Goddard Space Flight Center
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Technical Support Package

Flex Wedges

NASA Tech Briefs
GSC-14006

National Aeronautics and
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Technical Support Package

for

FLEX WEDGES
GSC-14006

NASA Tech Briefs

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Flex Wedges

A. General Purpose

The general purpose of the invention is to significantly and fundamentally improve the performance of the Basic Wedge. Wedges are inherently useful in the role of brake and clutch, but they are limited because when they are pressed down into a groove they tend to stick in that groove and it is difficult to remove them. This is particularly true of steep-angled wedge/groove combinations so they are frequently excluded from those applications. Also, their performance as a brake is directly related to the frictional properties of the wedge/groove interface surfaces and their frictional properties are very unreliable and unpredictable. This is especially true in space operations where lubricants are used that must perform in a vacuum. Flex Wedges can easily be extracted and do not stick in grooves, no matter how steep. When extracted, they come out with a mechanical advantage, and the steeper the wedge/groove angles, the easier they come out. But very steep-angled wedge/groove combinations are most effective in brake/clutch applications (just the situation where regular wedges are excluded) so Flex Wedges fundamentally improve wedge performance. Flex Wedges hold (in the brake/clutch role) much more effectively than basic wedges and so less insertion force is needed to achieve outstanding performance. This translates to smaller, more effective actuators to power the wedge brake/clutches and, still, a significant improvement in performance. Again, the general purpose of this invention is to significantly improve the performance, utility and predictability of the Basic Wedge geometry in all brake/clutch operations and, thereby to extend their use into realms and applications previously denied them.

B. Disadvantages of Prior Art

1. Basic Wedges function with the most holding force when they have steep angles and are used in grooves with matching steep angles, but in this instance, they frequently jam and cannot be removed under load except with great force.

2. Often, a Basic Wedge that has been under load cannot easily be removed even when that load is removed.

3. The force used to remove a jammed Basic Wedge is frequently unpredictable and erratic. Also, it jerks the device using the Basic Wedge in the process of unjamming same.

4. A Basic Wedge suffers parasitic frictional forces when it is being inserted in a groove which reduces its ability to frictionally hold as a brake/clutch.

5. The uncertainties of Basic Wedge performance limit its applications.

6. These uncertainties and erratic performance severely restrict the use of the Basic Wedge in precision, ultra-smooth operations not to mention the very significant wear and tear caused the Basic Wedge brake/clutch in the process.

D. IDENTIFICATION OF COMPONENT PARTS AND MODE OF OPERATION

A Flex Wedge System (see Figure 1 sketch) is essentially a Flex Wedge and its mating Fixture. The Fixture is configured and functions the same as any basic wedge system. The Flex Wedge uses flexures to assist in insertion and extraction and significantly improves brake holding performance, reliability and predictability while reducing wedge actuation force. The Flex Wedge consists of 2 or more Wedge Shoes (each, of which is separated from the others), a Wedge Compliance Flexure and a Flexure for each of the Wedge Shoes joining that shoe to the common Wedge Compliance Flexure. The outside of each Wedge Shoe is a wedge contact surface which mates with its respective Fixture contact surface, a Flexure joins the inside of each of the Wedge Shoes to the common Wedge Compliance Flexure and is normal to its respective Wedge Shoe contact surface. The Wedge Compliance Flexure is constructed so as to be very flexible in allowing the Wedge Shoes to adjust and line up with their respective Fixture contact surfaces but; to be very stiff in the direction of Wedge insertion/extraction travel and in the direction of the relative motion of Fixture and Wedge while acting as a brake.

Flex Wedge insertion (see Figure 2 sketch) is described below. Initially, the insertion of a Flex Wedge is the same as that of any other wedge (see Figure 2a) and is a function of the system wedge geometry.

$$\sum F = 0$$

$$F_f = \mu F_n \cos\phi_0 + F_n \sin\phi_0 = \frac{F_{st}}{2}$$

$$F_n\left(\sin\phi_0 + \mu\cos\phi_0\right) = \frac{F_{st}}{2}; \frac{2F_n}{F_{st}} = MA_g$$

$$\frac{2F_n}{F_{st}} = \frac{1}{\left(\sin\phi_0 + \mu\cos\phi_0\right)} = MA_g$$

Thus, we have what amounts to a mechanical advantage MA_g in brake friction holding strength because of the wedge geometry of the system.

But once wedge geometry stops insertion, the insertion forces acting on the Compliance Flexure put forces on each of the Wedge Shoe Flexures and, through them, the Wedge Shoes and the Fixture. These Wedge Shoe Flexures tend to bend, ever so slightly, and, in so doing spread the Wedge Shoes away from each other, pressing them firmly against their respective Fixture contact surfaces.

$$Rd\phi_i \tan\phi_i = dl_i$$

$$d5_i = \frac{dl_i}{\sin\phi_i}$$

$$\frac{d5_i}{dl_i} = MA_i = \frac{1}{\sin\phi_i}$$

For $\phi_0 = \phi_i = 10\deg; MA_i = 5.76$

Thus, we have a second mechanical advantage in insertion MA_i above the standard geometry effect described above. The overall mechanical advantage in generating normal forces to sustain brake friction holding is the product of the two (2) mechanical advantages described above or:

$$MA_{it} = MA_g \times MA_i = \frac{1}{\sin\phi_i\left(\sin\phi_i + \mu\cos\phi_i\right)}$$

And, since the actual brake holding friction force is the normal force times the coefficient of friction, we have:

$$F_{fh} = \mu MA_{it} F_{st} = \frac{\mu F_{st}}{\sin\phi_i\left(\sin\phi_i + \mu\cos\phi_i\right)}$$

Where $\phi_i \approx \phi_0 = 10$ deg; and assuming $\mu=0.3$;

$$MA_{it} = 12.3; F_{fh} = 3.7F_{st}$$

Flex Wedge extraction (Figure 2a and 2b sketches) will now be described. When the force inserting the wedge in the fixture is relaxed (or goes to 0), the Wedge Shoe Flexures relieve themselves of the bending torque stored in them during insertion by pushing the Wedge Compliance Flexure upwards. Thus, the normal forces are reduced to those of normal wedge geometry action. At this point, force is applied to the Wedge Compliance Flexure to extract the Flex Wedge. During this process, the Wedge Shoe Flexures each bend so as to foreshorten the effective distance between the Wedge Shoes. This, in turn, has the effect of pulling each of them away from its respective Fixture contact surface with a mechanical advantage MA_R for the extraction force. This action is independent of the coefficient of friction, is a function of geometry alone, and is, thereby, very predictable and reliable.

$$Dd\phi_R \tan\phi_R = dl_R$$

$$\frac{dl_R}{\sin\phi_R} = D5_R$$

$$\frac{D5_R}{dl_R} = MA_R = \frac{1}{\sin\phi_R}$$

For $\phi_R = \phi_0 = 10\,\text{deg}; MA_R = 5.76$

The basic operations of the Flex Wedge System having been described, some additional comments are in order. The Show Flexures can be very thin and flexible and still perform with great strength and rigidity in the directions that matter. At the same time, they can be very long in the Z direction and this makes them very strong and rigid in holding torque or force during normal wedge braking functions. Placing them normal to the Wedge contact surfaces means that normal forces act on the Wedge Shoe Flexures in pure compression so they can fail only in buckling. Thus, these flexures can easily resist even strong normal forces. That these flexures are relatively long in the Z direction will also help. The actions of the Shoe Flexures goes on relatively unaffected by the Wedge Compliance Flexure. The Wedge Compliance Flexure is flexible in twist about the Z axis and translation in X (Figure 1) but is rigid in all other directions (twist about X, twist about Y, translation in Y, translation in Z). Like the Wedge Shoe Flexures, they are thin but; long in the Z direction.

E. ALTERNATE EMBODIMENTS

Alternate embodiments are described below. Two (2) Outside Flex Wedge Variants are sketched in Figure 3. In the version shown in Figure 3a, there are two (2) Wedge Compliance Flexures, one for each Wedge Shoe Flexure. This has an advantage in that it is more compact than the version shown in Figure 3b. It is disadvantaged in that the Wedge Compliance Flexures are placed under a bending moment stress and so, in this respect, the system is weaker. The version shown in Figure 3b has only one (2) Wedge Compliance Flexure which services both Wedge Shoe Flexures. As Figure 3 shows, it is axially longer than that shown in Figure 3a but it is stronger. Two (2) more Flex Wedge Variants are sketched in Figure 4. In Figure 4a, a version using Parallel Wedge Jaws is shown. In this instance, each Wedge Shoe has two (2) identical Wedge Shoe Flexures which move such that the Wedge Shoes are constrained to move towards and away from each other and remain parallel to each other at all times. The particular version shown in Figure 4a is an Outside Wedge Systems. That is, as the Wedge Shoe Flexures bend upwards during insertion, their respective Wedge Shoes move towards each other and pinch the Fixture from the outside in. This configuration is very compact, much more so than those shown in Figure 3. Flex Figure 4 illustrates a Crossed Flexures Wedge configuration. This is an inside Wedge System. In this instance, it is very important to make the Wedge Fixture as narrow as possible. So, to this end, the Wedge Shoe Flexures are positioned, one behind the other (Figure 4c) so as to get the longest possible flexure in the narrowest possible Fixture. Of course, the Flex Wedge and the Fixture must both be longer to permit this. Figure 4c shows that the Wedge Shoes are each as long as the sum of the two (2) Wedge Shoe Flexures and each is attached to its respective Wedge Shoe in a cantilevered manner. This is to prevent the Flex Wedge from twisting axially under load. The width of this cantilever action. Figure 5 shows an Inside Parallel Wedge Jaws system as opposed to the Outside Parallel Wedge Jaws system shown in Figure 4. It, also, is very compact Figure 6 shows a Collette-style Flex Wedge with three (3) Wedge Shoes, each with its own Wedge Shoe Flexure and a two (2) Axis Wedge Compliance Flexure. This Collette-style Flex Wedge operates in a conical Fixture. An Inside Flex Wedge system is shown. It can be seen in Figure 6 how the Wedge Shoes flex radially outwards to press against the Conical Fixture. Of particular interest is the two (2) Axis Wedge Compliance Flexure. By placing Flexures one over the top of each other and at right angles to each other, the overall system is able to move in either the X axis direction or the Y axis direction (see Figure 6a) or in any direction in the X-Y plane. At the same time, it is stiff in the Z axis direction and in twist about Z.

Figure 7 shows a sketch of Flex Wedge with no Wedge Shoes. The tips of the flexures are rounded to form a bearing contact with the Fixture surface, other than that , it acts like a basic Flex

Wedge such as shown in Figure 1. Eliminating the Wedge Shoes, however, has both advantages and disadvantages. The main advantage is that the device can be made more compact by eliminating the Wedge Shoes. These take up space. Another advantage is that when the Flex Wedge is pulled out, it twists slightly and with flexure rounded tips at the points of contact with the Fixture.

F. CONTEMPLATED GOVERNMENT USE

This device was originated to form the basis for very efficient and effective brakes for precision actuators for space scientific instruments. The specific purpose in mind was microminiature brake/clutches for Voice Coil Actuators that hold position with power off for GSFC Space Telescopes such as Next Generation Space Telescopes (NGST). It can also form the basis for Space Robot grippers and foot grapple interfaces. But this is such a fundamental component that it will find its way into all types of electromechanical devices which will be used in many different aerospace applications. For example, this concept can be used in electromagnetic, electrostrictive, magnetostrictive, shaped memory alloy or heat expansion brake/clutches, to name just a few. It can also be used in all types of configurations (radial, translational, Outside, Inside, Parallel Flexure Pairs, etc.). This is such a fundamental and useful mechanical component that it expected to be a valuable NASA technology-transfer item to industry in all kinds of applications, many of which cannot even yet be imagined.

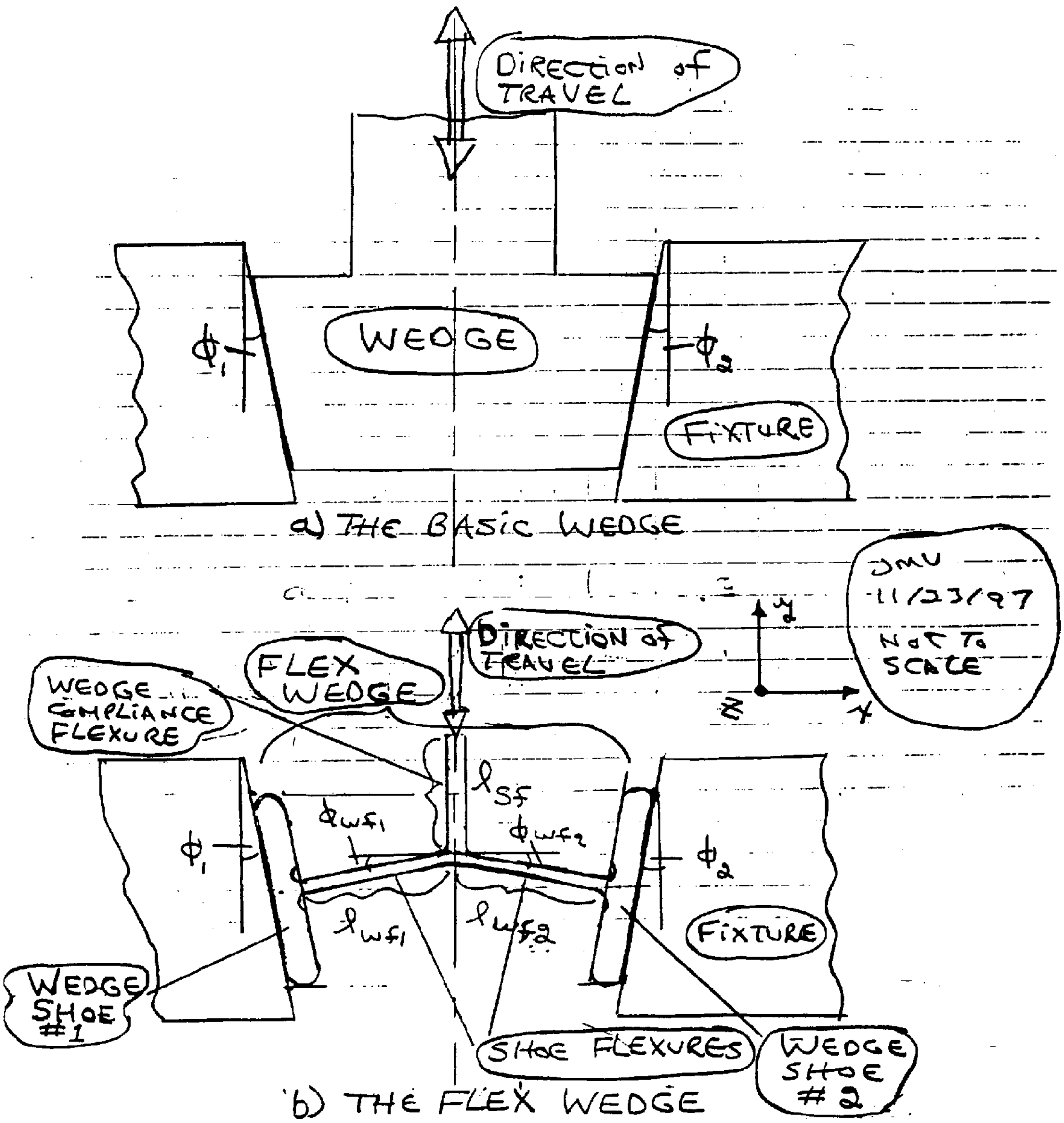

Figure 1

The Flex Wedge

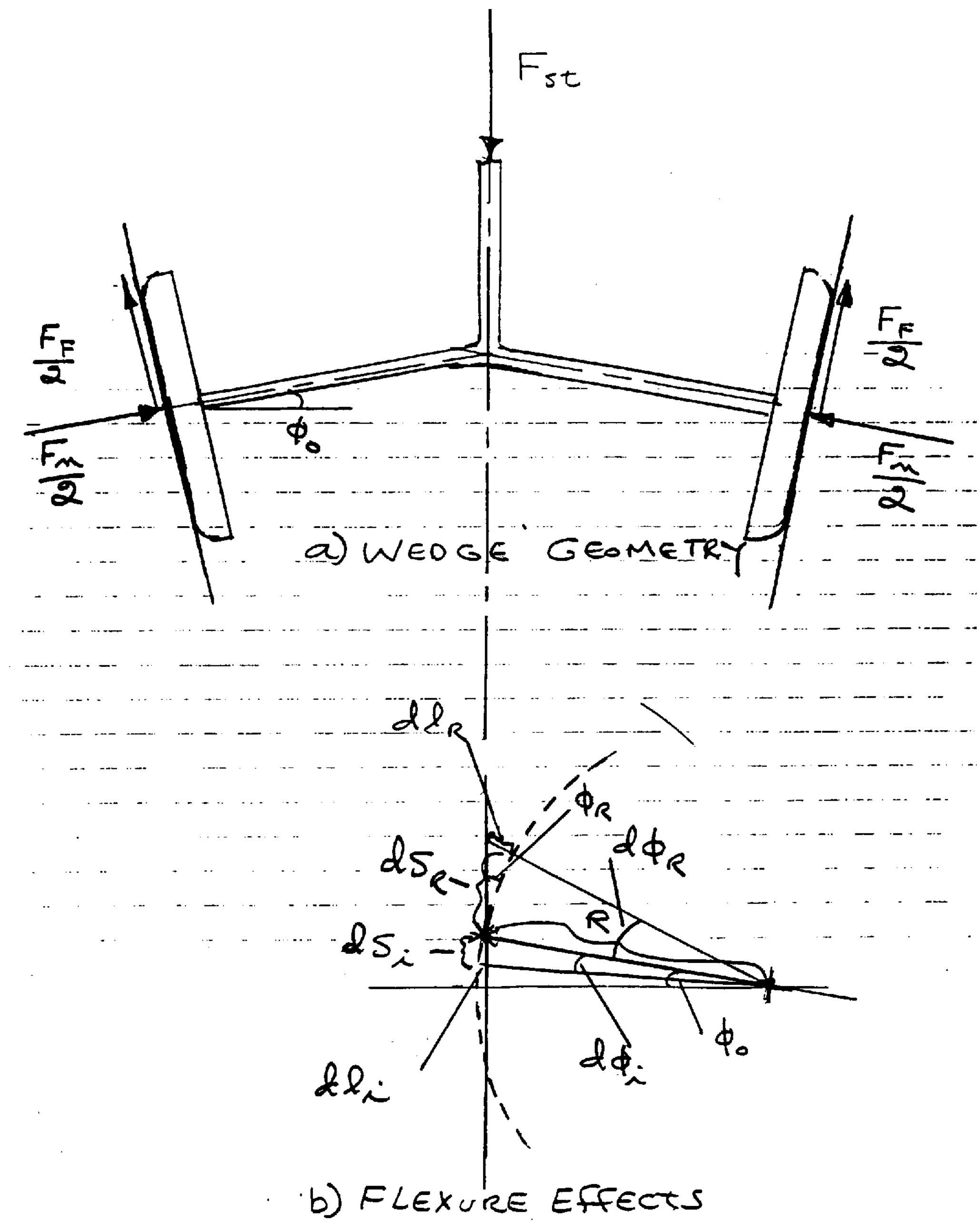

Figure 2

Wedging Effects

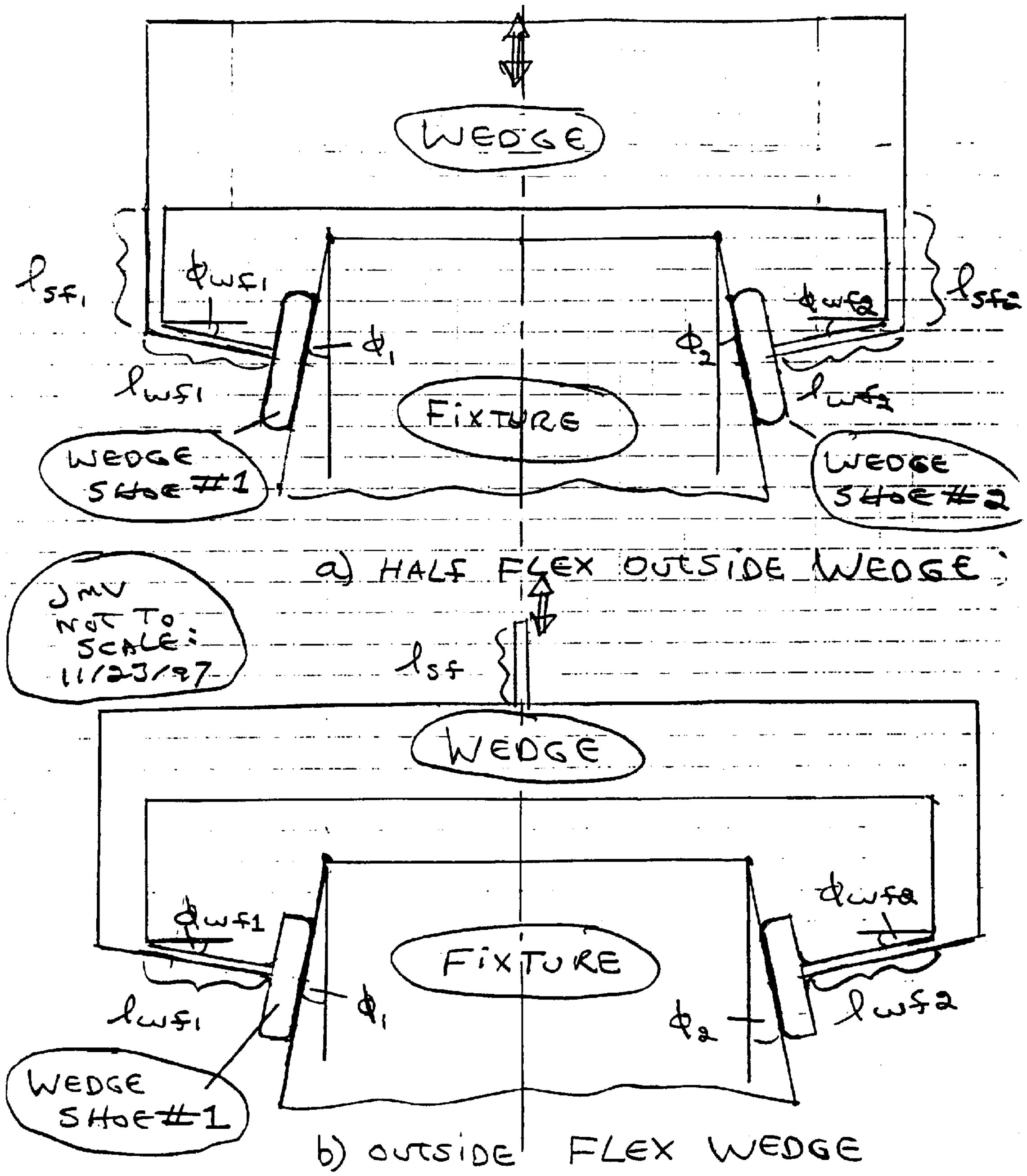

Figure 3

Outside Flex Wedge Variants

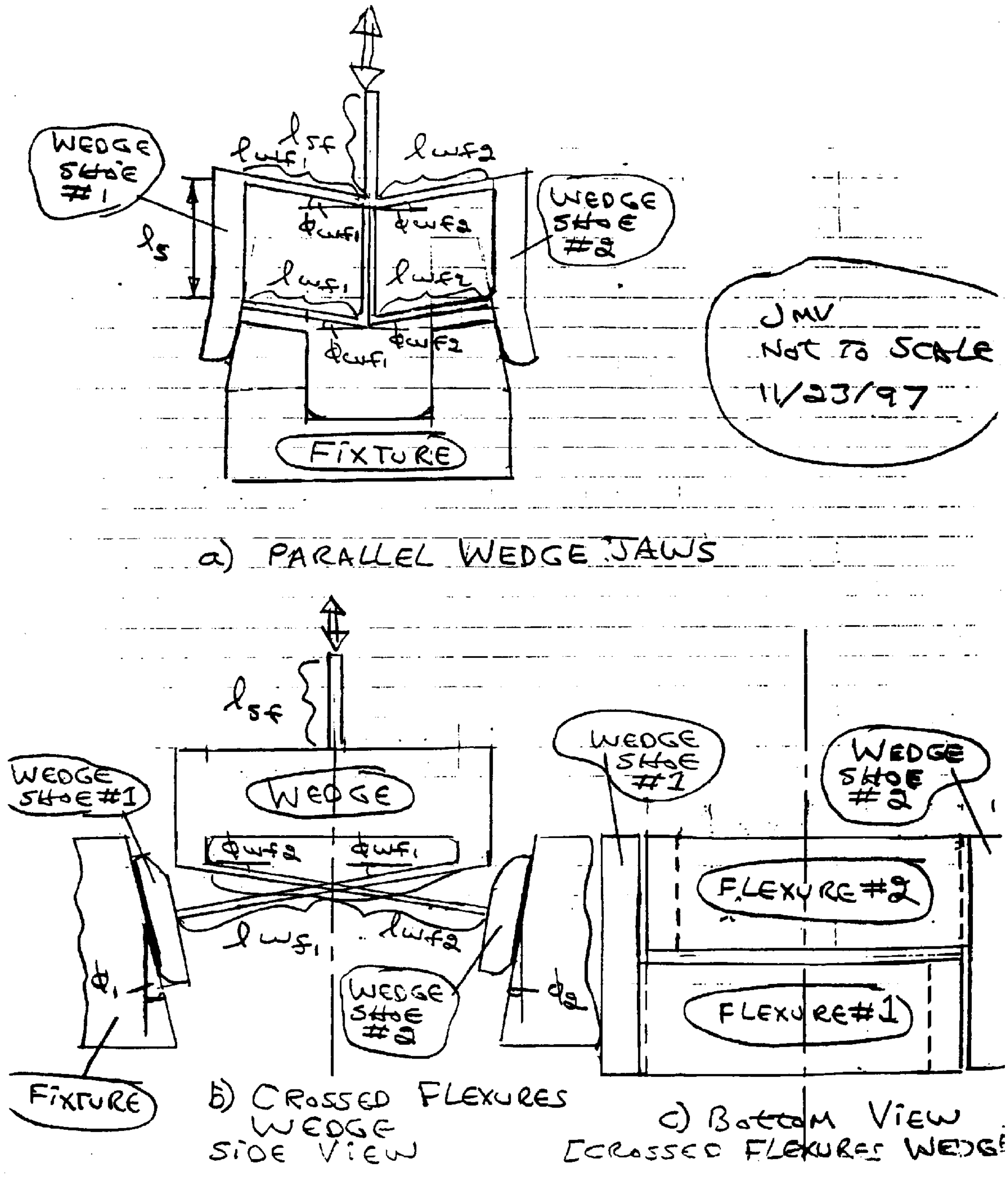

Figure 4

Flex Wedge Variants

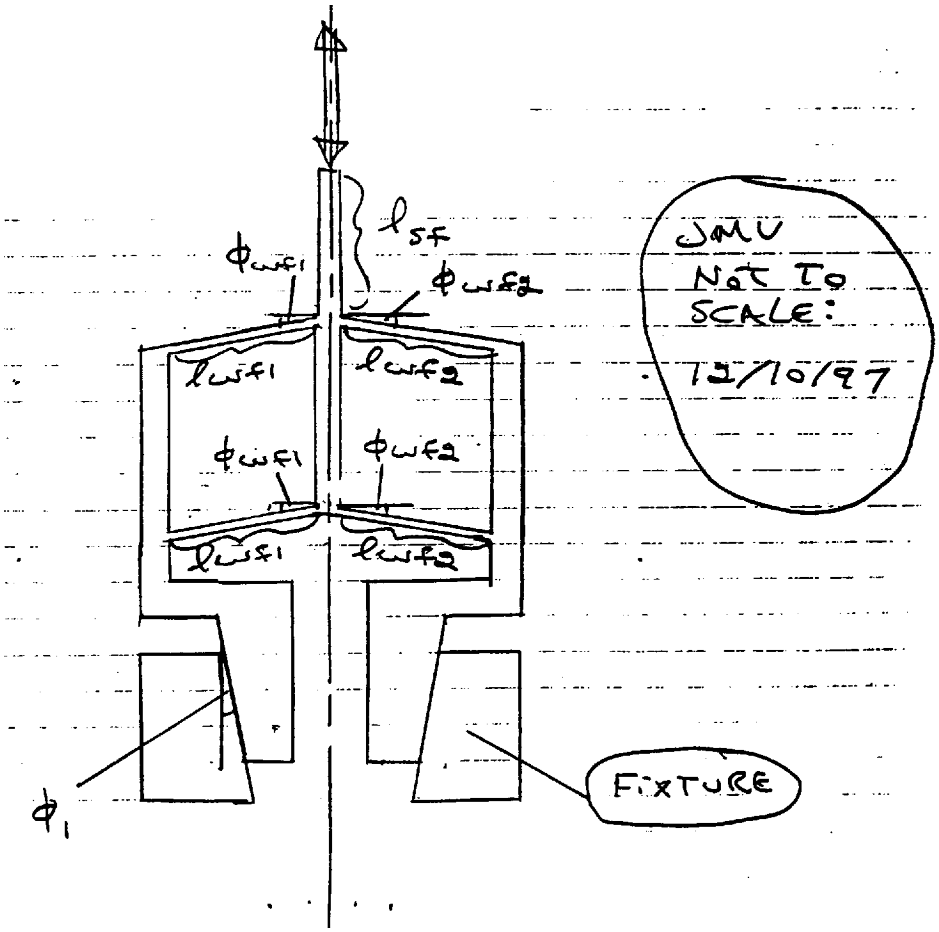

Figure 5

Parallel Wedge Jaws

(Inside Version)

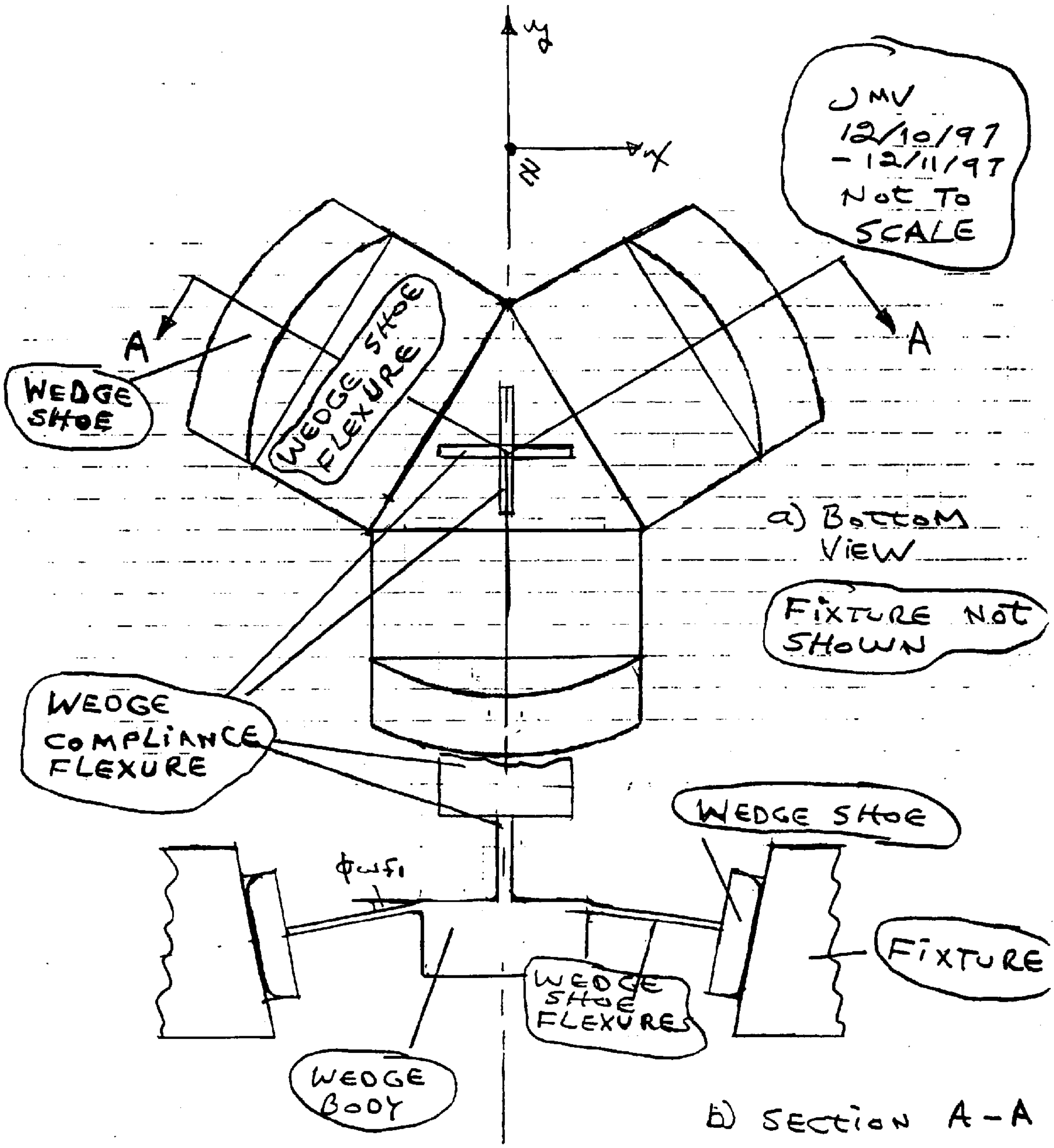

Figure 6

Collette-Style Flex Wedge

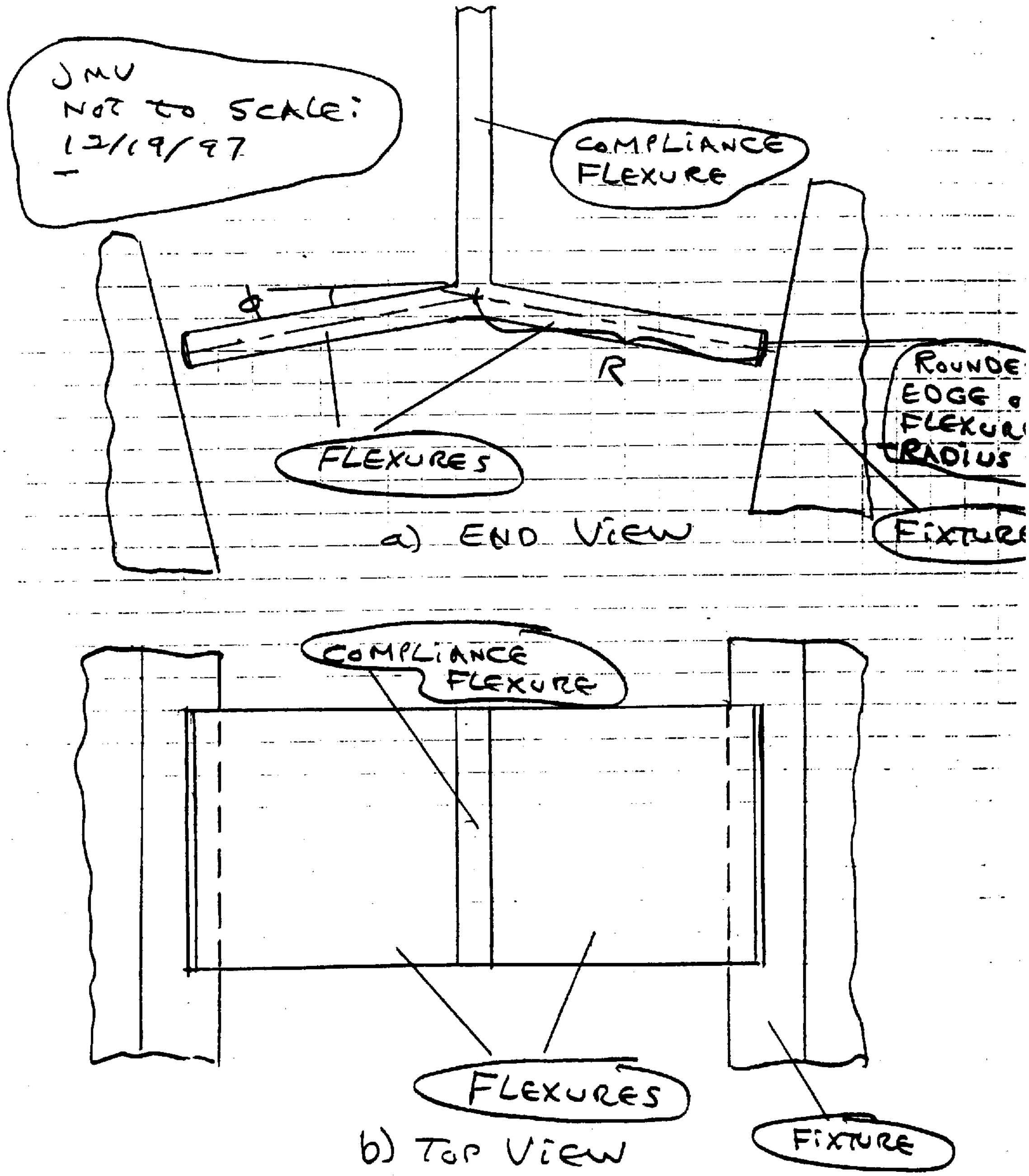

Figure 7

Flex Wedge Minus Wedge Shoes

(Rounded Edges)

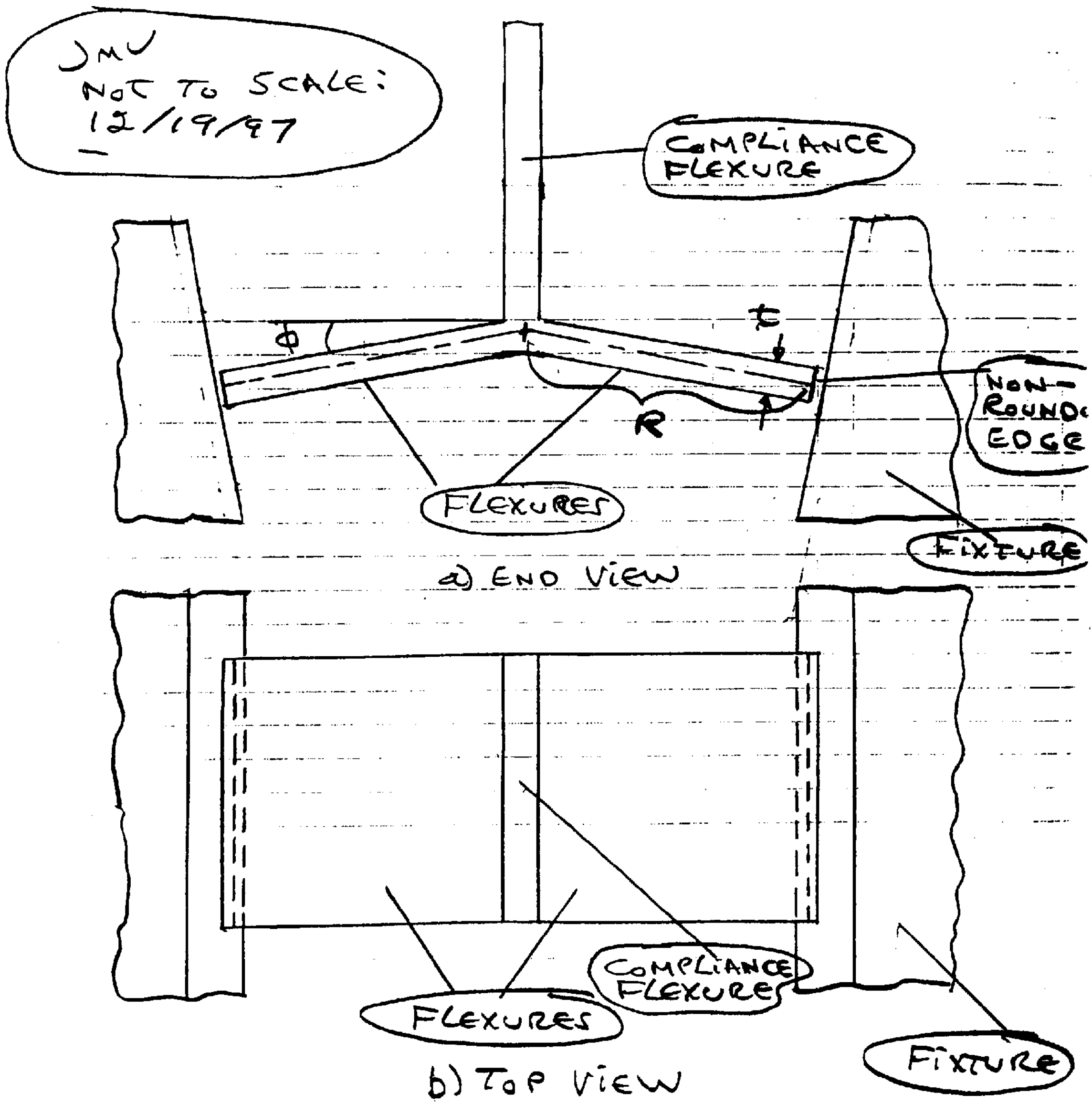

Figure 8

Flex Wedge Minus Wedge Shoes

(Non-Rounded Edges)

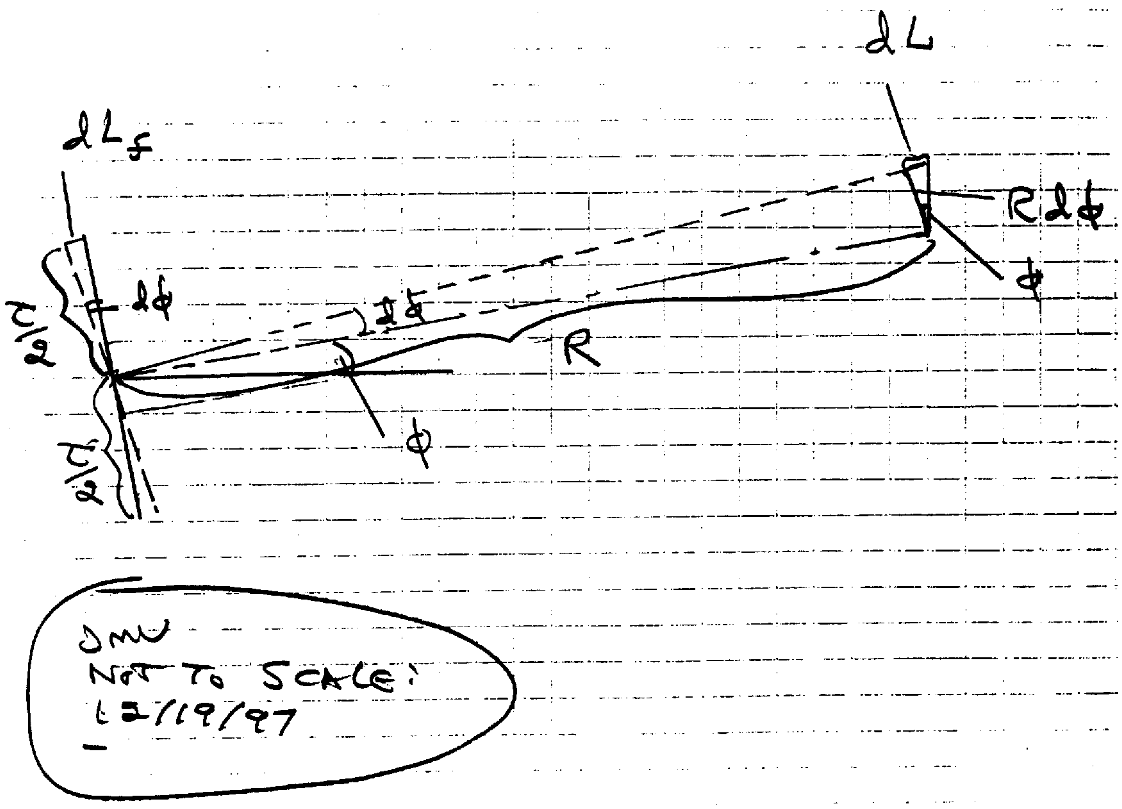

Figure 9

Flex Wedge Motions During Bending

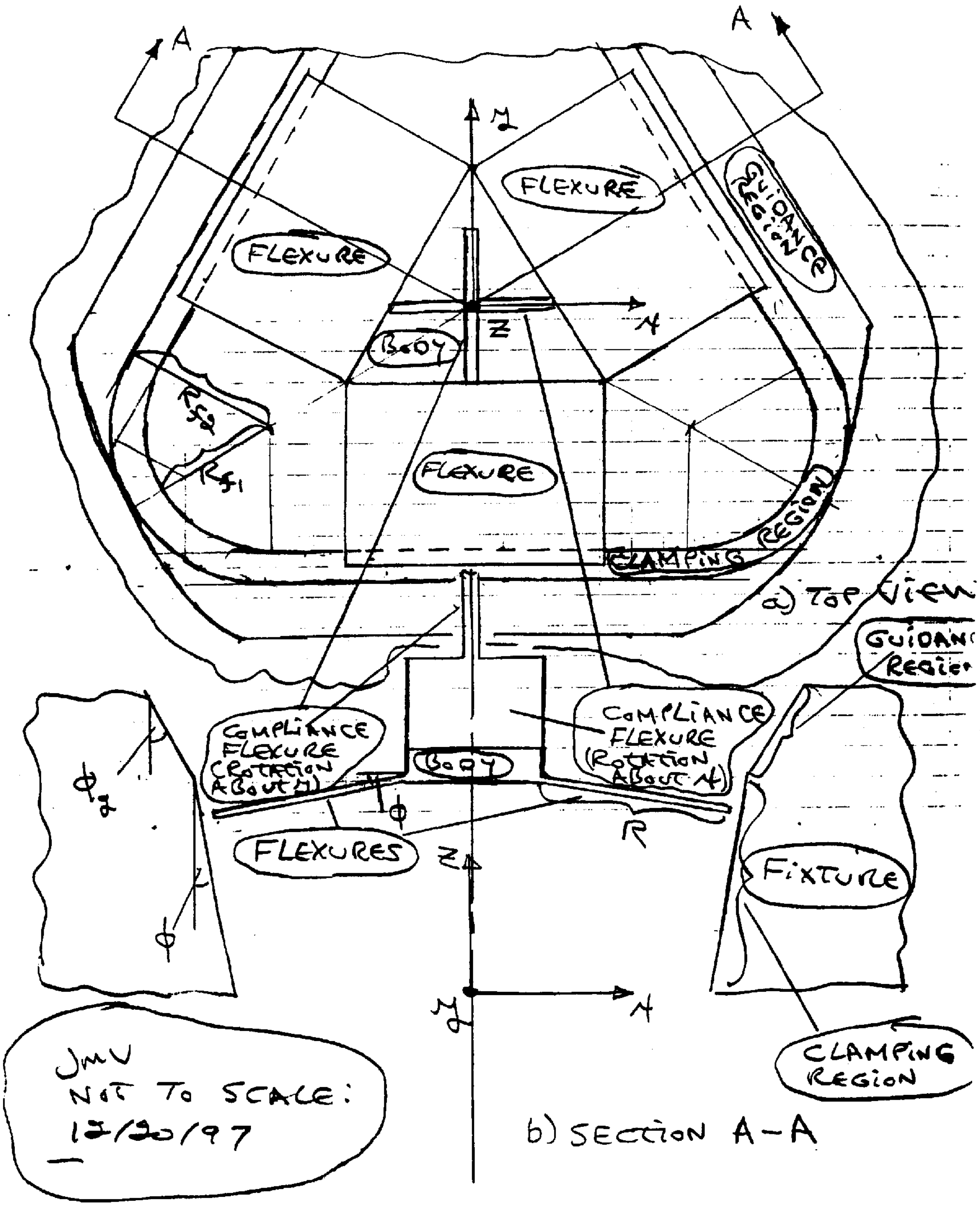

Figure 10

Collette-Type Flex Wedge

(No Wedge Shoes)

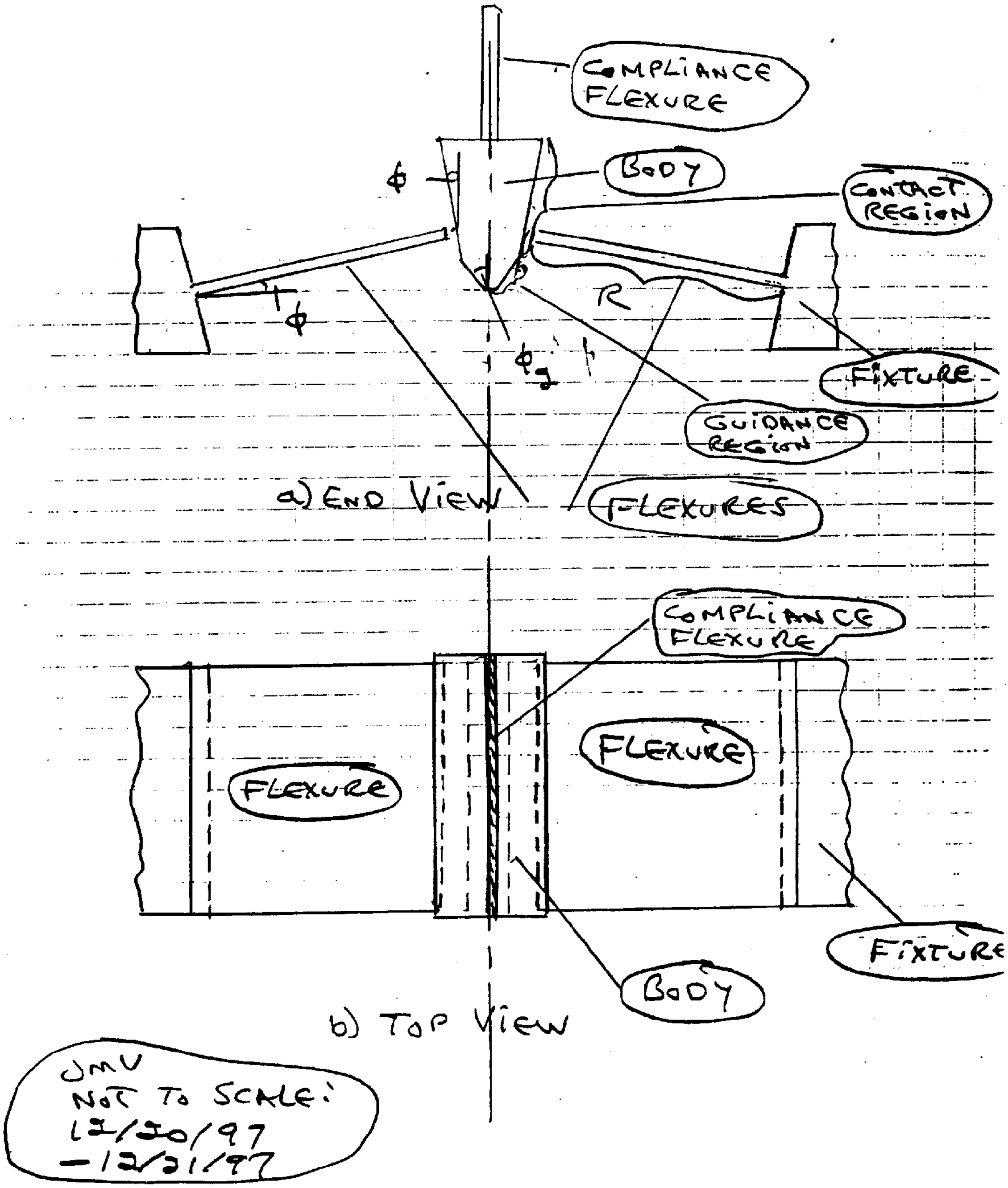

Figure 11

Outside Flex Wedge

(No Shoes)

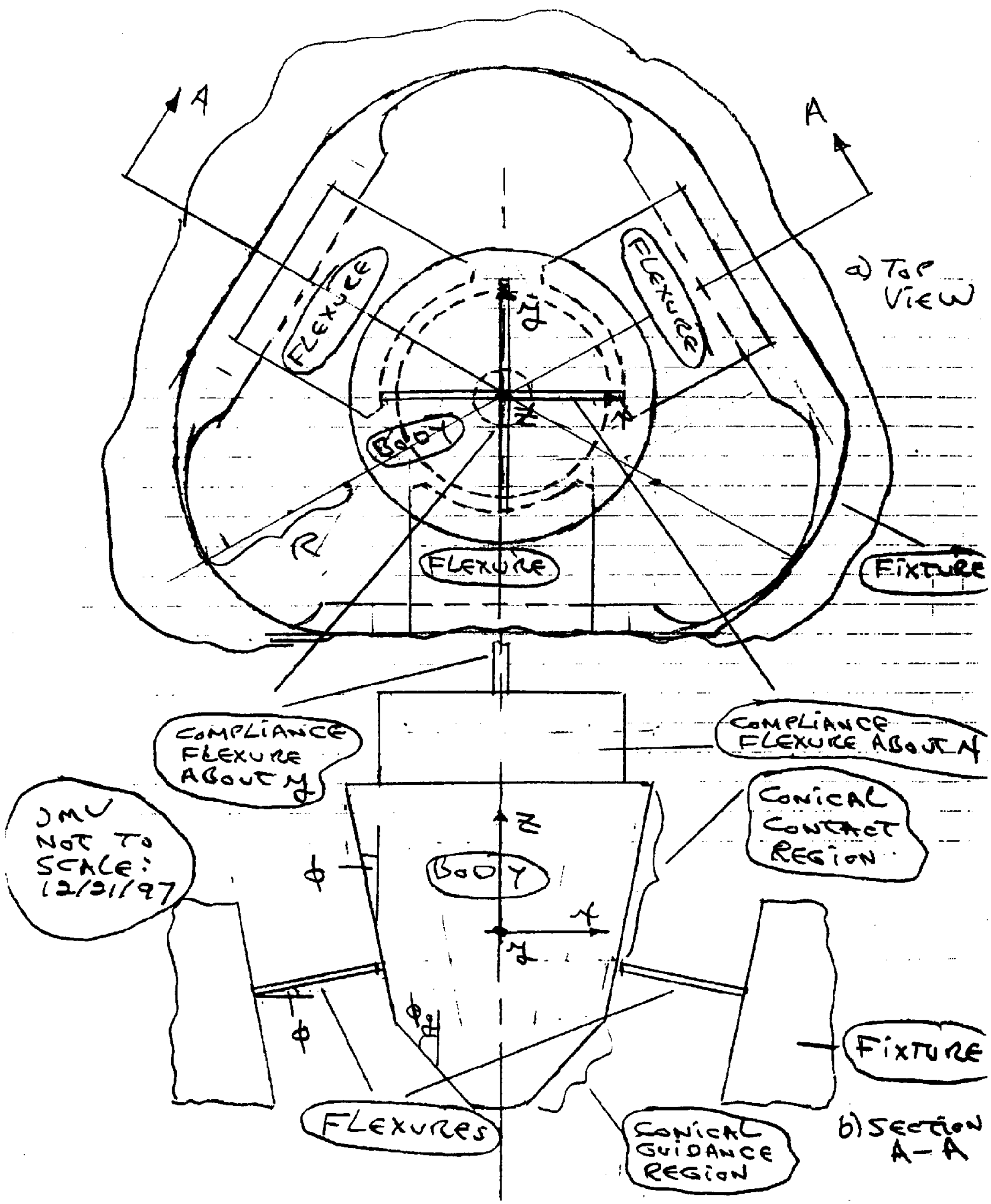

Figure 12

Outside Collette-Type Flex Wedge

(No Wedge Shoes)

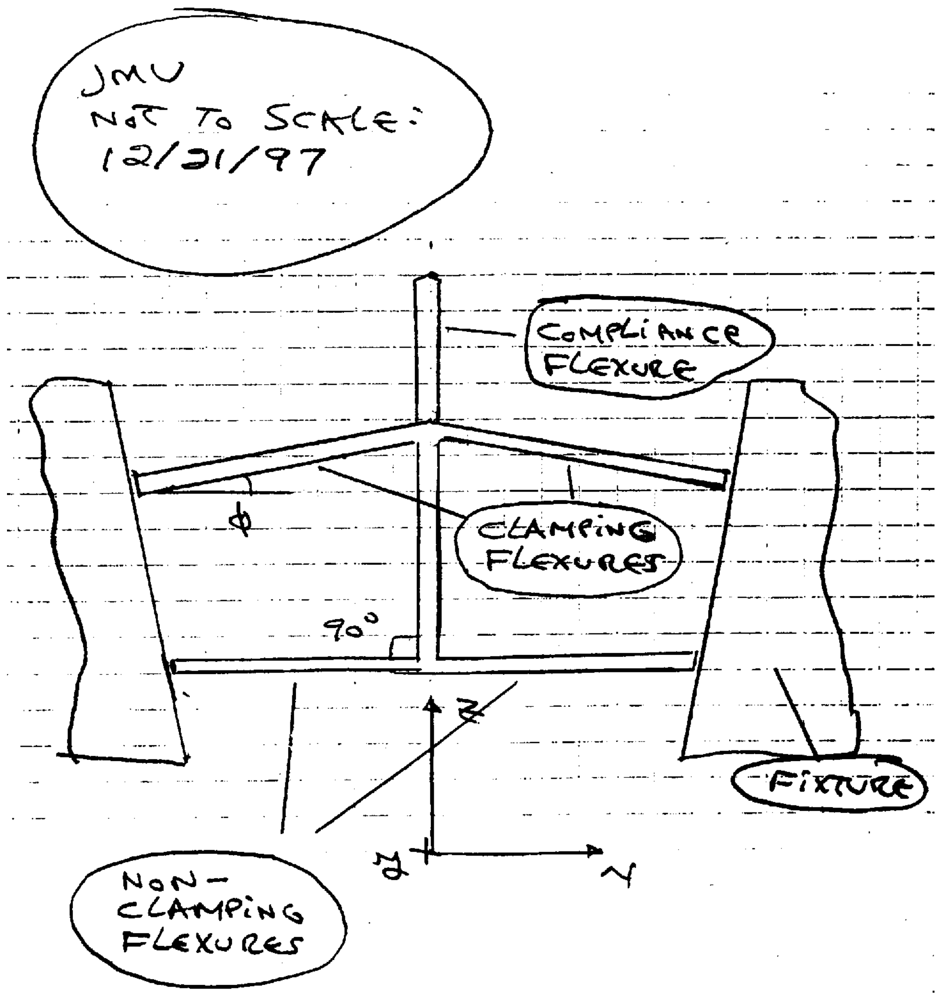

Figure 13

Flex Wedge Configuration to Constrain Twist About Y