Mechanical losses associated with the technique of silicate bonding fused silica to fused silica

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GEO 600 - Specifications — main suspension systems.

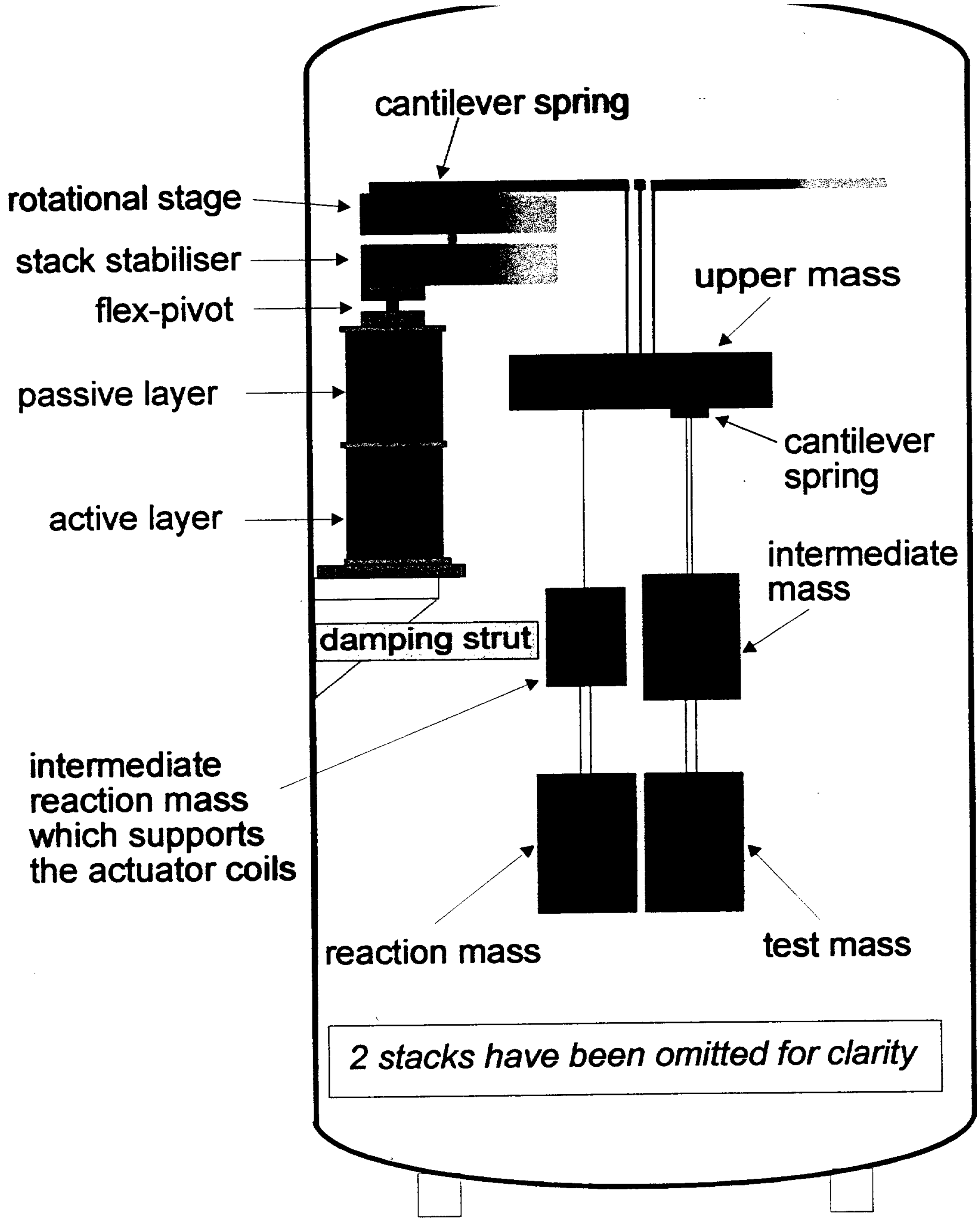
- **Seismic** Isolation Factors [@ 50Hz]

  Vertical: $\sim 3\times10^{6}$ [assuming 0.1% cross-coupling factor]

  Horizontal: $\sim 6\times10^{9}$

- Q pendulum $> 2\times10^{7}$

  Q internal, test masses $\sim 5\times10^{6}$



Schematic of test mass suspension
(view perpendicular to optic axis)

Fused silica developments at Glasgow

- Working towards construction of all-fused silica pendulums: 14kg silica masses on fused silica fibres

Measurements show:

- Material Q of suspension fibres:

  $Q_{mat} \sim 10^6$

- Pendulum Q of 100g all fused silica (welded) pendulum:

  $Q_{pend} \sim 9 \times 10^7$

  (for 1.9kg mass: $Q_{pend} \sim 1.4 \times 10^7$: with Univ. Perugia, VIRGO)

- Violin Q of fused silica fibres:

  $Q_{violin} \sim 4 \times 10^6$

All good enough for GEO 600 requirements - (7×10^{-20} m/$\sqrt{Hz}$ @ 50Hz)

need to continue work on scaling these to larger pendulums

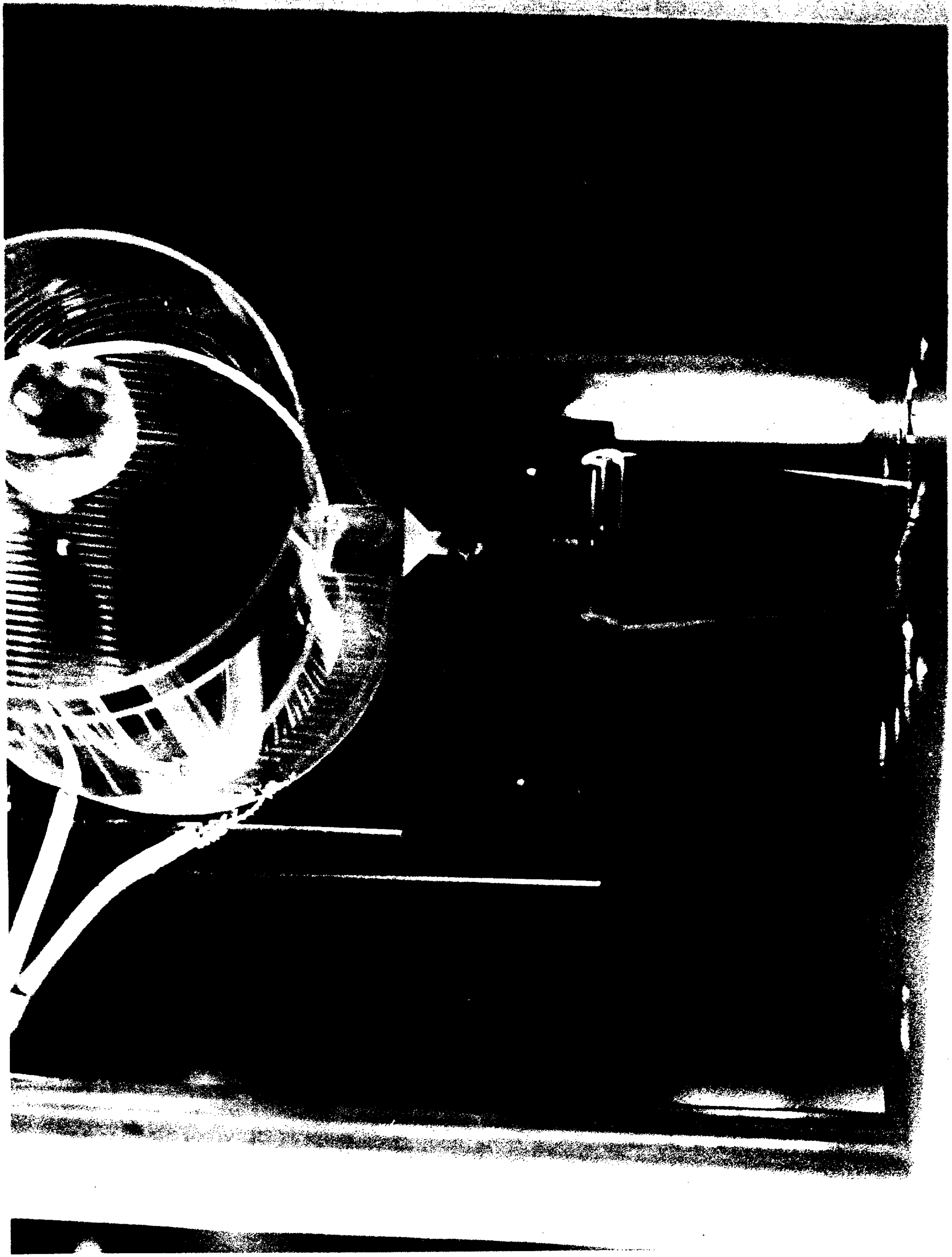
Need a method of jointing fused silica fibres to fused silica test mass which is:

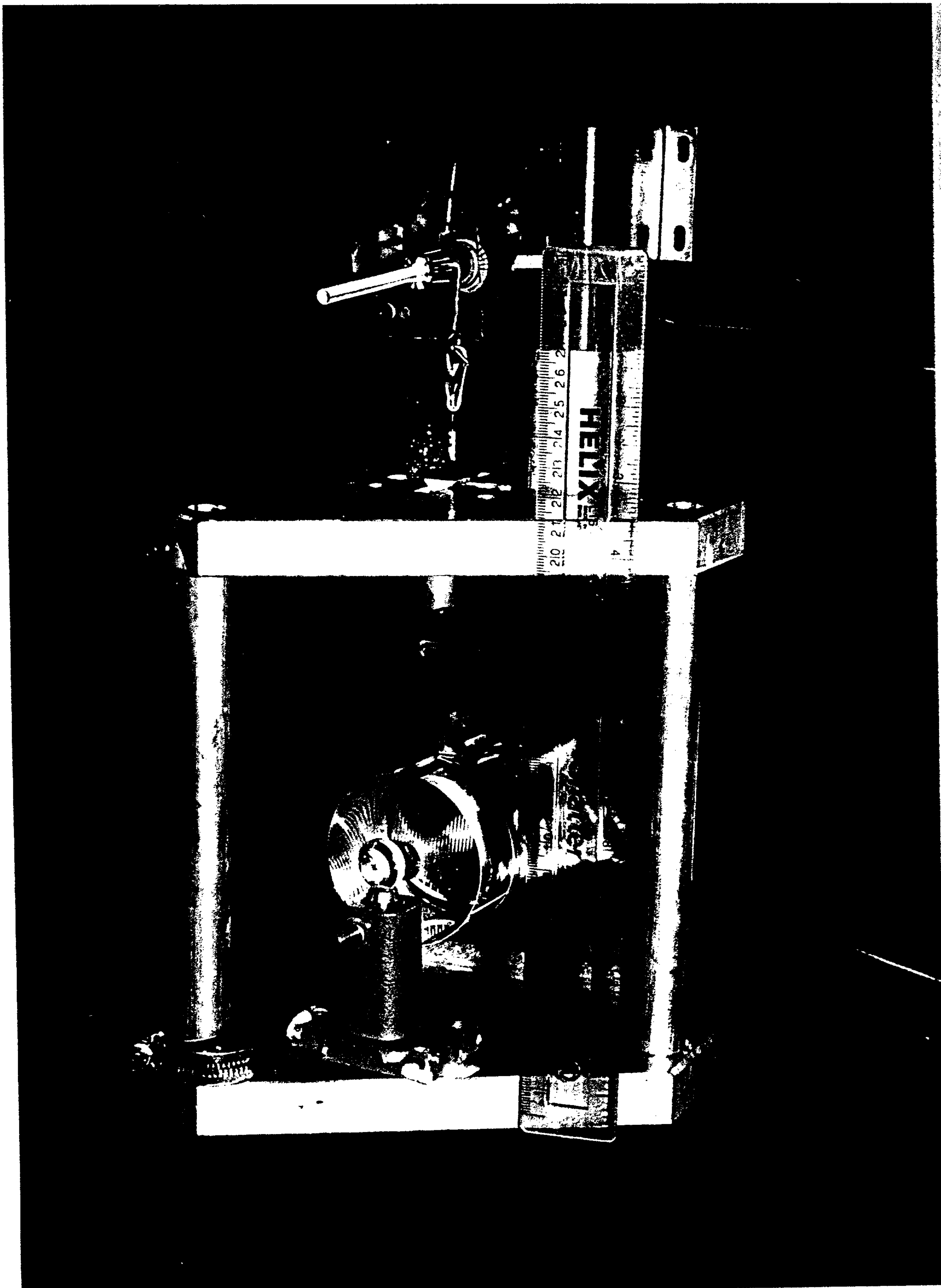
- mechanically strong
- of very low mechanical loss

→ investigate technique of <u>Silicate</u> <u>Bonding</u>

Developed by <u>Jason</u> <u>Gwo</u> at Stanford University for use in Gravity Probe B experiment.

GEO collaborating with GALILEO project on evaluation of this technique for use in Advanced gravitational wave detectors.




HELIX

RESULTS

Measured Q values for fundamental longitudinal modes of:

(a) CONTROL MASS

$(1.47 \pm 0.02) \times 10^6$

(b) MASS + KOH BONDED ATTACHMENT

$(1.40 \pm 0.02) \times 10^6$

Recall: At resonant angular frequency ω_0:

$$\phi(\omega_0) = \frac{1}{Q}$$

Then: Assuming all additional loss in measurent (b) is due to KOH bond we can write:

$$\underset{\text{loss due to bond}}{\phi(\omega_0)} = \frac{1}{Q_{\text{KOH bonded mass}}} - \frac{1}{Q_{\text{control mass}}}$$

$$= (3 \pm 1) \times 10^{-8}$$

$$\text{i.e.} \leq 4 \times 10^{-8} \qquad (\text{cf } 3 \times 10^{-8})$$

→ Suggests no significant loss introduced by placing bond under stress

(**nb:** wire breakaway conditions different in (a) and (b) above

CONCLUSIONS

Scale results to find expected loss resulting from area of KOH bond needed to support a kg GEO 600 test mass on fused silica fibres.

Bond area = × 5 smaller than used here

$\Rightarrow$ Expect loss : $\frac{4\times10^{-8}}{5} = 8\times10^{-9}$

Test mass = × 32 larger than used here

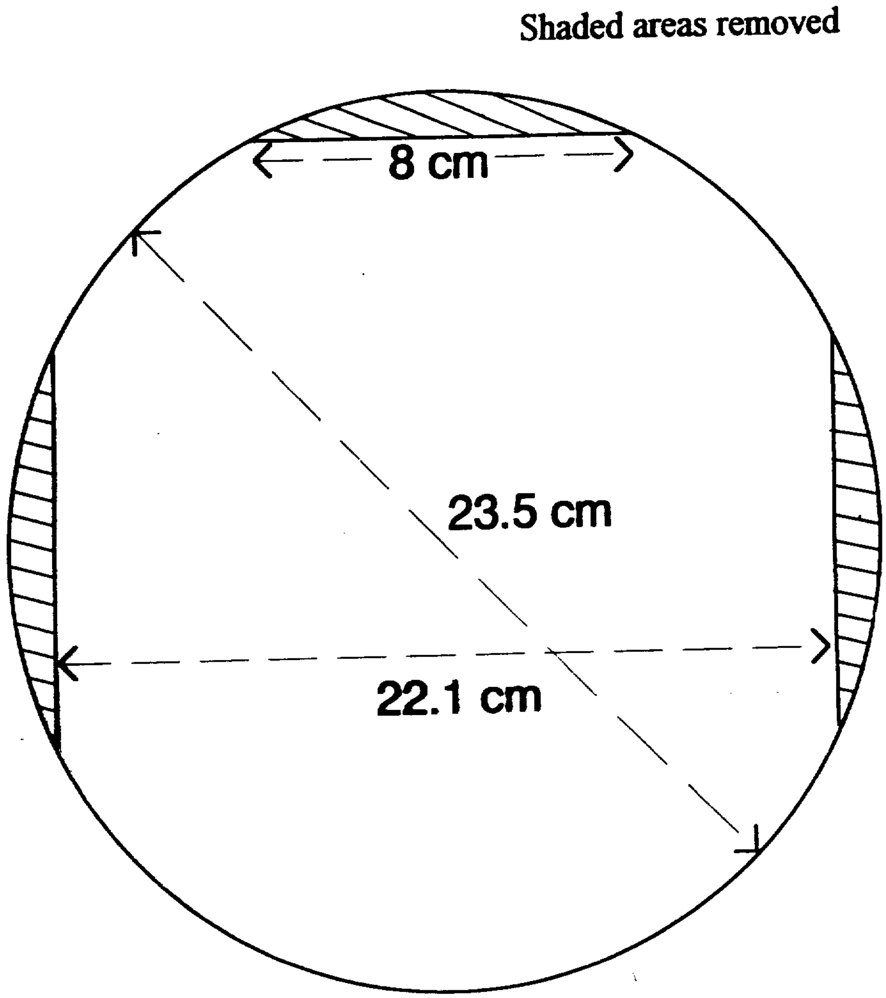
$\Rightarrow$ Expect loss : $\frac{8\times10^{-9}}{32} = \underline{2.5\times10^{-10}}$

ie: Negligible of internal loss of fused silica test mass

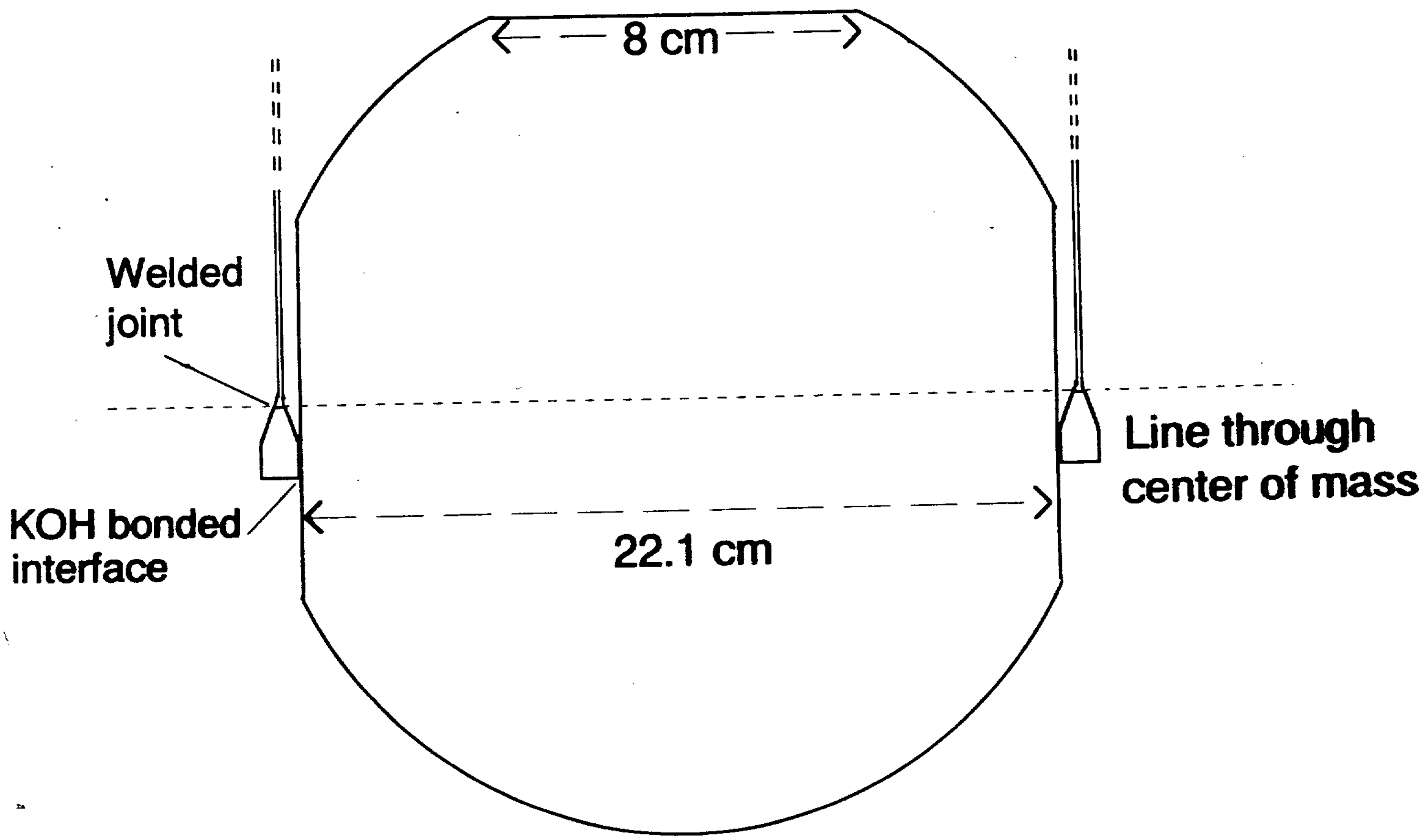
$\Rightarrow$ KOH bonding looks like an excellent method of producing low loss fused silica / fused silica joints.

\+ has potential to joint a number of ultra low loss materials ie. sapphire and silicon (see J. Gwo, R. Route, Stanford)

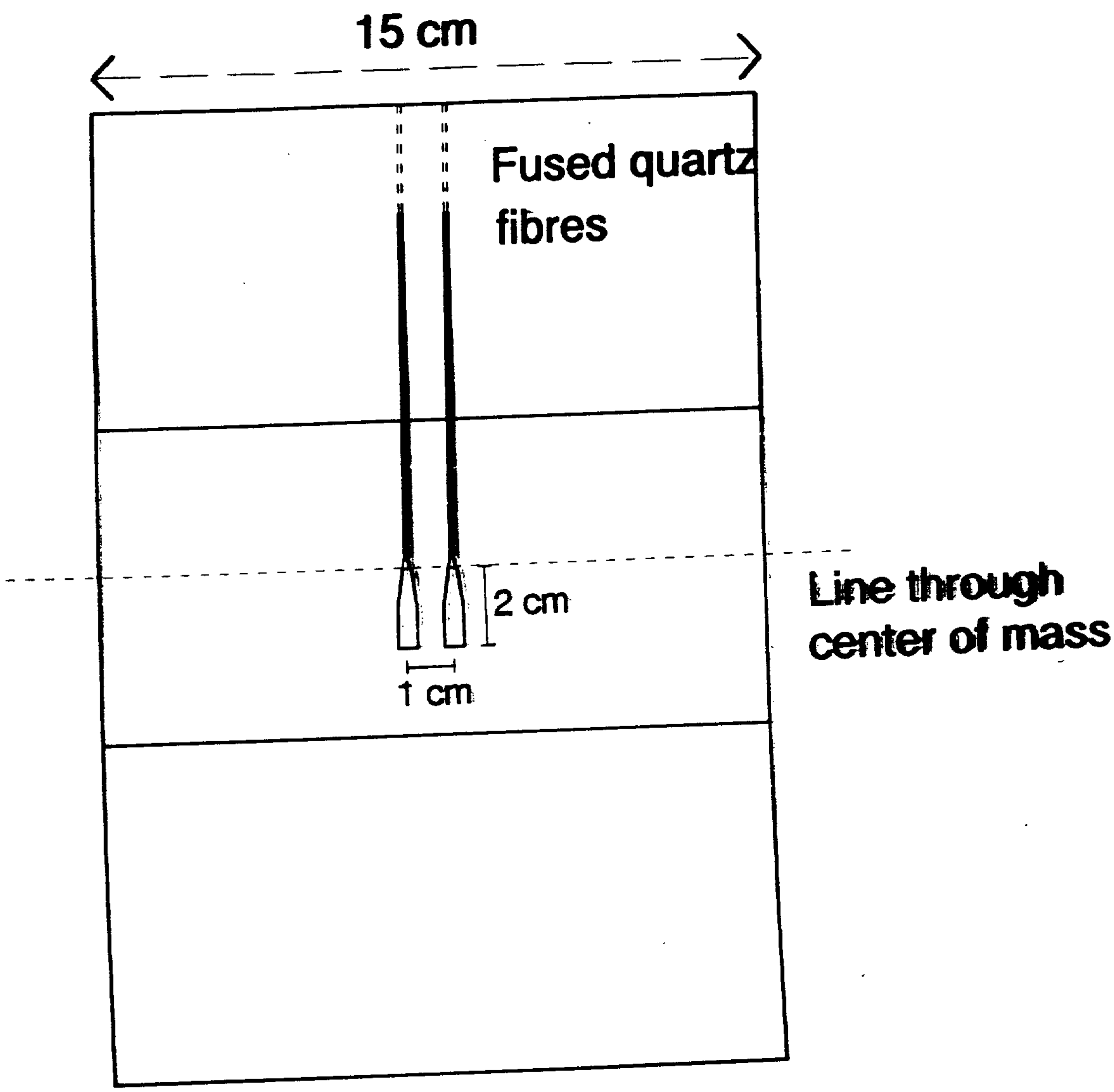
View of protoype GEO 600 test mass showing front face



View of protoype GEO 600 test mass showing front face and silicate bonded attachments

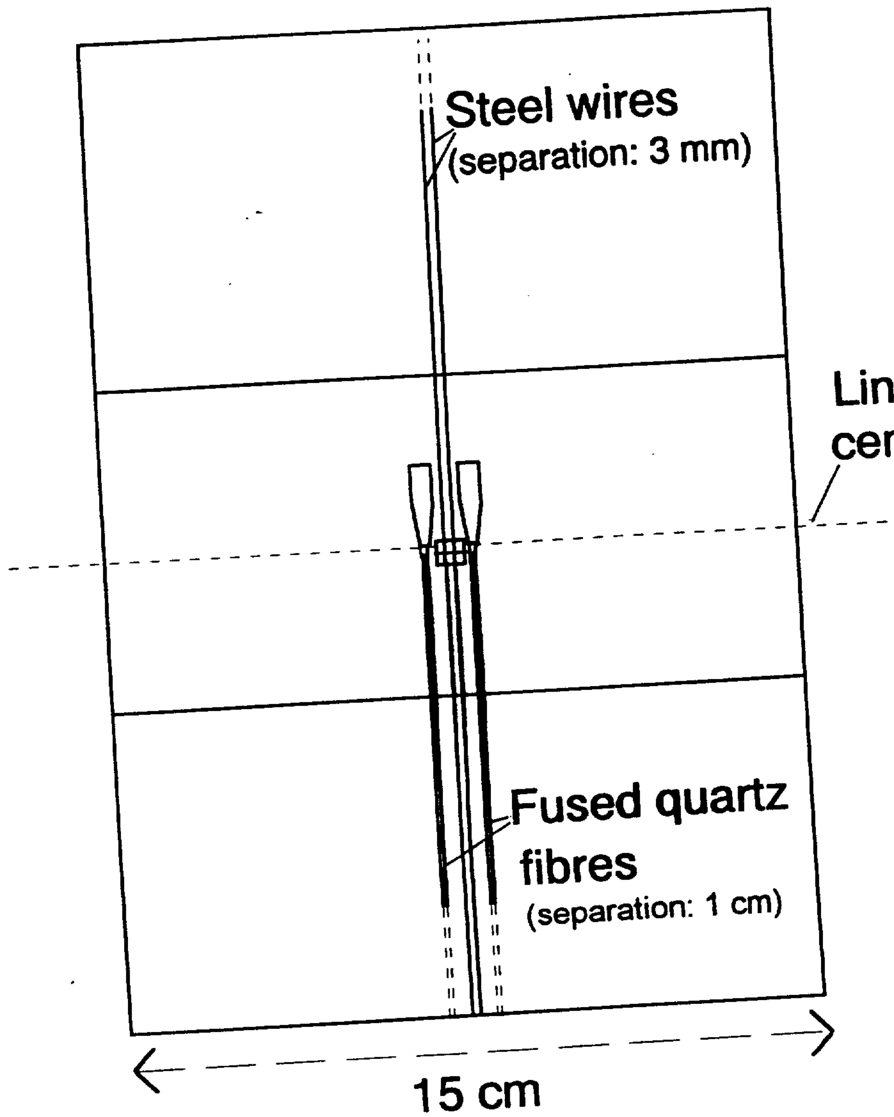


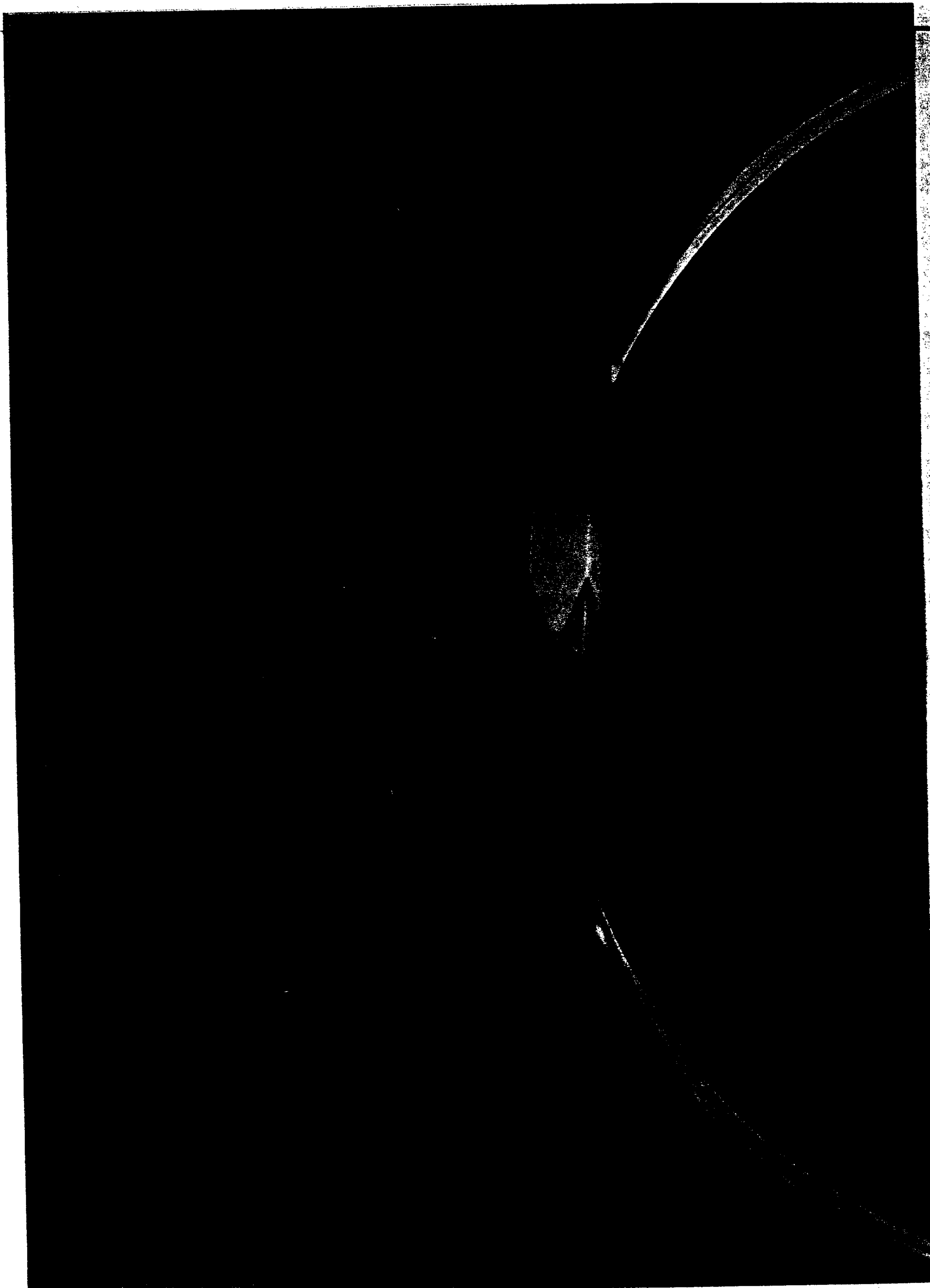
Side view of prototype GEO 600 test mass showing side view and silicate bonded attachments

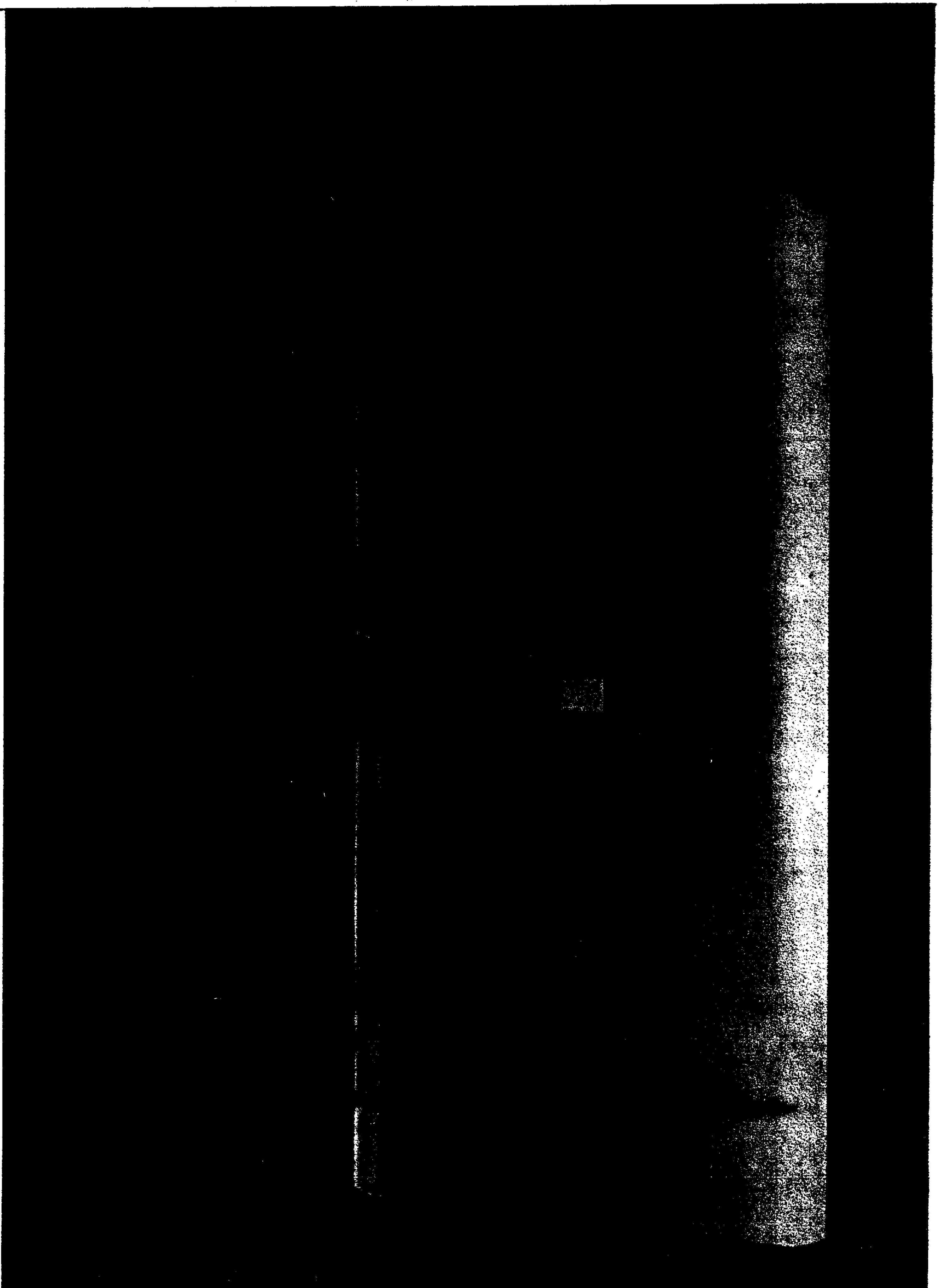


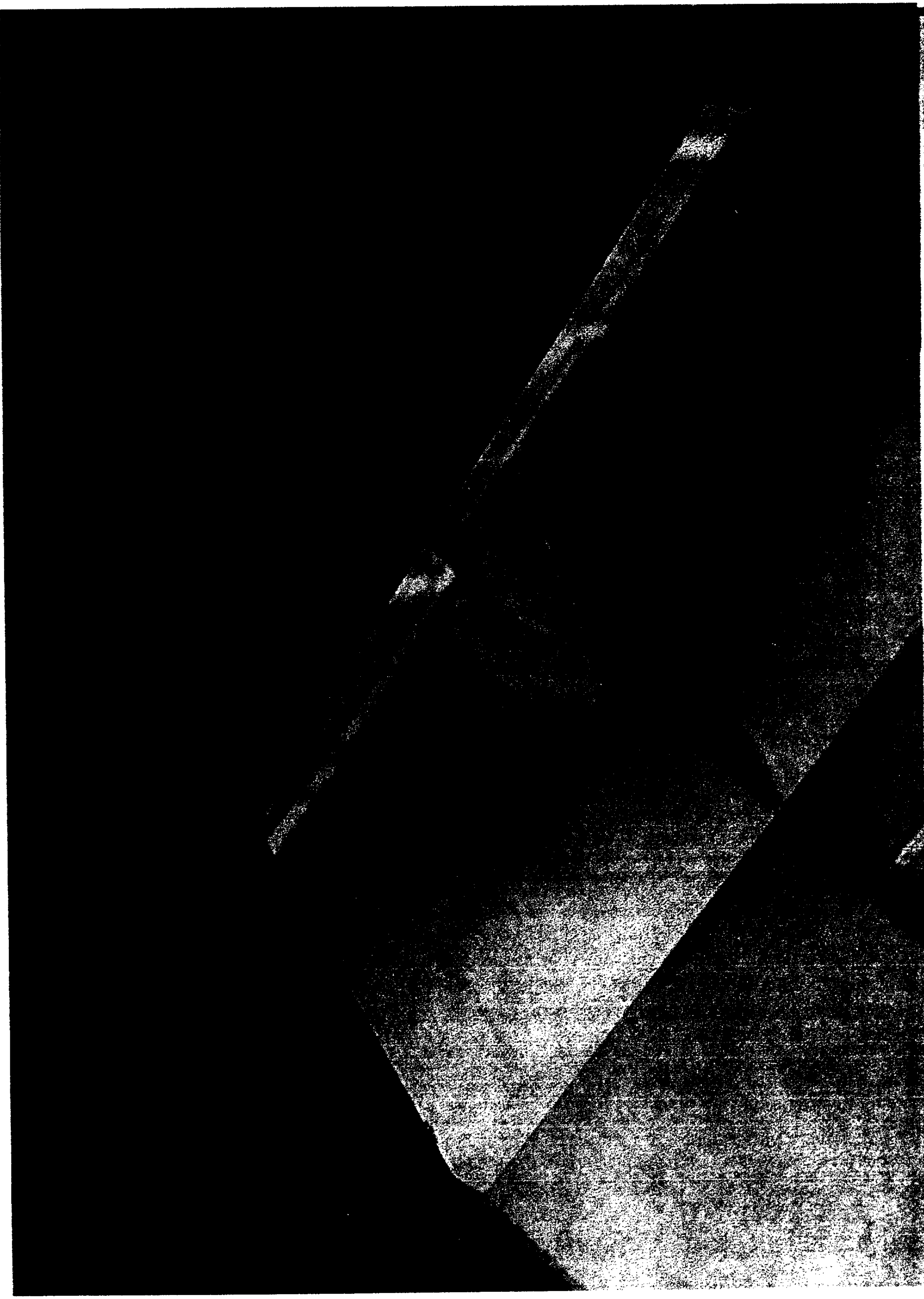
Side view of prototype GEO 600 test mass showing side view and silicate bonded attachments:

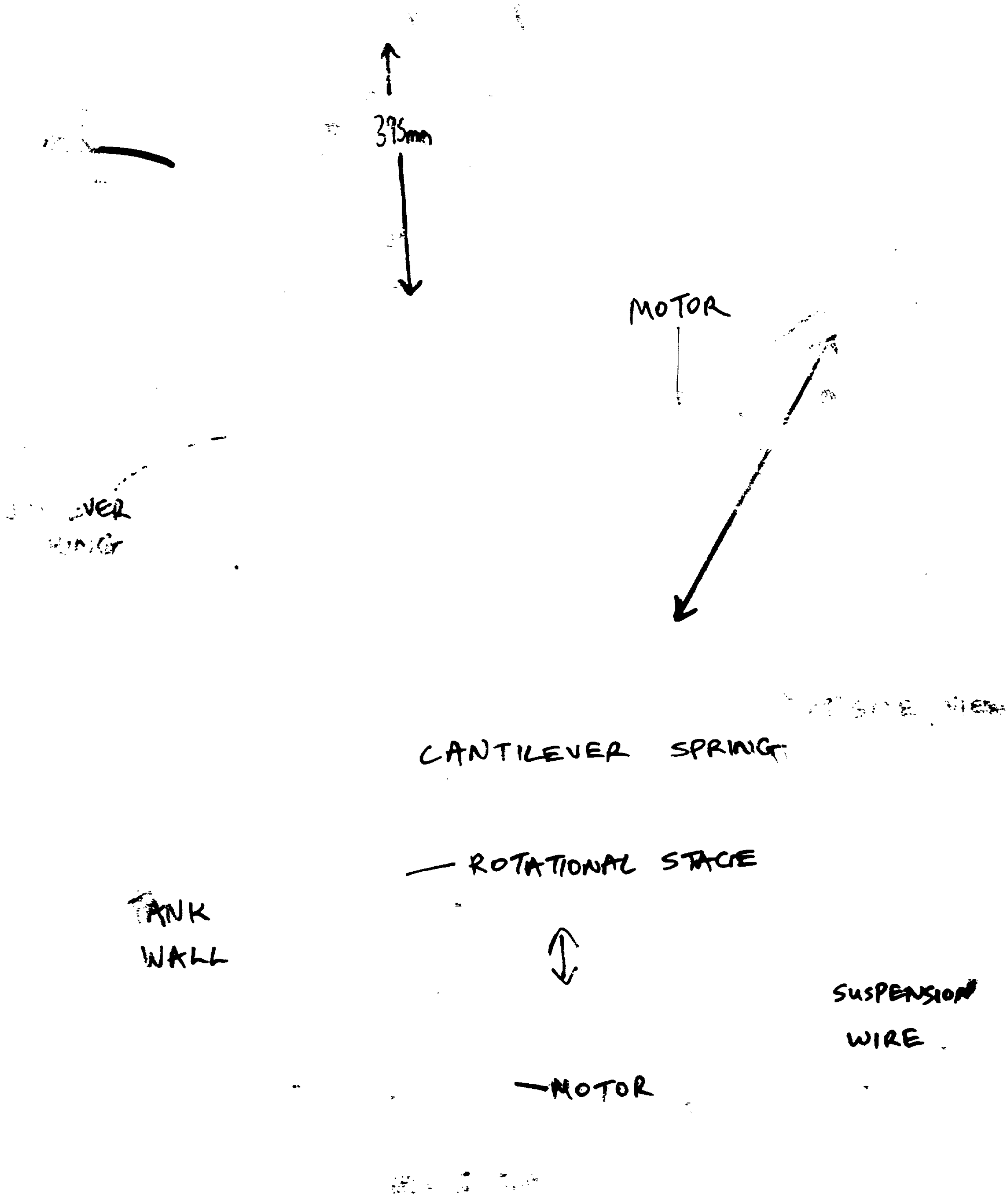
Intermediate mass





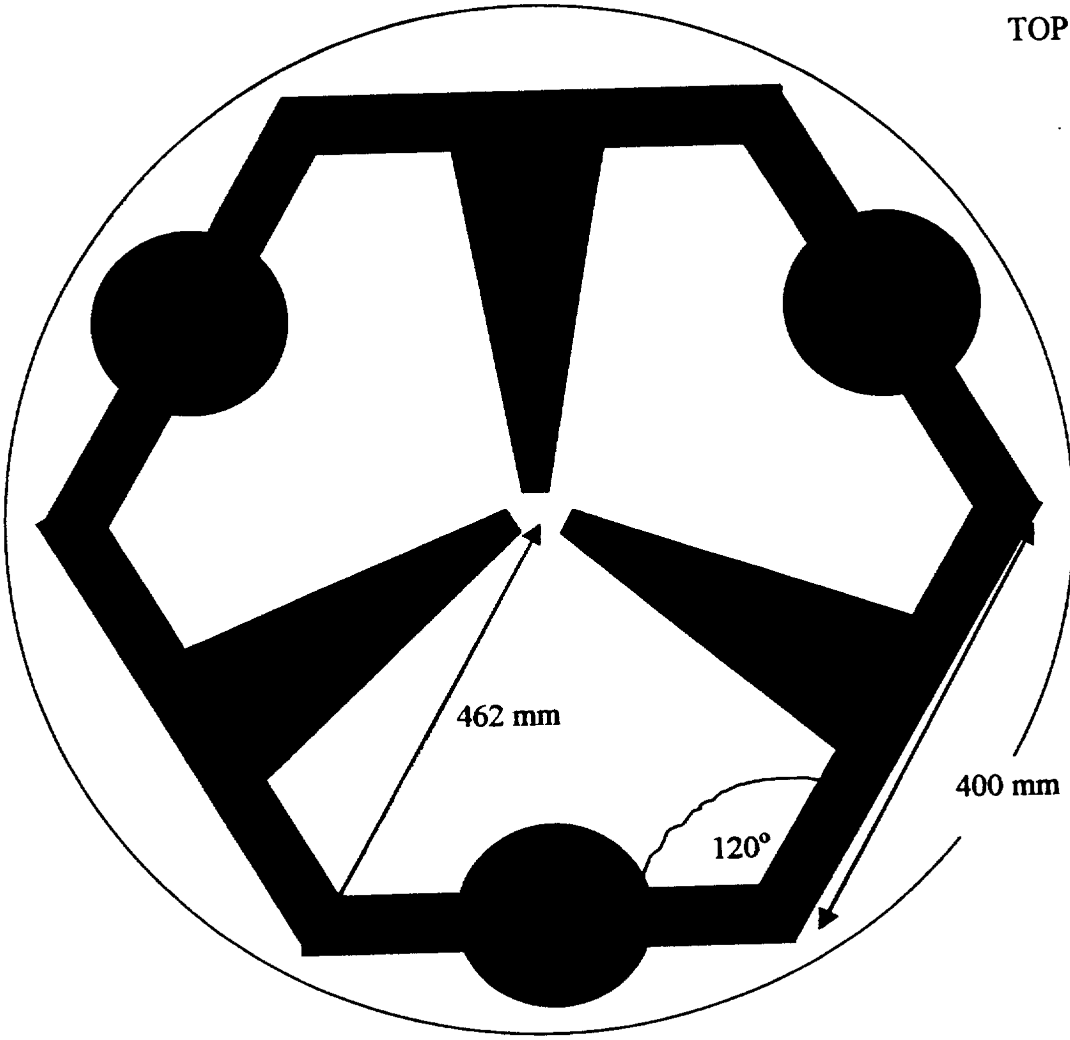


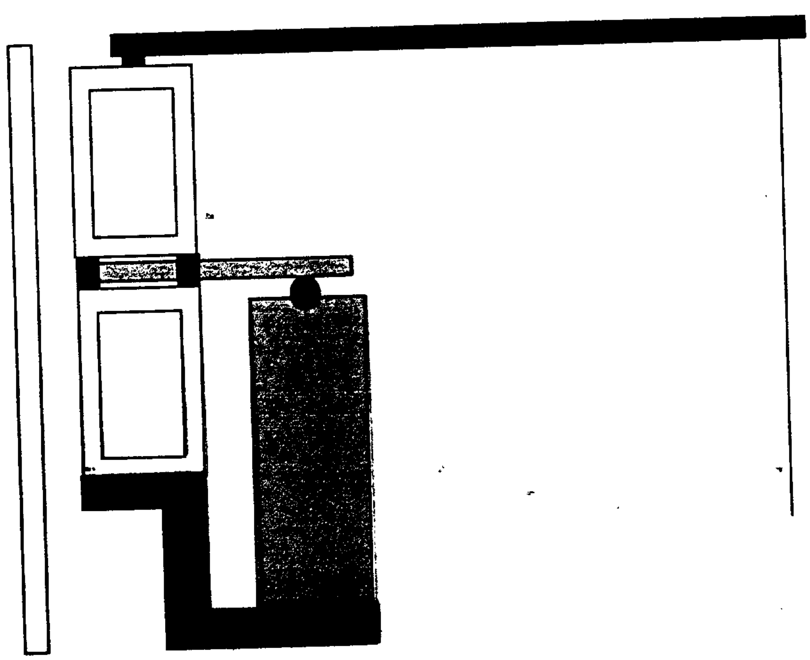



375mm
MOTOR
CANTILEVER SPRING
ROTATIONAL STAGE
TANK WALL
SUSPENSION WIRE
MOTOR

VIEWS of STACK STABILISER

TOP VIEW





OTHER ACTIVITIES

(M. PLISSI MAINLY)

1) MOTORISED & MANUAL ROTATION / TILT CONTROL OF MAIN SUSPENSIONS (TO WITHIN RANGE OF COIL - MAGNET ACTUATORS) (≈ m rad)

2) INTERFACING WITH (TRIPLE) PENDULUM (DOUBLE PENDULUM + EXTRA VERTICAL ISOLATION)

(UNCOUPLED) RESONANCES	ACTIVE*	PASSIVE
⟷ x, y	~45 Hz	~2 Hz
↕ z	~45 Hz	~12 Hz

* OPEN LOOP

AIMS OF ACTIVE STAGE.

1) SOME GAIN AT μ SEISMIC PEAKS (~ 10dB) (0.1 ~ 0.3 Hz)

2) SOME GAIN (AT ≈12 Hz ETC.) TO REDUCE TEST MASS VELOCITY AT SYSTEM RESONANCES. (~1 Hz TO 12 Hz)

3) GAIN AT 25 ~ >50 Hz FOR IMPROVED SENSITIVITY AT 50 Hz ~ 100 Hz (UP CONVERSION?)

4) INPUT FOR 1 Hz HORIZONTAL GEOPHONES FOR IMPROVED ISOLATION AT ~0.1 → 0.5 Hz (+10 dB)

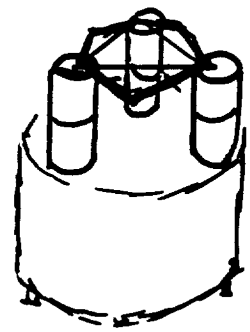
GEO 600 MAIN SUSPENSION

K STRAIN
12/3/98
+ M. PLISSI + C. TORRIE

①

ISOLATION STACKS

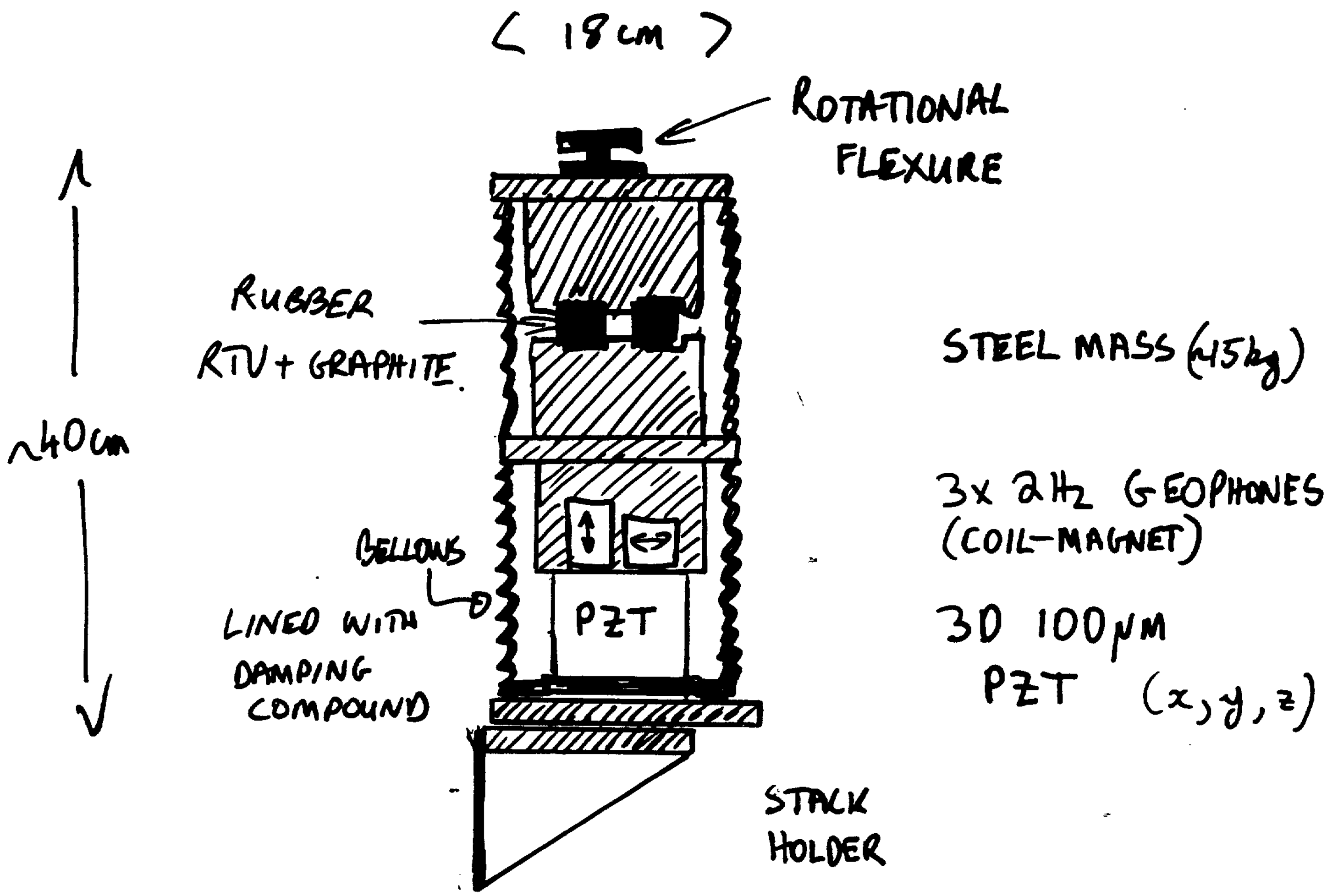
3 LEGS / TANK



ACTIVE + PASSIVE

↑ PZT + GEOPHONE

↑ RTV RUBBER (+ DAMPING)



SKETCH OF STACK LEG.

Note 1, Linda Turner, 04/20/98 05:16:34 PM
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