THE YB.02251 "TELEWRITER"
A BRITISH PORTABLE HELLSCHREIBER PRINTER / KEYBOARD-SENDER

Frank Dörenberg (www.hellschreiber.com)
Peter Prest

Version August 2019

CONTENTS

Page

Introduction .... *i*

The YB.02251 "Telewriter" 1

The printer of the Telewriter 3

The Telewriter font and keyboard-sender 5

The drive mechanism 10

The drive sequence 16

Circuit diagrams 22

The water container 24

References 26

INTRODUCTION

This document is closely based on the description of the “Telewriter” as published on the “Models from other manufacturers” section of my Hellschreiber-teleprinter website (www.hellschreiber.com).

In August of 2011, I received a message from David H. Jones in England. He recalled examining a rare start-stop Hellschreiber variant at the end of 1945, while he was working at the *Post Office Research Station* at Dollis Hill (north London). He was kind enough to write down his quite detailed memories (ref. A). The machine was portable, British-made, had a 3-row keyboard (no figure-keys), and an electrochemical Hellschreiber printer mechanism. The machine appeared to have been part of a small batch of pre-production prototypes.

Many years later, in April of 2018, the plot finally thickened when I was contacted by Peter Prest. He owns a machine that appeared to match David Jones's description, though adapted to series production and with a 4-row keyboard. Subsequent research has turned up two additional machines.

The machine shown on the cover page is one of the three known to still exist. It is in the collection of the Science Museum in London. It was donated to the museum in 1968 by B. Robertson, ref. K. The second machine carries serial nr. 109, and is in the collection of the Signals Museum at RAF Henlow/UK. The third machine is mounted on a board, rather than in a numbered carrying case. It is in the private collection of Peter Prest. In his analysis (ref. J), Peter construes that the machine was probably conceived in 1940, based on the operating instructions dating from the end of 1945 (ref. B), and assuming standard product development and procurement processes.

Peter has gone through great lengths, to get his machine up and running, to figure out the many intricacies of the drive mechanism (for which he adapted his machine to use a low-speed stepper instead of the full-speed original motor), reconstruct the font, dig up what little documentation is available in archives, locate the other two machines, etc. He also provided all of the photos of his machine used in this document, made mechanical drawings as well as the referenced audio and video recordings. It has been a great pleasure to have had the opportunity to accompany Peter during (t)his quest, as well as the many friendly exchanges we had in order to converge on a detailed understanding of how it all works, and arrive at a description that is correct and sufficiently detailed. It has been very interesting and rewarding project!

Frank Dörenberg

April 2019

ALL YOU COULD EVER WANT TO KNOW ABOUT
HELLSCHREIBER
HELLSCHREIBER
HISTORY, TECHNOLOGY, OPERATION, MODES, MODELS
www.hellschreiber.com

THE YB.02251 "TELEWRITER"

Figure 1: The Telewriter and its carrying case
(source unedited original photos: Science Museum in London, inventory nr. 1968-586)

The equipment label on the carrying case shows the following information:

- **YB.02251** is the part number. "YB" refers to the section "*Signal Stores, Automatic Telegraph, Line Transmission Equipment and Cryptographic Equipment*" of the British Army Ordnance Store catalog. I.e., it is a military teleprinter.
- "**Telewriter**" is the model designator.
- **G.T.L.**: unknown.
- Serial number **28**.

None of the three machines carries any identification of the manufacturer, unless "G.T.L." on the case label is a reference. However, research so far has not found a plausible explanation for this abbreviation.

Figure 2: Telewriters
(source: left - adapted from Fig.1 in ref. B; right - unedited original photo: ©2018 Peter Prest)

Note the hinged clear plastic hood to the left of the paper tape spool in Fig. 2. Most likely, its purpose is to protect the fragile printer wheel and the distributor rotor. Such hoods are not uncommon for conventional teleprinters of the same era, where they may also provide some noise reduction.

The unit is actually quite small: it measures a mere 13½x6½x9½ inch (WxHxD, ≈34x16½x24 cm). The case is made of dark brown paxolin (one of the trade names for phenolic resin bonded paper laminate, like pertinax). The machine weighs 24½ lbs (≈11 kg). It is powered by 12 Vdc, provided by two 6 Vdc / 16 Ah batteries.

THE PRINTER OF THE TELEWRITER

A regular Hellschreiber printer uses a spinning helix (spindle) to generate an inked spot that continuously sweeps across the width of a paper tape. The moving tape is tapped against the inked spindle, in the rhythm of received pixel pulses. The Telewriter uses a different approach: it creates such a sweeping spot with a printer wheel (a.k.a. "pecker wheel"). It has 5 tangential springs that are evenly spaced. At the end of each spring tab, there is a small chisel-shaped "pecker". It measures approximately 0.3 x 1 mm, see Figure 3 below. This suggests that printed characters are about 5 mm wide (twice as wide as standard Hellschreiber). Such a printer wheel prints a *single* line of text, unlike standard 1930s/1940s Hellschreiber spindles. This is consistent with the Telewriter using a start-stop system to synchronize sending and receiving machines, whereas standard Hellschreibers of that era use no synchronization.

The Telewriter does not use ink. Instead, it uses an electro-chemical process. A water container is inserted into the left hand side of the machine. Chemically impregnated paper tape passes over the wet wick in the top of the water container. This moistening "activates" the paper, just before it reaches the printer wheel. The tape has to be moist, so as to conduct electrical current.

Electrochemical telegraphy printing on paper tape dates back to the early 1800s by Samuel Thomas von Sömmering (a remarkable anatomist, physician, anthropologist, paleontologist, and inventor) in Prussia/Germany. It was improved upon several decades later (e.g., Alexander Bain; ref. C, D). It is unknown which chemical compound was used to impregnate the paper tape of the Telewriter. Rudolf Hell's original 1929 Hellschreiber prototypes used standard yellowish potassium ferr**o**cyanide (*prussiate of potash*, "gelbes Blutlaugensaltz", unlike the red ferr**i**cyanide). Often, ammonium nitrate was added as a deliquescent (to keep the paper damp). Passing current through the yellowish salt solution causes electro-oxidation that decomposes the salt solution into a compound called *Prussian Blue* ("preußisch Blau", "Berlin Blau"). The impregnated paper tape only turns dark blue at the electrode with the highest potential. Typically, a potential of about 1 volt suffices (which may explains the 30 ohms resistor in series with the printer wheel). The tape is bleached at the electrode with the lower/negative potential. Heating the compound, mixing it with a strong acid, and exposing it to UV light, causes toxic cyanide gas to be released. A description of how to impregnate tape and recipe for the chemical solution can be found in ref. L.

Prussian Blue dye has been used since the early 1700s, including for dyeing the cloth used for the uniforms of the Prussian military - hence its name. It is also gave its characteristic color to "blueprints": copies of technical drawings, based on a photochemical process involving Prussian Blue, widely used in the decades preceding the modern photocopier.

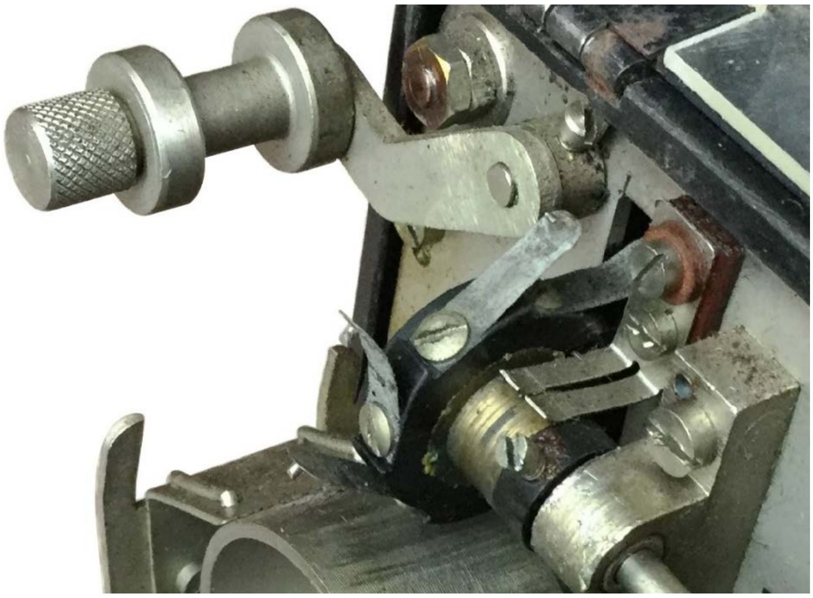


Figure 3: Close-up of the black "pecker wheel" with its five spring-loaded tips
(original unedited photo: ©2018 Peter Prest)

Note that the five tipped springs leafs are evenly spaced, but only around a *part* of the circumference of the printer wheel, almost as if a sixth one is missing:

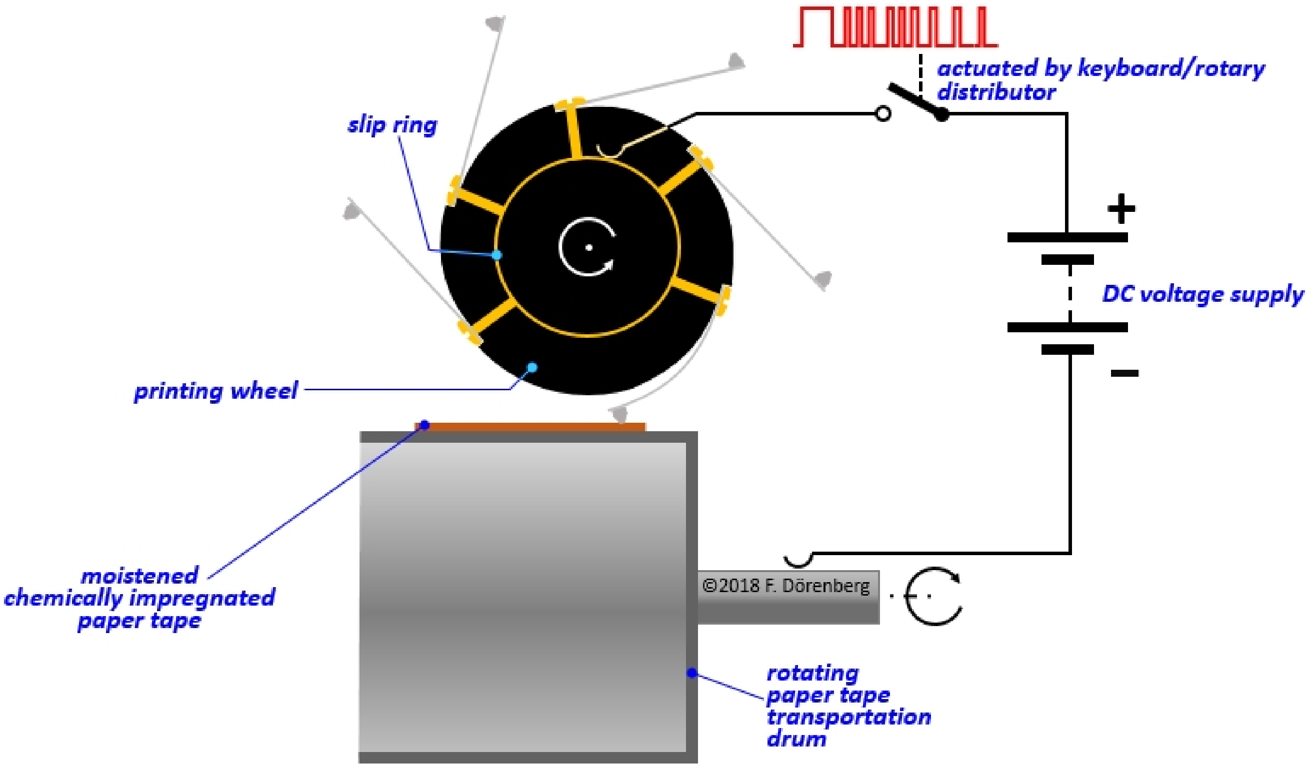


Figure 4: Principle of the Telewriter's electrochemical paper tape printer

The original reels of Telewriter paper tape carried the British Army Ordnance Store number YB 03858 (ref. K). Width of the paper tape is 11/16 inch (≈ 17.5 mm). This is slightly wider than the 15 mm standard Hellschreiber tape for printing two identical parallel lines of text, and much wider than the 9.5 mm tape used in single-line start-stop Hellschreibers made by Hell/Siemens-Halske. The paper tape transportation drum below the printer wheel has a diameter of 1.25 inch (≈ 3.2 cm).

THE TELEWRITER FONT AND KEYBOARD-SENDER

The Telewriter keyboard has a 4-row 38-key QWERTY layout with the keys **A-Z, 2-9**, **space**, **+ - /** and "·" The letter "**I**" is also used for "1", and the letter "**O**" for zero. For legibility of the printed text, only capital letters are used.

Figure 5: Four-row keyboard layout of the Telewriter machine
(original unedited photo: ©2018 Peter Prest)

The letter type on the keys closely resembles that of a 1930s portable typewriter of the *British Oliver Typewriter Company*. The keys are metal-rimmed, which is typical of typewriters of that era (Remington, Bar-Lock, Underwood, etc.).

The presence of the space key implies that the Telewriter is a start-stop teleprinter system: the sending and receiving machine are asynchronous. They are (momentarily) synchronized for each character, by a start pulse that is sent as part of the each character. Synchronous Hellschreiber machines do not have (nor need) a space character: they are not start-stop systems. Instead, they rely on sufficiently equal motor speeds, combined with always printing two identical parallel lines of text, one above the other. One line is always legible, even if speed differences cause the slanting of the printed text. Start-stop systems (esp. over radio, with noise, fading, and multi-path echoes) are vulnerable to false (or omitted) start-pulse detection.

©2018 Frank Dörenberg Model	Speed (char/min)	Character duration (msec)	Pixel column duration (msec)	Shortest pulse (msec)	Telegraphy speed (baud)	Font matrix (column x row pixels) [1]	Start pulse
Telewriter	160	375	46.88	6.69	149.3	8x7 (5x5)	Yes [2], 8 px
Feld-Hell	150	400	57.14	8.16	122.5 [3]	7x14 (5x10)	No
Presse-Hell	300	200	28.57	4.08	245 [3]	7x14 (5x10)	No
Hell GL	367	163	23.33	3.33	300 [3]	7x14 (5x10)	Yes [2], 8 px
Hell-80	300	200	28.57	3.17	315	7x9 (5x7)	Yes [2, 4], 5 px

Note 1: values in parentheses are for sub-matrix that is actually used for font pixels; font matrix definitions all include blank top and/or bottom row and blank first and/or last column.
Note 2: start pulse is hidden in the blank column(s) preceding the actual font columns, and is not printed.
Note 3: Hell "2 pixel rule" applies (pixel placement resolution is 1 pixel, but always ≥2 black or white pixels in series)
Note 4: in asynchronous (= start-stop) mode only.

Figure 6: Comparison of Telewriter with standard Hellschreiber fonts and speeds

The Telewriter uses the following bit-map font [1]:

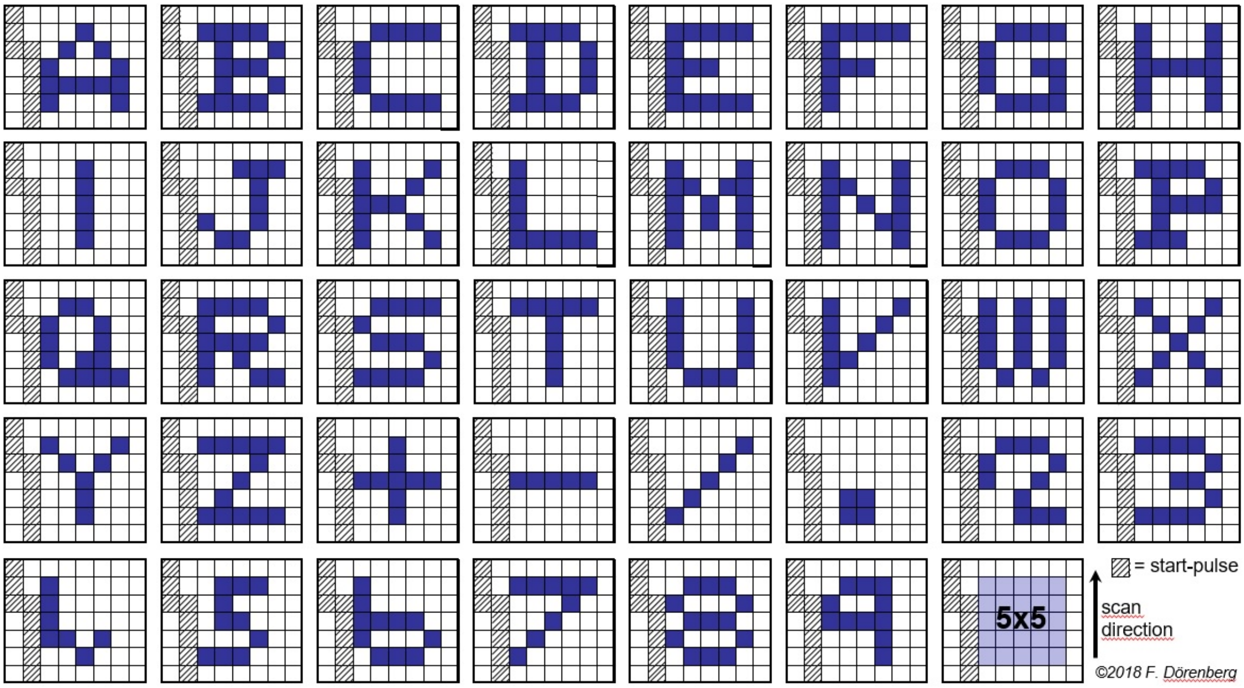


Figure 7: The font of the Telewriter - 5x5 pixels in an 8x7 field
(source: based on by signal tracing in a Telewriter machine by Peter Prest)

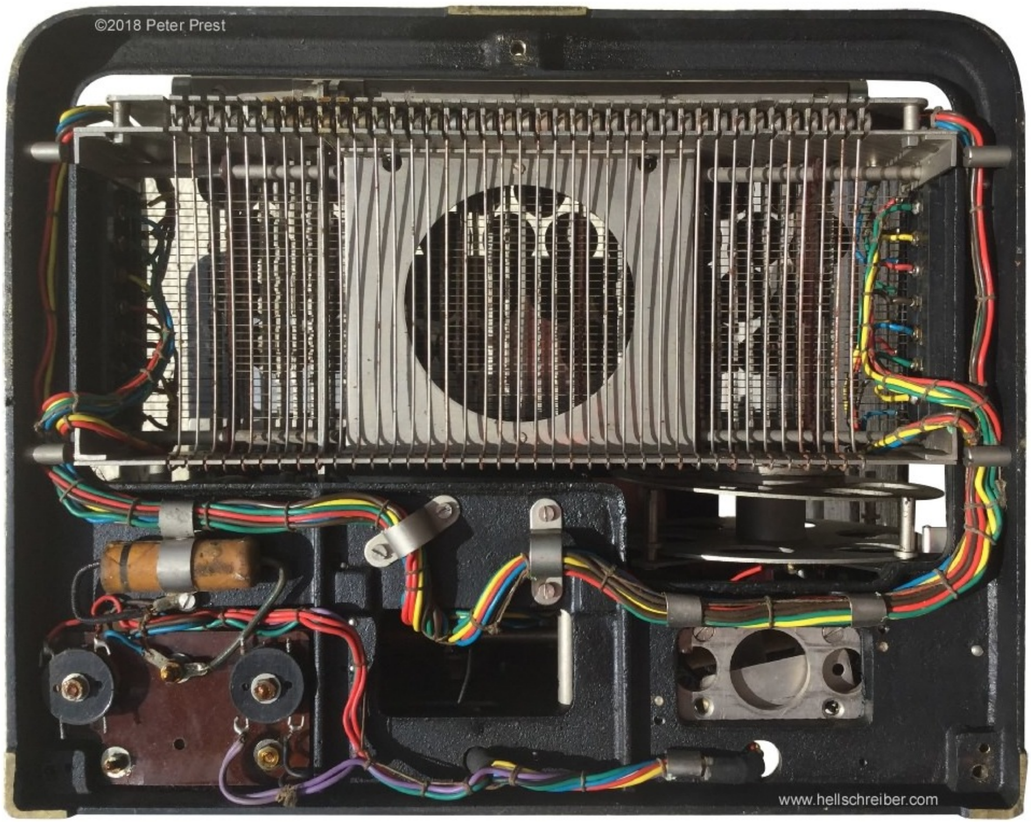


Figure 8: Bottom view of the Telewriter machine
(original unedited photo: ©2018 Peter Prest)

[1] The bitmap font was invented by Rudolf Hell ("father" of the Hellschreiber) in 1929.

As with all pre-1970s keyboard teleprinter systems (i.e., pre Hell-80), the machine has an electro-mechanical font "memory". It comprises an individually coded key bar for each key of the keyboard, a set of 30 cross-wire installed just below the key bars (see Fig. 8 and 9), and a scanning rotary switch with 56 contact studs (one for each pixel of the 7x8 font matrix, see Fig. 10).

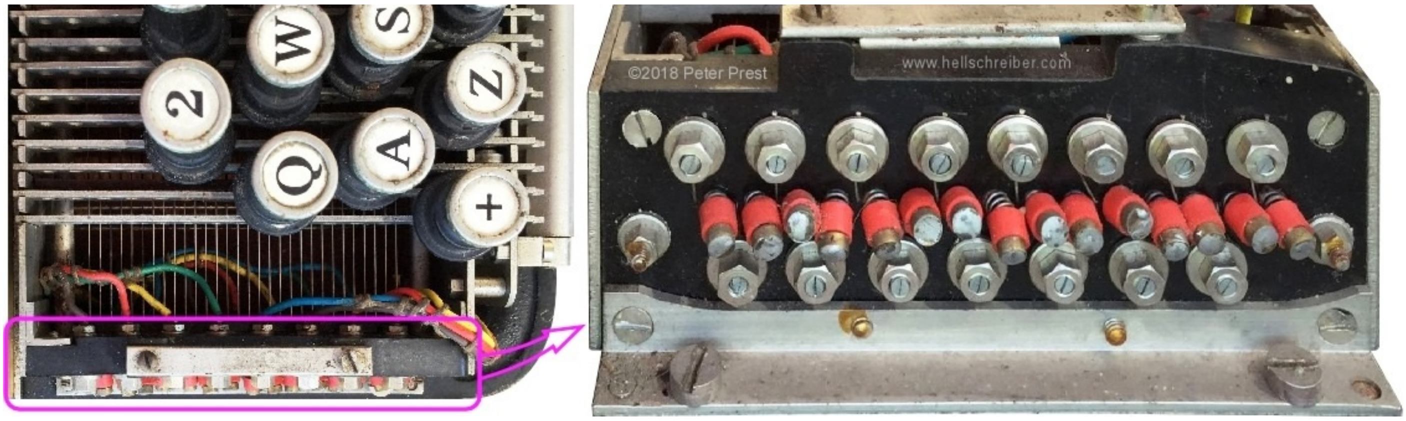


Fig. 9: Fixation & tensioners of the cross-wire ends (same on the right hand side of the keyboard)
(original unedited photos: ©2018 Peter Prest)

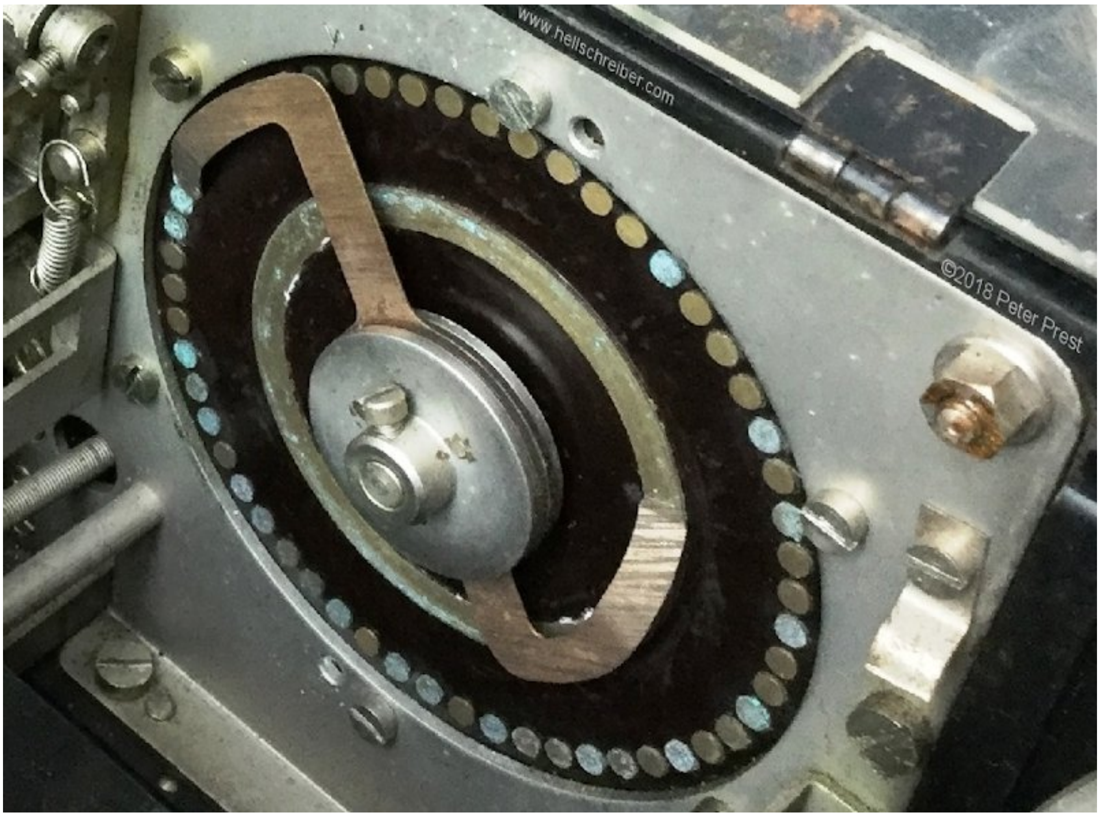


Figure 10: The rotary distributor of the Telewriter machine
(original photo: ©2018 Peter Prest)

The "scanning switch" distributor, with it turned brass studs embedded in black thermoplastic, may have been made by *Painton & Co. Ltd.* of Kingsthorpe/Northampton (est. 1935). Ref. A.

Figure 11: Painton & Co. Ltd. "Winkler" switch wafer and 1952 advertising

The 7x8 font matrix shown in Fig. 6 above, shows that first two columns are identical for all characters. These columns contain the start pulse of 8 pixel durations. This leaves a 7x6 sub matrix for printed character pixels. The last column is always blank, and provides the required spacing between printed characters. Of the remaining 7x5 sub-matrix, the top pixels (row 7) are also always blank. The reason for this is unclear, as a start-stop Hell-printer does not need this: it only prints a single line of text, not two identical lines that require spacing between lines. In the end, the font memory only accommodates a 6x5=30 pixel sub matrix. This is why there are 30 cross-wires installed below the key bars of the keyboard. Note, however, that the five pixels of the bottom row are not used in the actual font of Fig. R7. Most likely, these pixels (and associated cross-wires) were reserved for making the font more legible at some point in the future - as was done in the "real" Hell fonts.

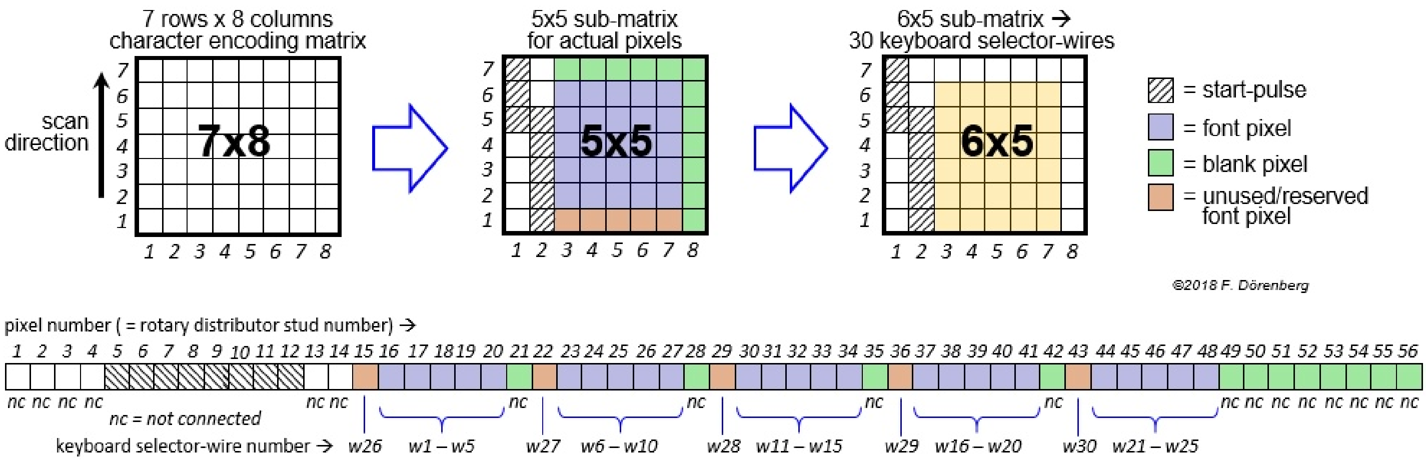


Fig 12: From full character encoding to "keyboard selector + rotary distributor" implementation

Each of the 30 cross-wires is connected to the corresponding contact stud of the rotary distributor:

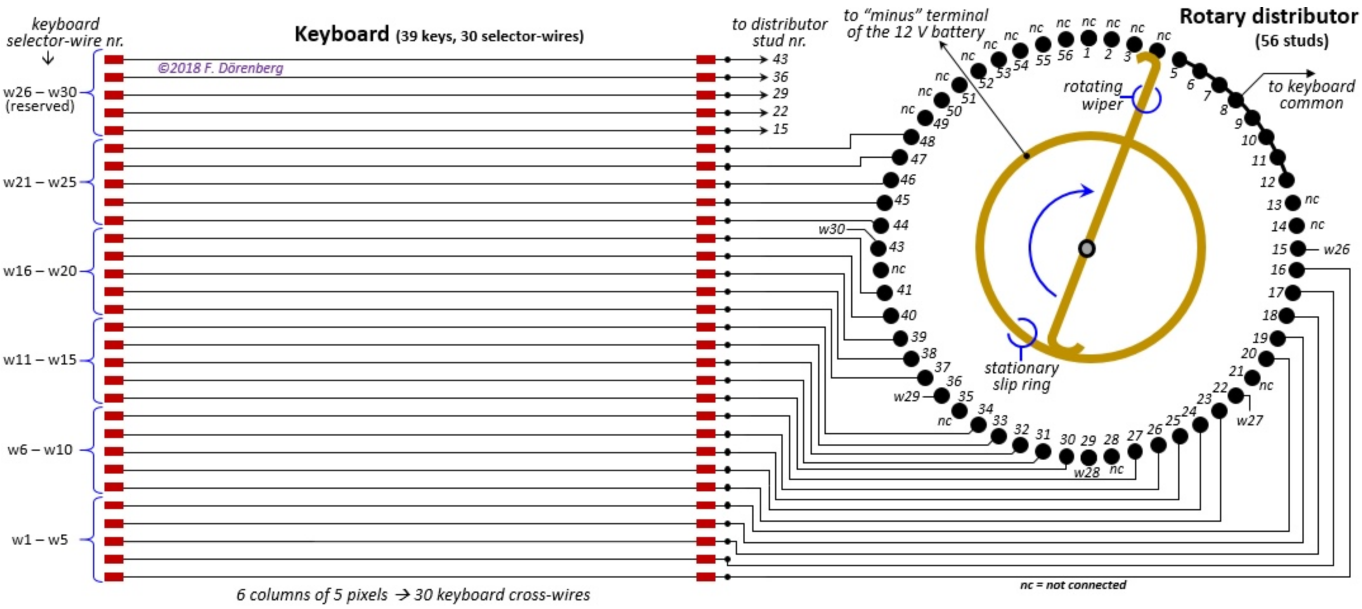


Figure 13: Connections between keyboard cross-wires and rotary distributor (distributor wiper shown at the rest position = stud 4; note: on the machine, stud 9 is at the top)

The contact studs that correspond to the start pulse pixels are hard-wired to the electrical "common" of the local key board and printer mechanism, and to the "L1" terminal of the 2-wire line that is connected to a remote Telewriter machine.

Each keybar has key-specific protrusions:

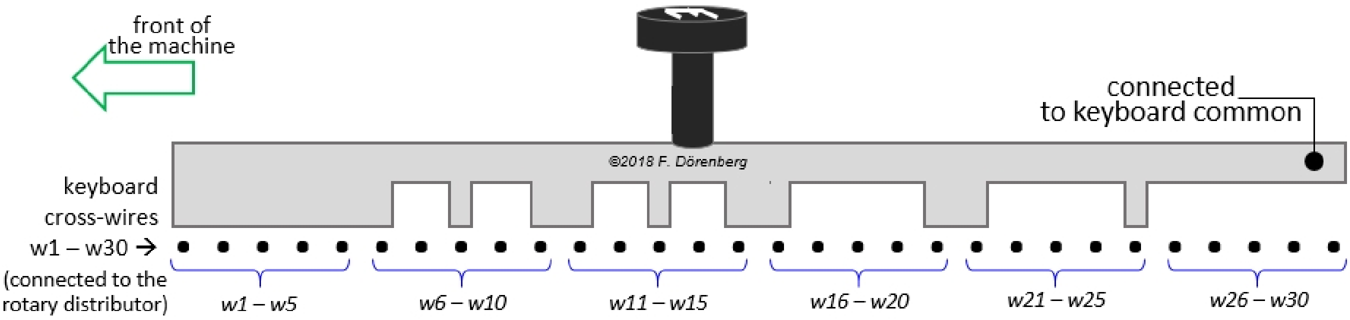


Figure 14: Keybar for the letter "E"

When a key is engaged by pressing it, the protrusions make contact with (only) the cross-wires that correspond to the pixels of that particular character. As in Creed teleprinters (in particular Creed model 3X), the keybar is perforated to save weight.

When the machine is turned on, the motor is running continuously. As described in detail further below, when a key is pressed, the wiper of the rotary distributor makes exactly one revolution at a speed that is equivalent to 160 rpm = 160 characters per minute = 160/60=2.67 characters/sec. Each time the wiper passes a stud contact that is connected to "common" via the cross-wires and the selected key bar, a DC voltage pulse causes a pixel dot to be printed by the local printer and simultaneously by the connected remote printer. When the distributor wiper transitions from one stud to the next, the contact is "make before break" (i.e., both studs are briefly connected). While printing a character, the paper tape smoothly advances over the width of a character and then stops, like the rotary distributor.

THE DRIVE MECHANISM

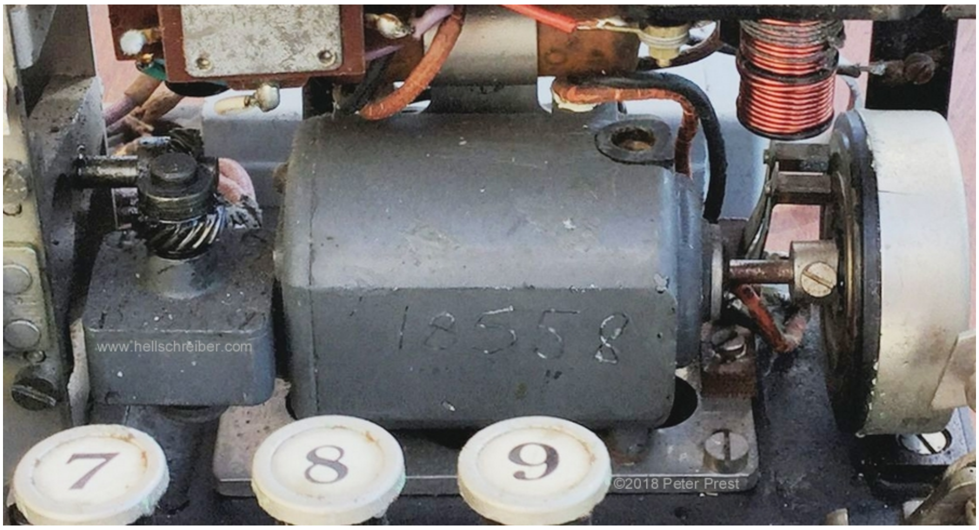


Fig. 15: 12 Vdc motor of the Telewriter machine in situ - with 90° gearing (left) and centrifugal governor
(original unedited photo: ©2018 Peter Prest; used with permission)

The motor has a centrifugal governor that is mounted on one of the two motor shafts. As visible in the photo above, the black disk of the governor has two slip rings on the shaft side. Two spring-loaded carbon brushes ride on these rings. Inside the governor, the rings are connected to the two contacts of the centrifugal switch. The governor has a diameter of 5 cm (2 inch).

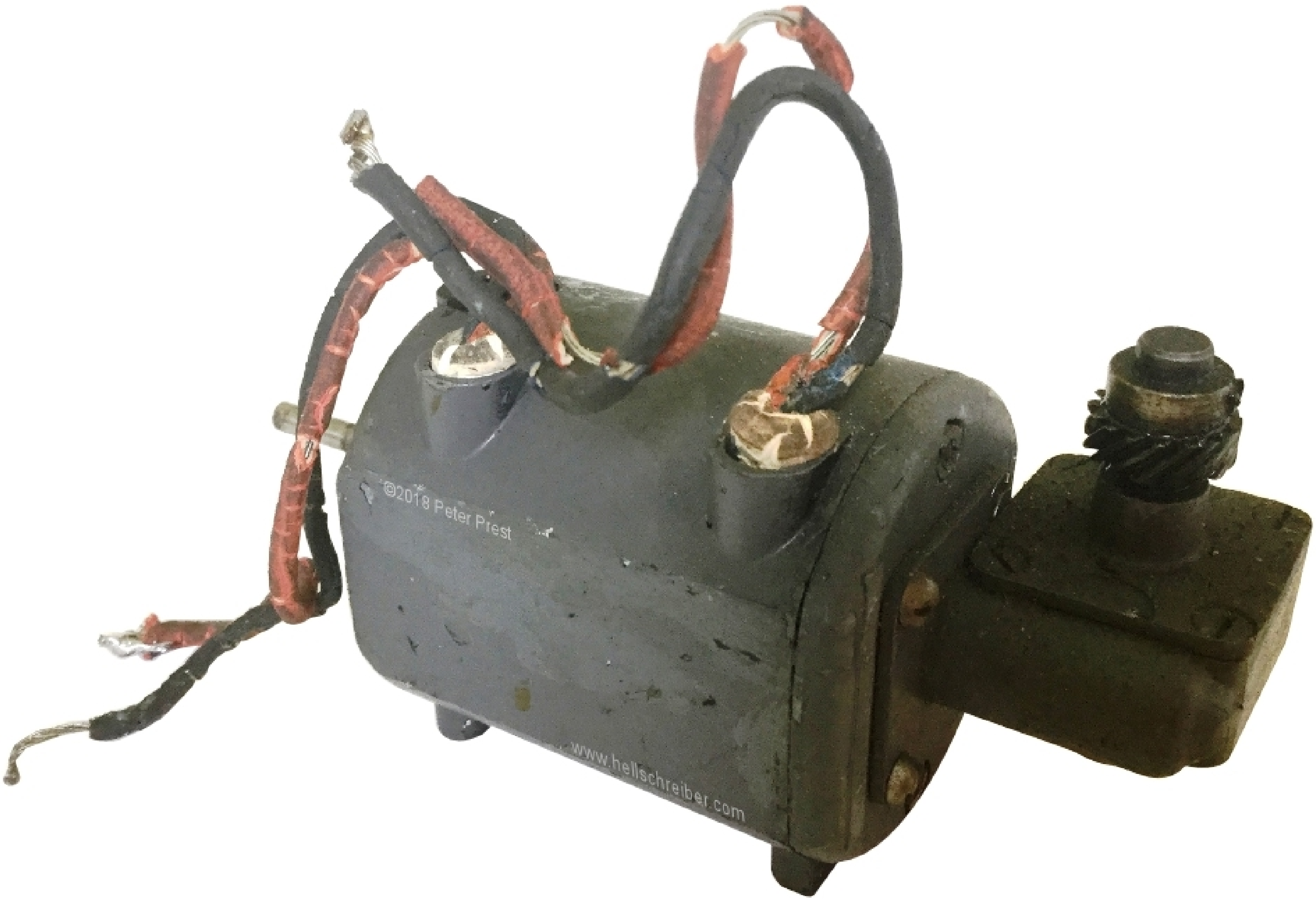


Figure 16: The 12 Vdc shunt field motor of the Telewriter machine - with the 90° gear box attached
(original unedited photo: ©2018 Peter Prest)

Figure 17: The centrifugal governor with its cover - for comparison, the governor of a 1930s Creed 7B teleprinter
(unedited original photo: ©2018 Peter Prest; source photo Creed governor: ref. E)

The manufacturer of the motor is unknown. Another such motor, known to be of WW2 vintage, has Air Ministry markings (embossed "crown + AM"), as well as "Type CM3 12 V" marked on one end bell of the housing.

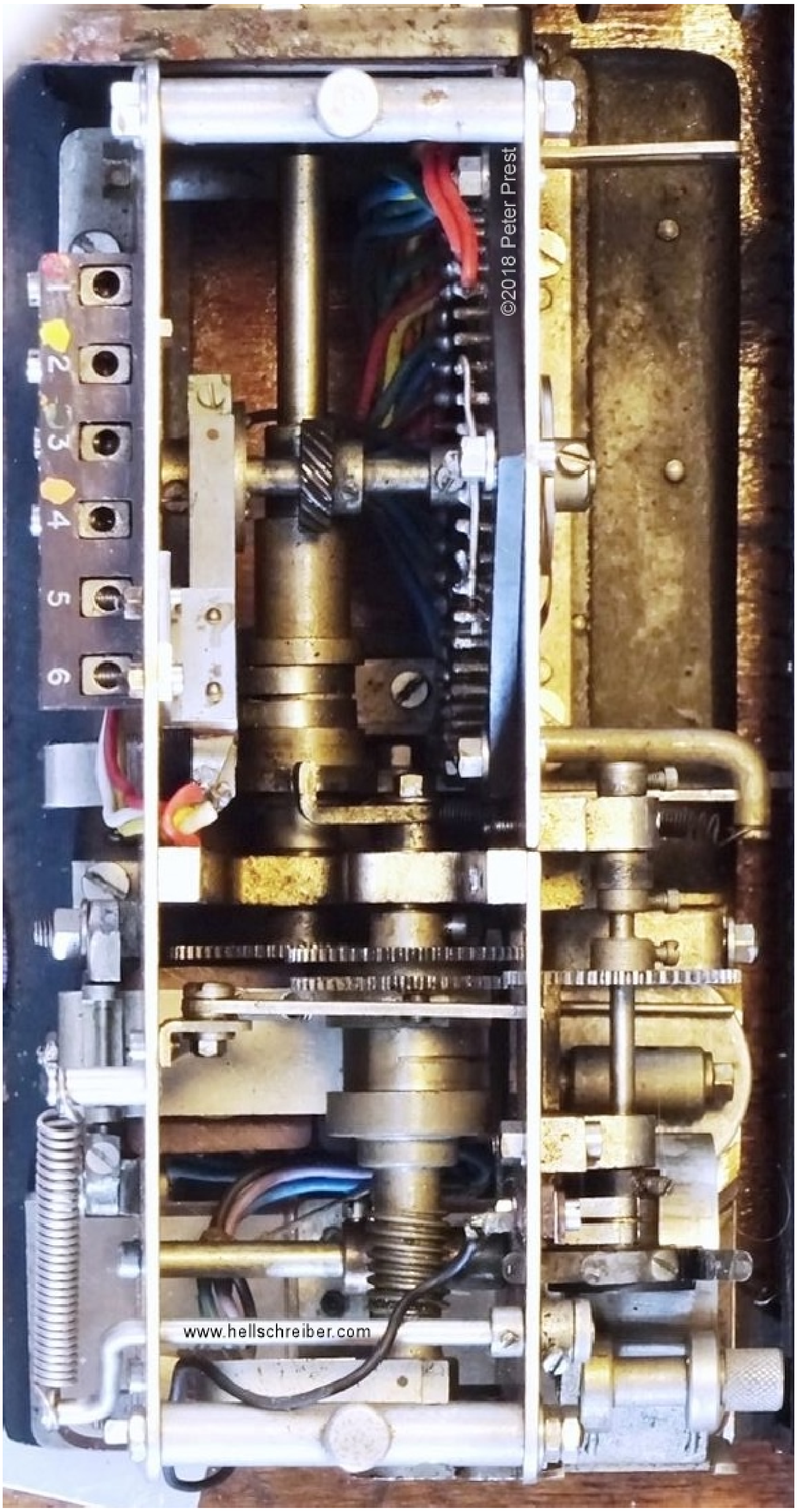


Figure 18: Top view of the drive mechanism
(original unedited photo: ©2018 Peter Prest)

Most of the driven shafts are supported by "Oilite" type bearing bushings (UK: bushes). The bearing sleeves are made of sintered porous bronze and are impregnated with oil, which makes them self-lubricating.

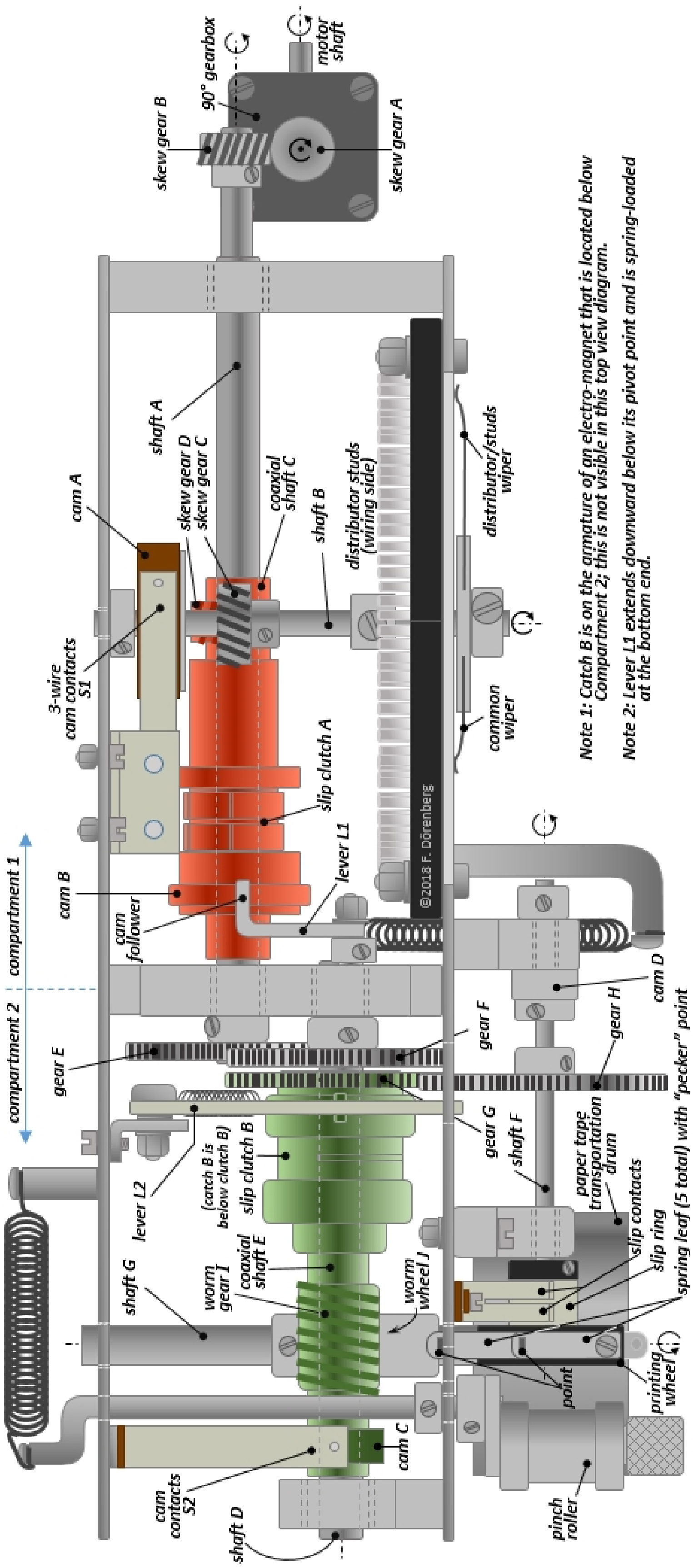


Figure 19: Drawing of the top view of the drive mechanism

Note: lever L2 does not interact with the drive mechanism; possibly it was used to hold coaxial shaft E during assembly of the machine.

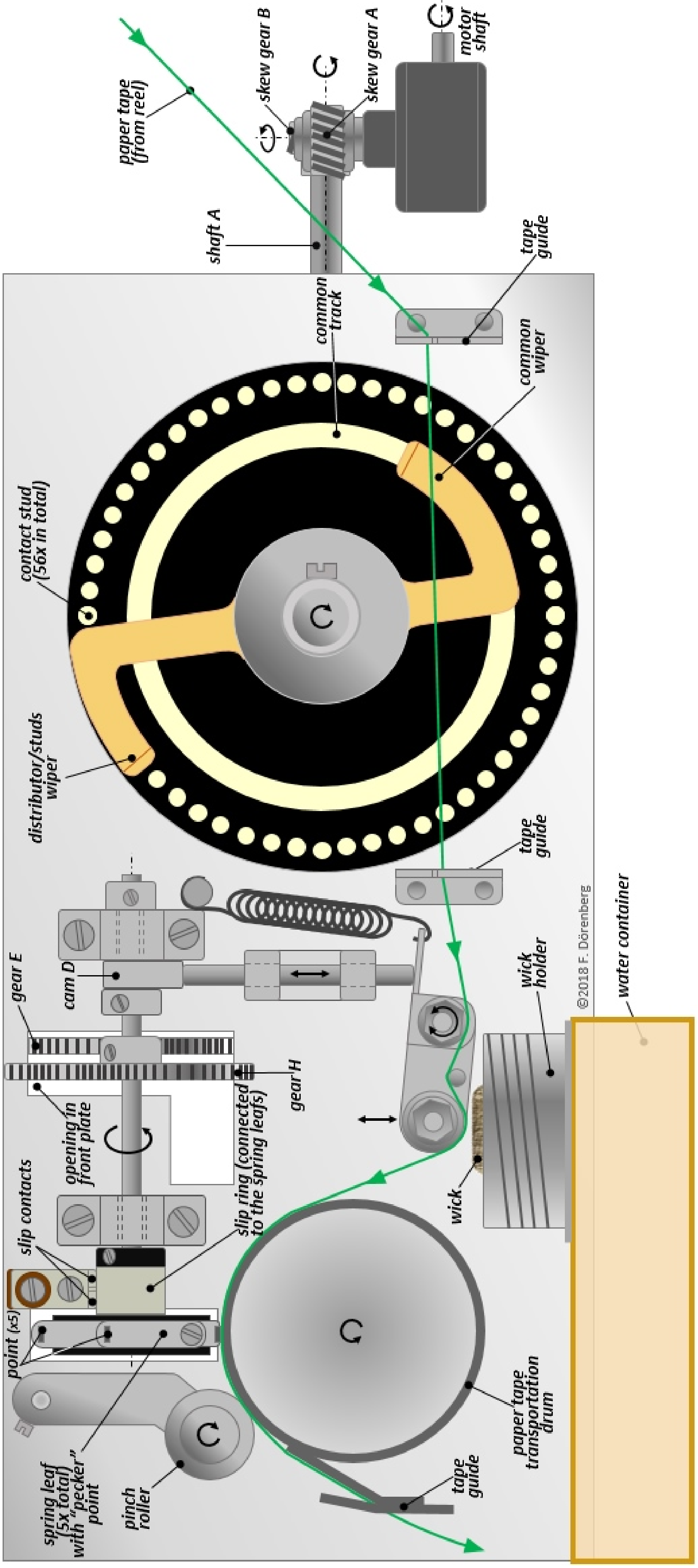
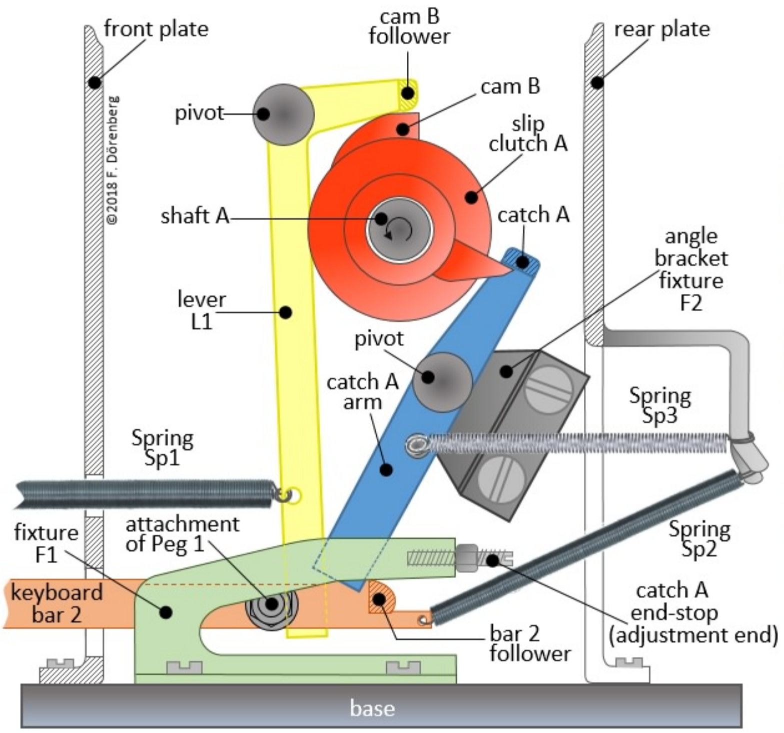


Figure 20: Drawing of the front of the mechanical drive unit with printer and distributor



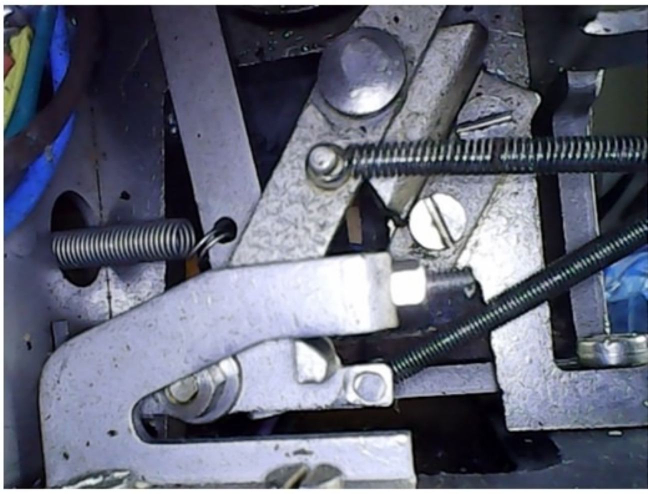


Figure 21: Interaction of keyboard bar 2 and slip clutch A
(photo and original drawing: ©2018 Peter Prest)

The fixture F1 (green), the Bar 2 Follower (orange), and springs Sp2 and Sp3 are also visible in Figure 22 below, through the bottom cut-out in the rear panel:

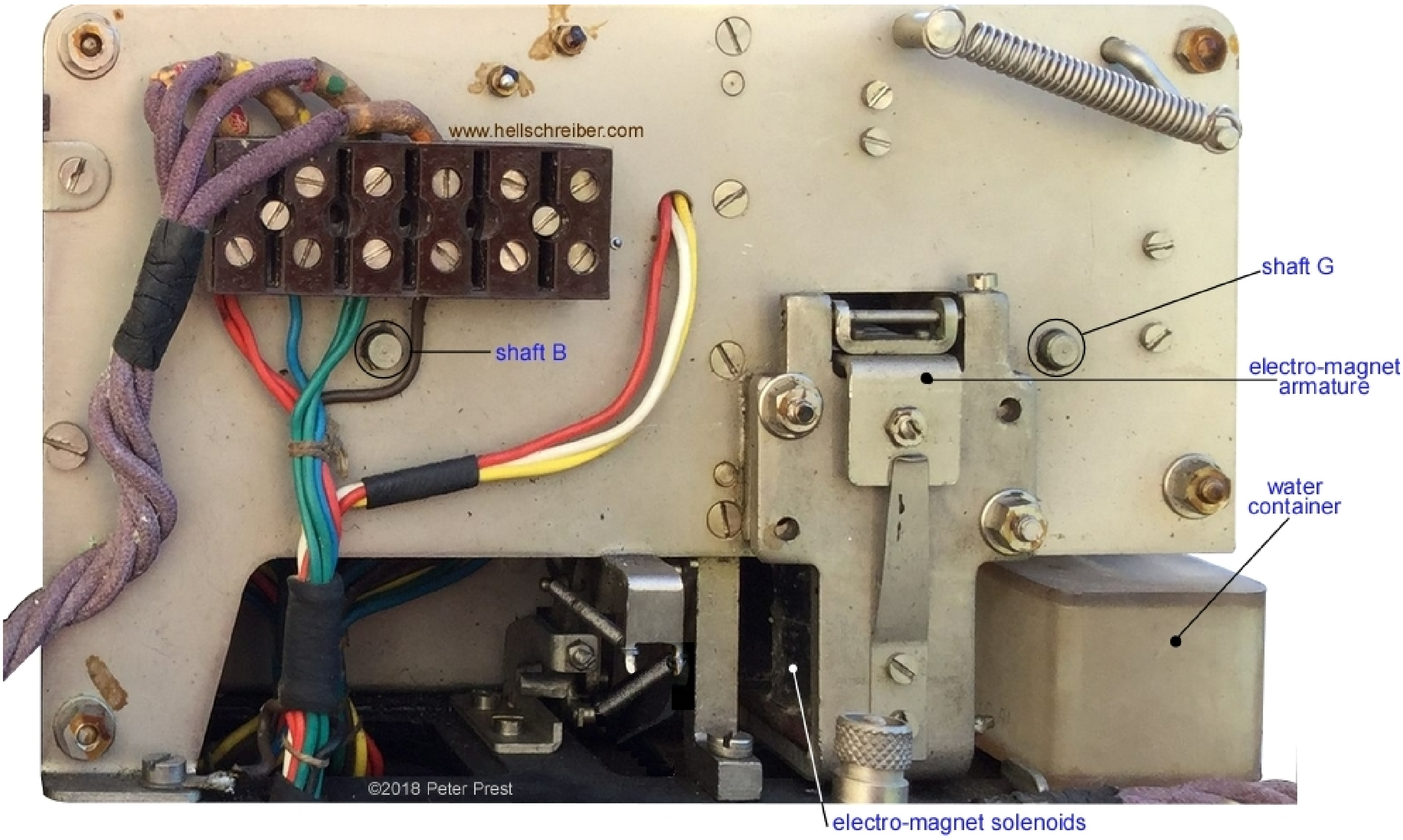


Figure 22: Rear view of the mechanical drive unit
(original unedited photo: ©2018 Peter Prest)

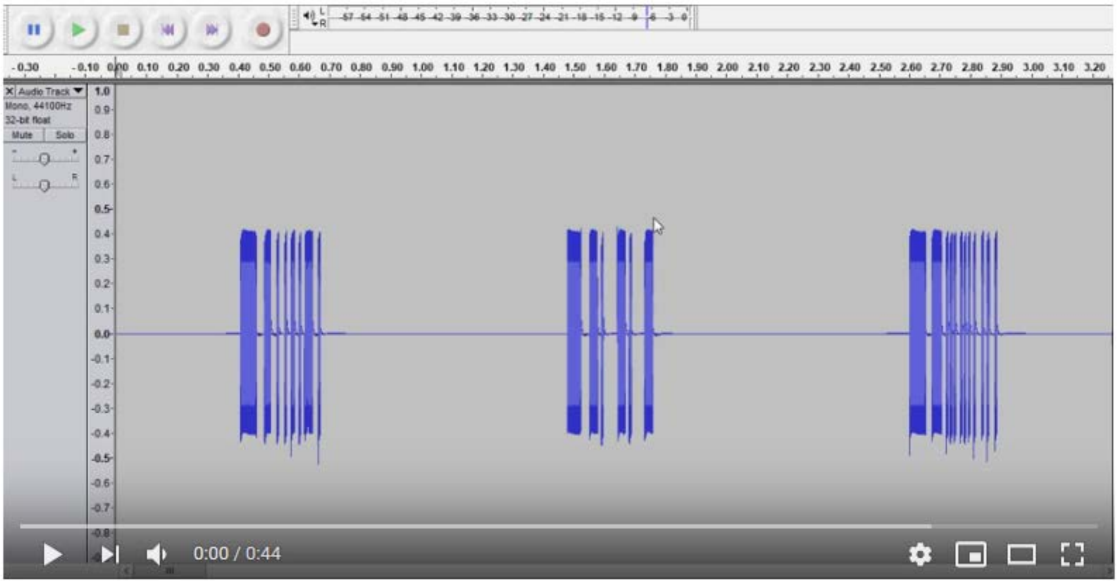
THE DRIVE SEQUENCE

Peter Prest analyzed the motion sequence of the machine with the help of a low-speed motor drive that replaced the original DC motor. Let's go through the mechanical drive sequence for local operation only. Refer to Figures 18 - 22 above, and the schematics in Figures 23 - 25 below:

- The machine is in the powered down state (Master Switch "off"):
    - A 12 volt /16 Ah battery is connected to the + and - terminals.
    - Terminals R1 and R2 are not bridged (they are only strapped for *line* operation, with one or more remote machines).
- The machine is turned on with the Master Switch, which is a 4PDT switch (four simultaneous toggle switches, MS1-MS4):
    - The contacts of MS1-MS4 toggle (see circuit diagram in Fig. 24 below, which shows switch positions for Master "off").
    - The motor starts and runs continuously (switch MS4 is closed).
        - The motor speed is regulated by the centrifugal governor switch S3 (see Fig. 16), which is placed in series with the DC motor's armature. The motor's field winding is energized permanently (as opposed to permanently energizing the armature and using the field winding for speed regulation).
    - Via a small 90° gear box (see Fig. 15, 19), followed by skew gears A and B, shaft A (located in Compartment 1) is now driven continuously. Ref. Figure 21.
    - At the far left end of shaft A (i.e., in Compartment 2), gear E permanently drives gear F. Hence, shaft D is also driven continuously.
    - Note that the coaxial hollow shaft C (colored red in Fig. 19) does not rotate yet! It is prevented from turning with shaft A, as slip clutch A is held by Catch A. Hence, shaft B (of the rotary distributor) does not rotate either.
    - Likewise, coaxial shaft E (colored green in Fig. 19) is at rest. It is prevented from turning with shaft D, as slip clutch B is held by Catch B. Hence, shafts F (= printer wheel) and G (= paper tape transport) do not rotate either.
    - Switch MS3 is closed, so the printer system is enabled.
- The drive system remains in this idling state until one of the keyboard keys is pressed:
    - The hinged keyboard Bar 1 is installed across the front of the keyboard mechanism (see the left hand image of Fig. 9), and passes underneath the SPACE key. If a key is pressed, the entire Bar 1 pivots, and its lower edge moves towards the front of the machine, away from the keyboard.
    - The movement of Bar 1 pulls keyboard Bar 2 (the orange item in Fig. 21) also towards the front of the machine (= to the left in Fig. 21). This causes the Bar 2 Follower to pull on the lower end of the Catch A Arm (blue in Fig. 21), such that Catch A releases Slip Clutch A (red in Fig. 21). As Bar 2 moves forward, the bend in the upper branch of Fixture 1 forces the Bar 2 Follower forward and downward. Spring Sp2 ensures that this follower follows the curved contour of Fixture 1.
    - Shortly after Slip Clutch A is released and now rotates with Shaft A, the Cam B follower of Lever L1 (yellow in Fig. 9) drops off the vertical edge of Cam B, as the lever is pulled by Spring Sp1. The lower end of this lever moves towards the front of the machine until it is stopped by Peg 1 that is mounted on Bar 2. The force of the spring is such that Bar 2 is kept in its forward position, and thereby Bar 1 in its downward pivoted position. Therefore, the pressed key remains pressed for the duration of the motion sequence, while preventing all other keys from being pressed. The forward motion of Bar 2 causes its follower to slide past the bottom end of the Catch A Arm. The latter then pops back against the adjustable Catch A End-Stop of Fixture 1, as it is pulled by Spring Sp3. This re-arms Catch A, for disengaging Slip Clutch A from Shaft A again at the end of the drive sequence.
    - The keybar (see Fig. R15) of the pressed key descends onto the 30 keyboard cross-wires (see Fig. R9, R10, R14). Each keybar has key-specific protrusions that touch a subset of these wires, and connect them electrically to keyboard "common". This wire subset corresponds to the pixels that make up the character that is selected with the pressed key (Fig. 6, 13). Each of the 30 cross-wires is connected to

one of the 56 studs of the distributor (though wires nr. 26-30 are held in reserve and are not used). Via the keybar protrusions, only the key-specific pixels are enabled.

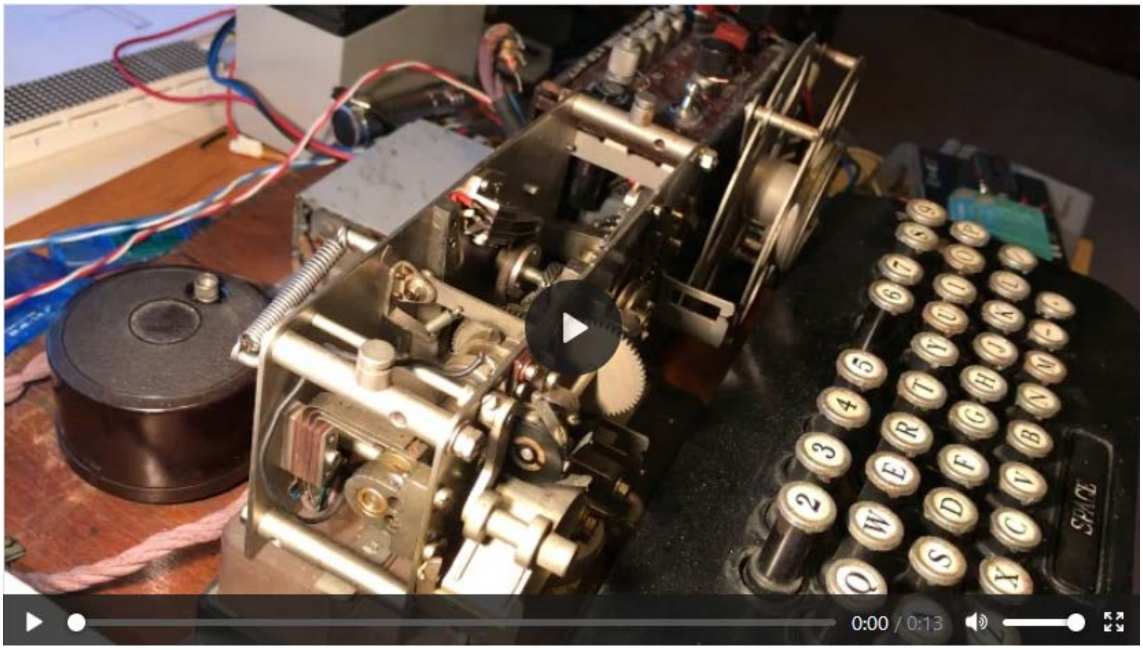
- As soon as, and as long as, Slip Clutch A is released, the coaxial shaft C rotates with the continuously turning shaft A. Via skew gears D and C, shaft B (= rotary distributor) now also turns. The distributor wiper (which was at rest at distributor stud nr. 4) rotates clockwise (looking at the front of the machine), and in sequence, makes contact with each of the 56 pixel studs.
- The rear part of Shaft B carries Cam A. When idling, the follower of the cam-driven contact S1 rests in the notch of Cam A and S1 is connected to terminal R1 (see Fig. 23-25). As shaft B starts to turn, S1 leaves the notch, is disconnected from R1, and makes contact with the 500 Ω resistor. At this point in the drive sequence, the distributor wiper passes "start pulse" studs nr. 5-12. These studs are hard-wired to keyboard "common". Hence, the electro-magnet is energized via switch MS3 and cam contact S2. This causes the spring-loaded Catch B to release Slip Clutch B
- Soon after the motion sequence starts, the cam briefly actuates cam contact S1 (see Fig. 19, 24, 25). This briefly connects one side of the two series-connected solenoids of the electro-magnet to +12 volt: via the 500 ohm resistor, cam contact S1, switch MS3, and cam contact S2.This connects the lower side of the solenoids to the negative terminal of the 12 volt battery. The resulting energization pulse causes the spring-loaded armature of the electro-magnet (see Fig. 22) to pull Catch B, which releases Slip Clutch B. In turn, this enables coaxial shaft E (green in Fig. 19) to rotate with the continuously turning shaft D. As shaft E rotates, Cam C changes the state of cam-driven contact S2. This causes the electro-magnet to be de-energized. I.e., the electro-magnet is only energized by a short pulse. Catch B is re-armed as soon as the solenoid energization pulse subsides. However, this catch cannot disengage Slip Clutch B until the end of the drive sequence.
    - The two solenoids of the electro-magnet are marked "500" in the original circuit diagrams (Fig. 23, 24). In the machine of Peter Prest, these components are actually marked "580 Ω" and "ST.39362 A". The buzzer relay is a British Post Office type, marked "4671 ACF W43.1", and its metal cover is embossed "AN".
- Coaxial shaft E drives shaft F (= printer wheel) via gears G and H. It also drives shaft G (= paper tape transport) via worm gear I and worm wheel J (see Fig. 19, 20). During the drive sequence, the printer wheel makes one revolution, whereas the paper tape transportation drum is rotated over the width of a printed character.
- During the remainder of the drive sequence, the wiper contact of the rotary distributor touches contact studs nr. 14-56 followed by nr. 1-3. Based on the pressed key, specific contact studs are connected to keyboard "common", via the protrusions of the associated keybar. Each time the distributor wiper passes over such a "pixel" contact, the scanning "pecker" of the printer wheel creates a blue pixel on the paper tape.
- Near the end of the drive sequence, the Cam B follower of Lever L1 is lifted again by Cam B (see Fig. 21). This causes the bottom of the L1 lever arm to move towards the back of the machine. This allows the keybar spring to push Bar 2 also backward, and release the pressed key by letting Bar 1 pivot back to its default position. At the same time, the rounded edge of the Bar 2 Follower rides over the bottom of the Catch A Arm (momentarily pushing the back end of Bar 2 downward), before reaching its initial position again.
- Catch A was already re-armed, shortly after starting the drive sequence. It will disengage Slip Clutch A from Shaft A when the Catch grabs the notch of that Slip Clutch again, at the end of the latter's revolution. Likewise, Catch B disengages Slip Clutch B from Shaft D.
- Both of the cam-driven switch contacts (S1 and S2) are also back in their starting state.
- This terminates the drive sequence, and the machine idles until the next key is pressed.



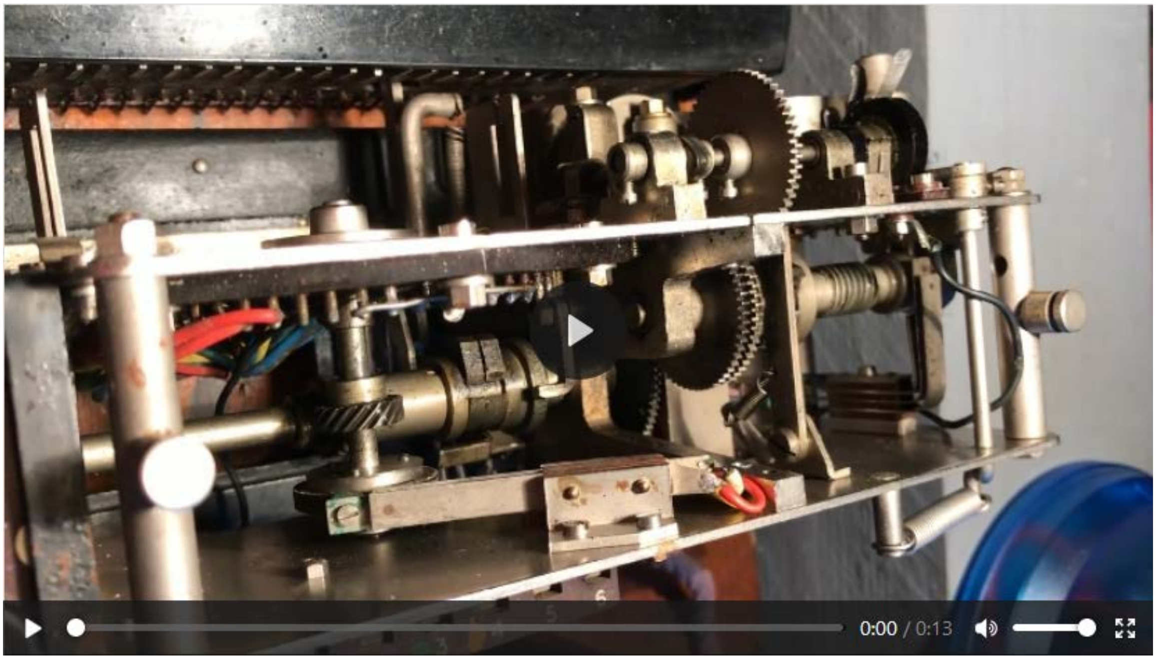
Recording of the Telewriter character set - distributor pulses converted to 1500 Hz tone pulses
Visit https://youtu.be/GIkyr7EPYsU ***to hear & see the above clip on YouTube (©2018 Peter Prest)***

The sequence of the recorded 38 characters follows the Telewriter keyboard rows from left to right: Q through P, A through /, + through •, 2 through 9. Note that the Telewriter uses bursts DC pulses, not tone pulses. For illustration purposes, the DC pulse sequences were converted to tone pulses with a tone frequency of 1500 Hz. Below are three video clips that show the motion of the distributor wiper, the printing wheel and paper transport drum below it, upon pressing one of the keyboard keys. To be able to show the entire drive sequence in slow motion, the original DC motor was replaced with a (whining) stepper motor.

VIDEO: Front view of the Telewriter - covers removed, single character motion sequence
Visit https://youtu.be/MSf0N2vLEnM ***to see the above video clip on YouTube (©2018 Peter Prest)***



Angle view of the Telewriter - covers removed, single character motion sequence
Visit https://youtu.be/stSGCWTN1Fw *to see the above video clip on YouTub (©2018 Peter Prest)*



Top view of the Telewriter drive system - covers removed, single character motion sequence
Visit https://youtu.be/x1kTa1jNO1M *to see the above video clip on YouTube (©2018 Peter Prest)*

When two Telewriter machines are connected, the following overall system circuit diagram applies:

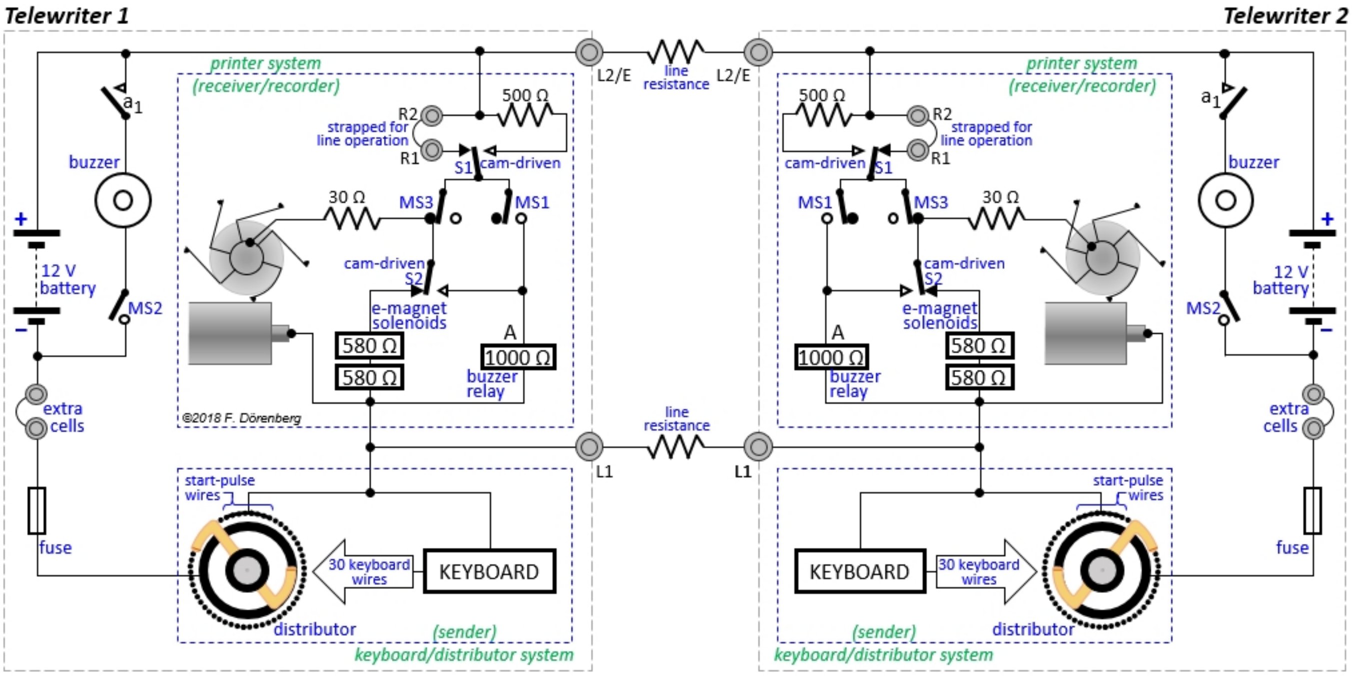


Figure 23: Telewriter circuit diagram - two machines interconnected
(switch contacts MS1-MS3 shown for Master Switch MS in "ON" position; MS4 is in the motor circuit - not shown)

The above diagram is based on the official *complete* circuit diagrams shown in Fig. 24 and 25 below. To make it easier to follow and understand the power and signal flows, the motor circuitry is not shown, and the layout has been rearranged. The diagram shows two Telewriter machines in the "line operation" configuration: in both machines, the terminals R1 and R2 have been strapped, and the two machines are interconnected via their L1 and L2/E terminals.

Let's assume that one machine is powered up and idling, whereas the second machine is powered off. Each machine has a "call buzzer". In both machines, the buzzer is normally "off". In the idling machine, this is because switch contact MS2 is open (Master Switch is ON), as is relay contact a_1. The associated buzzer relay cannot be energized, because switch contact MSN1 is open (Master Switch is ON). In the second machine, switch contact MS2 is *closed* (Master Switch is OFF), and relay contact a_1 is open.

Each time a key is pressed on the idling machine, it will go through a drive sequence as detailed above. Each time its rotary distributor makes a revolution, the start-pulse contact studs and the pixel contact studs of the pressed character (none for SPACE) cause the minus terminal of the 12 volt battery to be connected to the L1 terminal of the operating machine. Via the line wire, this terminal is connected to the L1 terminal of the "sleeping" machine, and the lower side of its buzzer relay. The plus 12 volt terminal of the operating machine is connected to *upper* side of the buzzer relay in this "sleeping" machine (via the L2/E line, the R1-R2 strap, and the closed MS1 contact). So, each pulse of the rotary distributor in the *operating* machine energizes the buzzer relay in the *sleeping* machine and briefly activates the buzzer. The buzzer pulses will prompt the operator of the "sleeping" machine to turn that machine on, which disables the buzzer (MS2 is open). At that point, the system configuration is basically that of two idling machines.

Standard operating procedure after turning the machine on, is to advance the moistened tape from the water container wick to the printer wheel, by pressing any key a sufficient number of times (ref. B). At the same time, this would signal "ready to receive message" to the operator of the calling machine, as we will see next.

When a key is pressed on either of the two idling machines, that sending machine will go through a complete drive sequence:

- The start pulse in the sending machine will cause the solenoids of the local electro-magnet to be briefly energized.
- The solenoids in the receiving machine are energized simultaneously. They are effectively connected in parallel with those in the sending machine: via the L1 and L2/E line connections, the R1-R2 strap, the (still closed) cam-driven S1 contact, switch contact MS3, and the cam-driven S2 contact. The energization pulse causes Catch B to release Slip Clutch B. The printer drive mechanism in this machine (Slip Clutch B, all downstream gears and shafts, the printer wheel and the paper tape transport) will go through the standard drive sequence.
- In the receiving machine, no key is pressed. Hence, its Slip Clutch A is not released and the rotary distributor remains at rest! Only the printer mechanism is activated!
- The motor in the receiving machine is powered by the local 12 volt battery, but the current for its electro-chemical printer comes from the battery of the sending machine, via its distributor.
- Upon completion of the drive sequence, both machines are in the idling state again.

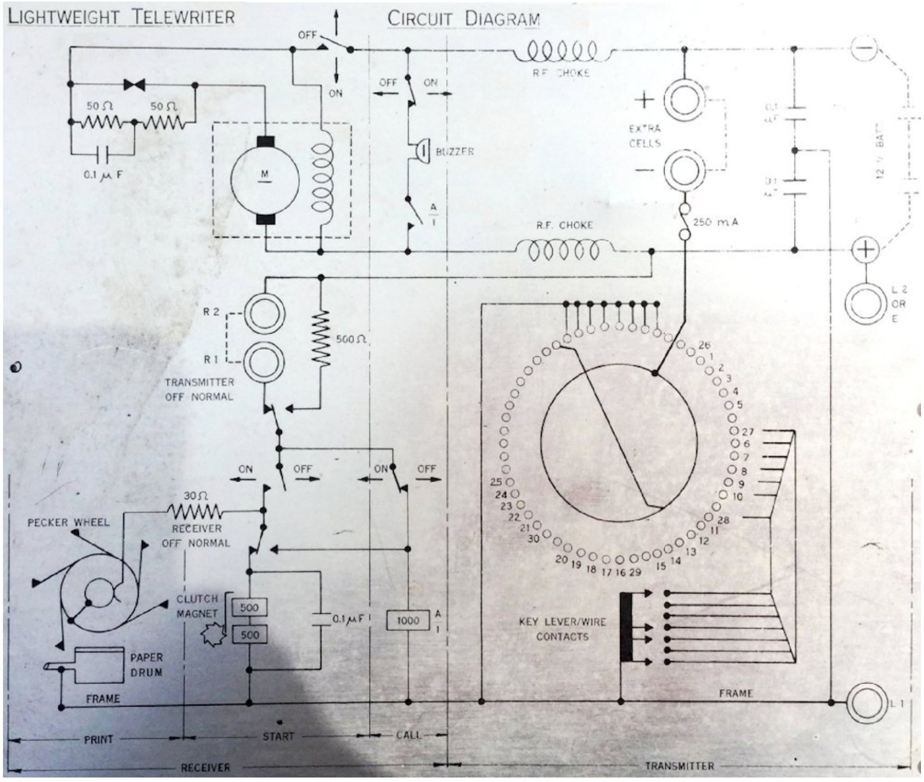


Figure 24: Telewriter circuit diagram - aluminum placard on the machine
(original unedited photo: ©2018 Peter Prest)

The circuit diagram shown in the 1945 instruction manual is slightly different (and improved):

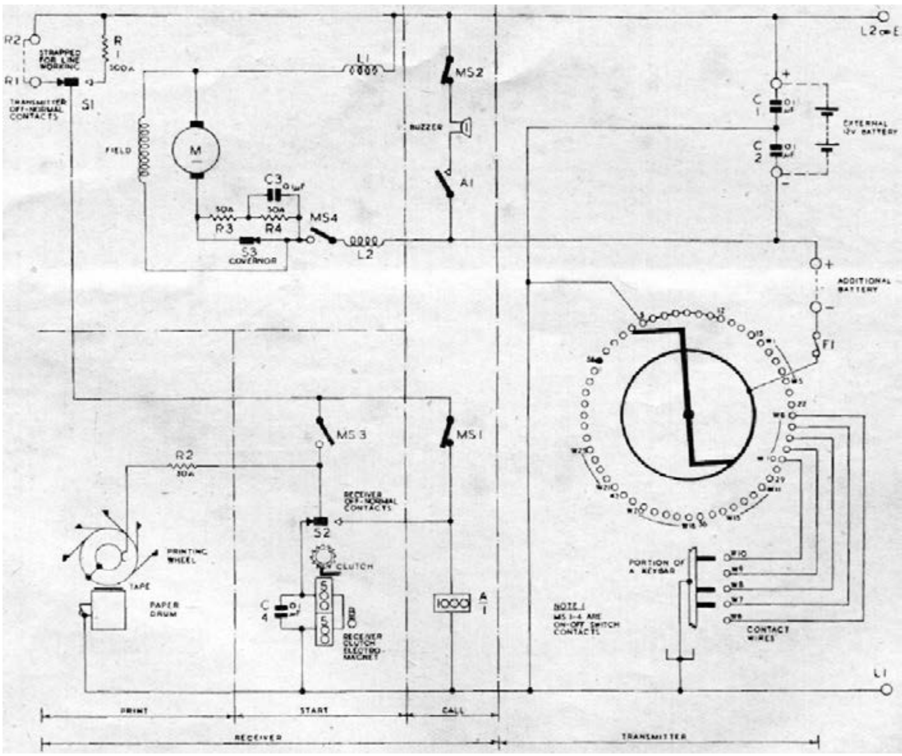


Figure 25: Telewriter circuit diagram - from the Work Instructions (manual)
(source: Fig. 5 in ref. 43B)

In Fig. 25, compared to Fig. 24, the "pecker wheel" is called "printing wheel", the 56 studs of the rotary distributor have been renumbered, all switch and relay contacts are labeled ("MS" refers to the 4DPDT On/Off **M**aster **S**witch, whereas S1 and S2 are cam-driven), correct symbology is used for those contacts, the buzzer is connected between the battery and the motor's RF choke inductors, and switch MS1 and buzzer relay contact A1 are swapped (Figure 25 reflects the actual wiring). The 30 ohm resistor in series with the printer wheel provides current limiting, in case the printer mechanism is inadvertently operated without paper tape while the machine is configured for line operation. I.e., R1 and R2 are strapped, there is no line resistance, and only the 250 mA fuse and the series resistor provide protection. To the right of the printer/distributor drive unit, there is an interconnection panel with the main switch:

Figure 26: Panel with main switch, fuse, and terminals for phone line & batteries (original unedited photo: ©2018 Peter Prest)

The panel has two phone line terminals that are labeled "*L1*" and "*L2 or E*". Communication between machines was via a 2-wire phone line, or a single-wire phone line with return via ground/**e**arth ("*E*"). This could be a point-to-point or an "omnibus" circuit (a.k.a. "party line", where the line is shared by multiple parallel terminals). As signaling was done with DC pulses, the phone lines could not include transformers. Up to four additional 1.5 volt cells (of an 8-cell battery) could be connected to the machine, to boost the line voltage so as to obtain sufficient signal current in the remote receiving machine(s) when operating with a line resistance above 1000 ohms (ref. B). When no additional cells are used, the terminals marked "EXTRA CELLS" are bridged. A 250 mA fuse is in series with the additional cells. The fuse holder is made by *Belling & Lee* and has a "10H/9613" military stores part number. The terminals marked "*R1*" and "*R2*" are to be bridged for line operation. See the schematics (Figs. 24 & 25 above) and the operating manual (ref. B). Note that the "+" of the 12 volt battery is connected to L2/"earth", not to L1!

Fig. 27: Top of the "incoming call" buzzer, made by Sun Electrical Co. Ltd., and 1918 SunCo advertising

THE WATER CONTAINER

The water container measures 3.5x2.75x1.09 inch (WxDxH, ≈ 8.9x7x2.8 cm). It is made of six separate pieces of yellowish celluloid-like translucent plastic. The material is about 0.085 inch thick (≈ 2.2 mm). The top and bottom pieces are L-shaped, see photos below. The side is a single strip that was softened and formed into the outline of an "L", and is sandwiched between the top and bottom pieces. The ends of the strip overlap by about half an inch (≈ 1^+ cm), and are glued together. There are three strengthening pieces installed on the outside of the container: a round piece underneath the circular base of the wick holder, a rectangular one underneath the spring-loaded container retaining clip, and a small round piece for the cap chain retainer. The first piece and metal base are fixed from below with four brass screws that are cut off and filed flat on the outside. The retaining clip is fixed with two brass screws and nuts. The screw cap and wick holder are made of nickel plated brass. The flat wick is about 0.7 inch wide (≈ 18 mm). The wick holder base holds a round plate with two projections that prevent the plate from turning. The plate holds a retaining clip with ends that are folded upward. The wick is passed upward on one side of the clip, across it, and down again on the opposite side of the clip, back into the container. The wick is long enough such that both ends lie on the bottom of the container. The plate can be pulled out, to refill the container with water, or to replace (or adjust) the wick. The wick is actually a long rectangular strip of coarse cotton-like cloth, folded over lengthwise, with the open edges sewn to form a long, closed flat envelope. The envelope is filled with a long strip of material, possibly felt.

Fig. 28: Top & bottom of the water container with screw cap - note wick holder and the coarse cloth wick

Figure 29: The water container, with the wick holder cap screwed on
(original unedited photos: ©2018 Peter Prest; used with permission)

In Figure 20 above, note that the just-moistened paper has to travel a certain distance to the printer wheel. Probably the width of a dozen or so printed characters. This is why the Working Instructions (ref. B, §6) state that before actually using the machine, the operator must "*depress any key several times until the damp part of the paper reaches the peckers*."

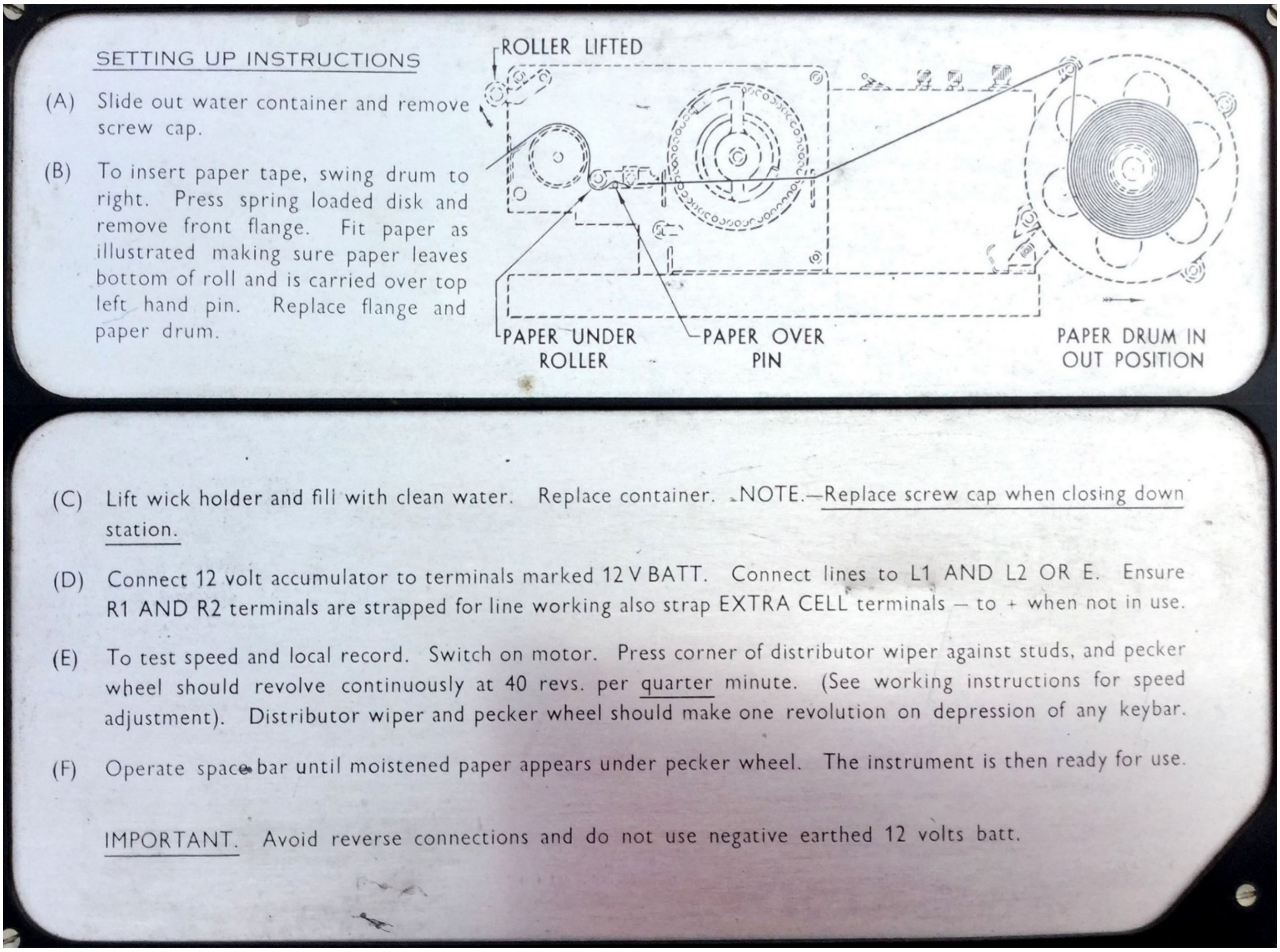


Figure 30: Setting up instructions - placards on the machine's paper stand (see Figure 2)
(original unedited photo: ©2018 Peter Prest; used with permission)

REFERENCES

NOTE: all referenced documents are included in this document as embedded attached pdf files! If necessary, toggle the left-hand tool bar to make the list of attachments visible.

- **Ref. A:** "A Portable Hellschreiber Variant", personal correspondence, David H. Jones, October 2011, January 2014, and April 2018, 4 pp.
- **Ref. B:** "TELEWRITER Working Instructions", YB 04159, The War Office, Whitehall, December 1945, 10 pp., printed by Fosh & Cross Ltd., London. Courtesy L. Meulstee.
- **Ref. C:** "Improvement in Electro-chemical telegraphs", Robert Smith, Alexander Bain, United States Patent no. 6837, 30 October 1849, 5 pp.
- **Ref. D:** pp. 70, 71 in "Use of electrochemical recording in medical instruments", N.K. Golobokii, pp. 70-73 in "Biomedical Engineering", Vol. 6, Issue 2, March 1972; accessed 18 November 2018; original article appeared in "Medistinskaya Tekhnika", nr. 2, March-April 1972, pp. 8-13].
- **Ref. E:** p. 2.3 in "Teleprinters", chapter 2 in "RSGB Teleprinter Handbook", A. Hobbs, E. Yeomanson. A. Gee, RSGB, 2nd ed., 1973.
- **Ref. F:** pp. 478, 479 in "The Royal Corps of Signals - A History of its Antecedents and Development", R.F.H. Nalder, 1958, Royal Signals Institution (publ.), London, 672 pp.
- **Ref. G:** pp. 160, 161 in "The History of British Army Signals in the Second World War: General Survey", R.F.H. Nalder, 1953, Royal Signals Institution (publ.), London, 377 pp.
- **Ref. H:** "Telewriter - First Echelon Work", Draft E.M.E.R. TELS T 223/1, Signals Research and Development Establishment (S.R.D.E.), Somerford, Christchurch Hampshire/England, March 1945, [note: the attached document only comprises the cover sheet]
  - E.M.E.R. = Electrical & Mechanical Engineering Regulation; TELS = EMER Group = Telecommunications, T = Section = Telephony; 22 = Equipment Designator = ???; 3 = Part Number; /1 = Mark.
- **Ref. J:** "Telewriter Procurement", Peter Prest, December 2018, 5 pp.
- **Ref. K:** "Letters from B. Robertson to the Science Museum in London, offering to donate his Telewriter", February/March 1968, 3 pp.
- **Ref. L:** Sheet 4 (pdf p. 8) in "Method of and apparatus for electrically recording and producing sound or other vibrations", Merle Duston, US Patent 2,030,973; Filed 13 August 1931, 12 pp.