Fatigue Test Hardware

by F.A.Conle
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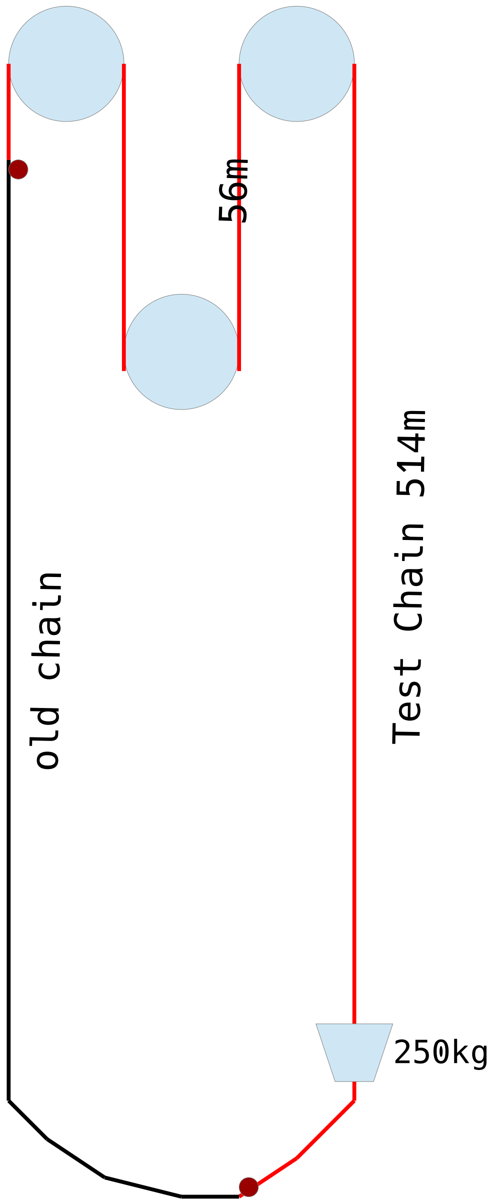
Early (first?) repeated load testing

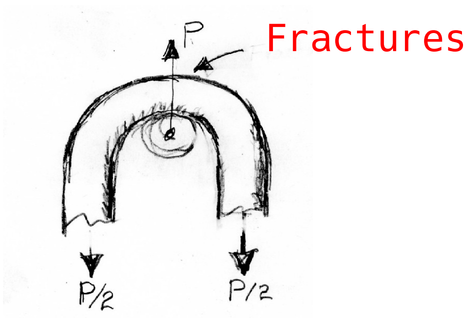


by Albert 1827.

Chains had replaced some hemp ropes in mine shafts but were failing when used at longer lengths.

Albert tested a high quality iron (steel?) chain which broke after 11,660 lifts in 10 weeks of use.

No figures are included with his text. He found that the chain link joints had hardened and most exhibited fine grained fracture surfaces when hit with a hammer.



Modern specimen tests confirm that at large strain amplitudes lower carbon steels cyclically harden, and fatigue fracture surfaces have a smooth "fine grained" appearance.

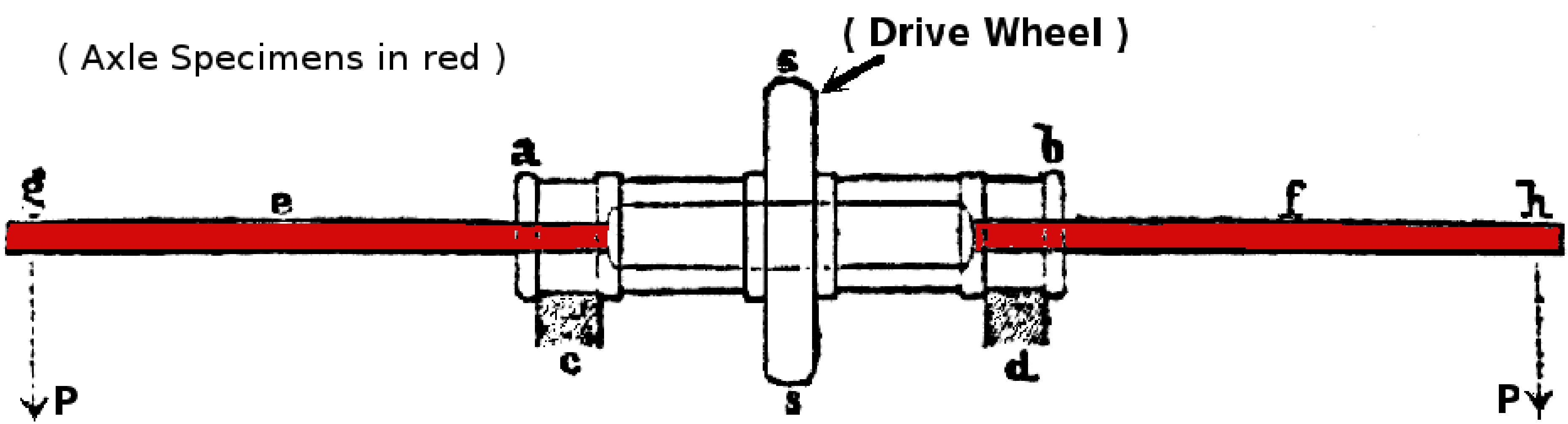
Paper translation available:

https://fde.uwaterloo.ca/FatigueClass/Notes/albert-at-Clausthal.txt

Original: https://fde.uwaterloo.ca/FatigueClass/Notes/albert-at-Clausthal.pdf

In 1858 August Wöhler, after measuring deflections and computing loads experienced by railway wagon axles, proposed a machine set-up to test full scale axles cyclically. (the deflection instrument is described in a later chapter)

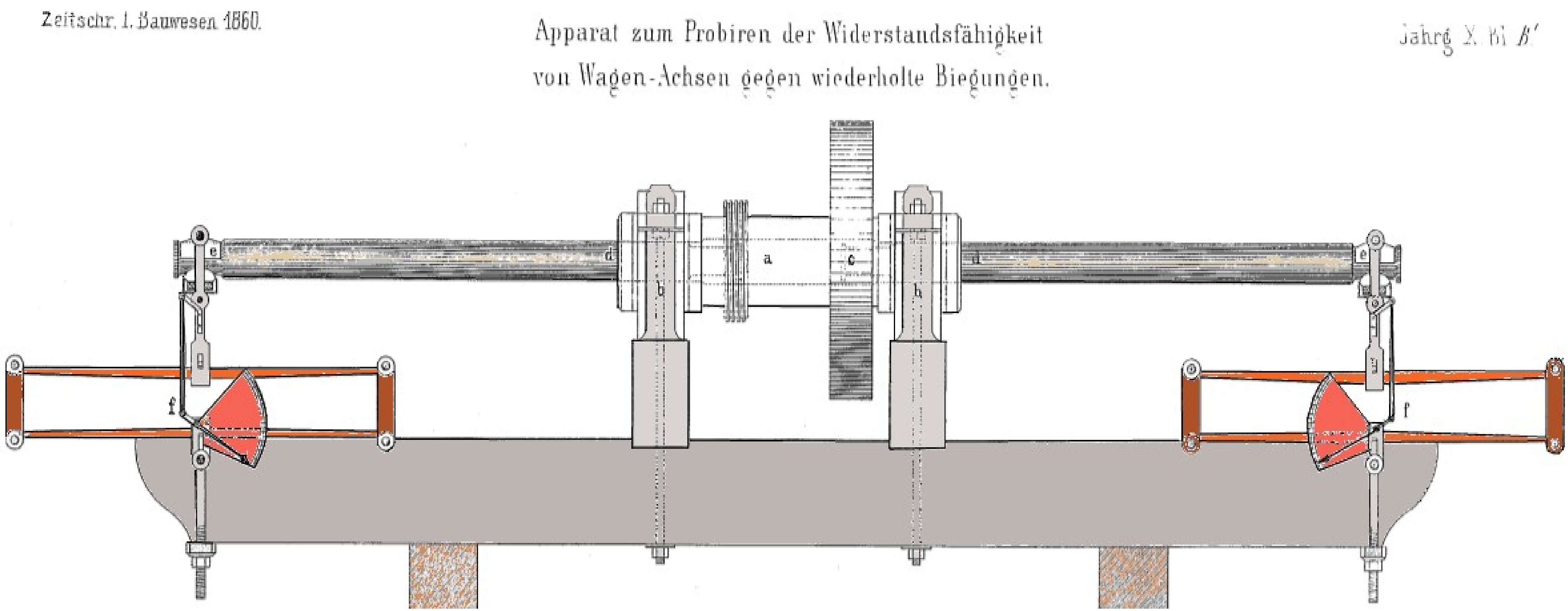
Ref.: Zeitschrift für Bauwesen, 1858, V8, pgs. 641-652



Es sei *ab* in vorstehender Skizze eine in zwei Lagern *c* und *d* ruhende gufseiserne Welle, in deren Enden zwei Achsen *e* und *f* so eingekeilt sind, wie bei den Radnaben eines Eisenbahn-Fahrzeuges geschieht.

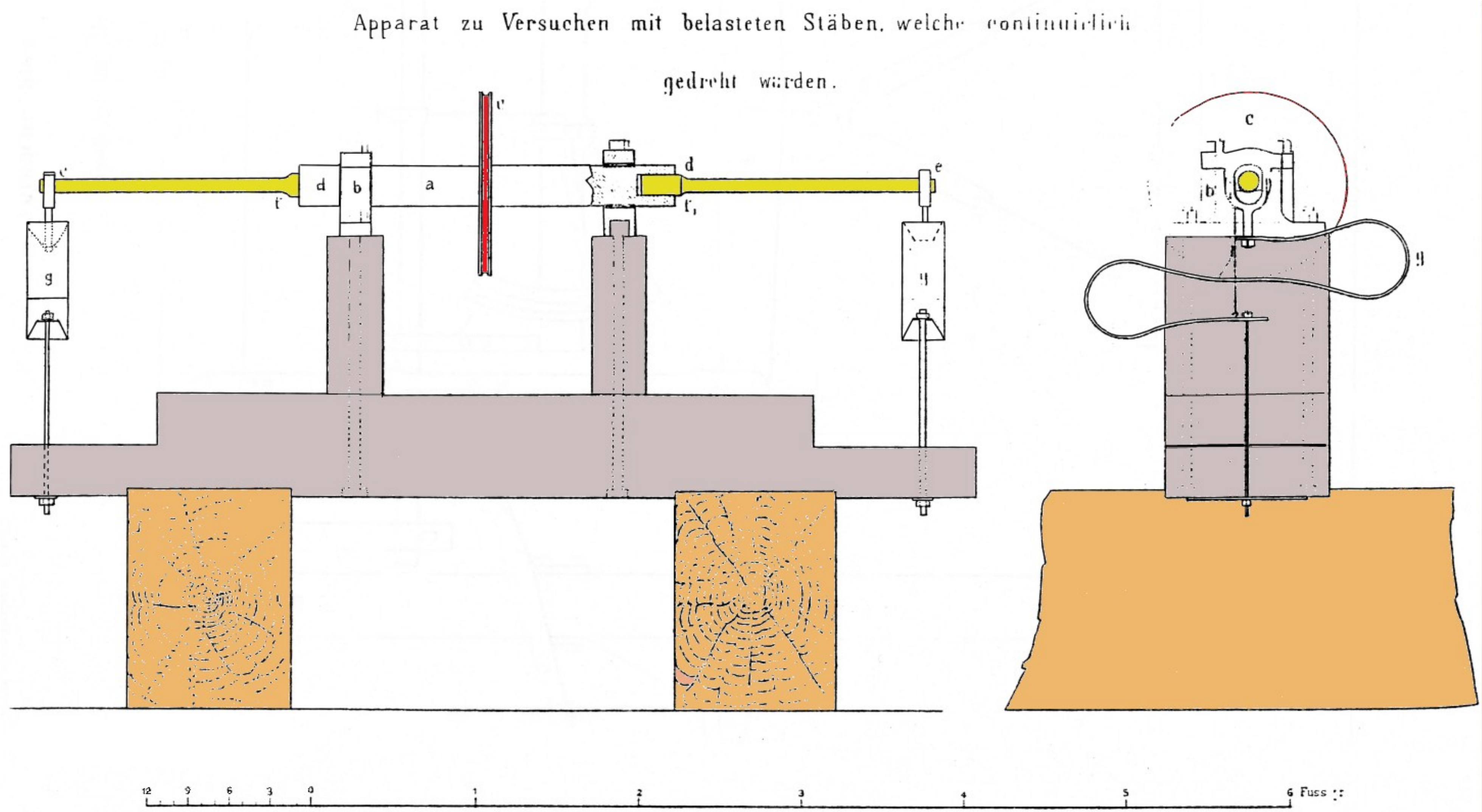
A full scale version of the test machine was described in a paper in 1860.

Note the leaf springs used to impose the cantelever end loads, and the deflection gauges that are calibrated to specific loads.



-but testing full scale components is expensive, and often difficult. In a paper from 1870 Wöhler described the use of a smaller machine.

The smaller scale,less expensive, machine tested
smaller specimens with stress concentrations similar to the full scale
axle at the wheel ends.

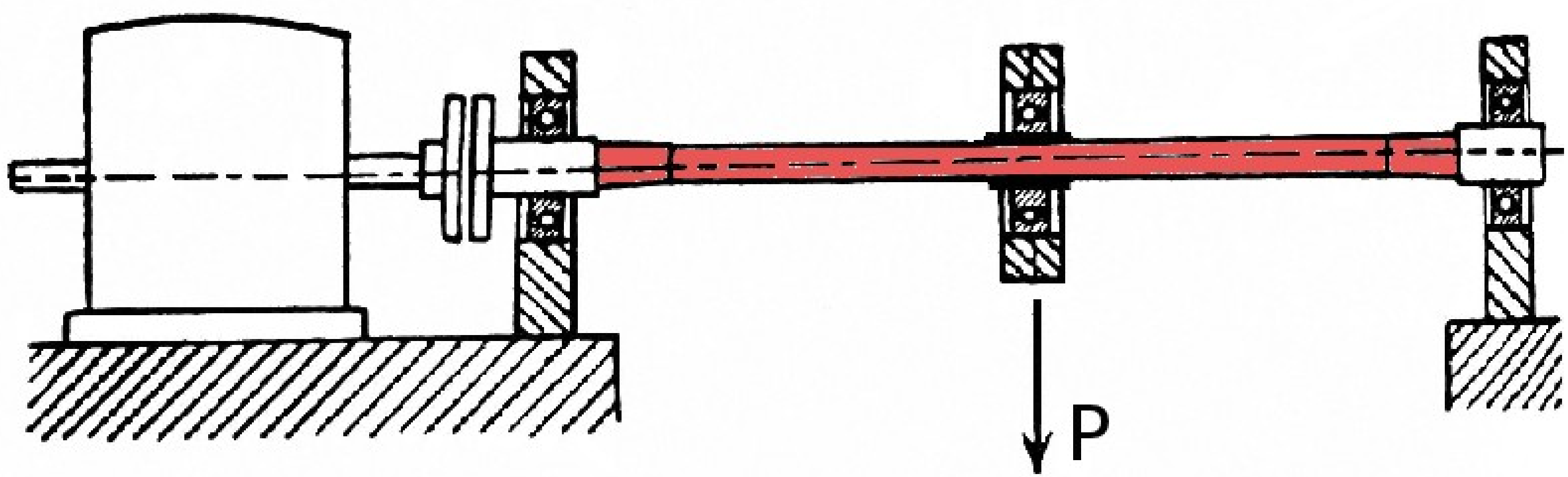


Zeitschrift fuer Bauwesen, 1870 V20 pg.97

Eventually simple 3 Point bending test machines were developed at the “Wöhler Institute”. In a 3Pt. bending test the hot spot is, unfortunately, under the load input point; which complicates the stress analysis.

The problem with long specimen rotating bending test machines is that the specimens are difficult and expensive to machine, and one can only estimate the surface stress, regardless of any cyclic hardening/softening effects.

Such machines are still used today for long life fatigue testing where plastic strains are small.



Ref.: E.H.Schulz, H.Buchholtz, “Ueber die Entwicklung der Dauerpruefung in Deutschland,” Proc. of Zurich Congress, Int. Assoc. for Testing Materials, Sep.6-12, 1931 pp.278-303

Fatigue test results circa 1929. Rotating bending vs. axial tensile strength. This relationship, a factor of 2, is still in use today to quickly estimate the fatigue strength.

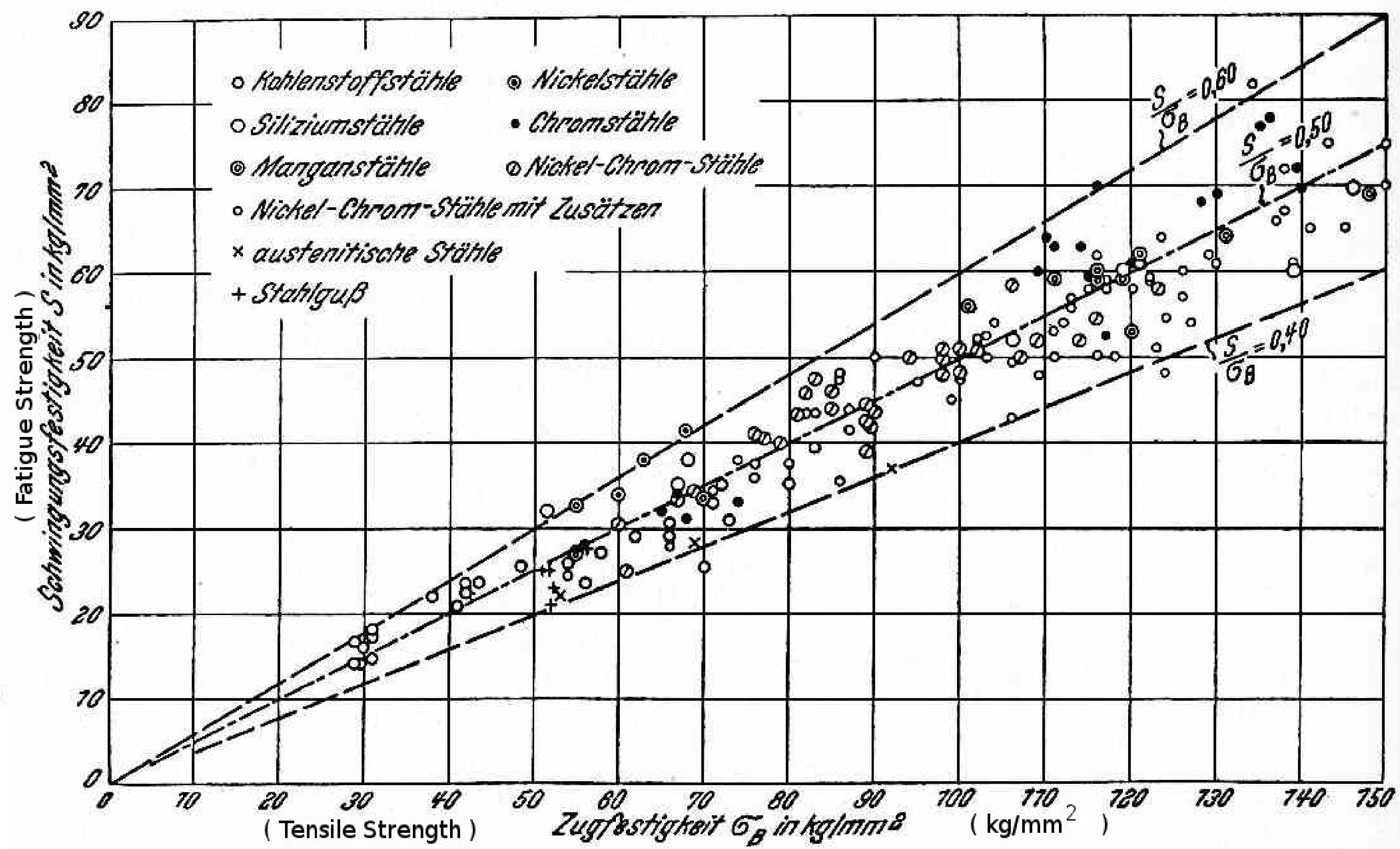
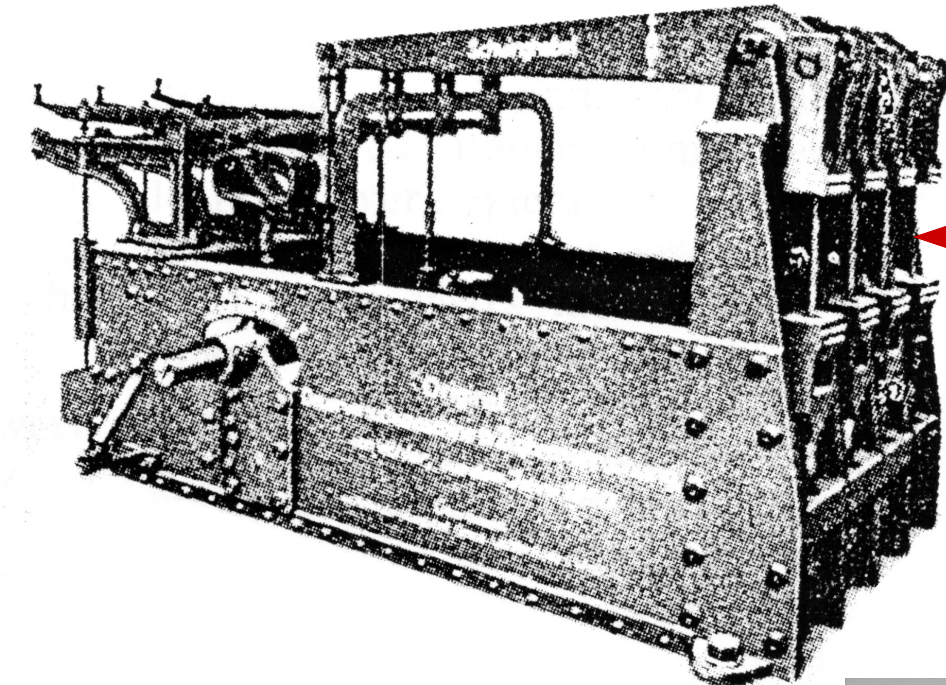


Abb. 15

Beziehung zwischen Wechselfestigkeit und Zugfestigkeit (nach *Mailänder*)

Ref.: E.Houdremont, R.Mailänder, Stahl u. Eisen V49 1929 pp.833-839.

Eventually Wöhler also created an axial fatigue test machine. It, and others, are shown in Ref. “Zeitschrift fuer Bauwesen, 1870 V20,pp.73-106



4 axial specimens in parallel

Further reading:
J.Y.Mann, “The Historical Development of Research on the Fatigue of Materials and Structures,” J. Australian Inst. of Metals, V3 N3 Nov.1958, pp.222-241

Figure attributed by J.Y.Mann to W.Deutsch Z. Metallkunde 1930, 22, 56.

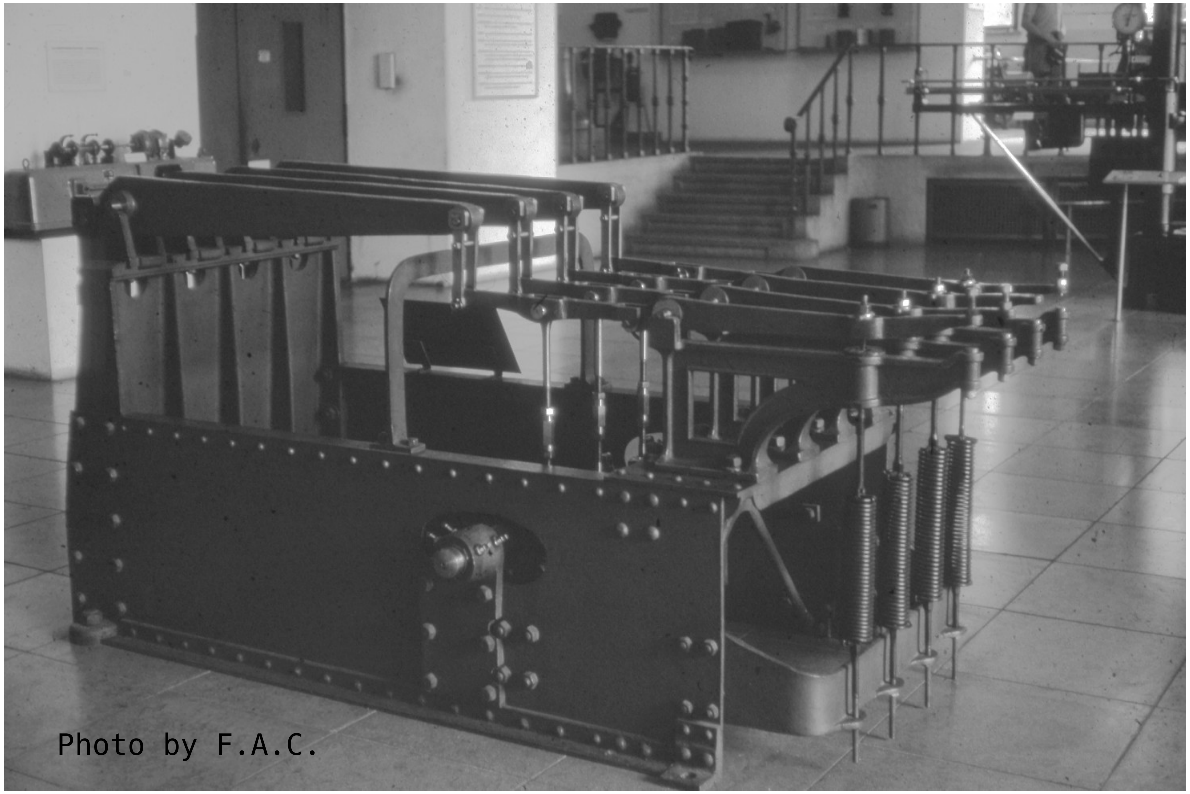
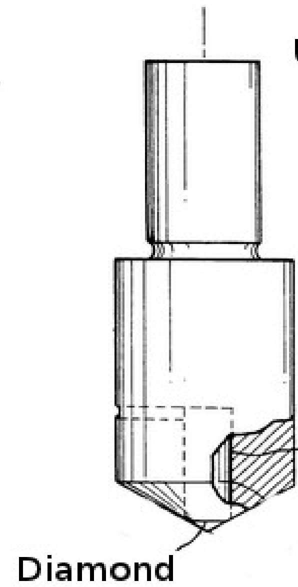
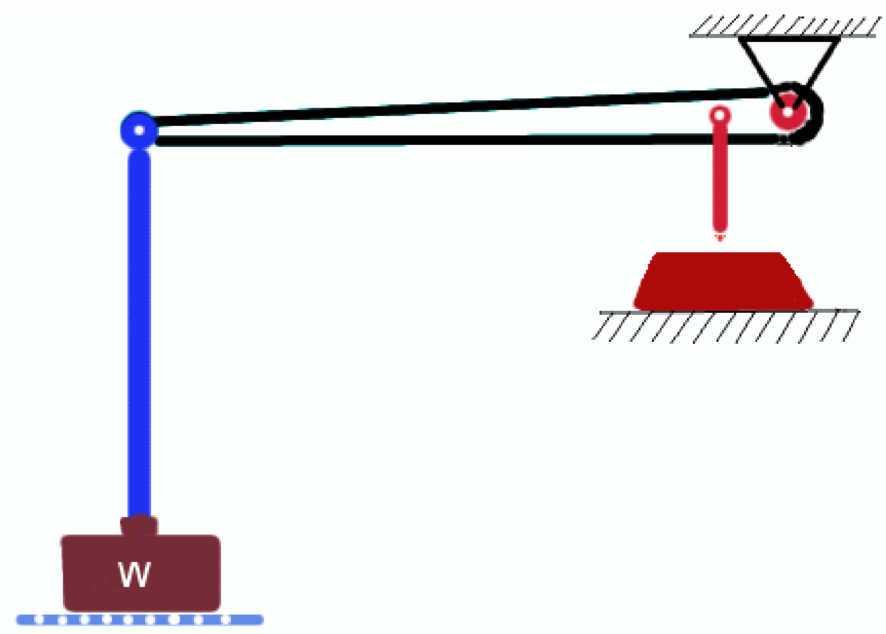


Photo by F.A.C.

Many of the early test machines used a lever scale, called a “Roman Scale or Balance” to impose the large loads on test components or samples.



The same principal is used in hardness test machines where the amount of penetration by a known indenter force reflects the hardness.



Wilson hardness tester.
For more info:
http://www.astm.org/COMMIT/E28Presentations/HistoryMechTesting.pdf

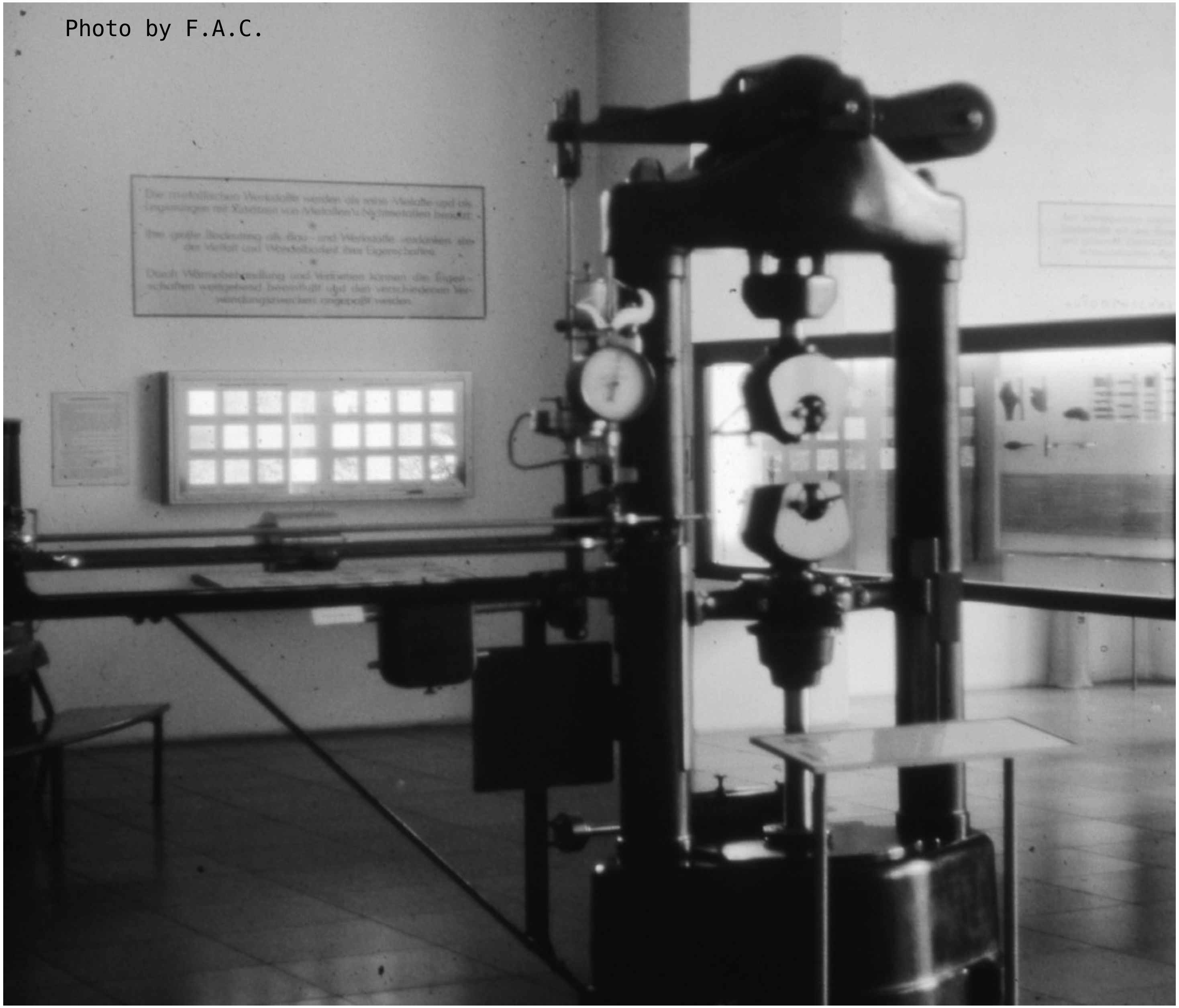


Photo by F.A.C.

A machine such as this was probably used by Bauschinger to perform axial tests in both tension and compression.

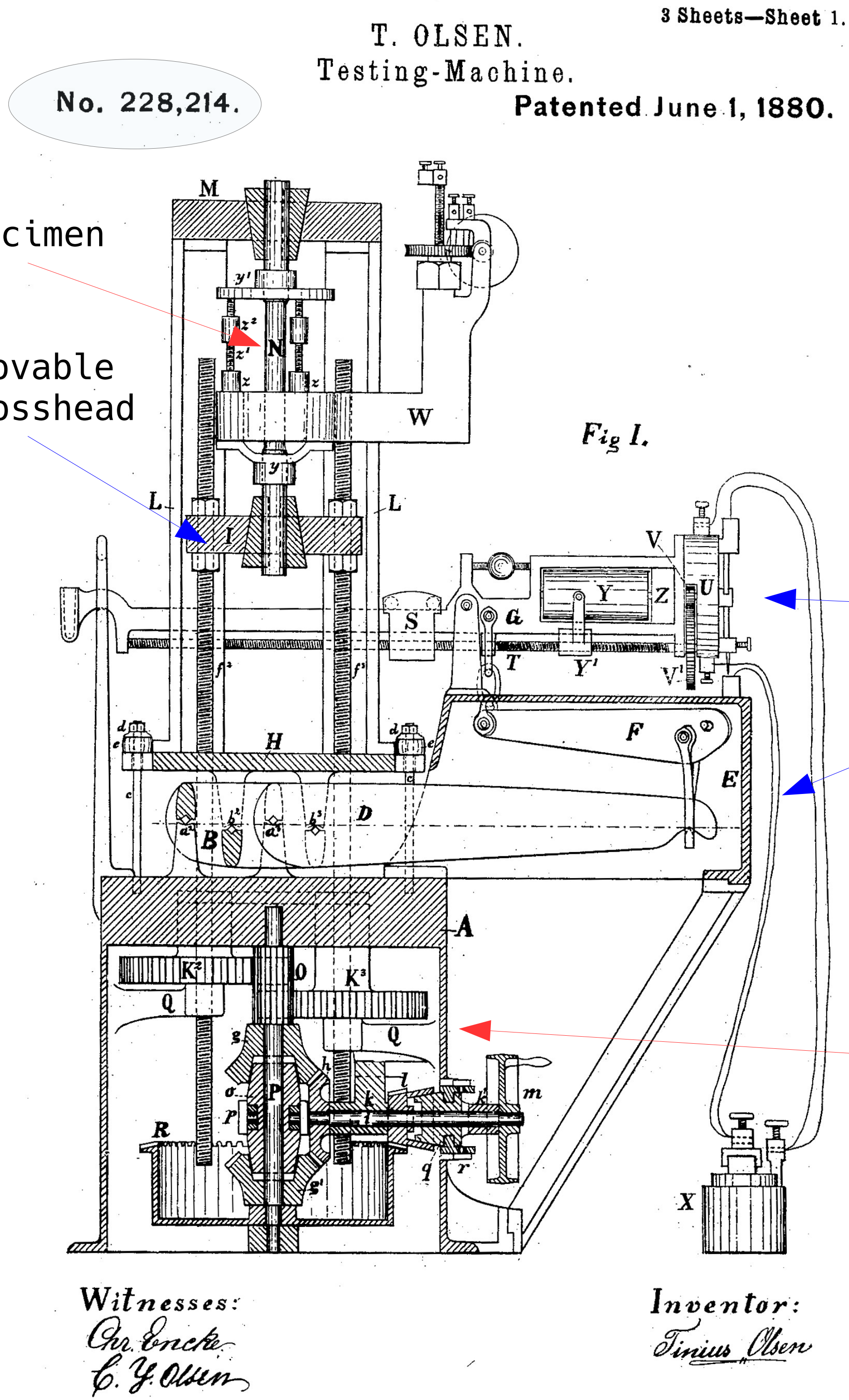
Note: I asked Tech Mus.
of Muenchen to confirm if
Bauschinger’s but received
no reply.
If someone has information
please let me know.
A better photo would be nice too :)

Some of Bauschinger’s test data is available:
https://fde.uwaterloo.ca/Fde/Loads/hindex.html

More on Bauschinger later.

Tinius Olsen Patent for a scales type test machine.

- **high complexity**
- **probably very expensive**

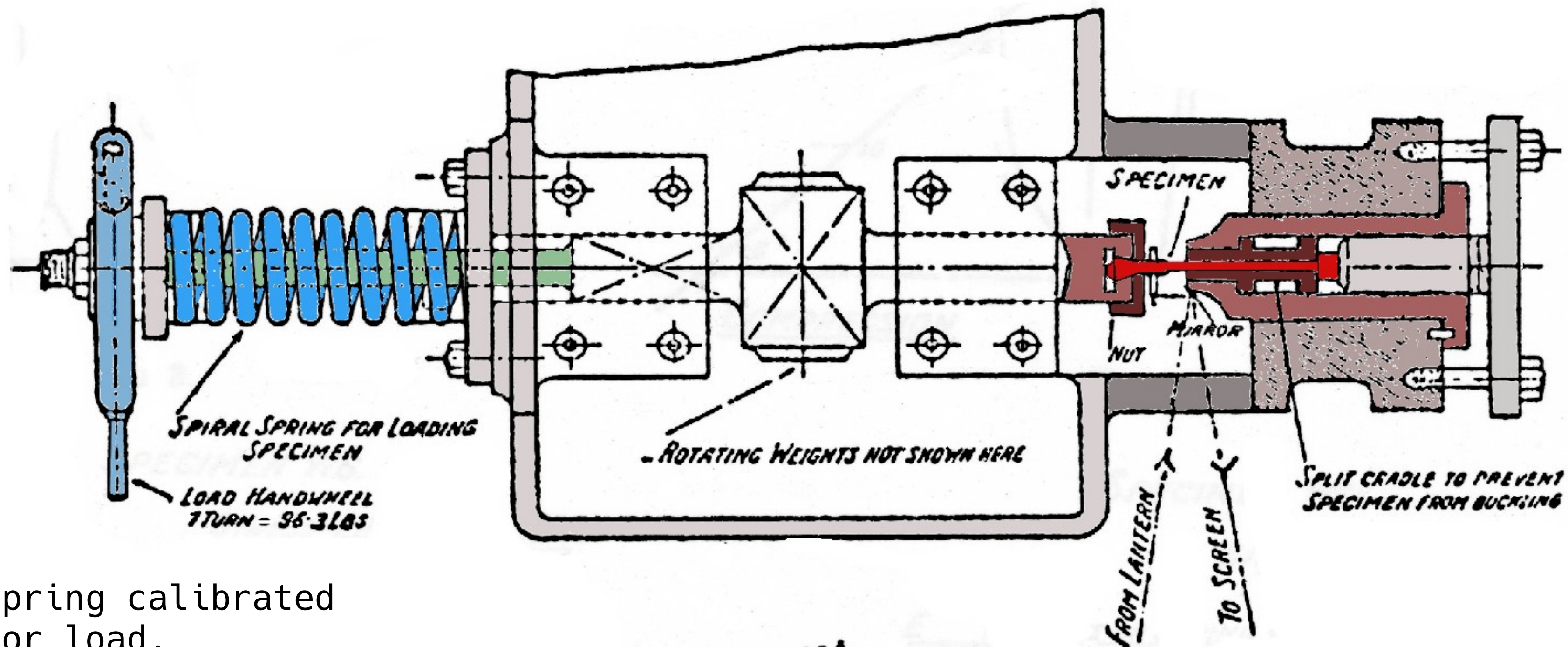


Specimen

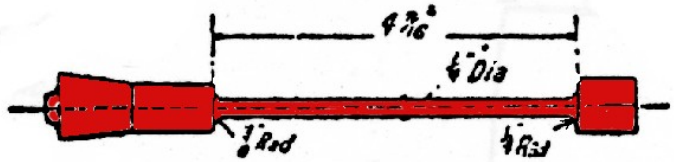
Movable Crosshead

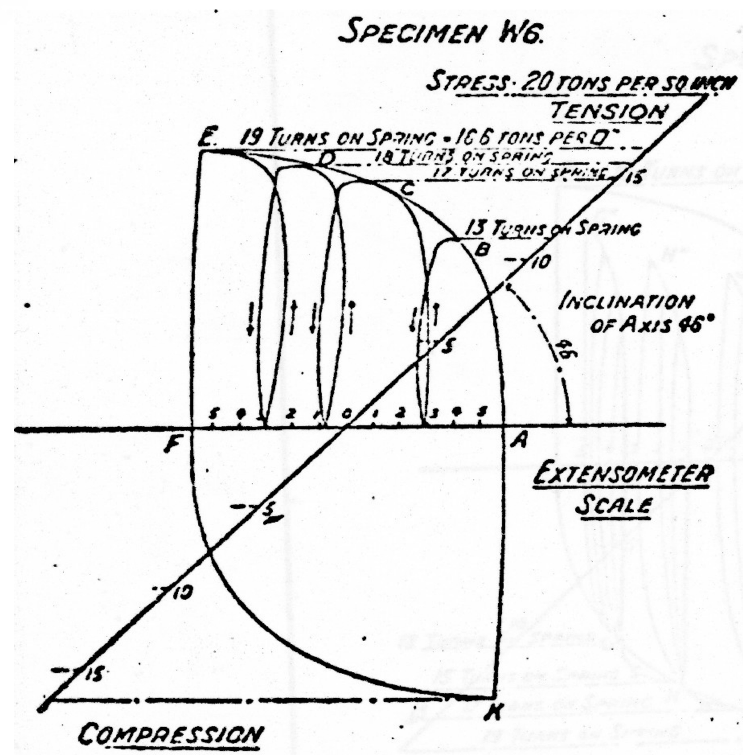
Lever mechanism for Load application

Transmission to move crosshead up or down



Spring calibrated
for load.





Smith & Wedgwood described their test machine in 1915.

[Ref.: J.H.Smith, G.A.Wedgwood, “Stress-Strain Loops for Steel in the Cyclic State,” JISI, V91 N1 1915 pp.365-397]

With a Martens type mirror extensometer they were able to measure stress-strain hysteresis loops.

An axial specimen resonance machine was developed by the Schenck Co. circa 1929. It too is described by Schulz & Buchholtz. The “driver” is electro-magnetic.

see: “Wicklung” (= Winding)

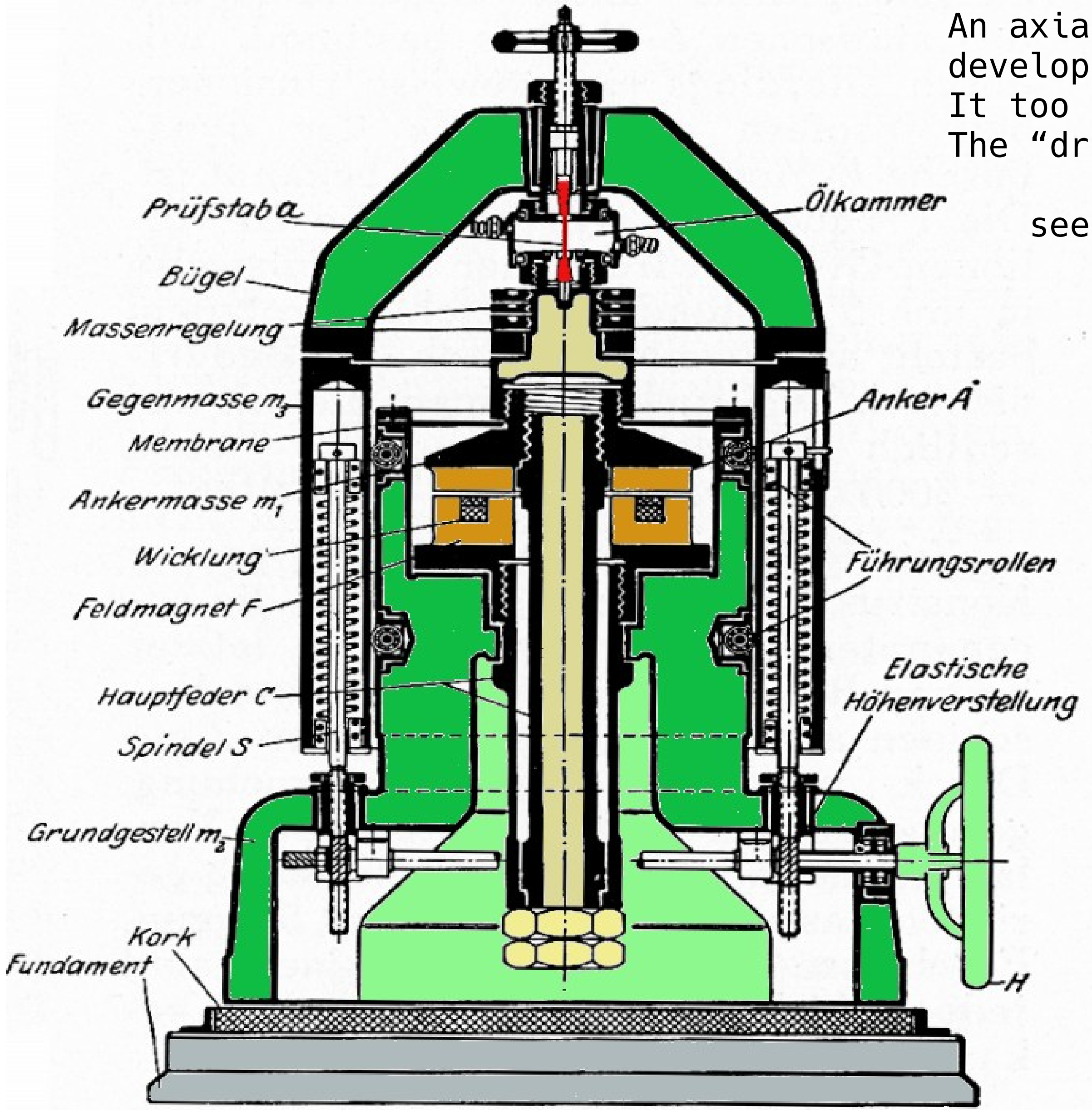


Abb. 2
Zug-Druck-Maschine von *Schenck*
Längsschnitt

Resonance machines are still used today to determine very long life fatigue

$Nf > 10^8$

Instron screw drives:

With the advent of electronic load cells it was possible to get rid of the Roman Scales type load measuring devices.

For many years Instron, and others, offered tensile and compression test systems that imposed the load by turning two long screws that moved the cross-head up or down.

This model is refurbished with a computer control. It is set up for tensile testing of specimens.

The possible specimen strain rates are fairly slow but this is normal for tensile tests and also safer than machines that apply loads very quickly.

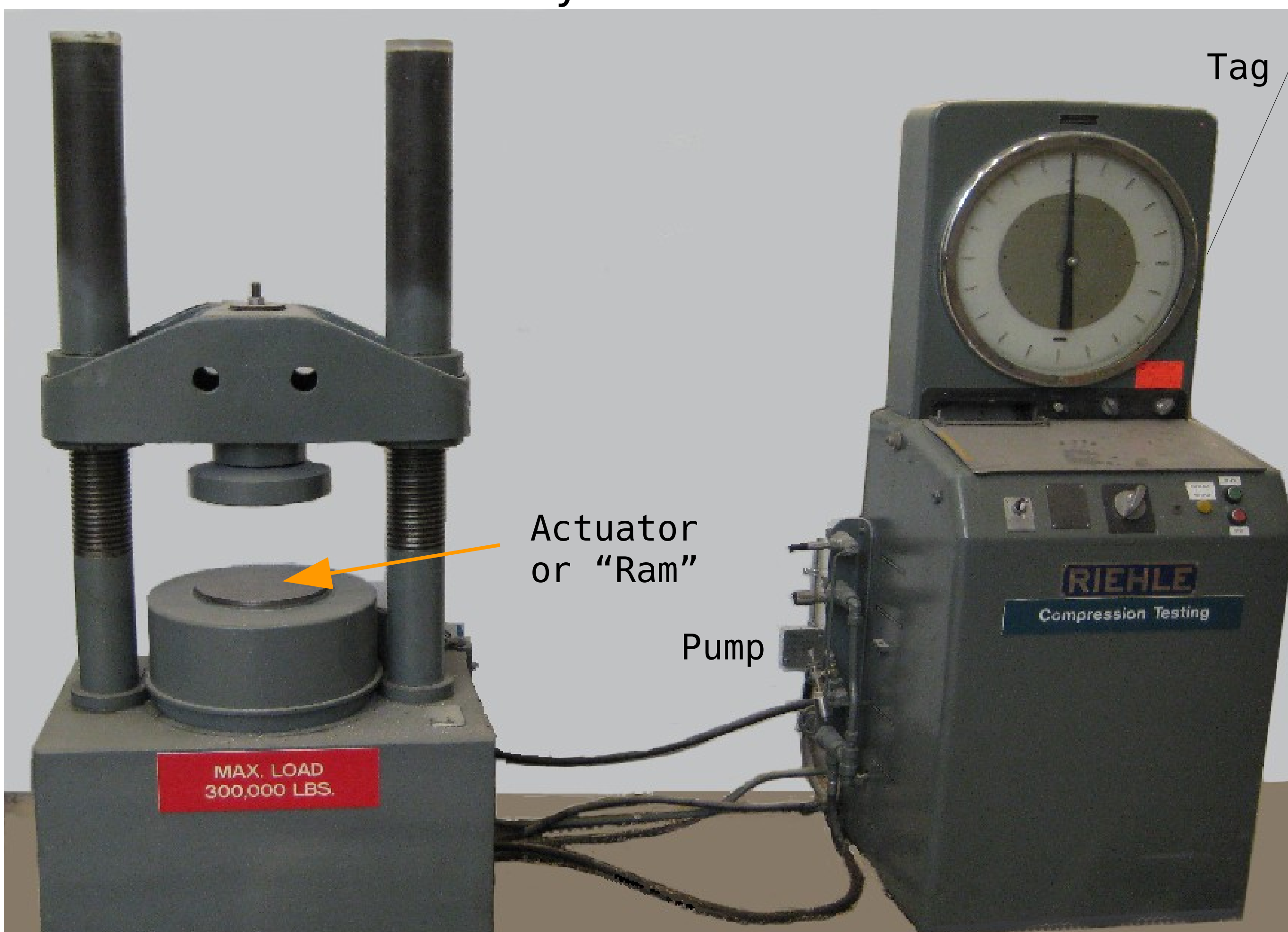
Photos courtesy of Frank Bacon Machinery

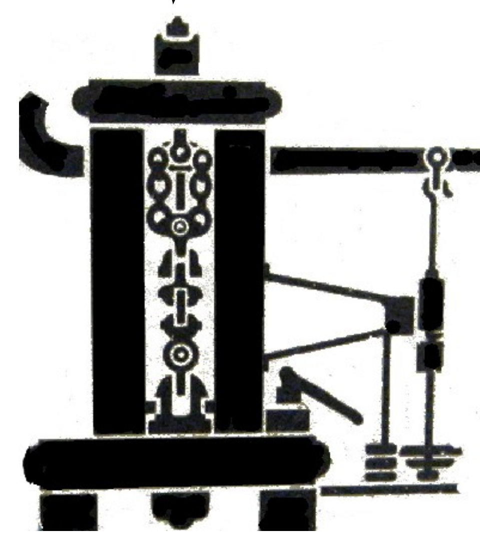
Companies that made lever loading machines eventually switched to hydraulics, usually oil.

Here the screw columns are just used to position the cross-head before testing; in this case concrete cylinder specimens.

Force is applied by a hydraulic actuator.

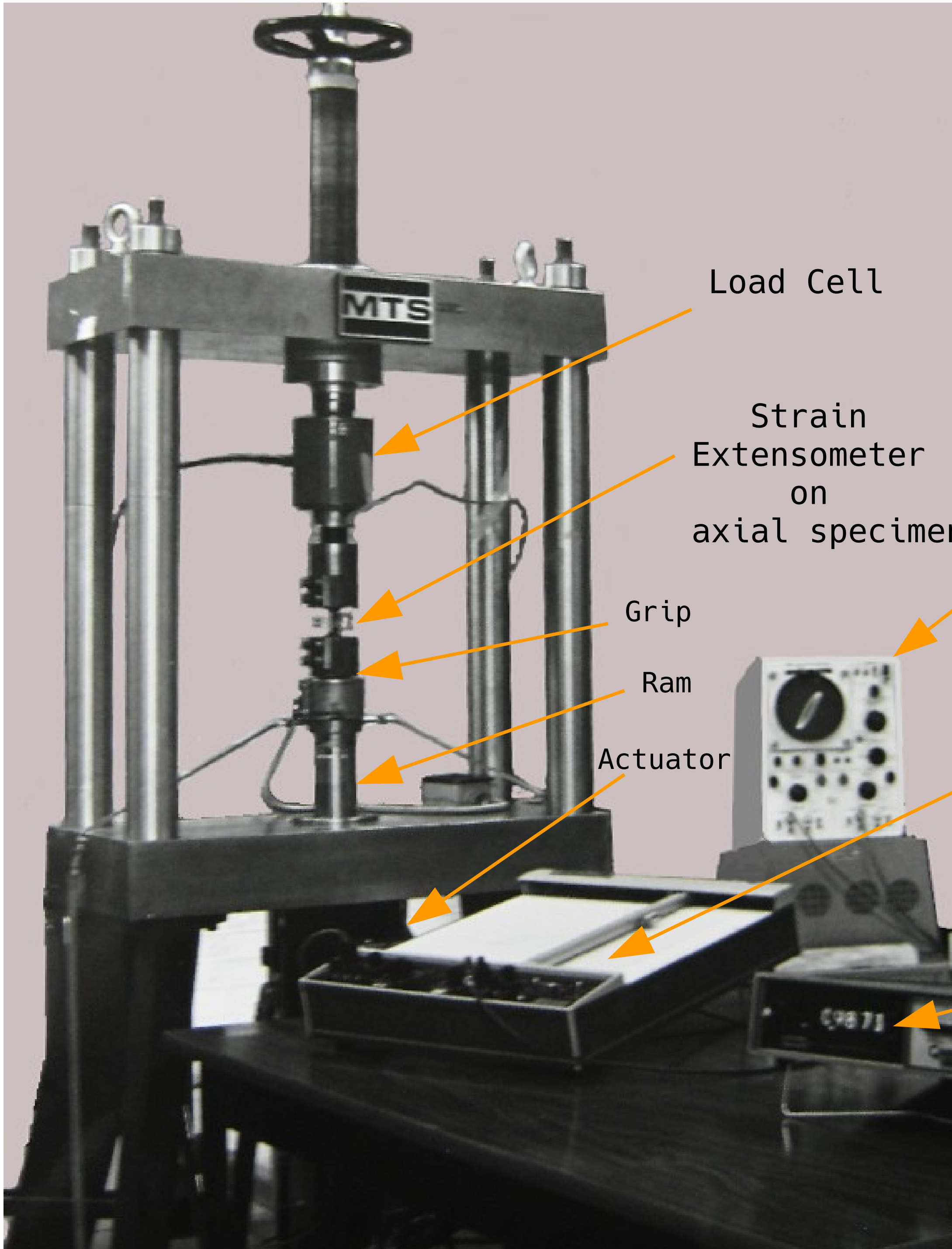
Riehle Hydraulic Press





Servo hydraulic fatigue test setup circa 1970

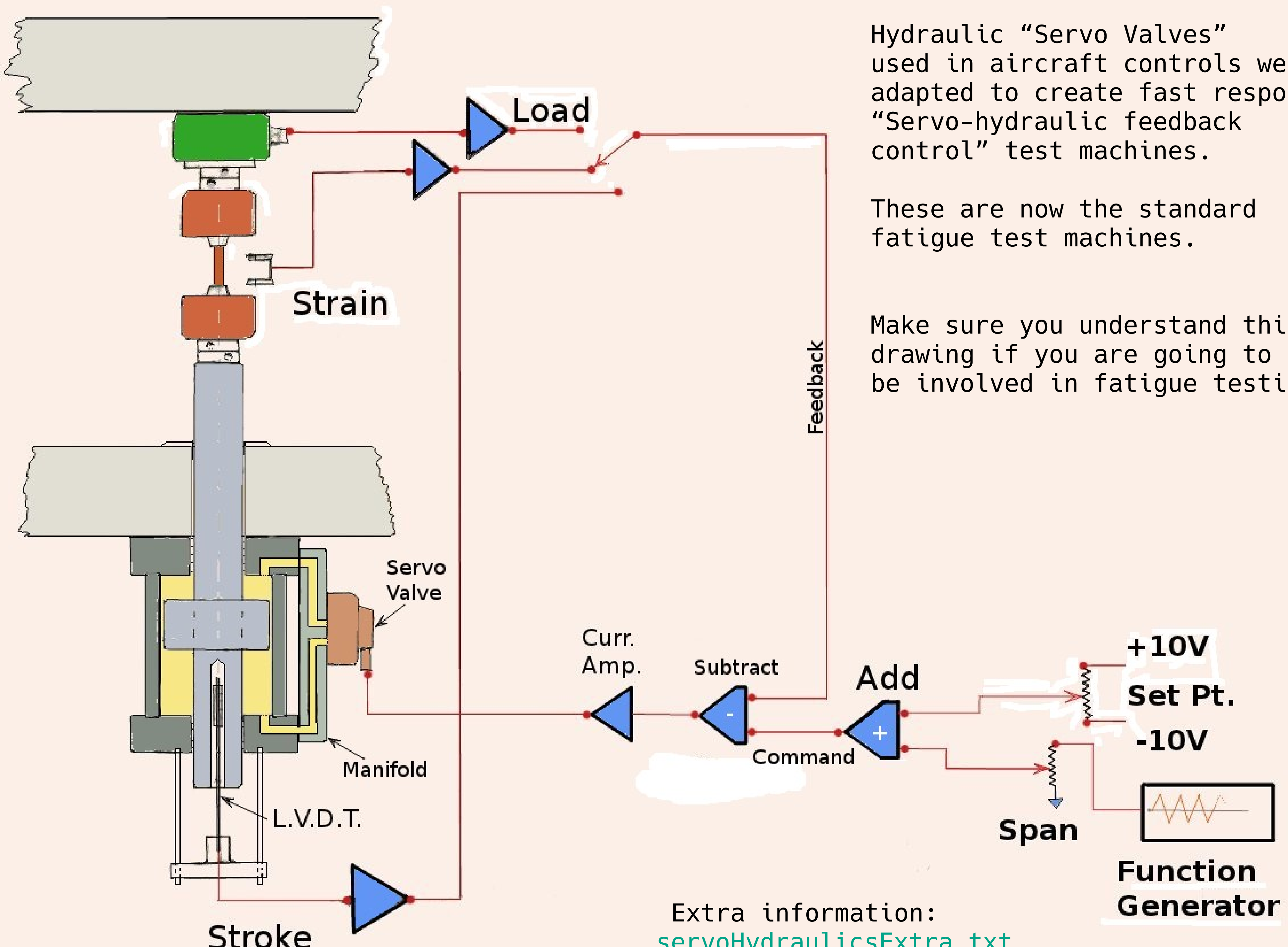
In a servo hydraulic system oil is pumped onto a piston that is located in an "actuator". The piston moves a ram, which attached to grip, provides the loading on the specimen.



Hydraulic “Servo Valves” used in aircraft controls were adapted to create fast response “Servo-hydraulic feedback control” test machines.

These are now the standard fatigue test machines.

Make sure you understand this drawing if you are going to be involved in fatigue testing.



Extra information:
servoHydraulicsExtra.txt

Instron/Schenck servo hydraulic

(I have not found a good picture yet)

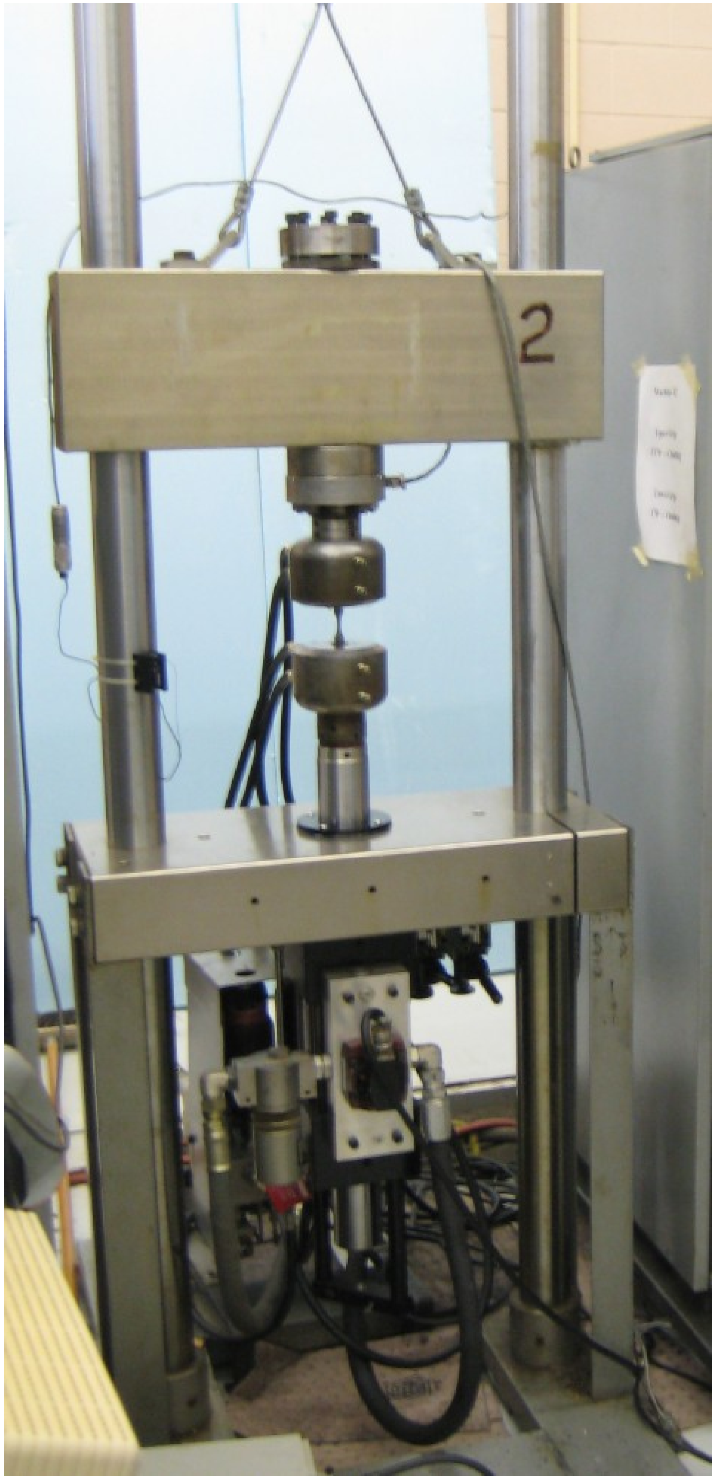
Generic servo-hydraulic

Given a good machining shop
it is fairly easy to create
a servo-hydraulic load frame.

Columns are purchased from
standard supplies.

Servo system, load cell,
controllers, etc are purchased
from existing suppliers.

Top and bottom plattens are
bored out together in one
operation.



U.Waterloo Fatigue
test Lab.

In the past many fatigue tests were done by rotating bending. If a servo-hydraulic system is available, bending tests can also be done, either in 3 or 4 point bending, or cantilever bending.

Shown here are examples of 4 point bend rigs.

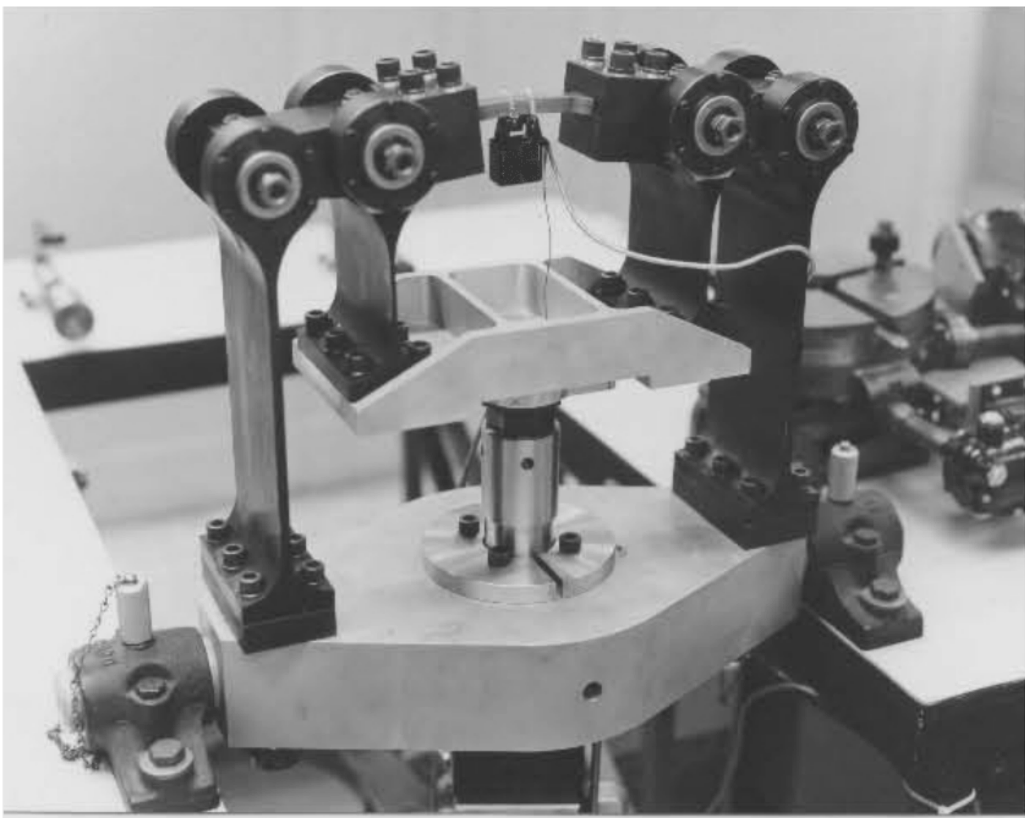


Photo contributed by M.Mitchell

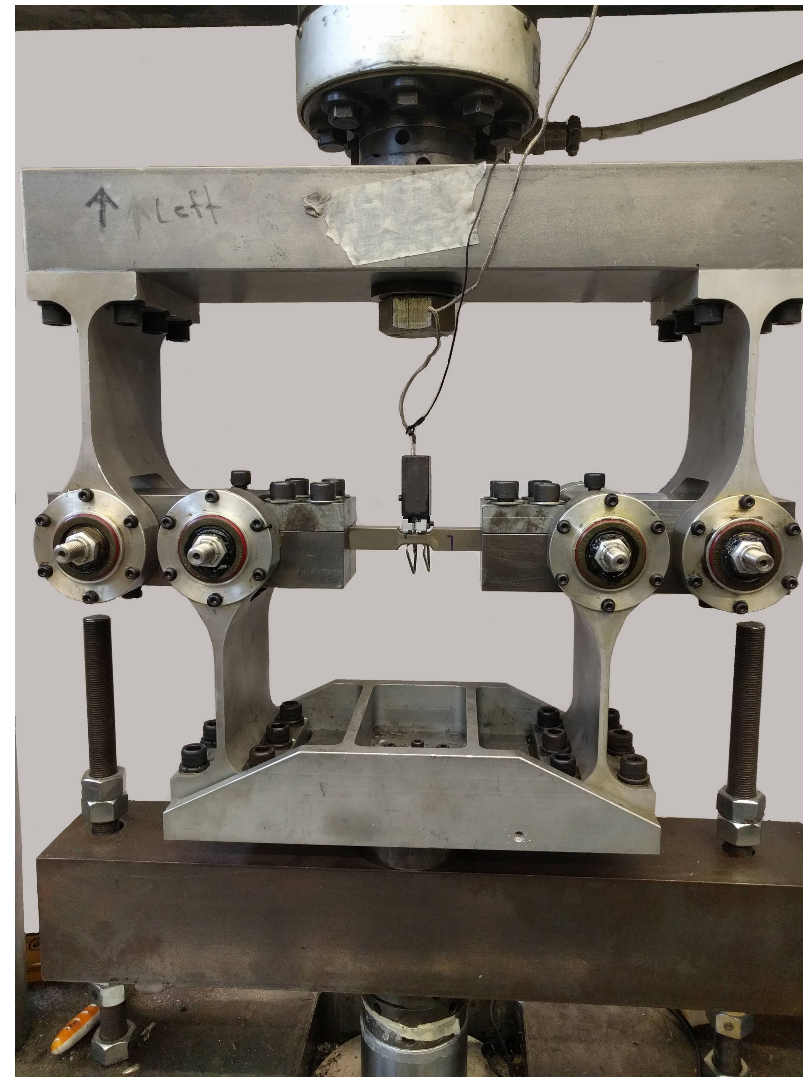


Photo contributed by W.Liang

Full scale vehicle servo hydraulic testing with wheel force transducers

Wheel Force Transducer
Mx, My, Mz and Fx, Fy, Fz

Servo-hydraulic Rams

Exercise: Which Forces, Moments do the 3 horizontal arms activate ?

Photo provided by Michigan Scientific Corp.
http://www.michsci.com

Wheel Force
Data Acq. Unit

If you have drawings or photos you wish to contribute to this web page please contact Al Conle or Carol Liang via the Fatigue Design & Evaluation Committee of SAE at https://www.fatigue.org/

(Comments or corrections are welcome too)