NEWSLETTER NUMBER 3

JANUARY 1977

FORCE PLATFORM GROUP

INTERNATIONAL SOCIETY OF BIOMECHANICS

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(The Newsletter is circulated free to members of the Force Platform Group. Membership enquiries to the Secretary).

It is with great regret that we record the death of Professor Dr. Jurg Wartenweiler, the first president of the International Society of Biomechanics. He exerted a great influence in the planning and development which resulted in the official founding of the Society in August, 1973, and he was always full of encouragement for the Force Platform Group. His patience, gentleness and enthusiasm will be missed by all of those who knew him.

Contents

The Force Platform Group of the ISB

The Group first formed in 1973 at the Fourth International Seminar on Biomechanics at the Pennsylvania State University, U.S.A. with an ad hoc committee of Peter Cavanagh (U.S.A.) and Don Grieve (England). Howard Payne (England) became 'catalogue editor' and produced two editions of "A catalogue of force platforms used in biomechanics research".

At the 1975 Fifth International Congress of Biomechanics at the University of Jyväskylä, Finland, the Group re-formed itself, and elected Peter Cavanagh as chairperson with Howard Payne as secretary. It was decided that six-monthly newsletters should be produced and sent to all members, who were asked to pay a US $5 subscription to cover the costs of producing and mailing the newsletter.

The biannual newsletter was initiated with the following objectives:-

(a) To provide a bibliographic service to Group members on a regular basis.

(b) To publish original articles on topics related to force measurement in human biomechanics.

(c) To provide a forum for questions and answers on related subjects.

In his 'Message' in the Newsletter No. 1 the Chairperson urged: "Firstly, please let the editor of the newsletter have any ideas that you might generate concerning material to be included in future editions. The newsletter is a far stronger means of communication than one meeting of the Group every two years, and in such a small group, we shall need input from almost every member. Secondly, if you are aware of force platform users who are not members of our group, please encourage them to get in touch with us so that we can benefit from their input".

Editorial

Dr. Peter Cavanagh, our Chairperson, has been in discussion and correspondence with the officers of the International Society of Biomechanics to determine our Group's relationship to the ISB and you will be pleased to know that we have been acknowledged as a sub-committee. Further discussions are needed to work out the details of the Group's function within the ISB and it is hoped that we can finalise these at the VIth International Congress of Biomechanics in Copenhagen, July 11-14, 1977 (Mailing address: VIth International Congress of Biomechanics, August Krogh Institute, Universitetsparken 13, DK 2100 Copenhagen, Denmark). Pending our Group meeting at the Congress, I am keeping our title as it is on this Newsletter.

Response to requests for material for this Newsletter has been very good as you can see by the excellent papers and bibliography that follow - so much so that we are holding over, until Newsletter Number 4, the register of members. If you have not already done so, please return the completed form sent out with Newsletter 2.

Please also make it a habit to send details of any new publications, preferably with a copy, to Barry Wilson (address in Bibliography in this issue), who is maintaining a computerised index which will be updated from time to time in the Newsletters. On behalf of all members of the FPG I would like to record our gratitude to Barry Wilson and his colleagues at Iowa University for providing us with this extremely useful service.

F.P.G. Income and Expenditure Account

for year ending August 1976

(covering issues of Newsletters 1 and 2)

Income	£	Expenditure	£
Membership subscriptions net of currency exchange charges and bank commission	139-73	Printing of Newsletter No. 1	71-70
		Postal charges for Newsletter No. 1	27-15
		Printing of Newsletter No. 2	41-75
		Postal charges for Newsletter No. 2	11-95
Sales of extra Newsletters	40-00	Bank charges	3-23
			155-78
		Balance being excess of income over expenditure	23-95
	179-73		179-73

Notes

(1) Savings were made in the costs of Newsletter No.2 by reducing the number printed and by sending copies by seamail where possible.

(2) Exchange rates have fluctuated considerably during the period above, but in August 1976 the rate was approximately £1 ≡ US $ 1-78

(3) The F.P.G. has a bank account in the U.S.A. containing approximately US $10.

A.H.P.

Design of Force Platforms Utilized at Indiana University[1]

By
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Biomechanics students at Indiana University may utilize either of two force platforms for the purpose of obtaining kinetic data during the performance of a motor skill. One platform, measures 2 feet by 3 feet, and is located in the Biomechanics Laboratory. A second, larger platform, measuring 4 feet square, is located in an athletic indoor field house which adjoins the building housing the Biomechanics Laboratory. In both locations, the force platforms are positioned in sunken pits when in operation so that the top surface of the force platform is flush with the surface on which the subjects will be performing.

In order to prevent the interference of forces exerted during a movement and the subsequent recording of data indicating forces below the actual exerted forces, both force platforms allow for some movement of the top plate without its coming into contact with the sides of the pit. The 2 x 3 force plate has adjustable set screws along the outer edges of the base plate which are positioned against the side walls of the pit for centering. The lower surface of the base plate of the 4 x 4 force plate has 4 positioning screws which mate with matching sockets permanently installed in the base of the pit. These positioning screws provide the means for mounting, properly aligning, and leveling of the force platform

[1]Appreciation is extended to Gerald L. Stout and his staff of the Electronics Department at Indiana University for technical assistance.

[2]Most of the material presented here was prepared by Sarah L. Smith.

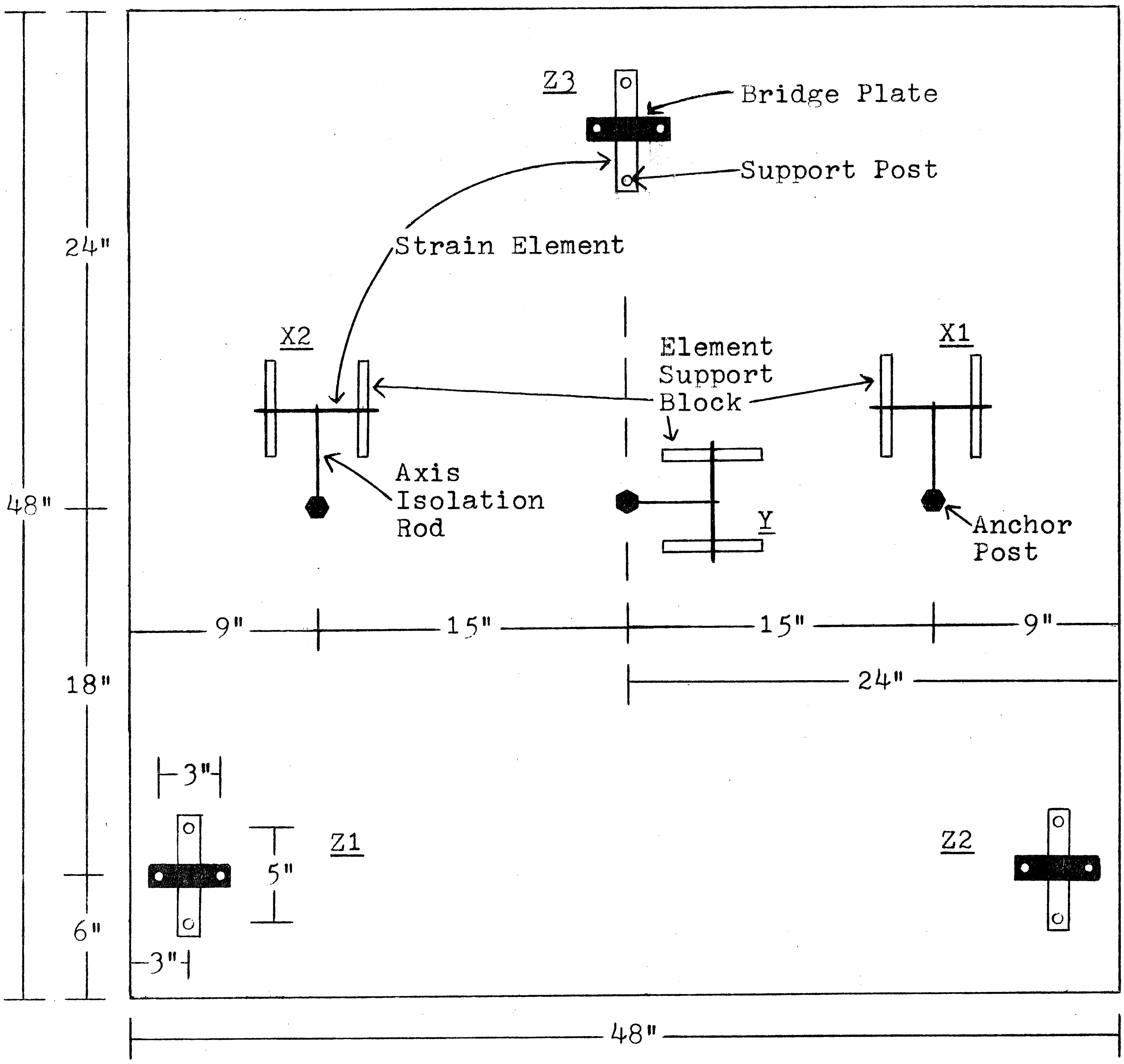
within the pit. Each of these positioning screws is located in one of the corners of the base plate at a point two inches from each adjacent side of the plate.

Although both force platforms are of similar construction, the exact specifications and dimensions which follow pertain to the larger or 4 x 4 force plate. Dimensions of the six gauge assemblies utilized in both force platforms are nearly identical and only their locations vary.

The base and top plates were constructed from two pieces of magnesium tooling plate 48" x 48" x 1"; no matching of these plates was necessary other than the drilling and tapping of holes. The top plate was suspended at a height of approximately 6" above the base. This suspension was accomplished through the strain gauge assemblies. The three Z-gauge assemblies were spaced so as to distribute the forces evenly across the top plate and respond to forces exerted in the vertical direction. The Y-gauge element was mounted at the geometrical center of the base plate; the two X-component assemblies were mounted on either side of and equidistant from the Y element. See Figure 1 for exact gauge locations.

Similar parts and materials were used in the construction for the individual gauge assemblies. Brown and Sharpe Ground Flat Stock was used to construct the strain responding elements. Baldwin-Lima Hamilton strain gauge, type FAE-50-12S6, were cemented to $\frac{1}{2}$" x 1" x 6" ground flat stock for the vertical components and $\frac{1}{4}$" x 1" x 6" material for the X and Y components. Four gauges, two on each 1" surface, were mounted on these steel bars to form the strain elements. Flexible leads were then soldered to the strain gauge elements and brought out to terminal strips mounted on the base plate. An axis isolation rod was utilized

Figure 1: Locations of Gauge Assemblies



(scale: $\frac{1}{2}$" = 4")

in each gauge assembly to form the connecting link between that part of the assembly attached to the top plate and that mounted to the base plate.

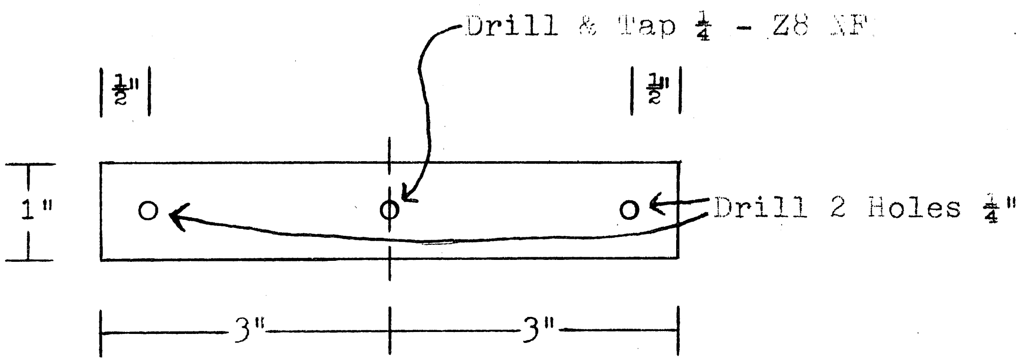
Supporting structures for the gauge assemblies were of differing construction. The X and Y strain elements were supported by two support blocks mounted to the base plate and one anchor post mounted to the top plate. The strain element was attached at either end to a support block, and connection with the anchor post was made by means of the axis isolation rod. In the Z-gauge assembly, the strain element attached directly to two support posts which were attached to the top plate. Two other support posts were mounted on the lower plate and each attached to one end of a bridge plate. The bridge plate was positioned perpendicularly to the strain element, and connection between these two parts was by means of the axis isolation rod.

Figures 2,3,4,5,6 and 7 show the exact dimensions of the various parts utilized in the construction of the gauge assemblies. Figures 8 and 9 show completed gauge assemblies for each of the two types utilized in the force platform.

The isolation rods served as de-coupling mechanisms between the axes. Movement is allowed by these rods in a perpendicular plane but not in the axial direction. In order to permit final adjustments and to minimize residual strain on the strain gauges, the isolation rods were threaded with fine threads on one end and course threads on the other end.

Integrated circuit operational amplifiers were used to amplify the output of each strain gauge. The sum from the X1 and X2 gauges reflect total force in the horizontal direction, and the difference obtained between these two elements represents the turning moment. After amplifier standardization and calibration, the force range for

Figure 2: Strain Element

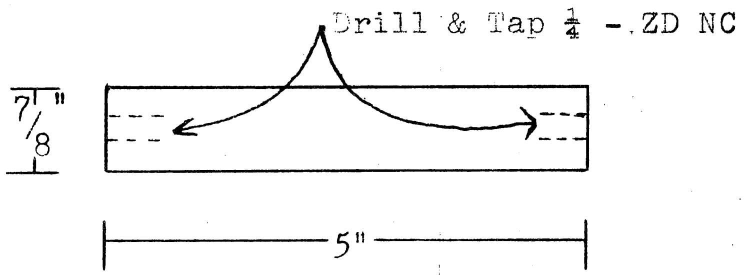


Make 3 PC ½" Ground Flat Stock (Z gauges)
Make 3 PC ¼" Ground Flat Stock (X & Y gauges)

Brown & Sharpe Aisi Type 01

(scale: ½" = 1")

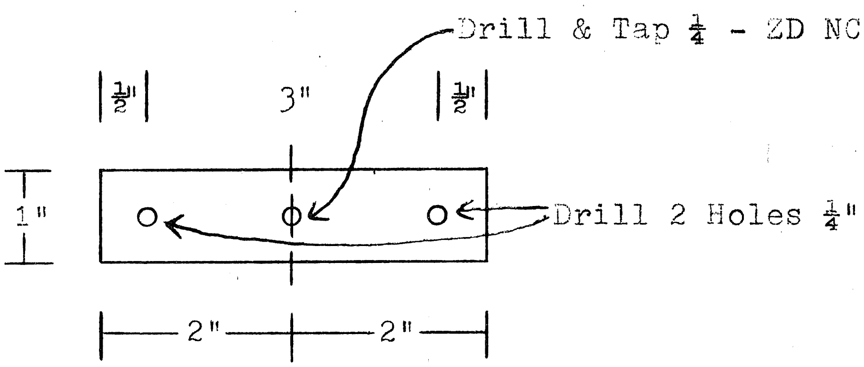
Figure 3: Support Post



Make 12 PC 7/8" Round Al Stock

(scale: ½" = 1")

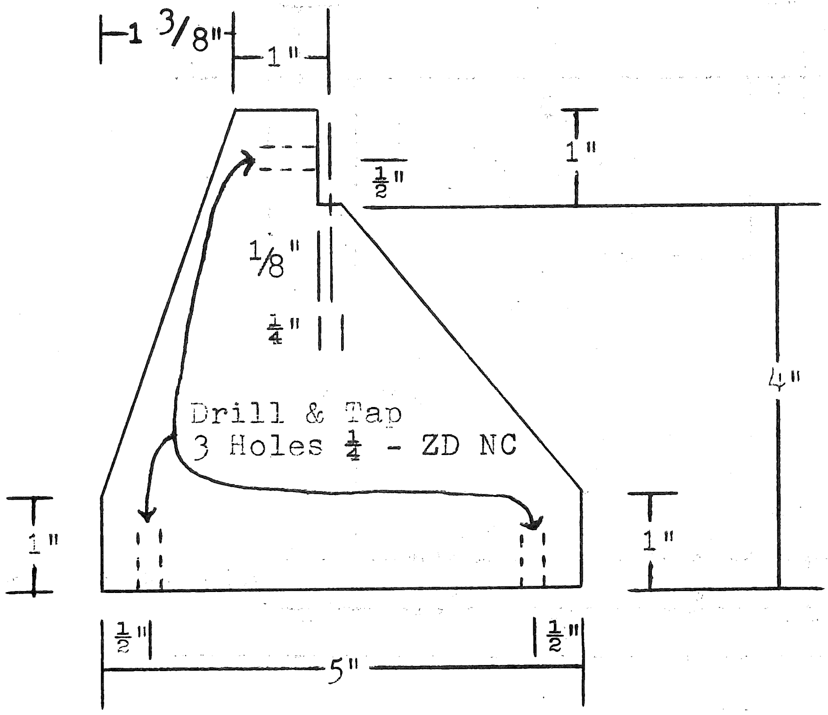
Figure 4: Bridge Plate



Make 3 PC ½" Ground Flat Stock

(scale: ½" = 1")

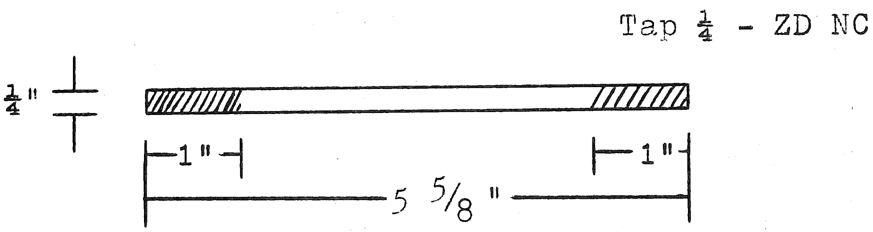
Figure 5: Element Support Block



Make 6 PC ½" 61 ST Al

(scale: ½" = 1")

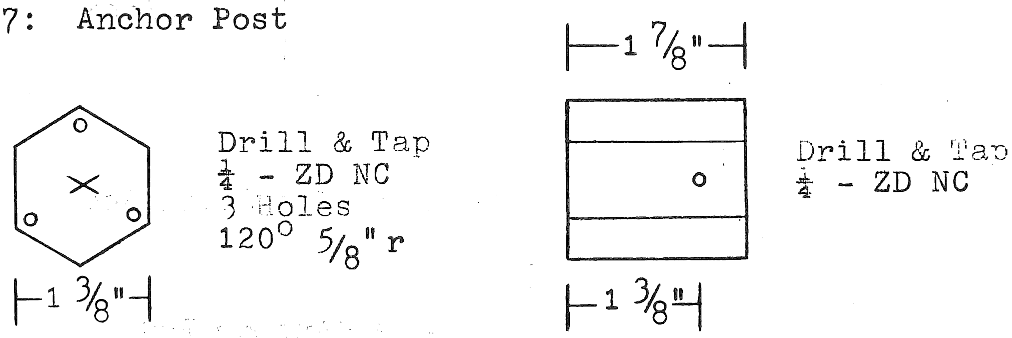
Figure 6: Axis Isolation Rod



Make 6 PC ¼" Steel Drill Rod

(scale: ½" = 1")

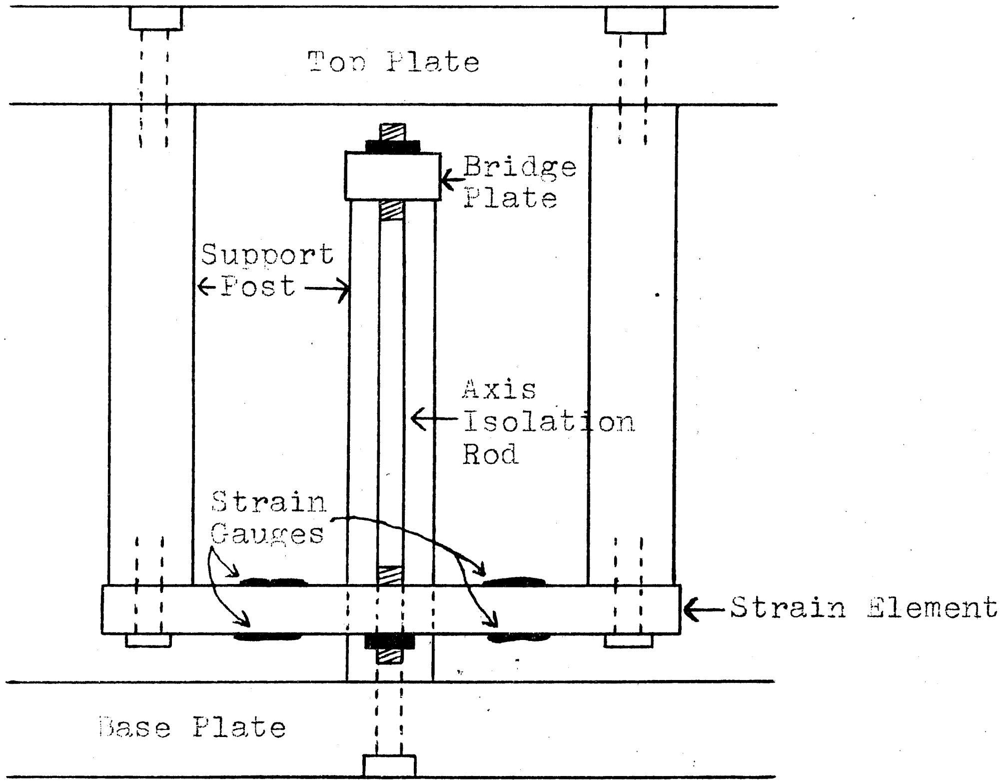
Figure 7: Anchor Post



Make 3 PC 1 3/8 Al Hex

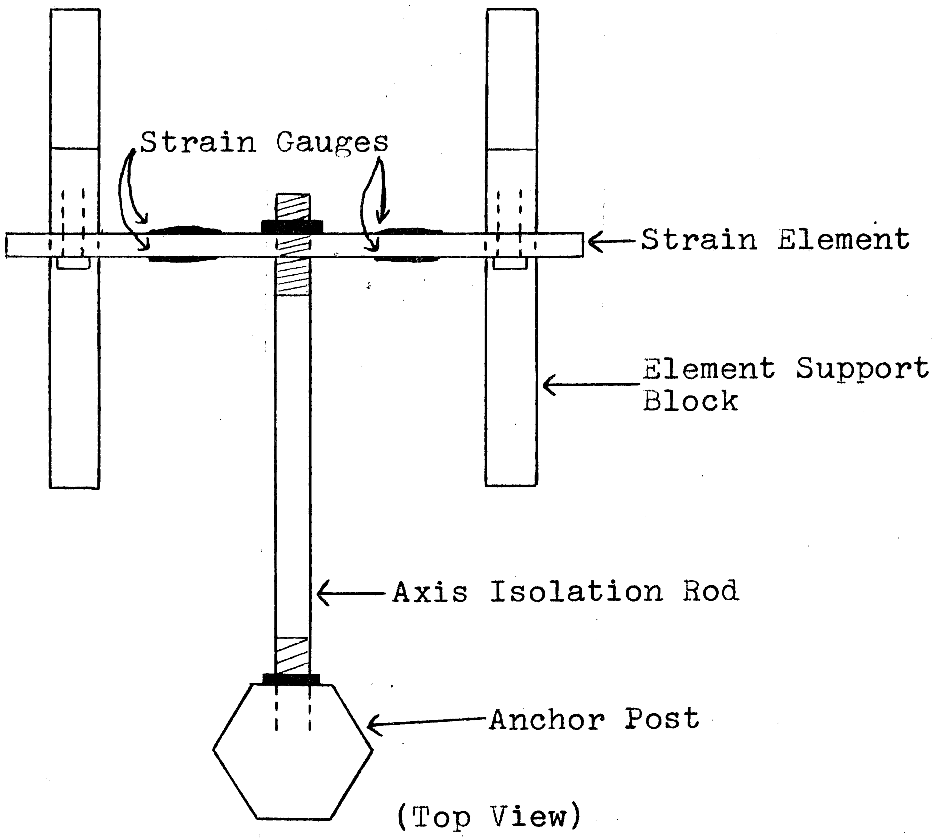
(scale: ½" = 1")

Figure 8: Z Gauge Assembly



(Side view with one support post not shown)

Figure 9: X or Y Gauge Assembly



(Top View)

each axis on a designated channel can be varied by the sensitivity controls on the recorder amplifiers according to the demands of the experiment.

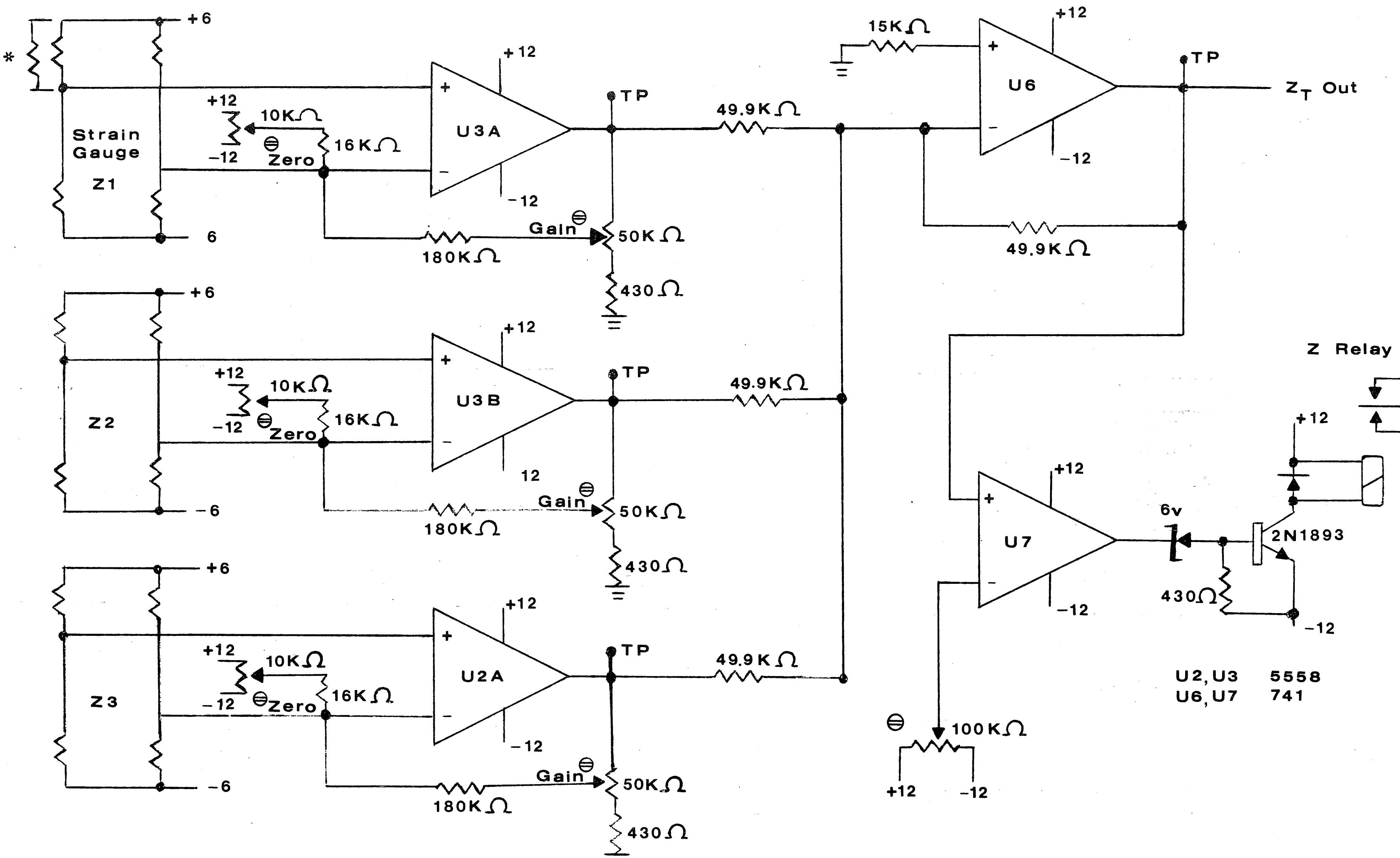
Figures 10,11, and 12 present the electronic diagrams for each type of gauge assembly. Figure 13 shows the strain element assembly.

Calibration of the force platform is accomplished through static loading of known weights. Vertical calibration is achieved by placing weights of a known quantity directly on the top surface of the force platform. In order to calibrate the X and Y channels, a cable, pulley, and winch system is utilized to obtain forces of a known dimension to be exerted in the desired direction. By making adjustments through the recorder controls, deflections made on the light sensitive paper can be equated with designated amounts of weight. The sensitivity for normal operation of the platform has been set at 100 pounds/$\frac{1}{2}''$ deflection in the vertical plane, 50 pounds/$\frac{1}{2}''$ in the X and Y planes, and 25 pounds/$\frac{1}{2}''$ for the turning moment.

The platform is capable of responding to orthogonal and torque forces of the following magnitudes:

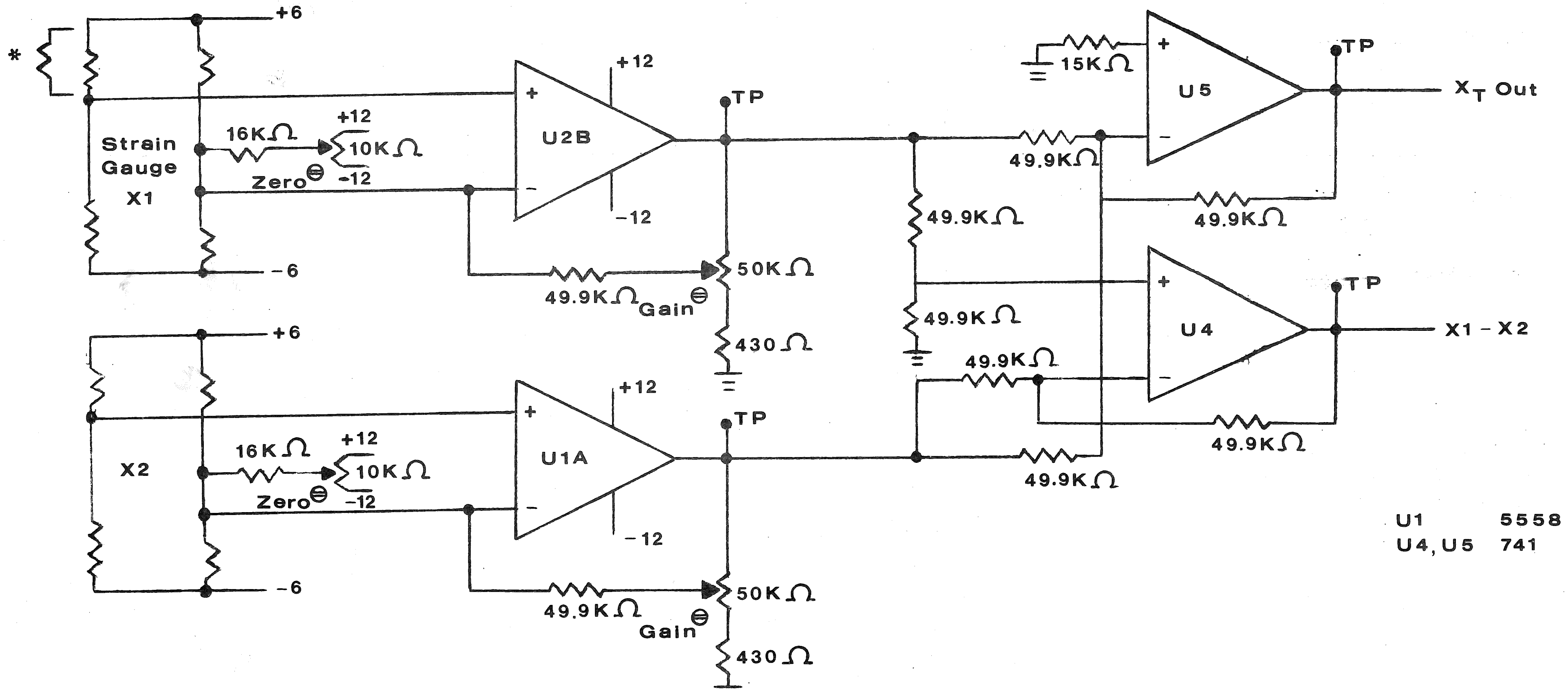
(a) vertical force - 1000 pounds
(b) X and Y forces - 500 pounds
(c) turning moment - 250 pounds.

Figure 10: Z-Axis Electronics



* Resistor Valve and Bridge Arm Selected to Establish Initial Bridge Balance

Figure 11: X-Axis Electronics



* Resistor Valve and Bridge Arm Selected to Establish Initial Bridge Balance

Figure 12: Y-Axis Electronics; Power and Meter Diagram

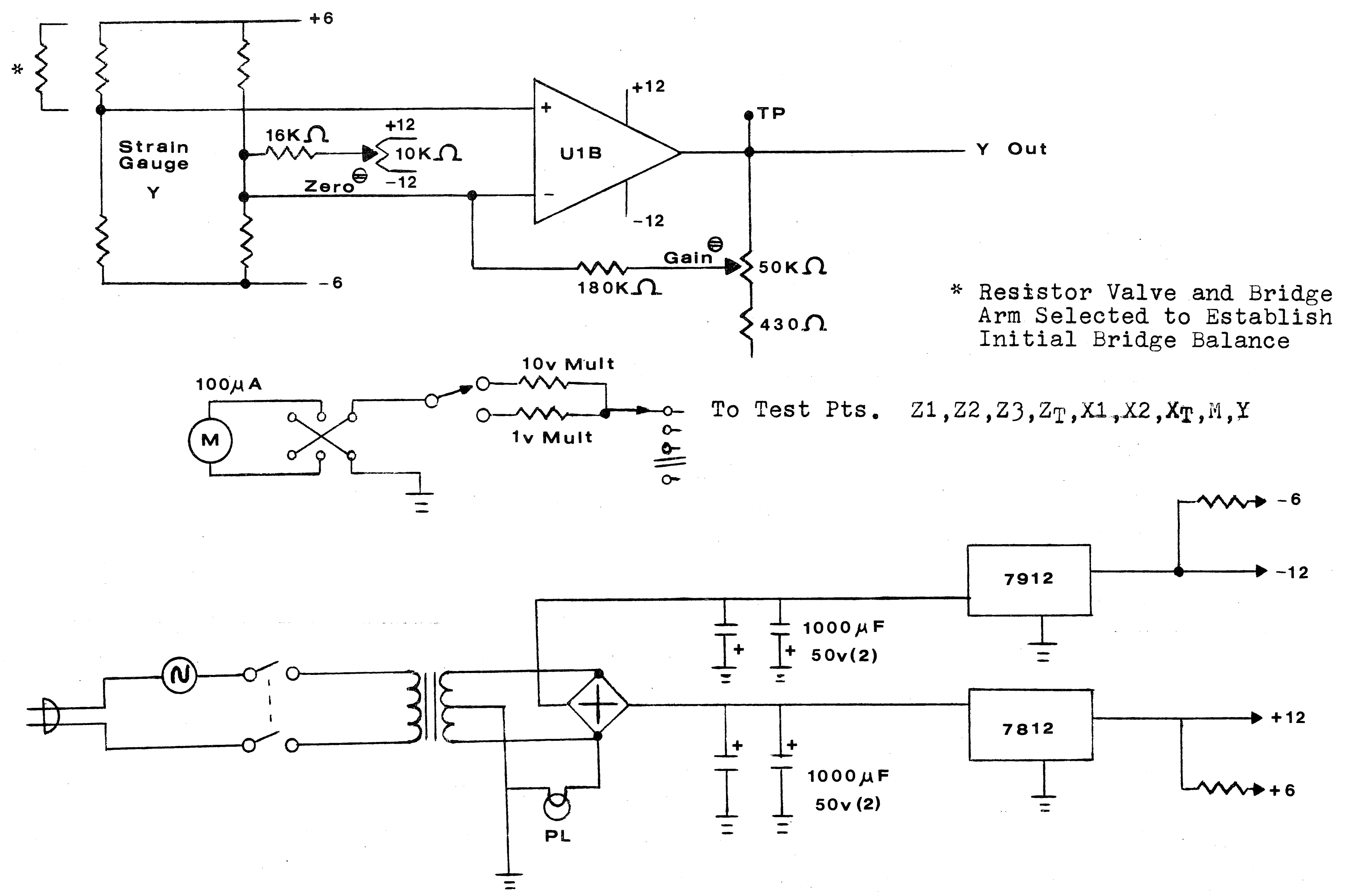
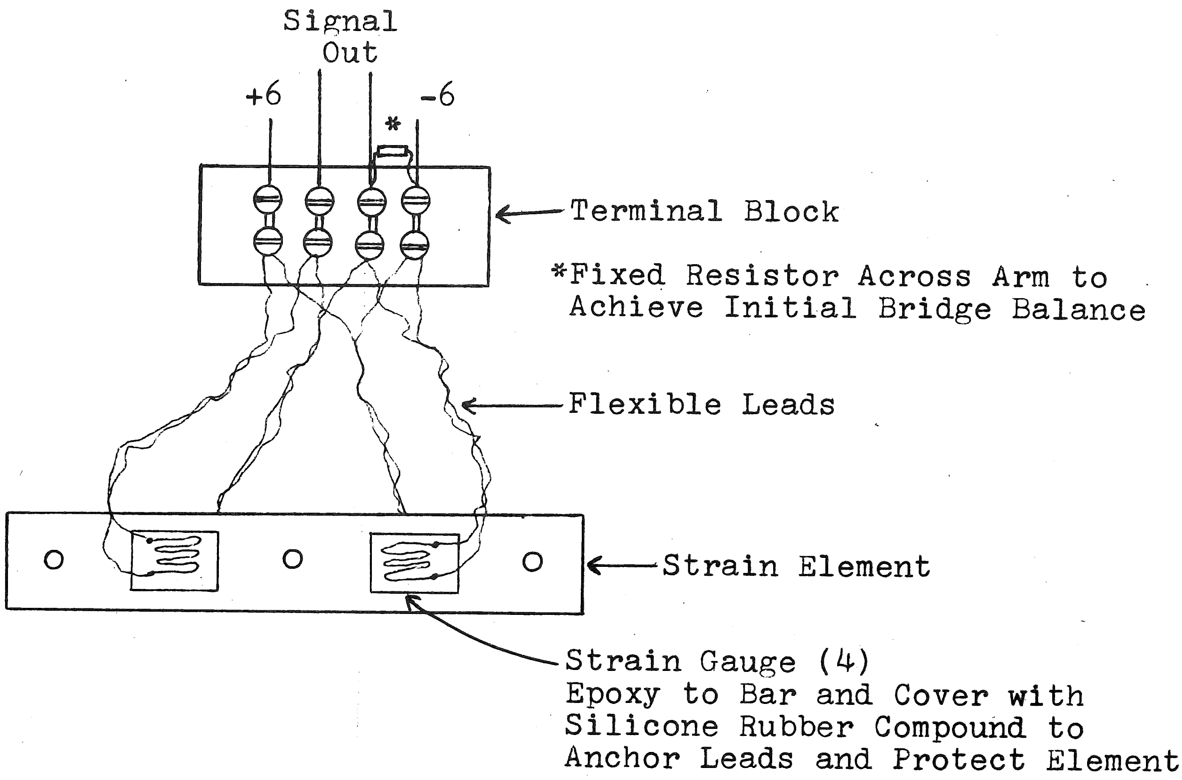
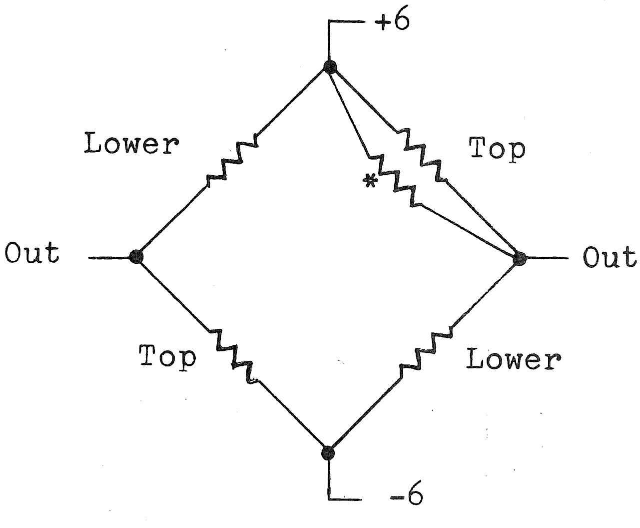


Figure 13: Strain Element Assembly





A FORCE PLATE in use at the Department of Health and Social Security London

USER

Mr. G. Judge
Measurements Laboratory,
Biomechanical Research and Development Unit (BRADU)
Roehampton Lane,
LONDON SW15 5PR
England.

DESIGN AND CONSTRUCTION

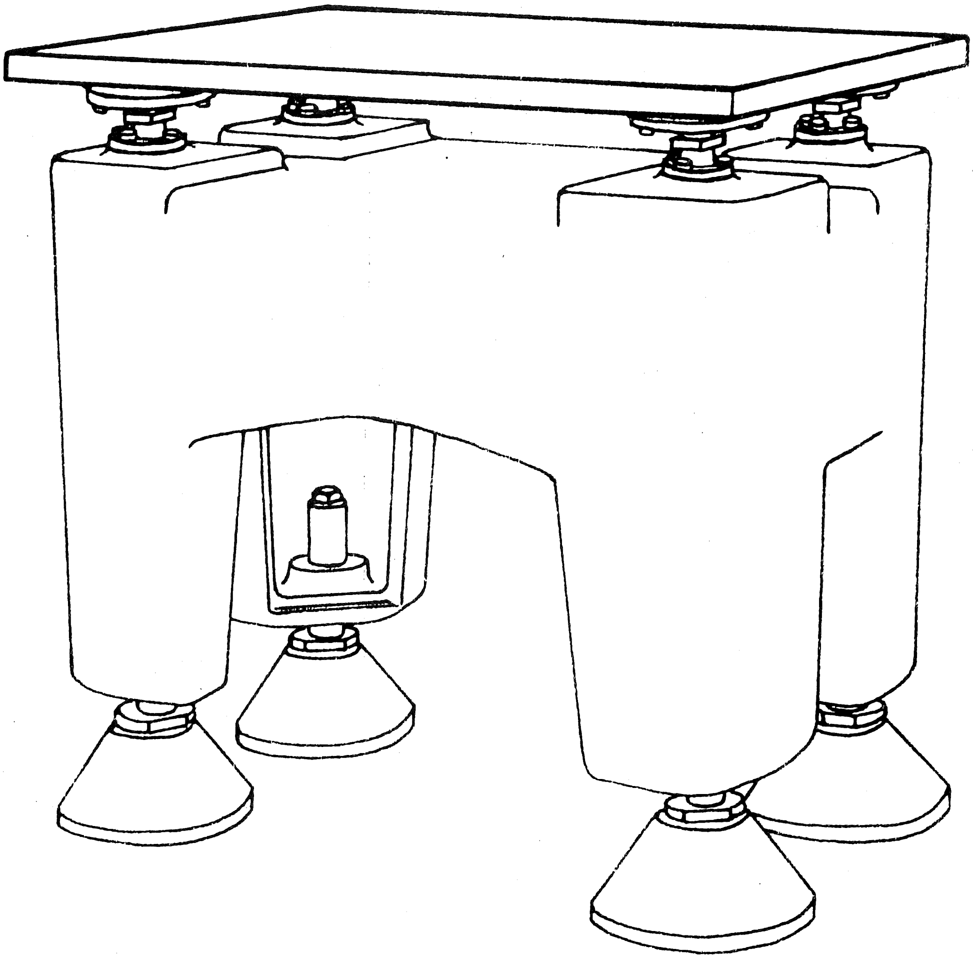
The 0.61m x 0.38m top plate is of sandwich construction; a central layer of aluminium honeycomb (Aeroweb[1]) is bonded between two sheets of a carbon filament filled resin material (Hyfil[2]), the whole being 30mm thick when topped by a suitable walking surface. This results in a plate with a very high stiffness/mass ratio.

The plate has bonded to its underside four small cast-iron pads, ground to give an overall flatness tolerance of 0.005mm. These and a similar set of pads on the base form the clamping arrangements for the four load cells, which are Kistler type 9251A three-component quartz force transducers.

As the Measurements Laboratory is on the second floor of the BRADU building, design of a base for the force platform system was aimed at providing a light, rigid structure so as not to lower the floor's natural frequency as would happen if a heavy base were used. An aluminium alloy casting was designed for this purpose and provided with adjustable feet, bringing the top plate up to the walkway level of 0.61m.

1: Bonded Structures Division, CIBA (A.R.L.) Ltd., Cambridge, England.

2: Composite Materials Division, Rolls-Royce Ltd., Derby, England.



SIGNAL PROCESSING

Kistler charge and summing amplifiers are used, but a BRADU designed analogue divider unit has been added which extends the range over which computation is feasible beyond that commercially available.

As an alternative to analogue processing, the charge amplifier outputs may be digitised on-line with subsequent analysis and visual display using the Laboratory's digital computing equipment.

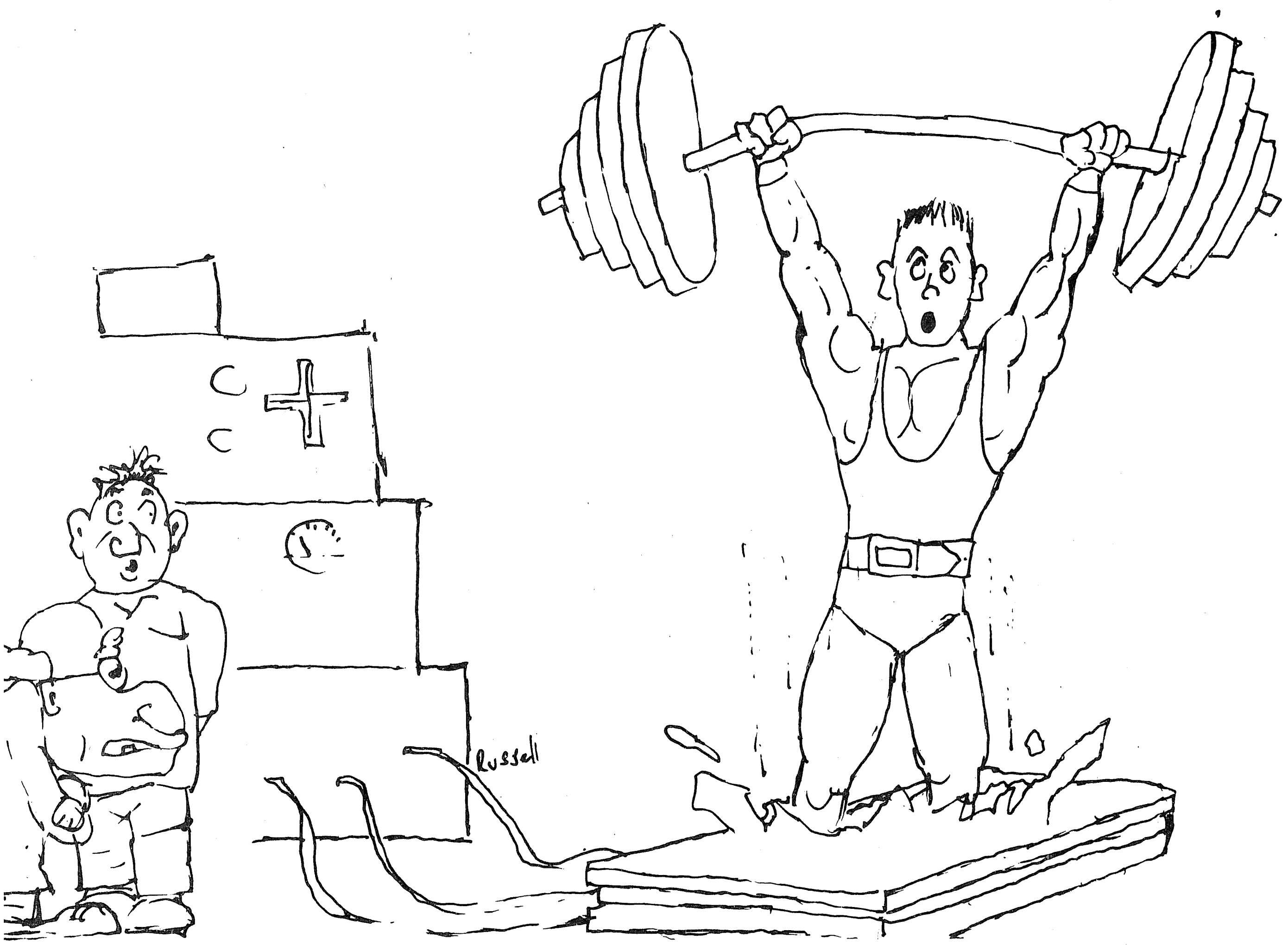
PERFORMANCE

As a result of the high stiffness/mass ratio of the top plate, the unloaded force platform has a lowest natural frequency of flexure of 650Hz.

In normal use, the accuracy of measurement of the load components parallel to the three main axes of the force platform is within ± 0.6% of full scale, wherever they act on the walking surface; and provided that the vertical load component exceeds 0.5% of its full-scale value, the centre of pressure co-ordinates can be computed to within ± 3.5mm of their correct values anywhere over the walking surface.

USES

The force platform is part of a comprehensive instrumentation facility for gait analysis, mainly concerned with amputee gait and leg prosthesis performance.



Some Clinical Applications of Force Platforms in the ETH Biomechanics Laboratory of Zürich

By

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Switzerland

Dynamic Measurements

A recent project was concerned with a gait analysis of patients with "claudicatio intermittens" (Dux, Ganganalyse, Diplomarbeit in Biomechanik, ETH Zürich, 1975). The gait of different patients was analyzed by different electronic and optical methods together with a force platform. The object of the study was to find parameters which describe the difference between the normal and the pathological gait. With the force platform measurements, differences in the contact time and in the amplitude of the brake-force in the a-p plane were found. Other differences were not found.

Another recently completed project was an analysis of the influence of shoe arch support (insole), (Eberle-Frey, Fuss-insuffizienzen und Schuheinlagen, Diplomarbeit in Biomechanik, ETH, Zürich, 1976). Fifteen decathletes were analyzed during running and jumping with and without the shoe arch support using film and force platform measurements. From the three measured force components the vectorresultants $F_{zy}(t)$, $F_{zx}(t)$ and $F_{xy}(t)$, were calculated by computer (see Figure 1). With the vectorresultants (also by computer), the angles described below were also calculated:

$$\phi(t) = \sphericalangle(F_z/F_{zy})(t)$$

$$\rho(t) = \sphericalangle(F_x/F_{xy})(t)$$

(The direction of general movement was along the x axis) expecting significant differences between shoes with and without shoe arch support. It seems that the angle $\rho(t)$ can be an indication of foot-deficiency (Figure 2). With the other force measurement parameters we could not find statistically significant differences.

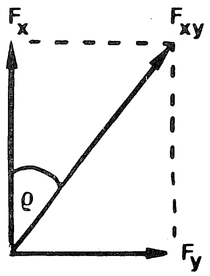


Figure 1. Angle ρ

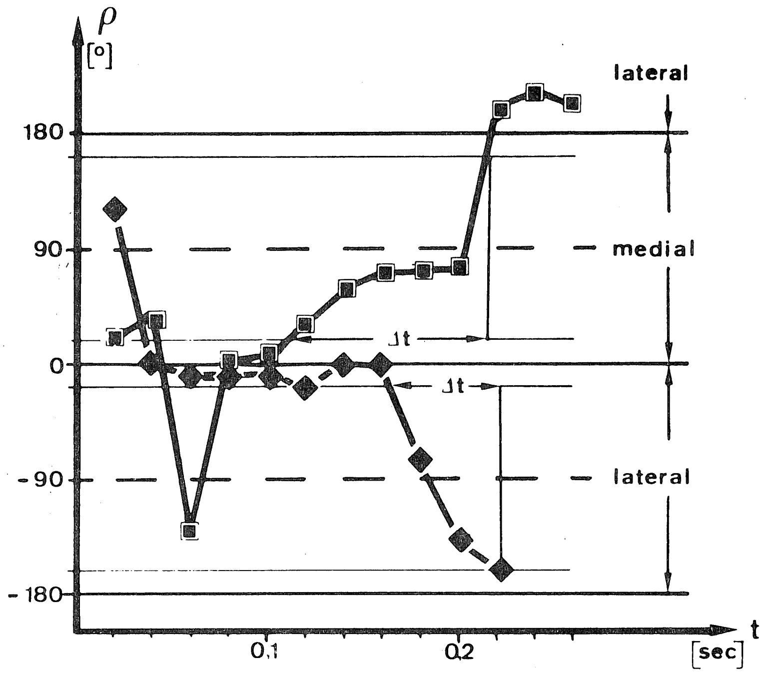


Figure 2. Angle ρ with and without shoe arch support

Static Measurements

In measuring the reaction forces on the floor produced by human microvibrations in the body, the subjects were instructed to stand as still as possible on a Kistler force platform. The force functions were rectified and integrated using the analog processor described by Neukomm (Messen biomechanischer Groessen Medizinalmarkt, 23 (1975) 8, pp. 247-250). With this "rectified impulse" normal and psychomotoric troubled children were analyzed. Some of the measured components show a significant difference between normal and psychomotorically troubled children. That signifies that this method can be used for a preliminary diagnosis of psychomotoric trouble (Nigg, Untersuchung ueber das menschliche Gleichgewichtsverhalten, ETH Zuerich, 1976).

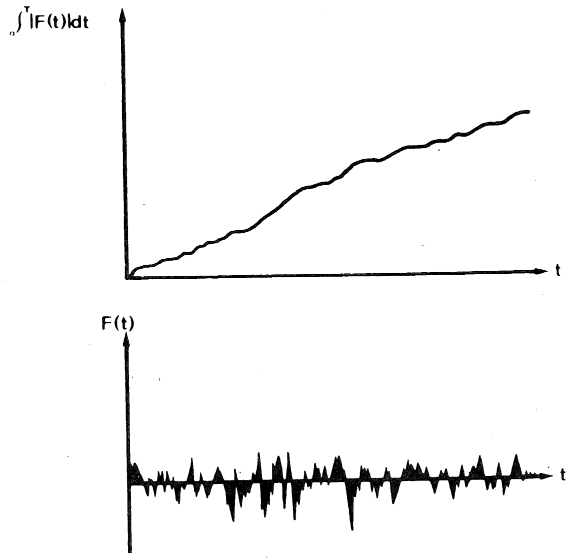


Figure 3. Rectified Impulse

Another application of this measuring method is in the field of psychological stress analysis. This human microvibration measurement seems to include much information that can be used for medical and psychological analysis, (Nuttli, Menschliche Mikrovibrationen und Stotterer, Diplomarbeit in Biomechanik, ETH Zuerich, 1976).

Problems of Force Platform Measurements

Using force-time-functions as a result of force platform measurements, there are many problems that are sometimes difficult to solve.

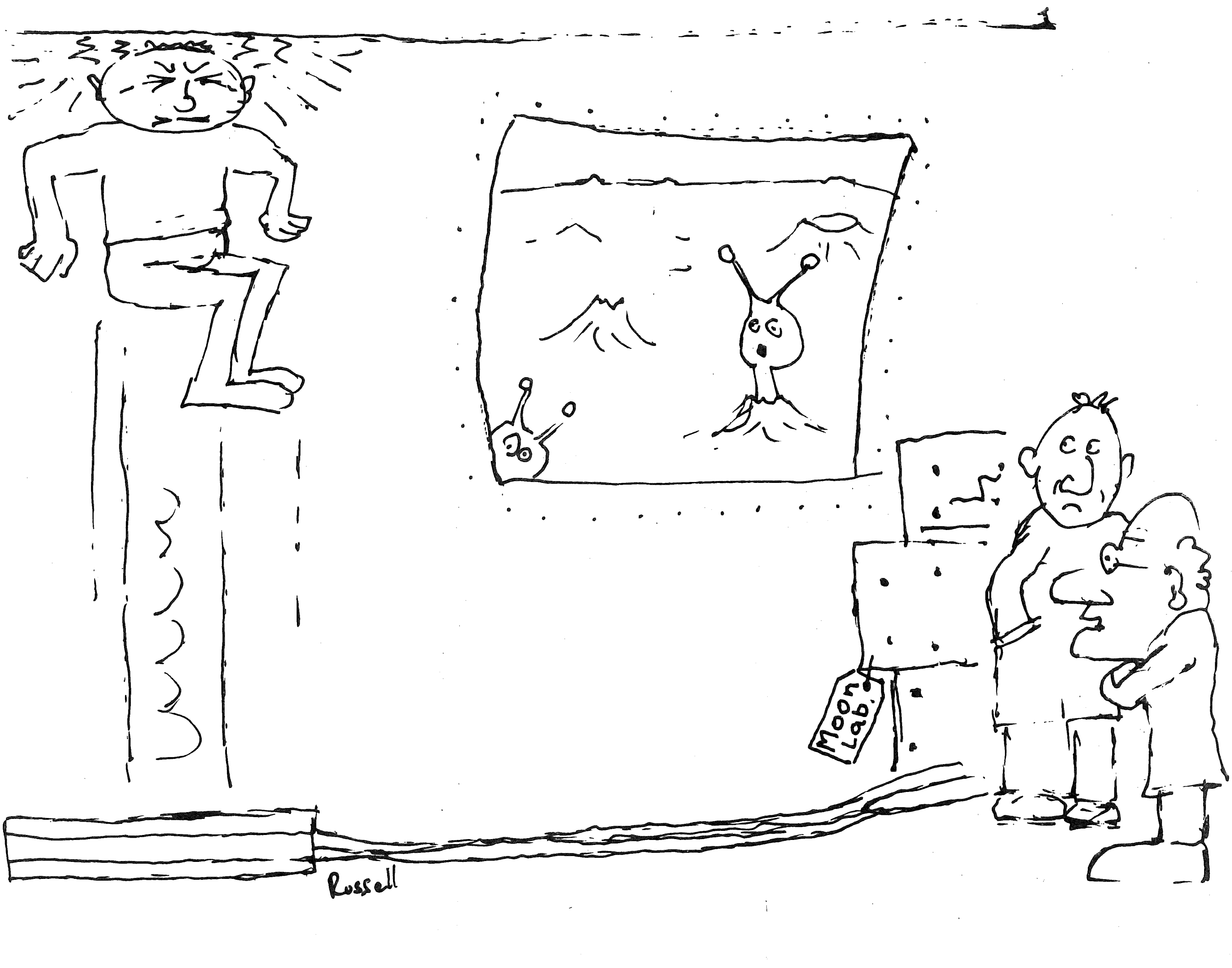
a. Prehistory. With the force platform only the contact interval of a step or a jump is measured. It may be that differences can be produced by the foregoing events. However, with force measurement we are not able to determine the influence of these foregoing events. Under these circumstances it may be necessary to add film analysis to force measurement.

b. The Force Distribution. In different studies we found sometimes that the resultant ground reaction force did not change even when film analysis parameters changed. It may be that the total human body equalizes small local changes in force so that the total reaction force does not change. Therefore, it is very often useful to have a more differentiated approach to the force measurement. This approach can be the use of different force transducers on the shoesole or using a force platform which is subdivided into subunits (Stokes, Force Distribution Under the Foot - A Dynamic Measuring System, Biomedical Engineering, April 1974).

c. Interpretation. Even if the force measuring system works perfectly there will still be problems; problems of interpretation of course. When, for example, you can measure the forces in a joint, what are the relevant values for the stress in the joint, the maximum amplitude, the integrated force, the mean force and other parameters? Also, how can we establish limits which define the safe operating range for this joint?

Conclusion

Based on our experimental data we know that there are different possibilities for using force platform measurements in the field of clinical research and clinical diagrams. It is essential that technical and interpretative problems are both considered.



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(Additions by editor from members' correspondence marked*)

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