Particulars of the GERMAN VDM ELECTRIC PROPELLER
Author(s): JOHN D. WAUGH
Source: *SAE Transactions*, Vol. 52 (1944), pp. 348-358, 392
Published by: SAE International
Stable URL: https://www.jstor.org/stable/44468139
Accessed: 11-06-2020 10:53 UTC

Particulars of the GERMAN VDM

by JOHN D. WAUGH
*Lockheed Overseas Corp.**

THE VDM electric propeller (Fig. 1) is designed and built by the Vereinigte Deutsche Metallwerke, Aktiengesellschaft, of Frankfurt-am-Main-Heddernheim, and Hamburg, Gross-Borstel, Germany. This engineering company has spent many years of research and development on the propeller and has refined it to the point where it is used almost exclusively on all types of operational aircraft in the Luftwaffe.

The exceptions are the Junkers hydraulic motor operated propeller and the Argus aerodynamically operated type. These propellers have a more limited range of adaptability than the VDM and are thus used less widely.

First public showing of the VDM was held at the International Air Meeting in Zurich, Switzerland, 1937. From that time till the outbreak of war, VDM achieved distinction in being fitted to the Heinkel fighters which established world speed records of 392.5 mph and 463.9 mph, and was also fitted to the Messerschmitt 109 fighter that attained 469.2 mph, the present official world's land plane speed record. The Dornier Do.18, which flew to a world's record for long distance, likewise mounted VDM propellers.

In England the VDM was given spinning and flight endurance tests by the Royal Aircraft Establishment, Farnborough, in 1938, and was approved for use on civil aircraft. Shortly thereafter Constant Speed Airscrews, Ltd., Warwick, obtained the sole British license to manufacture the VDM propeller and patented quick-detachable spinner. The present conflict stopped the production of the propeller, but did not stop production of the spinner, which was improved by Constant Speed Airscrews, and is now used in quantity by the Royal Air Force.

■ General Description

The VDM propeller is strictly unusual when compared to an American design such as the Curtiss electric, which uses the same general idea of control and operation by electricity.

Pitch-change energy is derived from a small reversible electric motor mounted on the engine crankcase and connected to the propeller by a flexible shaft. This shaft enters a small primary drive reduction gear box attached to a large annular gear box fixed to the rear of the propeller hub.

The outside of the annular gear box is secured against rotation with the hub by a bracket to the engine nose case and houses the epicyclic pitch-change gears, some of which rotate with the hub.

Pinion gears engage the outlet drive of the annular gear box and drive worm shafts entering the hub blade sockets and mesh with worm gears integral with the blade adaptors.

THE VDM electric propeller is used almost exclusively on all types of operational aircraft in the German air force.

This propeller, Mr. Waugh concludes after his thorough study, is versatile, well designed, and well constructed; however, it is not superior to comparable British and American units.

Pitch-change rate of the model described here is inadequate for high-performance aircraft, but the propeller is very easily and quickly disassembled and serviced. The model is easy to manufacture, but, because of the large numbers of small parts, takes longer for inspection and assembly than for American propellers.

The VDM spinner is well worth study, as it is superior to American spinners, at least from the removal and installation standpoint. It takes only a matter of seconds to remove or install the VDM spinner, while American spinners take much more time and effort.

■

THE AUTHOR: JOHN D. WAUGH (J '42) is technical project specialist for Curtiss-Wright Corp., Propeller Division. Previously, he was an instructor in aircraft propellers for Lockheed Overseas Corp., in England. Here all types of propellers had been studied by company technicians and RAF personnel using American-built equipment. He also performed a liaison function between the company and British propeller manufacturers and British Government technical agencies engaged in propeller work of all natures. For a time he was senior instructor in propellers in the Air Force Training Program.

The *Aeroplane* drawing in Fig. 2 shows the general arrangement of the component parts and driving mechanism.

Since the motive power for blade displacement is led to the propeller by a flexible shaft, it is obvious that any means of rotating the shaft will serve the same purpose as the electric motor. Accordingly, the VDM people made known that their propeller could also be supplied with hydraulic, pneumatic, mechanical, or manual means of operation.

All VDM propellers are of hollow-shaft construction for the purpose of having all types and models readily adaptable to motor-cannon installations. Likewise the pre-war

---

[This paper was presented at the SAE National Aeronautic Meeting, New York City, April 7, 1944.]

* Now with Propeller Division, Curtiss-Wright Corp.

ELECTRIC PROPELLER

hubs were built with a standard shaft bore which could be fitted with spline sleeves of any dimensions, making a VDM applicable to any domestic or foreign engine shaft.

Blade retention is accomplished by simply screwing a blade into the hub adaptor and locking it against rotation by a wedge ring. This applies to duralumin, magnesium, or compressed wood blades, though dural is chiefly used.

Blade cuffs are not used in conjunction with VDM blades because the blades are effectively flared down to the root and the hub is of small diameter permitting satisfactory cooling of closely cowled radial engines.

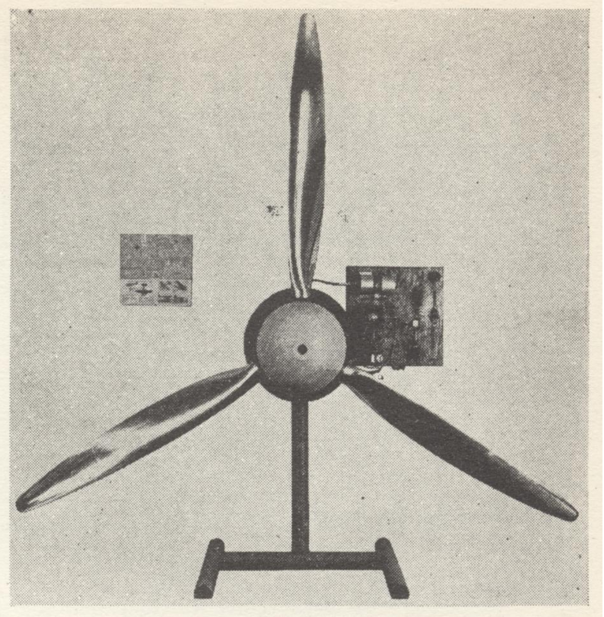
No special allowance is incorporated for the increased centrifugal twisting moment to low pitch of flared blades over nonflared blades because VDM blades are driven to low pitch and high pitch mechanically as compared to the Hamilton hydromatic, which depends upon the assistance of the centrifugal twisting moment to help motivate the blades to low pitch and must have blades designed with this factor considered. Of course, additional power is required to move the blades to high pitch when the centrifugal twisting moment is increased.

Control of the propeller is effected by conventional electric cockpit switches disposed cleverly for the convenience of the pilot. These switches enable the propeller to be operated on the ground with the engine dead, operated in flight in fixed pitch, selective pitch, constant-speed, and feathering. Reverse thrust control could be easily applied with no modification of the propeller. The blades will turn through 360 deg unless limited by electric motor cutout switches.

Electric and mechanical pitch indicators are supplied and installed with VDM propeller control systems. The electric indicator is generally used on multiengined ships where mechanical drives would be too long for satisfactory indication. The mechanical indicator is primarily for the short cable drive a single-engined ship affords. However, both indicators are sometimes used together – the electrical indicator on the instrument panel and the mechanical indicator in the engine nacelle where the pilot can observe it from his seat in a multiengined ship.

The exact value of a pitch indicator is not known to the writer; but discussions with flying personnel sum up to the conclusion that it is just another gadget. The Army Air Forces have evidently been of the same opinion because no propeller on an Army ship has used an indicator since the Lycoming-Smith mechanical propeller was in general use.

The Germans must believe that for certain military operations, such as dive bombing or long formation flights, an indicator of blade position will assist the pilot in more speedily selecting and synchronizing a given set of conditions of engine speed, flying speed, and power output. For "recipe book" pilots, this would definitely be an advantage.



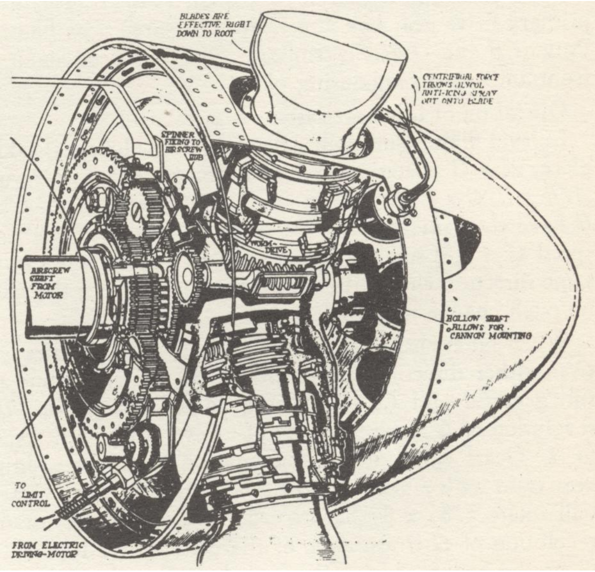
■ **Fig. 1 – Complete VDM propeller and electric controls**

■ Epicyclic Pitch-Change Gearing

The schematic diagram in Fig. 3 shows the disposition of the gears comprising the pitch-change train and illustrates the motor-to-blade relationship.

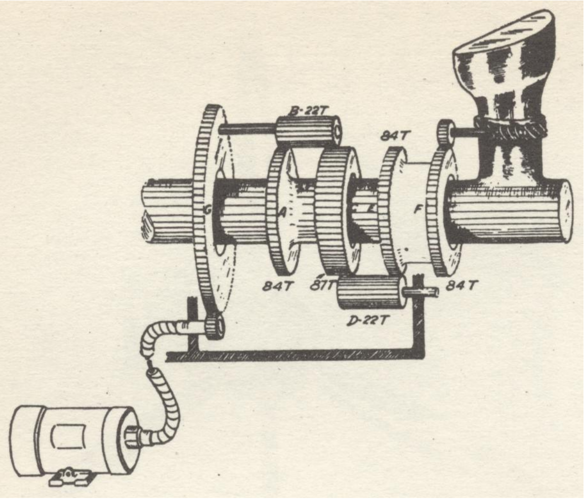
Gear *A* is splined to the hub and rotates at propeller speed. Gear *C* is free to rotate relative to the hub, and gears *E* and *F* are linked together and free to rotate relative to the hub.

Gears *A, E,* and *F* each have 84 teeth; gear *C* has 87 teeth cut on the same diameter blank as *A* and *E*. Thus, pinion gear *B*, with 22 teeth can mesh with gears *A* and *C;* pinion gear *D*, also 22 teeth, can mesh with *C* and *E*.



Copyright, *The Aeroplane*

■ **Fig. 2 – Perspective-sectioned view – VDM propeller**



■ Fig. 3 – Schematic diagram of VDM pitch-change gearing

Pinions *B* and *D* each use slightly less than half the face width of *C*, and use the rest of their width to mesh with their adjacent mating gears *A* and *E*.

At first glance this arrangement does not seem quite reasonable, but upon close examination of gear *C* the pitch of its teeth is found to be not exactly accurate with that of the pinions. This, however, has been so carefully calculated and the gears so precisely made that the arrangement works perfectly.

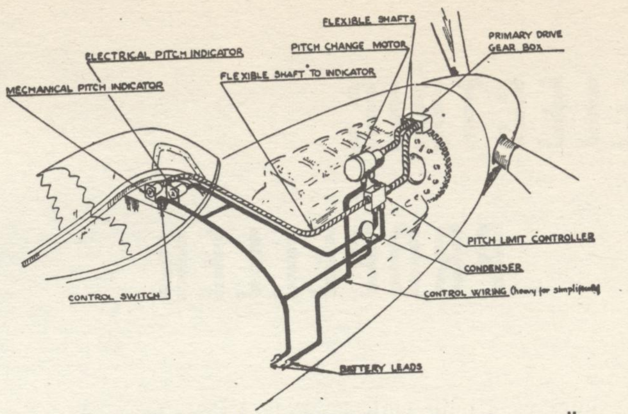
Gear *E* is linked to *F*, which meshes with the pinion and worm shaft driving the worm gear integral with the blade adaptor. Thus, it is apparent that any movement of the *E*, *F* combination relative to the hub will result in a pitch change.

Pinion *D* is free to rotate on a fixed shaft mounted in the gear housing, which is anchored to the engine. Pinion *B* is free to rotate on a fixed shaft mounted on the rear plate of the gear housing. This plate is fixed to gear *G* and is free to rotate relative to the gear housing and the hub, being isolated from each by roller bearings. Gear *G* has 150 teeth and is driven by a small 10-tooth gear in the primary drive gear box attached to the large gear housing. Pinions *B* and *D* are in triplicate, equally spaced about the front and rear gear housing plates.

Operation of this gear system is as follows:

In level flight condition, where no pitch change is taking place, gear *G* is stationary and a simple gear train results. $A/B \times B/C \times C/D \times D/E = 0$ and, as explained, *A* and *E* have the same number of teeth, *E* rotates at the same speed as *A* and since *A* is fixed to the hub, *E* rotates in the same direction and at the same speed as the hub; therefore, no pitch change takes place.

When pitch change is desired and the motor rotates gear *G* in either direction, planet gear *B* is rotated around the sun gears *A* and *C*, establishing an epicyclic train. One revolution of *G* moves *C* 3/87 of a revolution with respect to *A*. Gears *C*, *D*, and *E* can now be treated as a simple gear train with a gear ratio of 87/84 from *C* to *E*. Gear *E* will rotate $3/87 \times 87/84 = 1/28$ of a revolution for one revolution of *G* irrespective of the direction of rotation of *G* or the speed of *A*. *E* coupled to *F* and driving the worm gear to the blade completes the train and causes a pitch change.



■ Fig. 4 – Installation scheme of VDM nonautomatic propeller

■ Types of Installations

There are two types of installations of the VDM propeller in Luftwaffe aircraft:

1. The nonautomatic installation has both mechanical and electrical pitch indicators and depends upon pilot selection to operate the propeller at all times. This installation can be converted to automatic operation.

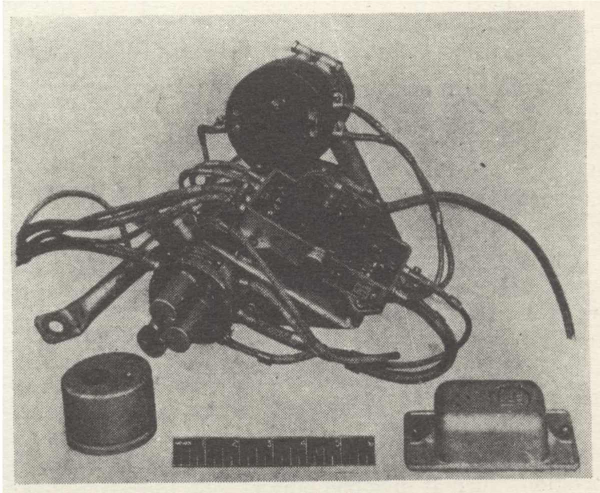
2. The automatic installation incorporates electrical and mechanical pitch indicators, a governor, and a relay, and will operate in constant speed after a fashion.

A description of these two systems follows.

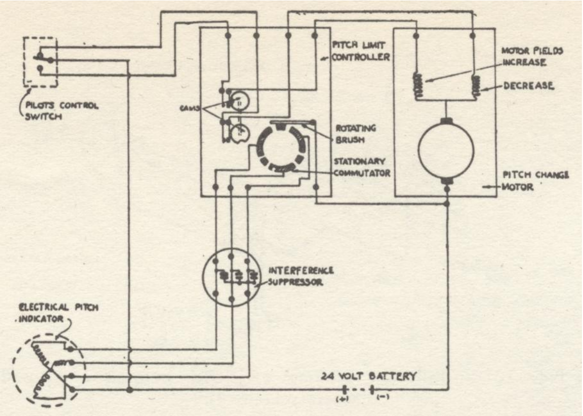
■ Nonautomatic System

Fig. 4 shows the nonautomatic propeller installation in an aircraft. Here it will be noted that a pitch-change motor and pitch-limit controller are connected to the propeller by two flexible shafts. From the other side of the pitch-limit controller another shaft goes to the mechanical pitch indicator in the cockpit. A control switch and electrical pitch indicator on the instrument panel and an interference suppressing condenser complete the control system. The motor, pitch-limit controller, condenser, and wiring are shown in Fig. 5.

By reference to Fig. 2 it will be noted that the motor and pitch-limit control shafts enter the primary drive gear box, where a reduction takes place. The motor shaft to blade reduction is 24,010:1, the pitch-limit control shaft



■ Fig. 5 – Motor, pitch-limit controller, and condenser of nonautomatic system



■ Fig. 6 – Typical VDM nonautomatic propeller wiring diagram

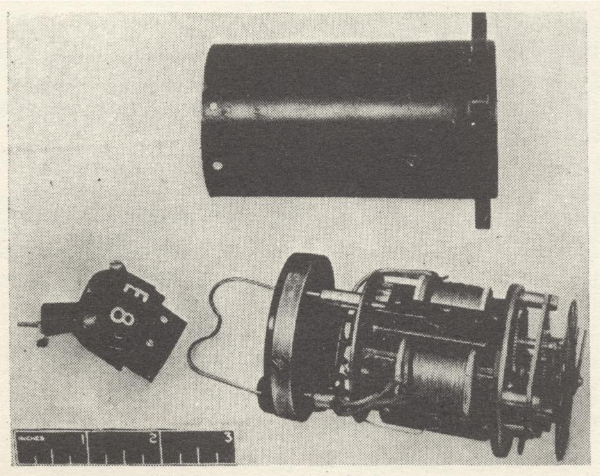
7139:1, making 1-deg pitch change equal 19.9 revolutions of the limit control shaft.

When the control switch is moved to the high-pitch or low-pitch position, current activates the reversible pitch-change motor and changes the pitch of the blades in a manner previously described. The primary drive gear box now rotates the shaft to the limit controller and mechanical pitch indicator. The shaft from the primary drive goes through the limit controller to the indicator and also operates a set of cams in the controller which will switch off the motor current when the blades reach a predetermined blade angle setting.

Electrical pitch indication impulses are also obtained from the pitch-limit controller. If feathering is desired, overriding the control switch in the high-pitch position will move the blades to the feathered position. This feature is found only on certain installations.

(a) The pitch-change motor for the nonautomatic system is of Bosch manufacture. Construction is of the completely enclosed series type; a pressed metal cover fits over the commutator end, and a flexible drive connection emerges from the anticommutator end.

The eccentrically mounted armature is carried in magneto-type bearings in the mild steel frame. Eccentric mounting of the armature allows for only one pole shoe, the magnetic circuit being completed through the pole case and armature. This pole shoe is made of mild steel and carries the two field windings of opposite polarity. One end of each winding is connected to one of the brushes. Flexible leads from the other brush and from the free ends of the field windings are taken to three terminals in the commutator end so that direction of rotation can be selected or changed by switching leads. Condensers are connected between the line brush and frame and between the free ends of both field windings and the frame.



■ Fig. 7 – Electrical pitch indicator

At a speed of 2400 rpm and an input of 24 v, 8.2 amp, the torque is 2.4 lb-in. Overall length 5½ in., diameter 3 in., weight 4¾ lb.

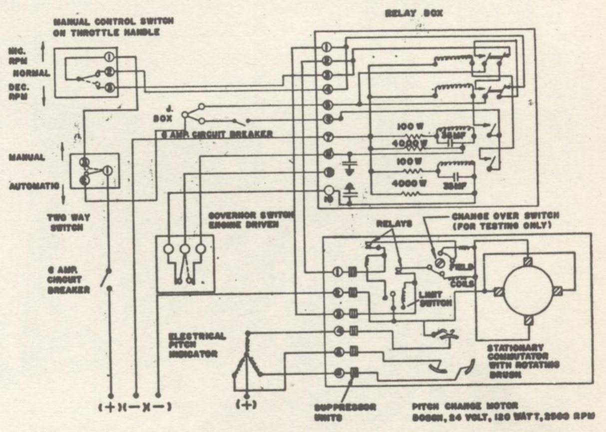
(b) The pitch-limit controller, as previously described, stops the pitch-change motor at the upper and lower limits of blade angle and sends impulses to the electrical indicator.

The motor control mechanism is gear driven at a reduction of 1000:1 by the flexible drive from the primary drive gear box. Two cams actuated by this reduction gearing open and close two sets of contacts which are in each of the two field circuits. The contacts are closed, completing each circuit in turn, until the preset high- or low-pitch position is reached. Here the proper contact is opened by its cam and the motor circuit is broken.

The pitch indicator operating mechanism consists of a fixed commutator having three main segments, each connected to the electrical pitch indicator. As the flexible shaft drives a rotating brush, at a reduction ratio of 15:1, around the commutator, a circuit is intermittently established through each segment of the commutator to the pitch indicator. Fig. 6 is the wiring diagram of the nonautomatic system.

(c) The electrical pitch indicator shown in Fig. 7 consists of three iron core coils mounted axially at an angle of 120 deg apart. A bipolar armature, of soft iron without windings, rotates on a spindle in the center of the three coils. This spindle drives the clockwork mechanism which operates the pitch-indicating pointers. The coils are connected to the three segments in the pitch-limit controller and are energized in turn, attracting the armature into rotary motion.

Each coil is provided with a U-shaped piece of soft iron pivoted on the side remote from the armature. When the coil is energized, this piece of iron is attracted to the iron core of the coil so that one tip projects through a hole in the core until it just touches an iron vane on the armature. This meeting short circuits the magnetic air gap between the iron core and the armature, thus acting as a magnetic



■ Fig. 8 – Typical VDM automatic propeller wiring diagram – Messerschmitt 109E lock preventing oscillation of the armature. An auxiliary lock for momentary holding takes the form of a spring-loaded pawl acting on a notched wheel in the clockwork gear train.

The face of the indicator is marked off like the face of a clock; with twelve equal divisions, each divided into five smaller units. Two clock hands, one short and one long, correspond to minute and hour hands. Each "hour" division equals 6 deg and each "minute" division equals 0.1 deg.

For every installation the take-off pitch is represented by 12:00 o'clock. So, if the clock hands sit at 3:30 o'clock, the pitch would be read as $3 \times 6 + 30 \times 0.1$ or 21 deg high pitch above take-off position.

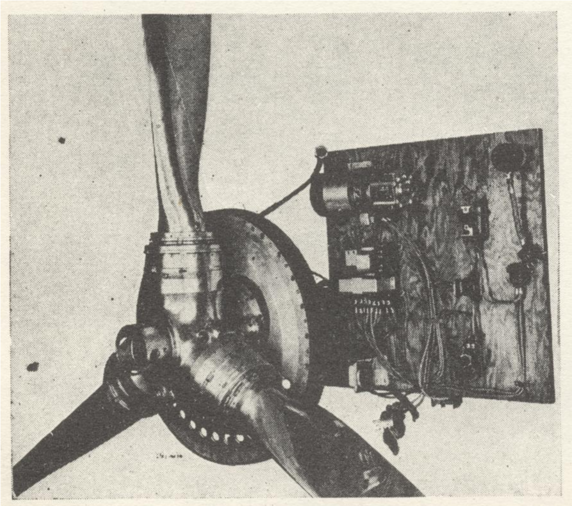
■ Automatic System

The automatic system consists of a pitch-change motor controlled by the pilot from a spring-loaded two-way switch located on the throttle handle, and by an engine driven governor actuating a relay. Selection of manual or automatic operation is obtained by a conventional selector switch. Fig. 8 shows the wiring diagram of the automatic system and Fig. 9 is a close-up of the actual components minus the governor. A circuit breaker of 6-amp capacity protects the automatic system from damage, but does not prevent use of the manual system should the automatic fail. Fig. 10 illustrates the automatic system installation.

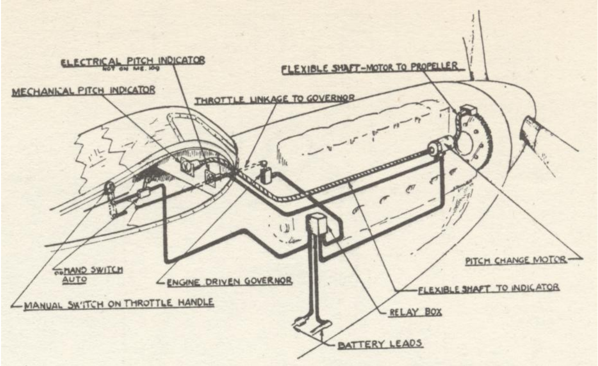
The manual or automatic switch is located just ahead of the throttle so that full-throttle position will put the switch in automatic, thus preventing overspeeding of the engine. However, the catch which puts the switch into the automatic position can be swung aside letting the throttle be opened while the propeller control system is in manual.

The propeller governor is a simple flyball-operated, single-pole, double-throw electric switch driven at one-half crankshaft speed by the engine crankcase gear box, which drives the machine gun interrupter and magneto. Throttle linkage to the governor operates on the idea of having a loading spring in the governor swinging in cam fashion against throttle-opening and flyball pressure.

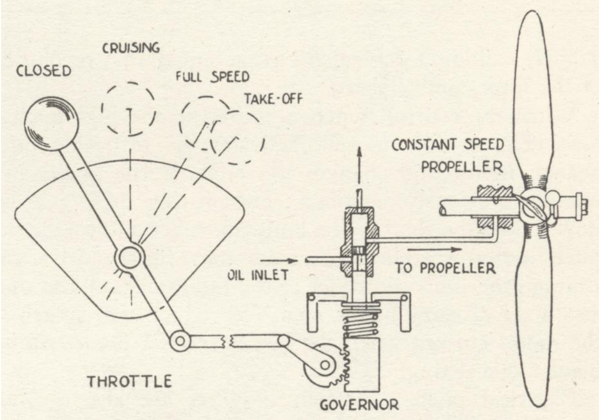
This single lever control, in which any rpm corresponds to a fixed predetermined value of manifold pressure, has virtue in that operation of the engine-propeller combination is much simpler for the relatively unskilled pilot with only slight loss of economy for some flight conditions.



■ Fig. 9 – Hub, motor, relay, and switches with covers removed



■ Fig. 10 – Installation scheme of VDM automatic propeller – Messerschmitt 109



■ Fig. 11 – Junkers-Hamilton automatic throttle-governor propeller control

Likewise, the manually operated low-pitch, high-pitch switch button which forms the throttle knob is a deliberate attempt, and accomplishment, to simplify operation for the pilot. Adoption of a similar system on American aircraft, fighters in particular, would probably prove very popular.

German views on automatic engine-propeller arrangements may be found in an article by K. A. Schmidt.[1]

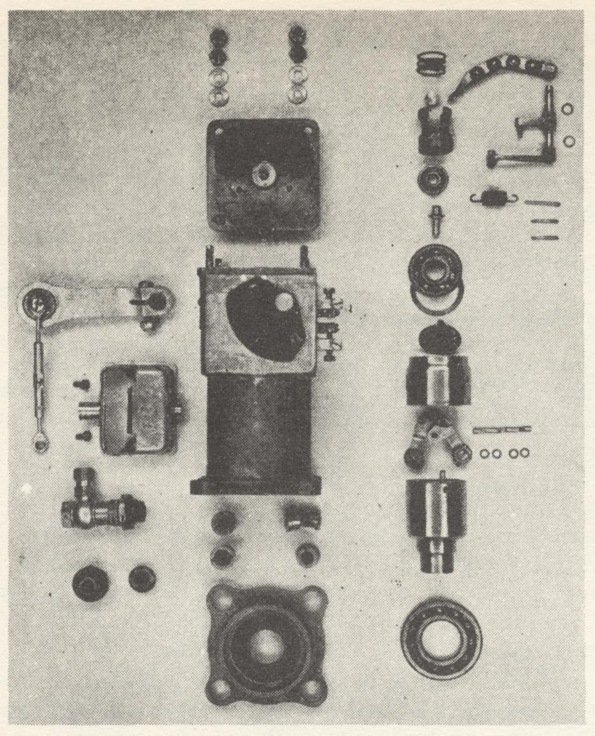
Fig. 11 is a schematic view of an early German throttle-propeller linkage, which the Junkers company applied to the Hamilton licensed constant-speed propeller and which they built at that time.

(a) The Bosch pitch-change motor for the automatic system differs greatly from the motor of the nonautomatic in that it incorporates the pitch-limiting contacts, the electrical pitch-indicating transmitter and provides the drive to the mechanical pitch indicator. These features eliminate the pitch-limit controller.

The motor is a four-pole series type with two sets of oppositely wound fields for reversing. The front end of the armature drives the flexible shaft to the propeller gear box while the rear take-off operates gearing to rotate the mechanical pitch-indicator outlet once for every 3.3 revolutions of the armature. Also rotated by this gearing is a small disc mounting a button which contacts a pair of brushes connected to two magnetic relays in series with the field coils. The disc limits the pitch range by contacting the brushes and actuating the magnetic relays – one for

---

[1] See *Aircraft Engineering*, Vol. 12, August, 1940, pp. 233-236: "The Bases of V. P. Airscrew Design," by K. A. Schmidt. From *Luftwissen*, October, 1939, pp. 267-273.



■ Fig. 12 – Disassembled electric governor

high pitch and one for low pitch. To obtain different values of pitch, one of the brushes contacted by the rotating disc is adjustable by screwdriver from outside the housing.

The electrical pitch-indicator transmitter takes the form found in the pitch-limit controller, that is, a stationary 3-segment commutator with a rotating brush. All leads from the motor are equipped with interference suppressing condensers instead of the single large condenser found in the nonautomatic system. The motor is rated at 2500 rpm, 24 v, 120 w. Weight is 8 lb, 4 oz.

(b) The manual control switch which forms the knob of the throttle lever operates the pitch-change motor in either direction when the system is in manual it is essentially a two-way press action switch, spring loaded in the central "off" position.

The switching mechanism consists of two silver-plated discs mounted on, but insulated from, two flat springs in which they "float." When the rocking lever forces one of the springs down, the "floating" disc contacts two small silver contacts mounted on short brass strips. The electric contact is made from the periphery of the disc contact to the fixed contacts.

The tendency of the discs is to rotate from the inertia of springing back, so a different point of contact is established at each actuation. A bakelite base forms the mounting pad for all contacts and springs. The switch is small, 2 x 2⅜ in. and weighs but a little over 5 oz.

(c) The electric governor, which is shown disassembled in Fig. 12, is manufactured by the Hamburger Metallverarbeitungs-Gesellschaft, of Hamburg. This company is evidently an accessories maker, constructing governors for VDM from VDM design.

The governor cap, body, and base are die cast from magnesium alloy and have very few machining requirements. Bronze bushings are pressed into the housing to carry small shafts and pins.

The body is divided into two main chambers; the lower chamber housing the speeder cup and flyweight assembly, and the top chamber housing the loading spring and actuating levers. One side of the top chamber is separate from the levers and houses only the current distributing contact arm.

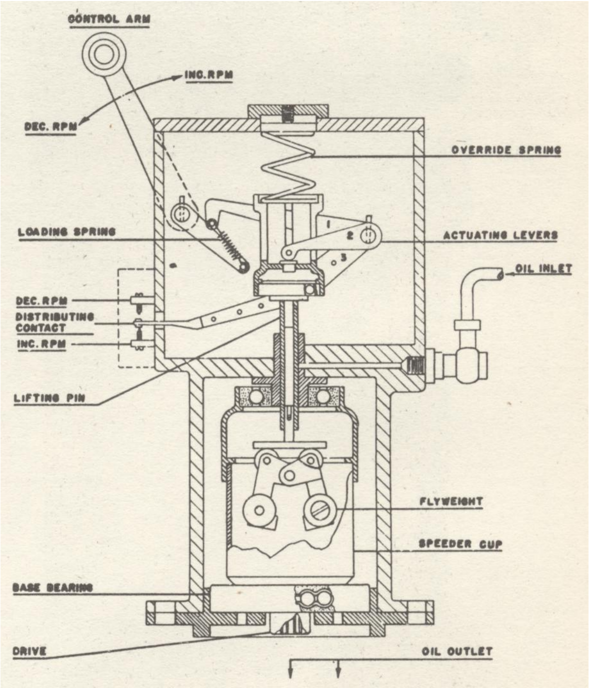
Oil from an outside pressure line is led to the lifting pin bushing connecting the upper levers with the flyweights in the lower chamber. From this bushing, oil distributed to the upper and lower chambers drains out the base. Small mesh wire strainers in the inlet elbow filter the incoming oil.

The control arm from the throttle linkage, which increases or decreases the tension of the loading spring, is equipped with a pointer marked off in the inevitable German vernier fashion. In conjunction with this pointer is a small plate screwed to the side of the governor and marked off in degrees from 0 to 80. As the control arm swings back and forth, the pointer with its vernier scale will indicate the degrees and fractions of degrees of travel.

The distributing contact lever emerges from its oil-tight compartment to meet the stationary decrease and increase rpm contacts mounted on the outside of the governor case inside a small aluminum cover.

Both moving and stationary contacts are made of silver and show no signs of burning. The increase rpm contact is adjustable by screwdriver from outside the contact cover. Both adjustable contacts are held in position by clamping screws.

The schematic cutaway view of the governor in Fig. 13 is intended to illustrate operation only. By reference to this drawing it will be seen that the small flyweights enclosed in the engine driven speeder cup will lift lever No. 2 via a pin when acted upon by centrifugal force. Levers 1, 2, and 3 are fastened to a common shaft by small taper pins. Thus, when lever No. 2 is lifted, No. 1 acts against tension applied by the loading spring. If the rotational velocity of the governor causes the flyweights to



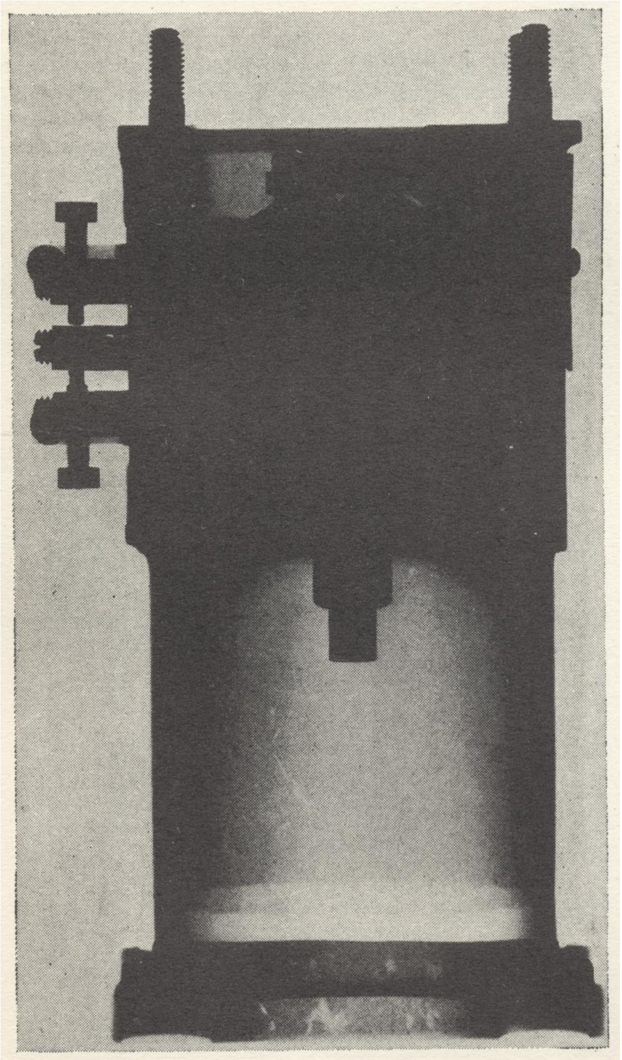
■ Fig. 13 – Cutaway view – VDM electric governor overcome the loading spring tension set by throttle linkage, levers 1, 2, and 3 are lifted to their upper limit. It will be noted that lever 3, the current carrying contact, will touch the decrease rpm contact and cause the relay to energize the pitch-change motor toward high pitch.

Conversely, if the loading spring tension is greater than the lifting force of the flyweights, lever No. 3 will be directed down to the increase rpm contact with a resultant correction of the blades to a lower pitch and higher rpm.

It is readily seen that this governor is limited in sensitivity and wholly lacking in any proportional correction of engine rpm. The Curtiss governor with its proportional correcting feature and the Hamilton governor with sensitive oil metering correction cannot even be compared to this German attempt.

Factory seals were on the specimen examined and all evidences were that it had not been in service long. Workmanship was of the poorest order yet found on a German device. Considerable hand fitting was roughly done. This points to either dilution of labor or production requirements; no similar indications, however, have been found on other propeller components.

Not even the most production-driven British or American propeller manufacturer would pass the fits found in this piece of work. The fit of the ball bearings gave the impression that gasoline had been used as a lubricant. The speeder cup consequently had enough play possibly to cause some binding of the lifting pin, although the design had clearly been intended to avoid this possibility.



■ Fig. 14 – X-ray of governor casting showing flaws

Fig. 14 is the picture of an X-ray taken of the governor body casting. Close examination revealed gas porosity and shrinkage flaws in sufficient quantity to cause rejection by Lockheed standards.

Accessibility of the contact points, and light weight (1 lb, 10 oz), are the only admirable features of this governor.

■ Constructional Details

In order to present as complete a picture as possible of different VDM installations and variations, different units, controls, and sources of data have been studied and liberally drawn upon.

The propeller assembly herein described is 11 ft, 6 in. in diameter and was taken from a Heinkel 115, twin float, mine-laying seaplane powered by two BMW 880 hp engines. The controls previously described came variously from a Heinkel and a Messerschmitt. The blade analysis is from the very thorough report of Rotol Airscrews, Ltd., on the propellers of a Heinkel 111 bomber.

Hub – The hub, which is shown in Fig. 15, is a one-piece forging, machined and ground over all in chrome-nickel steel similar to X4340. Blade sockets are recessed at the bottom to receive the inner journal bearing and are threaded at the rim with conventional V-threads to retain the blade bearing and adaptor housing.

Bosses on the sides of the blade sockets carry the worm drive shafts and house the bronze worms. The worm, which is denied end play by a close-fitting double set of ball thrust bearings, is keyed to its drive shaft, the shaft being carried by three sets of needle rollers running in direct contact with the hub.

An extension of the rear of the hub is splined inside to fit the engine shaft and tapered to fit the rear cone. The outside is splined and machined to receive the annular pitch-change gear box. A grease fitting between two hub sockets leads to the gear box shelf.

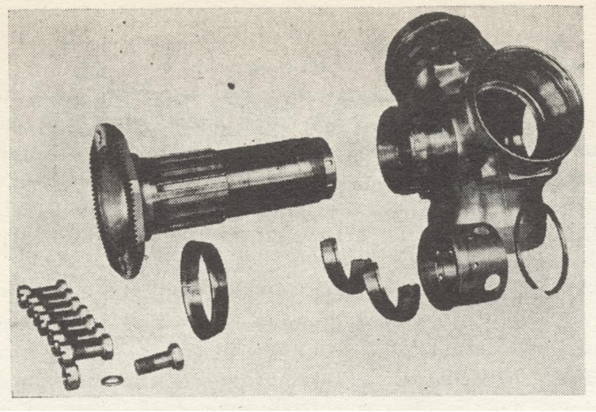
The center and front of the hub shaft bore are entirely hollow; the shaft splines being in the rear extension. This is a good feature from the standpoint of weight saving. A front cone taper and retaining nut snap ring recess are cut in the front of the hub.

Eight holes are drilled and threaded in each hub socket for the purpose of mounting the spinner and locking plates. These holes seem contrary to usual practice regarding a highly stressed propeller hub, but are evidently satisfactory in this instance because of thick walls and careful hand finishing of the holes.

The front of the hub is provided with a short annular extension which provides a seat for the spinner baffle.

The stub shaft which carries the hub is provided with a Hirth-type serrated flange held to the engine crankshaft flange by eight ground bolts. The rear cone is bronze, as is the split front cone. The retaining nut is drilled with small holes for locking purposes and large holes for installation and removal by a propeller bar.

The condition of the hub was found to be very good. Only the expected amount of galling between the hub and rear cone was evident. The rear shelf extension which carries the gear box was slightly pitted from fretting of the gear box on the shelf. This could be caused by improper



■ **Fig. 15 – Stub shaft, hub, cones, and retaining parts**

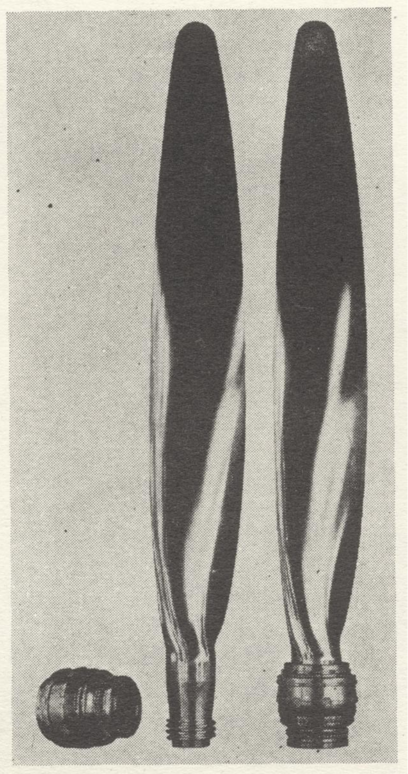
fit, insufficient area, poor retention, or vibration. However, not enough specimens have been examined to determine if this fretting is a habit of VDM hubs.

Cadmium plating on hub, stub shaft, retaining nut, and snap ring was in good condition, although quite thin.

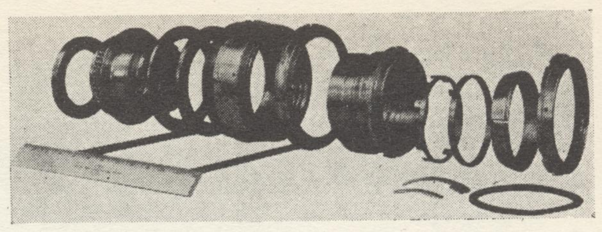
Blade Mounting – Blade mounting in the hub is accomplished by means of a unit assembly which houses an adaptor, threaded to mate the screw threads on the root of the blade, and equipped with radial bearings for bending loads and taper roller bearings for centrifugal loads.

Fig. 16 shows one blade mounting unit installed on a blade and one removed. Fig. 17 is an exploded view of the unit.

To explain the relation of parts and action of the unit, Fig. 18, a cross-section view, will best serve. In this view it will be seen the flanged engine shaft *a – b* is fastened to the hub boss *c* by a retaining nut *f*. The hub blade socket *d* has an extension socket *g* threaded into it. This extension carries the outer journal bearing *h,* which consists of 142 rollers 0.235 x 0.235 in. in two rows and provides a step and means of retention for the taper roller bearings *i,* which are 0.60 in. long and measure 0.368 in. in diameter at their large end. These taper rollers carry the centrifugal load of over 30 tons and are retained between two hardened races; the outer race tapered and the inner flat.



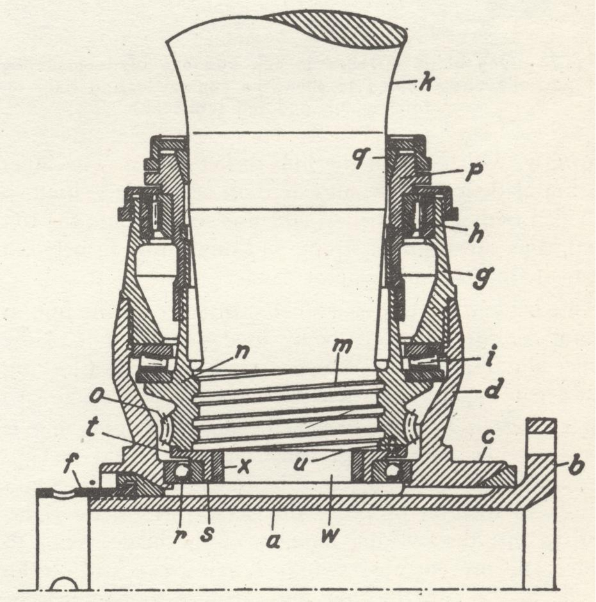
■ **Fig. 16 – Dural blades with mounting units installed and removed**



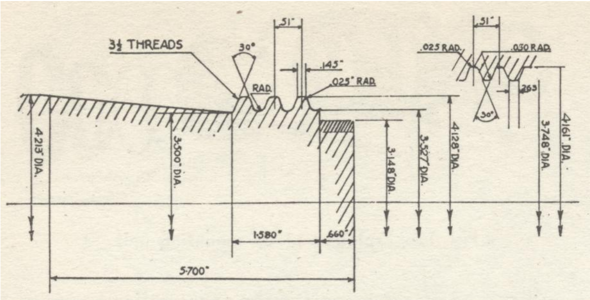
■ **Fig. 17 – Exploded blade mounting unit**

The dural blade *k* is held in the blade adaptor *n* by a screw thread *m*. The form of this screw thread and adaptor is shown in Fig. 19. A worm wheel *o* is cut and ground on the lower portion of the adaptor so that the blade may be rotated by the worm in the hub.

An extension *p* is screwed onto the adaptor, thus providing a race for the outer bearing and a cone seat for the conical locking ring *q* which is tightened down by a retain-



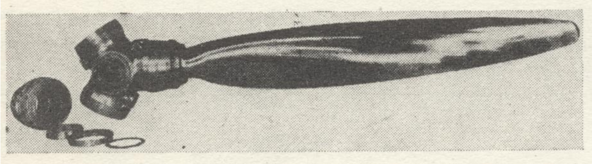
■ **Fig. 18 – VDM blade mounting**
a **Propeller shaft**
b **Flange to engine shaft**
c **Hub boss**
d **Blade socket**
f **Retaining nut**
g **Socket extension**
h **Outer journal bearings**
i **Thrust bearing**
k **Blade**
m **Screw threads**
n **Blade adaptor**
o **Worm wheel**
p **Adaptor extension**
q **Conical locking ring**
r **Inner journal ball bearing**
s **Adaptor flange**
t **Centering projection of adaptor flange**
u **Securing screws – flange to adaptor**
w **Blade journal – inner bearing**
x **Blade journal shell**



■ Fig. 19 – Thread form of VDM blade and adaptor

ing nut, effectively locking the blade from rotation within the adaptor. The adaptor extension is prevented from rotating relative to the adaptor by a castellated locking ring and circlip.

To establish a bottoming point for the blade, a flange *s* is centered by a projection *t* and secured to the adaptor by screws *u*. This flange then fits in the inner journal ball bearing *r*, which sits in the hub socket recess. The inner bearing blade journal *w*, an extension of the blade itself, is provided with a steel shell *x*, which is shrunk onto the soft dural, thus furnishing a strong and unyielding fit between the blade journal and adaptor flange.



■ Fig. 20 – One blade installed in hub and one blade mounting unit partially disassembled to show the conical locking ring, retaining nut, and felt seal

This blade mounting assembly is installed in the hub as a unit, considerable force being used to tighten it to the proper aligning marks. When correctly aligned, a locking plate secures against rotation.

If a blade is to be removed, the outer retaining nut is loosened, thus releasing pressure on the conical locking ring and allowing the blade to be unscrewed easily. On a right-hand rotation propeller the blade threads are right-hand so that the twisting moment of the blades tends to tighten and prevent unscrewing. A felt grease seal on the outside of the cone locking nut excludes foreign matter. Fig. 20 shows one blade in its mounting unit and in the hub, also a unit removed from the hub with the felt grease seal, locking cone retaining nut, and locking cone.

The condition of the units was generally good, with grinding marks visible on all bearing surfaces. However, the thrust bearing races and outer journal bearing races were brinelled somewhat. The reason for this was not apparent because several other VDM races have shown no such indications. Heavy grease similar to Mobilgrease No. 2 was found on the bearings in the lower part of the hub sockets with very little on the outer bearings. This seems odd in view of the nature of centrifugal force, but is not odd in view of the construction of the blade mounting unit, which prevents application of lubricant except when disassembled.

It is readily seen that the design of this blade mounting has admirable features, such as the wide spacing of the bearings which carry the bending loads and independence of the thrust bearings. Also, for easy handling, the unscrewing of the blade is a desirable feature.

On the other hand, the multiplicity of parts and manufacturing operations are not too desirable. The simplest and most easily handled type of blade mounting is the bearing stack arrangement wherein a stack of ball bearings carries both centrifugal and bending loads in combination. The Curtiss in the U. S. and Schwarz in Germany typify this method of construction.

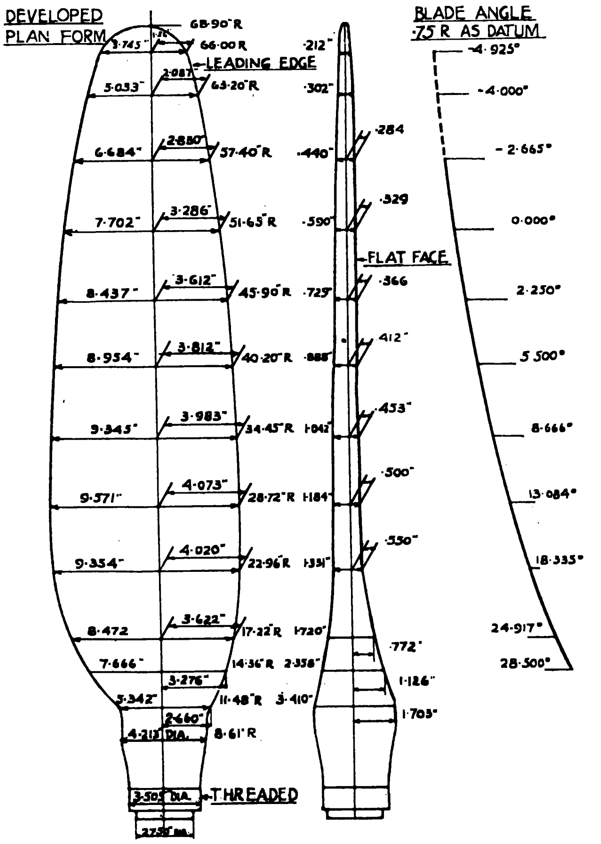
Apparently to avoid outstanding patents, the Germans developed their blade retention knowing that it was heavier and more complicated than foreign designs.

Blade – The blades are formed from duralumin forgings supplied by the Dürener Metallwerke A.-G. Tests of a Heinkel 111 blade have shown that the metal used conforms very closely to standard blade material.

Fig. 21 shows the plan form and angle distribution of the Heinkel 111 blade and illustrates how the airfoil section is carried down close to the hub. The method of screw thread blade retention was covered in the preceding discussion on blade mounting. The screw thread carries the centrifugal load, which is 33 tons at maximum rpm, while the bending load is carried by the locking cone at the outer portion of the hub socket and the inner journal.

The finish of the back of the blade was smooth while the face of the blade appeared as though it had been ground with about 120 grit. No anodic treatment was used – only a chromate primer covered with matt black paint.

Geometric properties of the airfoil cross-section are illus-



■ Fig. 21 – VDM Heinkel 111 blade – right-hand tractor trated in Fig. 22. Here it will be noted that the leading edge of the blade is sharper and tapers more gradually than comparable British or American designed blades. Very likely this airfoil is a type developed by the German Institute for Aeronautical Research. However, there is a great independence of thought and action amongst the German propeller builders, which leads them to adopt various developments only when it suits their previous designs. The single feature which the three principal German propellers have in common with one another is the worm drive from the pitch changing mechanism to the blades.

The estimated stresses in the blade root at take-off rpm are:

Maximum tensile stress due to bending = 1.19 tons per sq in.

Tensile stress due to centrifugal force = 2.37 tons per sq in.

Total maximum tensile stress = 3.56 tons per sq in.

Chemical composition of the blade alloy in per cent:

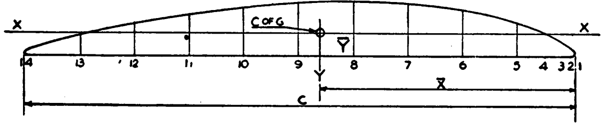
Copper	3.30
Iron	0.46
Silicon	0.43
Manganese	0.68
Magnesium	0.70
Titanium	0.02
Nickel	—
Chromium	—
Molybdenum	—
Aluminum	Remainder

The preceding blade data were obtained by Rotol Airscrews, Ltd., from a Heinkel 111 blade having a weight of 45.6 lb.

The Heinkel 115 blades, which were in the hub examined by Lockheed, have a different plan form and a weight of only 39 lb. Evidence of modification in service and our removal of metal in repair make this weight approximate.

Fig. 23 shows various propeller components and gives their Brinell hardness and tensile strength in tons per square inch.

Pitch-Change Gear Box – The annular gear box shown assembled and in relative position to the hub and shaft in Fig. 24 is mounted on the rear of the hub on an extension, also evident in the same figure. A set of splines prevents rotation and the three small setscrews apparent in the foreground secure the gear box axially. A small primary drive gear box is seen attached to the large annular gearing. This small box receives the flexible shaft drive from the motor and provides a reduction of motor speed for the driving of the large ring gear which starts the pitch change previously described. Also, the small gear box operates the pitch-limit controller and mechanical pitch indicator in the nonautomatic system.



ORDINATE NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
% OF CHORD	0	.0125	.025	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	1.0
% OF MAX. THICKNESS UPPER SURFACE	.135	.260	.332	.456	.635	.865	.974	1.00	.974	.890	.765	.590	.365	.070
% OF MAX THICKNESS LOWER SURFACE	.135	.041	.027	.013	0	0	0	0	0	0	0	0	0	.070

AREA = .72 C.T.M

YY = .0396 C³T.M

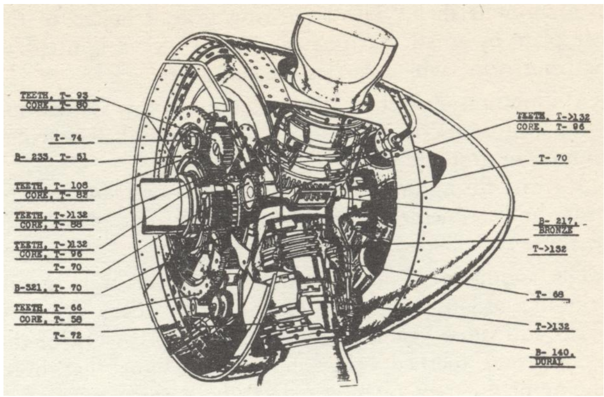
Ȳ = .415 T.M

IXX = .049 C.T.³M

X̄ = .464 C

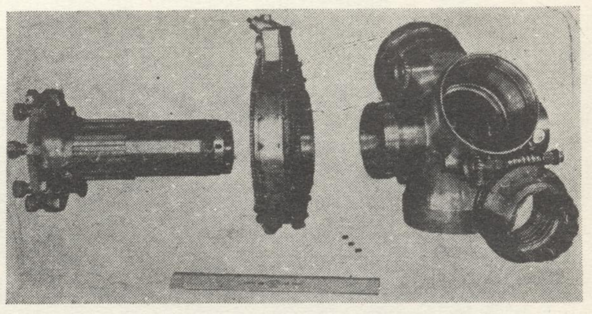
IXY = .0059 C.²T.²M

■ **Fig. 22 – Dimension and properties of VDM duralumin section taken at 0.75 radius**



Copyright, *The Aeroplane*

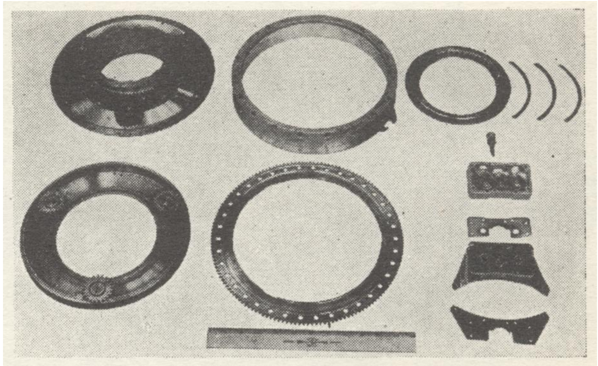
■ **Fig. 23 – Hardness and tensile strength of various propeller components**
***B* Brinell hardness**
***T* Tensile strength, tons per square inch**



■ **Fig. 24 – Stub shaft, gear box, and hub**

The primary drive gears are housed in a small aluminum-alloy gear box provided with ball bearings and mounted on the annular gear box by stamped aluminum brackets. A spring-loaded plunger impinging on a toothed wheel prevents rotation of the driving shaft from the motor, due to friction of the internal gearing attempting to rotate the large ring gear.

Fig. 25 is the layout of the gear box components. The front and rear plates are equipped with three planet gears



■ **Fig. 25 – Layout of annular gear box and primary drive gear box** mounted on ball-bearing pinion shafts and separated by an aluminum shell. The large ring gear is bolted to the rear plate by small machine screws. A sleeve is fitted to the front plate, which carries the sun gears.

A minimum of friction is experienced in this system due to the profuse use of roller, plain bronze, and ball bearings running in graphite grease.

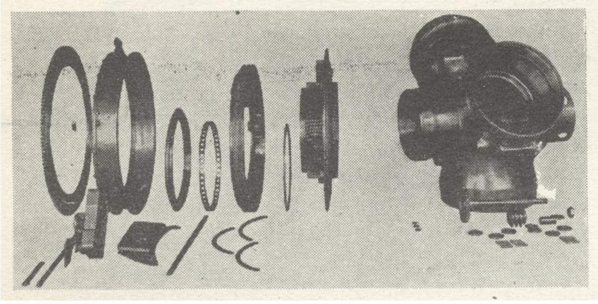
A grease fitting on the front plate allows replenishing of grease and a shielded perforation of the front plate vents the inner chamber to atmospheric pressure.

The condition of gears and bearings was very good. Grinding of all gears was of the first order; grinding marks still quite visible. The corrected tooth work of the middle, odd toothed, gear showed no signs that overlapping of different pitch gear teeth bore a penalty.

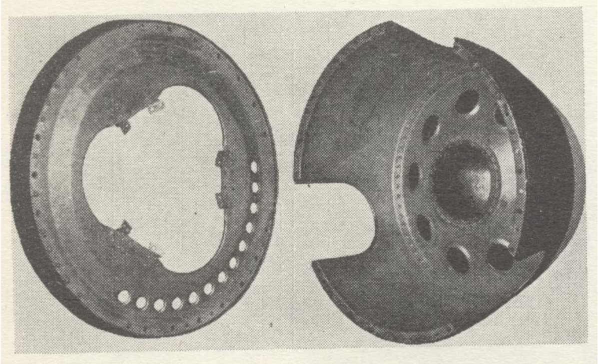
Fig. 26 is an exploded view of the entire pitch-change train. At the highest engine speed and rate of pitch change, the planet gears turn approximately 5900 + 400 rpm. The higher speed is encountered when the blades are turning to low pitch. Normally, the loads on the planets always act on the same side of the teeth and are very light when no pitch change is taking place. Under maximum conditions there is a tooth load of 165 lb at a velocity of 2800 fpm.

Spinner – The VDM spinner is one of the most unique features of the whole propeller assembly. It is composed of two major units; the diaphragm and the shell. These are shown in Fig. 27.

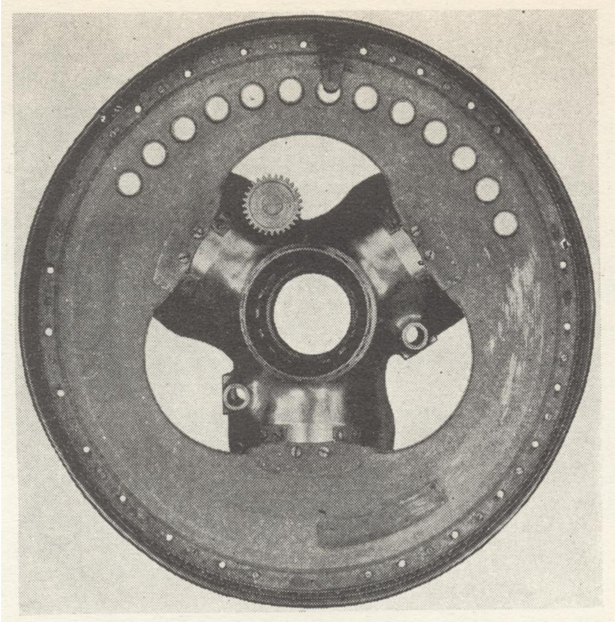
The diaphragm, a heavy gage dural stamping, is secured to the rear of the hub by brackets held to each hub socket by six capscrews. At the outer circumference of the diaphragm, a series of screws hold in place and allow limited rotation of a locking ring equipped with 21 keyhole slots designed to align exactly with 21 holes in the diaphragm when the locking ring is turned so that the round part of the keyhole slot is over the diaphragm hole. The locking ring securing screws provide small stud projections on the front face of the diaphragm between each hole. Fig. 28 indicates these features.



■ Fig. 26 – Exploded gear box in relative position to hub



■ Fig. 27 – Spinner diaphragm and shell



■ Fig. 28 – View showing method of spinner diaphragm attachment to hub

The spinner shell is formed of two pieces. The back half is flanged at its rear and recessed to accommodate the three blades. The center baffle is spun from the same piece of sheet dural which forms the back half. To this back half the domed front is flush riveted. A bakelite ring is secured to the center of the support baffle by a riveted channel ring.

The flange on the rear shell half has a series of holes punched in it which coincide with the stud projections of the diaphragm and 21 groove-necked studs which align with the locking ring holes.

When the shell of the spinner is aligned with the proper holes in the diaphragm and pushed into place, the groove-necked studs project through the locking ring holes in the diaphragm and the stud projections of the diaphragm project through the holes of the shell flange, while the bakelite ring in the shell baffle fits snugly over the shelf cut on the front of the hub.

Now a flat, forked key is inserted in a slot on the periphery of the diaphragm and moved in lever fashion so that the narrow part of the keyhole slot in the locking ring is rotated into engagement with the grooved neck of the shell studs; stud projections prevent any axial movement of the shell in relation to the diaphragm and the bakelite ring supports the shell in front.

This spinner is, of course, a rigidly attached type, but could easily be redesigned into a cushion-mounted type if the vibration characteristics of a particular installation dictated such action. VDM has built several types of armored spinners, but not in great quantity. It seems that the weight added is not commensurate with the safety obtained, particularly with the VDM wherein the pitch-change mechanism is at the rear of the hub.

Hydraulically operated propellers with frontally exposed mechanisms, such as Hamilton and Junkers, might possibly use armored spinners to advantage, although experience

concluded on page 392

phere. Since it is important that the intercooler should be mounted in such a position that the induction system is kept as short as possible, space limitations would probably mean that a sacrifice in intercooling efficiency would have to be made if direct aircooling of the charge was employed. This progressive development of the basic Merlin engine should do much to counteract any tendency to belittle the qualities of our military equipment and to exaggerate the good points of our adversaries' equipment.

Finally, I would like to say that the Merlin engine is the direct result of coordinated team work on the part of all sections of the Rolls-Royce company and to the wonderful energy, foresight, and understanding characteristics of E. Hives, the general works director. It is also due in a large measure to the great help and close cooperation given by the British Air Ministry.

I would also like to pay tribute to the Packard Motor Car Co., to George T. Christopher, its president, to Col. J. G. Vincent, and to the AAF for their wonderful work in connection with the Packard produced Merlin. Their labors have definitely contributed in effecting valuable improvements and I wish them every success in their continued efforts to satisfy the demands for still greater powers from the Merlin.

Particulars of the GERMAN VDM ELECTRIC PROPELLER

continued from page 358

has shown that very few projectile perforations of the pitch-change mechanisms occur. It would be easier to form the dome shell of the Hamilton hydromatic out of hardenable steel than enclose it in a heavy steel spinner possessing gyroscopic tendencies of a highly disagreeable nature.

No de-icing equipment was on the spinner examined and no locking key was furnished, a thin screwdriver worked easily.

■ Weights

	Weight of Assembly		Weight of Propeller	
Units	lb	oz	lb	oz
Hub	46	6	46	6
Blade Mounting	21	12	65	4
Blade	39	0	117	0
Gear Box	21	4	21	4
Spinner	8	6	8	6
Motor, Governor, Relay System	12	3	12	3
Total	....	....	270	7

Note: Missing installation parts would probably not weigh over 10-20 lb more. Total weight runs approximately 0.33 lb per horsepower.

■ Conclusion

The VDM propeller is versatile, well designed, and well constructed; however, it is not superior to comparable British and American units.

A pitch-change rate of 1 deg per sec is quite inadequate for a propeller installed on a high-performance aircraft. The Germans, realizing this, have installed a more rapid pitch-change mechanism on their latest model fitted to the Focke-Wulf 190 fighter. An inspection of the latest Focke-Wulf installation left the writer impressed by the ability of the VDM works to modify considerably their basic design when production is sorely needed.[2]

Service requirements are easily met in this propeller. A propeller bar, side cutters, hammer and drift, and a blade beam will enable a mechanic to remove the blades from the hub and the hub from the shaft. A screwdriver will suffice to make all adjustments to the motor and control system.

Lack of provision for adding grease to the blade bearings without disassembly is not such a good feature for a propeller whose makers claim 1000 hr of operation between major overhauls. Absence of any balancing means may indicate good manufacturing practices, but does not ensure the best of balance in subsequent overhaul without reducing weights of blades by filing.

Vibration characteristics of an early VDM propeller may be found in a paper by Karl Lürenbaum of the Deutschen Versuchsanstalt für Luftfahrt.[3] Here the VDM is referred to as the Hedder Copper Co. propeller and the HKW (Heddernheimer Kupferwerke) propeller.

The electric governor is greatly inferior to the finely built American governors which have been in use for almost ten years, with constant improvement. The relay is complicated and evidently not intended to be adjusted in the field. Pitch indicators are believed to be superfluous.

Production of the VDM must be in the high numbers because no part is particularly difficult to manufacture.[4] The great number of small parts are easily made, but are a nuisance for inspection and assembly. This was found in studying the propeller. Although magnaflux inspection of every steel part did not find a single bad indication, the process took three times as long as the same inspection of a Curtiss electric.

The VDM spinner is superior to American spinners, at least from the removal, installation standpoint. It is only a matter of seconds to remove or install the VDM, whereas American spinners take an infinitely longer time requiring wrench extensions and considerable effort on the part of the mechanic. Such mounting accomplishes nothing more in the way of support and loses a great deal in the matter of weight. That the VDM spinner has merit is demonstrated by the RAF's application of its principles to their own aircraft.

■ Acknowledgment

Sincere appreciation is extended to the British Air Ministry, the Enemy Aircraft Section of the Royal Aircraft Establishment, the Director of Scientific Research, and the propeller firms of Rotol and DeHavilland for supplying units and data for study.

The rest of the work was accomplished through the splendid cooperation of the engineering, photo, and propeller departments of Lockheed Overseas Corp.

---

[2] This change in design was necessary because of the addition of an engine-driven cooling fan to certain engine installations.

[3] See *SAE Journal*, Vol. 39, December, 1936, p. 475: "Vibration of Crankshaft-Propeller Systems," by Karl Lürenbaum.

[4] Since the preparation of this study on the VDM propeller, the VDM factory at Frankfurt, the whole industrial area of Hamburg, and the blade factory at Düren have been severely handled by bombers of the RAF and the Eighth Air Force. It is reasonable to suppose that production at these factories must be considerably disorganized or completely stopped.