engines;
- A range of scale models for discoid flying vehicles;
- Series of physical and chemical characteristics tables and performance calculations for 379 liquid propellants[9] and 115 solid fuels (!).

2. MAIN COMPONENTS OF THE *UDOVILUL-V* ROCKET ENGINE

In 1942, Nicolae Văideanu got published a description of his invention by the "Putna" Publishing House in Bucharest, under the title: *"UDOVILUL – an engine capable of 3,200 km/h"*. The main components of "Udovilul-V-1942" were:

1. Multiple burning chambers liquid fuel rocket engines with:
   - Laval expansion nozzles;
   - Supercharged ducts directing fuel components to the combustion chambers' injectors;
   - Ducts directing the hot gases extracted from critical sections of the combustion chambers;
   - Bypass ducts assuring accurate fuel components dosages.
2. The alternator – a mechanical device enabling automatic switching at pre-established intervals the alternative fuel components penetration in each combustion chamber,

[6]Some of these were written by personalities like Robert Esnault-Pelterie, Felix Michaud, Aurel Stodola, Hermann Oberth, Hans Thirring, Eugen Sänger, Max Valier, Franz Schule, Rudolf Roeder, Rudolf Fuchs, Walter Hohmann.

[7]The sounding rocket "N"-2 offered on 27.11.1964 to this institute was a project for a high atmosphere research rocket, and, temporary, it was a subject of cooperation with the institute. The rocket remained only a project, since further work was not the responsibility of Nicolae Văideanu. The "N"-2 rocket concept used components similar to those of "*Udovilul-V*" rocket, but with a single combustion chamber having the fuel injectors fixed on its upper part. The pumps and the gear box were driven by an improved gas turbine. The "N"-2 rocket nose could be removed after a previous decided time, while the meteorological equipment was started by a temporization relay, also with inputs from possible faults affecting the gas turbine.

The combustion chambers walls had helicoidally channels for cooling.

Trajectory stability of the rocket was provided by a special arrangement of the tail wings.

The simplified performances calculation from Văideanu's project provided following theoretical values: thrust 10 kN, weight (empty) 200 kg, max. altitude 88.5 km, operation time 70 seconds.

[8]Currently the National Meteorology and Hydrology Administration

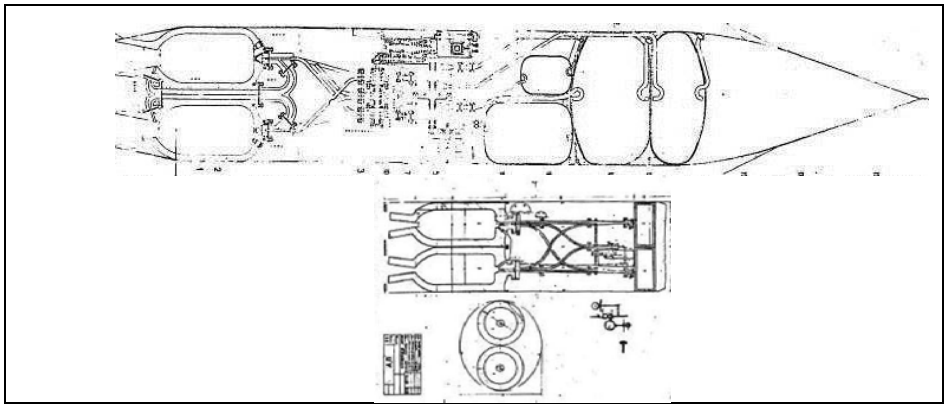
[9]Propellant – a chemical substance used in the production of energy or pressurized gas that is subsequently used to create movement of a fluid or to generate propulsion of a vehicle.

consequently assuring the cycle: combustion – cooling – combustion for each of the combustion chambers.

3. The time-relay, a mechanical time regulatory device attached to the alternator.
4. The main gas turbine driving the following devices: the alternator, the fuel pumps, the time-relay and the electromechanical Delco type device igniting the spark-plugs.
5. The centrifugal pumps for fuel components driven by the gas turbine through a gear box.
6. The electromechanical Delco type device for the spark-plugs ignition.
7. The electromechanical selector of electromagnetic waves for rocket guidance on trajectory.
8. The bypass valves adjusting the right fuel dosage in the "pre-chambers".
9. The tanks for the two catalytic gas turbine fuel components.
10. The main engine fuel components ducts.
11. The main engine fuel components tanks.
12. The rocket stabilization and control tail wings.
13. The rocket trajectory control elevons, functioning also as radio antennae and receiving control signals from the electro-mechanical selector.
14. Feeding ducts.
15. The rocket fuselage.

The project enabled also the design of parts used for other engine versions:

- Combustion chamber;
- The double gas turbine driving two cascaded hull rotors.



Presentation drawings of "Udovilul-V 1942"

3. THE UDOVILUL –V ROCKET ENGINE OPERATION

The functional concept of the project [7] shows that:

- The inventor focused on providing on-board energy supplies, enabling the rocket engine operation independently to the environment conditions.
- The initial gas turbine design considered the rotation initiation and provision of the starting energy by four small rocket combustion chambers, representing a common body around the main power shaft.
- The gas turbine design enabled its use as power supply for a rocket engine test rig.
- The first stage for operating the *Udovilul* engine was the inert gas pressure dislocation of the catalytic fuel components, nitrogen peroxide [N_2O_4] and potassium permanganate [K_2MnO_4].

- In *Udovilul-V* the gas turbine was driving following components: the alternator, the time relay; the centrifugal fuel pumps, the electromechanical Delco type device for spark-plugs ignition in the main combustion chambers.
- There were three types of centrifugal fuel pumps, the third being specially designed to enable cooling / refrigeration. The fuel pumps selection was deemed to enable a specific thrust. Their main power was determining the value of the torque provided by the main gas turbine shaft.
- The alternator was installed between the combustion chambers and the pumps, to enable automatic alternation of combustion and cooling. Each 90˚ turn of the alternator shaft would determine at the same time the automatic drainage of each chamber in a pair, and combustion within the other pair.
- The alternator was periodically driven by the time relay, a de-multiplication mechanism for the rotation movement of the main gas turbine shaft, enabling the adjusting of the combustion and cooling time within the combustion chambers.
- The bypass valve is the one ensuring the right supply of fuel components; coordinating with the alternators movement, this valve and its ducts prevent any explosion possibility.
- The spaying and mixing of the two fuel components was performed in the so-called pre-chambers, installed in the upper part of the main combustion chambers of the *Udovilul-V 1942* engine. The inventor himself described these conical "pre-chambers" as: *" […] in every 'pre-chamber' are many thin ducts: the first are the oxidizer directing spiral grooves, imprinted in the surface, the following are the fuel ducts, which are radial thin ducts, ending just in the carburant' grooves! This is why, I am sure the spraying and the mixing of the components would be the best! [...]"*
- The ignition of the fuel components was provided by a Delco type device, with certain particularities, such as the operation of this device during the whole active period of the engine (60-70 sec.), providing at the same time ignition and cooling according to the alternative cycle: "ignition – cooling – ignition".
- The inventor requested in 1941 a patent for an electro-mechanic selector of electromagnetic waves [6], a device converting electromagnetic signals received by the tail wings operating as antennas, in aero-mechanic action to enable automatic trajectory control by the tail wings.

4. THE INVENTOR'S MERITS

During his research, even with a restricted access to rocketry technology, the Romanian inventor Nicolae Văideanu gathered in his rocket engine *Udovilul V* certain important ideas [10]: The electro-mechanic selector, receiving electromagnetic signals to control the rocket movement on the trajectory and using the tail wings themselves as receiving antennas within this device [6].

- The construction of the rocket engine *Udovilul*[10] as a liquid fuel missile, including all components of modern rockets.
- Using a gas turbine[11] as a versatile power supply for rocket's mechanical devices.

[10]Thrust about 20kN, empty mass: 350 kg; fuel mass 304 kg; overall length 5,750 mm; maximum diameter: 428 mm; tail wings span 600 mm; active operation altitude: 70.2 km; mean acceleration: 4g; combustion chamber pressure: 35 kg/cm^2; operating time: 60 sec.

[11]Gas turbine power: 36 HP at 7,650 rpm; Pressure and temperature in the combustion chamber: 20 kg/cm^2 at 500˚C.

- Using the gas turbine as an independent power supply for a rocket engine test rig [9].
- The concept to use the alternative cycle ”combustion – cooling – combustion” and exclusive cooling use of one of the centrifugal pumps in the assembly.
- The advanced concept for that period to use a ”pre-chamber” to reduce the risk of fuel components explosion when mixing before ignition in the combustion chamber.
- Extraction of hot gases from the sonic flow areas of the reactive nozzles of the *Udovilul* engine to reduce turbulence in the combustion chambers.

AKNOWLEDGEMENTS

Between November 27th 1944 and January 27th 1945, Nicolae Văideanu was visited at his home in Orăștie by representatives of the US Embassy in Bucharest, having series of discussions, later on the inventor stating that most of his documents were photocopied.

Nicolae Văideanu displayed most of his scientific work in Bucharest at the Popular Astronomic Observatory (currently the Astronomic Observatory “Admiral Vasile Urseanu”), in May 9th and November 6th, 1968, and in Hunedoara at the Trade and Culture Centre between June 26th and July 10th 1969. Between 1960 and 1970, the inventor adapted his house in Orăștie[12] to create a permanent exhibition of his works.

Nicolae Văideanu in his house, (32, Eroilor Blvd., Orăștie) probably in 1980

During the last years of his life, Mr. Nicolae Văideanu presented personally his work to Prof. Nicolae-Florin Zăgănescu, Ph.D. (Eng.), who was at that time secretary of the Romanian Academy Astronautics’ Commission. The professor acknowledged their importance and tried to find ways to valorize them. He also wrote a paper about Nicolae Văideanu’s inventions, which he presented [10] at the XXXI Congress of the International Astronautical Federation, in Tokyo, Japan – September 21-28, 1980.

Unfortunately, Nicolae Văideanu passed away in 1981 and his house was later demolished by the communist authorities, many of his writings, books, rocket parts and scale models being

[12]Located in 32, Eroilor Blvd., Orăștie, Hunedoara County.

lost [11]. However, some of them have been preserved in a museum of the small town Orăștie, which awarded him posthumously the title of Honorary Citizen [12].

To this day, the works of Nicolae Văideanu remain little known and opinions about them may be very different, from skepticism [11] to enthusiasm [13].

However, we think that any engineer who tried to design something new in the domain of flight will understand the importance of having such enthusiastic forerunners. As Eugen Sänger (creator of Silver Bird, the precursor to Space Shuttle) once stated: *"Where is an enthusiast, there is a Peak of the World."*

The Annexes to this paper include transcriptions of the inventors' descriptions of *UDOVILUL* [engine R_1], the gas turbine [engine R_2], the electromagnetic radio control selector and presentation drawings published by Putna P.H. in Bucharest in 1942.

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ANNEX 1
DIRECT JET ENGINE / Patent No. 33354/1942

Definition-`R,1`is an engine based od direct jet propulsion.Still known under the name of `rocket` or engine with an ideal reaction, -an engine of personal device - built on the principle of reaction by burning of liquid and gas fuel.
This engine transforms into movement without any intermediary the energy contained by the fuel. The movement of the engine in one direction is determined by a quick and violent jet in a contrary direction, of a certain material it contains, and therefore it works independently of the surrounding elements: air, vacuum (void) and water.

Descript. -This engine is composed of two cylindric chambers for the combustion of the fuel and formation of the pressure necessary for the propulsion of the engine. Each of the two chambers have at their ends a truncated conic tube, based outwards for the expansion of the gazes burned under pressure. This is where the greatest part of the gas reaction acts. Each tube has another automatic tube with gas under pressure having two branches: one leading to a small gas turbine which works the pumps and the motric substances (fuel) alternator and second branch with gas under pressure leads to the injector. The gas conducted in this way works as a vehicle for forcing the high pressure chamber and for introducing the gas and the fuel together in this chamber. The walls of the combustion chamber are calculated so as to resist to usual pressures, unlike the walls of the chambers of `R,2`engine, which are calculated to resist to a pressure of 240 atmospheres, made of a steel with corresponding admissible sigma. The chambers have at their upper part a special injector (`pre-chamber`) for the mixing of motric substances (fuel components).
In every Chamber near the injector there is a sparking plug for the ignition of the mixture of motric substances. For greater assurance, the sparking plug works during the whole burning (combustion) period. The necessary current for the ignition of the sparking plug is supplied by an ignition system very much like a `Delco`, but much simplified by eliminating the current distribuitor, the current distribution being made in larger periods than at the common `Delco` and simultaneously with that of the motric substances by a certain mechanism.
Between the combustion chambers and the pumps is the motric substance alternator, through which all the substance tubes lead. This alternator is worked from time to time by a mechanism of demultiplication of the movements received from the gas turbine. Through this mobile mechanism we shorten or lenghten the periods of combustion or cooling in the combustion chambers. The alternator, by turning its axis with 90 degrees, causes the substances to drain in one chamber, once in the other, so that cooling follows each combustion period. Between the alternator and fuel tanks are three rotative centrifugal pumps worked by the gas turbine: two exterior pumps, one for fuel and one for comburant; the third pump in the middle ensures the cooling.

The pumps move the motric substances (fuel) and by the help of derived pipes and special valves one may take an absolutely exact quantity of moved substances for each of the two substances, i.e. these which are necessary for the proportionning of the fuel and comburant and these which are necessary for the combustion and the formation of pressure. Hence, they are sent to the alternator, injector and combustion chamber.

Functioning-The fuel either under pressure as are the gas fuels for ex. hydrogen or free as are the liquid fuels: kerosen, alcohol etc, are aspired by pumps from the respectives tanks and then forced through the tubes to the alternator which directs the fuel and comburant towards a chamber while the cooling air etc is led into another chamber with alternative periods of cooling and burning, commanded automatically by demultiplication mechanism which, by its movements, turns from time to time the axis of the substances alternator by 90 degrees. The substances are forced further towards the injector which mixes the fuel and the comburant in the best conditions for burning.
The substances, once in the combustion chamber, are ignited by means of a sparking plug and burned instantly, producing a large quantity of gases and great heat which increase the volume of these gases to which a high pressure is given , which, through their violent expansion (through the supercharged tube) move the body of the engine in one direction with the same violence as the gases escape in the opposite direction.

Innovat. and character.-Interior cooling (by water or other substance) of the two chambers, after the combustion of the substances, alternatively, once in the first chamber, than in the second. So we shall have in one chamber: 'combustion-cooling-combustion' etc, and in the other chamber the periods will be contrary to these, i.e., cooling-combustion-cooling' etc, these changes being automatically and instantly.

-As a consequence of this system of cooling (in opposition to the cooling of other rocket systems), the steel of which the combustion chambers are made can resist for a long time to a high temperature in these chambers, shortening the combustion periods bythe above-mentioned automatic alternation. for one of the great problems of the rocket engines: the deterioration of the material of which the combustion chambers are made, coming to the high temperature found here all the time

-The ratio or proportioning, by a special system of the substances, fuel and comburant and the mechanical regulation of the combustion and consequently ofthe formation of pressure in the chambers and of the higher or lower power of the engine reaction.

-The duration of an alternative period of combustion from the beginning of the combustion in one chamber and its end in the same chamber and the change with the cooling period in the same chamber is made and regulated in a mechanical way by an automatic alternator, by which these periods of combustion may be increased or decreased as required to the resistence to high temperature of the material of which the combustion chambers are made.

-The use of counter pressure to force the com-bustion chamber where we have high pressure continually,- for the introduction of motric substances in these chambers.

Possible uses

I. Surface torpedoes radio controlled or flying bombs with a speed over 1,500 km per hour;

II. Motor torpedo boats;

III. Submarines torpedoes with gyroscopic control;

IV. Stratospheric and atmospheric rockets etc.

ANNEX 2

`R.2` INTERNAL COMBUSTION REACTION TURBINE

-patented under Brevets Nos.33354/1942 + 37723/1944-

Definition-`R.2` is an engine with an ideal reaction, identical to `R1` with the difference that `R.2`is built on a rotor with all the technical and constructional consequences of this building and functioning.
The force developed by two (or four) combustion chambers set on the rotor acts directly on the rotor and is gathered for use from the axis of this rotor.

Function. -On a rotor made of two halves, fastened together by means of screws, are not the two or four combustion and pressure formation chambers which work alternatively. The chambers are supplied by the substances tubes; there are a third tube for cooling.

-The pumps are the same as those of `R.1`.Two substances pipes are set on one side of the rotor axis and inside of it, and one, that of the middle pump, is set on the other side of the rotor axis.

-Inside the axis the pipes meet two bars of the substance alternator which by rhythmic (to and from) movement along the axis open the way of the substances (fuel), towards one chamber and shut it towards the other, opening there the hole through which the cooling element penetrates into the chamber.

-The mechanism of the demultiplicating movements and substance alternation is the same as that of `R.1`. The ignition system is also the same, having only a special set up, towards a rotor which is turning round while it receives the high tension for the ignition

-The rotor axis is set on bearings and these are held by a support.

-`R.2`works in the same way as `R.1`with the difference that at `R.2`the force developed by the two or four pressure chambers makes the rotor on which they are built to turn in one sense (direction).

Inovations and charact. -`R.2`is an engine by which it is possible to test and verify practically in the laboratory all engines based on rocket principle, of course putting these engines in certain specific conditions.

-The use of the whole (or nearly the whole) force contained and developpes by burning substances and formation of pressure (thermal efficiency: 80 - 85 %).

-The steady, uninterrupted action on the rotor of the force developped through the burning substances.

-The use of the functionning of this rotative engine of the highest explosive gas or liquid fuels which cannot be used by rotative engine known so far.

-`R.2`is in fact an internal combustion reaction turbine which has solved the dream of all technicians!

Possible uses, I Practical testing and verifying all rocket engines

II. `R.2`can be used in the same field as `R.1`,as shown above, concerning the surroundings in which the engine works, with the only differencethat in as far as `R.2`is concerned (the developped force is gathered directly from a motric rotative axis).

III Different terrestrial uses as: autovehicles, streetcars, sub-ways etc

IV Submarines , vessels of any kinds etc.

ANNEX 3

RADIO CONTROL SELECTOR

-patented under No. 33269/o5.12.1941 -

Functioning--For an application of `R.l`to a torpedo or a flying bomb, it has devised an electromechanical selector for radio control, by tele-mechanical movements at a great distance and it can lead the torpedo or flying bomb by radio control.

-This selector consiste of a manipulator for transmitting of signals with a determinated duration and intermittence and with automatic repetition of the same signals in order to avoid perturbation of any kind (as atmospheric etc).

-Through this selector the waves are caught, modulated and transmited through a system of relays, mechanism and modalities the wanted movement;

-The possibility of obtaining many final commands is increased with this selector to 100 - 200 times, the smaller of greater figure depending on the number of mechanisms with which we provide the selector.

-The four systems of sets for the emmission of the commands in telemechanical field (i.e.:currents of different intensities, synchronism, different impulses and resonances) are not proper for radio control of a torpedo or the flying bomb, Therefore it has divised the above mentioned selector in order to perform safer commands and in a more frequent number without the use of synchronism or different currents.

-For the achievement of this selector, it has adopted the system of eliminating at every new advancing signal the mechanisms which don`t fulfill the conditions of the emitted signal-group so that after finishing the selection of a signal-group, a single mechanism remains for the wanted final command. A final command corresponds to an emitted signal-group but only if the signal-group has been emitted by our own station.

-The signal-group consists of a combination of certain signals, long and short waves.

-With the aid of several mechanisms, we can control a torpedo or a flying bomb.

-By one mechanism we cont-rol the chosen direction, leading it to right or to left; by another we might command the flying bomb altitude, hidding it for a few seconds in full speed. In this case, the flying bomb will have a special device provided with a membrane which owing to the differences of pressures, will automatically command the attitude of the flying bomb; meanwhile, it keeps moving on. Every deviation of the direction will be easily corrected by further radio control . The same possibilities for a torpedo.

-The selector mentioned above, is patented to the Patent Office of the Romanian Government, under `Brevet No. 33269 on 5th of December 1941.

ANNEX 4

N. VAIDEANU

UDOVILUL

MOTOR CU VITEZĂ DE 3200 KM. PE ORĂ

※

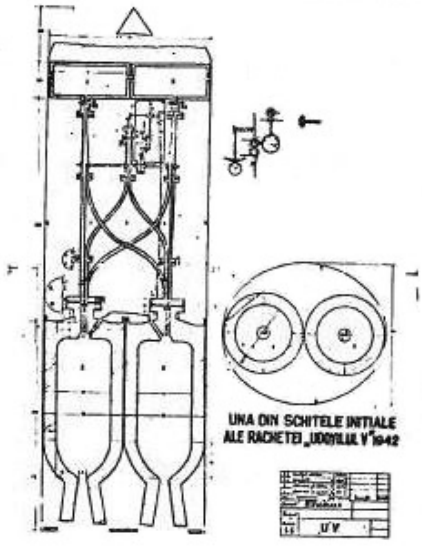
TIPOGRAFIA „PUTNA" — BUCUREȘTI, STR. MIHAI VODĂ Nr. 8
1942

Vaideanu's scientific work

RACHETA „UDOVILUL V" 1942, CU 4
CAMERE DE ARDERE (cu funcționare în cruce)
–cu turbina de gaz instalată între cornete cu gaze din convergentul camerelor de ardere.
–cu axul turbinei prin conducta centrală.

The gas turbine installing in UDOVILUL-V (1942) engine

General aseembly of the UDOVILUL (1942)



UDOVILUL-V (1942) first draft

TURBINA DE GAZ IN DUBLU TANDEM
(ALTERNATIVA TURBINEI SIMPLE CU RANDAMENT RIDICAT.
IN PLUS CU DOUA ROTOARE CU PALETAJE.)
(Brevet de invenție nr. 28.082/10.X. 1945 perfecționare
la brevetul nr. 33.354/1942 și brevetul nr. 37.723/1944