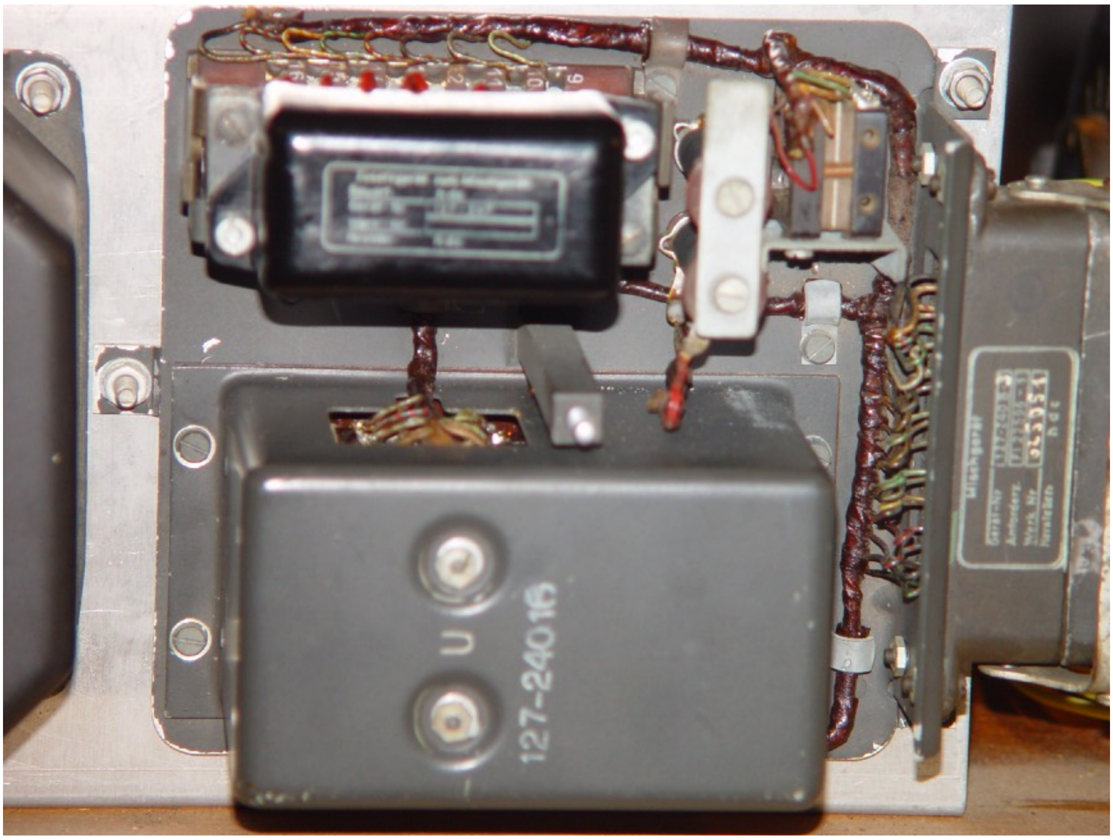
Siemens K12 Autopilot



Description of the K12 autopilot

Apart from the Patin master and daughter compass, the K12 autopilot consists of -

- a LKu 4 “Kurskreisel” directional gyroscope,
- a LKz 3 “Kurszieger” indicator,
- a Lrg 12 “Richtungsgeber” course adjustment switch,
- a LKMm “Kursmotor” course adjustment motor,
- a LMK 12 “Mischgerät” magnetic mixer unit
- a LRM 12 “Rudermaschine” servo unit,
- a LDK 1/1 “Dämpfungskreisel” damping gyroscope,
- a GDU 70/25 “Umformer” inverter,
- a LSch 4ü “Hauptschalter” main switch,
- a “Stützschalter” compass coupling switch,
- a “Wiederstandskasten” resistor box,
- a “Notauslöseknopf” emergency release knob (omitted in later installations).

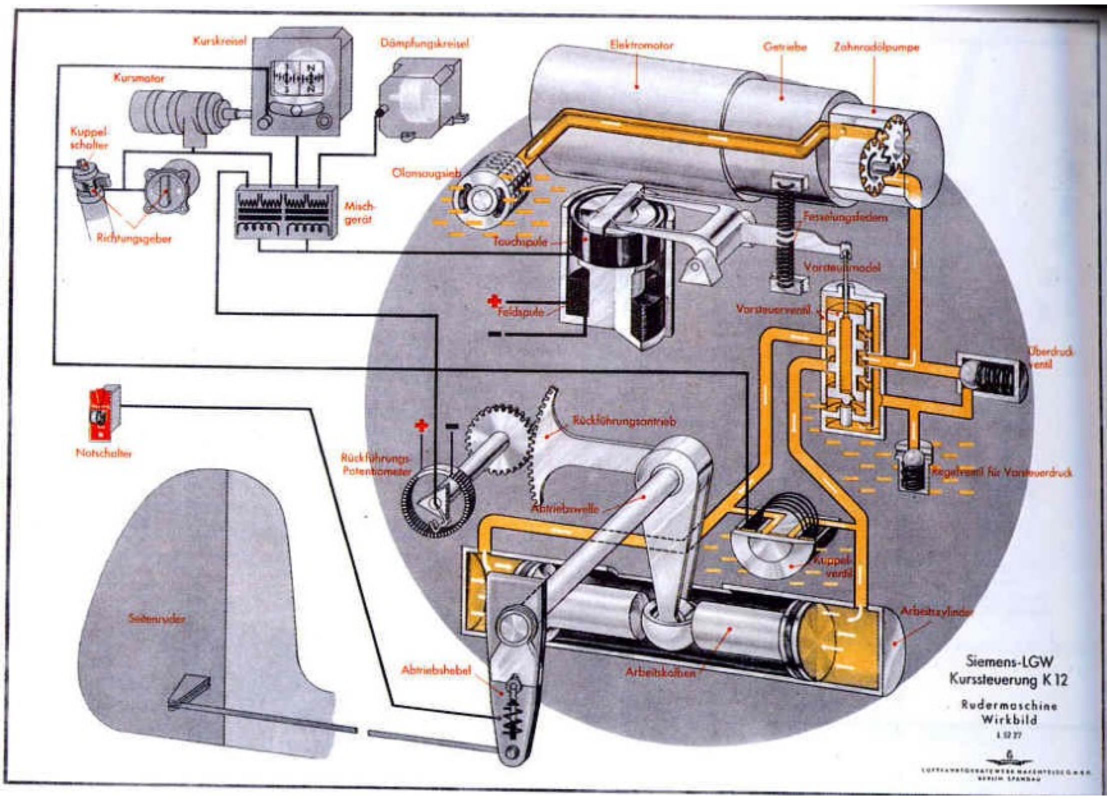


Figure 1: Overview of the K12 autopilot

Like with the K4ü, the K12 could be supplied with a variety in the configuration of the control switches, so that the system could be tailored to different types of aircraft.

The Lrg 12 “Richtungsgeber is slightly different to the Lrg 9 used with the K4ü. An on-off “Kopplungsschalter” switch was added to the top of the “Richtungsgeber”. This switch was placed in series with the “Hauptschalter” and the left knob of the “Kurskreisel” and controlled a magnetic valve in the

“Rudermaschine”. The “Rudermaschine” could now be engaged or disengaged with the “Koppelschalter” switch on the Lrg 12 placed on the control column.

In fact the LSch 4ü “Hauptschalter” was no longer required, but was retained purely to keep the operational interfaces of the K12 identical to those of the K4ü, so that flight crew did not have to be re-trained.

The Functioning of the K12 autopilot

The principles of the autopilot

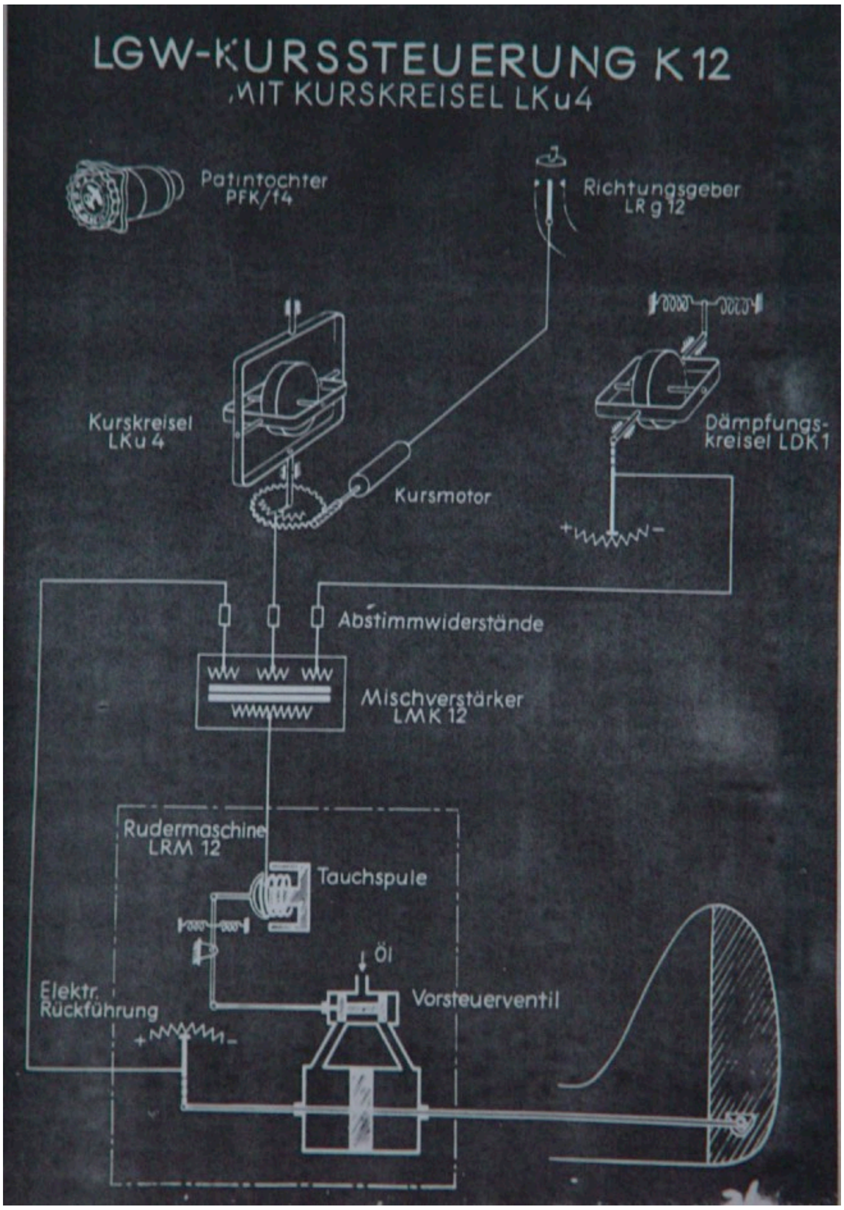


Figure 2: Principal schematic of the K12 autopilot

The operating principals of the K12 autopilot are identical to those of the K4ü autopilot. A key difference is how the various input and feedback signals are processed.

In the K4ü system the electrical signals from the “Kurskreisel” and “Richtungsgeber” were converted to a mechanical movement by using an electromagnet. This signal, and the signal from the damping gyroscope and the feedback signal from the output lever were mechanically added by a system of rods and levers to produce the input signal to the hydraulic control valve.

In the K12 system, the various components providing signals and feedback were all separate units using electrical DC signals. To process these various electric signals a new solution had to be found. The German Luftwaffe deemed amplification by radio valves as far too unreliable to be used in a critical system like the autopilot so an alternative method of electronic addition and amplification of DC signals was required.

The solution that Siemens chose was the magnetic amplifier, at the time quite a revolutionary technology. Magnetic transformers are well known for voltage conversion of AC voltages, however they cannot normally be used to transform DC voltages (and the signals used in autopilots are quasi DC signals). It was however discovered that the transformation characteristics of a transformer can be altered by saturating the magnetic field it’s core. If a DC voltage is used to control the saturation of the core, the transformation of an AC voltage applied to the same core will change. By developing special core materials, special transformers could be constructed where the transformation characteristics could be controlled and varied over a sufficiently large range by the DC input voltage. By rectifying the resulting output AC voltage a linear amplification of the DC input voltage to a DC output voltage could be achieved. By applying several DC input windings to the core, several DC input signals could be added to generate a single DC output.

The resulting “Mischgerät” is a compact and completely solid state DC mixing and amplifier unit. Because it has no moving parts or radio valves, it was a very reliable technology, not equalled until the introduction of modern solid state electronics.

The following sections only deal with the differences to the K4ü components. For an explanation of the common components, see the equivalent sections in the K4ü chapter.

The “Kurskreisel” or “Kurszentrale”

The K12 autopilot used the same combination of Patin PFK/f2 “Führertochterkompass”, LKu 4 “Kurskreisel” with LKz 3 “Kurszeiger” and LKMm “Kursmotor” to adjust and generate the course set-point for the autopilot.

Instead of the LKu 4 “Kurskreisel, the K12 could also be fitted with the Patin PKZ 14 “Kurszentrale”. The “Kurszentrale” is a directional gyroscope unit with automatic synchronisation facilities which can be fitted anywhere in the aircraft. When the “Kurszentrale” is used, there is not longer the need to fit the

“Kurskreisel” and “Kurszeiger” to the instrument panel. Only a Patin PKT/f2 or PKT/f4 instrument will be required for course indication. The Patin Kurszentrales will be discussed in a separate chapter.

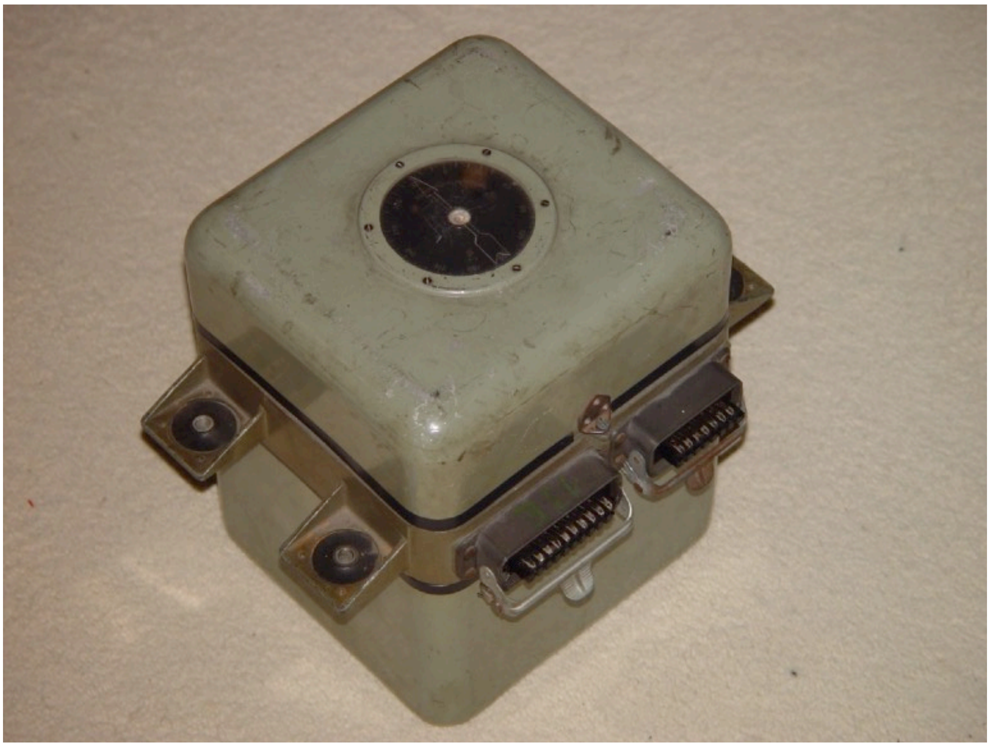


Figure 3: Patin PKZ 14 "Kurszentrale"

The “Richtungsgeber”

The K12 autopilot uses a Lrg 12 “Richtungsgeber” mounted on the control column of the pilot. This course adjustment switch has a neutral position in the centre and two positions marked “L” for left and two positions marked “R” for right. Turning the switch to the first position causes the “Kursmotor” to turn at a course adjustment rate of 1 degree per second, turning the switch further to the second position doubles this rate to 2 degrees per second. The switch locks into the second positions (Left or Right).

A “Koppelschalter” switch is mounted on top of the “Richtungsgeber”. This allows the pilot to engage or disengage the “Rudermaschine” by flicking the switch with his thumb. There is no longer a need to take the hand off the control column to operate the autopilot with the “Hauptschalter”.

Figure 4: Lrg 12 "Richtungsgeber"

The “Wiederstandskasten”

Initially the existing LKW 1/4ü and LKW 3 “Wiederstandskasten from the K4ü were used. For later K12 autopilot installations, an improved “Wiederstandskasten” was developed. In the new unit, the resistors originally housed in separate boxes were combined into a single unit. The new “Wiederstandskasten” also contains two relays. One relay is used to lower the 36V 500Hz AC feed to the “Mischgerät” when the “Koppelschalter” is switched off. The other relay switches a resistor parallel to the “Kursmotor” once it is running, which essentially sharpens up the response of the autopilot to the “Richtungsgeber”.

Figure 5: Late type K12 "Wiederstandskasten"

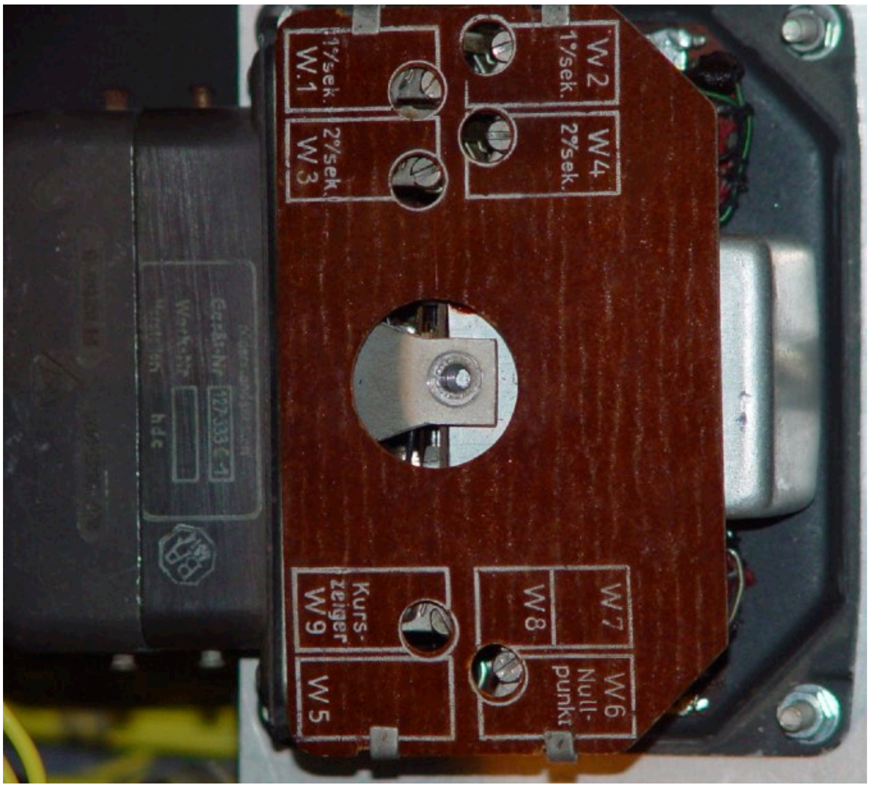


Figure 5: "Wiederstandskasten" with the cover remove. The functions of the adjustable resistors are clearly marked.

The "Dämpfungskreisel"

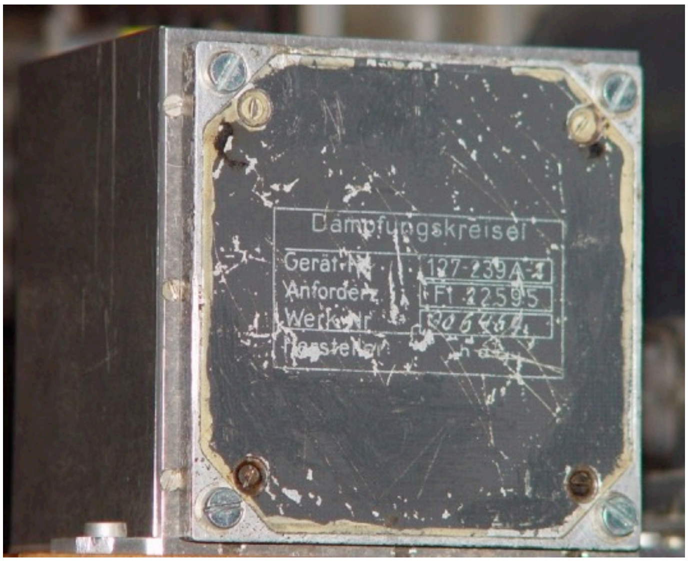


Figure 6: Reverse of the LDK 1 "Dämpfungskreisel" showing typical markings

The LDK 1 "Dämpfungskreisel" measures the rate of turn of the aircraft about the yaw axis by means of a spring-retained gyroscope. A new form of ball gyroscope is used, whose precessional torque, proportional to the rate of turn, is balanced by the restraining spring. The resulting movement is transfered by a potentiometer to an electrical control value. Instead of the pneumatic cylinder used in the K4ü, the LDK 1 incorporates an eddy current damping brake. The voltage supplied to the windings of this brake is proportionate to the deflection of the gyroscope, so that the braking effect increases with deflection of the gyroscope.

The LDK 1 “Dämpfungskreisel” is now a small, self-contained unit, that can be placed anywhere in the aircraft. It was designed to be plugged into a special base, so that the unit could be quickly replaced during servicing of the aircraft.

Figure 7: LDK 1 "Deampfungskreisel"

The “Mischgerät”

The LMK 12 “Mischgerät” is the heart of the K12 autopilot. As already described, the “Mischgerät” contains a magnetic amplifier. In fact, the magnetic transformer is duplicated as part of a balanced circuit, so that the output signal can be made independent from the external magnetic influences such as the earth’s magnetic field.

Figure 8: the LMK 12 " Mischgerät "

To ensure that the transformation characteristics of the transformers remain constant, a temperature control is built into the unit. A heating winding coupled to a bimetal switch keep the transformers in a set temperature range.

Four DC input circuits are divided over the two coupled magnetic transformers, the signal from the “Kurskreisel”, the “Dämpfungskreisel”, the feedback from the “Rudermaschine” and the “Vorgabe”signal from the “Richtungsgeber.

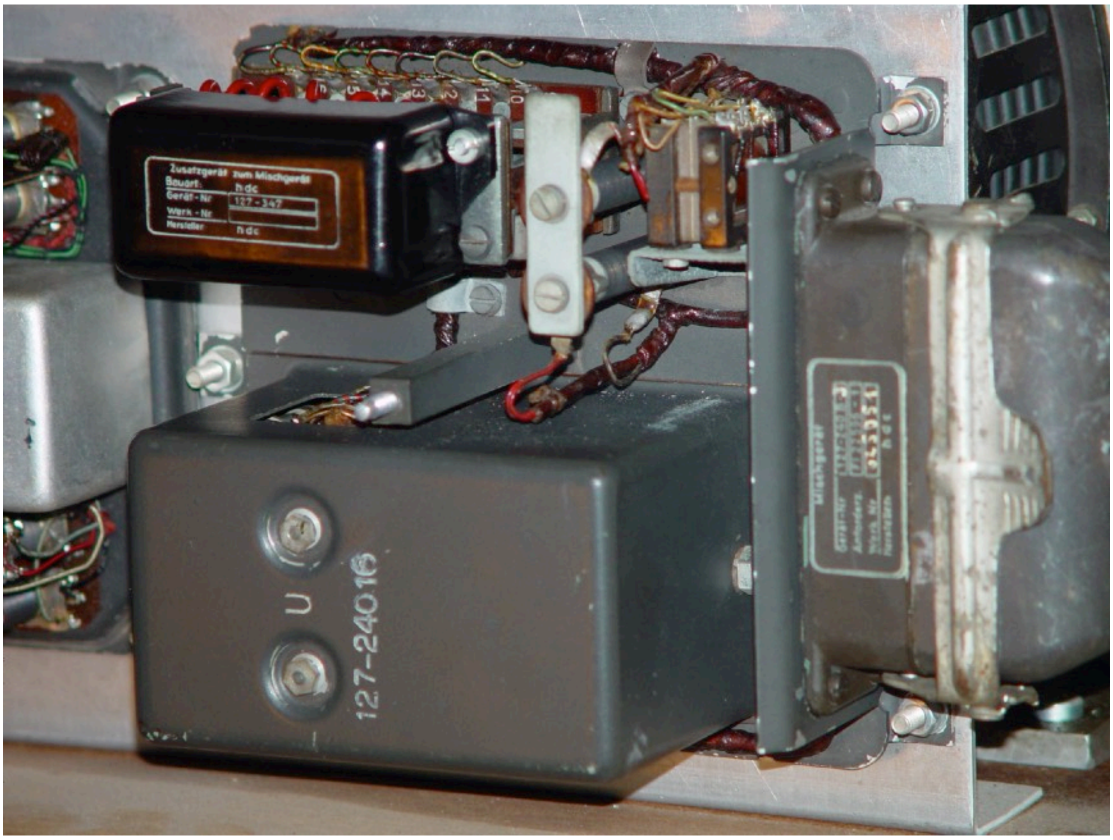


Figure 9: The LMK 12 " Mischgerät". The actual magnetic transformers are contained in the seperate unit marked 127-24016. Also note the black plug in unit with the resistors.

The AC voltage used by the “Mischgerät” is 500Hz supplied by the “Drehtromumformer”, reduced from the original 36V by a voltage divider.

The strength of each input signal can be adjusted with series resistors contained on a plug-in unit. For a particular aircraft type, the balance of input signals would be unique and a plug-in unit with that aircraft type’s specific resistor values would be inserted into the “Mischgerät”.

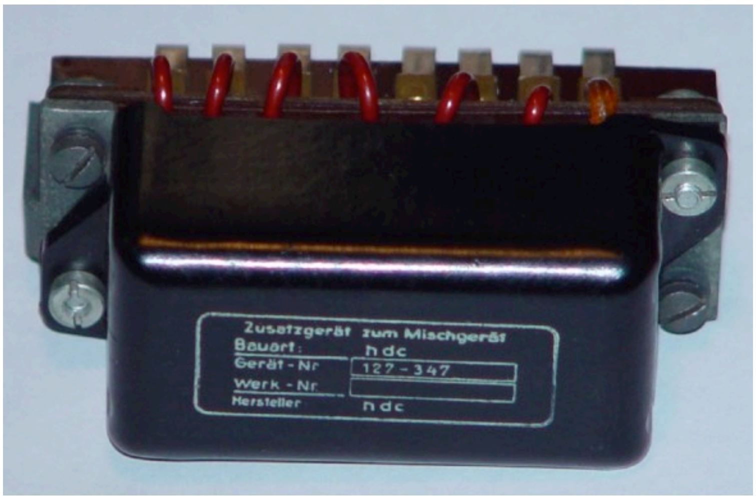


Figure 10: the "Zusatzgeraet" plug in unit containing the signal strenght resistors. Each aircraft type would have a specific set of resistors inserted.

The “Mischgereat” is a light and compact unit, that can be built anywhere in the aircraft.

The “Drehstromumformer”

Because the motor on the “Rudermaschine” no longer acts as a generator, a separate 500 Hz, 36V three phase generator is required to power the gyroscopes and provide the AC voltage to the “Mischgerät”. A GDU 70/25 – 70/23k “Drehstromumformer” or similar type is used.

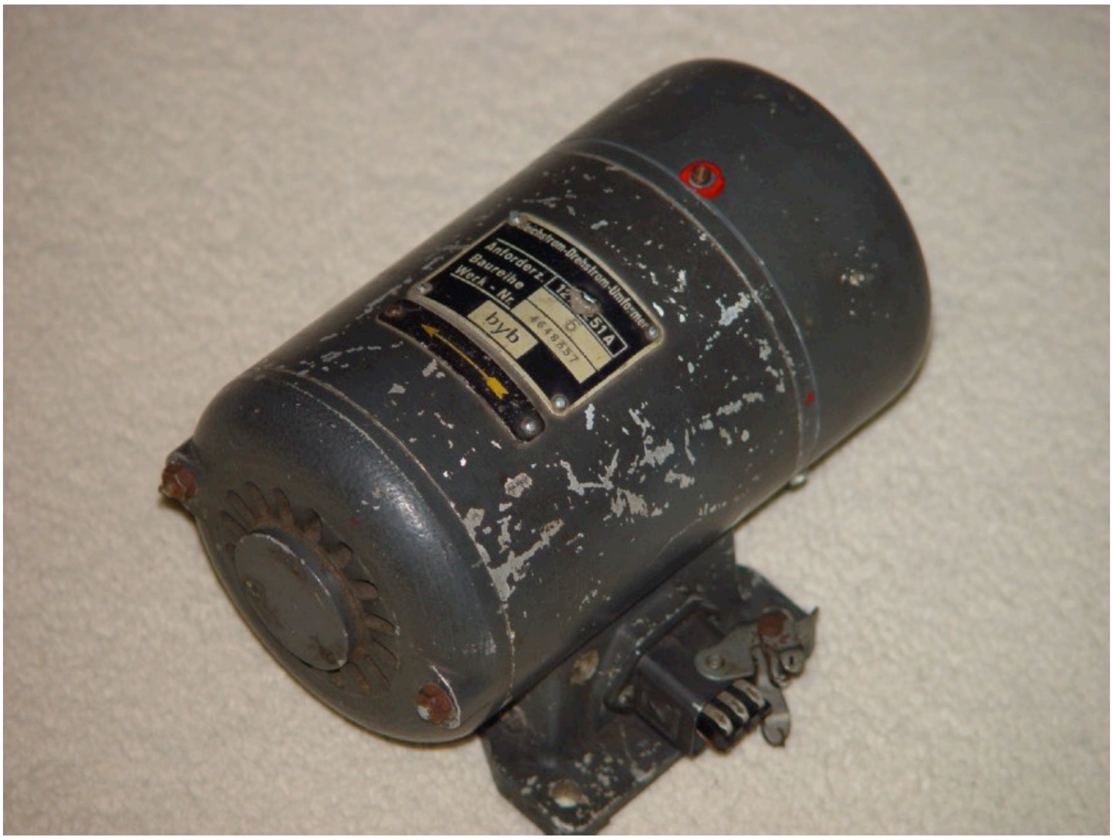


Figure 11: A slightly heavier type of GDU "Drehstromumformer"

The “Rudermaschine”

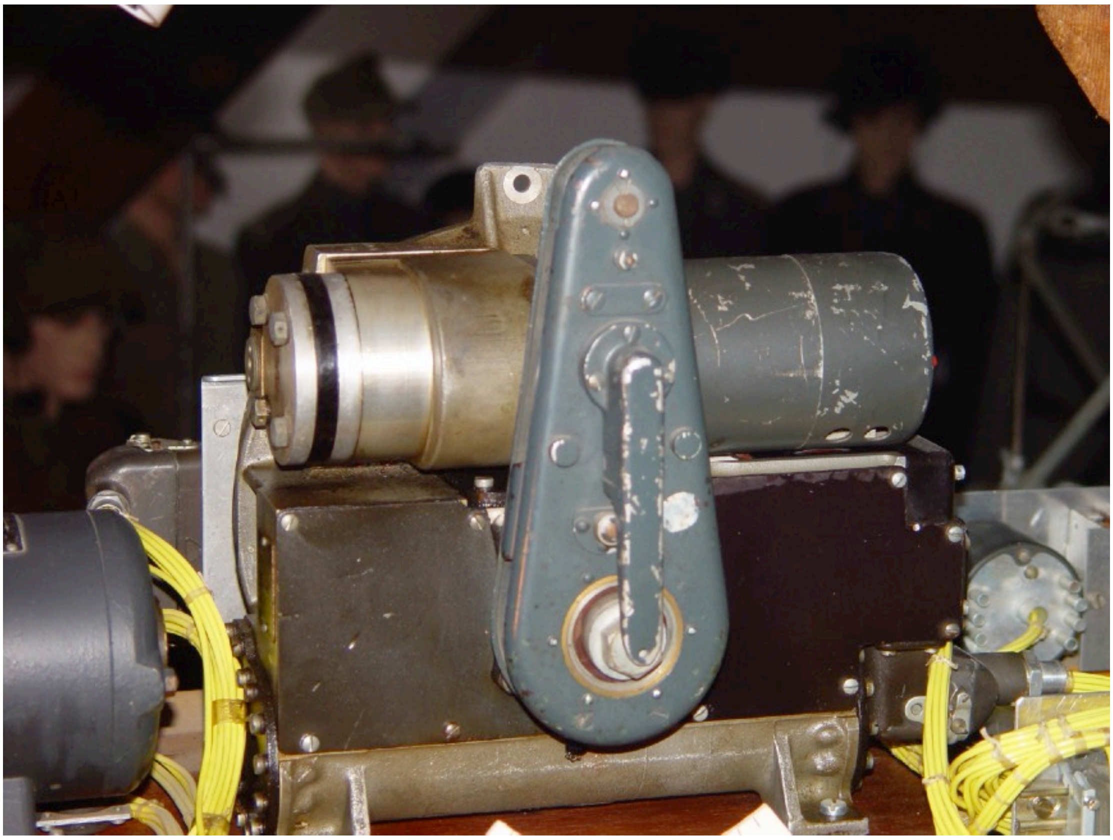


Figure 12: The LRM 12"Rudermaschine". Note the output lever normally connected to the rudder.

The LRM 12 “Rudermaschine” servo unit translates the electrical output signal of the “Mischgerät” into a force to operate the rudder. Like in the LRM 4ü “Rudermaschine” the LRM 12 is an electro-hydraulic unit. An electric motor drives and oil pump which supplies oil pressure to the two sides of a piston dependent on the position of a control valve. The oil system is hermetically sealed and one side of the “Rudermaschine” acts as a spring compartment to deal with the expansion of the oil due temperature differences. The duplicate electrical signal from the “Mischgerät” is fed to two coils of an electromagnet, called the “Tauchspule”, when the balance between these two windings is disturbed, the “Tauschspule” will move up or down, actuating the hydraulic control valve via a lever.

Due to a redesigned hydraulic circuit, the hydraulic pump in the LRM 12 no longer has to operate against full working pressure when the control valve is in the neutral position. This reduces the power requirements when the “Rudermaschine” operates around the neutral position considerably.

A fail-safe “Koppelventil” coupling valve between the cylinders on opposite sides of the piston is only closed when electrically energised. By switching off the “Koppelschalter” on the Lrg 12, or pushing in the left knob on the “Kurskreisel” or by switching the “Hauptschalter” to the “1” position, the electrical current to the coupling valve is broken and the autopilot is disengaged. Should there be an electrical power failure, this will also automatically disengage the autopilot.

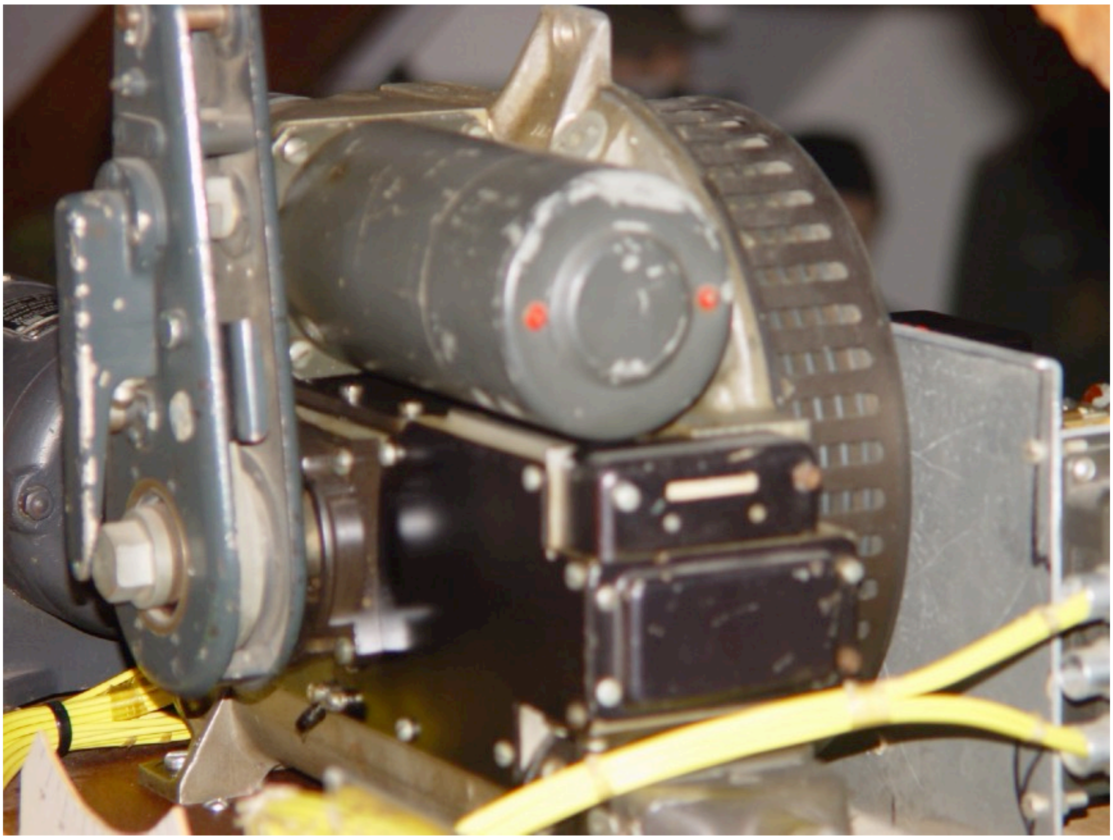


Figure 13: The front side of the LRM 12 “Rudermaschine”. Note the electrical motor placed on top to drive the oil pump. The baffled oil reservoir can be seen on the right side of the machine.

Since the LRM 12 “Rudermaschine” no longer contains the “Dämpfungskreisel”, it no longer has to be mounted as rigidly as the LRM 4ü. It can be placed anywhere in the aircraft, as long as the mounting is strong enough to deal with the torque of the rudder controls.

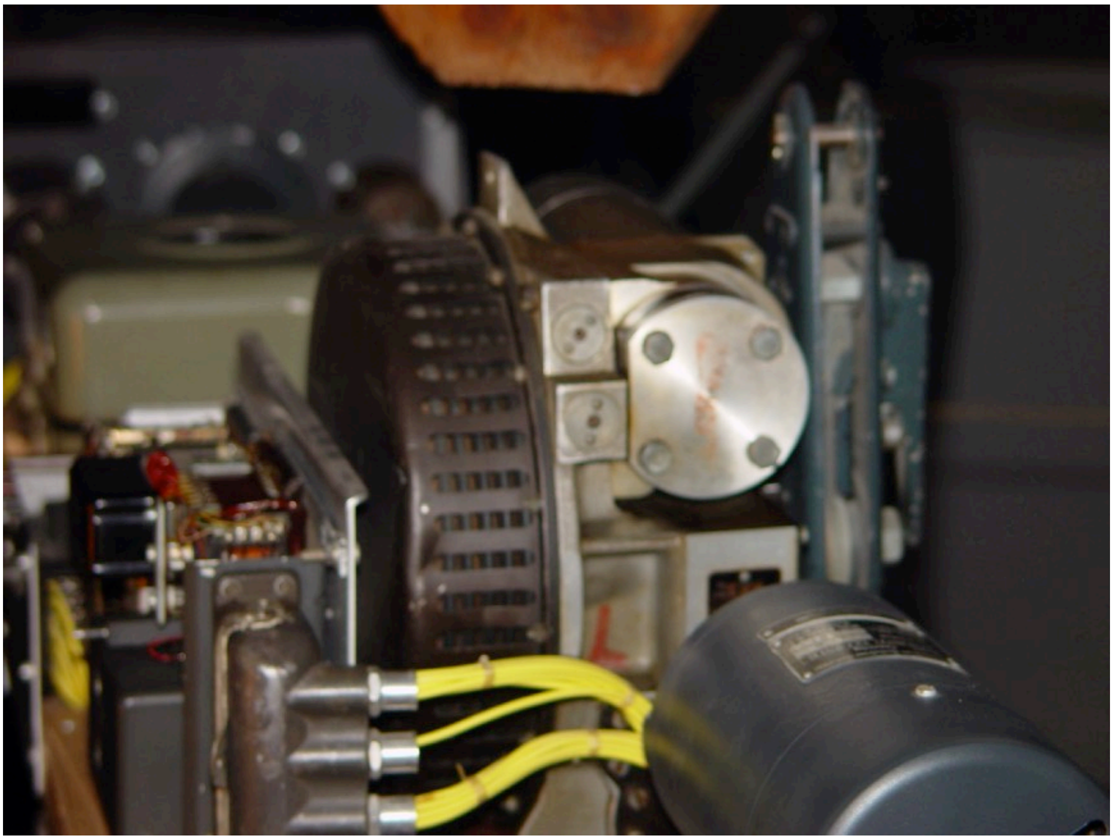


Figure 14: Reverse side of the "Rudermaschine". Note the baffled oil reservoir on the left. The blank metal cover contains the oil pump.

The “Hauptschalter”

Although not required the LSch 4ü “Hauptschalter” main switch was retained for compatibility reasons. Although the descriptions of the autopilot state that only the “Umformer” runs up at the “1” position with the “Rudermaschine” only starting in the “2” position, the schematics show the “Rudermaschine” also running up at the “1” position with the “2” position only serving to energise the “Koppelschalter”. The functionality evident in the early schematics fully mimics the functionality of the K4ü autopilot, while the separately switched “Rudermaschine” makes more operational sense. Probably both functionalities of the “Hauptschalter” could be encountered.

Operating the K12 autopilot

During flight preparation, check that the left control knob of the “Kurskreisel” is pushed in, that the “Hauptschalter” is set to “0” and that the “Koppelschalter” on the controlcolumn is switch to “aus”. Check that the rudder moves freely. Check that the “Richtungsgeber” on the control column is in the central position and that the “Stützschalter” (typically placed near the bomb aimer’s position) is switched to the “on” position. Check that the emergency release pull knob is secured in place. Check that the rudder is placed in the central position.

Switch on the electrical supply to the autopilot and the Patin compass system and switch the “Hauptschalter” to “1”. If the Patin compass is not yet aligned, use the “Richtungsgeber” on the control column to turn the compass to the 12 o’ clock position. Once the Patin compass is aligned, align the top and bottom scales of the “Kurskreisel by turning the left control knob. Check that the “Kurszeiger” functions correctly by moving the left bottom knob slightly left and right. When the two scales of the “Kurskreisel” correspondent, the “Kurszeiger” should be in the central position.

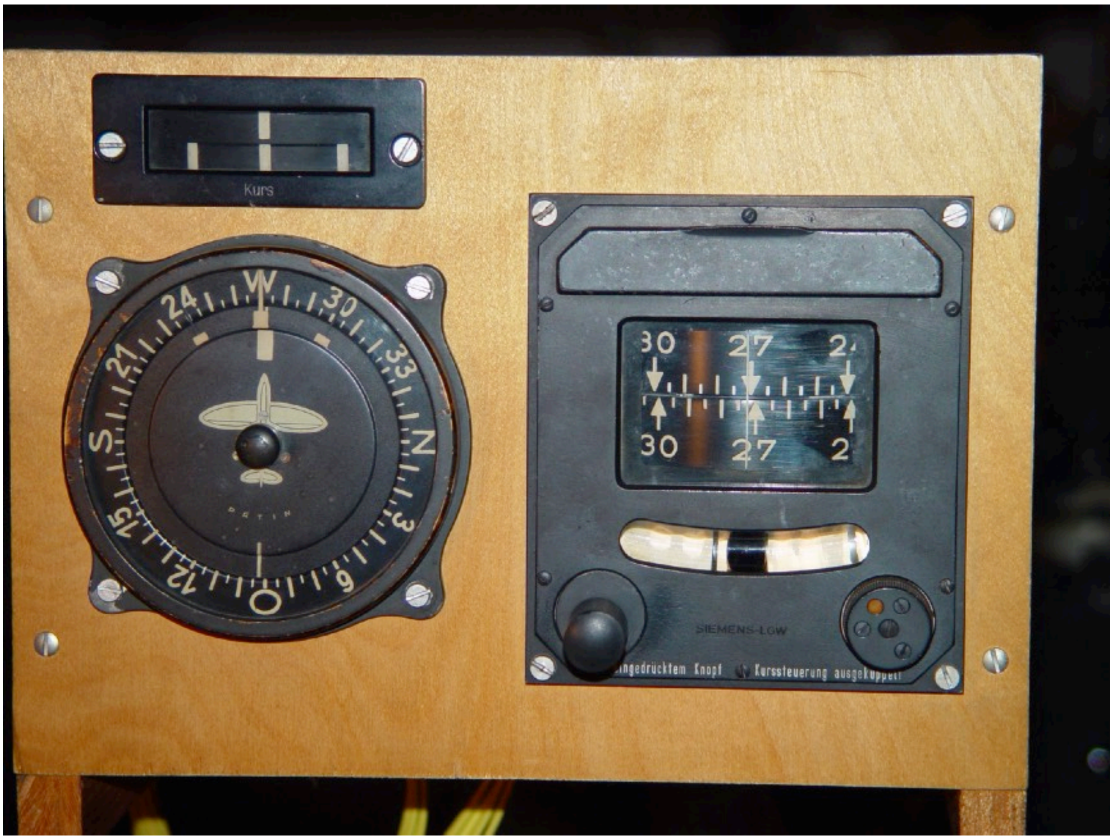


Figure 15: All the instruments are aligned on a course setting due West. The rudder should stay central.

After about two minutes, pull out the left control knob of the “Kurskreisel. The two scales of the “Kurskreisel” should stay synchronised and the “Kurszeiger” should remain centered.

Switch the “Hauptschalter” to “2”. At this stage the rudder should still move freely. Switch the “Koppelschalter” on the control column to the “ein” position. The rudder should now be fixed in the central position. Check that by applying maximum force to the rudder pedal, the rudder can be moved. When force is released, the rudder should return to the central position.

By moving the “Richtungsgeber” on the control column left, the rudder should move left and vice versa. Return the rudder to the central position with the “Richtungsgeber” and switch the “Koppelschalter” back to position “aus”. Check that the rudder can freely be moved.

The autopilot is now checked and ready to be engaged.

As a last preparation for the flight, use the “Richtungsgeber” to set the heading for the first leg of the flight.

After taxying and take off, the pilot turns the plane towards the desired heading. Once on the heading, switch on the autopilot by switching the “Koppelschalter” on the control column to position “ein”. The airplane now automatically holds its course. The pilot only has the control the pitch and roll of the aircraft.

Changes to the direction can be made by moving the “Richtungsgeber” to the left or right. For larger course changes, the “Richtungsgeber” can be locked in the 2 degree per second position. The pilot needs to control the roll of the aircraft during the turn by keeping the slip indicator in the “Kurskreisel” centered.

During a bomb run, the control can be taken by the bomb aimer. By moving a slide switch on the “Richtungsgeber” placed near the bomb sight, the autopilot will be controlled by the bomb aimer. An indicator will alert the pilot that the control has been taken by the bomb aimer. In emergencies the pilot’s “Richtunggeber” can overrule the bomb aimer’s control. As long as the pilot’s “Richtungsgeber” is kept in the neutral position, the bomb aimer has control over the course of the aircraft. To avoid unexpected adjustments by the Patin magnetic compass, the “Stützschalter” is switched to the “off” position by the bomb airmer. The course set point is now purely controlled by the gyroscope in the “Kurskreisel” and has no link to the magnetic Patin compass.

The bomb aimer, while peering through the bombsight, can now adjust the aircraft’s course by moving his “Richtungsgeber” left or right. Very small and accurate adjustments can be made.

When the bomb run is complete, the bomb aimer switches the “Stützschalter” back to the “on” position and moves the slider on his “Richtungsgeber” back to the “off” position to give control back to the pilot.

If a malfunction occurs the pilot can disengage the autopilot by moving the “Koppelschalter” on the control column back to the “aus” position. Pushing in the left control knob on the “Kurskreisel” or switching the “Hauptschalter” to the “1” position should also have this effect. If the rudder is still not moving freely, there is likely to be damage to the steering mechanism unrelated to the autopilot.

After the flight, push in the left control knob of the “Kurskreisel” and place the “Hauptschalter” in the “0” position. Report any problems encountered during the flight to ground staff.

The K12 demonstration rig

In order to demonstrate the K12 autopilot, the components need to be mounted on a turntable that can mimic the movements of the aircraft.

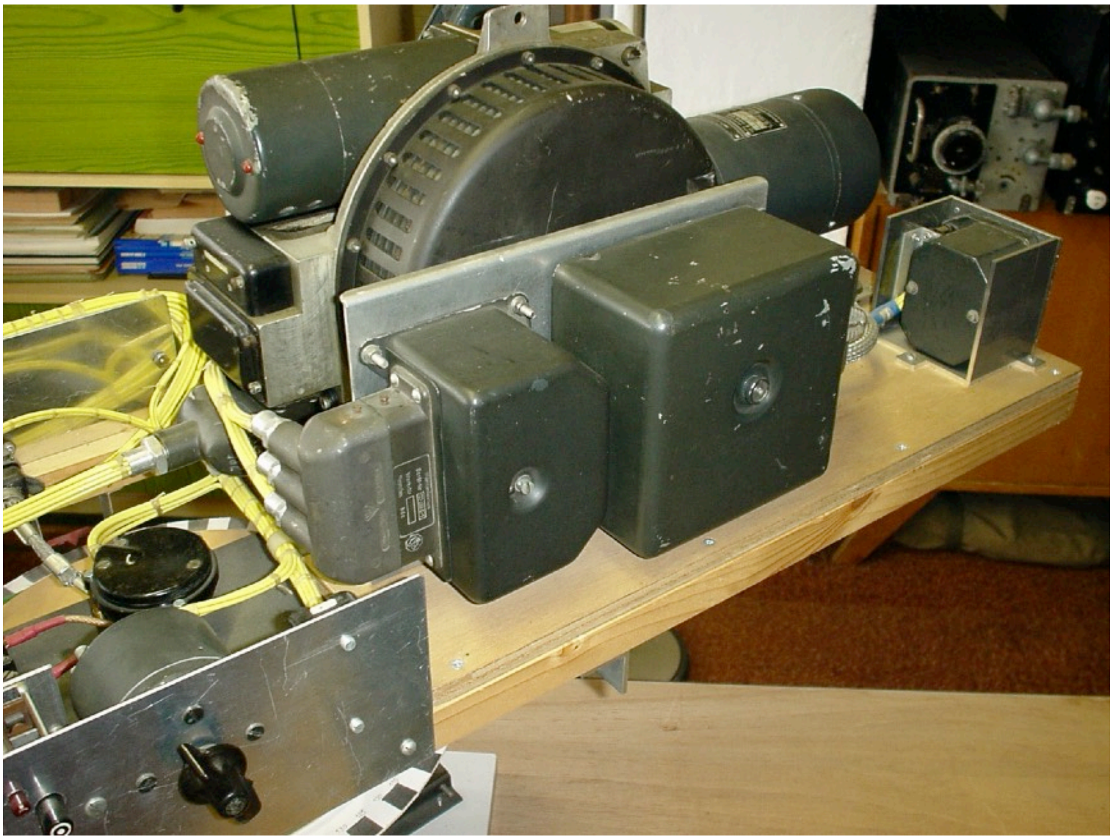


Figure 16: Overview of the K12 autopilot components mounted on the frame. In front the "Wiederstandskasten" and "Mischgerät" with the "Deampfungskreisel" on the far right. In the back the "Rudermaschine and "Umformer".

The components of the K12 autopilot are significantly lighter so that no large counterweights are required when the components are adequately distributed across the turntable. With the instrument cluster on one end, and the “Rudermachine” the other components can be placed to balance the weight.

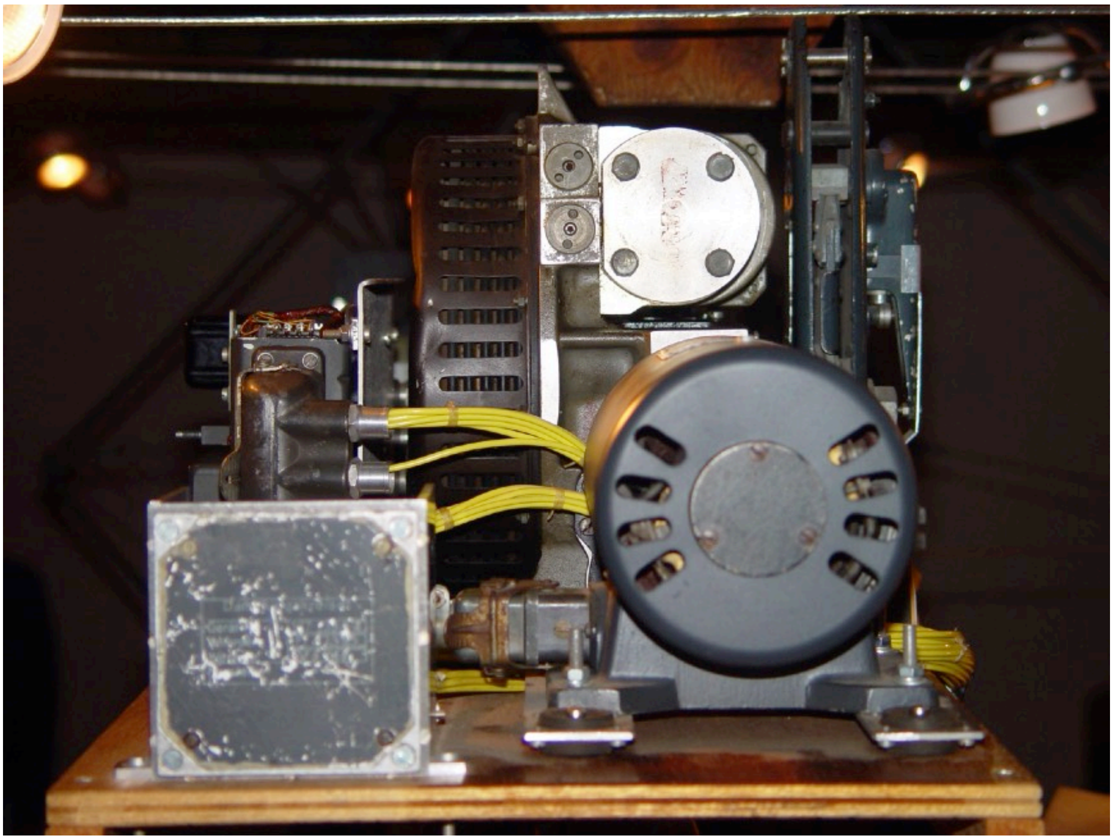


Figure 17: Backside of the rig. Note the "Deampfungskreisel on the left and the "Umformer" to the right. The "Rudermaschine" can be seen behind the "Umformer".

The principal construction and the drive mechanism for the turntable are identical to the one used on the K4ü, for a description see the equivalent section in the K4ü chapter.

Because the LRM 12 “Rudermaschine” includes a feedback resistor, a separate resistor and mechanism connected to the output lever is not required. The feedback resistor of the “Rudermaschine” can be used to provide the input signal for the electronic drive unit used for turning the rig.

As with the K4ü the instruments are placed on a headboard on the far end of the rig, with the electrical controls to the right side and the cable termination block to the left.

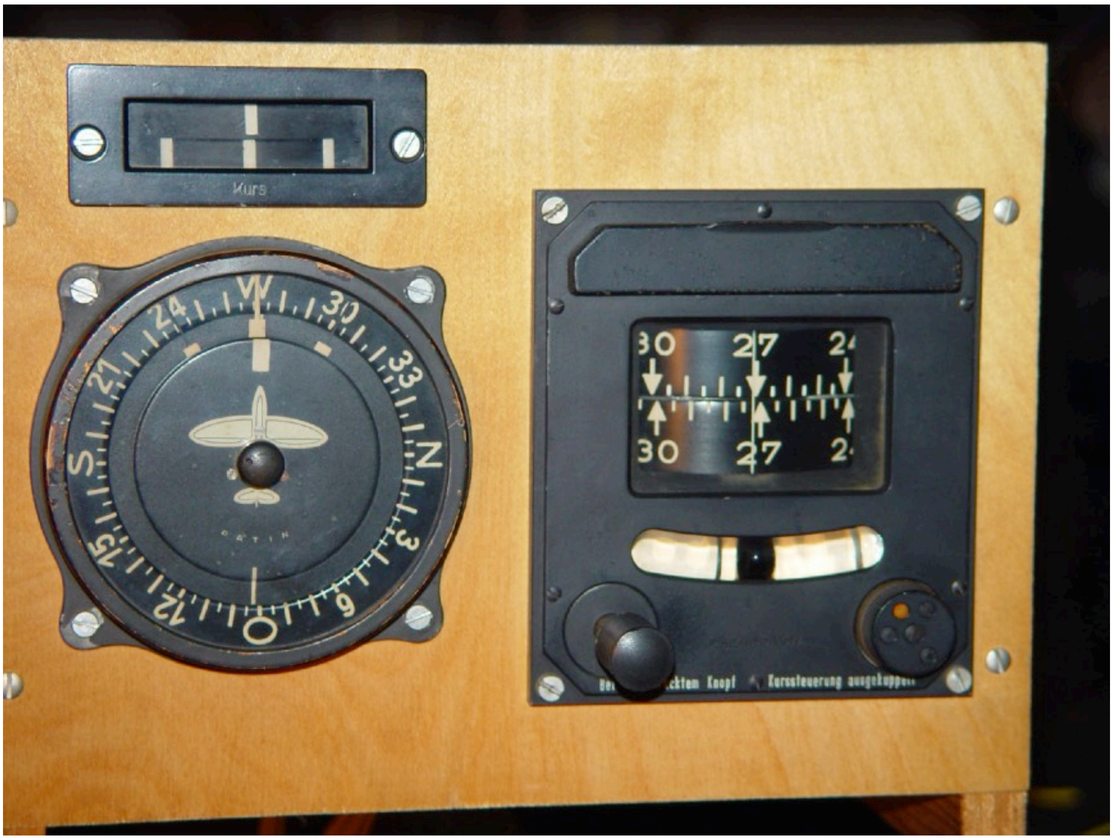


Figure 18: The standard autopilot instrument cluster placed on the far end of the rig.

In order to calibrate the autopilot, the large drive wheel attached to the base of the rig and the output lever of the “Rudermaschine” have been fitted with gradations.

Again late war style cabling using individual yellow wires has been used in the rig which have been terminated as per original specifications. a thin multicore cables run from the termination block though the headtube to connect to the Lrg 12 “Richtungsgeber”.

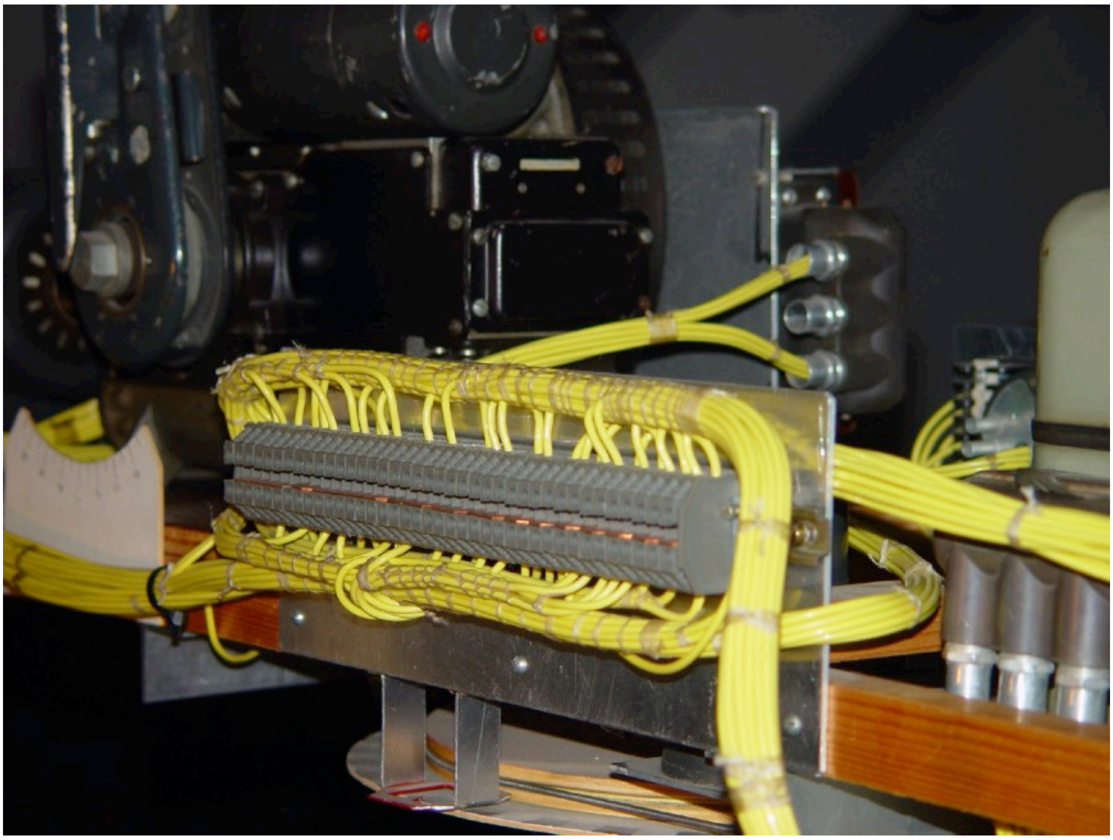


Figure 19: Cable termination block placed on the left side of the demonstration rig using typical late war yellow cabling.

Operating the demonstration rig

The rig can be operated as described in the “Operating the K12 autopilot” section. As the “Hauptschalter” is moved to the “1” position, the “Umformer” first starts up and the gyroscopes can just be heard running up.

During the running up, the set course can be selected by engaging the Lrg 12 “Richtungsgeber” and the “Kurskreisel” synchronised with the left knob. After the synchronisation is complete, the left knob is pulled out.

The “Hauptschalter” is now moved to positon “2” causing the “Rudermaschine” to start. Like the LRM 4ü, the LRM 12 is quite noisy. With the “Koppelschalter” still in the “aus” position, the output lever can be moved freely by hand. The autopilot is now ready for operation.

By flicking the “Koppelschalter” on the “Richtungsgeber, the “Rudermaschine is engaged. It is immediately noticeable that the K12 is a much faster system, and the output lever is constantly making smaller and faster adjustments. As the rig is pushed out of alignment, the lever immediately responds and the movement is arrested and the rig is brought back in alignment.

The K12 demonstration rig is not as critically damped as the K4ü demonstration rig; if a large disturbance is made, it takes several swings to get the rig back on the set course with the output lever of the "Rudermaschine" running out to it's maximum range. Running the autopilot before the gyroscopes are properly run up reveals and oscillation with a period of about once ever 1.5 seconds.

The non-criticality of the system is in part due to the relative lightness and lower intertia of the rig but it mainly because the adjustment resistors in "Mischgerät" are still the original ones as used in the aircraft that it was taken from and have not been specifically tuned to the demonstration rig.

When the "Richtungsgeber" is engaged, the rig starts turning at the selected turn speed. The autopilot is constantly working and manages to keep rate of turn constant with the output lever making constant small adjustments.

By switching the "Koppelschalter" on the Lrg 12 to the "aus" position, the output lever of the "Rudermaschine" is immediately released and remains in a static position. Because the electronic drive unit is still getting a turn signal the rig will keep rotating until the lever is returned to the central position by hand.

After switching off the autopilot by turning the "Hauptschalter" back to the "1" position, the rudermaschine stops while the gyroscopes keep running. As the "Hauptschalter is moved further back to the "0" position, the "Umformer" and the gyroscopes start running down. The "Umformer" does not stop immediately; the gyroscopes generate enough power to keep the "Umformer" running on reverse power for another 30 second or so. After the "Umformer" has come to a standstill, the gyroscopes can be heard slowly running down.

Now all switches and controls can be reset and the rig put in it's parking position, ready to fly the next "mission".