The Elektros ETEM 101 Electrostatic TEM

Designed by Gertrude Rempfer

Electrostatic TEMs

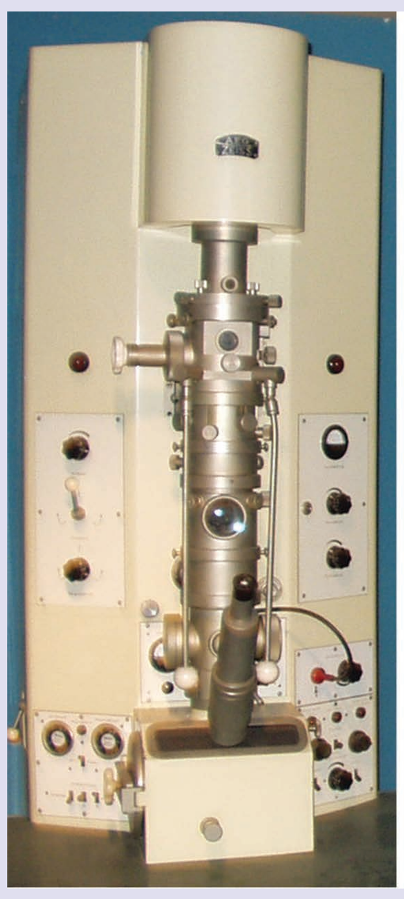
The possibility of both magnetic and electrostatic electron lenses was first realized by Busch, in 1926. In the 1930s, electron microscopes with magnetic lenses were being developed by Ruska and colleagues at the Technical University and at Siemens, both in Berlin, while Brüche and colleagues developed electron microscopes with electrostatic lenses at the AEG research laboratory, also in Berlin. In the late 1930s to mid-1950s, electrostatic TEMs were also built by GE and Farrand in the US, in Switzerland by Trüb, Täber & Cie., by Zeiss-Jena, and in France by CSF. The maximum accelerating voltage eventually increased to 70 kV and resolution reached nearly 1.5 nm.

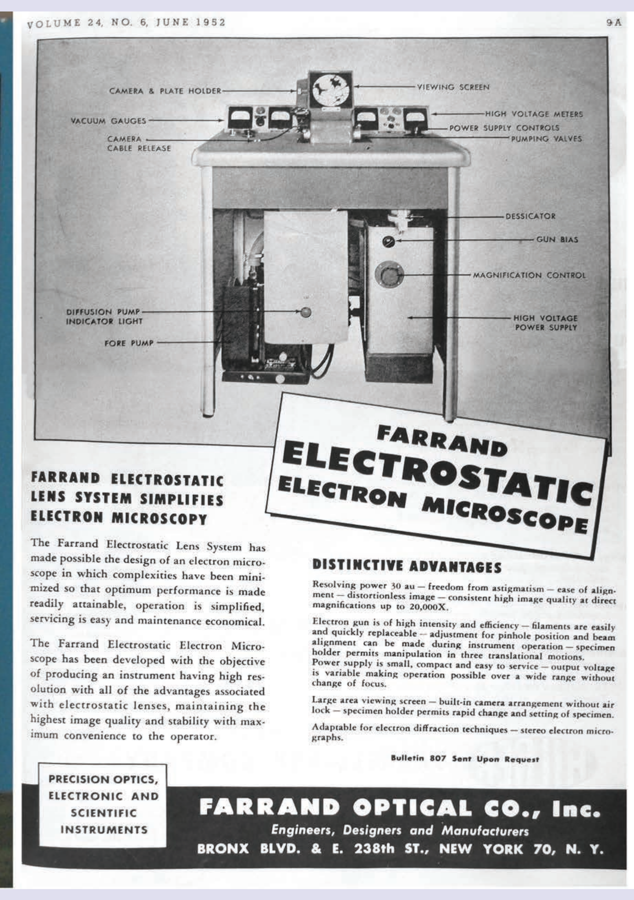
Development of electrostatic TEMs was terminated in the 1950s because magnetic TEMs could have higher resolution (the lenses had shorter focal lengths and lower aberrations), and a higher acceleration voltage (electrostatic lenses operated at nearly the accelerating voltage, thus insulation was a problem). Today, electrostatic columns are found in FIB instruments and in some SEMs (e.g. "micro-SEMs").

Rempfer's involvement with earlier electrostatic TEMs

Left: A 1949 AEI/Zeiss EM8 electrostatic TEM. AEG electrostatic TEMs were designed by H. Boersch and H. Mahl. The first model, EM5, was available in1940, EM6 in 1944, EM7 in 1947, and EM8-I in 1949. In 1949, Zeiss took over production of this type up until 1956, ending with the EM 8-IV. Rempfer tested this 1949 TEM while diverted from Farrand to the Naval Research Laboratory. She found it wanting: "AEG gave electrostatics a bad name". This TEM is now in the collection of the National Museum of the History of Medicine.

Right: A 1952 advertisement for a Farrand electrostatic TEM, based on a Rempfer design. Farrand insisted on some design features (including the inverted column shown here), which Rempfer felt were inadvisable, and she left the Ferrand company. This TEM, constructed after Rempfer left Ferrand, in 1951, was never successfully deployed. While at Farrand, she was not allowed to publish, and most patents (e.g. real-time stereo) were assigned to Rüdenberg. Rüdenberg, a consultant to Farrand, tried to defend his original patent for the EM, which he filed days after Ernst Ruska's first lecture presenting the EM.





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FARRAND ELECTROSTATIC ELECTRON MICROSCOPE

FARRAND ELECTROSTATIC LENS SYSTEM SIMPLIFIES ELECTRON MICROSCOPY

The Farrand Electrostatic Lens System has made possible the design of an electron microscope in which complexities have been minimized so that optimum performance is made readily attainable, operation is simplified, servicing is easy and maintenance economical.

The Farrand Electrostatic Electron Microscope has been developed with the objective of producing an instrument having high resolution with all of the advantages associated with electrostatic lenses, maintaining the highest image quality and stability with maximum convenience to the operator.

DISTINCTIVE ADVANTAGES

Resolving power 30 au — freedom from astigmatism — ease of alignment — distortionless image — consistent high image quality at direct magnifications up to 20,000X.

Electron gun is of high intensity and efficiency — filaments are easily and quickly replaceable — adjustment for pinhole position and beam alignment can be made during instrument operation — specimen holder permits manipulation in three translational motions.

Power supply is small, compact and easy to service — output voltage is variable making operation possible over a wide range without change of focus.

Large area viewing screen — built-in camera arrangement without air lock — specimen holder permits rapid change and setting of specimen.

Adaptable for electron diffraction techniques — stereo electron micrographs.

Bulletin 807 Sent Upon Request

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Comparison between magnetic and electrostatic lenses

Note that the magnetic lines of force are contained within an electrostatic lens, but not within a magnetic lens. Thus, with an electrostsatic lens there is no leakage of fields to other lenses.

- No re-alignment when changing focus or magnification.
- No image rotation.
- High-mag focus is retained at all magnifications.
- The specimen is not in a magnetic field.
- Influence from external electrical fields is minimized.

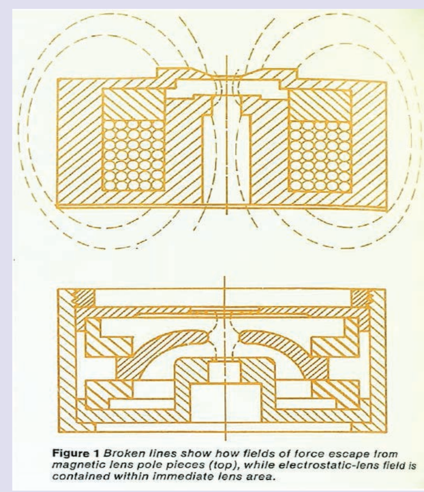
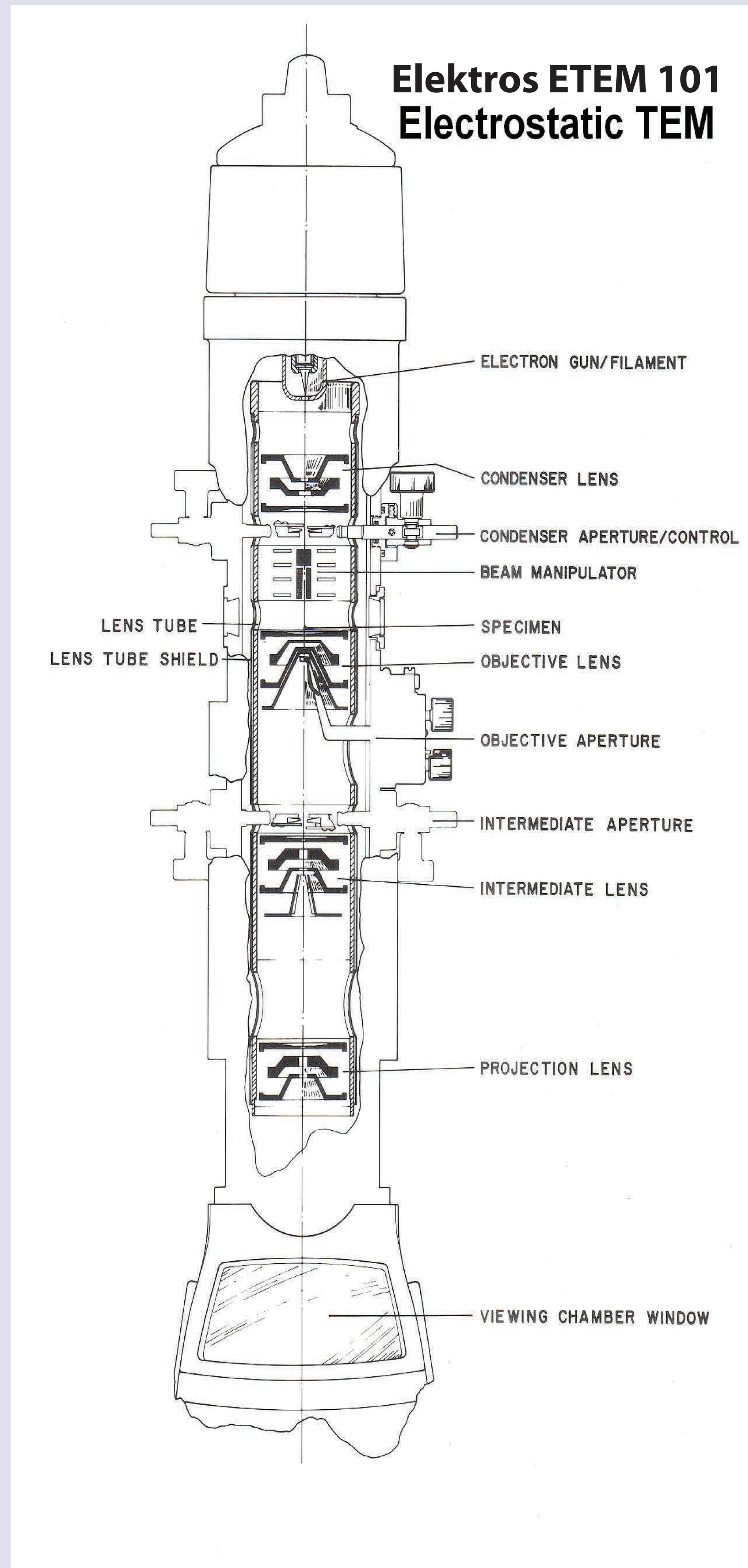


Figure 1 *Broken lines show how fields of force escape from magnetic lens pole pieces (top), while electrostatic-lens field is contained within immediate lens area.*



ETEM 101 column

Development of the Elektros ETEM101

Gertrude Rempfer worked part-time for Tektronix starting in 1963. Working with her former student, Tom Holce, prototype electrostatic TEMs (shown at top left and middle) were built there around 1968. Tektronix was initially interested in commercialization, under the trade name MIkros. The Tekronics museum has a 1969 version of one of these TEMs, shown at top right).

Rempfer then moved to the Elektros company, a Tektronics spin-off formed in 1970, in Tigard, OR. The company, whose President was Bert Cathery (shown at lower left operating a prototype), included Jon Orloff, who later recounted some of its history, and Arnold Frisch, who complely redesigned the electronics from the Tektronics Mikros prototype. Construction at Elektros and operation by Rempfer (in a Tek/OPB video) are shown here in the bottom row. From 10 to 40 ETEM 101 TEMs (depending on the source of information) were produced before Elektros closed its doors in 1973.

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elektros *presents:*

The ETEM 101 Transmission Electron Microscope and the IES Image Enhancement System

Since it takes up only 9 square feet of floor space **complete** with IES video monitor, and can be moved on its own casters, the **ETEM 101** can be brought to class as a teaching aid, then returned to the lab to continue its tasks as research tool. Its mobility allows several different departments to share the advantages of the microscope, making it even more economical to own.

The **ETEM 101** is synonymous with versatility. It offers not only the standard operating modes—bright field, dark field and selected area diffraction—but features **exclusive on-screen stereo viewing.** Of course, all of these operating modes, including stereo, may be displayed on the **IES's** TV screen.

At the heart of the **ETEM 101** is a **completely automatic vacuum system.** The system is activated by push-button controls to start the vacuum sequence, open the camera, open the column, or turn off the system. Typical operating vacuum is in the 10 5 torr range, and is constantly monitored by means of LED digital readouts and a lighted vacuum schematic on the microscope's front panel.

As the most compact, versatile **TEM** on the market, the **ETEM 101** combined with the **IES IMAGE ENHANCER** makes an ideal addition to laboratory or classroom situations.

The **ETEM 101** utilizes four electrostatic lenses which **NEVER** require adjustment. The lenses and other electron optical components are precision machined and contained in a rigid lens tube.

An electronic fine focus control is provided, calibrated in 0.2-micron increments for precision through-focal series and inside-focus micrography.

Functional construction of the electron source enables the user to **change filaments within five minutes,** and the filament is easily adjusted while the microscope is operating.

A specimen chamber airlock obviates the need to vent the entire column to atmosphere for a specimen change—the microscope is operable within 10 seconds after specimen insertion.

The image-recording system of the **ETEM 101** is automatic and cleanly functional. It includes automatic exposure meter, electrostatic shutter, and digital counters for micrograph serial number and exposures remaining. Each micrograph is automatically imprinted with a serial number and **magnification micron marker.**

The standard camera accepts 6.5x9cm glass plates or cut film, and a 70mm, 50-exposure roll-film camera is available. Each camera is door-mounted for full access during film change or maintenance; compartmented cassettes allow easy access to exposed plates without advancing the complete series.

about the **IMAGE ENHANCER** . . .

TV DISPLAY

Its magnification capability enables the user to "zoom in" on what appears as very small detail even at top microscope magnification, and view it on the TV monitor screen enlarged an additional 22 times. Focusing and astigmatism correction become almost pleasurable. And the entire staff or class can watch —without needing dark-adaptation.

Another great advantage of the **IES** is its versatility in presenting the enhanced image. The video output can be displayed simultaneously on as many as 30 monitors of any size, which greatly increases the system's usefulness as a teaching tool.

INTENSIFICATION

It provides the ability to view images too dim to see on a normal TEM viewing screen. Information can be obtained from even the lowest contrast specimen.

UTILITY GAIN

Because the operator can decrease the level of microscope beam current required for good illumination, a specimen that would be destroyed in one minute of viewing under normal illumination levels can be viewed for over **three hours** without damage.

SIGNAL PROCESSING

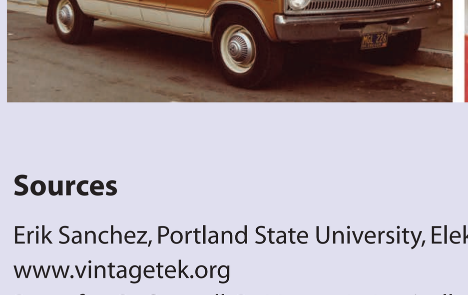
The video signal can be fed directly into image analyzing computers or stored in scan-converter systems or on video-tape. The signal can also be processed by other kinds of image enhancement systems, either directly or from one of the stored forms.

Both the **ETEM 101 and IES** are warranted against defective materials and workmanship for one year. This warranty is supported by a one-year full service contract. Service is provided by a network of over fifty trained service engineers throughout the country.

elektros inc
10500 s.w. cascade drive
tigard, oregon 97223
(503) 620-2830

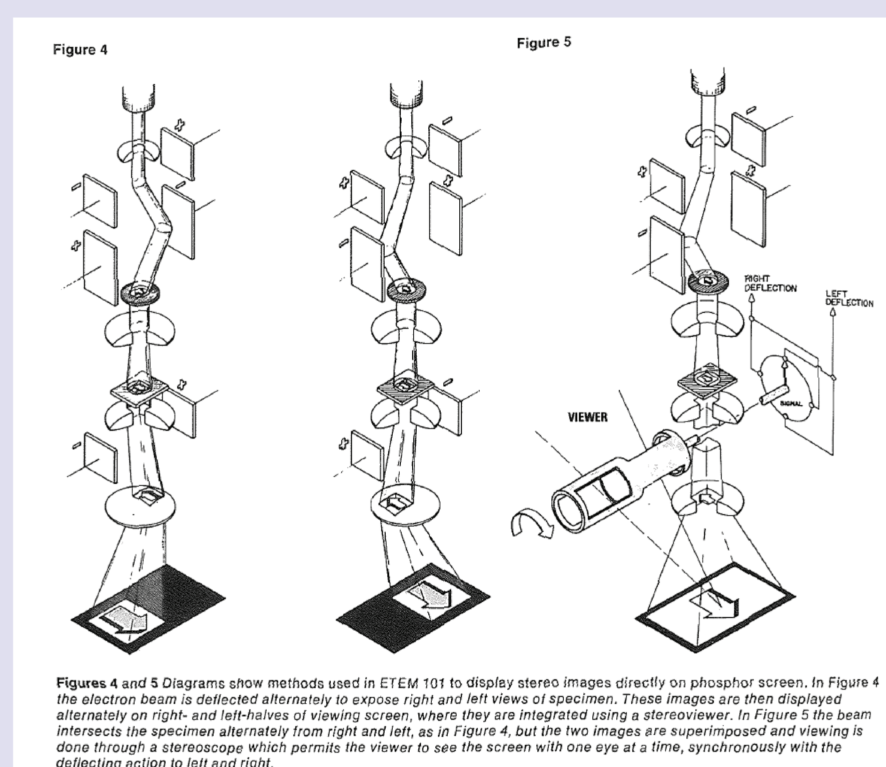
eastern region
485 main street
fort lee, new jersey 07024
(201) 461-3880

western region
p.o. box 31153 diamond hts. station
san francisco, 94131
(415) 398-5641



Method for real-time stereo

By means of beam tilt, coupled with a shutter-type stereoscope, each eye sees only the image from one tilt direction. This was accomplished by plates below the intermediate lens that shifted the beam, and an aperture above the objective lens that prevented side-by-side overlap. Viewing is in real time, directly on the fluorescent screen. Rempfer patented this system in 1949 while working at Farrand.



Figures 4 *and* **5** *Diagrams show methods used in ETEM 101 to display stereo images directly on phosphor screen. In Figure 4 the electron beam is deflected alternately to expose right and left views of specimen. These images are then displayed alternately on right- and left-halves of viewing screen, where they are integrated using a stereoviewer. In Figure 5 the beam intersects the specimen alternately from right and left, as in Figure 4, but the two images are superimposed and viewing is done through a stereoscope which permits the viewer to see the screen with one eye at a time, synchronously with the deflecting action to left and right.*

A sample micrograph from an ETEM 101

This image of a thin, stained plastic section of brain tissue shows typical results from an ETEM 101, provided as an "advertising" image. Note that stain granularity of such traditional specimens limits resolution to 2 or 3 nm, so a resolution of 1.2 Å, even at 40 kV, provides perfectly satisfactory results. This was borne out In the 1970s, in a comparison between the ETEM 101 and a Philips EM 300, which was carried out at the Armed Forces Institute of Pathology. An ETEM 101 was still used for routine TEM, with a paper published as late as 1988 (not shown here): Tiekotter, K.L. (1988) Histofluorescent and ultrastructural identification of aminergic processes in the opisthaptor of the marine monogene, *Microcotyle sebastis* (Polyopisthocotylea: Microcotylinae). Proc. Helminthol. Soc. Wash. 55(2):229-245.

Marketing the Elektros ETEM 101

The ETEM 101 is mounted on hydraulically retractable casters, so it is easily moved. The lenses do not need water cooling, and an air-cooled diffusion pump is used, so it only needs to be plugged into a 120VAC, 10A outlet. It weighs about 700 lbs., so it is stable when the casters are retracted. A special van was used to bring it to exhibits. Although Elektros closed its doors in 1973, results from the ETEM 101 were last displayed at M&M in 2003. An advertising brochure is shown here. About 40 ETEM 101s may have been constructed, but not all were sold. At least 10 survive and three or four are still operational.

- The lens voltages and the accelerating voltage are supplied by the same power supply, so high electrical stability is not necessary.
- Electrostatic lenses have no hysteresis or image rotation.
- Electrostatic lenses are self-shielding because there are no magnetic polepieces, which have a magnetic field outside the lens. This also means that the specimen is not in a magnetic field.
- Because there is no leakage of magnetic field between lenses, it is not necessary to align the lenses when changing acceleration voltage or magnification.
- The ETEM 101 uses beam tilt to produce stereo images, which can also be viewed directly on the phosphor screen using a mechanical-shutter viewer synchronized with the beam tilt. The beam-tilt system can also be used as a focus wobbler: By rotating the beam in a circle, an artificially enlarged aperture is created, which makes astigmatism correction (by a six-plate electrostatic stigmator) easier.
- Electronic image shift is available, to which a specimen-drift-correcting voltage ramp can be applied using a joystick.
- The stage has 360-degree rotation and 12–degree tilt for (mechanical) stereo. The z-control, used for focusing, has 100-nm dial steps, which can be used for height measurement.
- Focus is independent of magnification, so accurate focus, done at high magnification, does not have to be readjusted at lower magnification.
- The size of the condenser or selected-area aperture can be continuously adjusted by a crossed-forks mechanism.
- The accelerating voltage is continuously adjustable up to 40 kV.
- Resolution is about 12Å.

Sources

Erik Sanchez, Portland State University, Elektros/Rempfer archives; email exchanges from Ed Sinclair and Dennis Tillman
www.vintagetek.org
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