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SHORT SURVEY

of a test of the rail fastening for railway tracks with wooden sleepers equipped with Double Shank Elastic Rail Spikes DS 18 manufactured by Messrs. Hoesch Rothe Erde-Schmiedag AG, Werk Dörken, Gevelsberg

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Dr. Ei/Schw/Pe

Short Survey

of a test of the rail fastening for railway tracks with wooden sleepers equipped with Double Shank Elastic Rail Spikes DS 18 manufactured by Messrs. Dörken Aktiengesellschaft, Gevelsberg / Westfalia.

1) General remark:

The fastening of rails on wooden sleepers by means of Double Shank Elastic Rail Spikes DS 18 manufactured by Messrs. Dörken Aktiengesellschaft, Gevelsberg/W. had been tested at the Institution for Railway Construction and Road-Making of the Polytechnic Academy, Munich, as to its applicability on running tracks. The detailed results of the tests carried out had been put down in the Institution reports No. 358 of 23/8/67, No. 362 of 30/8/67, No. 371 of 24/10/67, No. 385 and 386 of 31/1/68. Below is a summary of these five test reports.

2) Material tested

Messrs. Dörken Aktiengesellschaft, Gevelsberg/Westfalia, had put at the disposal of the Institution the Double Shank Elastic Rail Spikes DS 18 - the shanks of which had a length of 130 or 110 mm each (appendix 1) - which were required for carrying out the tests. These spikes were inspected on their correspondence with the dimensions and the weight of each spike was determined. Before carrying out the tests, the spikes were provided with the necessary preliminary tension.

The Institution itself procured the new beech wood sleepers form 1 of the Federal German Railways (impregnated with coal tar) which were needed for the test. In order to reduce the influence of the sleeper wood as far as possible and to allow to obtain a sufficiently well-founded average value, the Institution chose extremely good sleepers which had possibly not faced edges and did not show any visible defects.

The beech wood sleepers for the additional series of tests which was carried out with used sleepers - being 18 years old and impregnated with coal tar - had been removed 1965 from the heavily charged track of the Federal German Railways between Harburg and Bremen - after having been installed for 16 years. Since that time the sleepers had been on stock on the premises of the Institution.

The percentage of moisture in the impregnated beech wood sleepers had been stated by means of the kiln-drying process according to DIN 52183. For this test small test pieces are weighed, kiln-dried at 1o3° C and weighed once more after having been cooled down.
The determination of the specific weight of the particular sleeper wood was done by cutting off a suitable testing piece which was exactly measured and weighed.

The Institution also provided the rail sections form S 54 and S 64 (see appendisis 2 and 3) which were destined for the test. These sections did not show any scar of rust affecting their durability. They were cleaned of any surface rust and cautiously rubbed with a dry cloth, especially for the tests regarding the resistance against rail creeping and twisting. For the driving-in and pulling-out tests the upper bows of the Elastic Rail Spikes were cut off and a strengthening joining part welded to each of the shanks which allowed to screw on a thrust or traction bar. Thereby special attention had to be paid that the shanks of the Double Shank Elastic Rail Spikes did not alter their original form.

3) Carrying out the tests and their results.

3. 1. Preliminary note

The determination of weight and dimensions made before the tests have brought about the following results:

	minimum	maximum	average
weight of each DS 18/110	1021	1035	1028 g
weight of each DS 18/130	1105	1141	1120 g
percentage of moisture in the new beech wood sleepers	14.9	17.8	15.8 %
percentage of moisture in the old beech wood sleepers	12.9	13.4	13.2 %
specific weight of the new beech wood sleepers	0.847	0.862	0.858 kg/cdm
specific weight of the old beech wood sleepers	0.800	0.807	0.804 kg/cdm
actual dimension in the middle of the shank of the DS 18 used for the extraction tests	17.8/18.0	17.9/18.3	17.9/18.1 mm

Afterwards the following tests had been carried out and thereby were obtained the results which are described below:

3.2. Static gauging of the Elastic Rail Spikes:

In order to determine the deflection graph, two Double Shank Elastic Rail Spikes each were driven into the gauging device of the universal oscillation testing machine beside a short rail section (appendix 5) for the static gauging tests and the testing force was obtained by pulling up the rail. Thereby all deformations had been determined in relation to the testing force.

In order to determine the percentage of both - the elastic and plastic deformation - the load was applied in steps, whereby the spikes were unloaded after each stage of loading. During each testing series there had been carried out several gaugings, namely:

- a first load served for measuring the deflection of the spikes
- a second load served for determining the conditions for driving-in of the spikes in the running track
- a tenth load served for measuring the plastic deformation after ten times of loading and unloading the track.

The results of this testing series at two different load stages are shown on append. 1 - 3.

The static gauging shows that the deflection graph has a progressive course which is especially to be seen during the tests up to 2600 kp. This is due to the modifying position - caused by the growing load - of the point between the Elastic Rail Spikes and the rail base, where the load is applied to. Thus the static stress does not grow in linear direction with the growing load. This characteristic feature of the Elastic Rail Spike is a favourable one in respect to a possible excessive stress. Thus the increased adhesion pressure arising in case the Elastic Rail Spikes are driven-in too far is considerably reduced, even if the sleeper surface is only slightly deformed.

3.3. Continuous tests with oscillating load on the Double Shank Elastic Rail Spikes.

The continuous tests with oscillating load acting on two Elastic Rail Spikes on each side of the rail were carried out on the same gauging device and with the same testing machine as described under 3.2. The pulsating frequency amounted to approx. 11 Hz (= 660 proceedings loaded - unloaded/min.). The amplitude of oscillation which had to be constant was electronically supervised. In accordance with the conditions for admission issued by the Federal German Railways, it has to be Δs = 1.4 mm. Under operating conditions an amplitude of oscillation (spring deflection) Δs = 1.4 mm during the pulsating process includes more than a twofold safety. For instance the amplitude of oscillation in straight tracks is approx. 0.2 mm and in narrow curves of the track approx. 0.4 to 0.6 mm on the outer side of the rail.

When carrying out these tests, a determined upper load was taken as a basis, whereas the load from below was applied in accordance to the spring deflection of Δs = 1.4 mm and it was tried to attain a limited number of proceedings loaded - unloaded of about 5 millions. The results of these continuous tests with oscillating load are shown on encl. 4.

During the continuous test No. 3 with oscillating load (upper load P_o = 1700 kp) at approx. 4.7 millions of proceedings loaded - unloaded happened a lasting breakage of the bow of an Elastic Rail Spike shortly before attaining the wanted limit. In the same moment the safety device of the testing machine switched off. Thus after having installed another DS 18, it was possible to pulsate the undamaged Elastic Rail Spike up to the number of 5 millions of proceedings loaded - unloaded without breakage. At a repeated test (No. 4 - P_o = 1700 kp) with a new pair of Elastic Rail Spikes, both DS 18 stood again the test of 5 millions of proceedings loaded-unloaded without lasting breakage. When repeating the static gauging of these two Elastic Rail Spikes, the deflection graph showed a somewhat more steep course (encl. 5) in comparison to the 10th loading and unloading proceeding. This was evidently due to the modified position of the point where the load was applied to. Because of the considerably less oscillating amplitude, this cannot happen in practice. The 8 pieces of Double Shank Elastic Rail Spikes DS 18 required for the continuous tests with oscillating load were statically gauged as described under 3. 2. The results of the first, second and tenth load can be seen from encl. 6 and 7. When comparing them with the results under figure 3. 2 (encl. 1 and 2) one can see a good accordance, although these Elastic Rail Spikes were taken from another lot.

Based on the results of the continuous tests with oscillating load, an adhesion pressure of about 1800 kp should not be exceeded.

3.4. Continuous tests with bi-axial oscillating load by means of a cross-bar oscillator, the whole rail fastening installed on wooden sleepers.

When carrying out continuous tests with oscillating load by means of a cross-bar oscillator (appendix 6), bi-axial forces are applied to the rail head, as this is the fact on the running track in track curves during operation. For this test the Institution has developed a cross-bar oscillator which enables it to resolute the vertical testing force of the universal oscillation testing machine into a corresponding vertical and horizontal force. For this test, the rail fastenings are installed in the testing machine on test sleepers which are considerably shortened.
For main tracks with rails S 49 (width of rail base = 125 mm - appendix 4) principally 2.5 millions of proceedings loaded - unloaded with 15 Mp each of vertical testing force are applied to in the normal position I for each testing sleeper. This results in 7. 5 Mp of vertical and 4. 6 Mp of horizontal testing force for each rail and sleeper bed.

The vertical testing force of 7.5 Mp corresponds to an axle load of 20 to 25 Mp taking into consideration the distribution of load on the rail and the divergence existing in practice; the horizontal force corresponds to the lateral force below a locomotive with 21 Mp axle load on a track with a radius of approx. 300 m, whereby the distribution of load on the rail is taken into consideration. x) Because of the 2.5 millions of proceedings loaded-unloaded, operating conditions of 3 to 6 years are imitated; see the table below for an average axle load of approx. 22.5 Mp and about 350 days per year:

Duration of operation (years)	Load per day (Mp)
3	54 000
4	40 500
5	32 500
6	27 000

The following measuring and determining was continuously carried out at the moment of application of the testing forces as well as during the continuous oscillation stress:
The increase of the distances of the rail head (gauge widening)and the rail base, the tilting of the rails, the pressing-in of the rail bases into the sleeper surface, the reduction of the adhesion forces of the Elastic Rail Spikes etc. Likewise the corresponding amplitudes were determined.

In addition on load stage II were provided 0.5 millions of proceedings loaded - unloaded during the test with rail S 54 and 1.5 millions of proceedings loaded - unloaded during the test with rail S 64. Thereby the vertical testing force amounted to 19.6 Mp. This results in 9.8 Mp of vertical and 6.0 Mp of horizontal testing force for each rail and sleeper bed. The comparable axle loads in the running track can be supposed with approx. 27 to 33 Mp.

For these tests on new beech wood sleepers impregnated with coal tar the adhesion pressure of the DS 18 was deliberately chosen high with about 2600 kp for each Elastic Rail Spike, i.e. the Double Shank Elastic Rail Spikes were exposed to a greater stress. Because of the very progressive course of the deflection graphs in the upper sphere, this fact resulted in a greater reduction

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x) see serial measurements at the rail for determination of the guiding forces, Birmann - Eisenmann, ETR - issue 5/1966

- 7 -

of the adhesion pressure at the beginning which in consequence was reduced again because of the exceeding stress of the Elastic Rail Spike.

The results of the oscillating load tests on a cross-bar oscillator with new sleepers equipped with rail S 54 and S 64 are shown on the encl. 8 and 9 and summed up in the survey (encl. 11).

The tests on load stage I with rail S 54 as well as with rail S 64 are showing that up to approx. 250 000 proceedings loaded-unloaded at first there had been a greater increase of the rail head distance (gauge widening) and a greater reduction of the adhesion forces of the Elastic Rail Spikes. This is evidently due to the fact that the rail fastening is still adapting at the beginning.

The deformations or alterations remaining at the end of the tests (after load stages I and II) are put down in encl. 11 (survey) which shows that the average gauge widening amounted to approx. 5 mm. This value is considerably lower than the gauge widening admitted in main tracks by the Federal German Railways, being 30 mm. The increase of the distance between the rail bases was not more than abt. 2 mm, and the average reduction of the adhesion forces of about 950 kp was only unimportant in regard to the adhesion forces of about 2500 to 2600 kp which were applied to each Elastic Rail Spike before the test.

As with growing age wooden sleepers are liable to a biological decay, the results of the tests on new hardwood sleepers cannot give a sure answer on the reaction of such sleepers after 10 years of lying time in the track.

Therefore in addition there had been carried out oscillation load tests with the cross-bar oscillator with rail S 54 and 18-year-old beech wood sleepers impregnated with coal tar (further details fig. 2). Contrary to the new hardwood sleepers which had a boring hole diameter of 18 mm, the diameter of the boring hole for the old wooden sleepers was chosen 19 mm. This was done in order to make allowance to the influence of aging. During this test the adhesion forces was 1900 kp for each spike. The shortened test sleepers which were needed for the tests were always cut out of the middle of an 18-year-old sleeper.

Differently to the oscillation load tests on the cross-bar oscillator with rail S 54 and new hardwood sleepers, during load stage II the old testing sleepers were submitted to 0.7 millions of proceedings instead of 0.5 millions of proceedings. As had been stated with the new beech wood sleepers before, the tests with the 18-year-old sleepers proved again that the largest alteration of the gauge widening and the adhesion forces arose during the first 250 000 proceedings loaded - unloaded.

The results are shown in the encl. 10 and recapitulated in the survey (encl. 12). The results show that the remaining gauge widening with old sleepers is only slightly greater than with new hardwood sleepers. The reduction of the adhesion forces of the Elastic Rail Spikes on the outer side of the rail amounting to 650 kp at the end of the test was less than with new sleepers despite of the 18-year-old wood. The statement that the reduction of the adhesion pressure of the Double Shank Elastic Rail Spikes was less than with new sleepers, is due to the fact that during the test the Elastic Rail Spikes were only driven-in with 1900 kp. As the deflection graph of the Elastic Rail Spikes shows an almost linear course up to this load, deformations of the sleeper surface have not such an extensive influence

In addition to the oscillation load tests at the cross-bar oscillator, the surfaces of the rail bed of two new and two old sleepers each were statically loaded in steps up to a specific pression on the surface of 50 kg/cm^2 after having terminated the oscillation load tests on the cross-bar oscillator. Afterwards the deformations (remaining and total) were measured. Moreover the test was repeated on the same sleeper in an area which had not been submitted to the said oscillation load test.

The results of this additional test are put down in the encl. 13 and 14. It can be seen that the old sleeper wood is deforming about 12 to 13 % more when comparing it to the new sleepers. The increase of resistance of the rail bed surfaces because of stress caused by the oscillation load tests amounted to approx. 15 % with the new sleepers and to approx. 13 % with the old sleepers.

Because of the additional tests with 18-year-old sleepers, it can be supposed that the tested rail fastening being installed on beech wood sleepers impregnated with coal tar will have a long duration of life.

3. 5. Repeated static driving-in and pulling-out tests with Double Shank Elastic Rail Spikes DS 18, length of shanks 110 or 130 mm each.

In order to have a possibly uniform influence of the wood and to obtain in each case the average resistance against driving-in and pulling-out respectively, a sequence of 10 static driving-in and pulling-out tests according to append. 7 had been carried out on each of 4 new beech wood sleepers of the same kind which were impregnated with coal tar and had boring holes of 17, 18 and 19 mm.

On the other hand the testing series with the 18-year-old sleepers which had been taken off from a running track, should have a boring hole which was somewhat widened because of the stress during the long time of operation. Therefore the largest boring hole diameter for new sleepers - being 19 mm - had been chosen.

In order to allow a comparison between the shanks of 110 and 130 mm length of the Double Shank Elastic Rail Spikes DS 18, each test sleeper was submitted to the tests with the shanks of both lengths.

As indicated before under fig. 2, the bows of the Elastic Rail Spikes were cut off and threaded bars welded to the Spike in order to be able to drive-in and pull-out the Elastic Rail Spikes several times in succession.

The results of the tests with new beech wood sleepers are shown on the encl. 15. As you can see from it, the values of the resistance against pulling-out obtained with boring holes of 17 mm dia. are partly essentially above those stated with boring hole diameters of 18 and 19 mm. With the 17 mm diameter, however, in some cases were stated small cracks when driving-in the Elastic Rail Spikes in the sleeper wood, whereas with the 18 mm diameter boring hole no cracks arrived in any case. Regarding this fact, it is recommended to use a boring hole diameter of 18 mm.

The divergence of the stated resistance against adhesion is within the limits of the values which are normal for tests with wood. During the tests with new beech wood sleepers, the average and the smallest resistance against pulling-out at the 1. and 10. static test of pulling-out amounted to:

Diameter of boring-hole 18 mm

DS 18/130	Average value	Min. value
1st pulling-out	5079 kp	4300 kp
10th pulling-out	3875 kp	3700 kp
decrease	1204 kp = about 24 %	600 kp = about 14 %
DS 18/110		
1st pulling-out	4840 kp	4450 kp
10th pulling-out	3598 kp	3400 kp
decrease	1242 kp = about 26 %	1050 kp =about 24 %

In comparison to the proposed max. adhesion pressure of 1800 kp for each DS 18, the tests with new beech wood sleepers - impregnated with coal tar - showed for the DS 18/130 after ten times of driving-in and pulling-out a 2.2 fold safety in regard to the average value and a 2. 1 fold safety in regard to the min. value. Withe the DS 18/110 the safety amounts to about 2. 0 fold or about 1. 9 fold in the same order of succession.

In practice these values should probably be higher because of the corrosion of the shanks. Further the bending moment which is effective in the shanks when the Elastic Rail Spike is under tension, is also contributing to increase the resistance against pulling-out. Under this aspect, Double Shank Elastic Rail Spikes with shanks of 110 mm length seem to be sufficient for the use on beech wood sleepers. With soft wood sleepers, we recommend the use of Double Shank Elastic Rail Spikes with shanks of 130 mm length.

On encl. 16 one can see the resistance against driving-in and pulling-out stated on 18-year-old beech wood sleepers having boring holes of 19 mm dia. On this enclosure are compared the said values of the old sleepers with those obtained with new sleepers having the normal boring hole of 18 mm dia. According to this comparison, the resistance against pulling-out which was stated after the tenth sequence with the Double Shank Elastic Rail Spikes DS 18/130 was 12 % less and with the Double Shank Elastic Rail Spikes DS 18/110 16 % less with the old sleepers

3. 6. Static and pulsating tests of rail creep-ing and twisting with the whole rail fastening on new beech wood sleepers impregnated with coal tar.

The resistances against rail creeping and twisting are important for the rail creeping safety as well as the stability of the endless welded track.

The tests were carried out statically as well as pulsating, a vibrator causing at the same time an oscillatory inferference with suitable frequency and amplitude.

For the tests the sleeper sections with their complete rail fastening which was installed in their middle, were mounted in a rigid stretching frame (see app. 8). Thereby the rail creeping and twisting forces were determined by means of a calibrated traction bar, whereas the distances of rail creeping and of twisting were determined by means of an inductive distance measuring device. The twistings were determined in angular degrees. All movements were brought about without any impact by means of an hydraulic press and the determined forces as well as the corresponding distances were registered by an XY-writer.

2 static and 2 pulsating rail creeping tests followed by a twisting test were carried out on each sleeper. The adhesion pressure being applied to each Double Shank Elastic Rail Spike amounted to approx. 1900 kp = about 3800 kp for each rail supporting point.

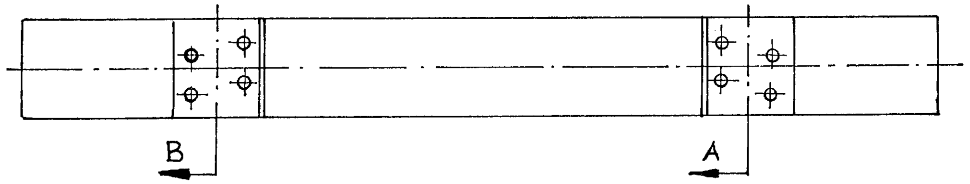
The rail creeping resistances which were determined by 8 tests each are shown on encl. 18.

The initial resistance amounted to:

statically	1760 up to 1950 = on an average 1862 kp; this comes to about 46. 5 up 51. 5 = about 49 % on an average of the adhesion pressure applied to each rail supporting point;
pulsating	1260 up to 1520 = on an average 1372 kp; this comes to about 33 up to 40 = about 36 % on an average of the adhesion pressure applied to each rail supporting point.

With long-welded tracks these stated rail creeping resistances are sufficient to avoid that a brekage opening might become dangerous for operation in winter in case of low temperature. A good ballasting of the sleepers has to be provided for.

Considering the lower illustrated arrangement of the Double Shank Elastic Rail Spikes DS 18 on the beech wood sleepers - on the right side the tests "A" and on the left side the tests "B" - the twisting tests were carried out in 2 twisting positions:



The results of the tests for both arrangement of the Elastic Rail Spikes were different ones. These results of the static as well as of the pulsating twisting tests are shown on the encl. 19 (for position "A" and on encl. 20 (for position "B").

In order to obtain an equal resistance against twisting for both directions, it is recommendable to drill the sleepers as shown above. Hereby the average value obtained with both arrangements can be used for the judging. These average resistances against twisting are graphically shown on encl. 21 and are:

static	at = 0,1°	91,1 mkp
	at = 1,0°	198,0 mkp
pulsating	at = 0,1°	45,6 mkp
	at = 1,0°	86,2 mkp.

In comparison to the K fastening (GEO fastening) which is used by the Federal German Railways the tests of the resistance against rail creeping and twisting showed results which are within the limits of divergence being normal for this rail fastening. Thus when using Double Shank Elastic Rail Spikes DS 18 on long-welded tracks, there are prevailing about the same conditions as with the rail fastening "K" - as regards the opening of breakage gaps in winter and the buckling safety in summer. In this connection it should be mentioned that the buckling safety depends to a great extent on the resistance against lateral creeping of the track panel. This requires a good lateral ballasting of the sleepers.

4. Conclusion.

The continuous oscillation load tests carried out by means of a cross-bar oscillator and using a rail fastening with Double Shank Elastic Rail Spikes DS 18 directly applied to beech wood sleepers impregnated with coal tar shows that one can expect a long duration of life in the running track with axle loads from 25 to 30 Mp and their corresponding rail profiles. Considering the partly great guiding forces at track curves with small radius and the diminishing resistance of the sleeper wood with growing time of lying (biological aging of the wood) it is advisable to use a steel sole plate between the rail and the sleeper for narrow curves and for heavily charged tracks.

In case of a boring hole diameter of 18 mm, the sleeper wood did not show any cracks after having carried out the pulling-out tests. The stated resistances against pulling-out the spike shanks of 130 and 110 mm length showed still sufficient safety against self-acting loosening of the spikes even after 10 times of pulling-out. The results of the tests carried out with 19-year-old sleepers were only 12 % to 16 % below the values stated with new sleepers.

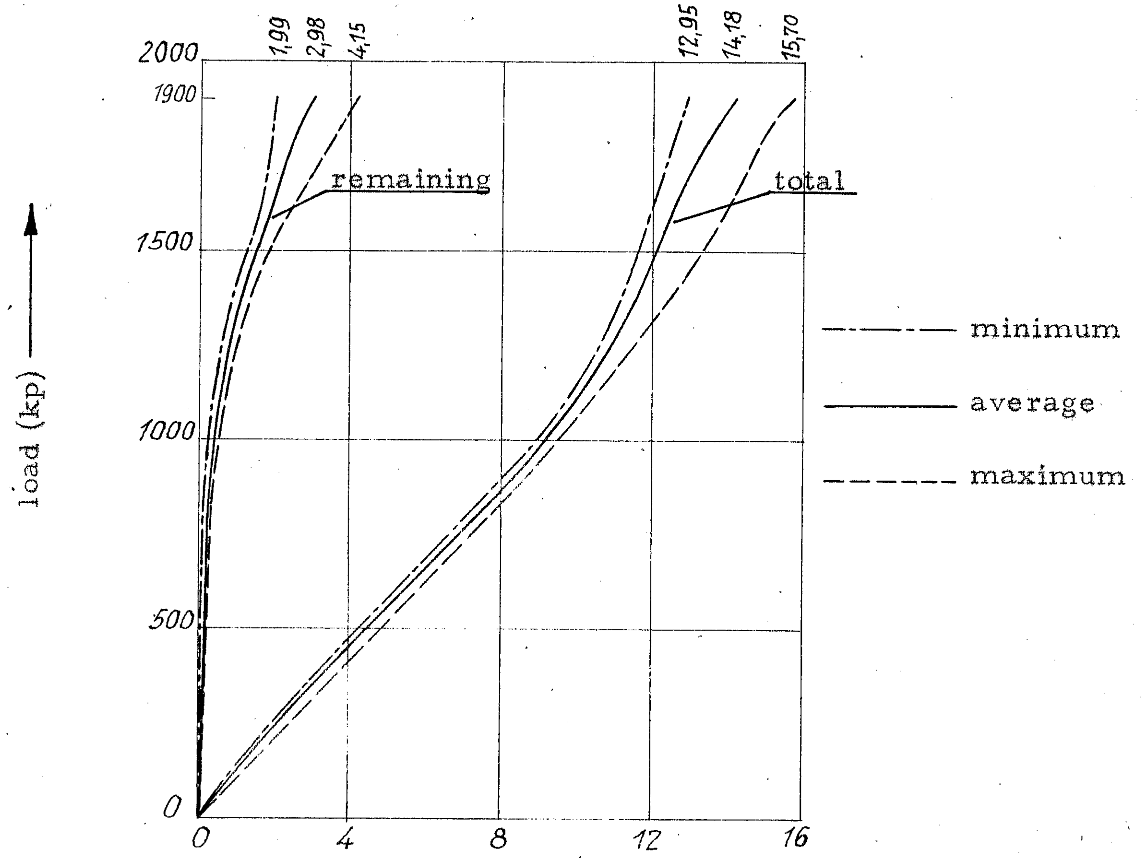
During the continuous oscillation load tests up to a limit of 5 millions of proceedings loaded-unloaded, on each pair of Double Shank Elastic Rail Spikes with an amplitude of $s = 1.4$ mm and an upper load of about 1700 kp on each DS 18, there had been no lasting breakage. Regarding this fact, the adhesion pressure of 1800 kp for each Double Shank Elastic Rail Spike should not be exceeded when installing the Spikes.
The tests concerning resistance against rail-creeping and twisting showed that the rail fastening with Double Shank Elastic Rail Spikes DS 18 meets the requirements of long-welded tracks.

When using soft wood sleepers and having high axle loads as well as heavy traffic, it is recommendable to examine by means of continuous oscillation load tests on a cross-bar oscillator, whether a sole-plate should be used in order to protect the rail bed.

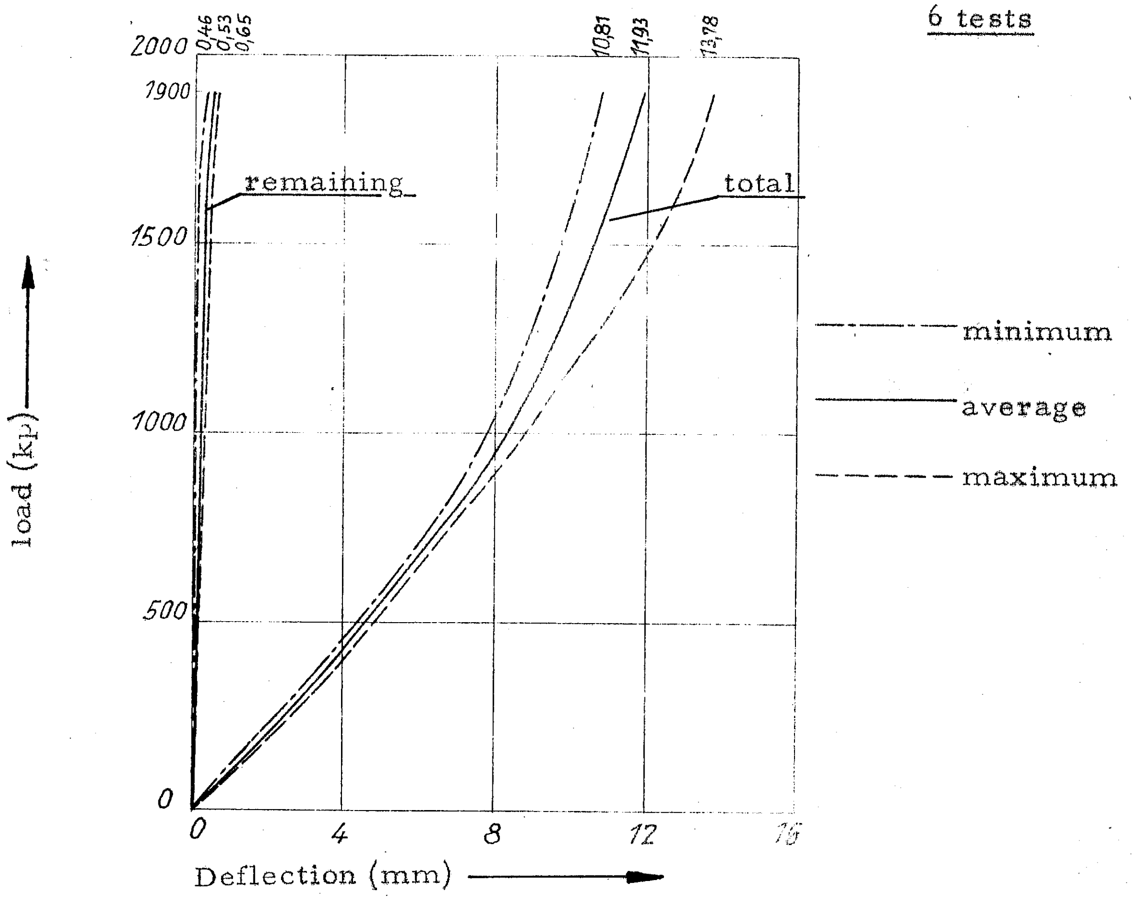
signed: Dr.-Ing. Eisenmann
scientific councillor

Gauging of the Double Shank Elastic Rail Spikes DS 18, deflection graph of the first load (preliminary tension); average and limit values taken from 8 tests.

(P_{max} = 1900 kp)

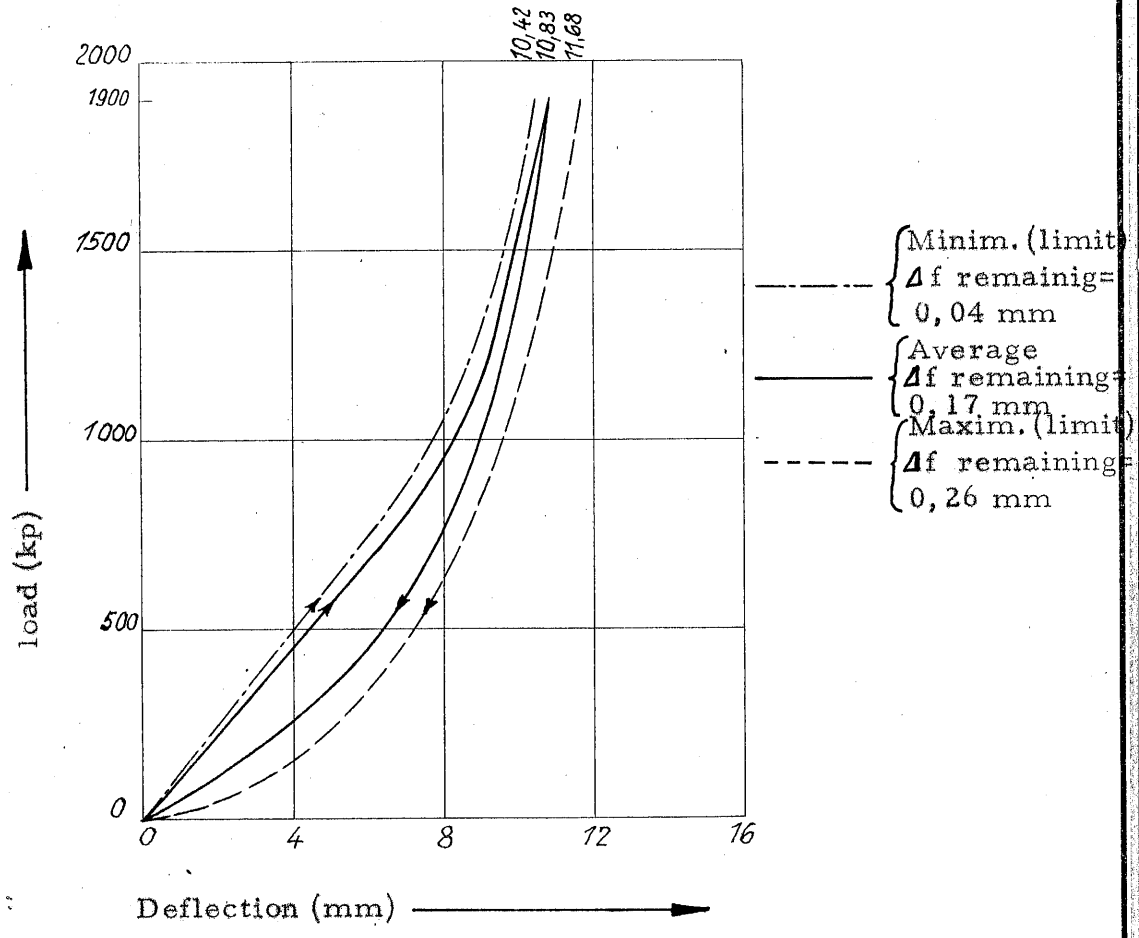


Deflection graph of the second load; average and limit values taken from 6 tests



Gauging of the Double Shank Elastic Rail Spikes DS 18, Deflection graph of the 10th loading and unloading without intermediate unloading; average and limit values from 10 tests.

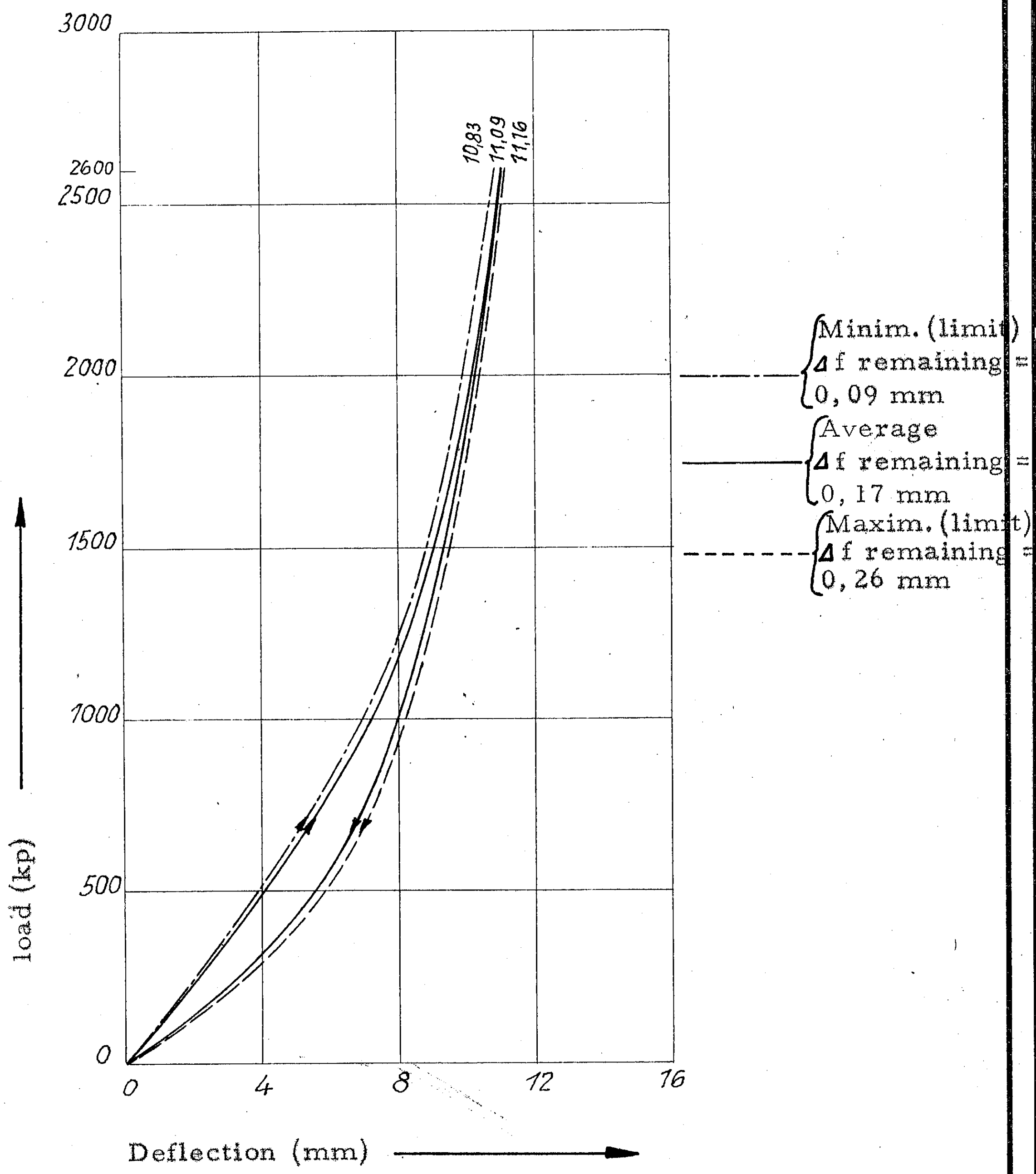
(P_{max} = 1900 kp)



Enclosure 2

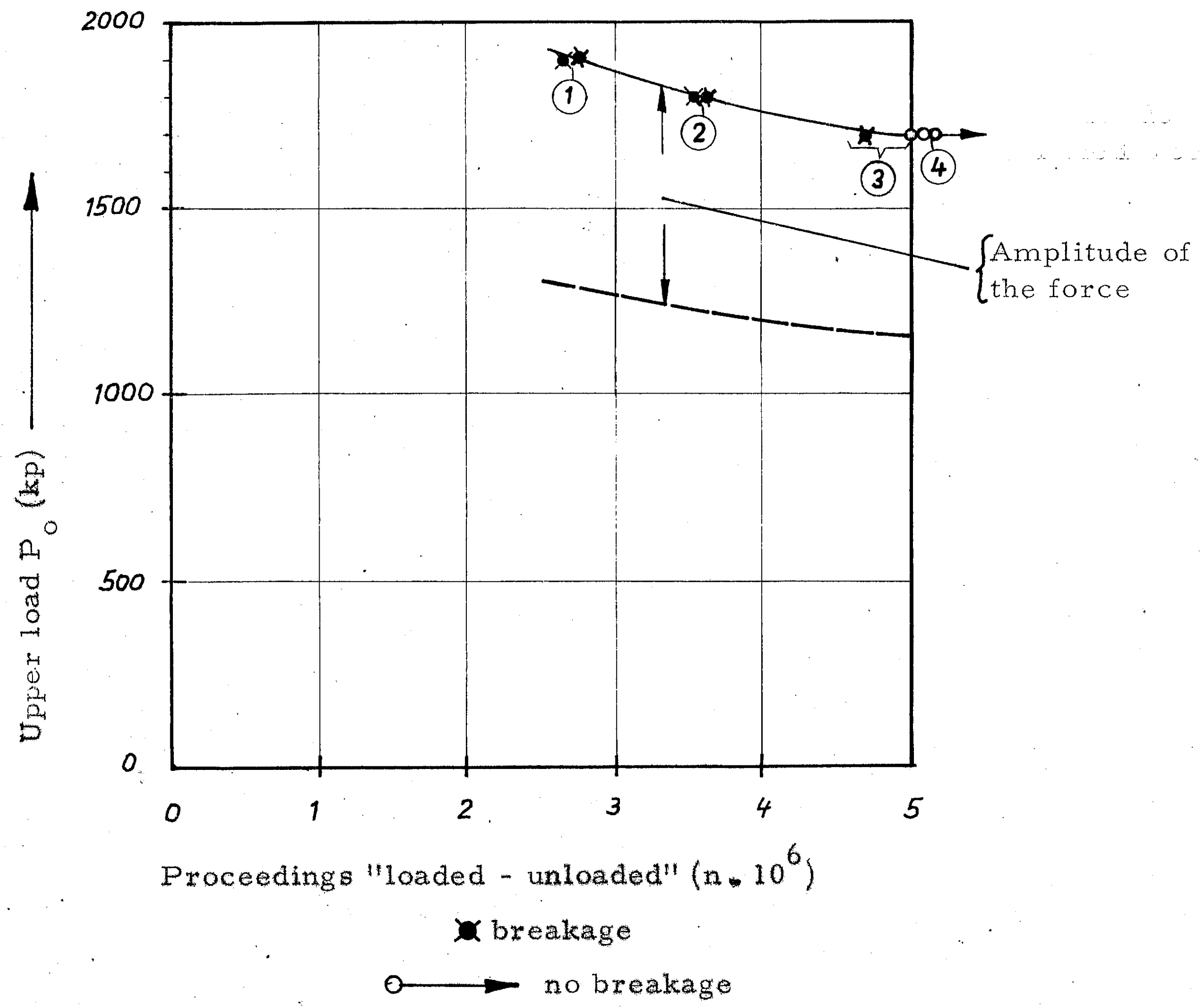
Gauging of the Double Shank Elastic Rail Spikes DS 18, Deflection graph of the 10th loading and unloading without intermediate unloading; average and limit values from 8 tests.

(P_{max} = 2600 kp)



Results of the continuous tests with oscillating load with two Double Shank Elastic Rail Spikes each on a rail section

(4 continuous tests with 2 DS each)

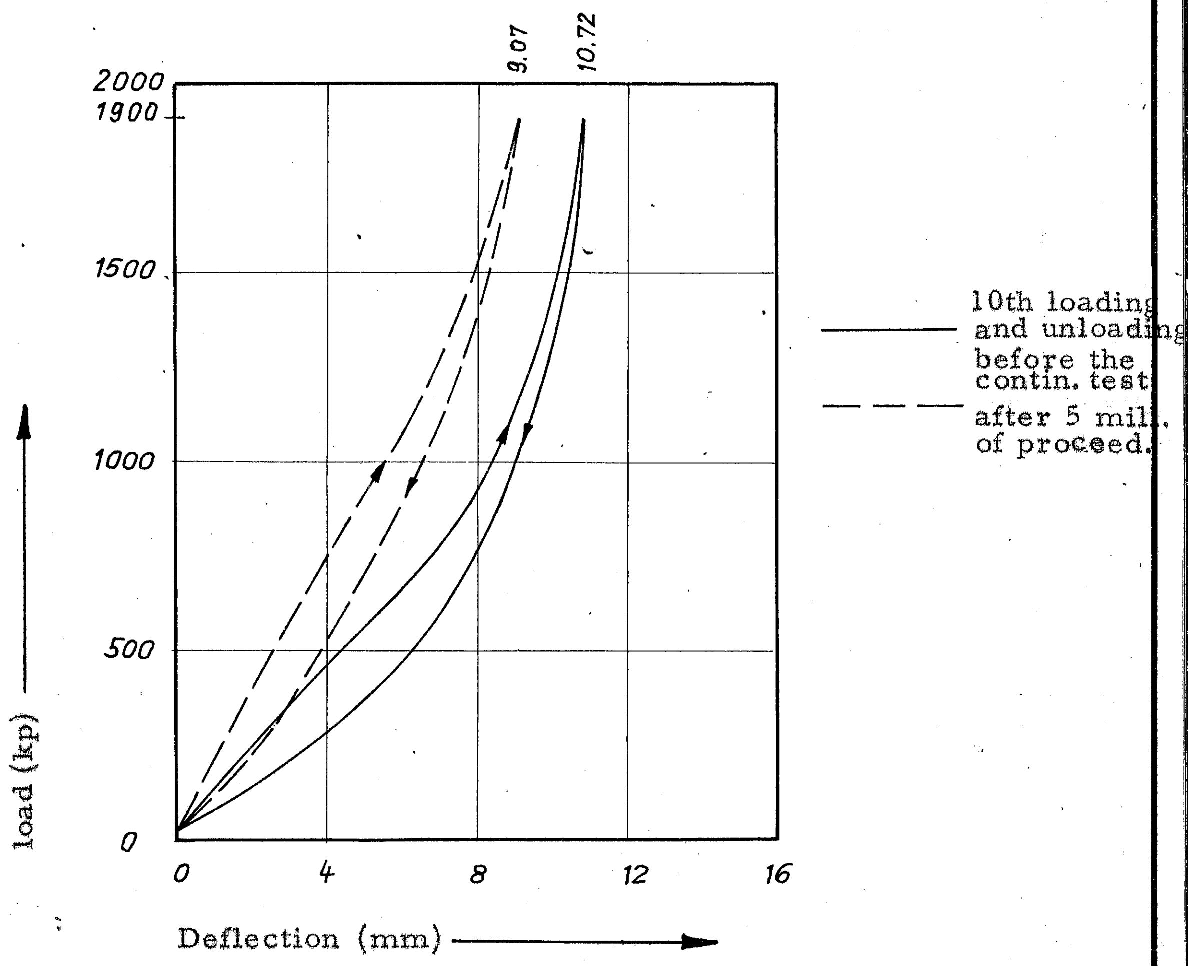


Remark: to test 3 see fig. 3.3

Enclosure 4

Comparison of the gauging of the 10th loading and unloading without intermediate unloading before the continuous oscillation load test and after 5 millions of proceedings "loaded-unloaded" at P_o = 1700 kp and Δs = 1.4 mm.

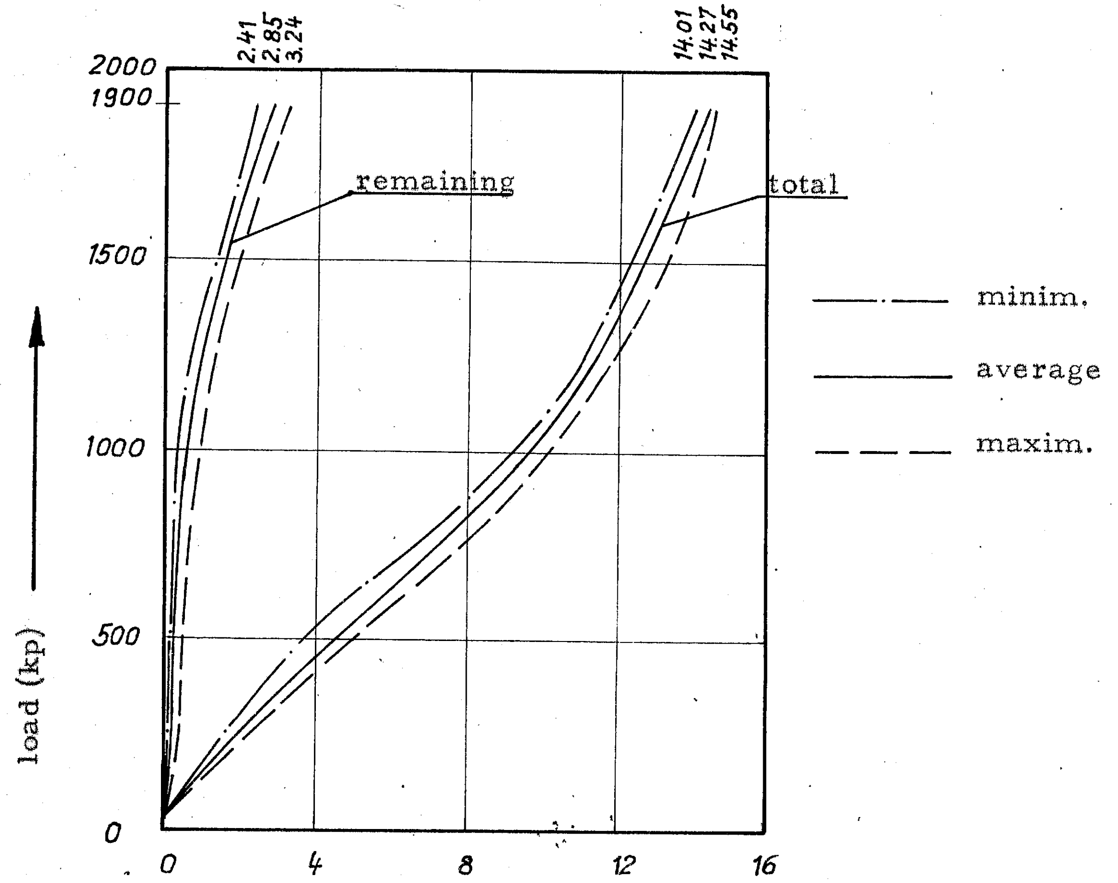
(average of 2 samples - test 4)



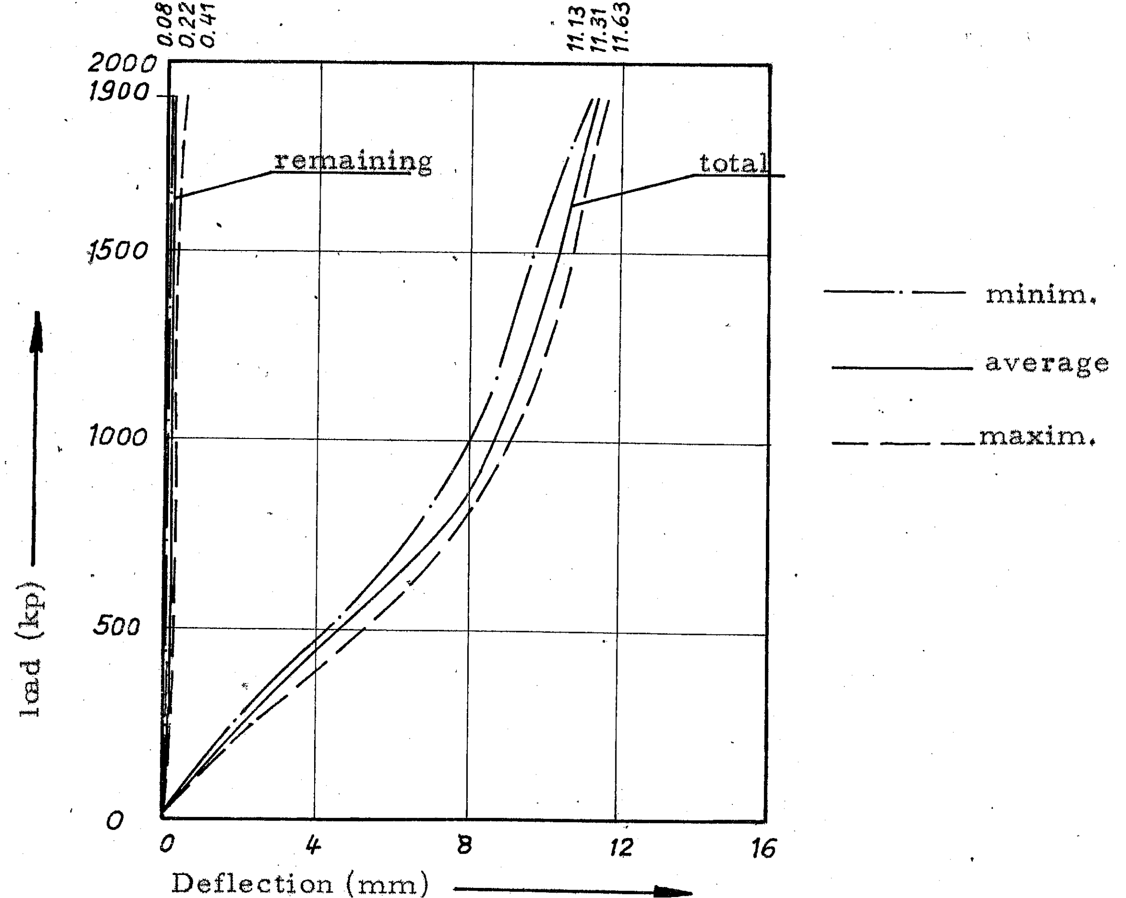
Enclosure 5

Gauging of the Double Shank Elastic Rail Spikes DS 18 before the continuous oscillation tests. Deflection graph of the 1st load (preliminary tension); average and limit values of 8 tests.

(P_{max} = 1900 kp)

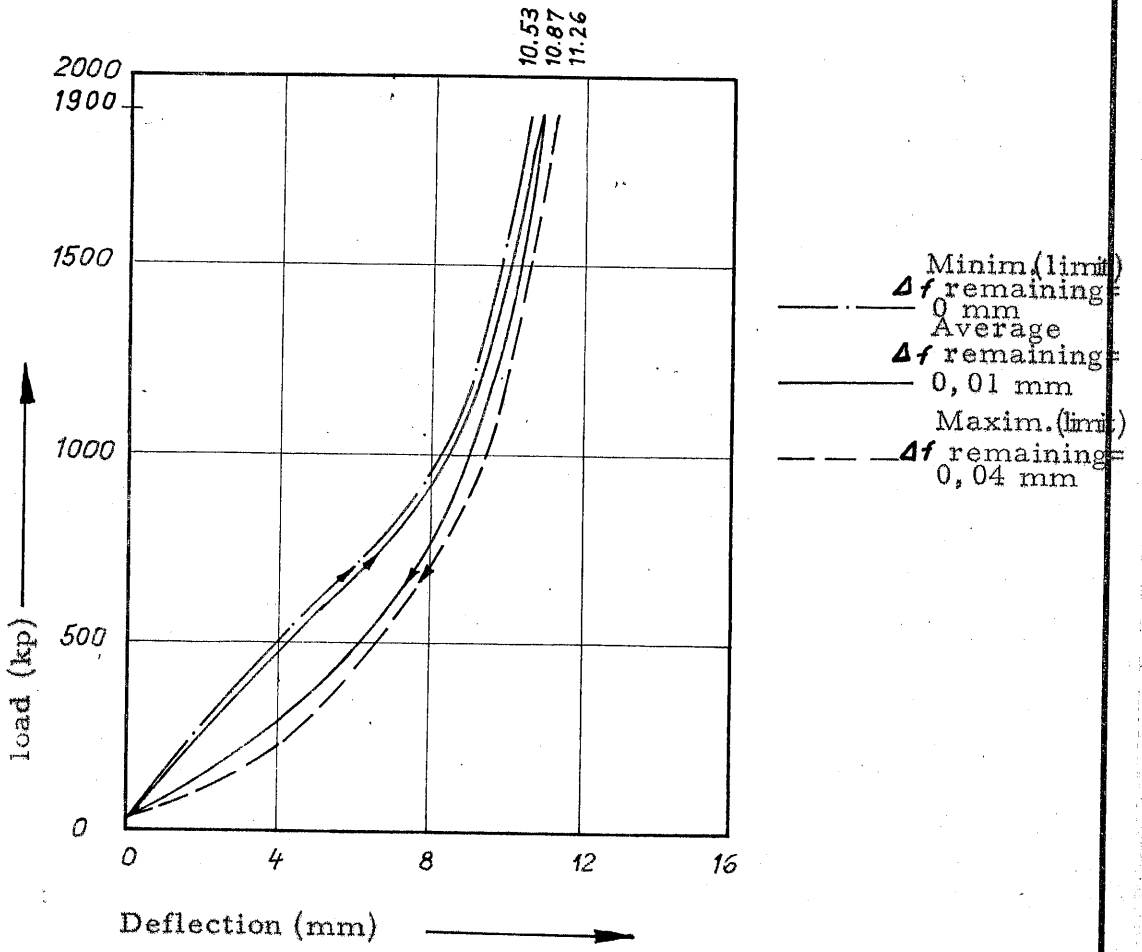


Deflection graph of the 2nd load; average and limit value of 8 tests.

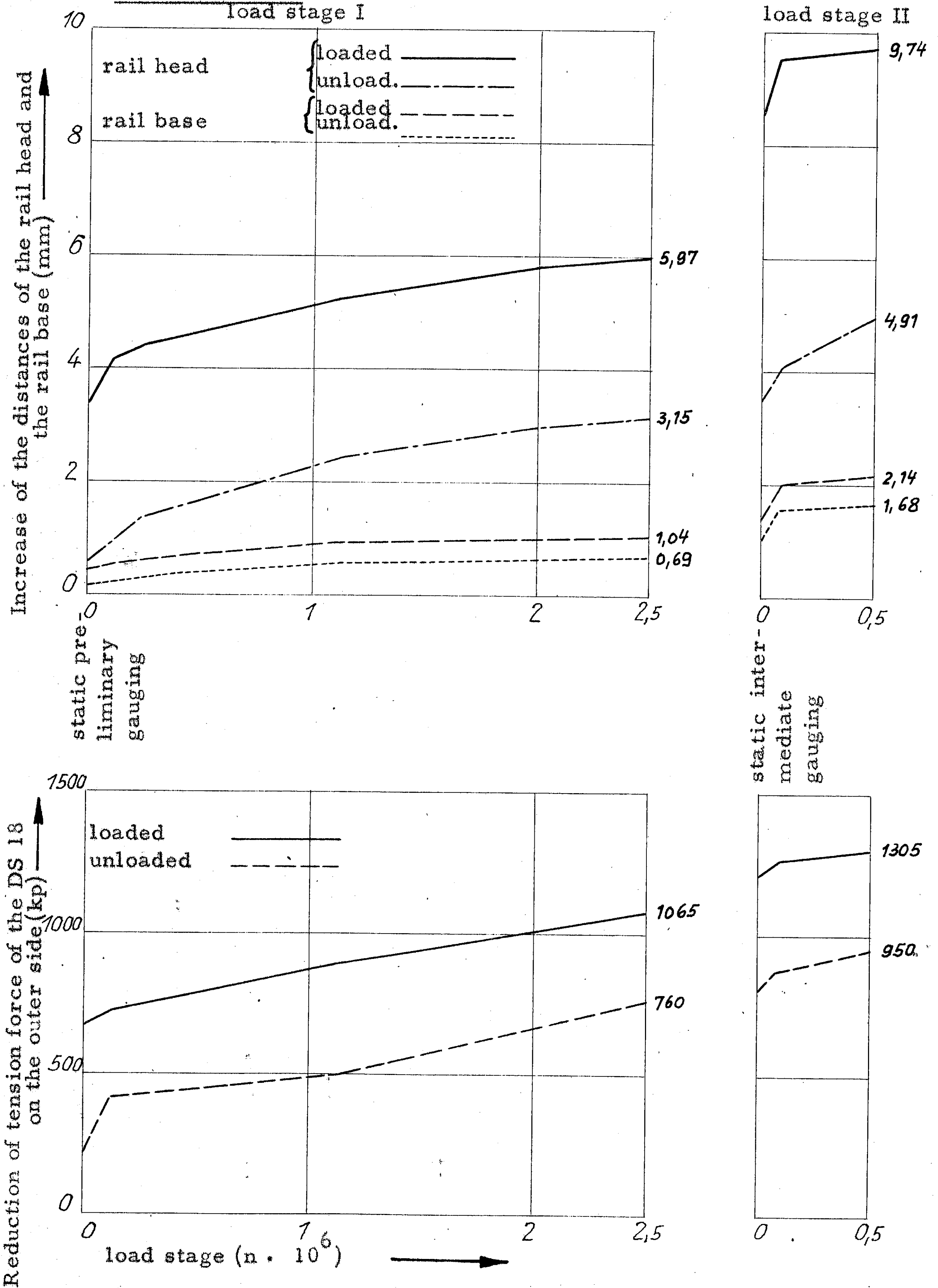


Gauging of the Double Shank Elastic Rail Spikes DS 18 before the continuous oscillation load tests, deflection graph of the 10th loading and unloading without intermediate unloading; average and limit values of 8 tests.

(P_{max} = 1900 kp)

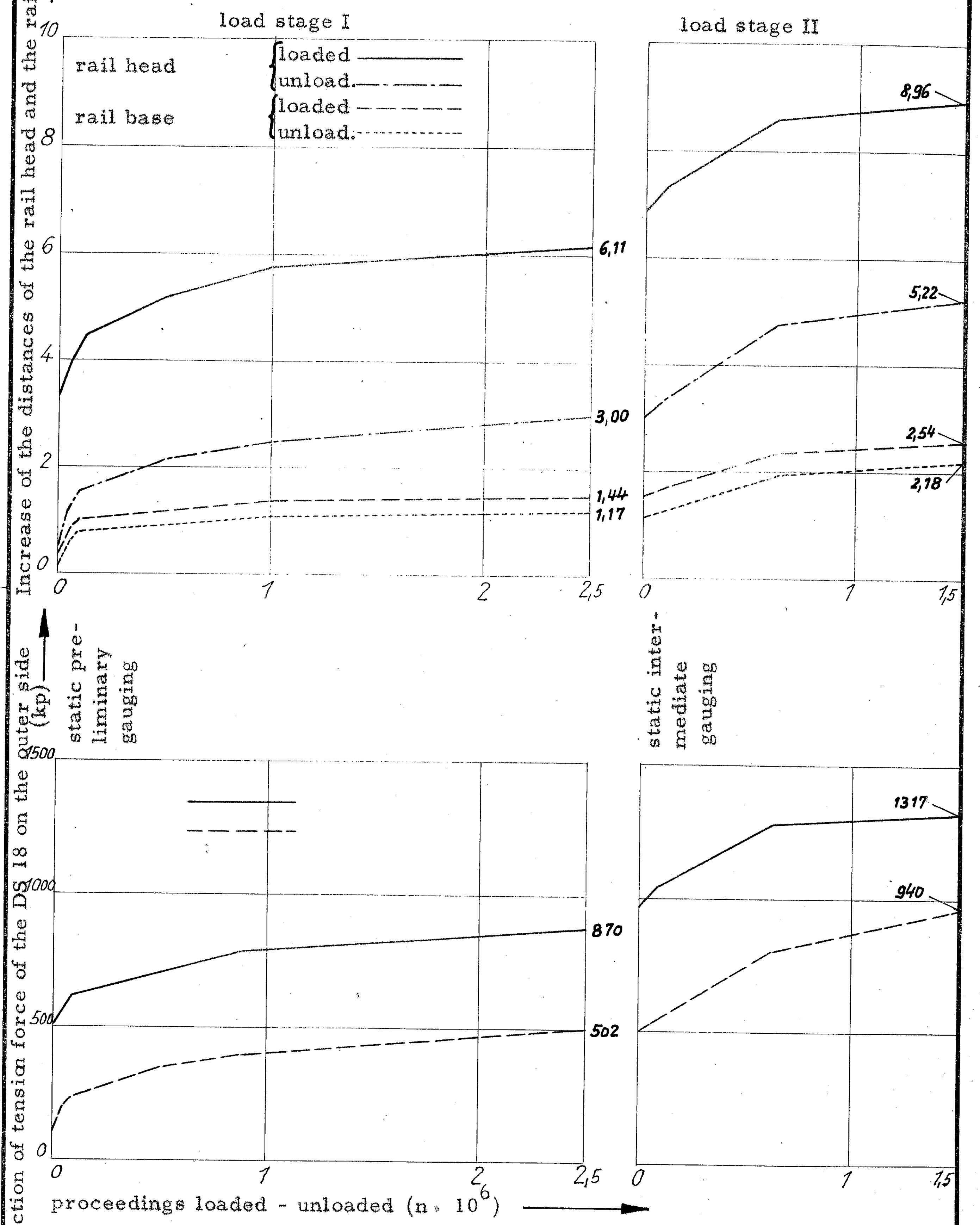


Continuous oscillating load test by means of a cross-bar oscillator on rail S 54 fastened on new beech wood sleepers (impregnated with coal tar) with two Double Shank Elastic Rail Spikes DS 18, average value of 2 tests.



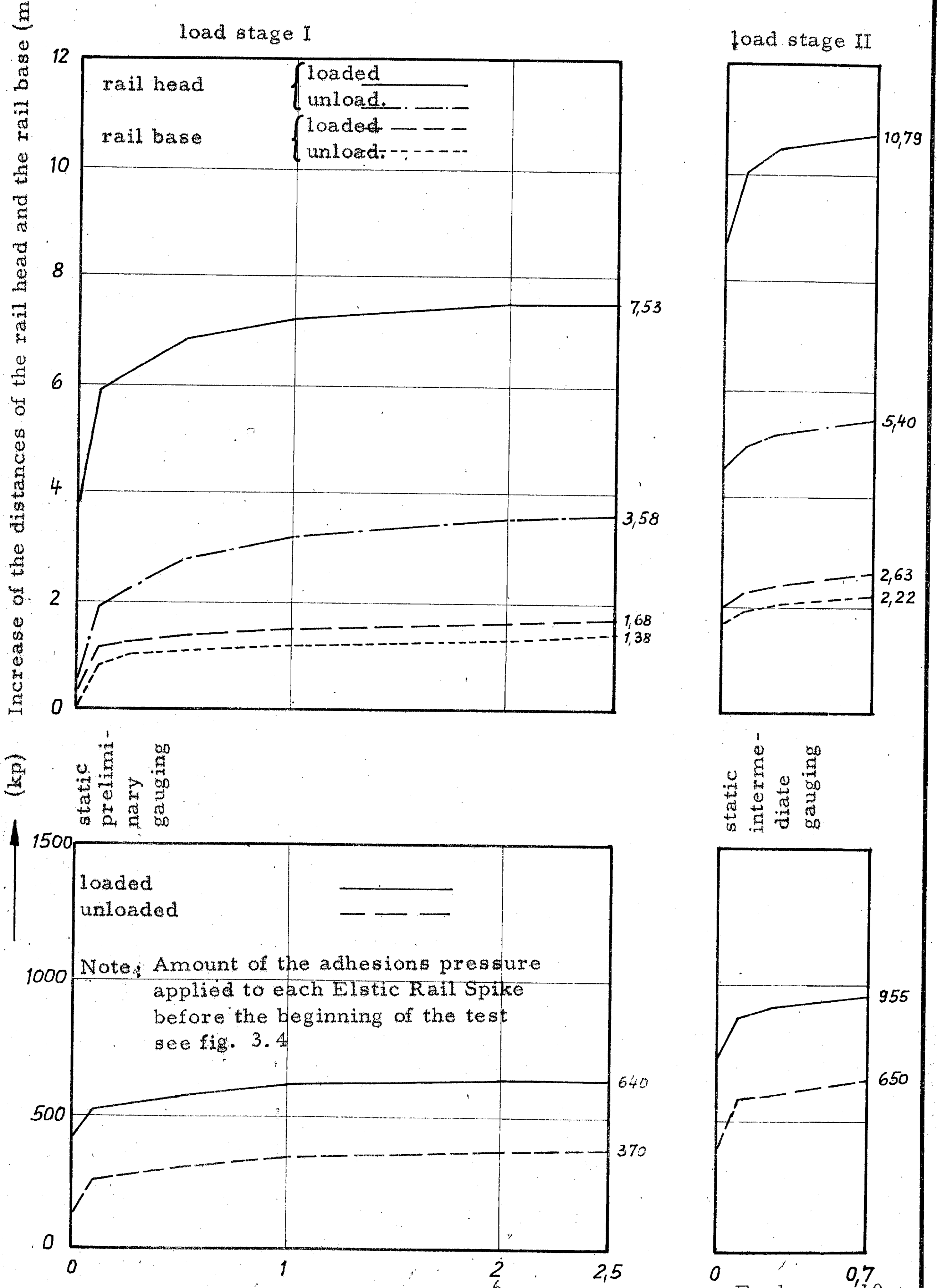
Note: Amount of the adhesion pressure applied to each Elastic Rail Spike see fig. 3.4. (before the beginning of the test)

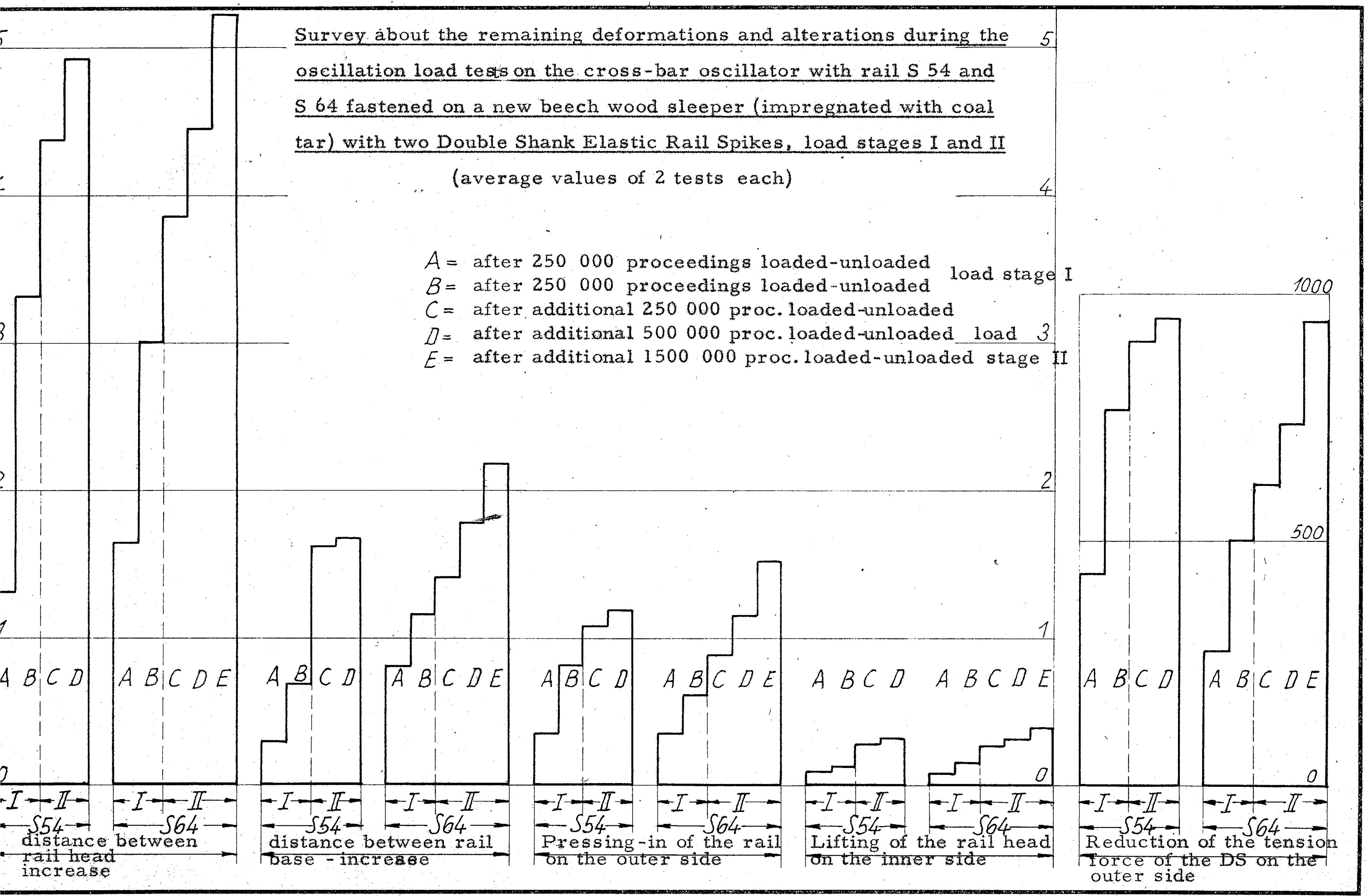
Continuous oscillation load test by means of a cross-bar oscillator on rail S 64 fastened on a new beech wood sleeper (impregnated with coal tar) with two Double Shank Elastic Rail Spikes DS 18, average value of 2 tests.



Note: Amount of the adhesion pressure applied to each Elastic Rail Spike see fig. 3.4. (before the beginning of the test)

Continuous oscillation load test by means of a cross-bar oscillator on rail S 54 fastened on a old beech wood sleeper (impregnated with coal tar) with two Double Shank Elastic Rail Spikes DS 18, average value of 2 tests.



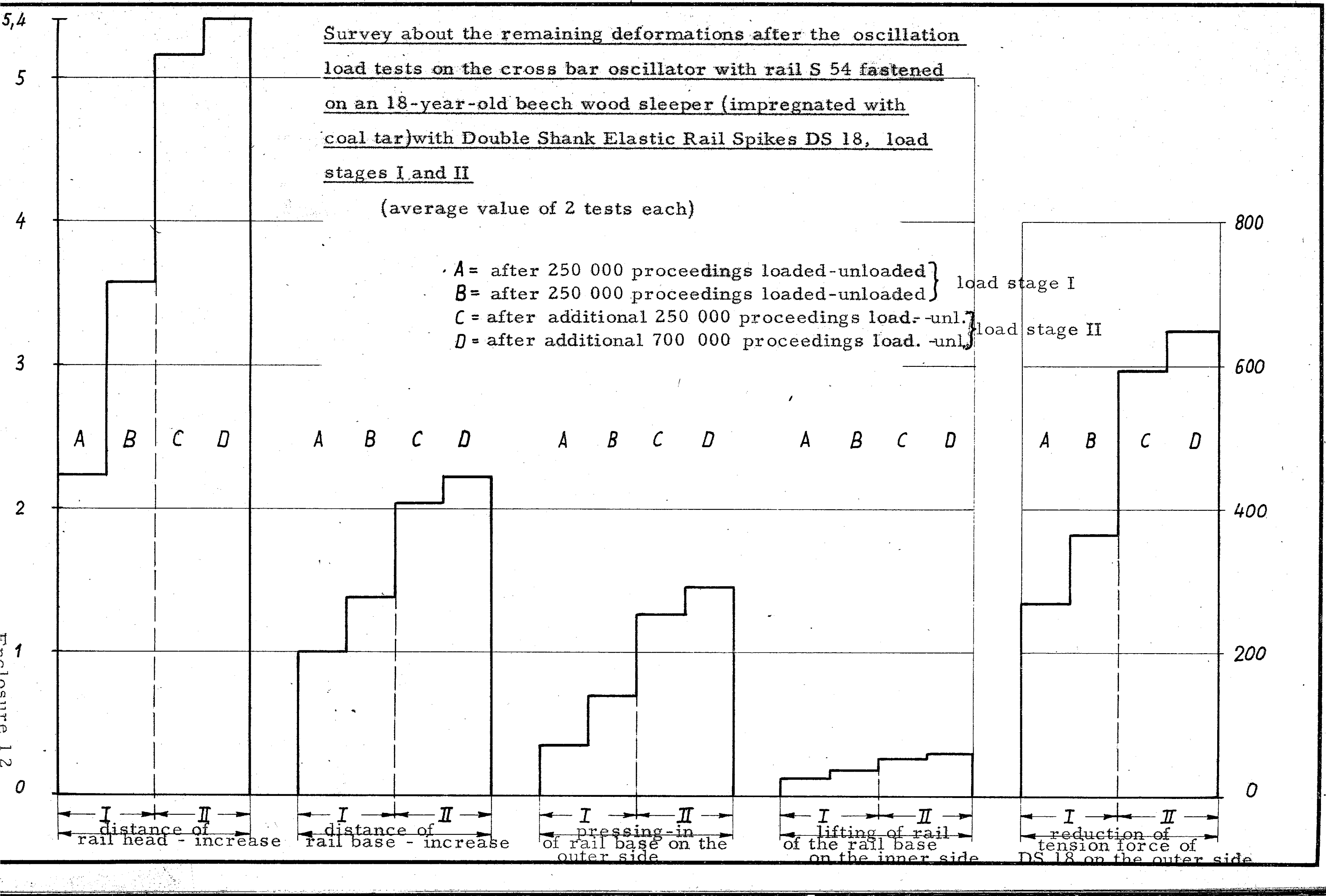


Survey about the remaining deformations and alterations during the oscillation load tests on the cross-bar oscillator with rail S 54 and S 64 fastened on a new beech wood sleeper (impregnated with coal tar) with two Double Shank Elastic Rail Spikes, load stages I and II

(average values of 2 tests each)

A = after 250 000 proceedings loaded-unloaded load stage I
B = after 250 000 proceedings loaded-unloaded
C = after additional 250 000 proc. loaded-unloaded
D = after additional 500 000 proc. loaded-unloaded load stage II
E = after additional 1500 000 proc. loaded-unloaded

Enclosure 12



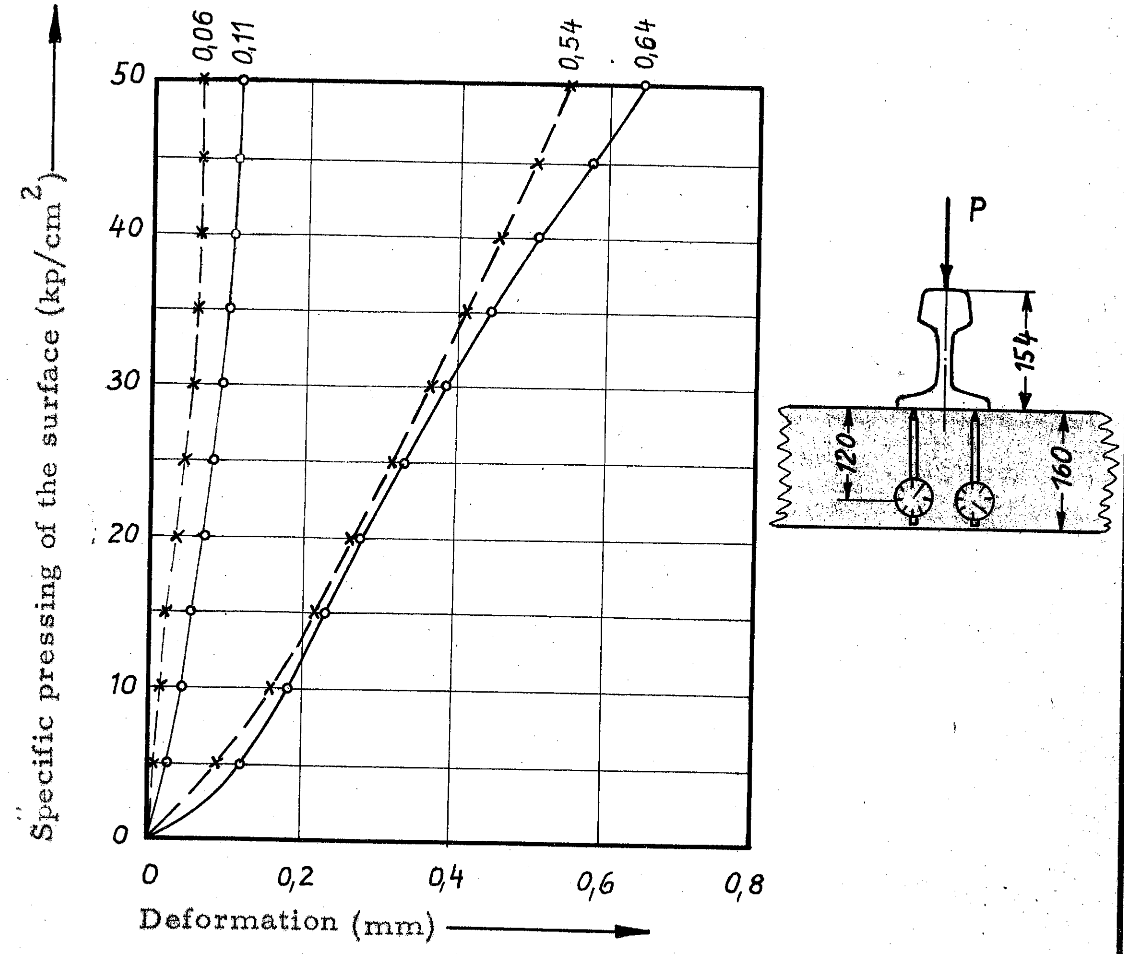
Survey about the remaining deformations after the oscillation load tests on the cross bar oscillator with rail S 54 fastened on an 18-year-old beech wood sleeper (impregnated with coal tar) with Double Shank Elastic Rail Spikes DS 18, load stages I and II

(average value of 2 tests each)

A = after 250 000 proceedings loaded-unloaded } load stage I
B = after 250 000 proceedings loaded-unloaded }
C = after additional 250 000 proceedings load.-unl. } load stage II
D = after additional 700 000 proceedings load.-unl. }

Static pressure tests beside the rail beds before and on the rail beds after the oscillation load test on a cross-bar oscillator with rail S 54 resting directly on new beech wood sleepers.

(average of 4 tests each on 2 sleepers)

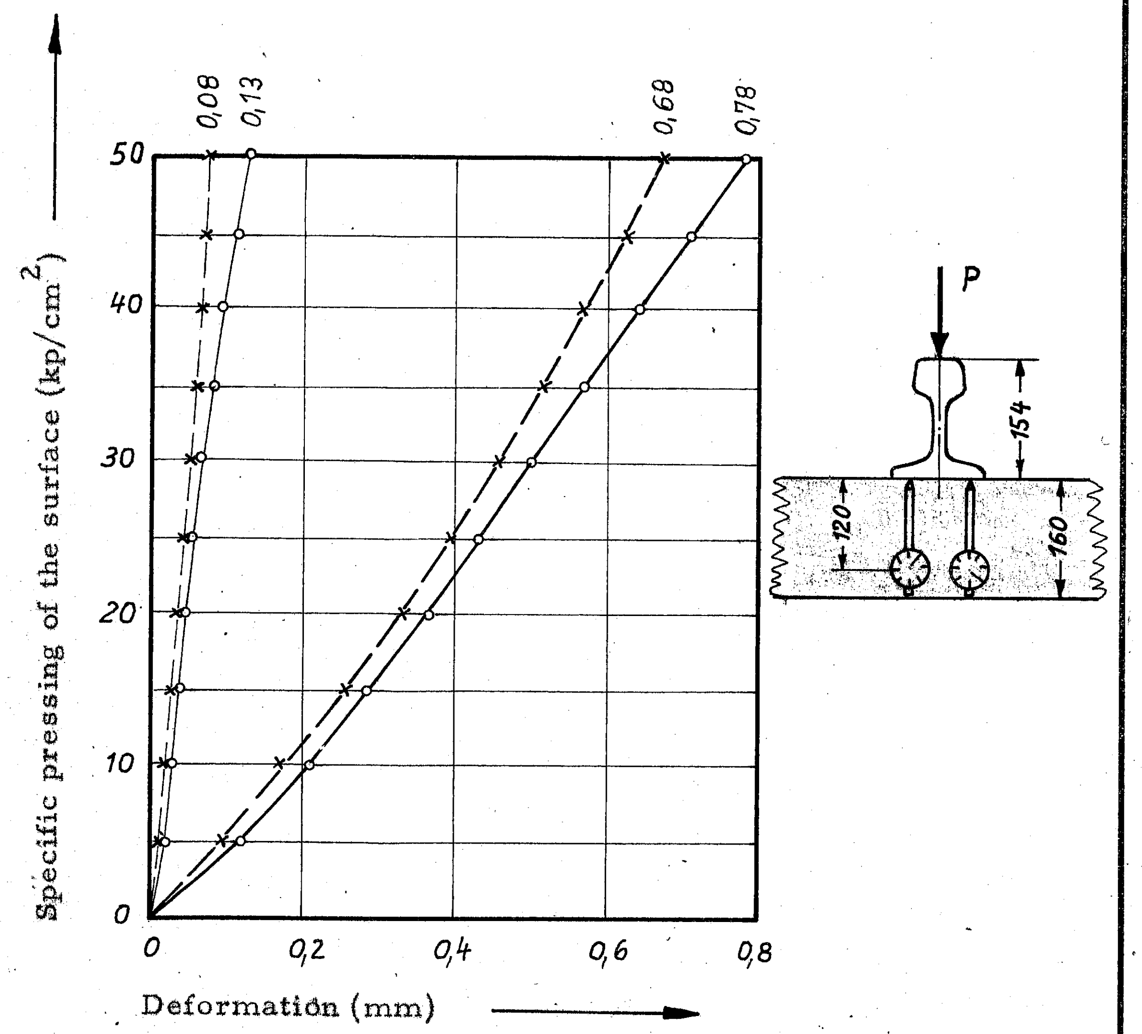


o———o	total	deformation of the rail bed after the oscillation load test on a cross bar oscillator
x— —.—x	remaining	
o━━━o	total	deformation beside the rail bed before the oscillation load test on a cross bar oscillator
x-----x	remaining	

Note: The surfaces beside the rail beds on which the pressure is acting were slightly planed.

Static pressure tests beside the rail beds before and at the rail beds after the oscillation load test on a cross bar oscillator with rail S 54 resting directly on an 18-year old beech wood sleeper impregnated with coal tar

(average of 4 tests each on 2 sleepers).



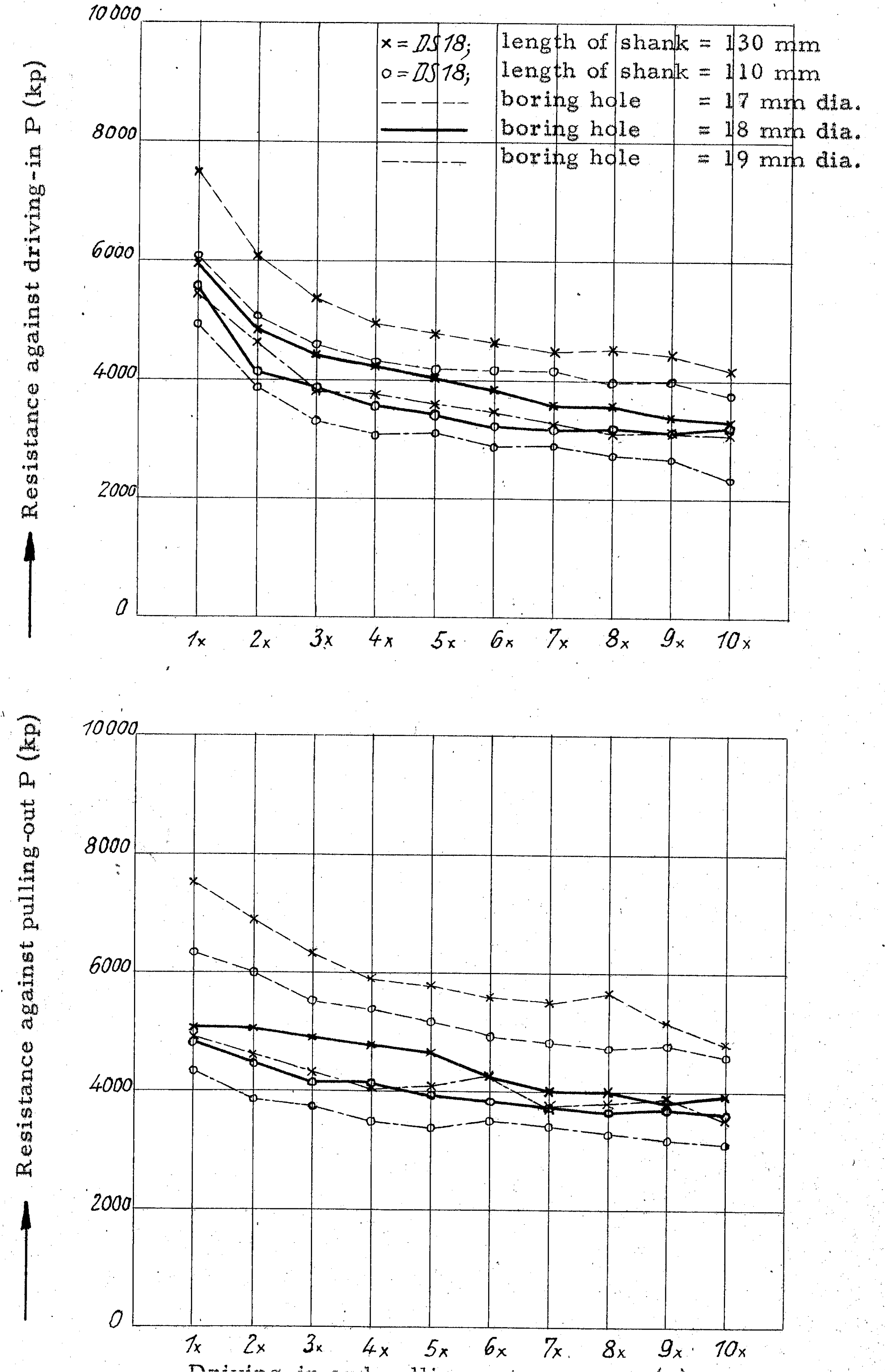
o———o total
x— — —x remaining
{deformation of the rail bed after the oscillation load test on a cross bar oscillator

o———o total
x– – – –x remaining
{deformation beside the rail bed befor the oscillation load test on a cross bar oscillator

Note: The surfaces beside the rail beds on which the pressure is acting were slightly planed.

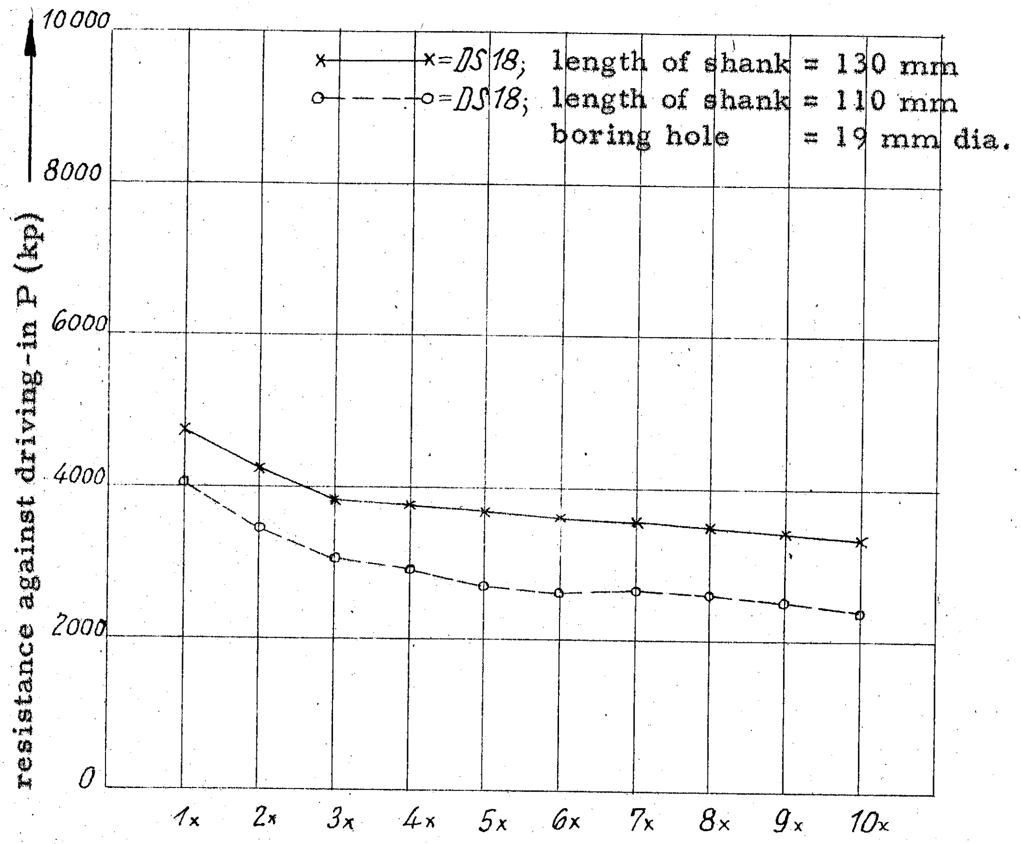
Repeated static driving-in and pulling-out tests with Double Shank Elastic Rail Spikes DS 18, length of shanks = 130 and 110 mm, out of new beech wood sleepers impregnated with coal tar.

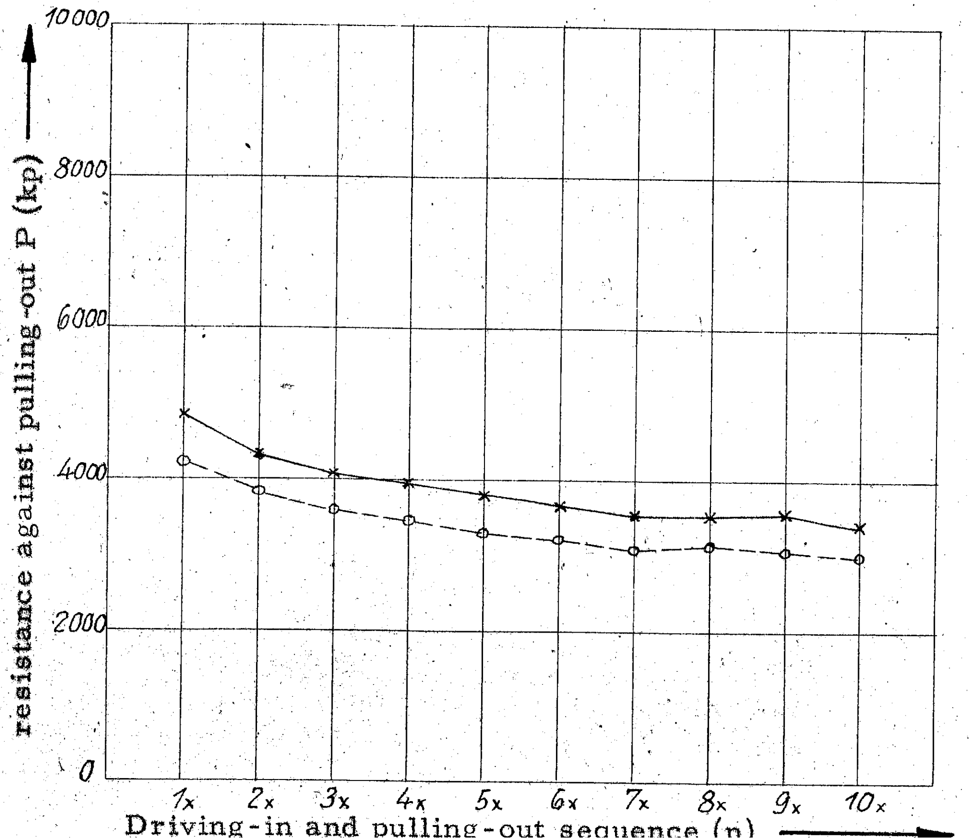
(average value of 4 testing series each)



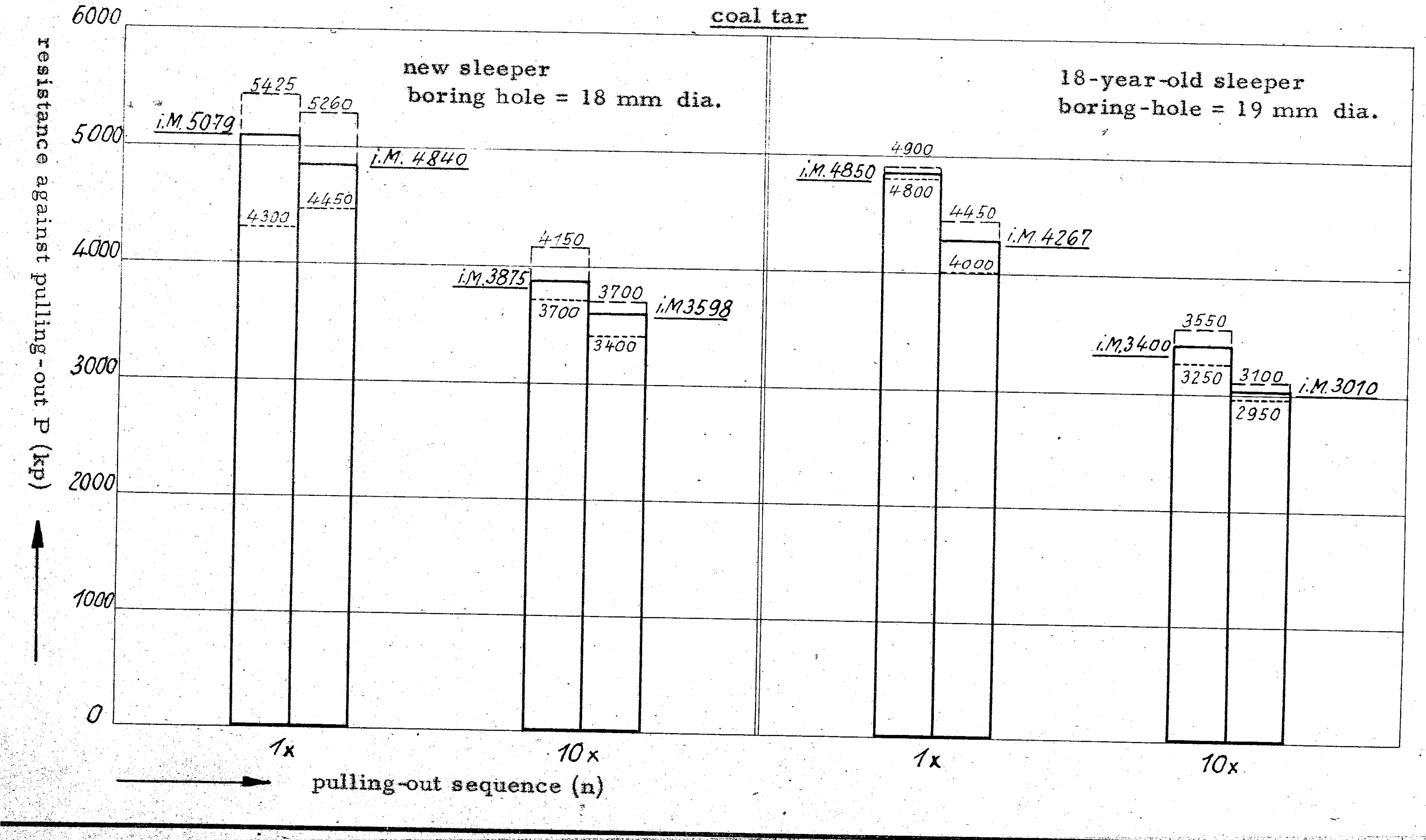
Repeated static driving-in and pulling-out tests with Double Shank Elastic Rail Spikes DS 18, length of shanks = 130 and 110 mm, out of 18-year-old beech wood sleepers impregnated with coal tar.

(average value of 3 testing series each)



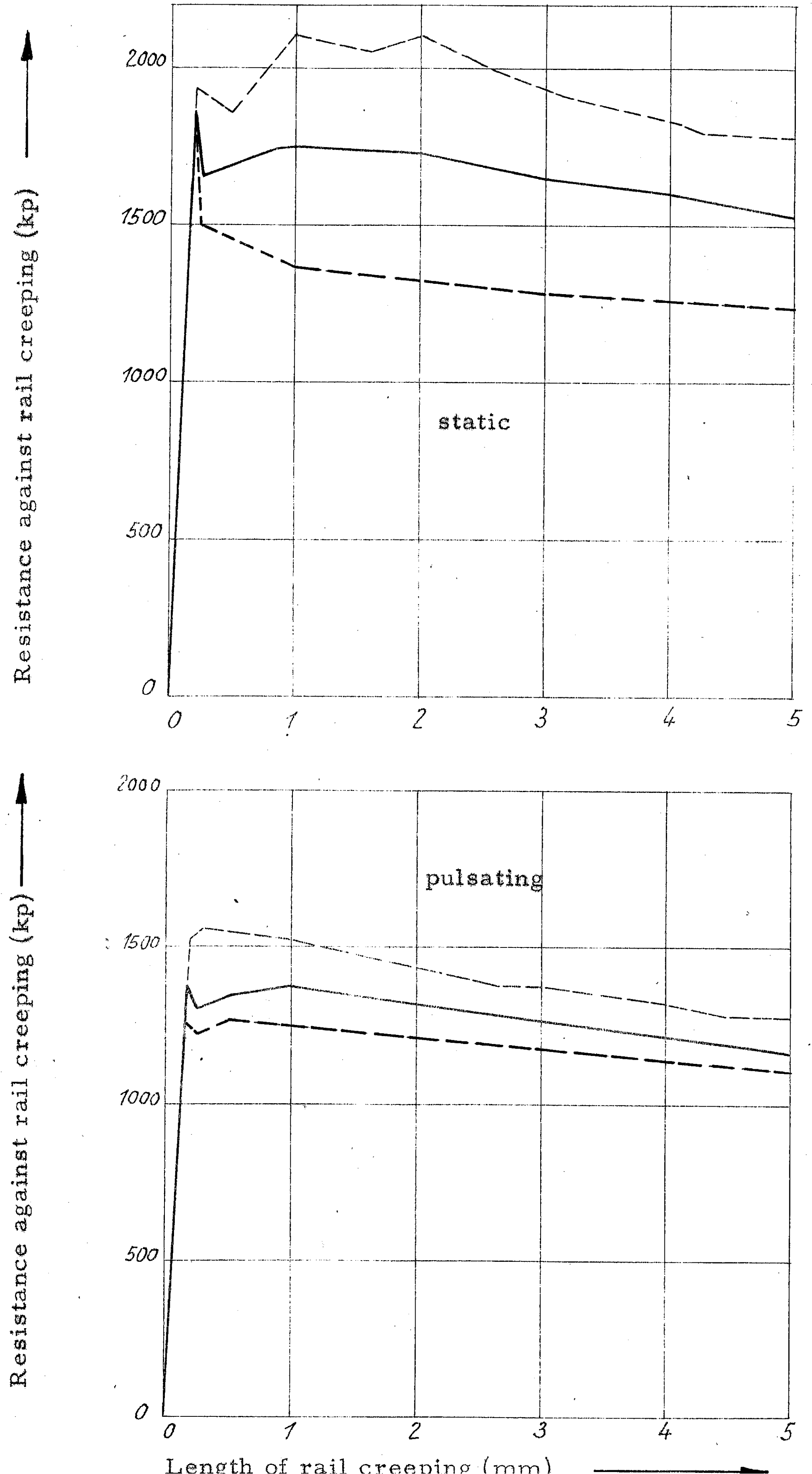


Survey of the resistances against pulling-out obtained during the static pulling-out tests with Double Shank Elastic Rail Spikes DS 18, length of shank 130 and 110 mm out of new and old beech wood sleepers impregnated with coal tar



Static and pulsating rail creeping tests with a rail fastening consisting of rail S 54 and two Double Shank Elastic Rail Spikes DS 18 being installed directly on a new beech wood sleeper impregnated with coal tar

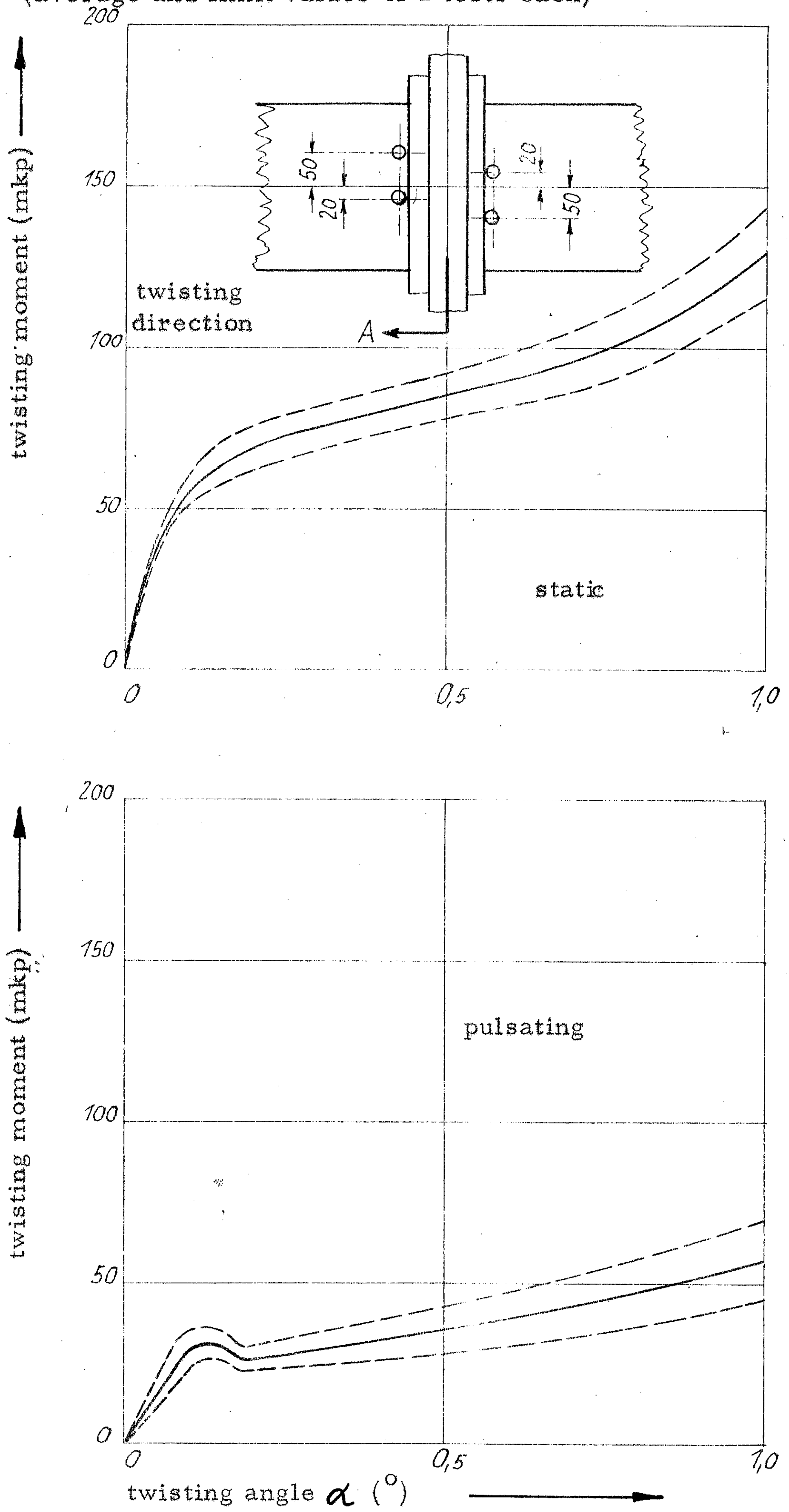
(average and limit values of 8 tests each)



Adhesion pressure applied to each DS 18 before beginning the test = abt. 1900 kp and 3800 kp respectively for each rail supporting point.

Static and pulsating twisting tests with a rail fastening consisting of rail S 54 and two Double Shank Elastic Rail Spikes DS 18 being installed directly on a new beech wood sleeper impregnated with coal tar; testing series: twisting direction A

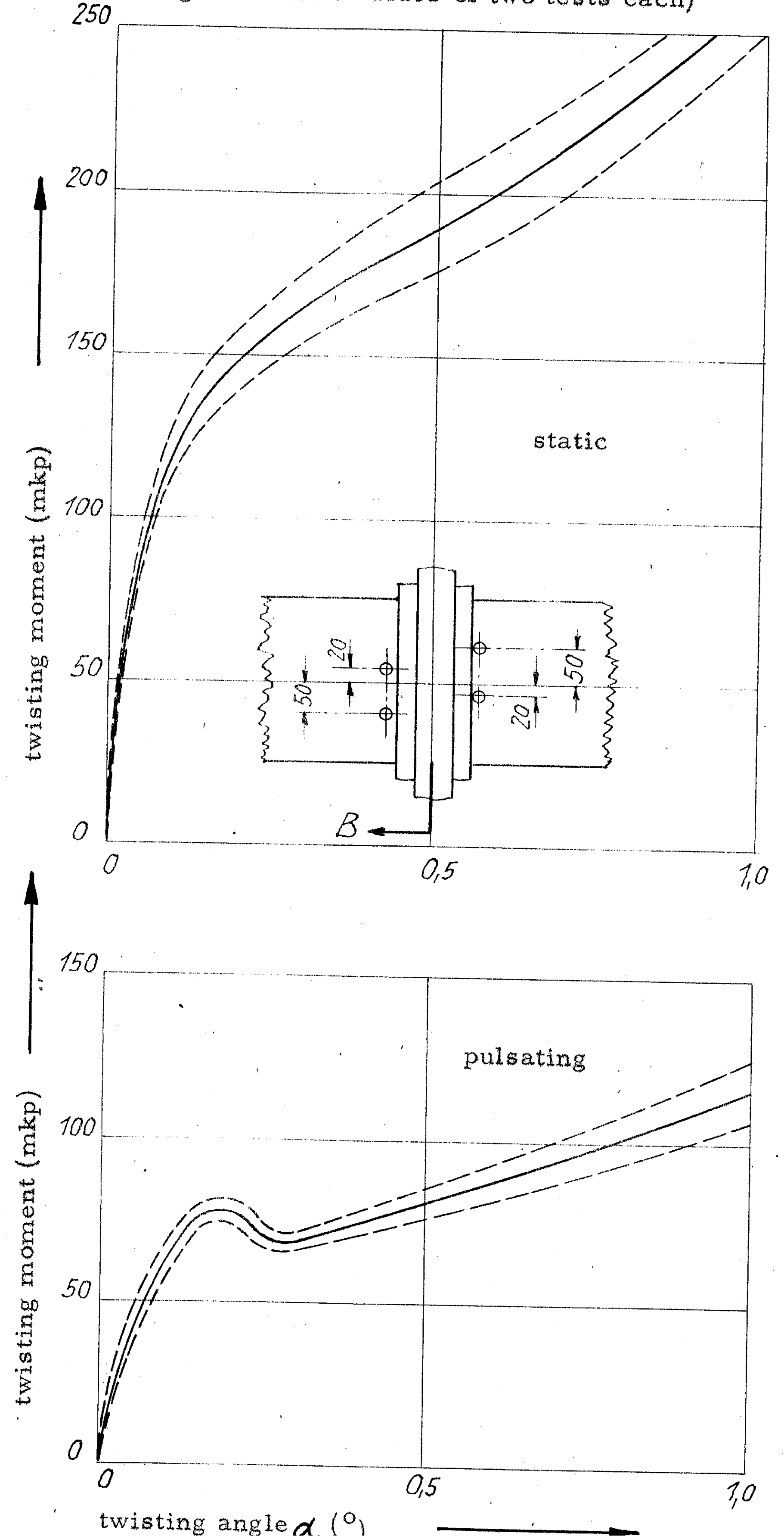
(average and limit values of 2 tests each)



Adhesion pressure applied to each DS 18 before beginning the test = abt. 1900 kp and 3800 kp respectively for each rail supporting point.

Static and pulsating twisting tests with a rail fastening consisting of rail S 54 and two Double Shank Elastic Rail Spikes DS 18 being installed directly on a new beech wood sleeper impregnated with coal tar; testing series: twisting direction B.

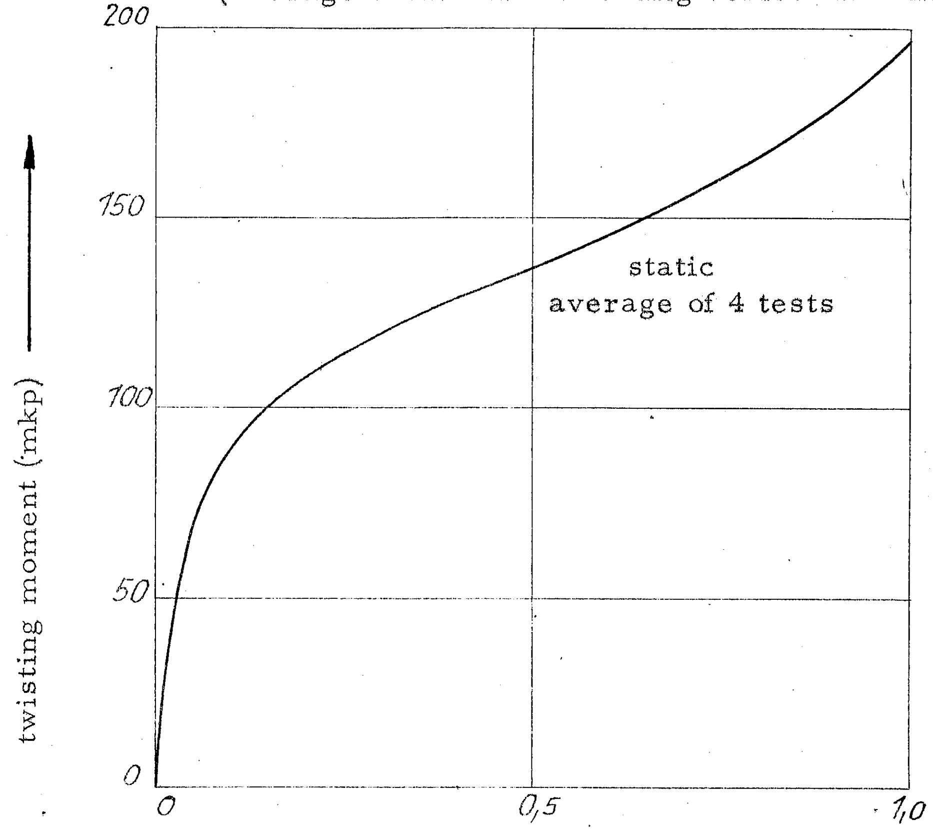
(average and limit values of two tests each)

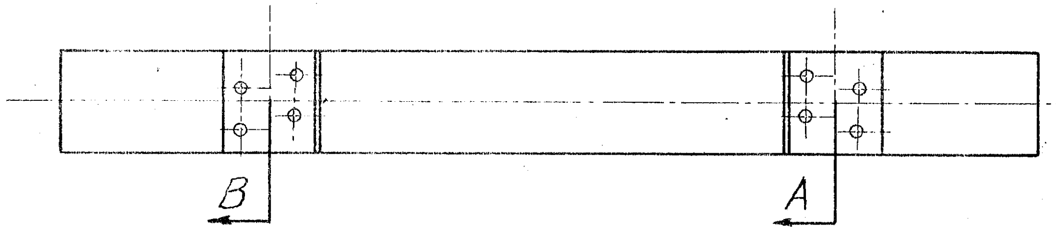


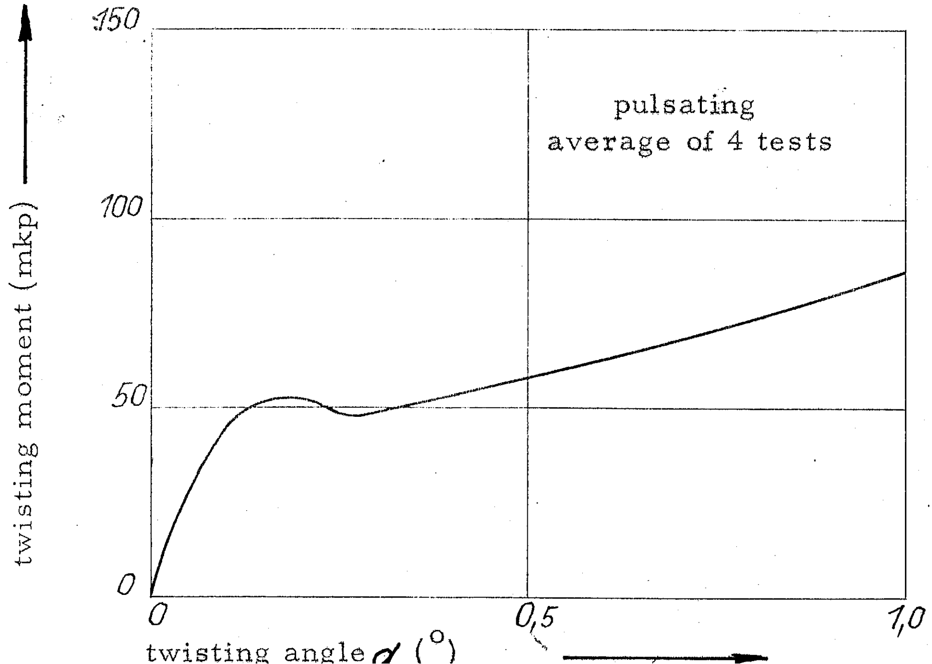
Adhesion pressure applied to each DS 18 before beginning the test = abt. 1900 kp and 3800 kp respectively for each rail supporting point.

Average resistance against twisting obtained from the static and pulsating twisting tests with a rail fastening consisting of rail S 54 and two Double Shank Elastic Rail Spikes DS 18 being installed directly on a new beech wood sleeper impregnated with coal tar.

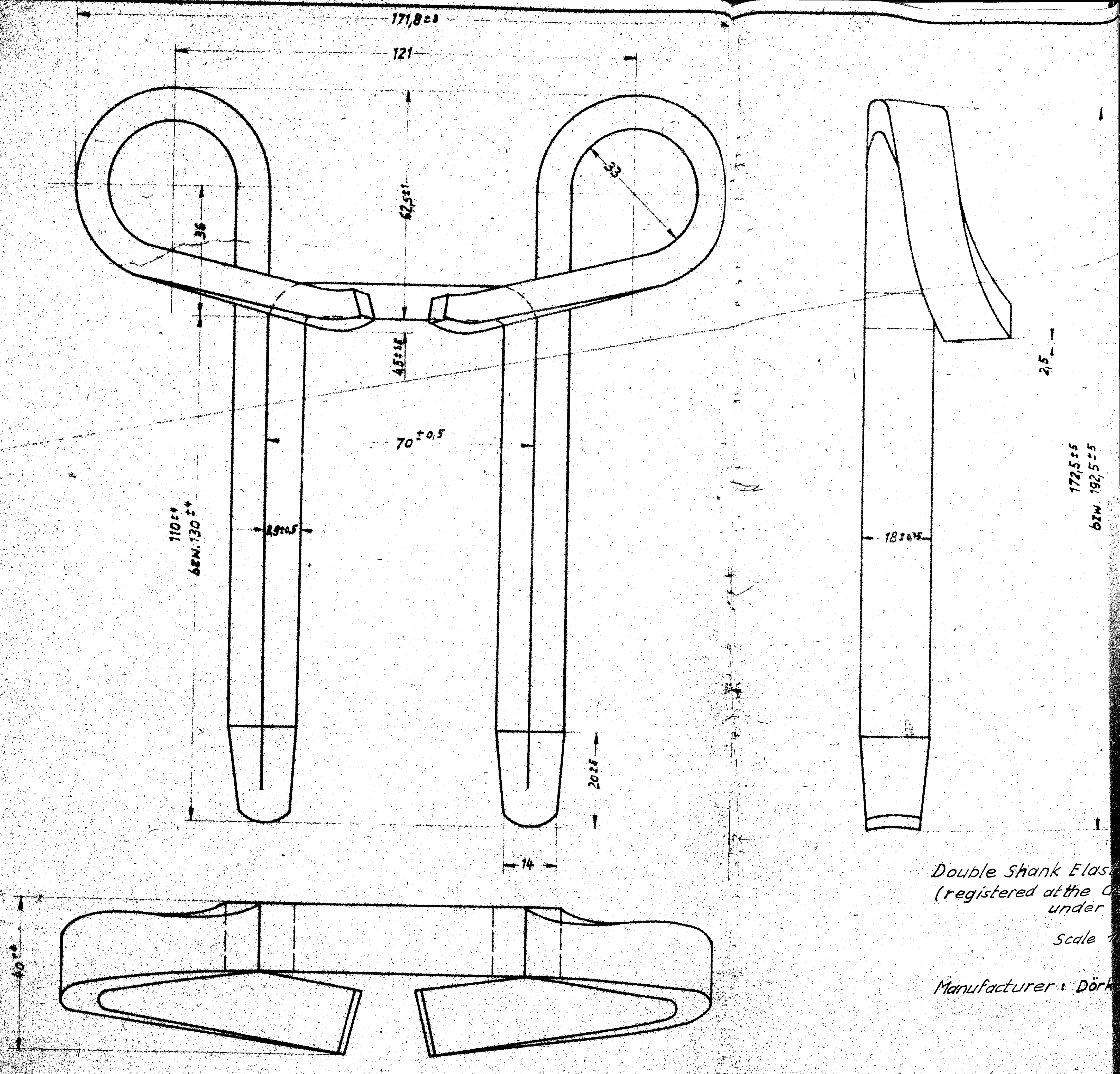
(average values of the testing series "A" and "B")







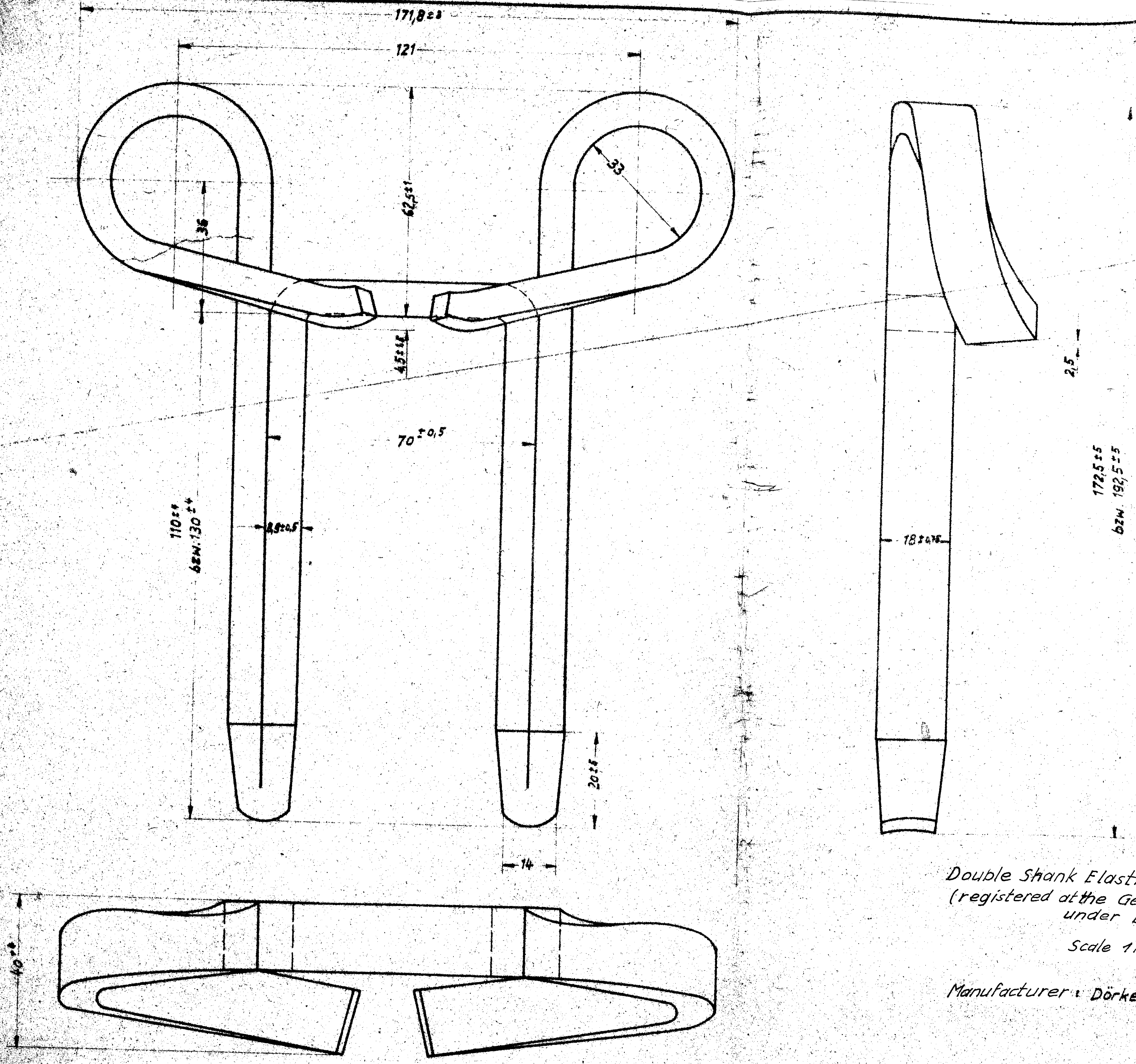
Adhesion pressure applied to each DS 18 before beginning the test = abt. 1900 kp and 3800 kp respectively for each rail supporting point.



Double Shank Elast
(registered at the G
under

Scale 1

Manufacturer : Dörk

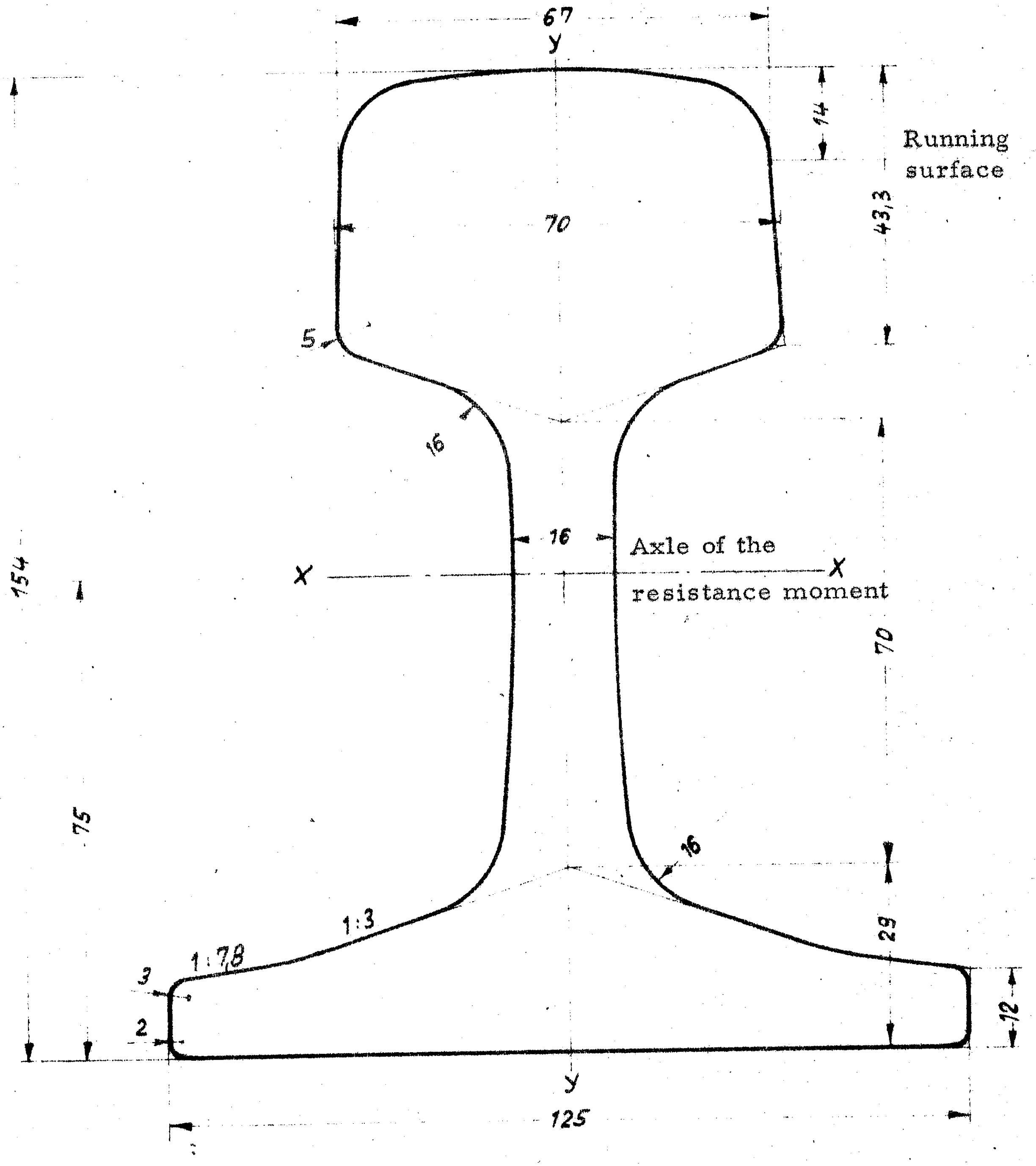


Double Shank Elastic Rail Spike DS 18
(registered at the Geman Federal Railways
under Dna 4)

Scale 1 in 1

Manufacturer : Dörken AG Gevelsberg i.W.

RAIL S 54



Cross section surface:

Rail head = 3 219 mm^2 = 46,3 %
Web of the rail = 1 337 mm^2 = 19,3 %
Rail base = 2 392 mm^2 = 34,4 %
Total surface = 6 948 mm^2 = 100,0 %

Moment of inertia J_x = 2 073 cm^4
Moment of inertia J_y = 359 cm^4
Moment of resistance W_x = 262 cm^3
Moment of resistance W_y = 57 cm^3

weight = 54,54 kg/m

$$\text{Stability} = \frac{\text{width of rail base}}{\text{height}} = 0{,}815$$

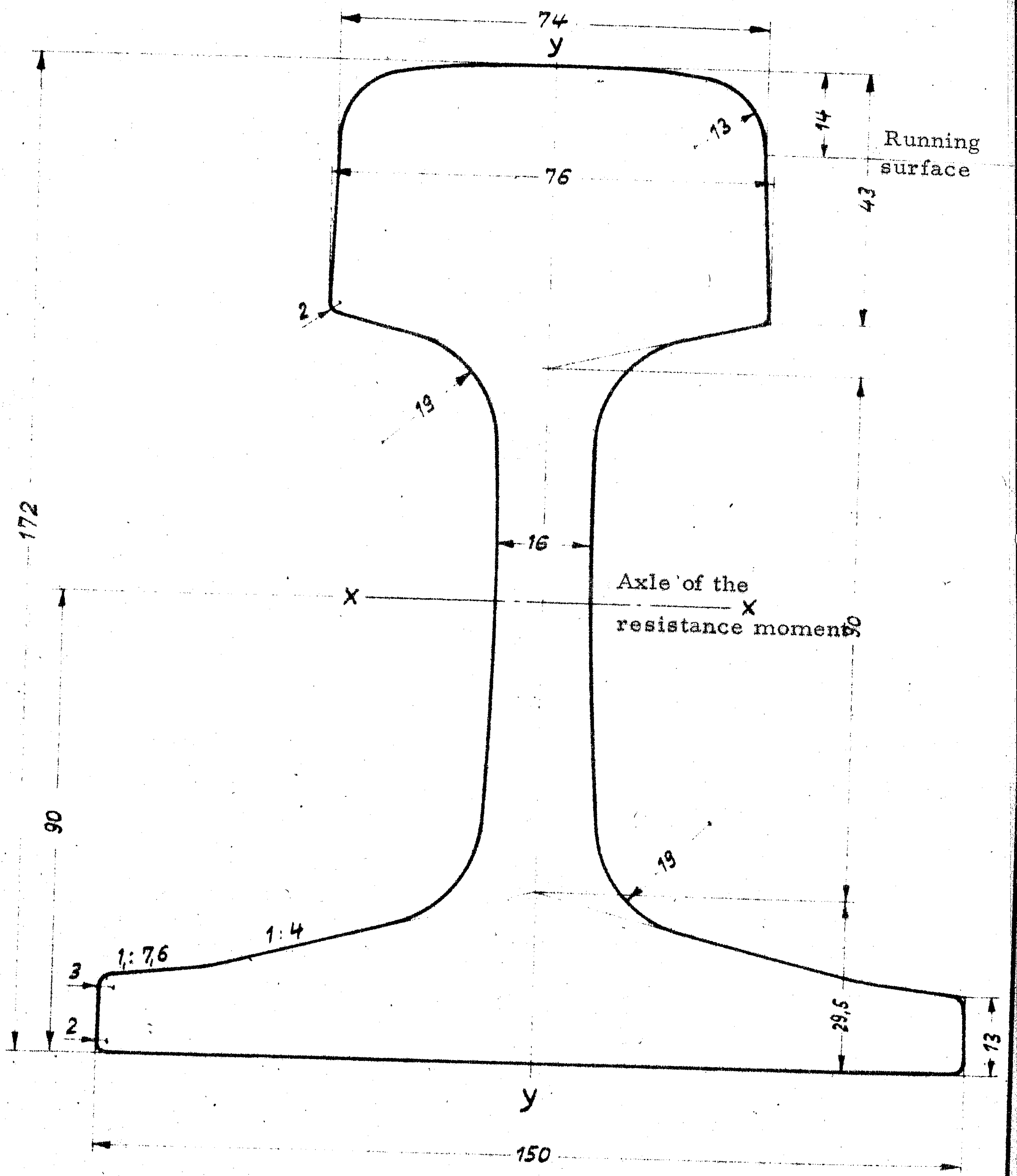
$$\text{Grade} = \frac{W_x}{F} = 3{,}77$$

$$\text{Relation} = \frac{\text{rail head surface}}{\text{rail base surface}} = 1{,}35:1$$

Appendix 2

Technische Hochschule München

R A I L S 64



Cross section surface:

Rail head	= 3441 mm²	= 41,61 %
Web of the rail	= 1772 mm²	= 21,43 %
Rail base	= 3057 mm²	= 36,96 %
Total surface	= 8270 mm²	= 100,00%

weight = 64,92 kg/m

Moment of inertia	$I_x = 3252\ cm^4$
Moment of inertia	$I_y = 604\ cm^4$
Moment of resistance	$W_x = 356\ cm^3$
Moment of resistance	$W_{x_u} = 403\ cm^3$
Moment of resistance	$W_y = 80{,}5 cm^3$

$$\text{Stability} = \frac{\text{width of rail base}}{\text{height}} = 0{,}87$$

$$\text{Grade} = \frac{Wx}{F} = 4{,}3$$

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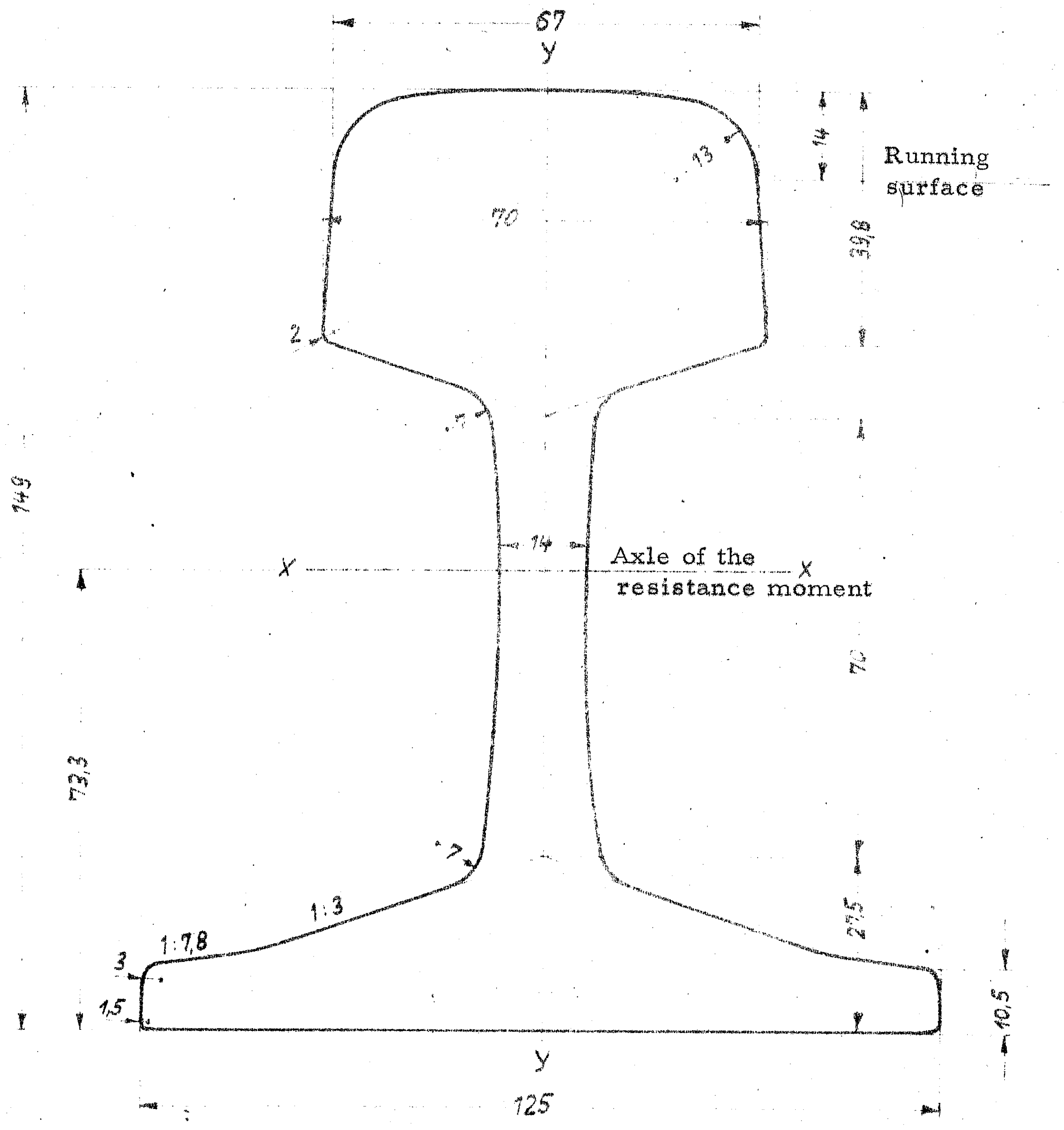
R A I L S 49



Cross section surface:
Rail head = 2 988 mm^2 ≈ 47,5 %
Web of the rail = 1 106 mm^2 ≈ 17,5 %
Rail base = 2 203 mm^2 ≈ 35,0 %
Total surface = 6 297 mm^2 ≈ 100,0 %

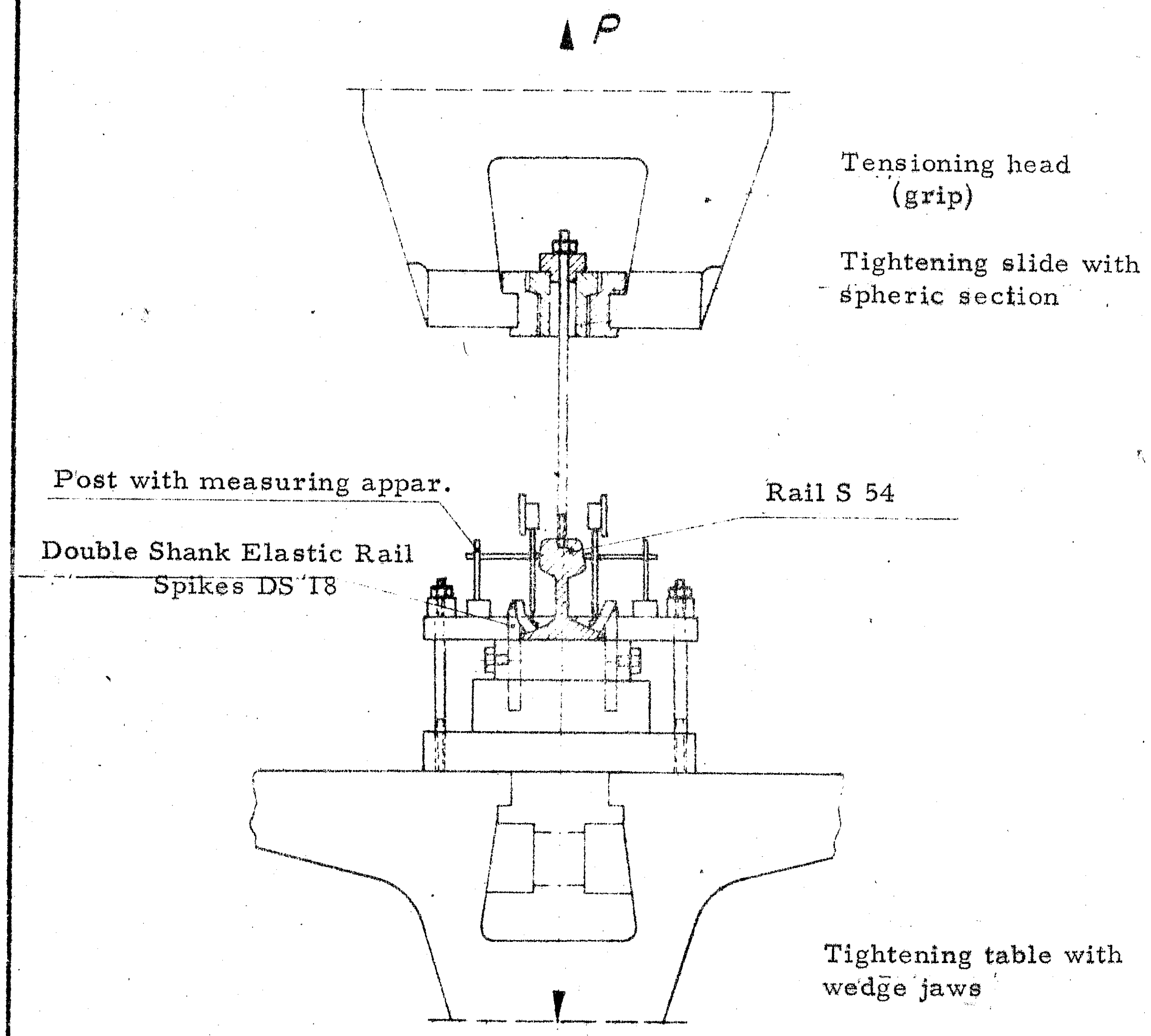
weight = 49,43 kg/m

Moment of inertia $I_x = 1819\ cm^4$
Moment of inertia $I_y = 320\ cm^4$
Moment of resistance $W_x = 240\ cm^3$
Moment of resistance $W_y = 51\ cm^3$

$$\text{Stability} = \frac{\text{width of rail base}}{\text{height}} = 0{,}84$$

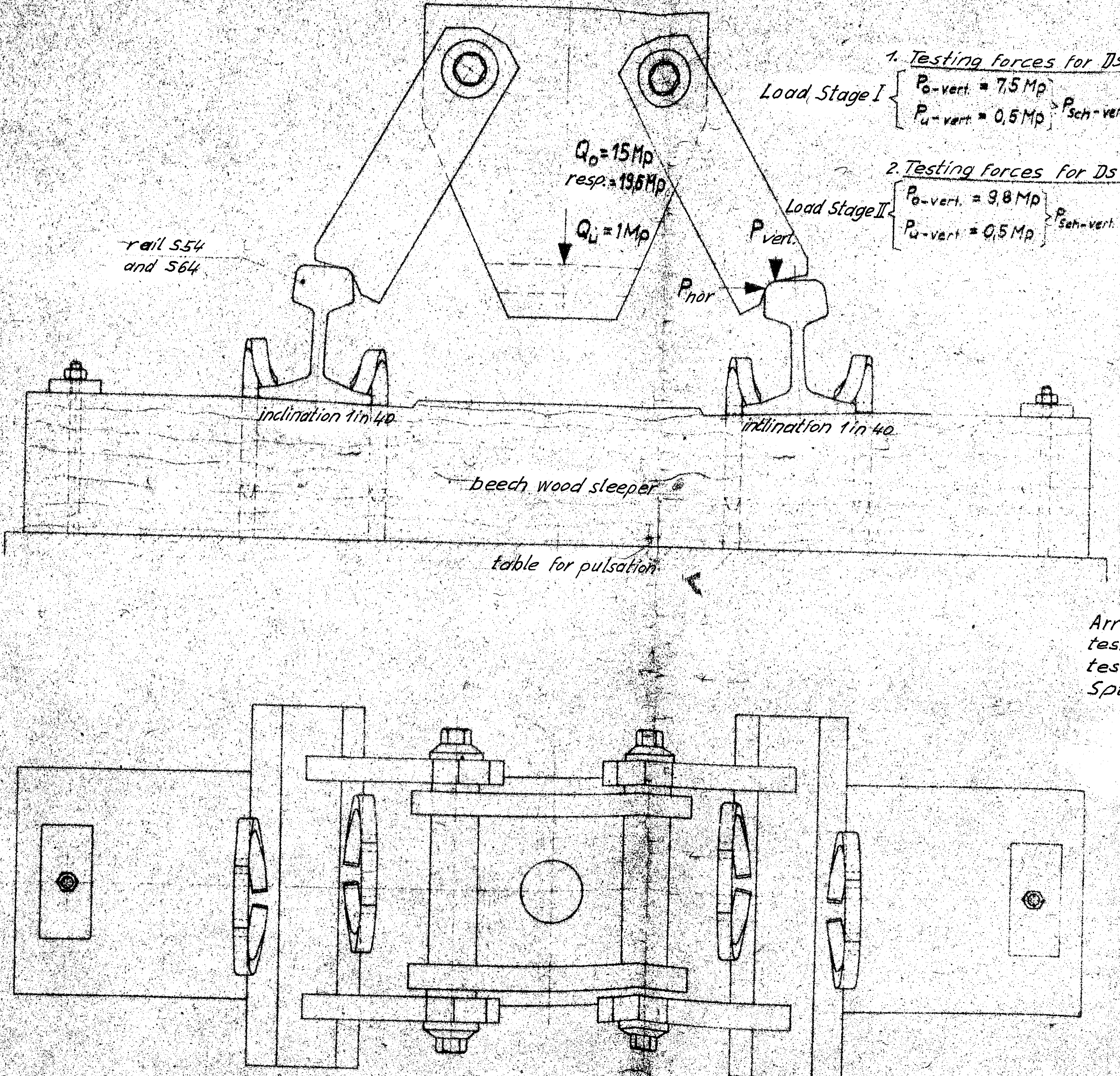
$$\text{Grade} = \frac{Wx}{F} = 3{,}81$$

$$\text{Relation} = \frac{\text{rail head surface}}{\text{rail base surface}} = 1{,}36:1$$



Diagram

of the test arrangement for static driving-in and pulling-out tests for gauging of the rail fastening with Double Shank Elastic Rail Spikes DS 18 with rail S 54



1. Testing forces for Ds 18 and for rail S54 and S64

$$\text{Load Stage I}\left\{\begin{matrix} P_{o-vert.} = 7{,}5\,\text{Mp} \\ P_{u-vert.} = 0{,}5\,\text{Mp}\end{matrix}\right\} P_{sch-vert.} = 7{,}0\,\text{Mp} \quad \left.\begin{matrix} P_{o-hor.} = 4{,}6\,\text{Mp} \\ P_{u-hor.} = 0{,}3\,\text{Mp}\end{matrix}\right\} P_{sch-hor.} = 4{,}3\,\text{Mp}$$

2. Testing Forces for Ds 18 following 1. for rail S54 and S64

$$\text{Load Stage II}\left\{\begin{matrix} P_{o-vert.} = 9{,}8\,\text{Mp} \\ P_{u-vert.} = 0{,}5\,\text{Mp}\end{matrix}\right\} P_{sch-vert.} = 9{,}3\,\text{Mp} \quad \left.\begin{matrix} P_{o-hor.} = 6{,}0\,\text{Mp} \\ P_{u-hor.} = 0{,}3\,\text{Mp}\end{matrix}\right\} P_{sch-hor.} = 5{,}7\,\text{Mp}$$

Arrangement of the continuous oscillation test on the cross-bar oscillator for the test of Double Shank Elastic Rail Spikes Ds 18

(with rail S54 and S64 installed directly on a new beech wood sleeper impregnated with coal tar.)

Scale 1 in 5

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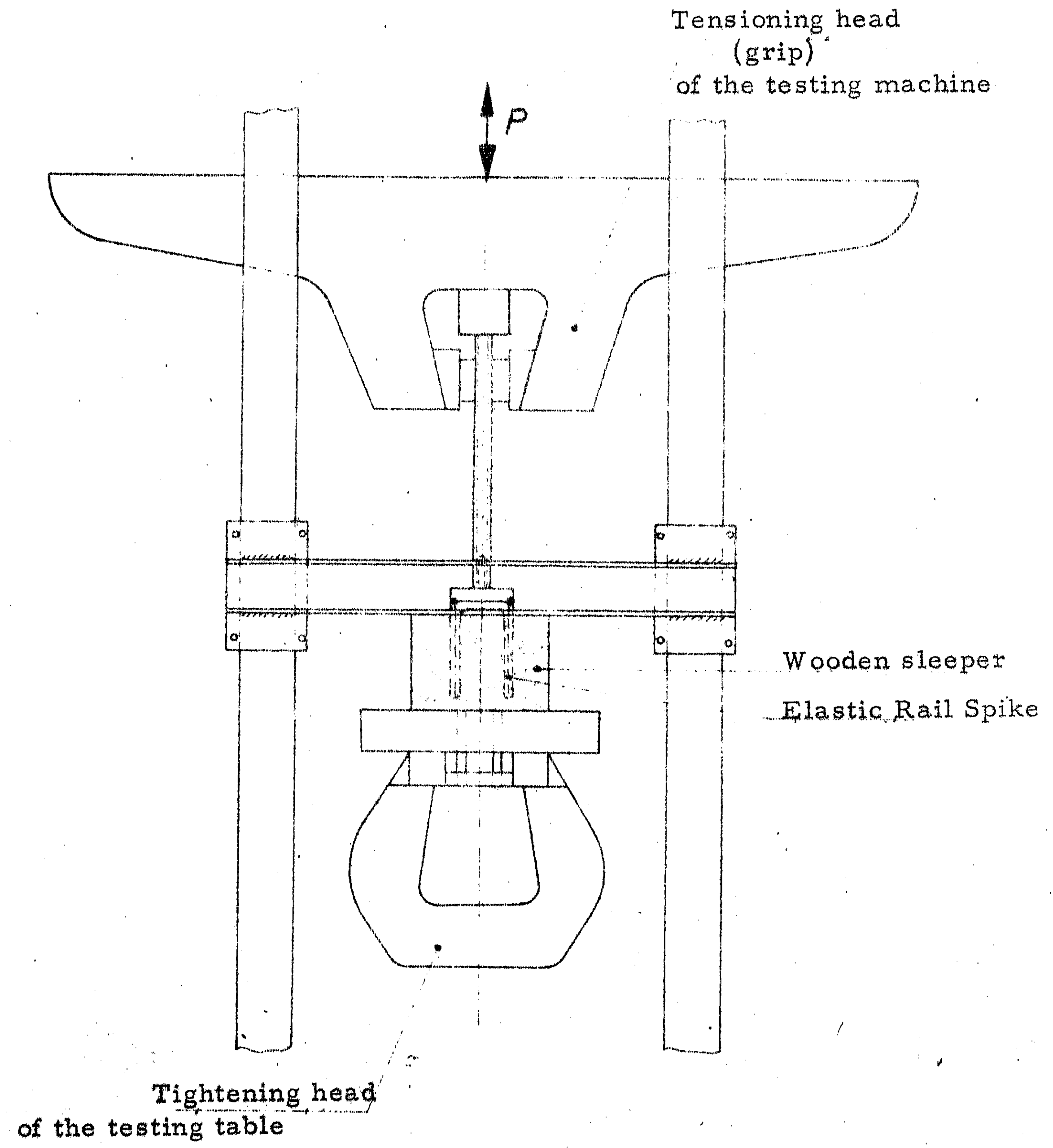
Institut



Diagram

of the test arrangement for static driving-in and pulling-out tests with Single Shank (ES 18) and Double Shank Elastic Rail Spikes (DS 18) out of hardwood and softwood sleepers.

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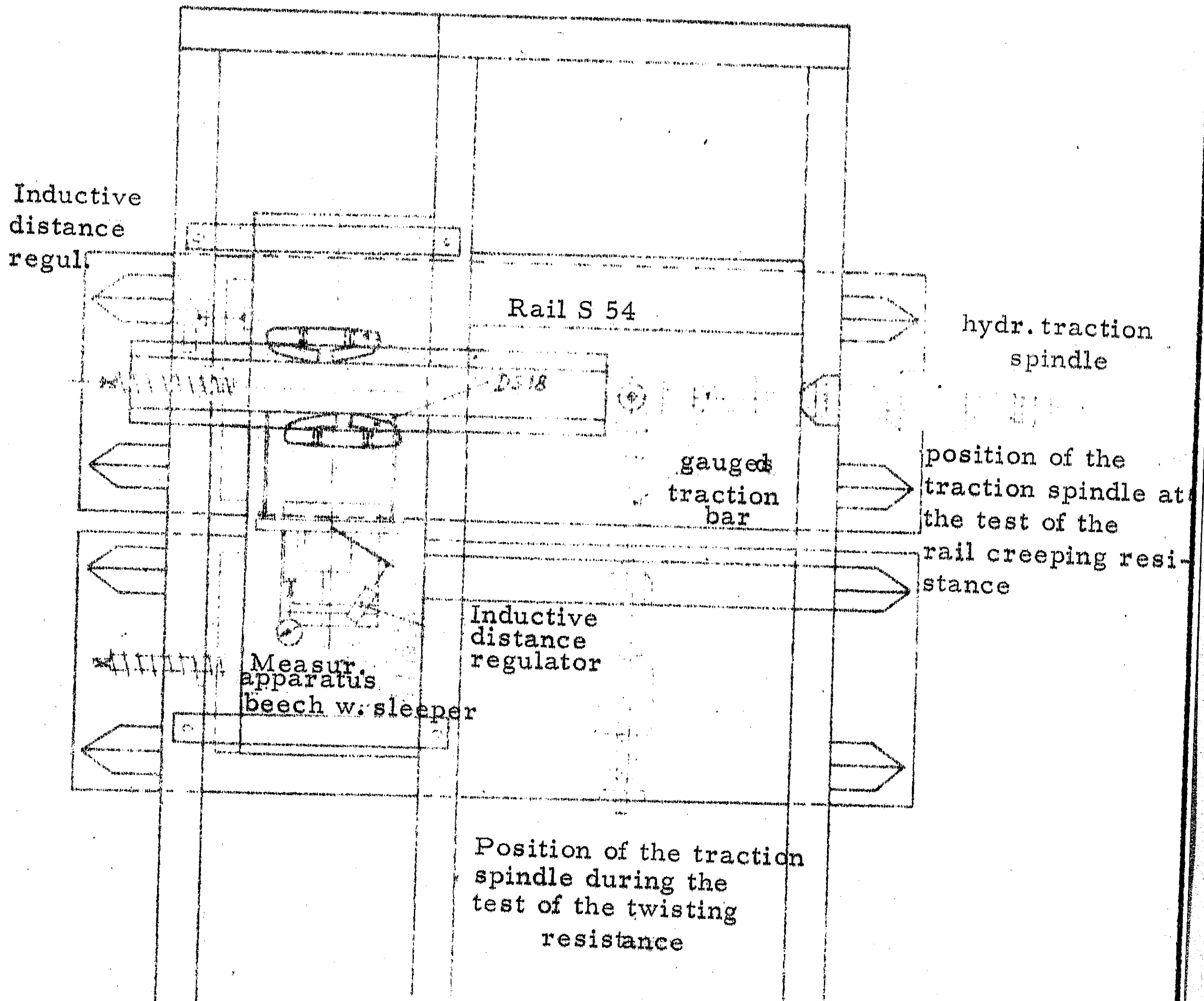

Diagram of the stretching panel for the tests of the rail creeping and twisting resistances.

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