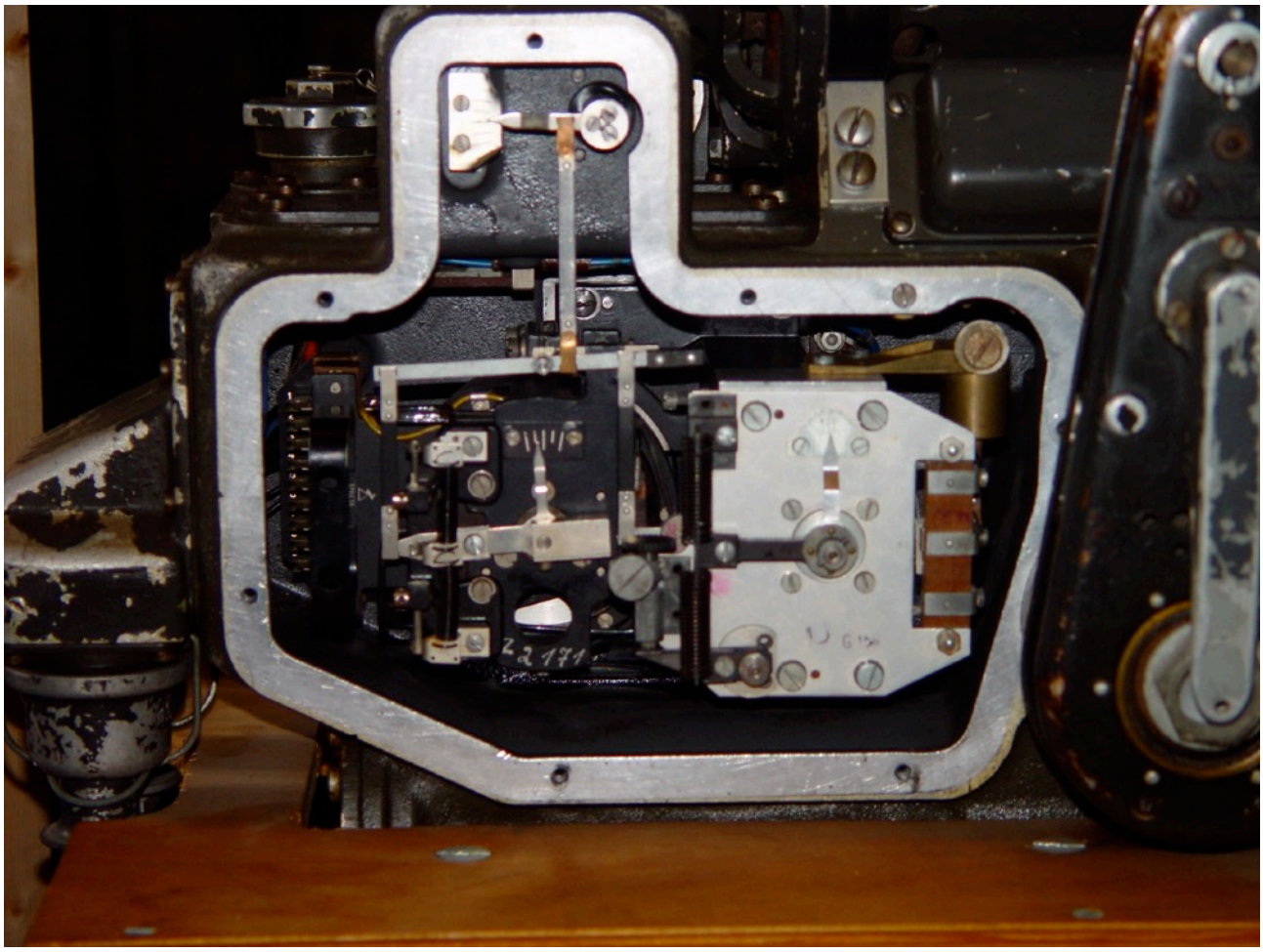
# Siemens K4ü Autopilot



## General

One of the most widely used “Kurssteuerungen” used by the Luftwaffe was the K4ü system built by Siemens (Luftfahrt Geraete Werke Hakenfelde).

Siemens started the development of their K4 system from about  The Luftwaffe required the system to be compatible with the Patin remote compass system. Together with some other lessons learned in early applications of the K4, this led to the development of the K4ü (The ü stands for “überarbeitet” which means “revised”) More than 50.000 examples of this autopilot were built between about 1938 to 1945 and were used in aircraft like the Messerschmitt Bf110, Junker Ju88 and Heinkel He111.

## Description of the K4ü autopilot

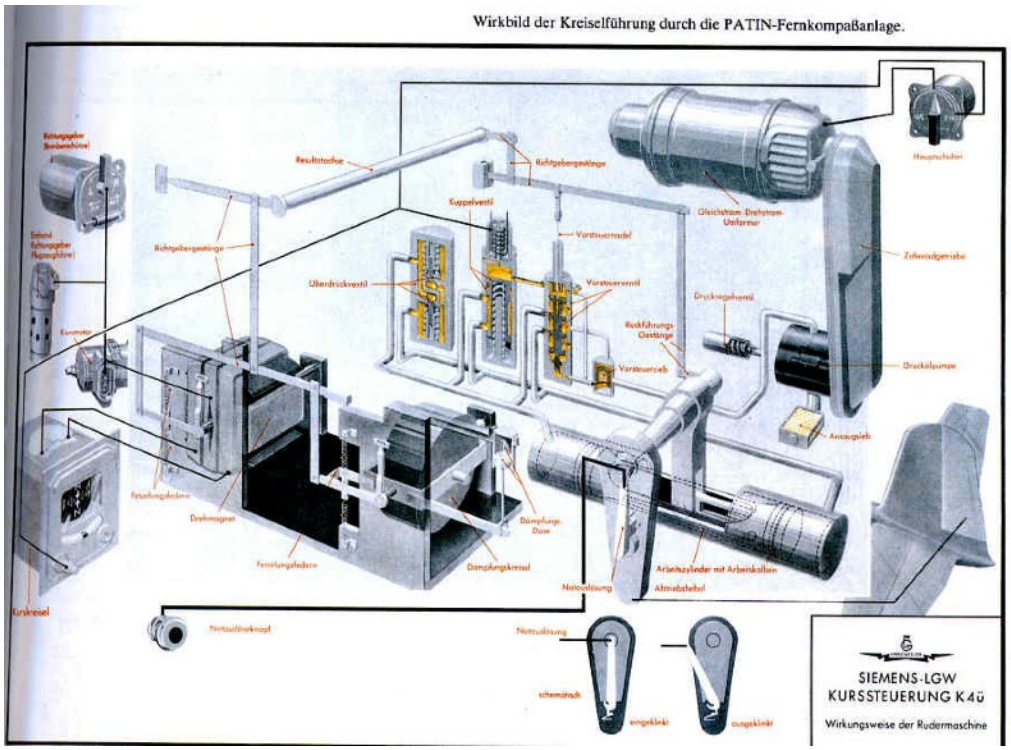



**Figure 1: Overview of the K4u installation**

Apart from the aforementioned Patin master and daughter compass, the K4ü consists of -

- a LKu 4 “Kurskreisel” directional gyroscope,
- a LKz 3 “Kurszieger” indicator,
- a Lrg 9 “Richtungsgeber” course adjustment switch,
- a LKMm “Kursmotor” course adjustment motor,
- a LRM 4ü “Rudermaschine” servo unit,
- a LSch 4ü “Hauptschalter” main switch,
- a “Stützschalter” compass coupling switch,
- a LKW 1⁄4ü “Wiederstandskasten” resistor box,
- a LKW 3 “Wiederstandskasten” resistor box,
- a “Notauslöseknopf” emergency release knob.

A number of variations of the K4ü system could be supplied, denoted by a number behind the name, for example K4ü-1 or K4ü-7. These versions differed mainly in the number and configuration of the control switches, so that the system could be tailored to different types of aircraft. For example, an additional Lrg 5 or Lrg 10 direction switch could be placed at the bomb aimer’s position. With a special extension this switch could even be coupled to the Lotfe bombsight so that aircraft could be adjusted during the bomb run. For twin engined aircraft a LDS 10-2/4 “Einmotorenflugschalter” or single engine flight switch could be added, which automatically changed the balance of the autopilot to deal with the drag of a feathered propeller. Additional resistor boxes would be needed to tie these various optional switches into the K4ü autopilot.

## The Functioning of the K4ü autopilot

### The principles of the autopilot

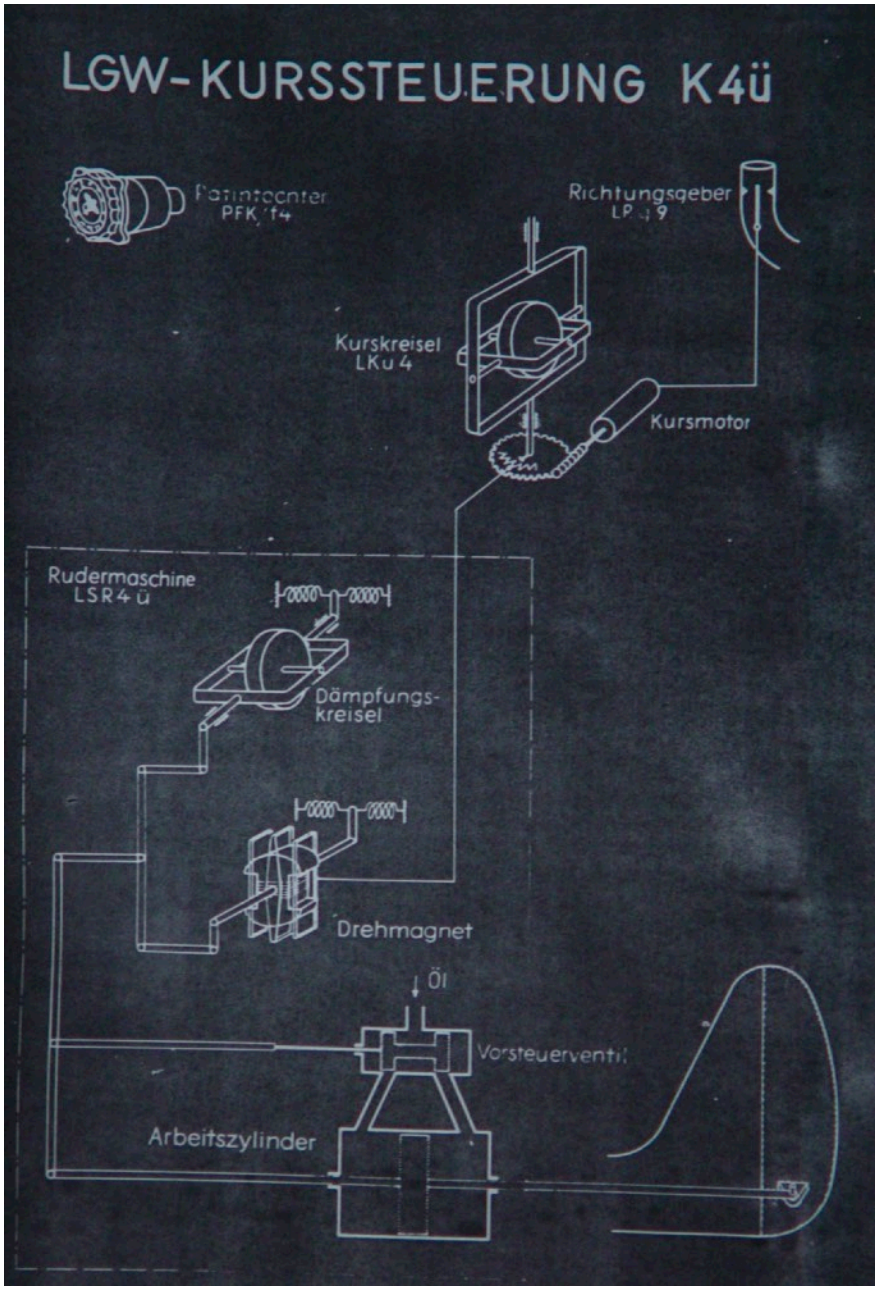



**Figure 2: Functional overview of the K4u autopilot**

To understand the functioning of the autopilot, a little bit of control theory must be understood.

First of all there needs to be a stable set-point, a set course that the aircraft needs to fly towards. If the aircraft deviates to the left of the set course, the system needs to steer the aircraft back to the right and vice versa.

The force generated by the measuring system is far too small to operate the rudder of the aircraft directly, so the second requirement is a large power amplification.

Because there is a time delay between the disturbance of the set course and the action of the rudder, this system tends to oscillate unless stabilised or “dampened”. On slower aircraft the aerodynamics of the aircraft itself have a stabilising effect, but as aircraft got faster and “slippier” another means of damping these oscillations was required.

So thirdly a “damping gyroscope” or “Dämpfungskreisel” is required. This gyroscope measures the angular velocity of the aircraft. If this angular velocity signal is added to the course deviation signal a “proportional, derivative” control system is created which was proven to be effective in early war aircraft with a relatively low natural resonance frequency.

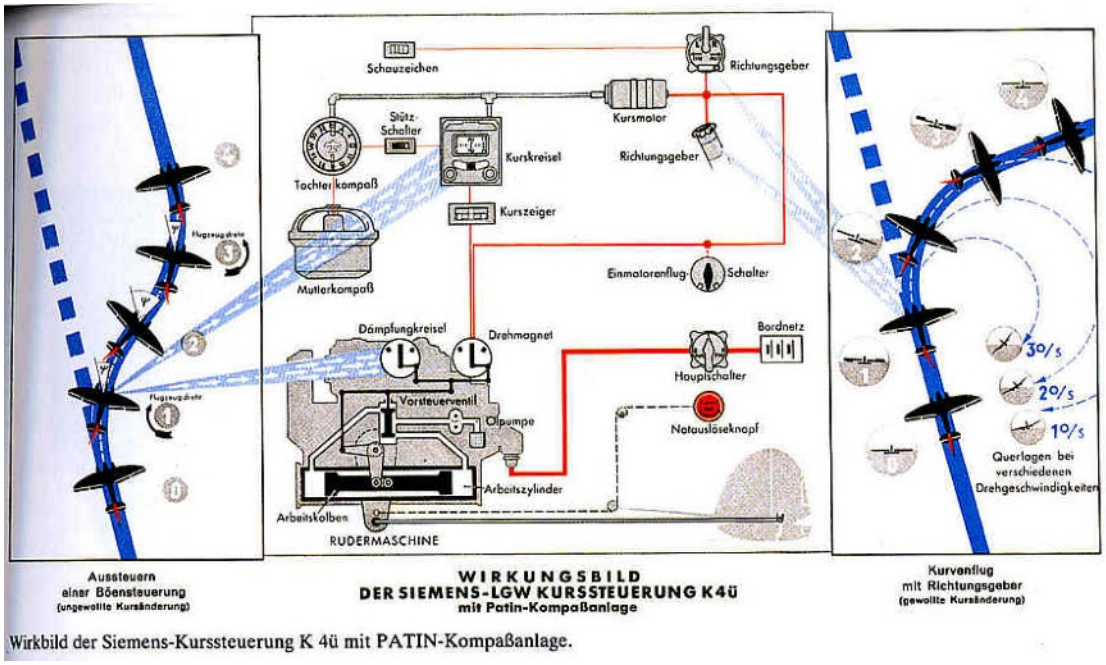



**Figure 3: Principle working of the autopilot. Note the 4 stages of a disturbance indicated on the left of the drawing and which parts of the autopilot engage in countering the disturbance**

## The Patin “Führertochterkompass” and the “Kurskreisel”

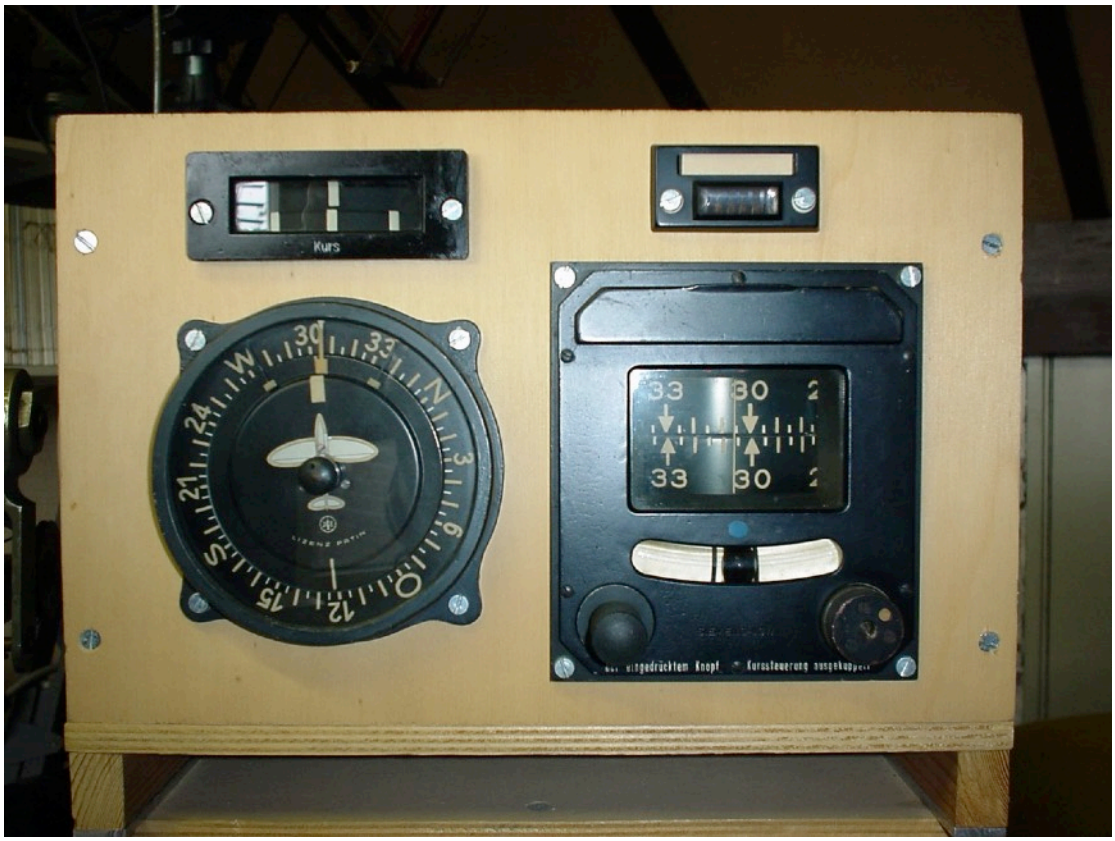



**Figure 4: The principle instrument cluster used with the K4u autopilot. Left top the "Kurszeiger" placed above the "Fuhrertochterkompass". Top right the indicator that the bomb aimer has taken control over the "Kurskreisel"**

The first task was to provide a stable set point or “course”. Since the magnetic Patin compass system is not stable enough to provide a signal directly to the autopilot, a LKu 4 “Kurskreisel” directional gyroscope is used to stablise the course heading.

A directional gyroscope is typically accurate in the short term, but due to internal friction and even the rotation of the earth will slowly drift out of kilter. The solution was use the magnetic Patin compass to influence the setpoint of the directional gyro.

A special repeater compass, the Patin “Führertochterkompass” PFK/f3 was fitted with an output resistor which provides a positive or negative output voltage dependent on a deviation to the left or right. This output resistor only works within +/- 30 degrees of the setpoint, for this reason all Patin repeaters have markings to indicate +/- 30 degrees from the setpoint. The output voltage of the Patin repeater adjusts the “Kurskreisel” readout at about 1 degree per minute. Because the swinging of the magnetic compass is much faster, the effect is that “Kurskreisel” integrates or averages the magnetic course.

**Figure 5: A Patin PKT/f3 "Fuhrertochterkompass". Note that this version has two plug sockets on each side of the instrument.**

The actual set-point of the “Kurskreisel” and the Patin repeater is adjusted with the “Kursmotor”, an electric motor that is connected via shafts and gears to the back of the “Kurskreisel” and the Patin repeater. The top scale of the “Kurskreisel” shows the set course, which is synchronised with the course at the 12 o’clock position of the Patin repeater. If the aircrafts is heading exactly towards the set point, the bottom scale of the “Kurskreisel” correspondents to the top scale, and the aircraft symbol on the Patin repeater points at 12 o’clock.

**Figure 6: Back of the "Fuhrertochterkpompass" showing the plug sockets and bottom rear the entry of the driveshaft of from the "Kursmotor"**

The “Kurskreisel” has two control knobs on the front panel. One, on the bottom right of the instrument, is connected to the “Kursmotor” input. Operation of the “Kursmotor” can be verified by observing the rotation of the setting knob. The other, slightly larger, control knob is placed on the bottom left of the instrument. When pushed in, the gryosocope is locked

and turning the knob allows the bottom scale (connected to the gyroscope) to be set manually. When pulled out, the gyroscope can freely rotate. When pushed in, a bypass valve in the “Rudermaschine” will be openened effectively switching the autopilot off.

**Figure 7: The Lku 4 "Kurskreisel"**

The “Kurskreisel” also includes a slip indicator, placed just below the course indicator. This indicator consists of a small ball in the curved liquid filled tube. This allows the pilot to keep the forces felt in a turn pointing down the vertical axis of the aircraft by controlling the roll.

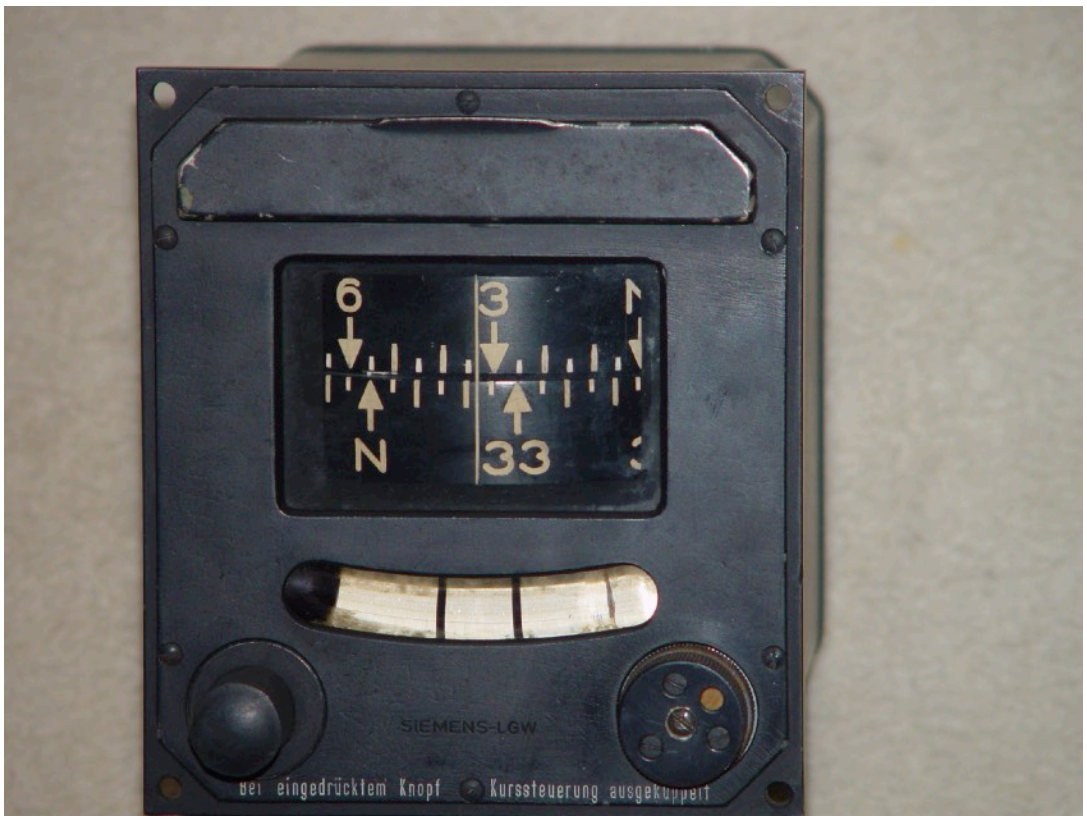



**Figure 8: The "Kurskreisel" showing the two scales, the slip indicator and the control knobs. The hinged lid at the top contains two light bulbs for instrument lighting.**

The “Kurskreisel” generates a signal for the autopilot if the flown course deviates from the set course. Part of the cooling air coming of the gyroscope is blown through two slits towards two heated resistors, coupled in a bridge or “bolometer” circuit. A small deviation from the setpoint causes more cooling air to hit one resistor than the other, causing an imbalance in the bolometer circuit and a positive or negative output signal depending on the direction of the deviation. This setup provides a highly accurate and virtually frictionless measurement between the set course and the indicated course.

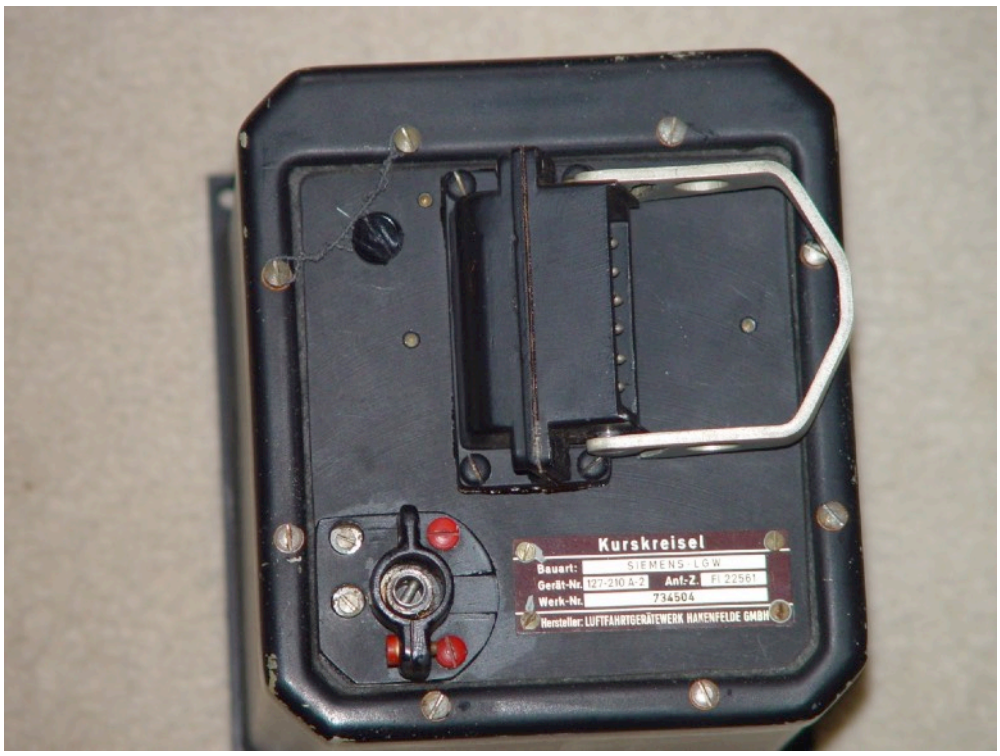



**Figure 9: Rear view of the "Kurskreisel" showing the plug connection and bottom left the input shaft connected to the "Kursmotor"**

## The “Kurszeiger”

The output signal of the “Kurskreisel” provides the first requirement of the autopilot, the stable set point. The output signal is also fed to the LKz 3 “Kurszieger”, which shows a magnified version of the difference between the actual and set course as measured by the “Kurskreisel”. To keep his airplane on a set course, the pilot can focus solely on the “Kurszieger” and keep the indicator centered. When engaged, the autopilot will effectively keep the “Kurszeiger” centered automatically.

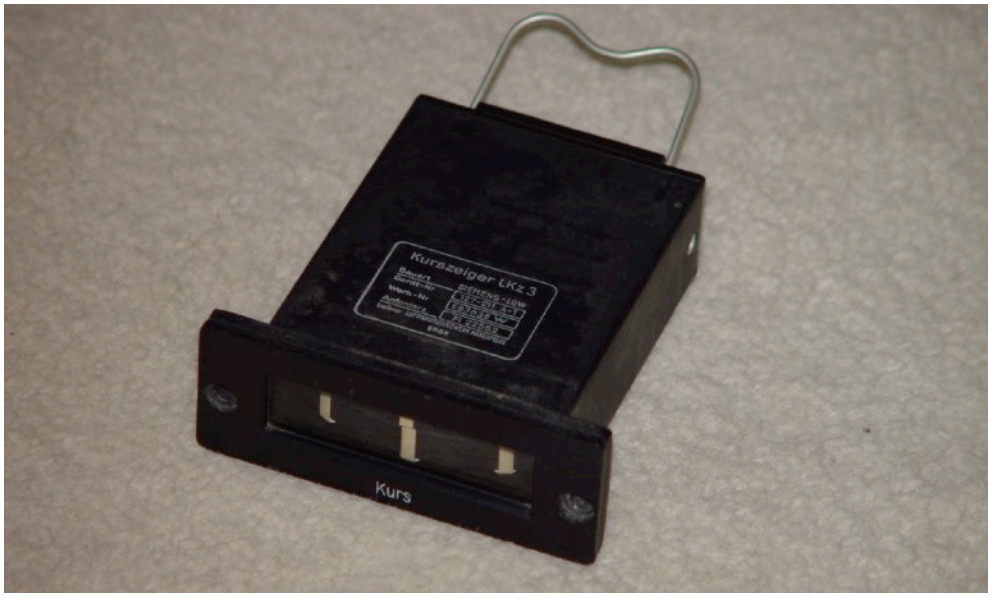



**Figure 10: "Kurszeiger"**

## The “Richtungsgeber”

The “Kursmotor” or course adjustment motor is operated by the Lrg 9 “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).


**Figure 11: The "Richtungsgeber" was normally build into the control column with only the top black bit showing. It would be operated by pushing the slider to he left or right with the thumb**

The correct rate of turn can be adjusted with the resistors in the “Wiederstandskasten”. If the “Richtungsgeber” is engaged while the autopilot is switched on, the whole aircraft will change course at a rate of 1 or 2 degrees per second. The pilot only needs to control the pitch and roll of the aircraft while in a turn.

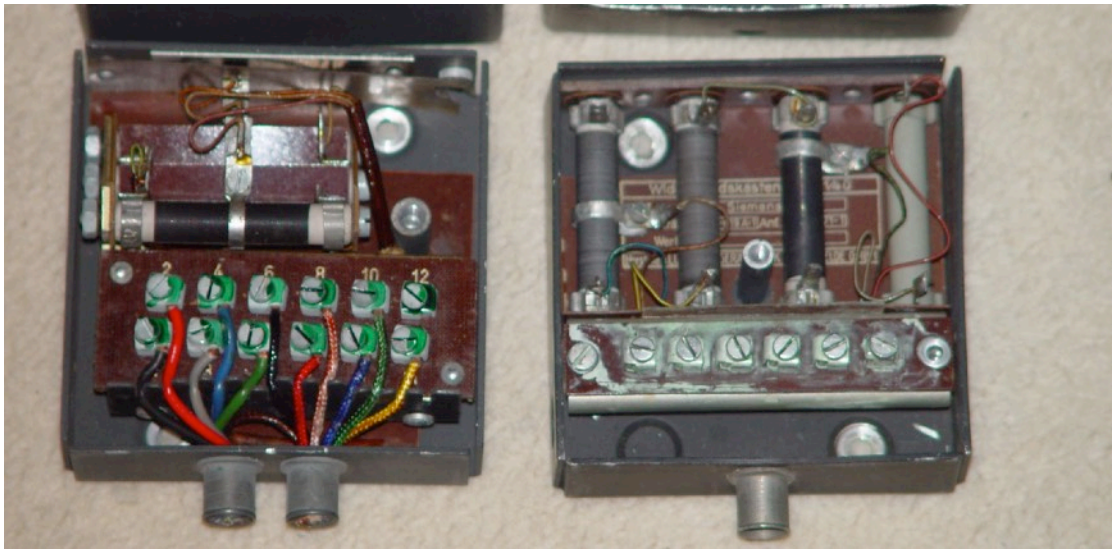


**Figure 12:Left a LKW 3 “Wiederstandskasten” with three variable resistors to regulate the spend of the “Kursmotor”; Right a LKW 1/4u "Wiederstandskasten" showing variable resistors for balancing the “Kurskreisel” bolometer cuircuit and a fixed series resistor for the “Kurszeiger”**

## The “Kursmotor”

The LKMm “Kursmotor” is a small electric motor, driving the course setting adjustments of the Patin repeater and the “Kurskreisel” via shafts and gears. The motor has an internal gearbox to reduce the turnings speed. The stator field is permanently connected to the 24V supply, while the rotor winding is fed through a resistor box by the “Richtungsgeber”. The resistors in the resistor box are adjusted so that the “Kursmotor” changes the set course at 1 or 2 degrees per second.


**Figure 13: a "Kursmotor" . Note the warning that the output shaft should not be turned manually as the motor contains a self locking gear mechanism**

## The “Rudermaschine”

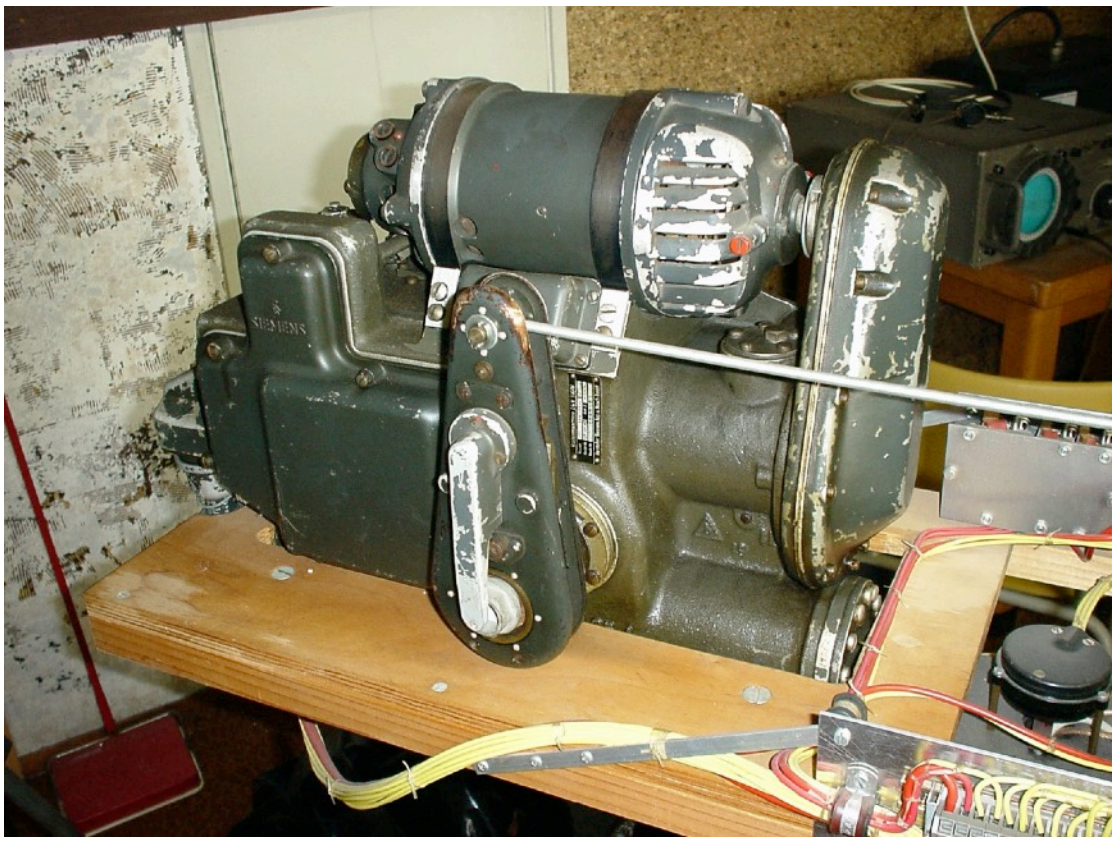



**Figure 14: The "Rudermaschine". Note the output lever connected, normally connected to the rudder.**

The signal form the “Kurskreisel” is of course far to small to operate the rudder of the aircraft directly, the signal has to be amplified many thousands times to give sufficient force to operate the rudder. This second requirement is fulfilled by the LRM 4ü “Rudermaschine” servo unit.

The “Rudermachine” first translates the incoming electrical signals from amongst others the “Kurskreisel” into a mechanical movement which connects to a control valve via a lever system. A hydraulic pump provides oil at high pressure which is fed to one side or the other of a piston depending on the position of the control valve. The piston is coupled to an output lever, which in turn connects to the rudder of the aircraft.

Several mechanical input signals are combined by using an interconnected lever system to drive the single control valve. In this way, the position of the rudder is fed back to the control valve so that the position of the output lever becomes proportional to the input signals.

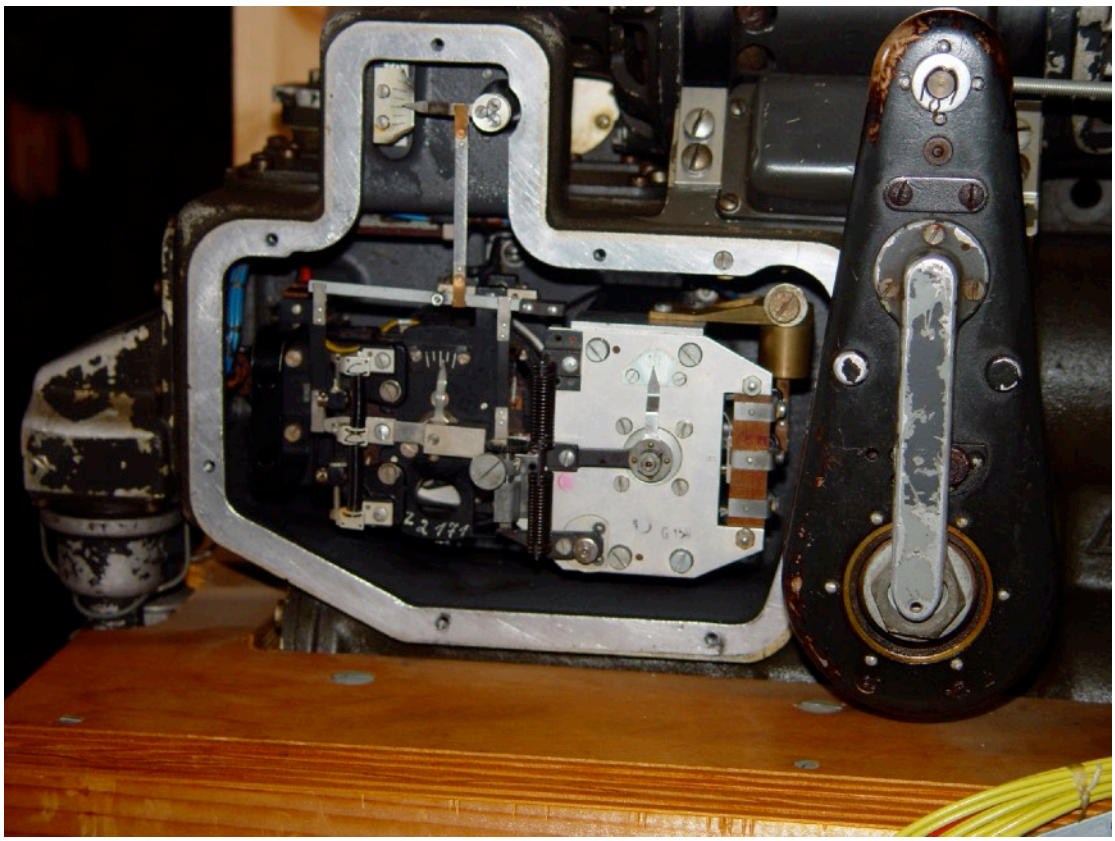


**Figure 15: The "Rudermaschine" with the cover removed revealing the control mechanism. The “Daempfungskreisel” sits on the right behind the clear aluminium plate, note the brass cylinder and piston attached to the gyroscope. Also note the various levers and connecting beams.**

The damping gyroscope of the K4ü is also built into the LRM 4ü “Rudermaschine” and is also connected to the lever system that moves the control valve. By adjusting the tension of springs and a small pneumatic damper connected to the damping gyroscope, the amount of damping signal can be adjusted to suit the type of aircraft.

Overpressure valves in the oil circuit to the pistons are set so that the pilot can just about overpower the piston by the force of his leg on the rudder pedal. An emergency coupling in the output lever can be used to disengage the “Rudermachine” in case of a malfunction. This emergency coupling is connected by a steel cable to a pull knob situated near the pilot.

The electric motor that drives the oilpump of the LRM 4ü “Rudermachine” also generates 500 Hz 36V three phase current to drive the gyroscope in the “Kurskreisel” and the damping gyroscope inside “Rudermaschine”.

The LRM 4ü “Rudermaschine” was conceived as an all in one unit, providing power supply, measurement of angular velocity, signal calculation and amplification and steering power. This made it a relatively compact system that was simple to connect. There were also no external oil lines connecting oil pump to servo, making it a very reliable system.

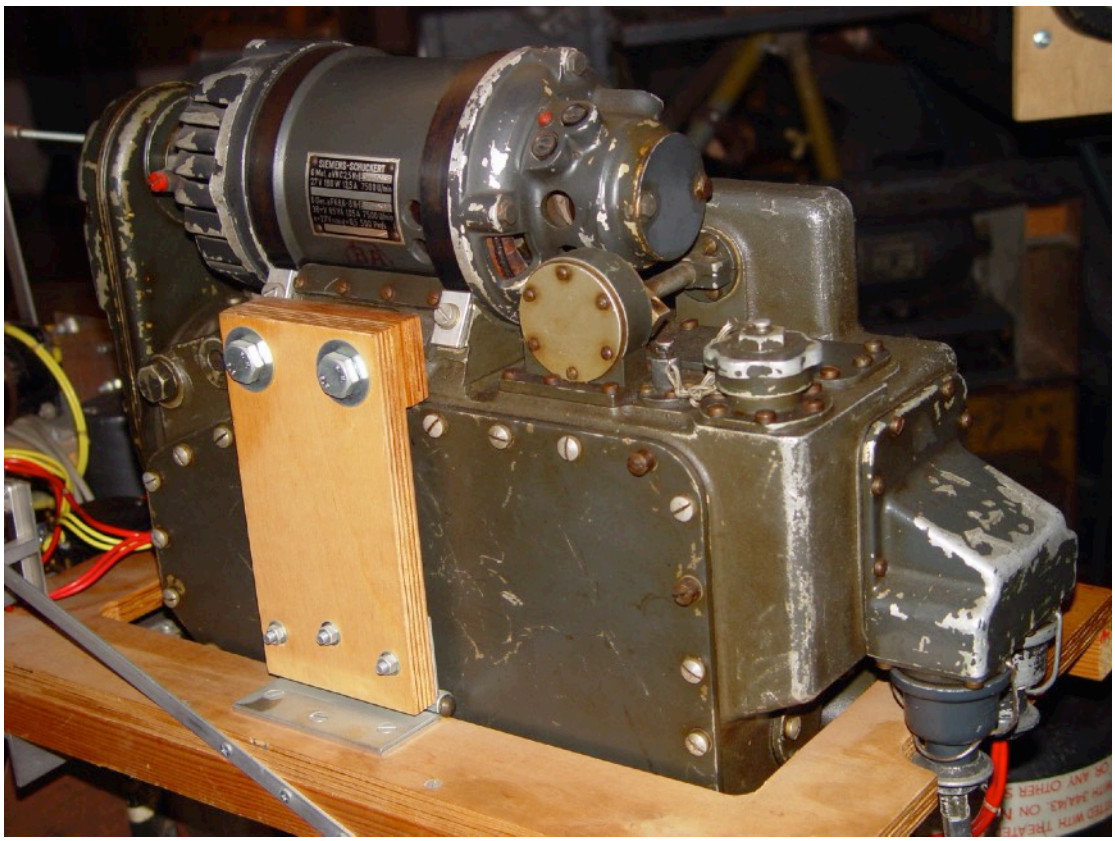


**Figure 16: Reverse side of the "Rudermaschine". Note the shaft running across the top: this connects the electromechanic mechanism to the oil valve.**

A disadvantage of combining the measurement of angular velocity and steering power into one unit is that the LRM 4ü “Rudermaschine” had to be mounted very rigidly, as tiny movements of the “Rudermaschine” would influence the “Daempfungskreisel” and cause unwanted oscillations.

## The “Hauptschalter”

The LSch 4ü “Hauptschalter” main switch has three positions, in position “0” the autopilot system, including the “Kurskreisel”, is switched off. Position “1” starts the motor generator on the “Rudermaschine” which supplies the gyroscopes in the “Rudermaschine” and in the “Kurskreisel”. As long as the switch remains in this standby position, a valve inside the “Rudermaschine” equalises the pressure between both ends of the piston and the output lever of the “Rudermaschine” can be moved freely. In Position “2”, the valve between the two sides of the piston is closed and the “Rudermaschine” controls the rudder; the autopilot is switched “on”

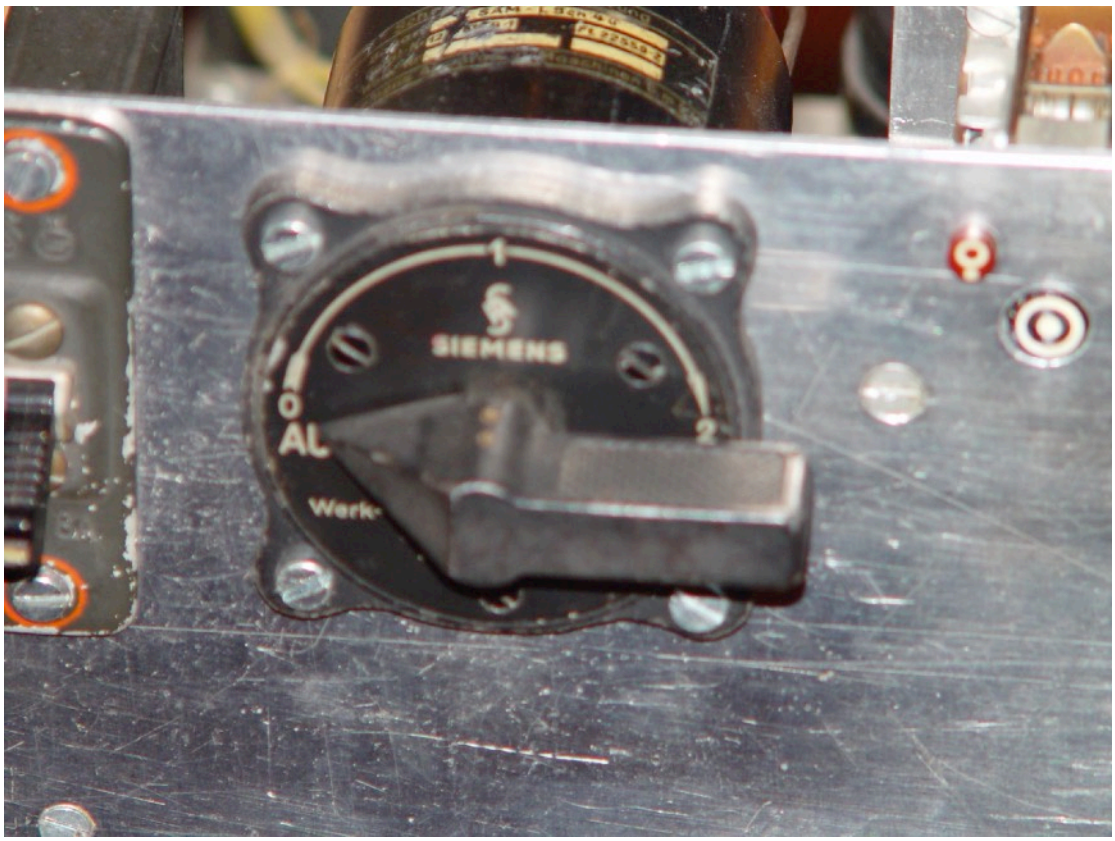



**Figure 17: The "Hauptschalter"**

## The cable termination blocks, cables and numbering

All cables to the individual components of the autopilot are connected to a cable termination block. The exact configuration of this block would depend on the subtype of the K4ü autopilot and the type of aircraft. A relic of a surviving termination panel shows two strips of terminals side by side with the LKW 3 and LKW ¼ü “Wiederstandskasten” fitted to the far side of the panel.

**Figure 18: An original relic distribution board for the K4u autopilot. Note the remains of the "Wiederstandkasten" on the far end**

A separate smaller “Patin Verteiler” termination block would be used to connect the Patin master compass and one or more Patin repeaters. Patin and Siemens were rival firms, and their respective parts of the autopilot system were never fully integrated!

Early in the war, the German Luftwaffe specified “LSA Luftfahrtkabel” cabling. These are typically 2, 3, 5, 7 x 0.75 mm2 or 10, 12, 14 x 0.5 mm2. Single core cables 1 x 1 mm or 2,5 mm2 for typically used for power supplies. The multicore cables had individually coloured rubber insulated wires, with a rubber mantle and a lacquered woven outer sheath. Later in the war, cables were constructed from individual wires, typically using yellow plastic coated cable bound together with waxed twine.

Each autopilot component and cable would be marked with a number, all autopilot components would be prefixed with a “K” for “Kurssteuerung”. Cable numbers would be typically be suffixed with a “K” but examples of a prefix “K” are also sometimes found. These numbers are typically hand painted on the components, while the cables use printed or stamped cable tags. The existence of these numbers on components is a good indication that they are “flown” examples taken from aircraft rather than stock items.


**Figure 19: a Lrg 5 and LKW 5, Note the various "K" numbers painted on the components.**

## Operating the K4ü autopilot

During flight preparation, check that the left control knob of the “Kurskreisel” is pushed in and that the “Hauptschalter” is set to “0”. 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.

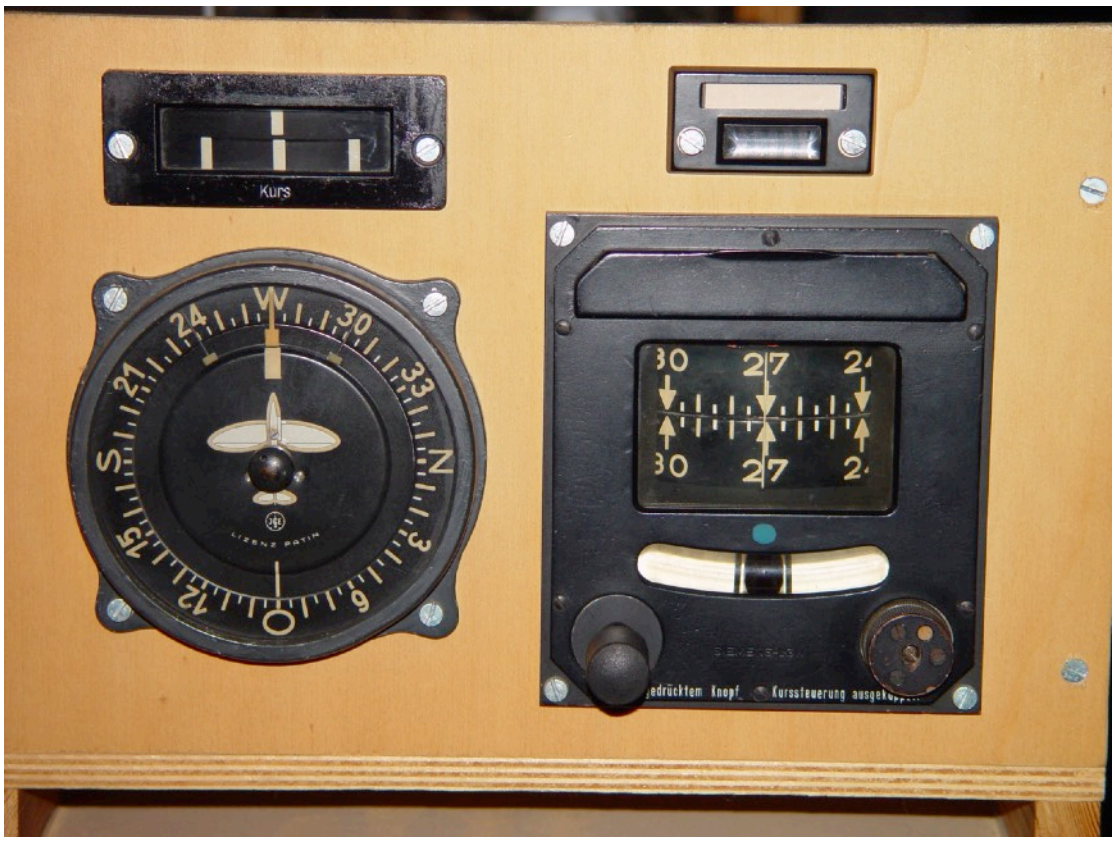



**Figure 20: All the instruments are aligned on a course setting due West. The rudder should stay central.**

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”. 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 “Hauptschalter” back to position “1”. 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 turning the “Hauptschalter” to position “2”. 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.

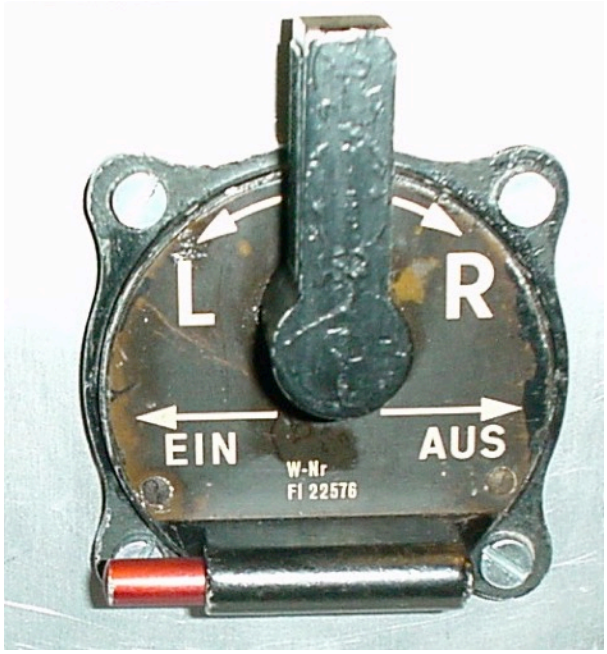



**Figure 21: a Lrg 5 switch as used by the bomb aimer. Note the slide switch is moved to the left “Ein” position indicating the bomb aimer has control**

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 “Hauptschalter” back to the “1” position. Pushing in the left control knob on the “Kurskreisel” should also have this effect. If the rudder is still not moving freely, the pilot can disconnect the autopilot by pulling the emergency release knob. After the emergency release knob has been pulled, the autopilot can no longer be used and has to be checked and reset by ground staff.

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 K4ü demonstration rig

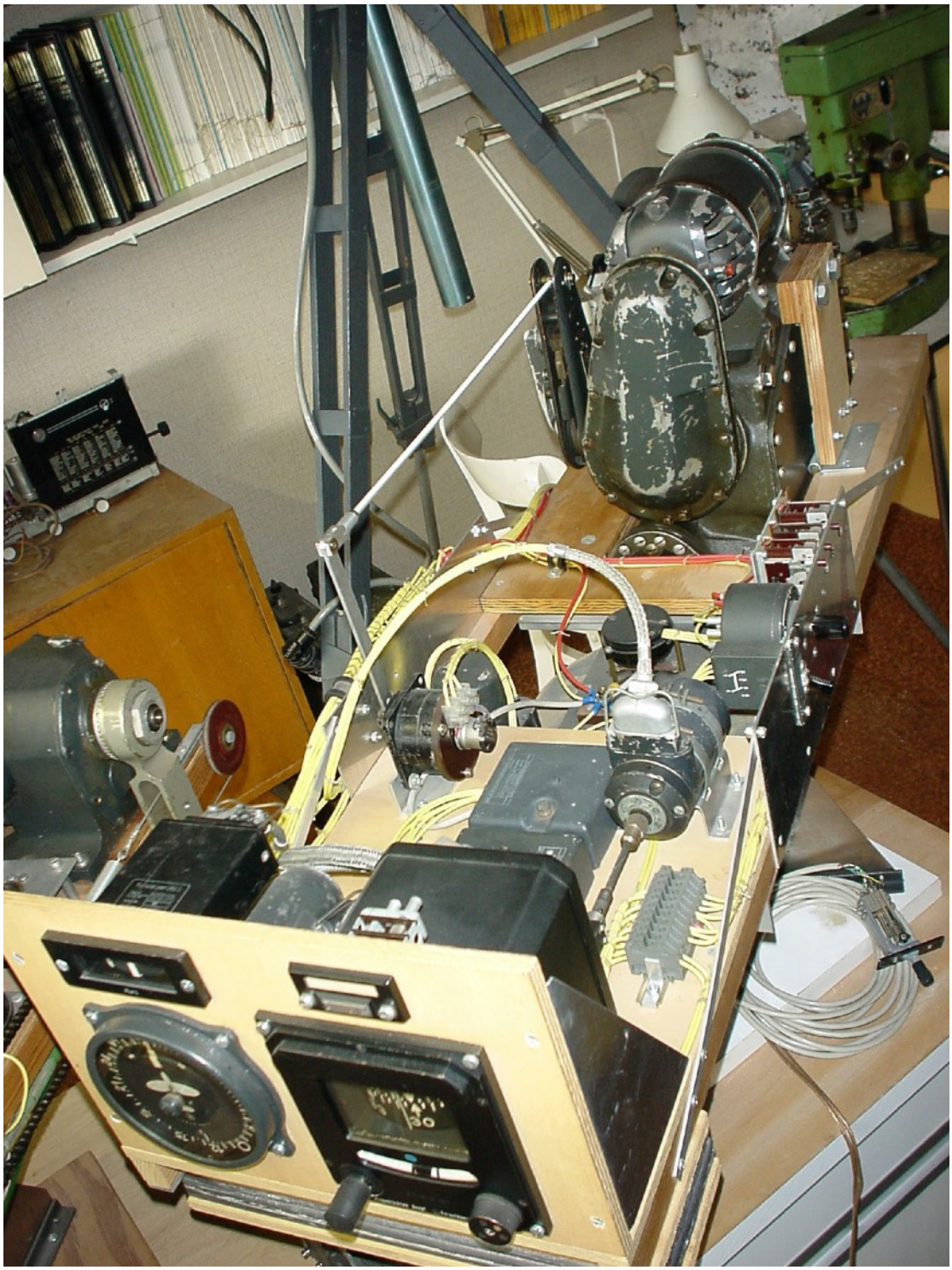


**Figure 22: Overview of the K4u demonstration rig**

In order to demonstrate the K4ü autopilot, the components need to be mounted on a turntable that can mimic the movements of the aircraft.

Since the LRM 4ü “Rudermaschine” alone weighs a hefty 23 Kg, a similar counterweight will be required to balance the turntable, so a sufficiently sturdy pedestal and bearing must be used. A modified bicycle headtube and fork assembly is ideally suited to form the main bearing of the turntable. This also allows supply cables etc. to pass through the tube to the turntable.

The turntable needs some form of rotational drive, to mimic the function of the rudder in the aircraft. The drive must sufficiently “loose” at rest so that the frame can easily be turned by hand to mimic a disturbance, while enough torque must be delivered to overcome the inertia of he heavy rig. So a variable torque, low speed drive is required.

This is achieved by driving a large wheel fixed to the pedestal of the turntable with a small electrical motor fixed to the rotating part of the turntable via a belt.  The motor used is a 24V Luftwaffe dual stator series motor. This motor can turn clockwise or counter-clockwise depending on which stator winding is powered. Even though there is a large gearing ratio between the electric motor and the pedestal wheel, the motor still has to turn very slowly, much slower than what the motor was designed for.

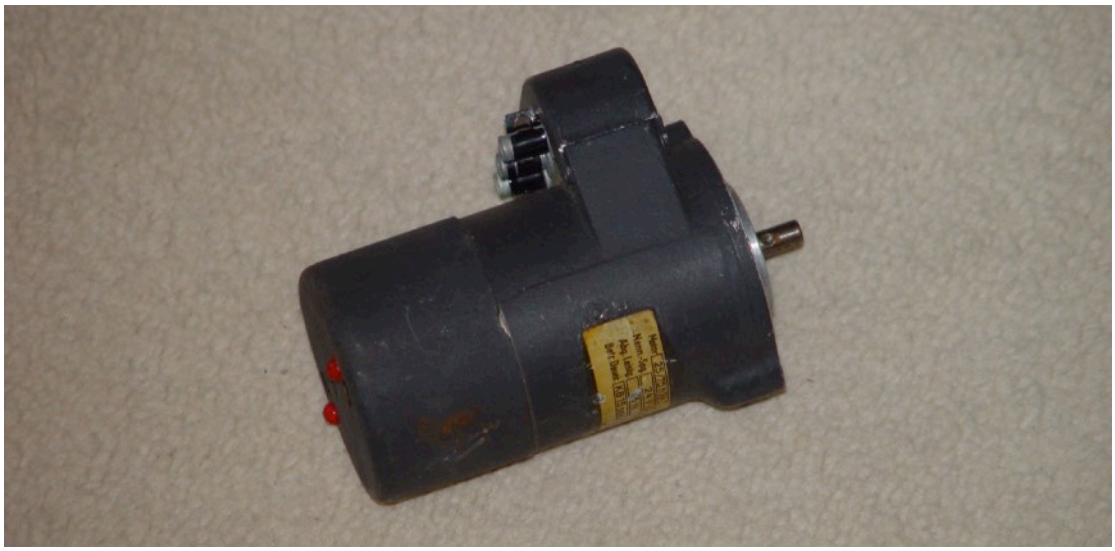


**Figure 23: Dual winding series motor used to drive the turntable. These are normally used as an electric trim motor on the Fw 190.**

The motor is powered by an electronic drive unit, which translates the position of a potentiometer to a clockwise or anticlockwise rotation of the motor. Rather than regulating the voltage to the motor, the drive unit supplies 24V pulses alternatively to both stator windings of the motor with a pulse frequency of about 20 Hz. By varying the duty cycle (e.g making the clockwise pulse longer than the anti-clockwise pulse) the motor can be made to turn very slowly but with full torque.

At a duty cycle of 50%, the motor vibrates at 20 Hz, this vibration helps to overcome the overall friction in the drive system, but is also creates a small vibration in the turntable which helps the Patin compass system to work properly. The motor provides no net torque, and the turntable can be freely rotated by hand.

The potentiometer can be connected to a lever which can be connected to the output lever of the “Rudermaschine” so that the rotation of the turntable is controlled by the autopilot.

This “loose” drive mechanism combined with the high weight of the “Rudermaschine” and counterweights create a turntable with a relatively large angular momentum and low resonant frequency comparable to the typical aircraft that the K4ü autopilot was used in.

Because of the ferrous compontents in the turntable and the electrical currents flowing in the autopilot cabling, a magnetic compass would be greatly disturbed. In a real aircraft, the Patin “Mutterkompass” could be placed in a non-affected position in the back of the fuselage, but in the demonstration rig this is not feasible. For this reason and to save space, the Patin “Mutterkompass” has been replaced with a desyn transmitter placed above the headtube of the turntable. The runner of the desyn is connected via a shaft to the base of the pedestal while the housing is fixed to the turntable. With the base oriented towards the magnetic North, the desyn transmitter will now provide a signal proportionate with the orientation of the turntable and will mimic the magnetic “Mutterkompass”.

Now the various components of the K4ü autopilot can be placed on the turntable. With the heavy “Rudermaschine” to one side, the other components are place on the opposite side, still a significant counterweight is required to balance the turntable.

The instruments are place on a headboard on the far end of the rig. The Patin “Führertochterkompass” is aligned to the left of the “Kurskreisel” to ensure the drive shaft runs straight. The “Kurszeiger” is mounted above the “Führertochterkompass” while the indicator showing that the bomb aimer’s “Richtungsgeber” is engaged is placed above the “Kurskreisel.

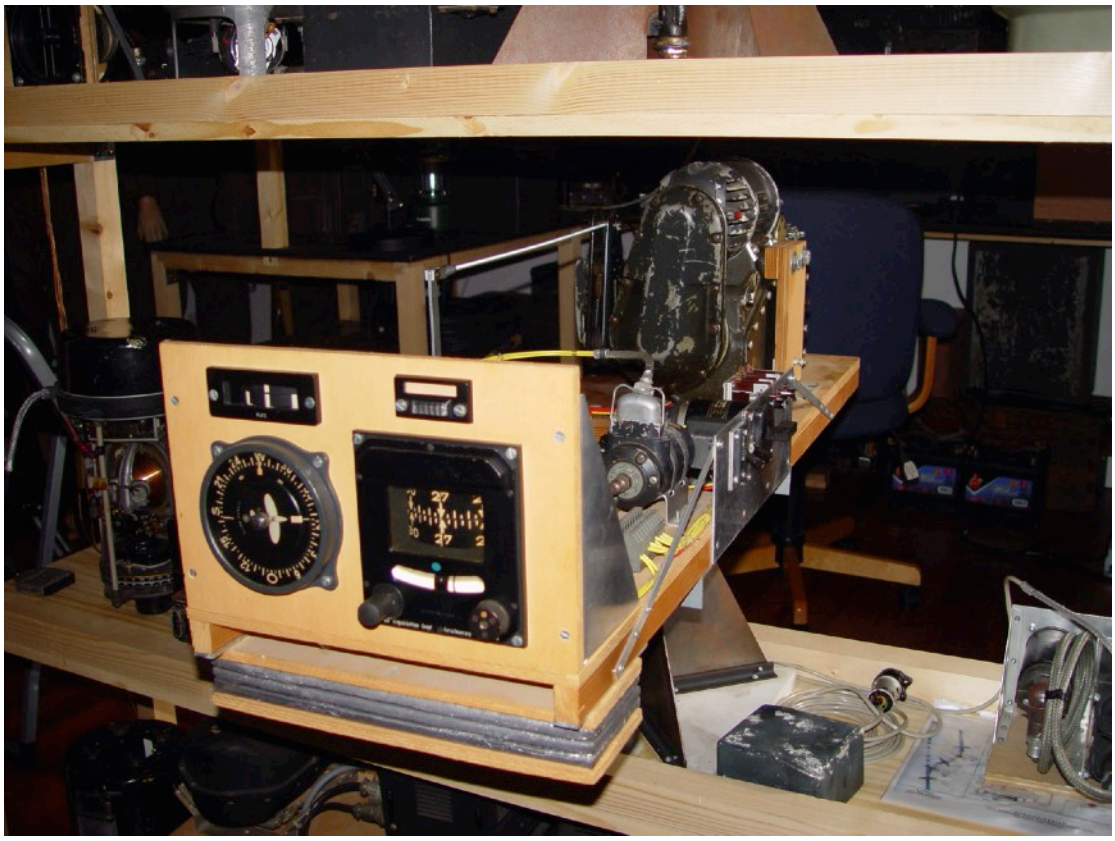


**Figure 24: front panel with the instrument cluster. Note that the rig was swithed off while taking the photograph, hance the instruments are not indicating correctly.**

The “Kursmotor” is aligned directly behind the “Kurskreisel” so that all the drive shafts are straight and at right angles. The electrical controls including the “Hauptschalter” and the “Stützschalter” are placed on the left side of the turntable. An additional switch has been included to switch on the drive motor of the turntable.

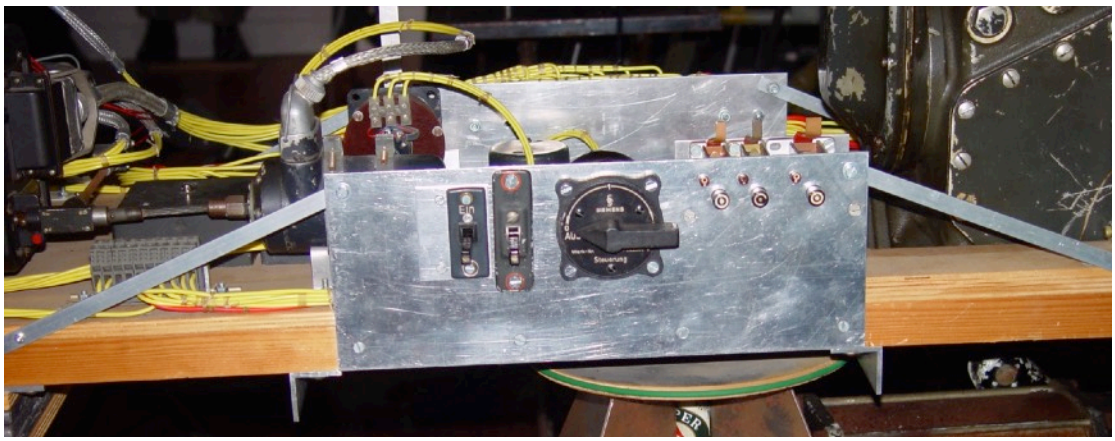


**Figure 25: Control panel with power switches, "Hauptschalter", "Stutzschalter" and a switch for the turntable drive motor.**

A cable termination block has been placed on the other side of the turntable. All cables to the individual components of the autopilot are routed to this termination block.

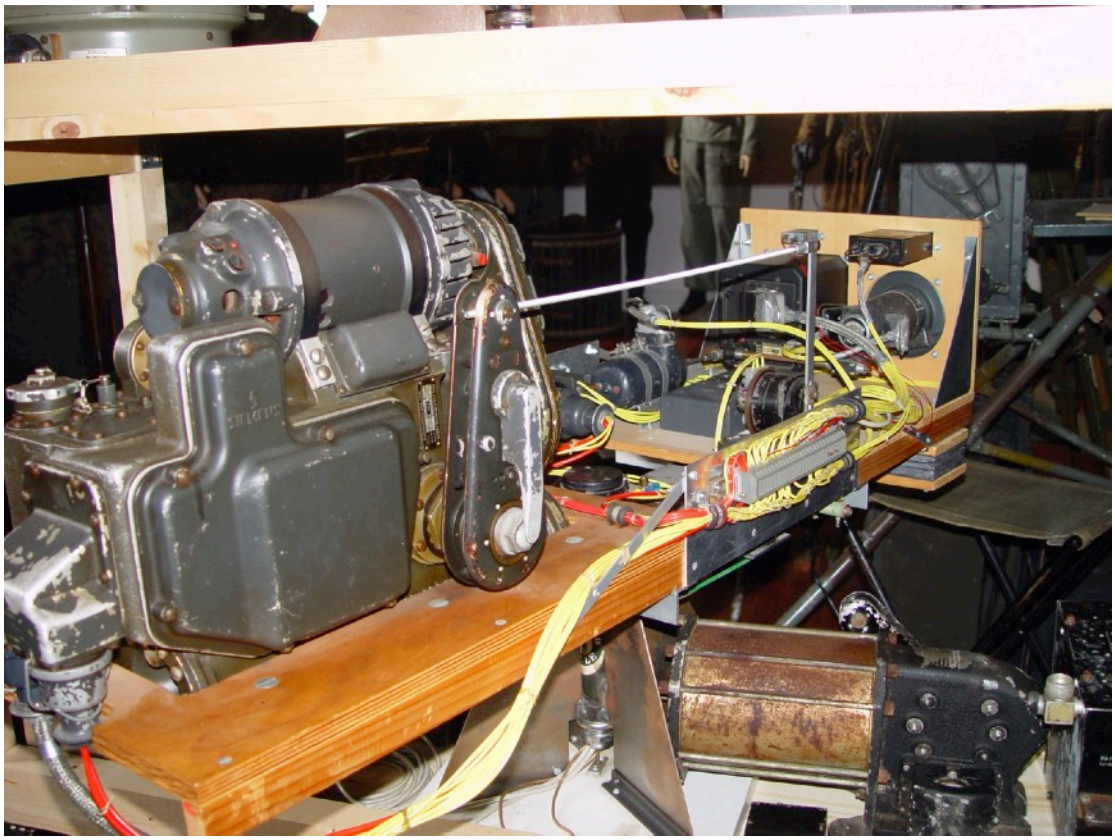


**Figure 26: Termination block and cabling on the side of the rig.**

The LKW 3 and LKW ¼ü “Wiederstandskasten” have been placed behind the instruments. The separate “Patin Verteiler” is placed under the driveshaft of the “Kursmotor”

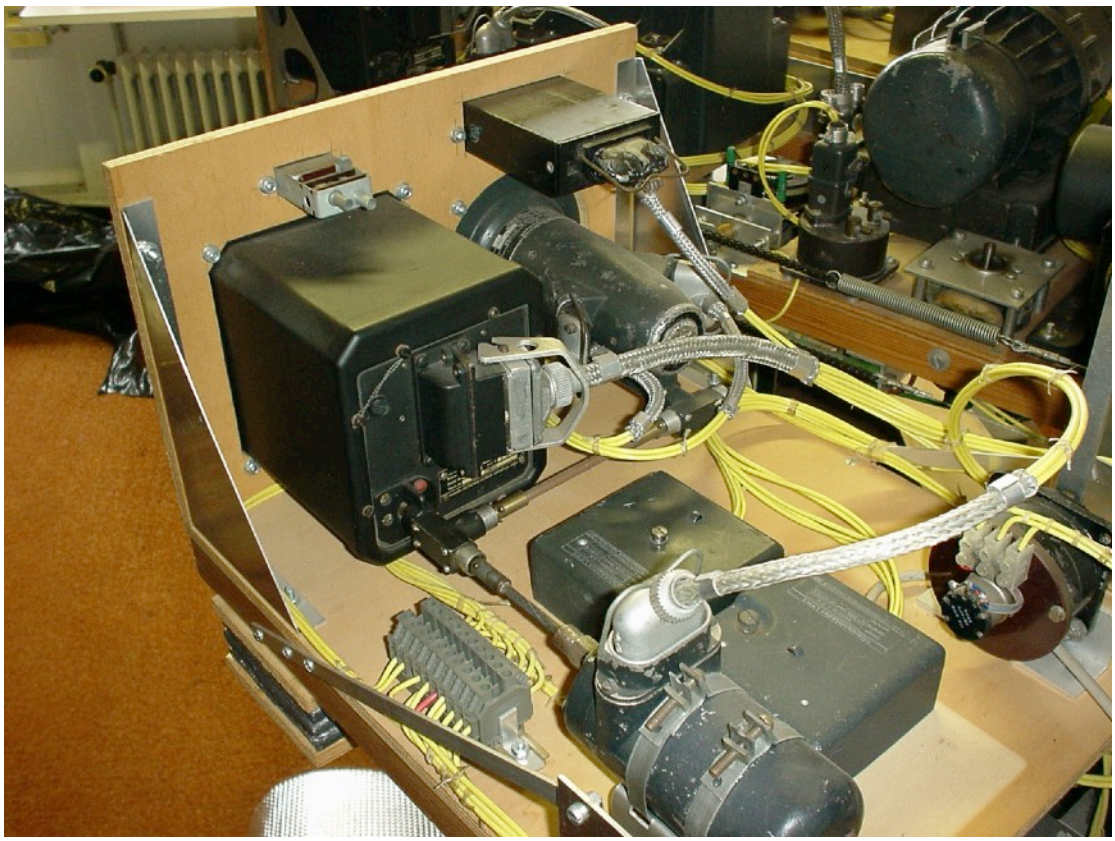


**Figure 27: The rear of the instrument cluster showing the "Kursmotor", the two "Wiederstandskasten". In front of hte "Kursmotor" is the "Patin verteiler". On the right of the picture is the potentiometer that controls the turntable drive motor.**

Late war style cabling using individual yellow wires has been used in the rig which have been terminated as per original specifications. Two thin multicore cables run from the termination block though the headtube to connect to the “Richtungsgebers”.

The version recreated in this demonstration rig is a K4ü-6 which has an additional Lrg 5 “Richtungsgeber” and LKW 5 “Wiederstandkasten”. A separate panel containing the Lrg 5 and LKW 5 can be placed near the turntable.

## Operating the demonstration rig

The rig can be operated as described in the “Operating the K4ü autopilot” section. As the “Hauptschalter” is moved to the “1” position, the “Rudermaschine” springs to life making a lot of noise, and the gyroscopes can just be heard running up.

The rig allows the effect of the dampening gyroscope to be demonstrated by switching the autopilot on before the damping gyroscope is properly run up. The rig will swing up to 30 degrees left and right of the set course with a frequency of once every 3-4 seconds. As the damping gyroscope speeds up, the amplitude of the swings diminishes. After about 2-3 minutes the rig gets stabelised.

Once the gyroscopes are properly run up, the system becomes critically damped. If the frame is swung by hand to one side, the autopilot immediately reacts by giving full counter rudder to arrest the swing. Once the rig starts swinging back to the setpoint, the autopilot regulates the rudder so that the rig returns at a constant rate of turn of about 2 degrees per

second towards the setpoint. As the rig arrives back at the setpoint, there is a small overshoot after which it settles back onto the set course.

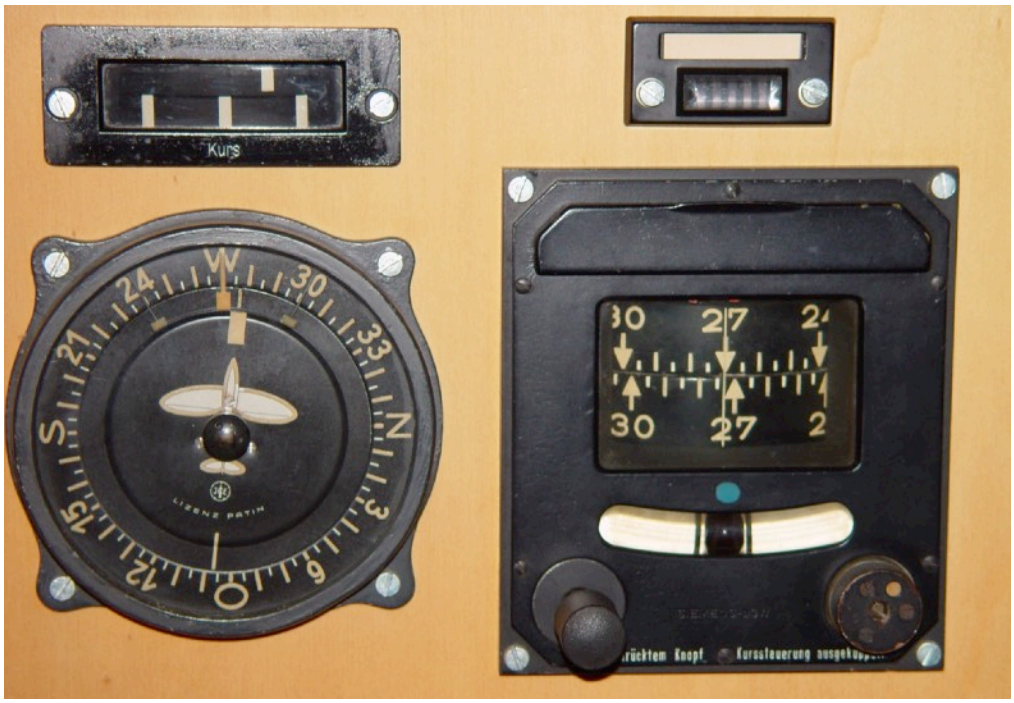



**Figure 28: A disturbance has put the rig a few degrees off-course. Note how the "Kurszieger" is amplifying the indication of the "Kurskreisel".**

To turn the rig, the “Richtungsgeber” is engaged and the “Kursmotor” starts turning the set course on the instruments. The signal of the “Richtungsgeber” is also fed to a winding on the electromagnet in the “Rudermaschine”. This signal is called the “Vorgabe” or bias and it overcomes the tendency of the damping gyroscope to keep the system static. As soon as the “Richtungsgeber” is engaged, the “Rudermaschine” gives a steering pulse to the rudder, which starts the rotation of the rig. The damping gyro will now keep the rate of turn constant as long as the “Richtungsgeber” is engaged. If the resistors in the “Wiederstandkasten” are properly adjusted, the rig should turn at the same speed as the adjustment of the setpoint by the “Kursmotor”. This can be verified by observing the “Kurszeiger”, as it should stay more or less centered during the turn. As the “Richtungsgeber” is released, a pulse of counter rudder is given to arrest the rotation.

If the switch on the bomb aimer’s Lrg 5 “Richtungsgeber” is engaged, the indicator above the “Kurskreisel” shows white. The rig can now be turned by operating the Lrg 5. The design of this switch with a long handle allows very short and accurate steering pulses to be fed to the autopilot. In this way, the rig can be pointed within a fraction of a degree. For full accuracy, the “Stützschalter” should be switched off.

With the “Stützschalter” back on, the effect of the Patin “Führertochterkompass” PFK/f3 on the Kurskreisel can be demonstrated. This effect is called “Überwaching” or overseeing of the directional gyroscope. First, the gyroscope is brought out of alignment by momentarily pushing in the left knob on the “Kurskreisel” and turning the rig by hand 5 degrees or so from the setpoint (the autopilot will not react to this disturbance as pushing in the knob disengages the autopilot). When the knob is pulled back out, the autopilot will react by aligning the (now slightly offset) bottom scale with the fixed top scale of the “Kurskreisel”. The “Kurskreisel” and the “Kurszeiger” will now look fully aligned, but the Patin

“Führertochterkompass” is showing a course about 5 degrees from the 12 o’clock position. The output resistor in the “Führertochterkompass” will now give a small signal to the “Kurskreisel”, turning the bottom scale at about one degree per minute. Since the autopilot is however keeping the bottom and top scale of the “Kurskreisel” aligned, the only movement spotted will be a very slow turning of the rig and a very slow return of the Patin “Führertochterkompass” towards the 12 o’clock position.

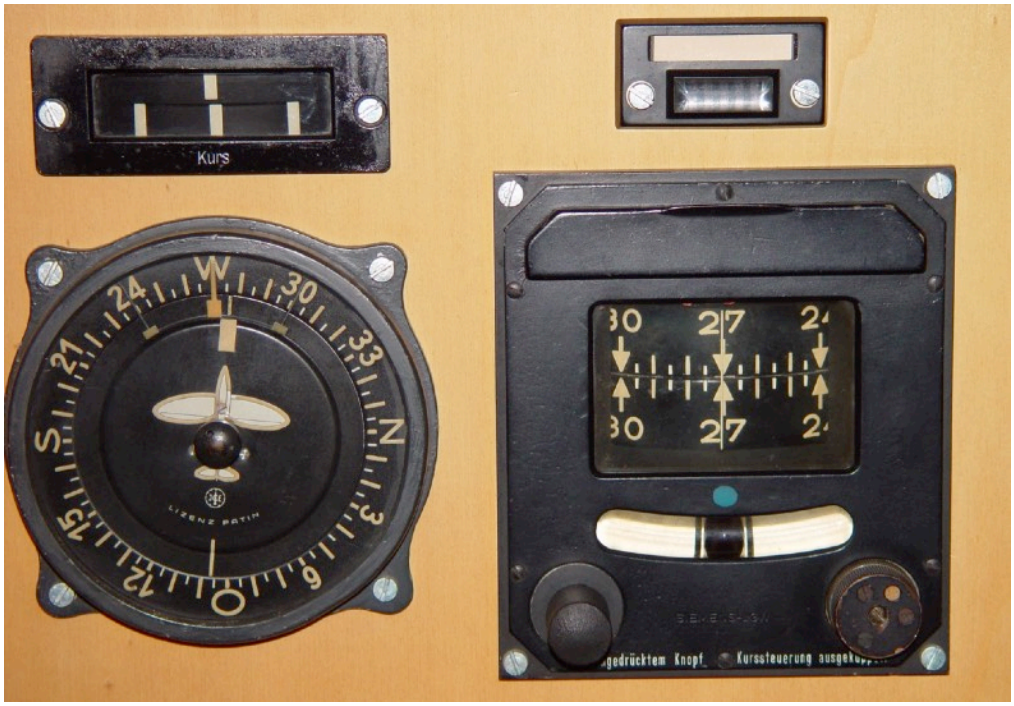



**Figure 29: Misalignment between the magnetic and gyro compass. With the "Stuetzschalter engaged, the aircraft will turn back to a Westerly magnetic course at a rate of 1 degree per minute.**

By removing the cover from the “Rudermaschine”, the interplay between the electromagnet and the damping gyroscope can be observed. Both inputs, as well as the lever connected to the valve have small pointers and scales over a 20 degrees range. The output shafts of the electromagnet on the left and the damping gyroscope on the right are connected to centring springs which are factory adjusted and balanced on the electromagnet. The springs on the damping gyro can be replaced or adjusted to suit the aircraft as can the small cylinder and piston damper connected to right of the gyro.

For example if the “Richtungsgeber” is engaged, the electromagnet will turn about 5 degrees to the left which moves the valve lever by about 1 degree left. This will result in a rudder movement, which starts to turn the rig. Almost immediately, the damping gyro will react with a small, opposite rotation of about 1 degree. The resulting rotation of the valve lever is only a fraction of a degree, just enough to maintain the rotation rate of the rig.

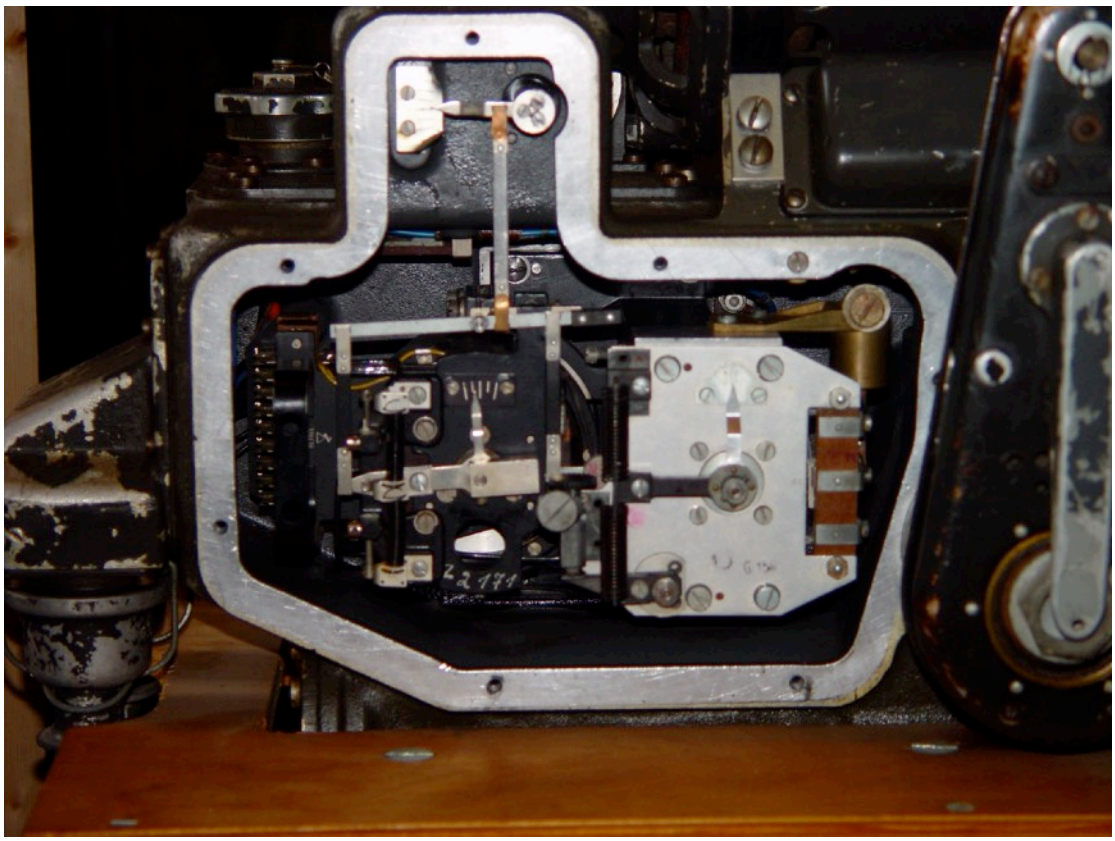


**Figure 30: The "Rudermaschine" at work. Not the deflection of the various indicators**

After switching off the autopilot by turning the “Hauptschalter” back to the “0” position, it is satisfying to hear the gyroscopes run down. A good condition gyroscope should run down for at least 10 minutes, if not bearings should be cleaned and greased.

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