Cylinders in Vs

An optomechanical methodology

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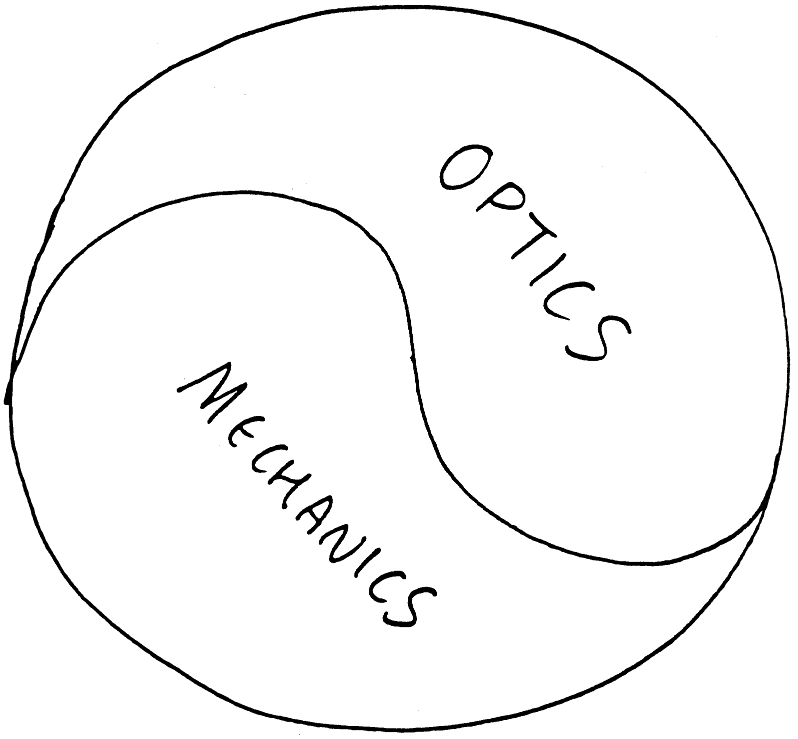


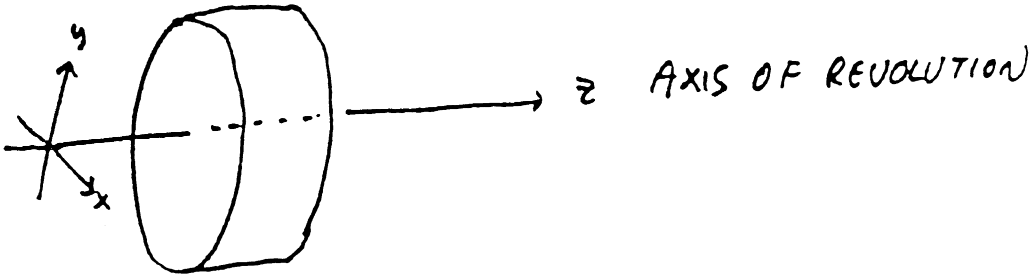
AN OPTICAL SYSTEM IS A MECHANICAL SYSTEM SOME OF WHOSE PARTS TRANSMIT OR REFLECT LIGHT.

MECHANICAL TECHNIQUES CAN/SHOULD BE USED WITH OPTICS

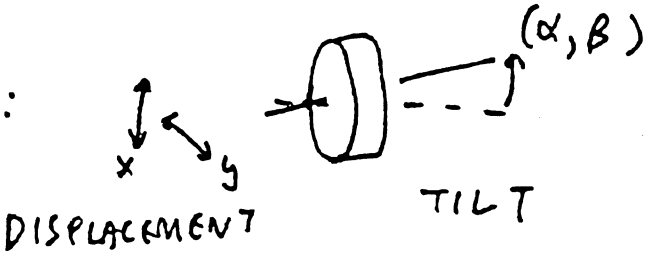
OPTICAL TECHNIQUES CAN/SHOULD BE USED WITH MECHANICS

OPTICAL ENGINEERS SHOULD BE PRACTITIONERS OF BOTH

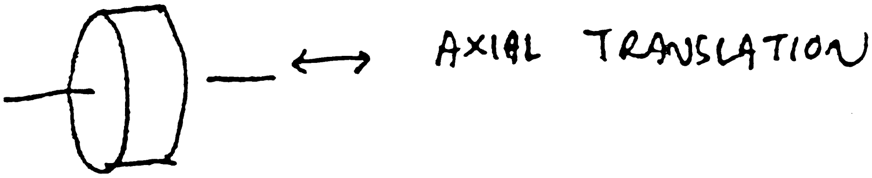
ROTATIONALLY SYMMETRIC OPTICS



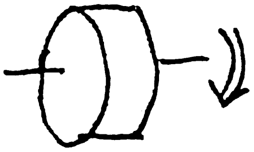
CRITICAL:



LESS CRITICAL AND/OR REQUIRING ADJUSTMENT AND/OR REQUIRING MOTION (FOR FOCUS, MAGNIFICATION CHANGE, ETC)

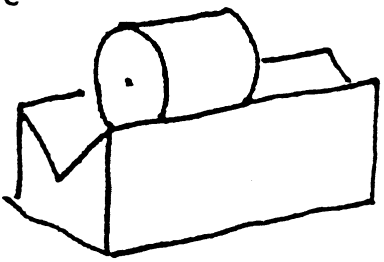


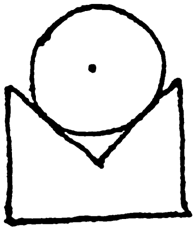
IRRELEVANT



OR ADJUSTABLE TO MINIMIZE RESIDUAL ASYMMETRIES

THESE PROPERTIES ARE OBTAINED WITH A CYLINDER IN A V





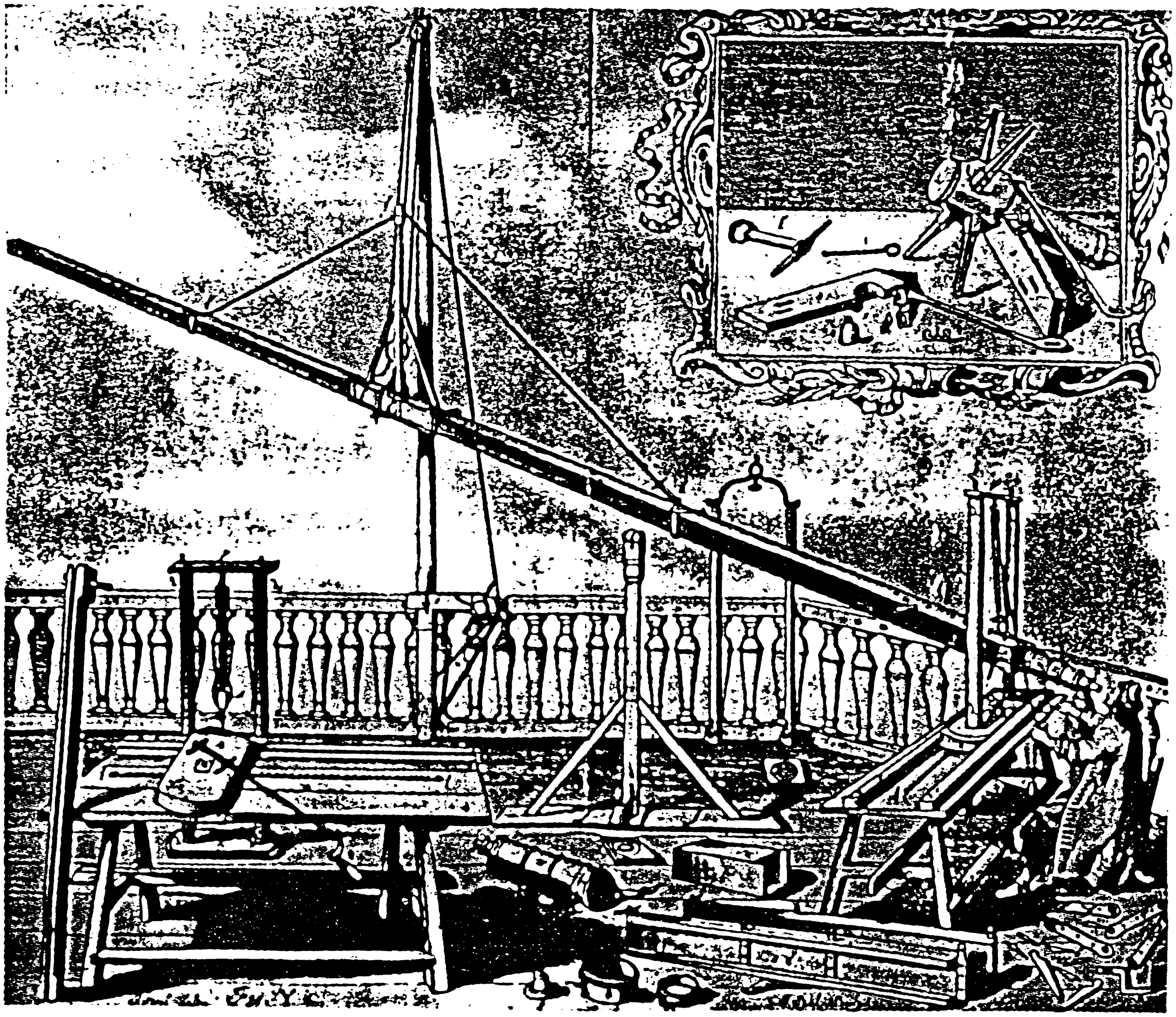


Fig. 23—Hevelius with a long telescope

(Science Museum, London. British Crown copyright)

Upon hearing of Huygens' discoveries, Hevelius planned several new telescopes. He had himself studied the problem of Saturn's appearance, and the Dutchman's work convinced him of the superiority of long-focus object-glasses. The outcome was that he made telescopes of 60 and 70 feet focus and, finally, one of 150 feet, all of which he described in his *Machinae Coelestis*.[10] The lenses for the 150-foot were made by a local glassworker ' expert in all kinds of mechanical as well as optical studies ',[11] and occasioned less trouble than the mounting. For this, Hevelius used wood. A paper tube, although light, would have been too flimsy and fragile, an iron tube too heavy and costly. The tube was sectional, each section consisting of two 40-foot wooden planks fixed at right angles to each other.[12] Three or four of these sections, joined end to end, made a two-sided trough; at the further end was the objective cell, at the other, the eyepiece. This arrangement, braced by wire stays, answered for night use but, during twilight or moonlight, the eyepiece had to be shielded from stray light. Hevelius, therefore, fixed wooden apertures or ' stops ' at intervals along the tube.[13] These not only assisted in its re-alignment but added to the rigidity of each section. The entire apparatus was suspended from a mast 90 feet high[14] and was operated from below by means of ropes and pulleys.

KING "THE HISTORY OF THE TELESCOPE"

parallel to one another. They may be attached to the board by plasticene, red wax, or sealing-wax, or they may be drilled and screwed on. Two such boards may be built up in one line or making an angle with one another. They can be temporarily attached to the table with small lumps of plasticene under their corners.

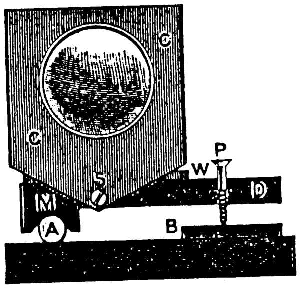


FIG. 58.—End view of Home-made Bench.

Temporary lens stands can be made of wood as shown in Figs. 57 and 58 A small piece of wood D has two blocks M, N glued on, which have a V cut in them to slide on the rod A of the bench (Fig. 58). A screw P is put through the other end, which will rest on the glass B. The lens is either inserted in a turned recess in C and held in place by a spring of brass wire, which fits in the recess, or it may be simply attached with a few pellets of plasticene round its edge. The screw P enables the lens to be raised or lowered, and rotating C on the screw S moves the lens transversely across the bench. Thus it can be centred. A weight W of sheet lead is necessary to keep the stand from tipping over. The heavier the lens stand is the steadier it is; thus stands of similar design in cast-iron are much to be preferred to wooden ones. They need not be filed up. P and S can be two set screws; the feet will of course be cast on; a washer can be put between C and D to allow C to turn smoothly; C may be made of wood.

39. For my own experimental work I have found a piece of angle brass, supported horizontally at a convenient height on a kind of heavy retort stand, with the V upwards, very convenient. The lenses must be mounted in short lengths of brass tube ("telescope tube"), which must all be of the same diameter. They will then always be coaxial. I use tubes of two sizes, the one sliding in the other; the lens is ground to such a size that it just fits in the outer tube and shoulders against the inner tube; the lens is held in, either by a wire spring ring, which goes tightly into the outer tube, or by another very short length of the inner tube. Any number of lenses can be put up in a row, and will at once be coaxial, and have their planes normal to their common axis. They can be slid to and fro, or lifted off, or put back instantly. In this way experimental microscopes, telescopes, etc., can be set up in a few minutes, or the best arrangement of lenses for any particular purpose can be easily tried. Stops can, of course, also

be mounted in the same way, in the same or similar tubes. A two-foot length of one-inch angle brass, and tubes $1\frac{1}{8}''$ diameter, 1", 2", and 4" long, are convenient sizes for most purposes. I have also found $\frac{1}{2}''$ angle brass and $\frac{5}{8}''$ tubes very good.

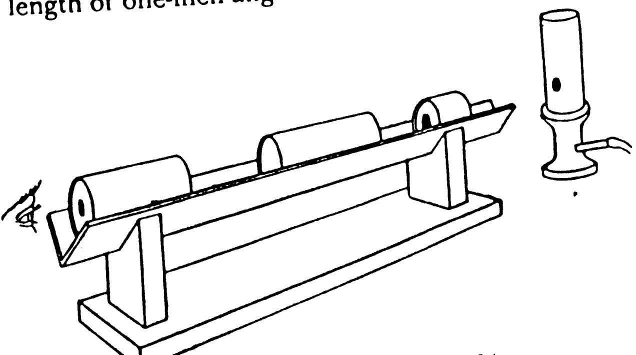


FIG. 59.—V Bench for Lenses of Uniform Diameter.

Rule of Signs.

40. In all formulæ, measurements from the surface of the lens or mirror towards the light will be considered positive, those from the surface away from the light, negative. To apply this, imagine yourself standing at the surface where reflection or refraction is occurring, and turn so that the incident light falls upon your face. If by walking forwards from the surface, you come to any point, the distance of that point from the surface is to be considered positive. But if to reach a point it is necessary to turn round and walk in the other direction, that distance is to be reckoned negative.

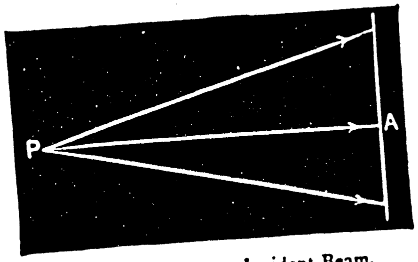


FIG. 60.—Divergent Incident Beam.

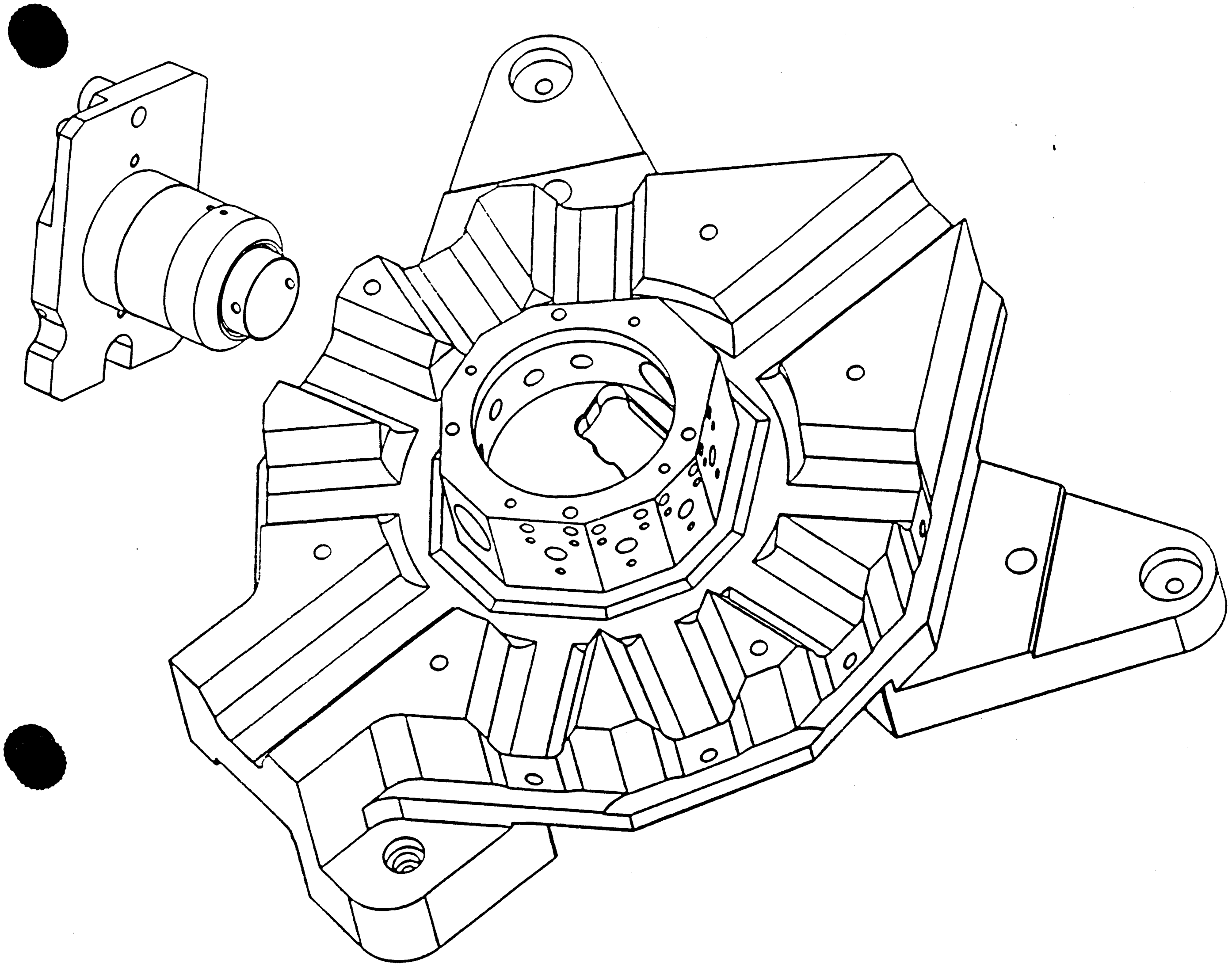
EXAMPLES.[1]

i. A divergent beam falling on a lens or mirror (Fig. 60). Suppose A to be the surface of the mirror and P the bright point. Applying the above rule, we see that the distance AP is positive.

ii. A convergent beam falling on a mirror or lens (Fig. 61). If a beam travel in the direction BQ and fall upon the surface A,

CLAY 1911

HOW THIS STARTED



"Cylinders in Vs—An Optomechanical Methodology," Douglas S. Goodman, SPIE Proceedings 3132 *Optomechanical Design and Precision Instruments*, Santa Diego, CA, July, 1997

"More Cylinders in Vs," Douglas S. Goodman, SPIE Proceedings 4198, *Optomechanical Engineering*, Boston, MA, November, 2000

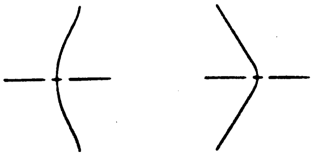
"Multi-Laser Print Head," Douglas S. Goodman, Jeffrey W. Robleee, William T. Plummer, Peter P. Clark, SPIE Proceedings 3430, *Novel Optical Systems*, Santa Diego, CA, July, 1998

"High Brightness Multi-Laser Source," Douglas S. Goodman, Wayne L. Gordon, Richard Jollay, Jeffrey W. Roblee, Paul Gavrilovic, Dmitri Kuksenkov, Anish Goyal, Qinxin Zu, SPIE Proceedings 3626A, San Jose, January, 1999

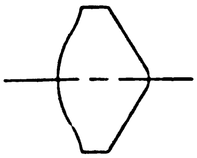
"Description and Applications of High Brightness Multi-Laser-Diode System," Raj Singh, Aland K. Chin, Qinxin Zu, Fred Dabkowski, Richard Jollay, Douglas Bull, Joseph Fanelli, Douglas S. Goodman, , Jeffrey W. Roblee, William T. Plummer, SPIE Proceedings 3945A (LASE 2000), San Jose, January, 2000

ROTATIONAL SYMMETRY

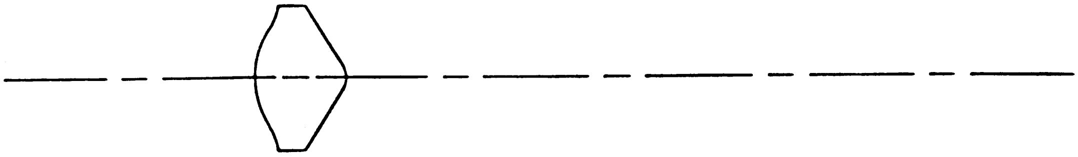
TWO SURFACES OF REVOLUTION



SINGLET WITH SURFACE AXES COLLINEAR



"CENTERING"

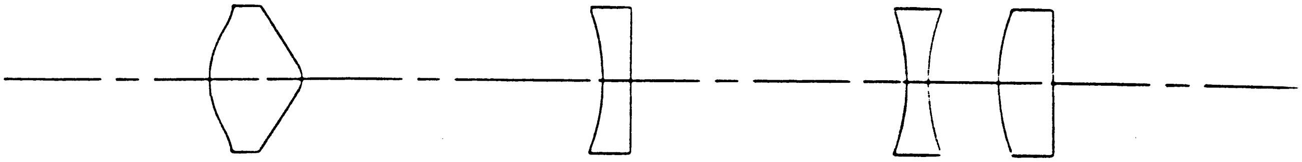


THE AXIS OF AN ELEMENT IS BROUGHT INTO
COINCIDENCE WITH A DESIGNATED SYSTEM AXIS.

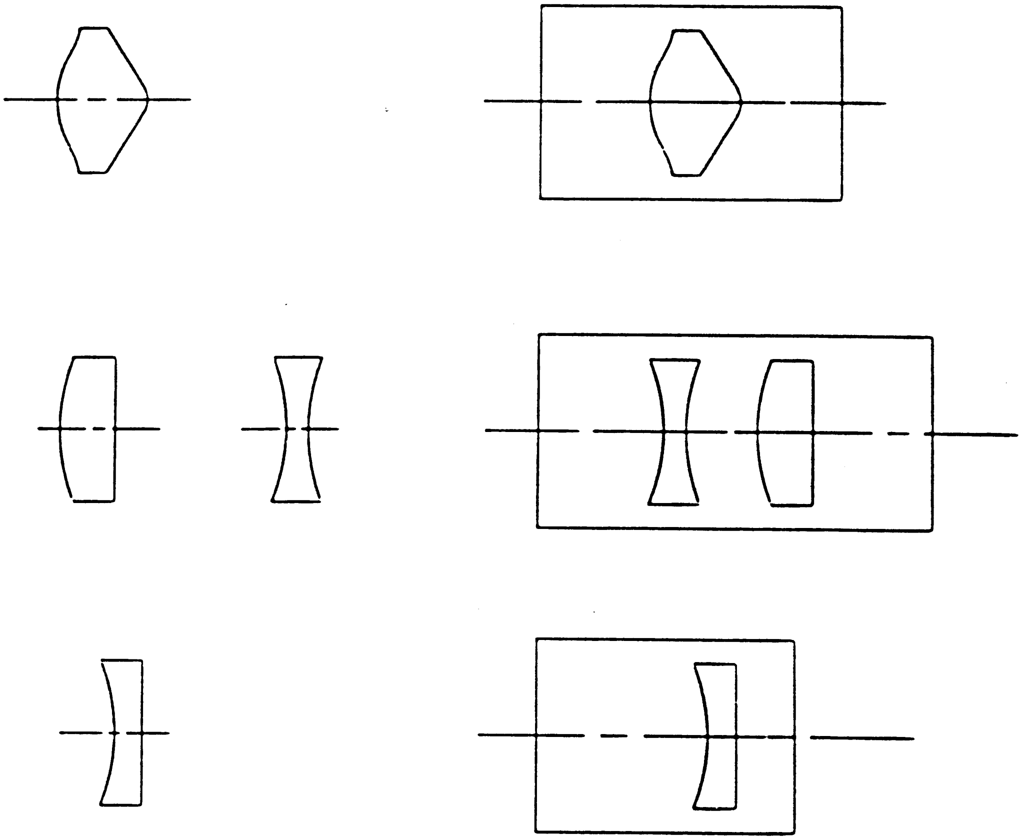
THIS REQUIRES FOUR DEGREES OF FREEDOM.
TWO DOF REMAIN:
- AXIAL POSITION
- ROTATION ABOUT THE AXIS

THE BASIC IDEA

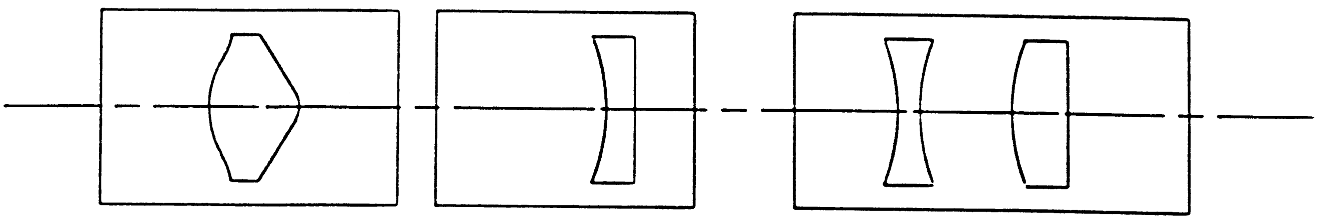
THE DESIRED SYSTEM

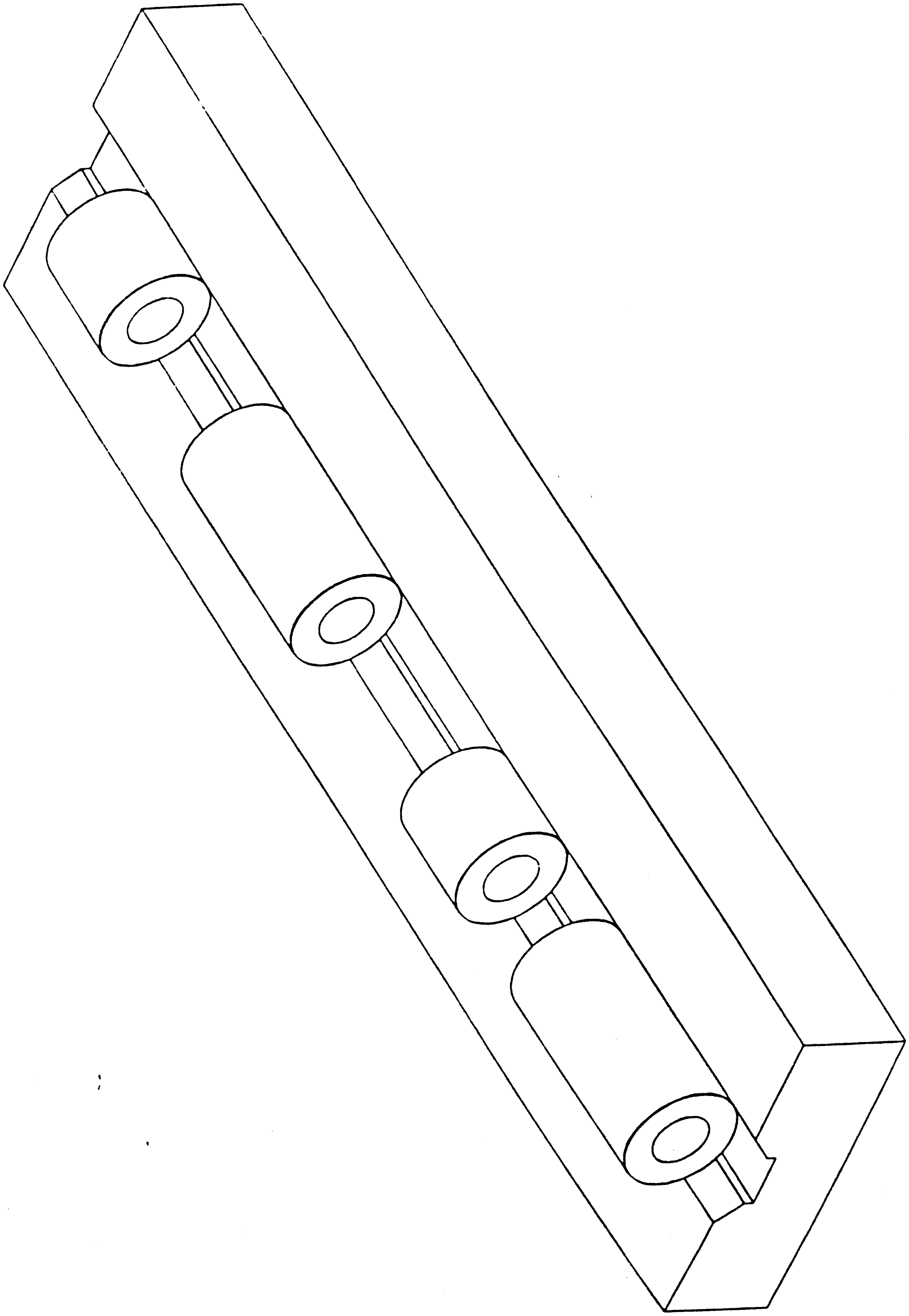


LENSES CENTERED IN CYLINDERS

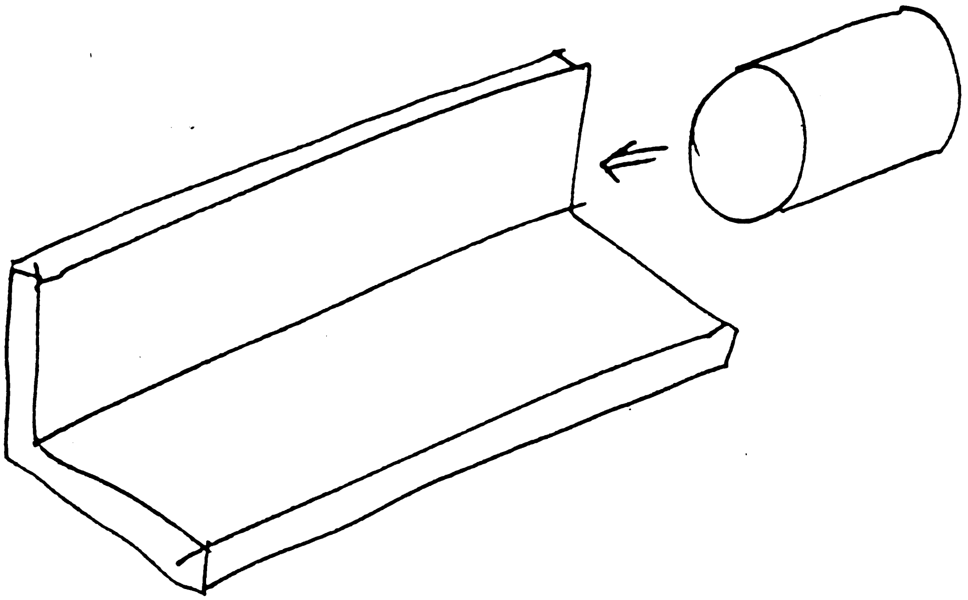


CYLINDERS CENTERED IN A V





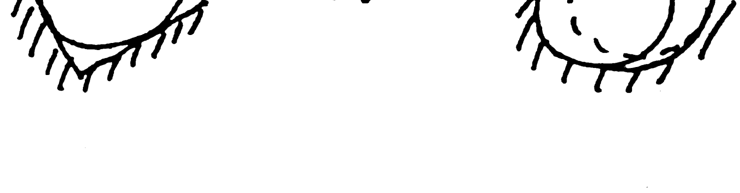
CYLINDERS IN A V



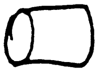
- NO LATERAL DISPLACEMENTS OR TILTS
- ROTATION CAN OCCUR
- AXIAL POSITION ADJUSTABLE

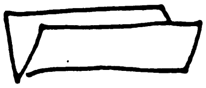
EXACTLY WHAT THE OPTICS LIKES

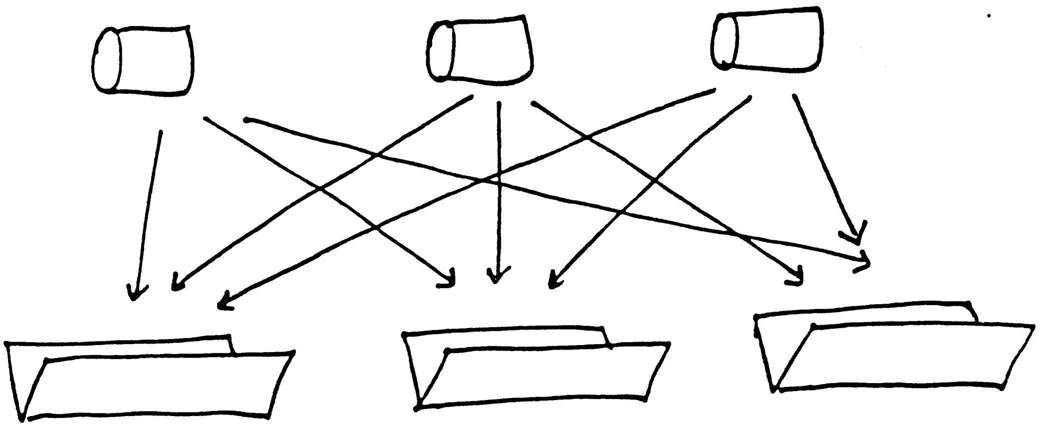
REPEATABLE POSITIONING



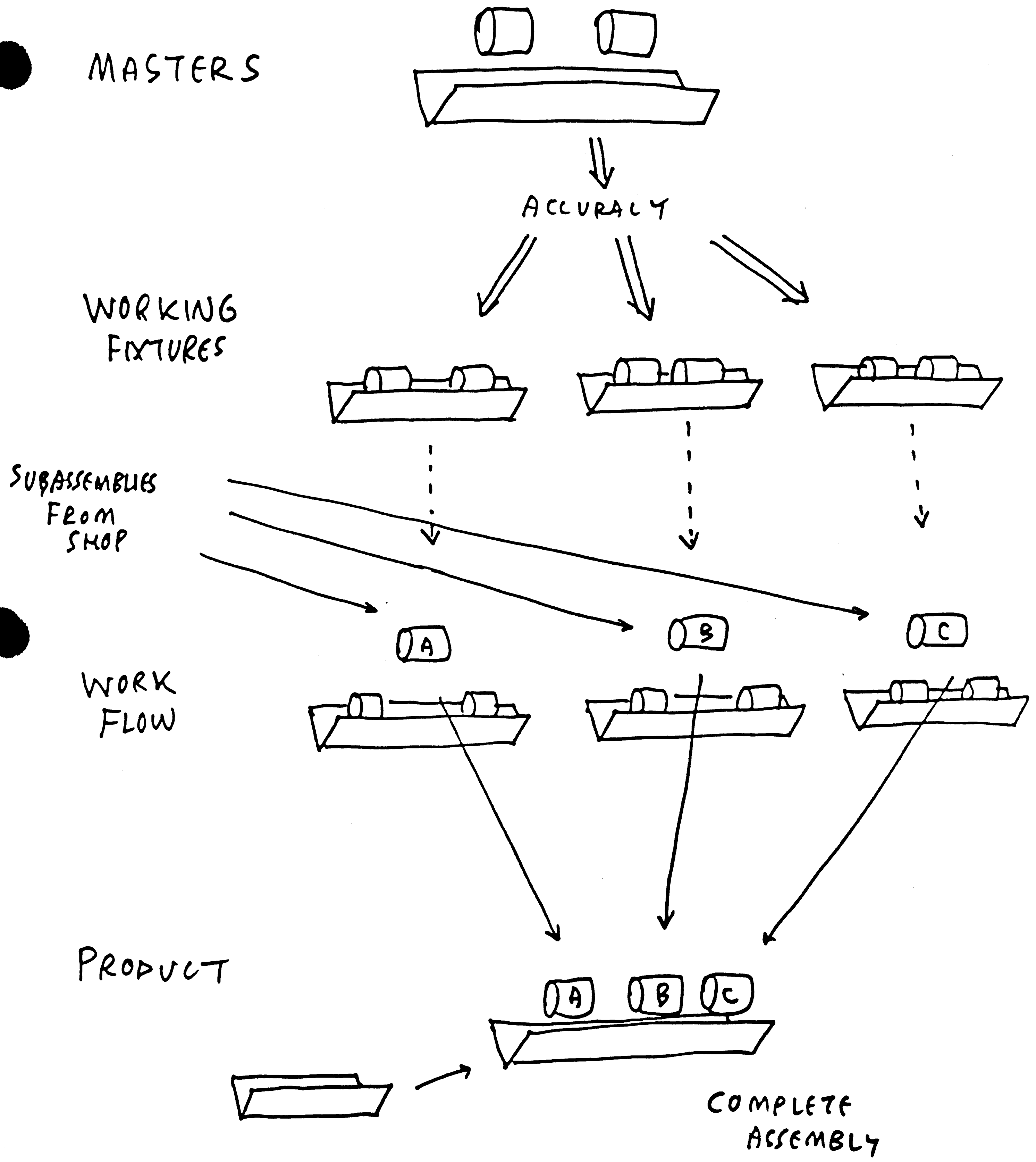
INTERCHANGEABILITY
OF
PERFECT CYLINDERS IN PERFECT Vs

ALL  ARE IDENTICAL* SAME DIAMETER

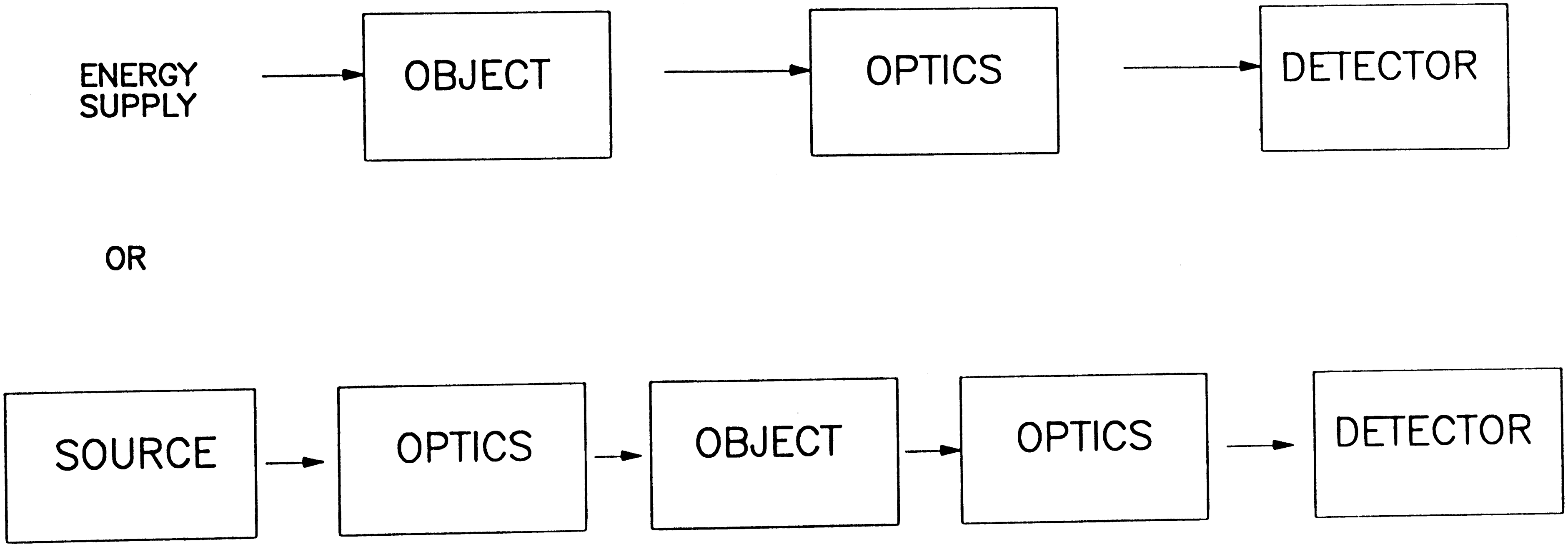
ALL  ARE IDENTICAL*



* IF PERFECT


MASTERS
ACCURACY
WORKING FIXTURES
SUBASSEMBLIES FROM SHOP
A
B
C
WORK FLOW
PRODUCT
A
B
C
COMPLETE ASSEMBLY

MOST OPTICAL INSTRUMENTS

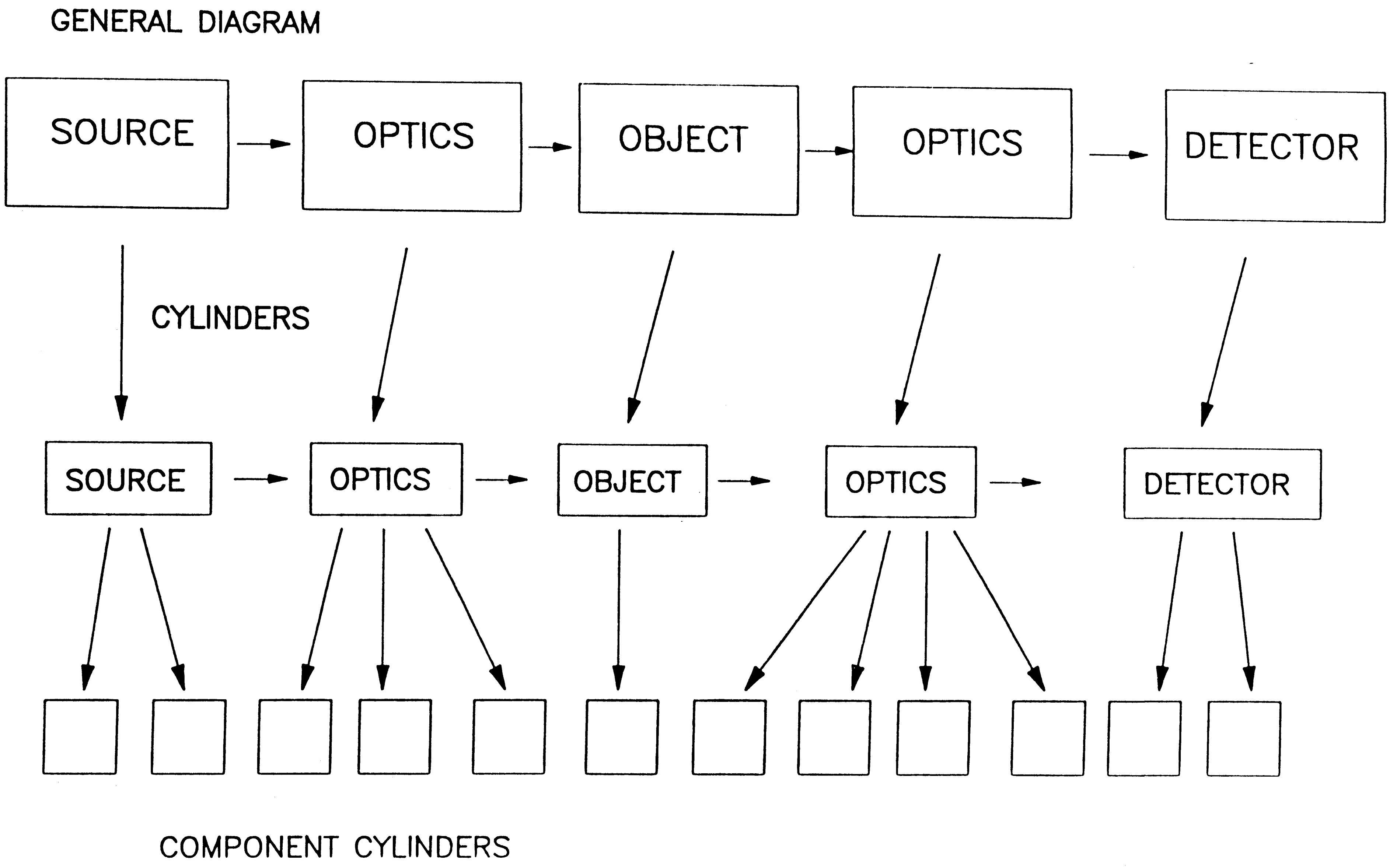


ENERGY SUPPLY → OBJECT → OPTICS → DETECTOR

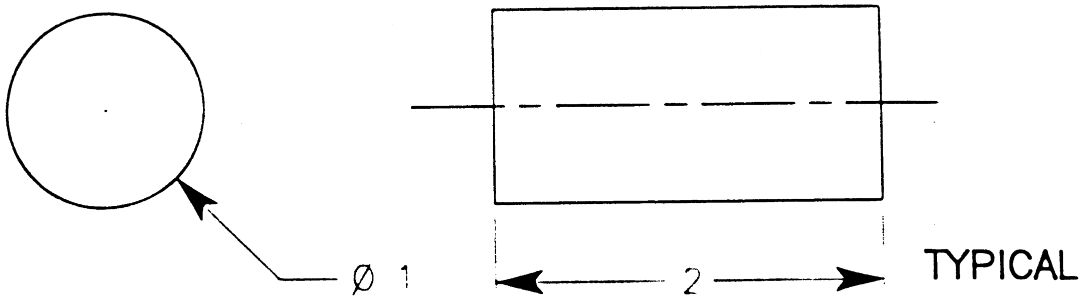
OR

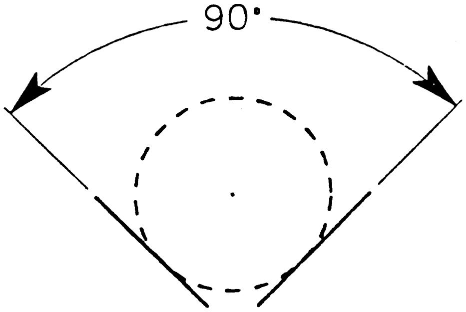
SOURCE → OPTICS → OBJECT → OPTICS → DETECTOR

CYLINDER–IN–V APPROACH

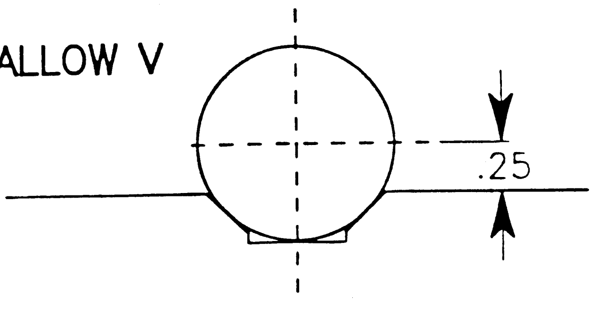


ONE INCH DIAMETER CYLINDER

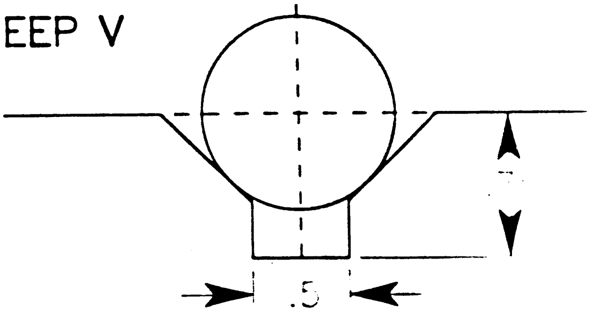


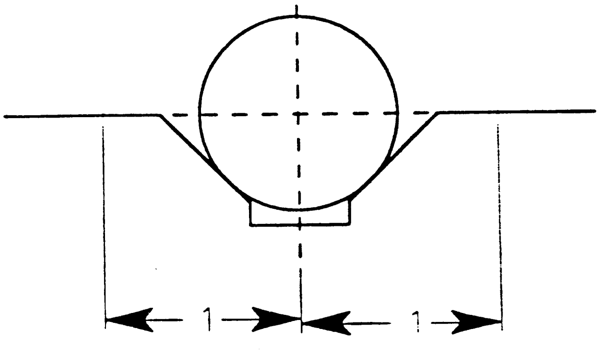


SHALLOW V



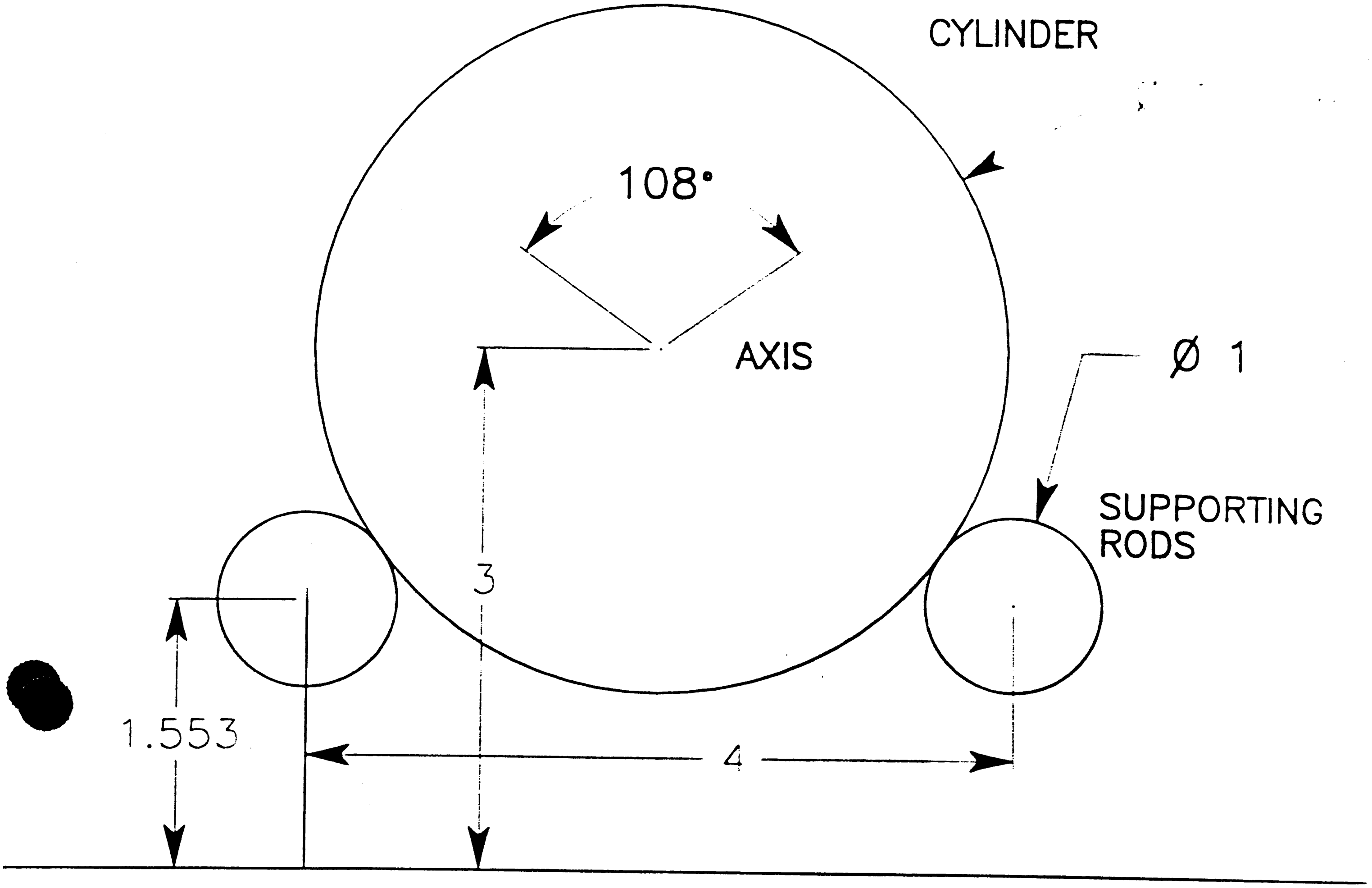
DEEP V

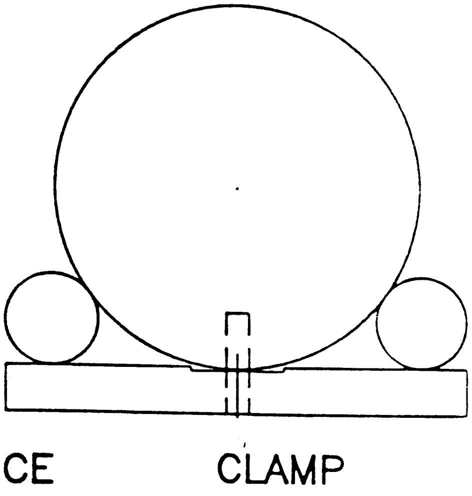




ROWS OF 1/4-20 HOLES

100 MM CYLINDER





100 mm IS A LITTLE LESS THAN 4'''
STOCK CAN BE MACHINED QUICKLY.

THOMPSON RODS 1" DIAMETER

RODS SEPARATED BY 4"

CENTER LINE 3" ABOVE TABLE TOP

V ANGLE IS A CONSEQUENCE OF OTHER CHOICE

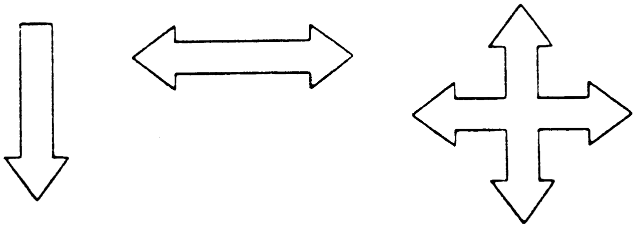
AS MANY EVEN NUMBERS AS POSSIBLE

DRAWING CONVENTIONS

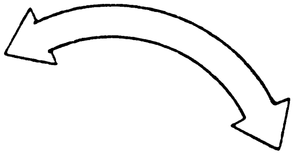
LIGHT RAYS

POINTERS

TRANSLATION

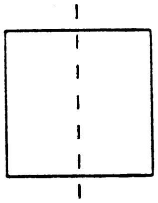


ROTATION

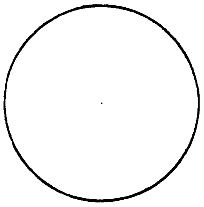


AXIS × AND

OPTICAL SYMMETRY PLANE



CYLINDER END VIEW

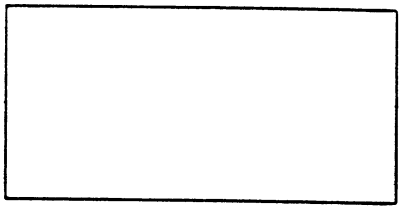


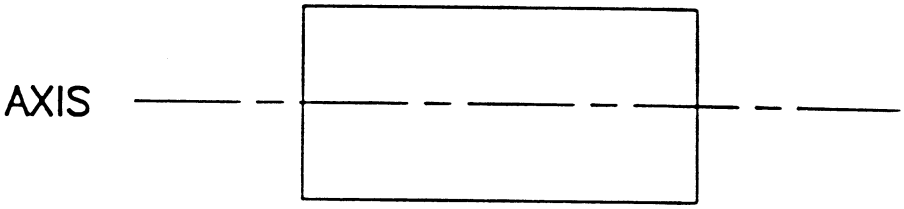
USUALLY, NO OPTICAL
ELEMENT IS SHOWN

CYLINDER SIDE OR TOP VIEW

TOP, SIDE AMBIGUITY

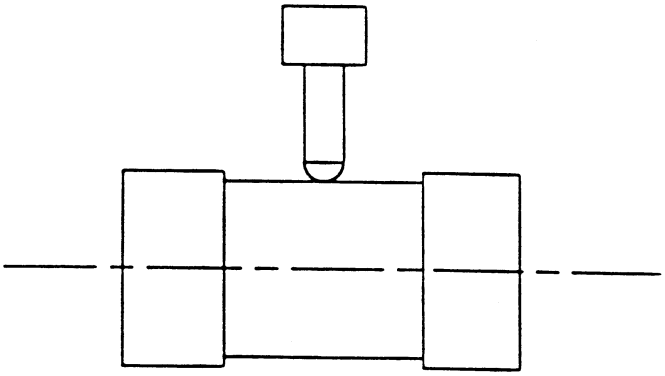
PLAIN CYLINDERS USUALLY DRAWN



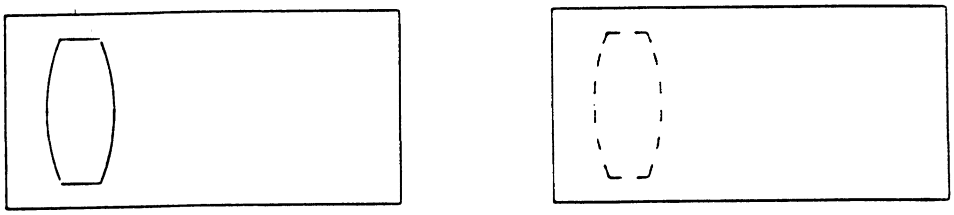


NO DISTINCTION IS MADE BETWEEN THE CYLINDER AXIS
AND THE V AXIS UNLESS THEY ARE DIFFERENT.

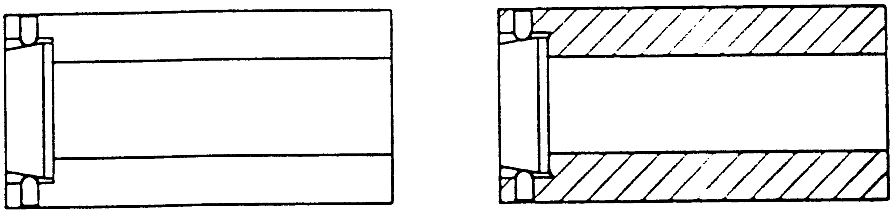
A CYLINDER HELD IN
POSITION IN A V



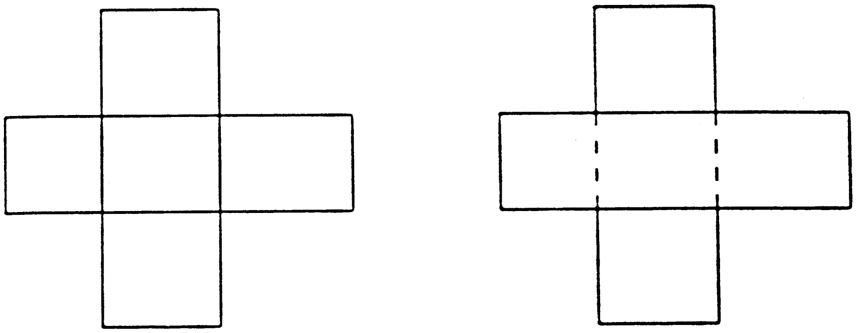
SCHEMATIC FOR A LENS MOUNTED INSIDE A CYLINDER



SECTIONS MAY BE PLAIN OR CROSS HATCHED.



HIDDEN LINES ARE SOMETIMES DASHED, SOMETIMES SOLID.



VS

GENERAL DEFINITION

PLANAR VS
90° AND 60°

MONOLITHIC VS

FABRICATED VS

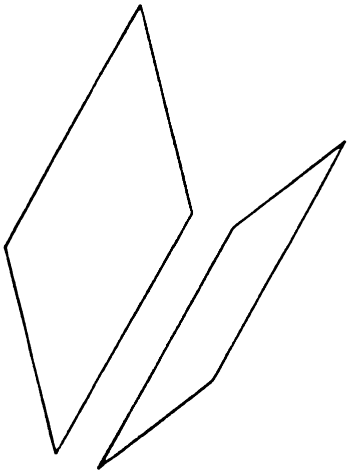
MIXED VS

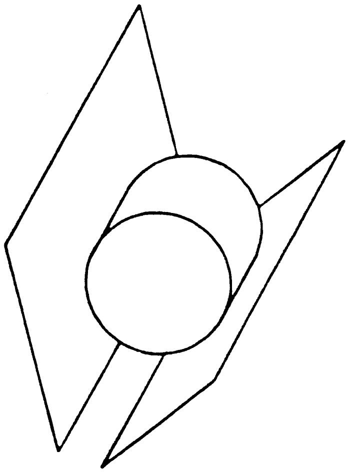
AUXILIARY PARALLEL STRUCTURES

STRAIGHTNESS TESTING

THE PLANAR V

ANY TWO NON–PARALLEL PLANES MAKE A V

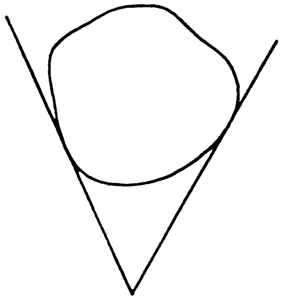


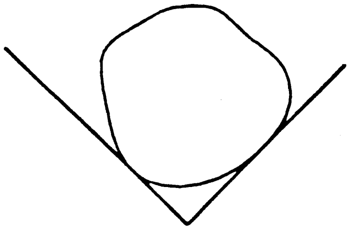


THE V IS STRAIGHT IF THE CONTACT SURFACES ARE FLAT.

FOR STRAIGHTNESS, THE TWO SIDES CAN BE FABRICATED AND MEASURED SEPARATELY.

THE ANGLE IS NOT CRITICAL FOR A SINGLE V.
IT ONLY MATTERS IF IMPERFECT SYLINDERS ARE SWITCHED BETWEEN DIFFERENT VS.





VS

GENERAL DEFINITION

PLANAR VS
 90° AND 60° VS

MONOLITHIC VS

FABRICATED VS

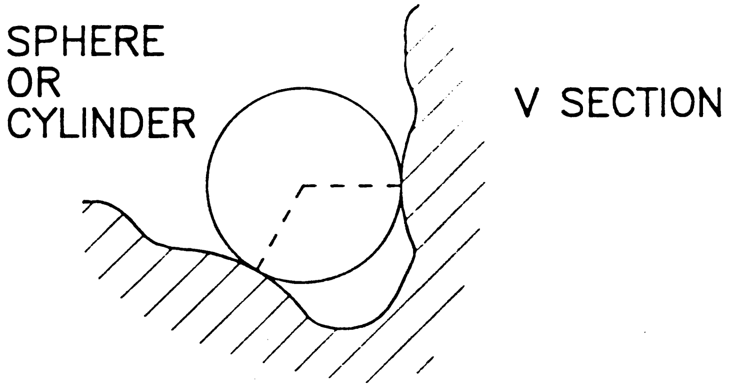
MIXED VS

AUXILIARY PARALLEL STRUCTURES

STRAIGHTNESS, QUALITY

TESTING

GENERAL DEFINITION OF A V FOR A ROUND CYLINDER



A SHAPE THAT A SPHERE CAN ROLL WITHIN WITH TWO CONTACT POINTS SO THAT THE SPHERE'S CENTER MAKES A STRAIGHT LINE

A SHAPE WITH WHICH A ROUND CYLINDER MAKES CONTACT ON TWO PARALLEL LINES

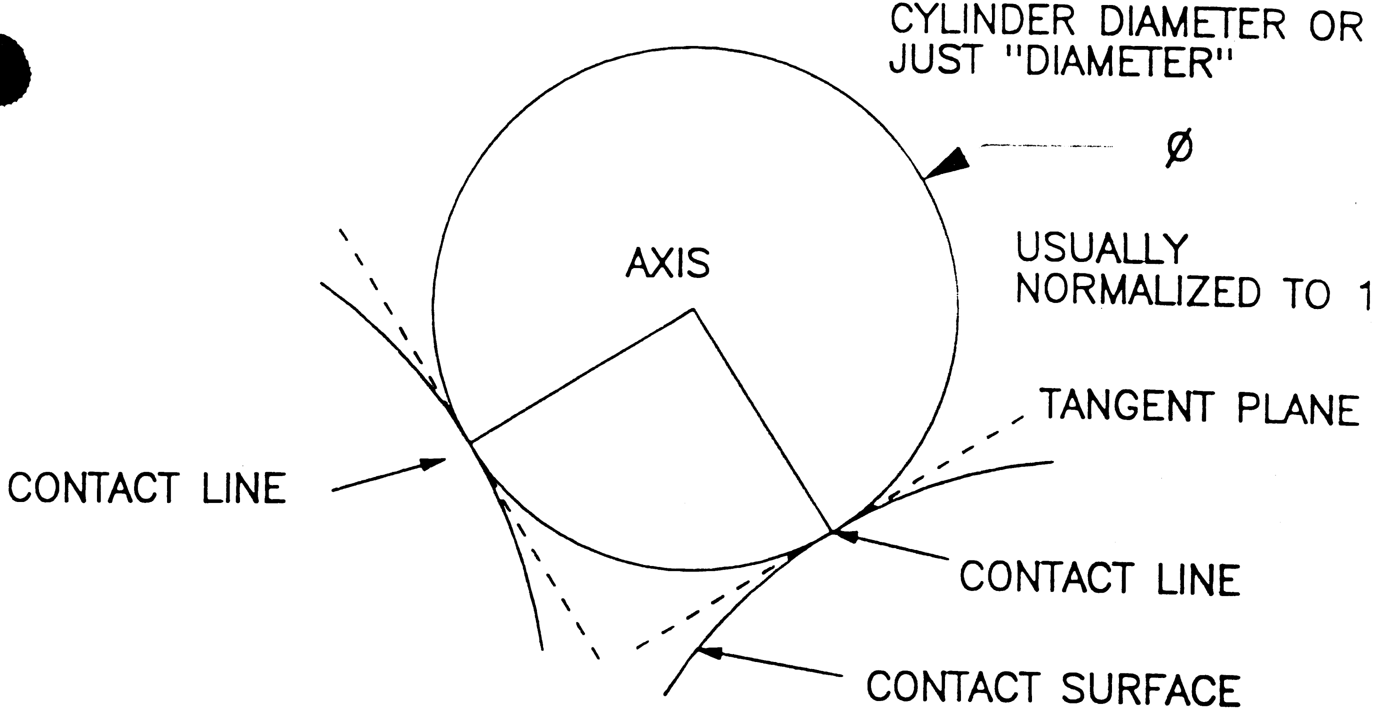
A "FIGURE OF EXTRUSION"

ONE DICTIONARY DEFINITION OF CYLINDER:
"THE SURFACE TRACED BY ANY STRAIGHT LINE . . .
MOVING PARALLEL TO A FIXED STRAIGHT LINE."

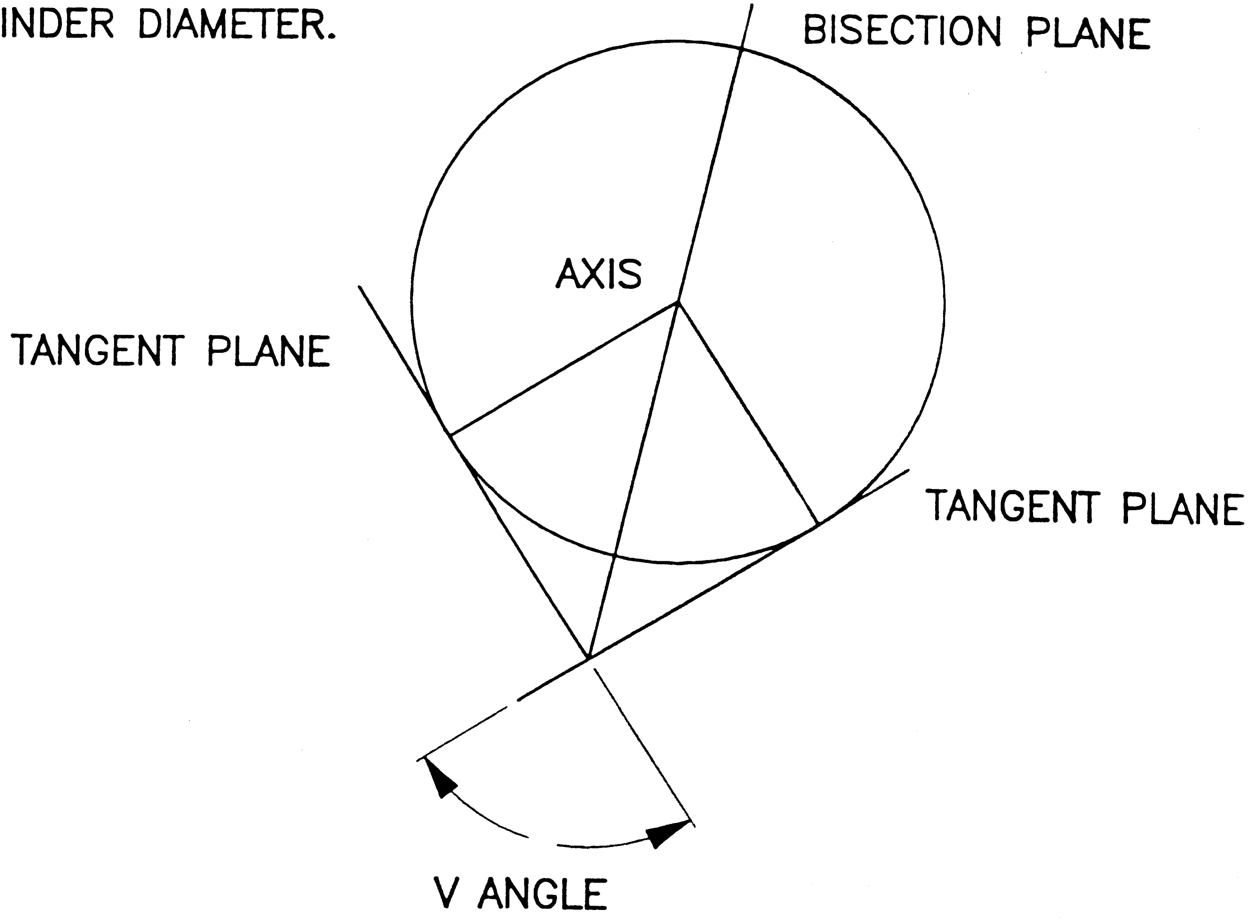
A SHAPE IN WHICH A ROUND CYLINDER CAN TRANSLATE AND ROTATE AXIALLY

PROVIDES FOUR CONSTRAINTS TO A "DUMBELL" SHAPE, LEAVING THE DEGREES OF FREEDOM OF AXIAL ROTATION AND TRANSLATION

DEFINITIONS

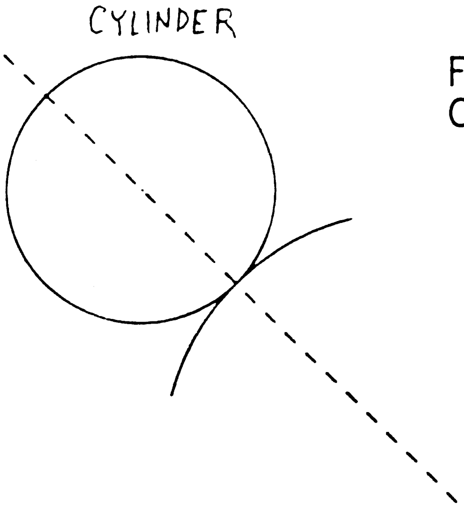


CONTACT LINES VARY WITH CYLINDER DIAMETER.



CONTACT SURFACE CURVATURE

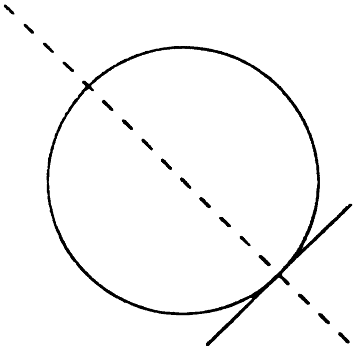
CONVEX



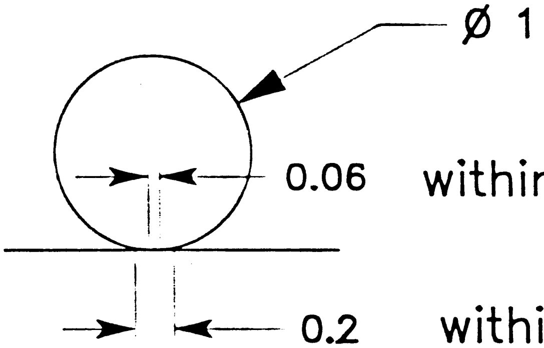
FOR EXAMPLE,
OBTAINED WITH RODS

LEAST CONTACT AREA,
MOST KINEMATIC

PLANAR



PROXIMITY OF PLANE TO
CYLINDER

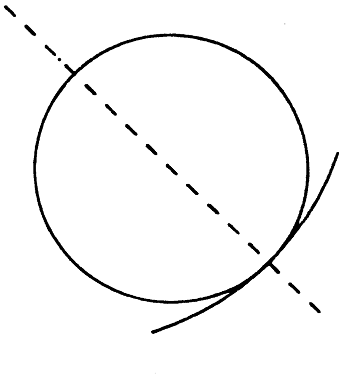


within 0.001

within 0.010

BEWARE OF DUST

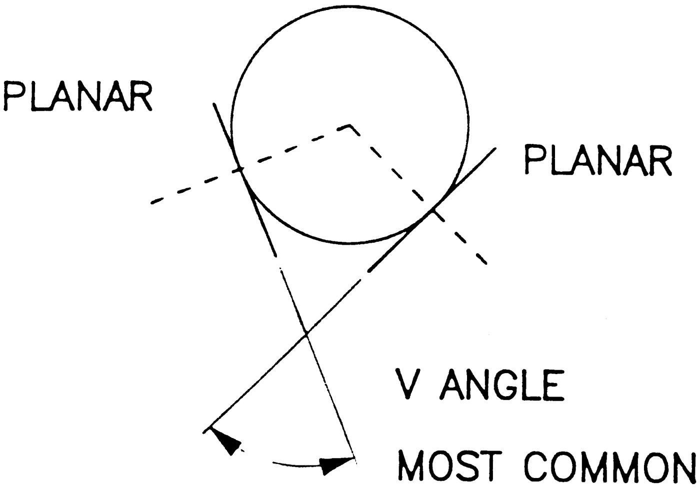
CONCAVE



GREATER SURFACE AREA,
REDUCED STRESS

PLANAR VS

DEFINITION: CONTACT SURFACES ARE PLANAR



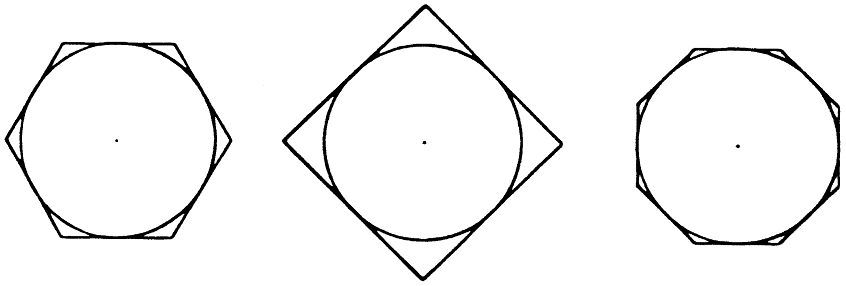
MOST COMMONLY 90° AND 60°

SPECIAL PROPERTIES OF PLANAR VS

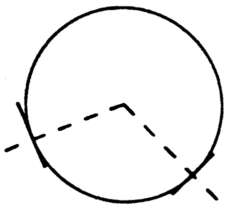
IF THE TWO CONTACT SURFACES ARE FLAT, THE V IS STRAIGHT, REGARDLESS OF THE ORIENTATIONS OF THE SURFACES.

THE EASIEST TYPE OF V TO PRODUCE USING STANDARD MACHINE TOOLS

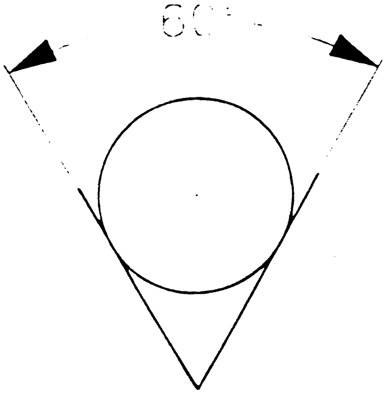
WORKS WITH BOTH ROUND AND SIMPLE NON-ROUND (SQUARE, HEXAGONAL, OCTOGONAL) CYLINDERS WITH SAME AXIS.



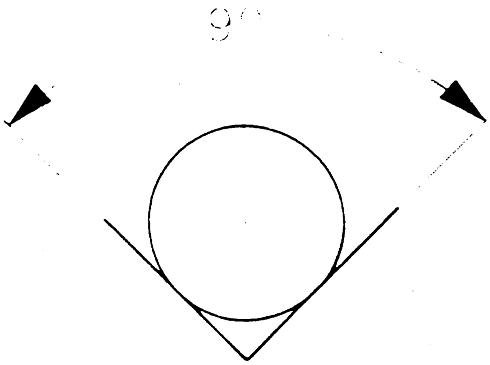
THE CONTACT SURFACE CAN BE NARROW:



COMPARISON OF 90° AND 60° VS

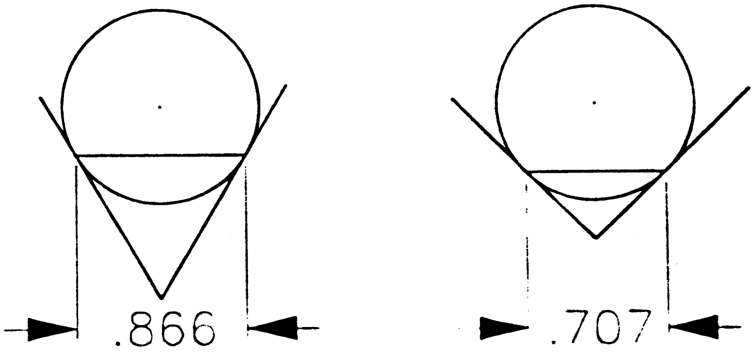


FAVORS LATERAL
REPEATABILITY

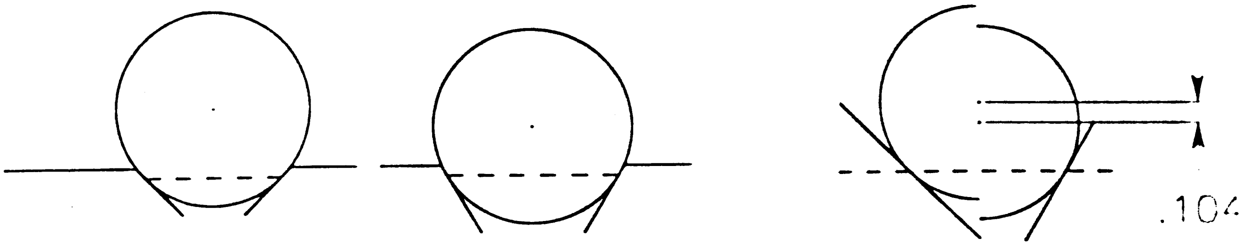


EQUAL RESTRAINT IN BOTH
DIRECTIONS

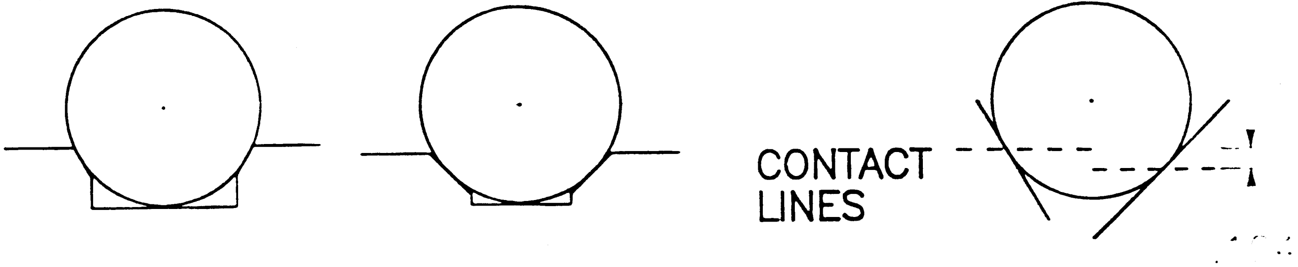
CONTACT LINE
SEPARATION



SAME CONTACT LINE PLANE

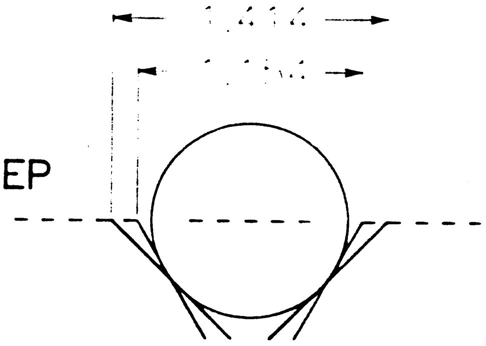


SAME AXIS

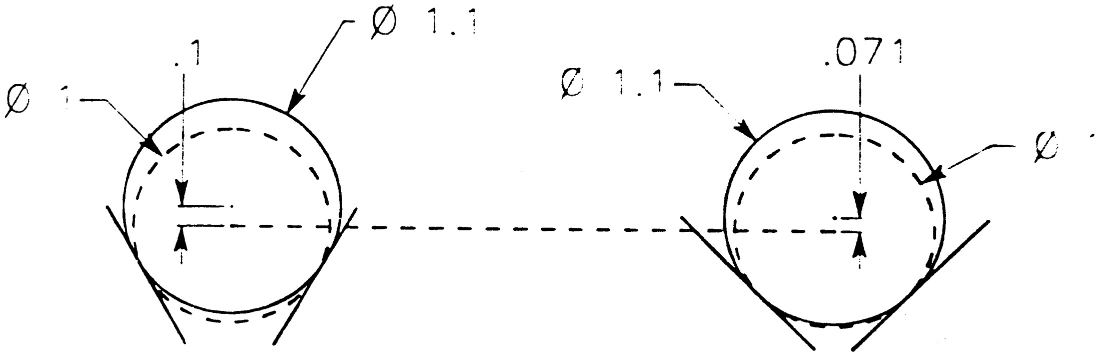


60° AND 90° COMPARISON

CYLINDER 0.5 DEEP

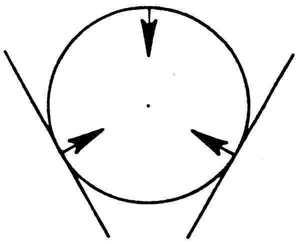


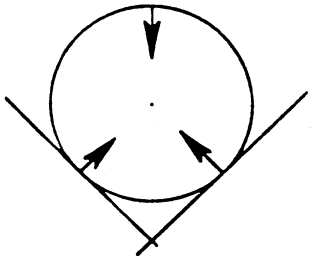
DIFFERENT WIDTHS AT
THE TOP OF THE V



CENTER HEIGHT INCREASE / DIAMETER INCREASE = 1 , 0.7

FORCES WITH CLAMPING IN BILATERAL SYMMETRY PLANE

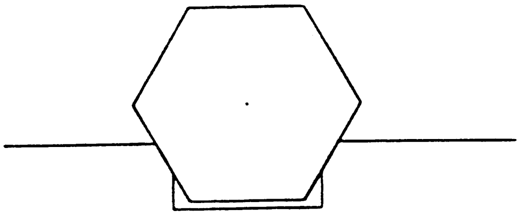




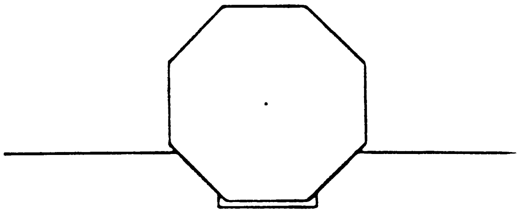
SYMMETRICAL FORCES,
LESS DISTORTION FOR
GIVEN FORCE

60° AND 90° VS WITH NON-ROUND CYLINDERS

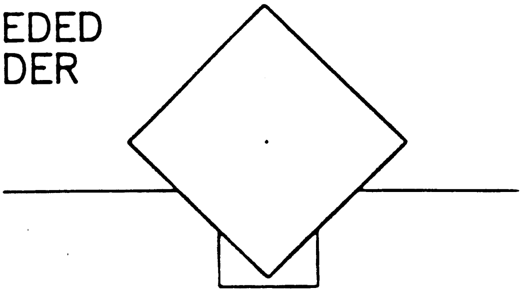
SHALLOW 60° V SUPPORTS A
HEXAGON CYLINDER



SHALLOW 90° V
SUPPORTS AN
OCTAGONAL CYLINDER

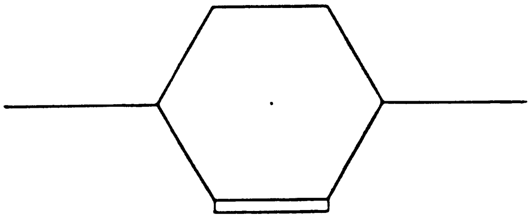


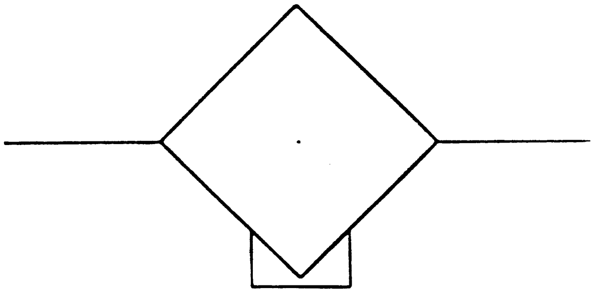
ADDTIONAL DEPTH NEEDED
FOR A SQUARE CYLINDER

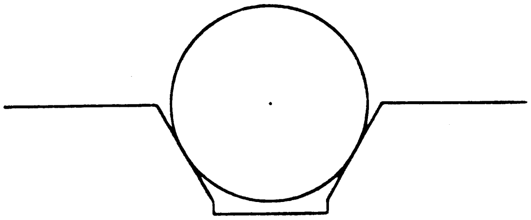


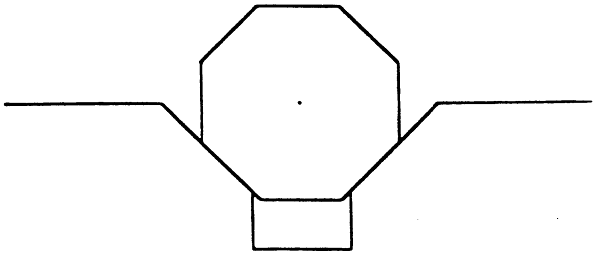
ONE CORNER OF THE SQUARE CAN BE REMOVED FOR A
SHALLOW V.

0.5 DEEP



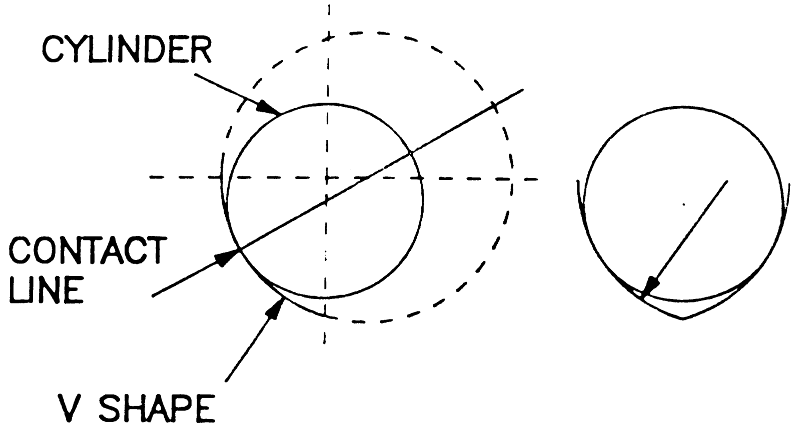


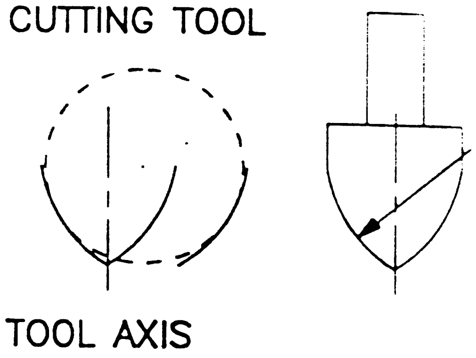




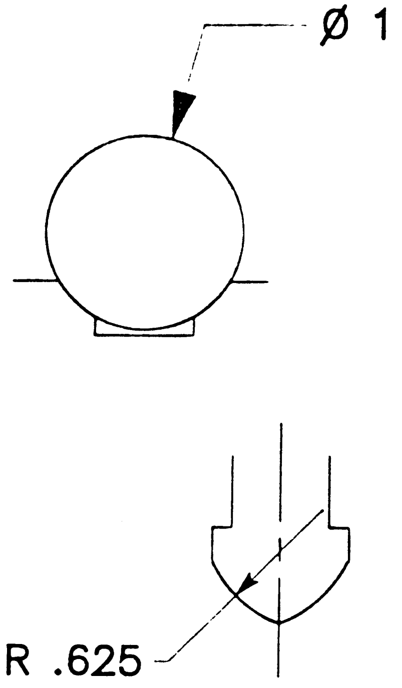
CONCAVE V EXAMPLE

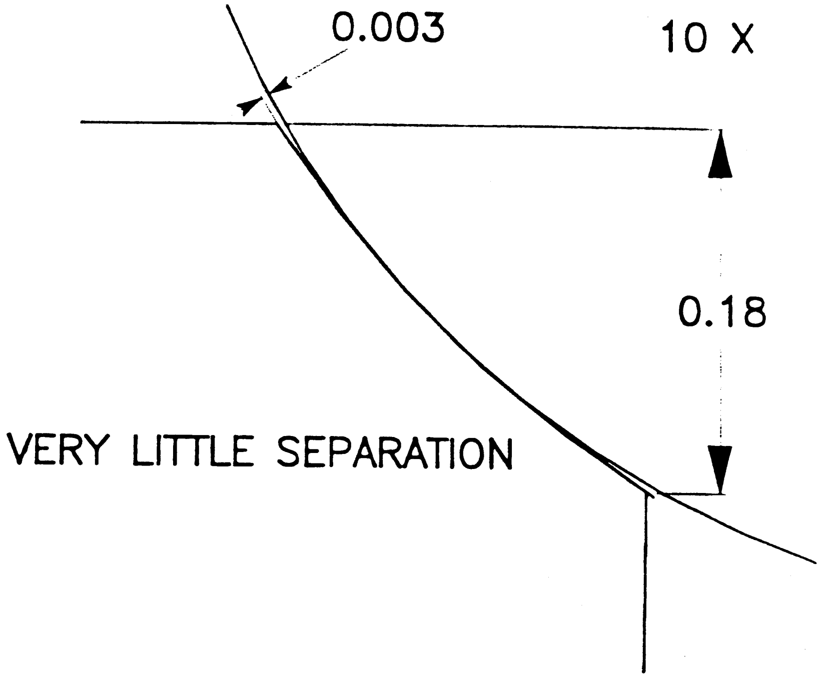
LAYOUT AND TOOL DESIGN





EXAMPLE:
V ANGLE 90°
CUTTING TOOL PROFILE DIAMETER = 1.25 X CYLINDER DIAMETER





POSSIBLY USEFUL FOR HEAT CONDUCTION ?

MONOLITHIC VS

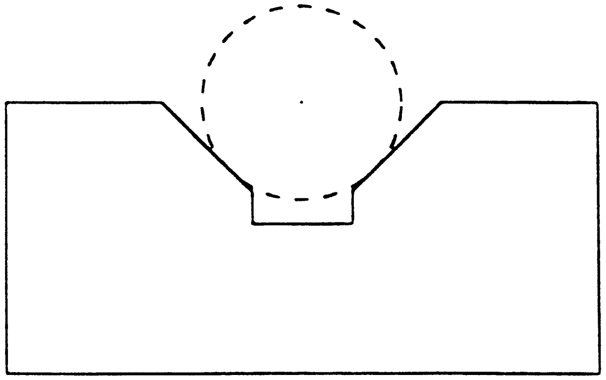
DEFINITION:
BOTH CONTACT SURFACES ARE PART OF THE SAME PIECE

OTHER TYPE IS "FABRICATED V"

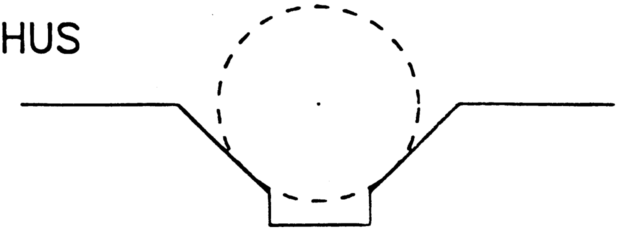
CAN BE BASED ON
BARS
PLATES
CASTINGS
EXTRUSIONS

FOR LOW ACCURACY, UNMACHINED EXTRUSIONS MAY WORK.

EXAMPLE OF PLATE TYPE



USUALLY DRAWN THUS

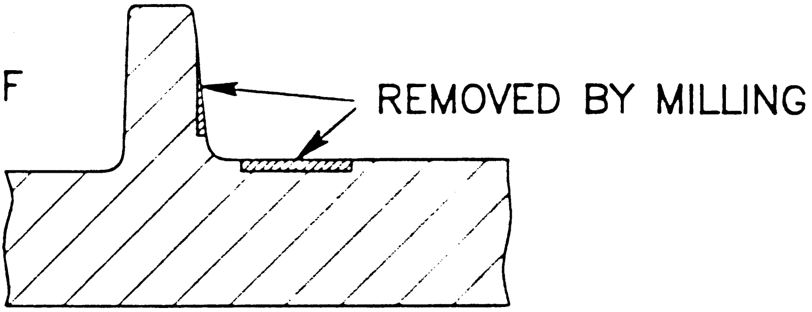


VS IN CASTINGS

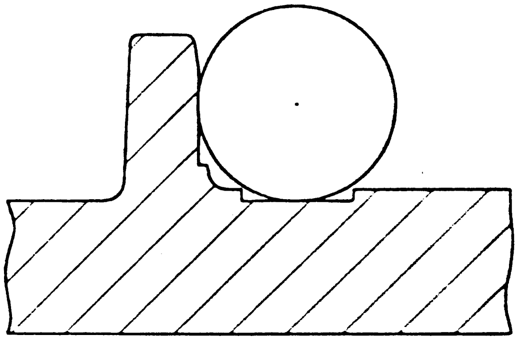
- CASTINGS CAN BE DESIGNED SO LITTLE MACHINING PRODUCES PLANAR VS.

EXAMPLE

CASTING, WITH RELIEF

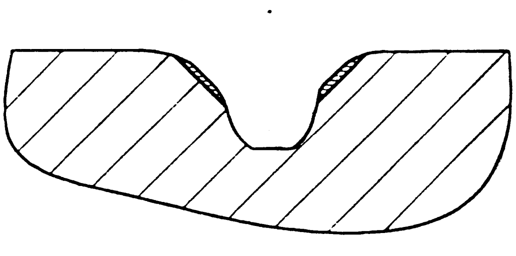


RESULT

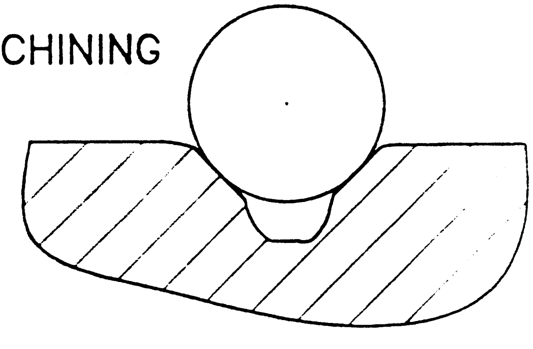


EXAMPLE

CASTING

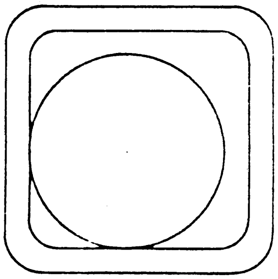


AFTER MACHINING

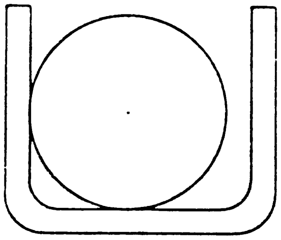


SEPARATED ALIGNED V SECTIONS CAN BE PRODUCED.

WITH EXTRUSIONS

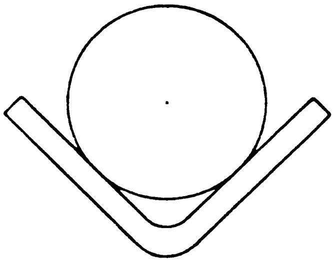


OFF THE SHELF



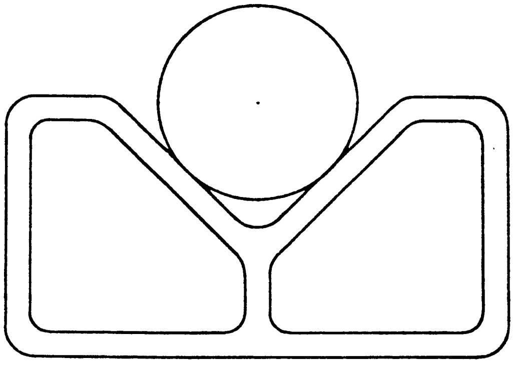
OFF THE SHELF

WITH OR WITHOUT MACHINING



INEXPENSIVE

SPECIAL



FABRICATED VS

DEFINITION:
CONTACT SURFACES ARE ON SEPARATE PIECES

EXAMPLES

ROUND RODS

PIECES WITH FLATS
- SQUARE
- HEXAGONAL
- OTHER

A TABLE TOP CAN PROVIDE ONE CONTACT SURFACE.

MAY OR MAY NOT BE MACHINED AFTER ASSEMBLY.

FABRICATED LS

TWO PART

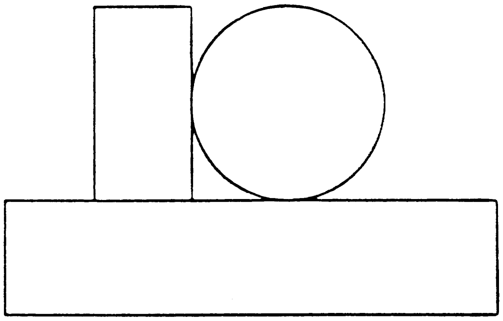
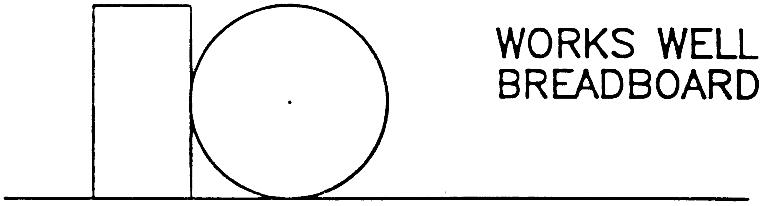


TABLE TOP
AND A WALL



WORKS WELL WITH
BREADBOARD TABLES

TABLE TOP

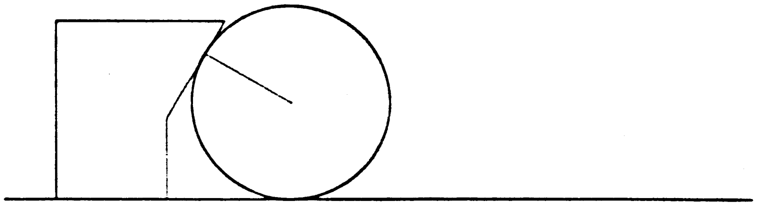
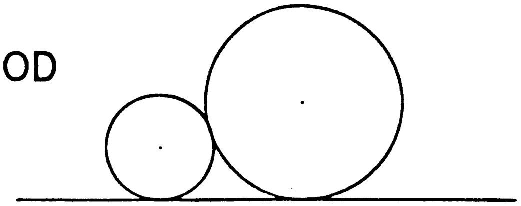
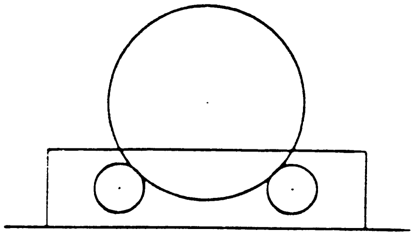
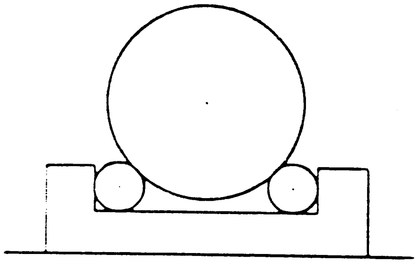


TABLE TOP AND FIXED ROD

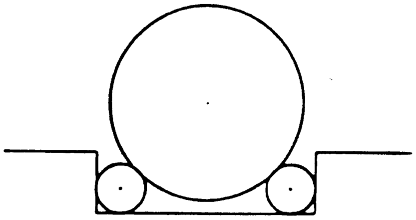


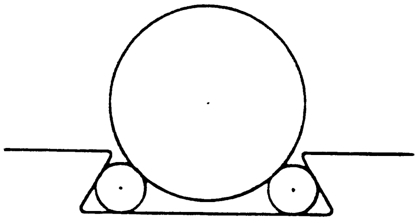
WITH ROUND RODS

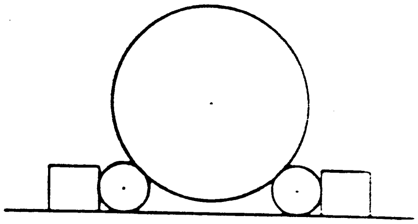


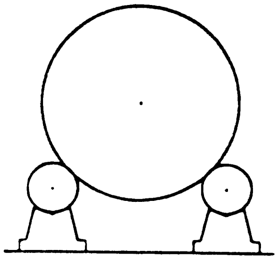


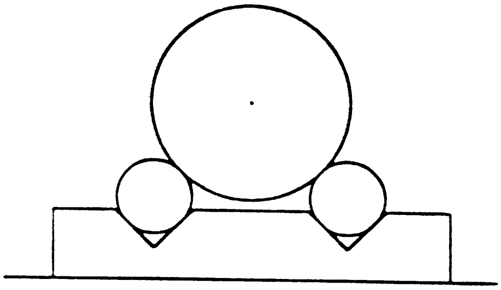
END SUPPORT



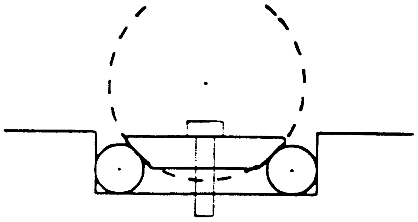


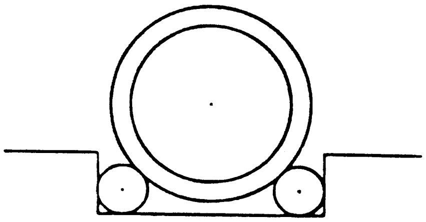






ROD RESTRAINT

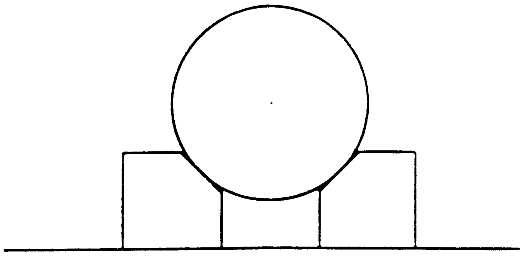


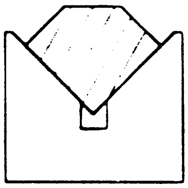


ROD RESTRAINED WITH EMPTY CYLINDER RESTRAINED BY SOME MEANS

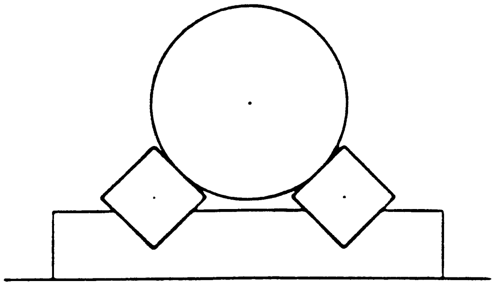
WITH NON-ROUND RODS

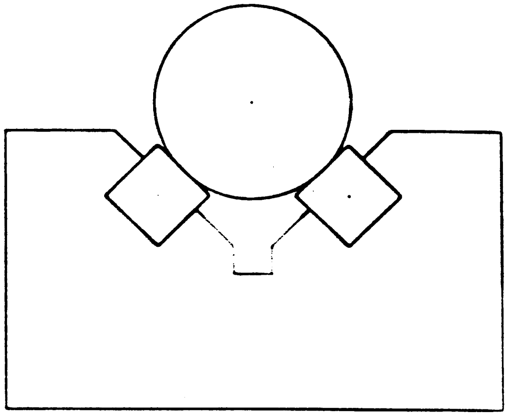
TWO NOMINALLY PLANAR SURFACES ARE USED



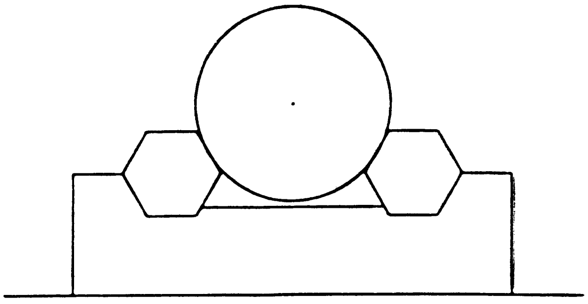


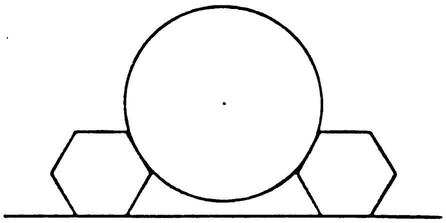
ARRANGEMENT FOR GRINDING





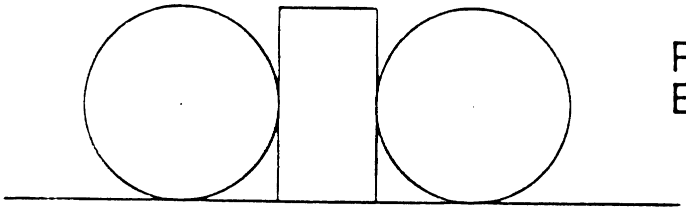
HEXAGONAL RODS



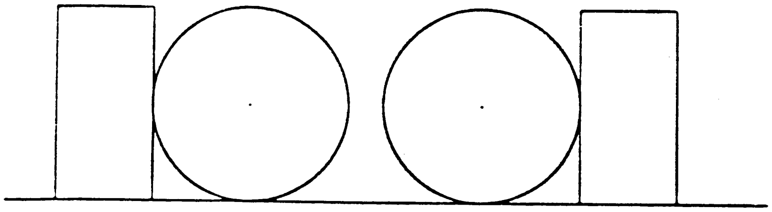


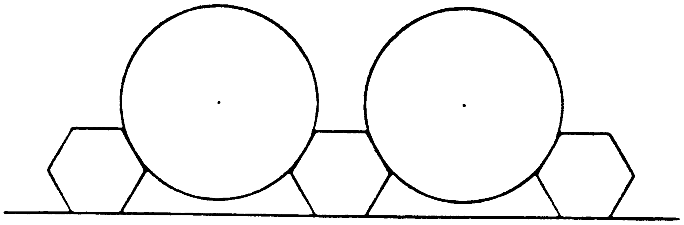
MULTIPLE FABRICATED VS

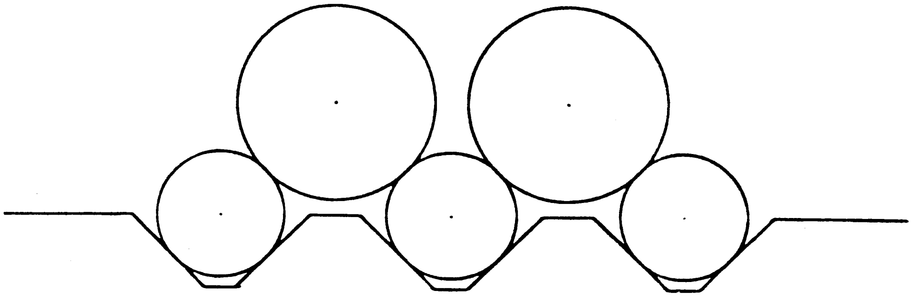
EXAMPLES



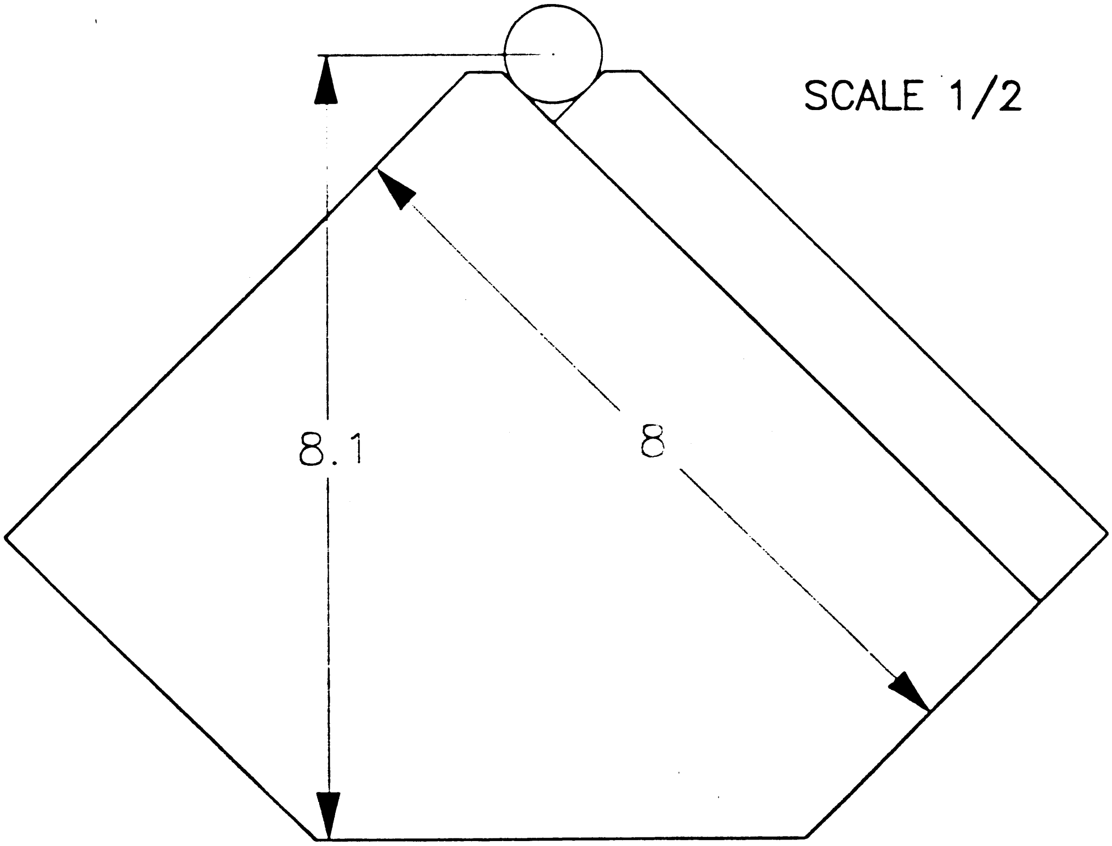
PARALLEL AXES
EASILY OBTAINED







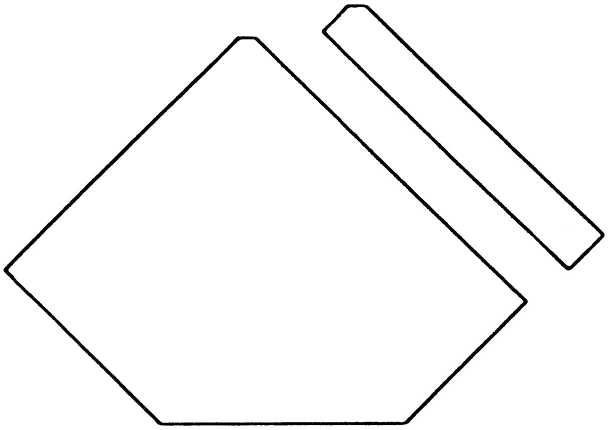
FABRICATED GRANITE MASTER V



SCALE 1/2

MADE BY RAHN

1 MICRON STRAIGHTNESS OVER 1 YARD LENGTH

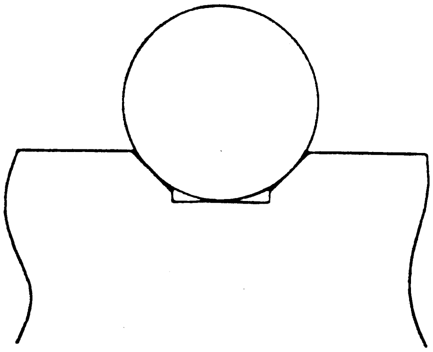


TYPE OF V CHANGED

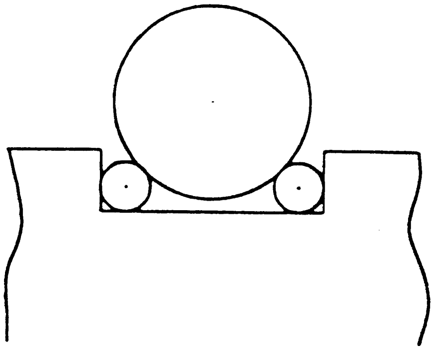
- THE TYPE OF V CAN CHANGE.

EXAMPLE:

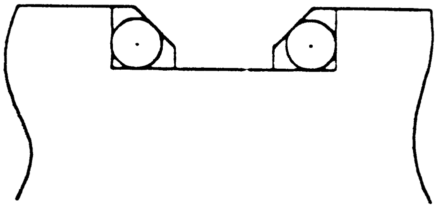
SHALLOW 90° V



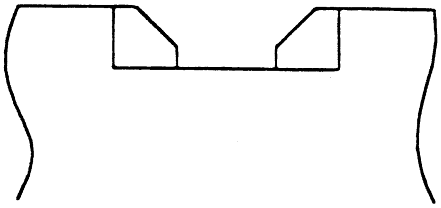
ROD OR BALLS



RELATIONSHIP



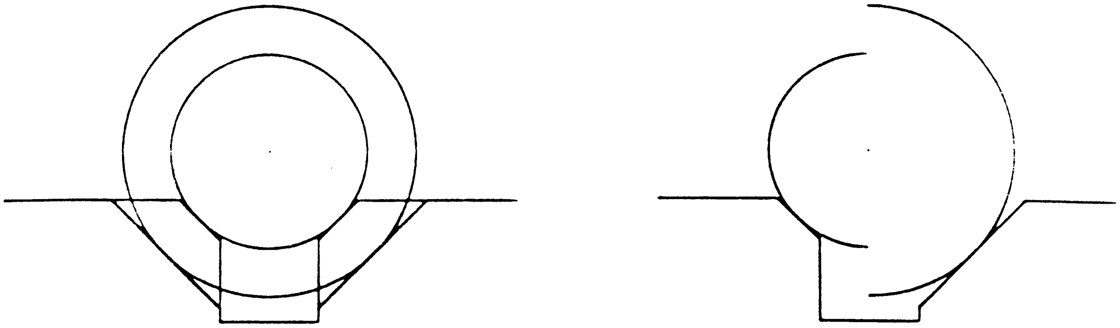
MACHINING
RELATIONSHIP

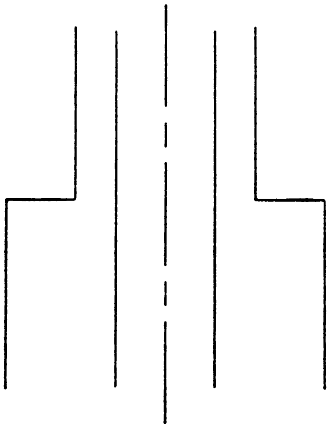


V SYSTEM FOR TWO SIZES OF INLINE CYLINDERS

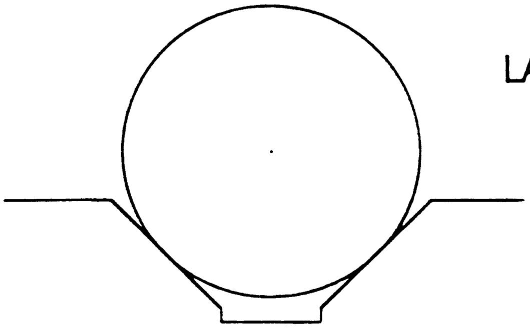
EXAMPLE:

SAME AXIS

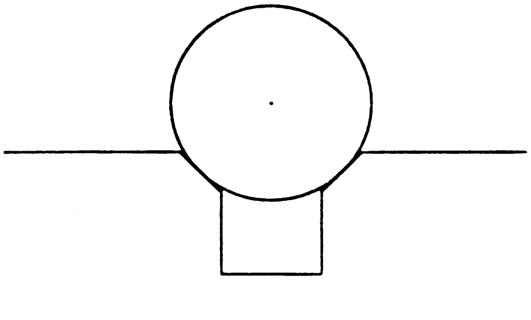




LARGE CYLINDER



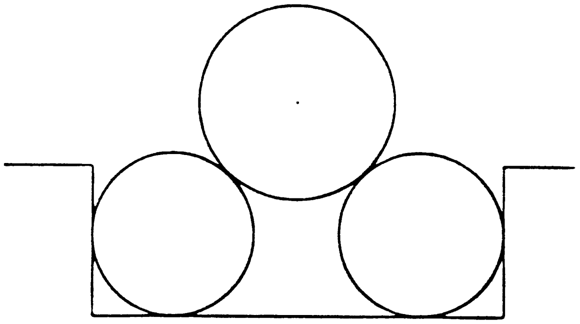
SMALL CYLINDER



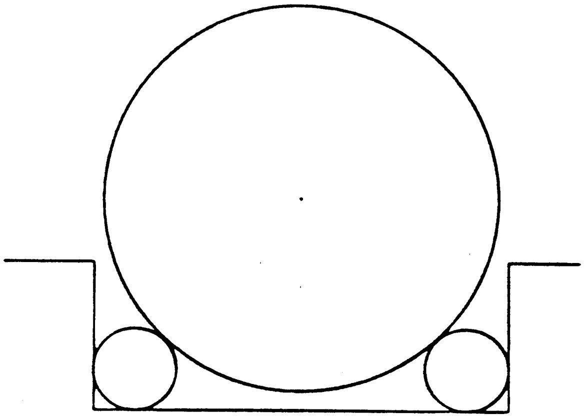
V SYSTEM FOR TWO SIZES OF INLINE CYLINDER

EXAMPLE:

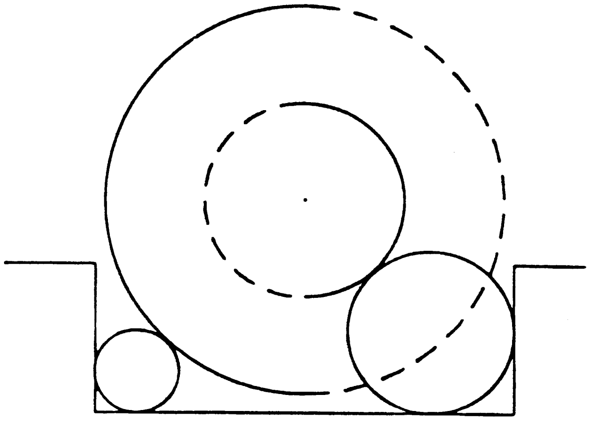
SMALL CYLINDER,
LARGE RODS



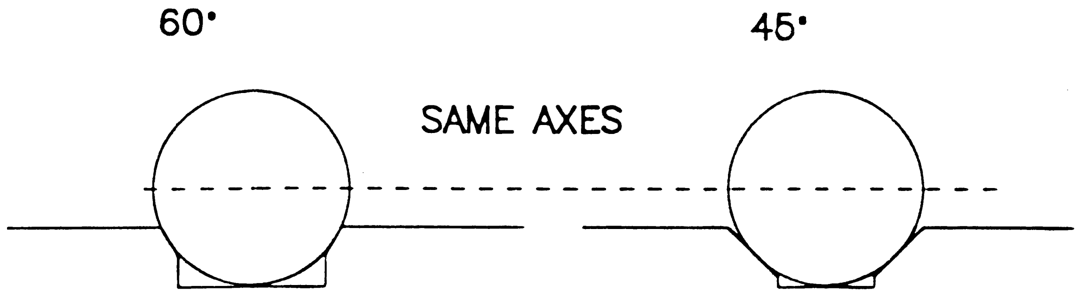
LARGE CYLINDER,
SMALL RODS

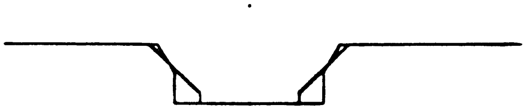


SAME AXIS

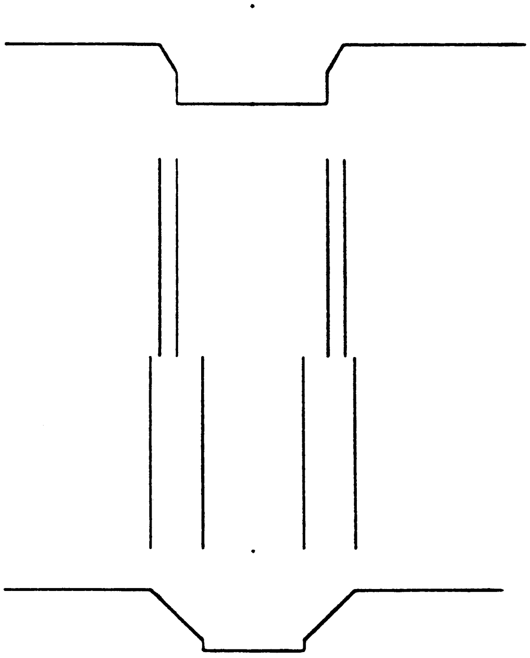


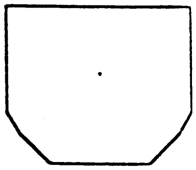
SWITCH BETWEEN 60° AND 90° VS





CONTACT LINES

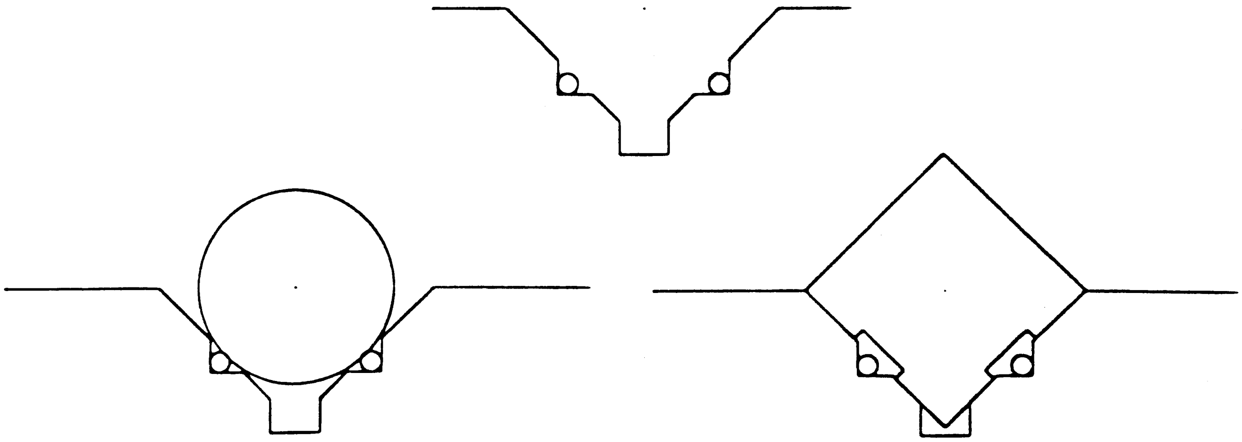




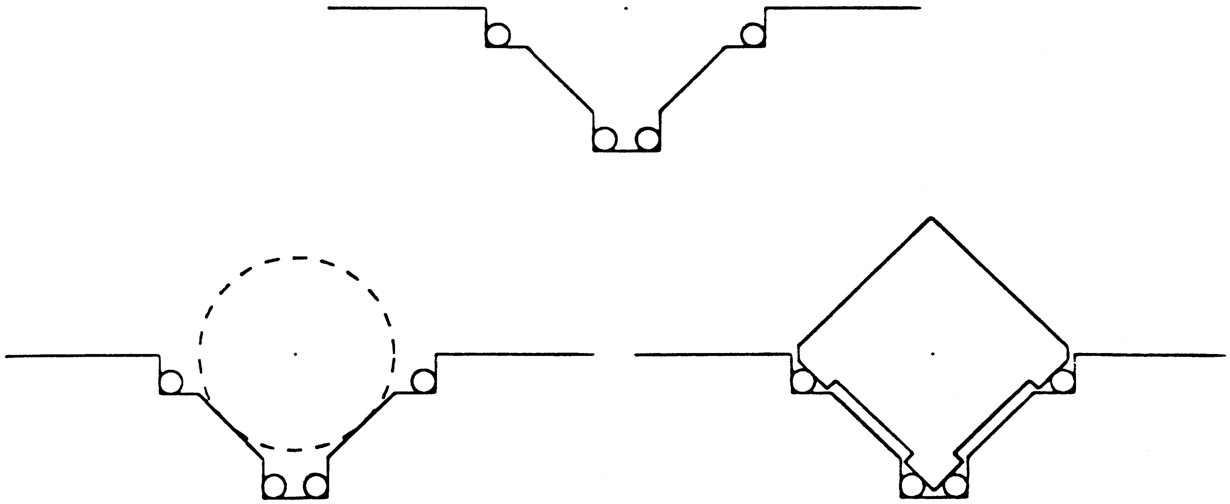
DUAL ANGLE NON–ROUND CYLINDER

ROLLERS

ARRANGEMENT IN WHICH ROUND CYLINDERS ROLL AND SQUARE ONES DO NOT



ARRANGEMENT IN WHICH MODIFIED SQUARE CYLINDERS ROLL AND ROUND ONES DO NOT



MISCELLANEOUS

SUBMERGED CYLINDERS

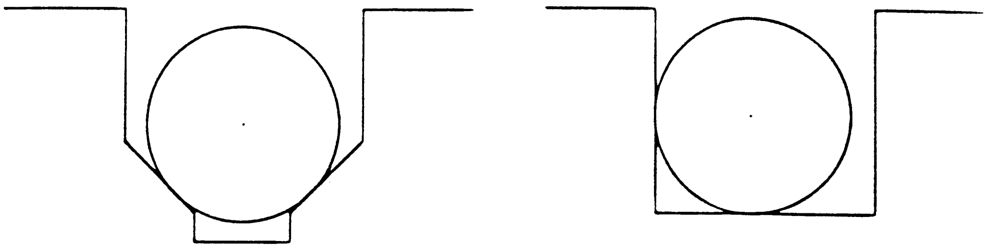
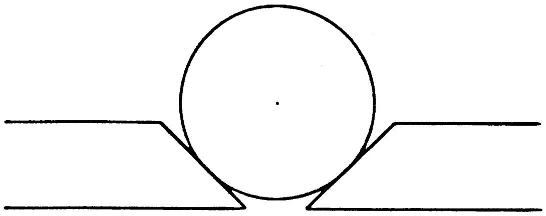
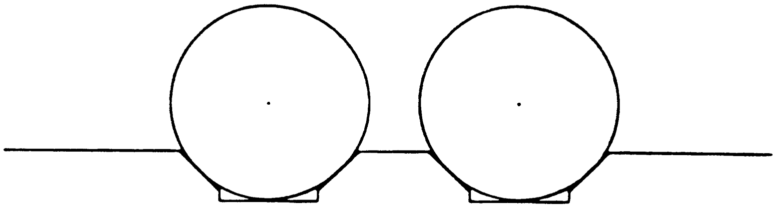


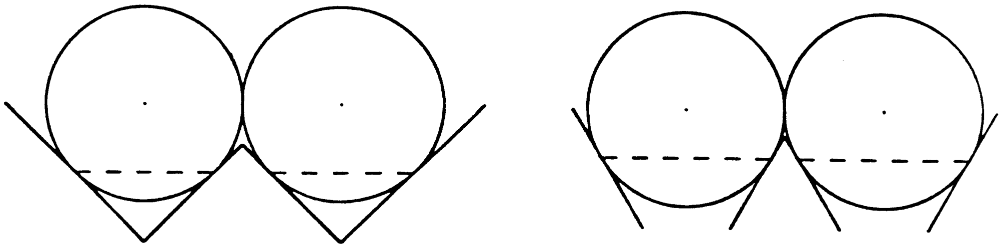
PLATE WITH THROUGH HOLE OR SLOT



SIDE-BY-SIDE VS



BOTH 60° AND 90° VS ALLOW PROXIMITY



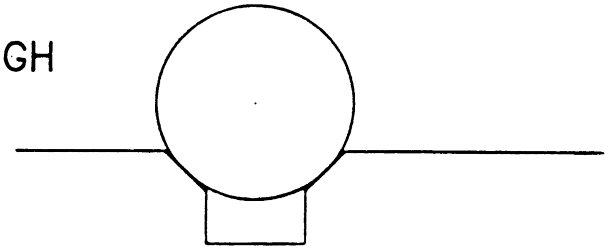
PARALLEL AUXILIARY STRUCTURES

MACHINED PARALLEL TO A V IN THE SAME SETUP.

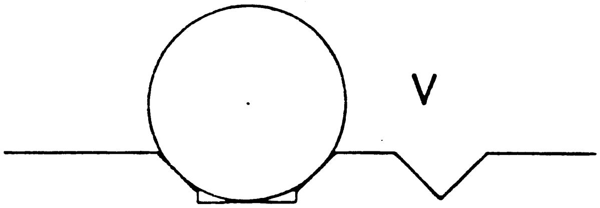
CAN BE USED FOR METROLOGY, AXIAL MOTION, CLAMPING.

EXAMPLES

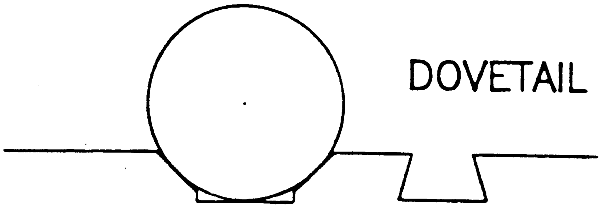
CENTRAL TROUGH



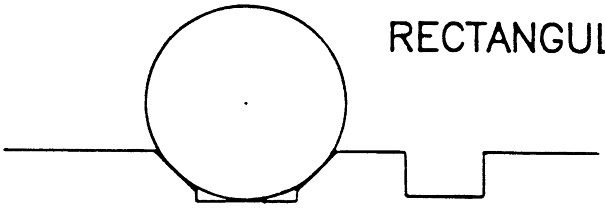
V



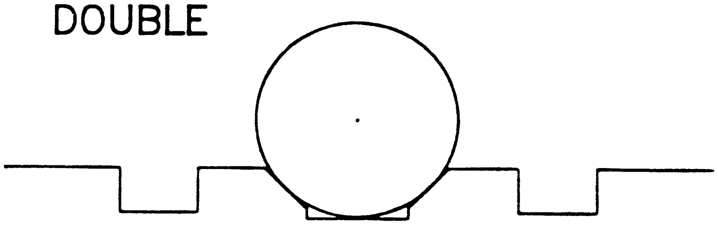
DOVETAIL



RECTANGULAR TROUGH

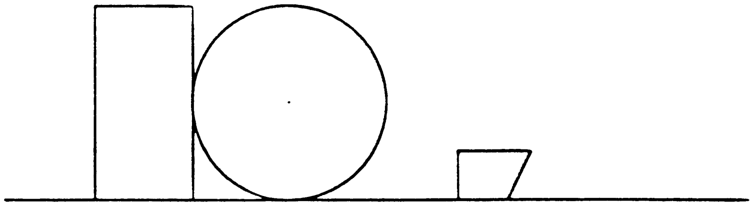


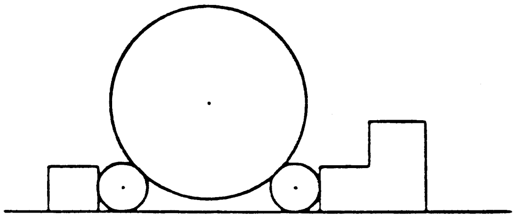
DOUBLE

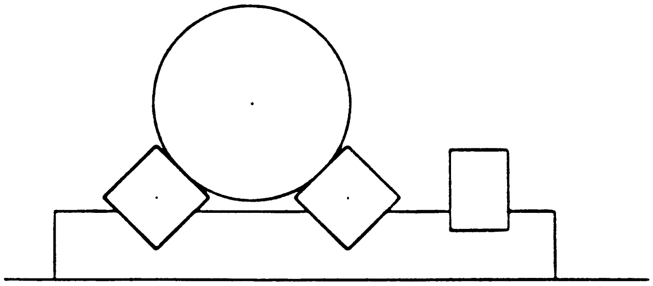


PARALLEL AUXILIARY STRUCTURES

EXAMPLES OF FABRICATED ONES







TESTING VS

FUNCTIONAL TESTS VS ABSOLUTE TESTS

STRAIGHTNESS OF V

RELATIONSHIP OF V TO OTHER APPARATUS

TESTING PLANAR VS FOR STRAIGHTNESS

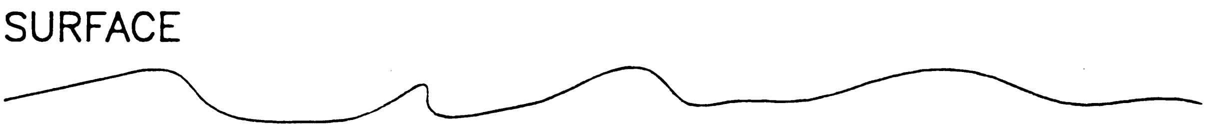
- COMPLETE V
- ONE CONTACT SURFACE AT A TIME

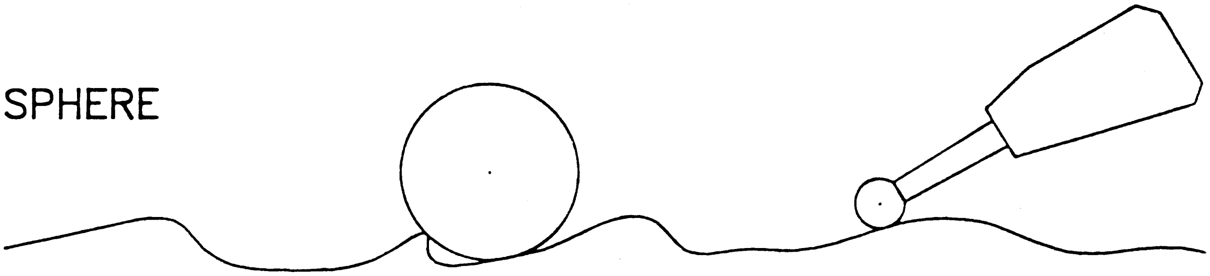
SURFACE PLATE
COORDINATE MEASURING MACHINE
OTHER

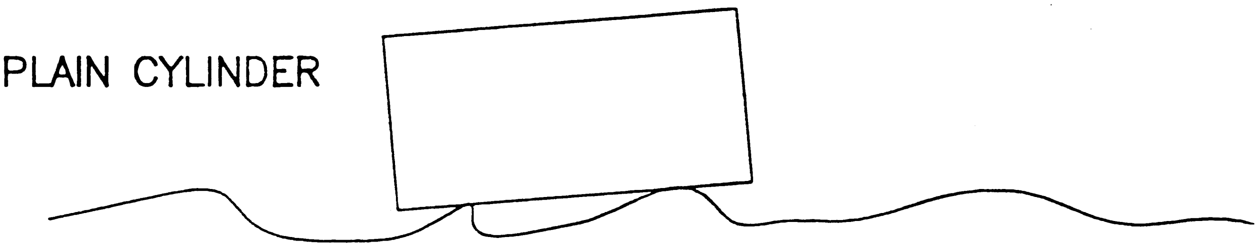
MANY TESTS SHOWN ARE FOR PLANAR VS ONLY

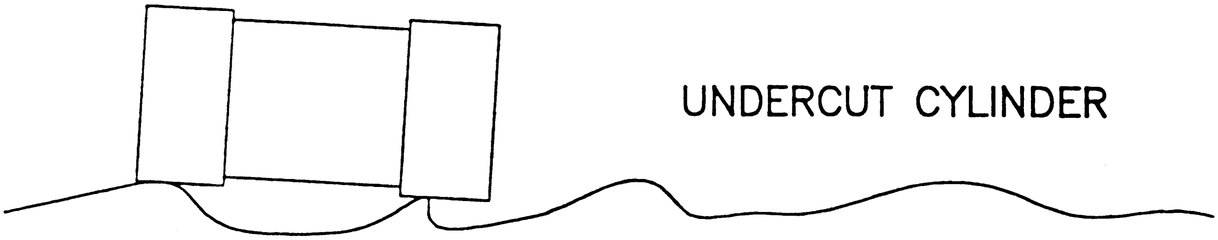
SURFACE IRREGULARITIES

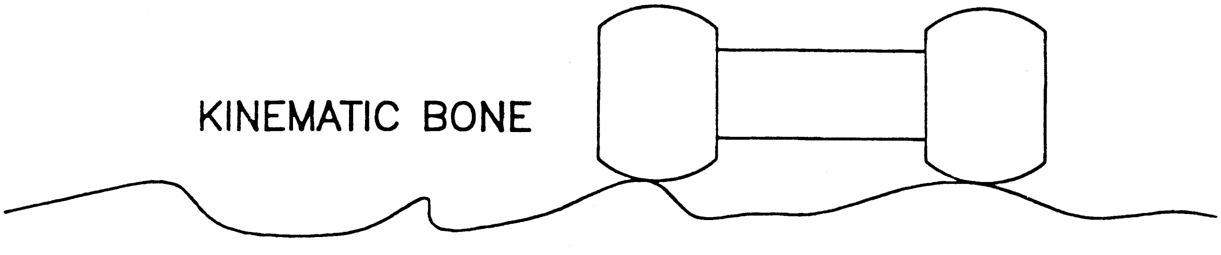
SURFACE IRREGULARITIES AFFECT DIFFERENT OBJECTS DIFFERENTLY



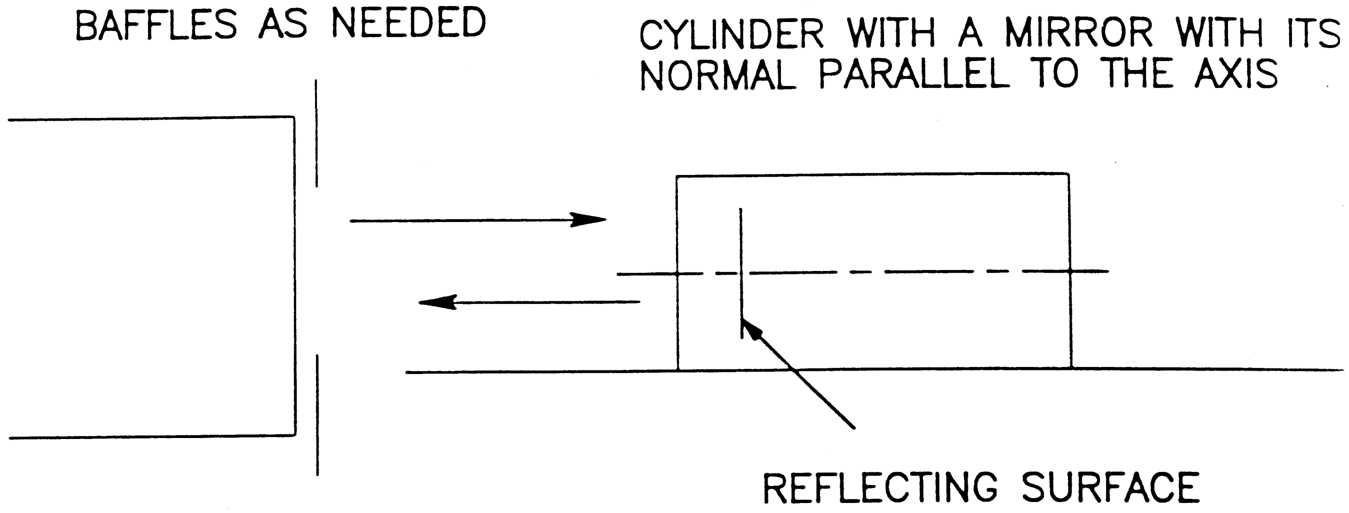




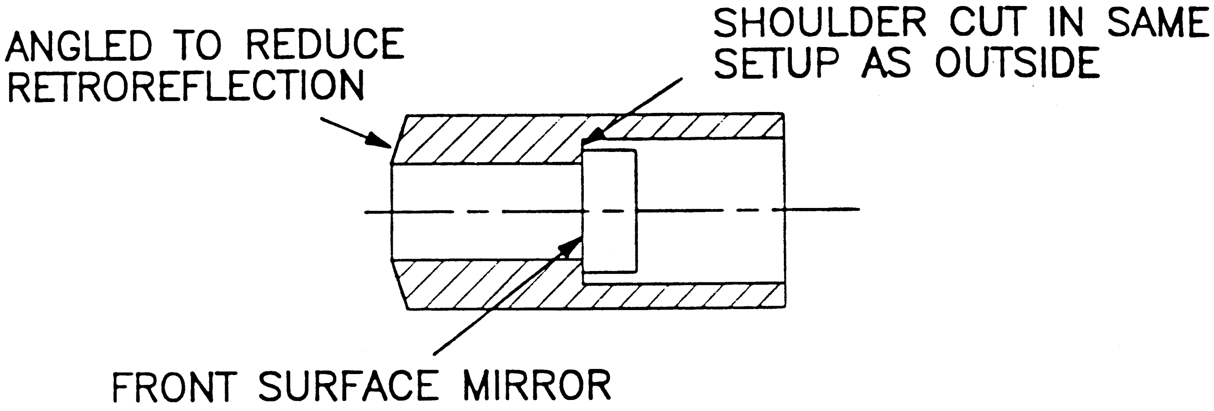




AUTOCOLLIMATOR



A MIRROR CYLINDER DESIGN

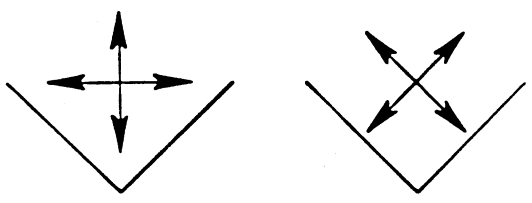


TEST THE MIRROR ORIENTATION BY ROTATING ITS CYLINDER.

AUTOCOLLIMATION WORKS WITH ANY TYPE OF V.

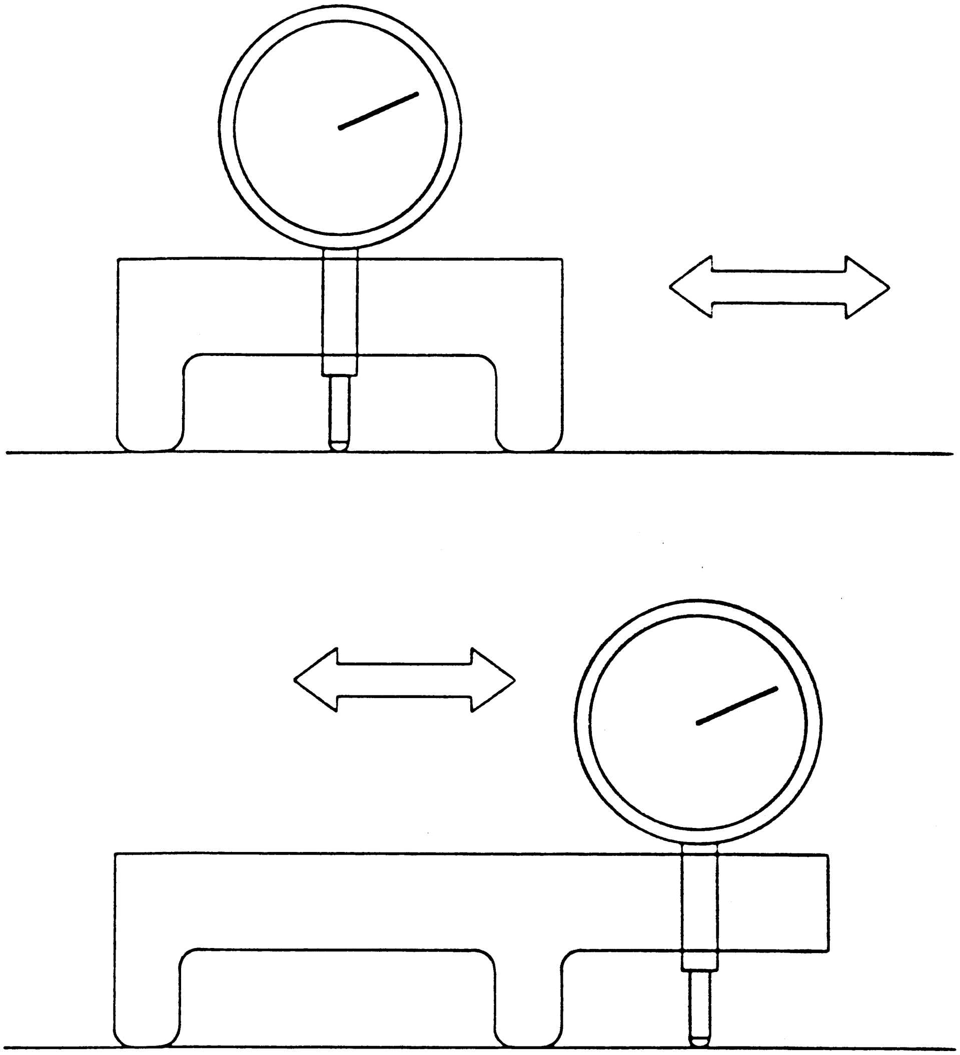
THE CYLINDER LENGTH AND TYPE SHOULD EMULATE THAT USED TO HOLD OPTICS.

POSSIBLE COORDINATE SYSTEMS:



SELF–SIMILARITY TESTING

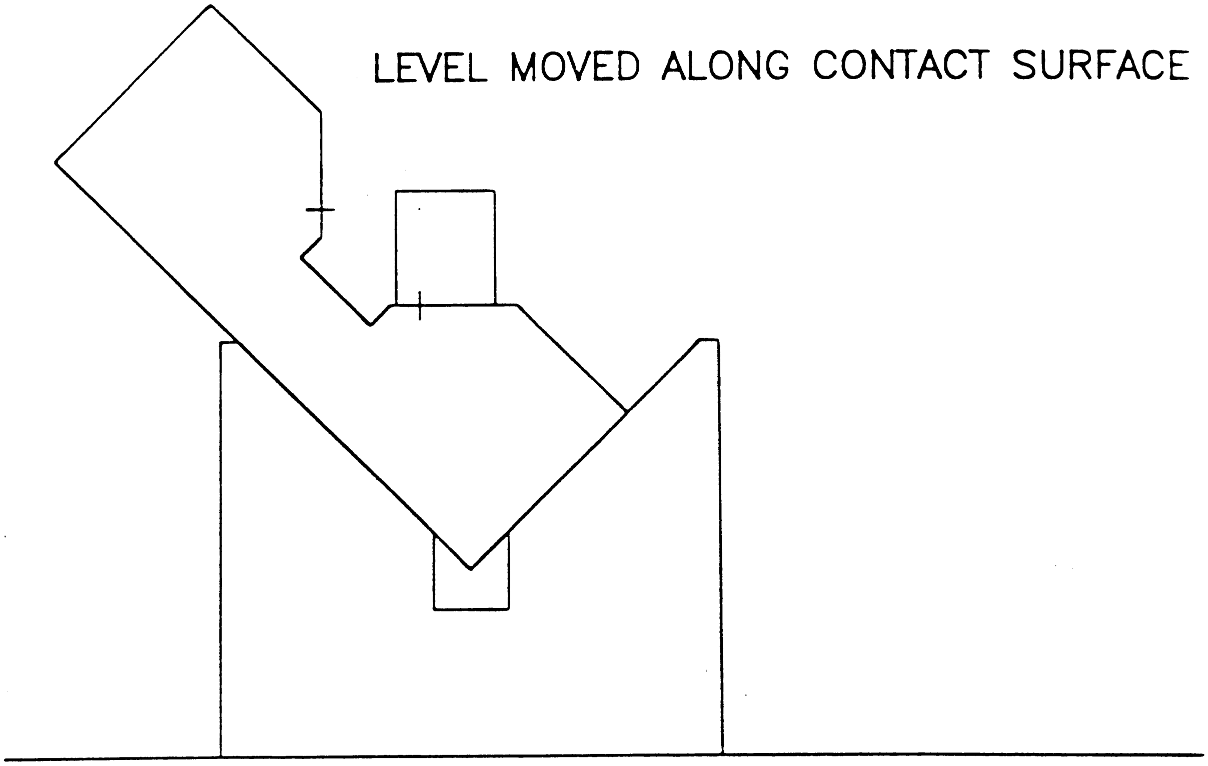
CAN BE USED FOR PLANAR VS.



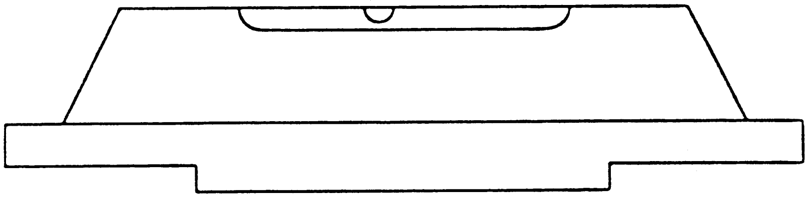
SELF–SIMILARITY ALONE DOES NOT DETECT CONSTANT CURVATURE.

FOR THIS, CALIBRATE AGAINST A FLAT.

LEVEL

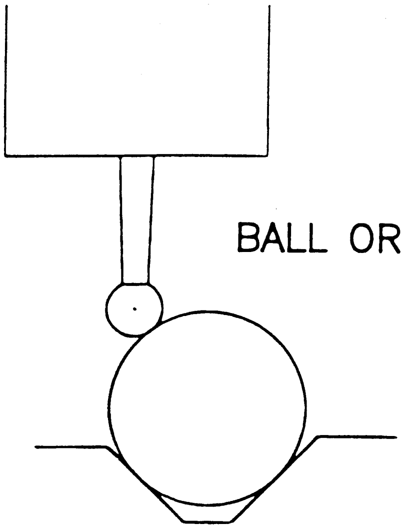


LEVEL MOVED ALONG CONTACT SURFACE

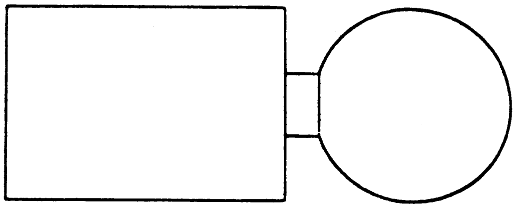


CYLINDER SIZE CARRIER

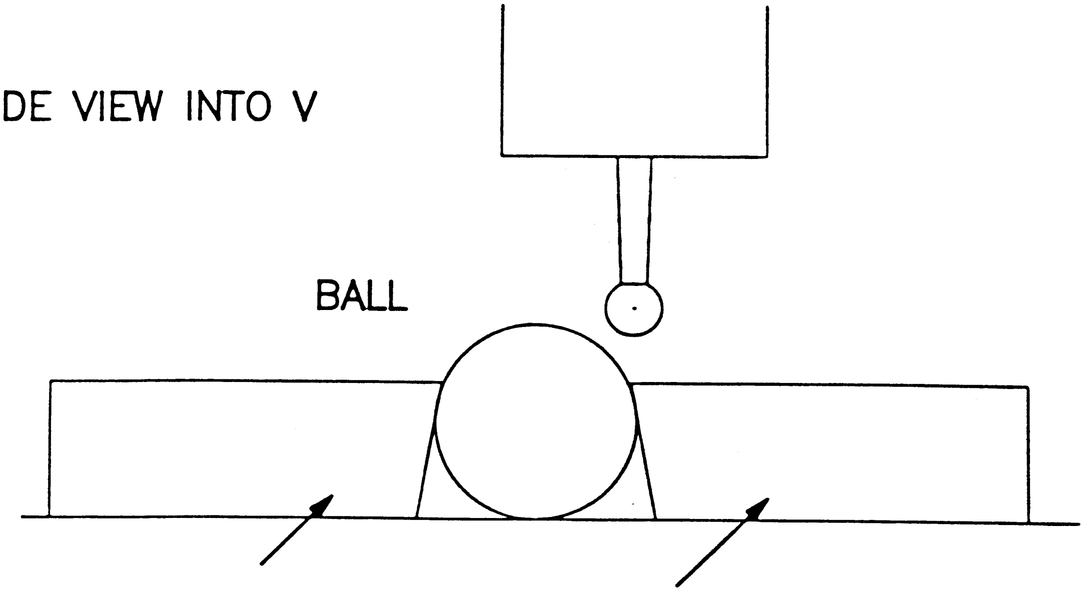
COORDINATE MEASURING MACHINE



BALL OR CYLINDER OR CYLINDER WITH BALL



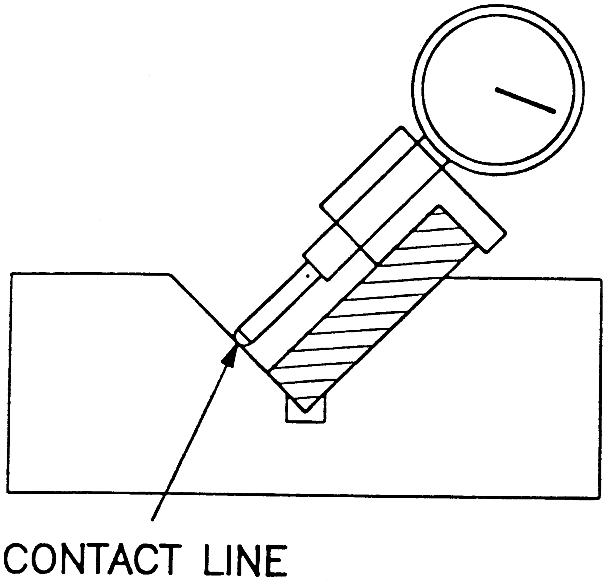
SIDE VIEW INTO V

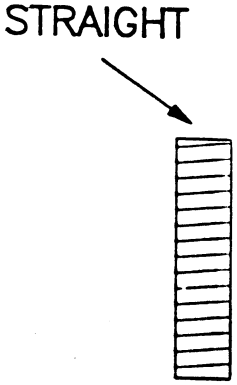


HARD RUBBER OR SIMILAR HIGH FRICTION RESTRAINERS
TO HOLD THE BALL STILL

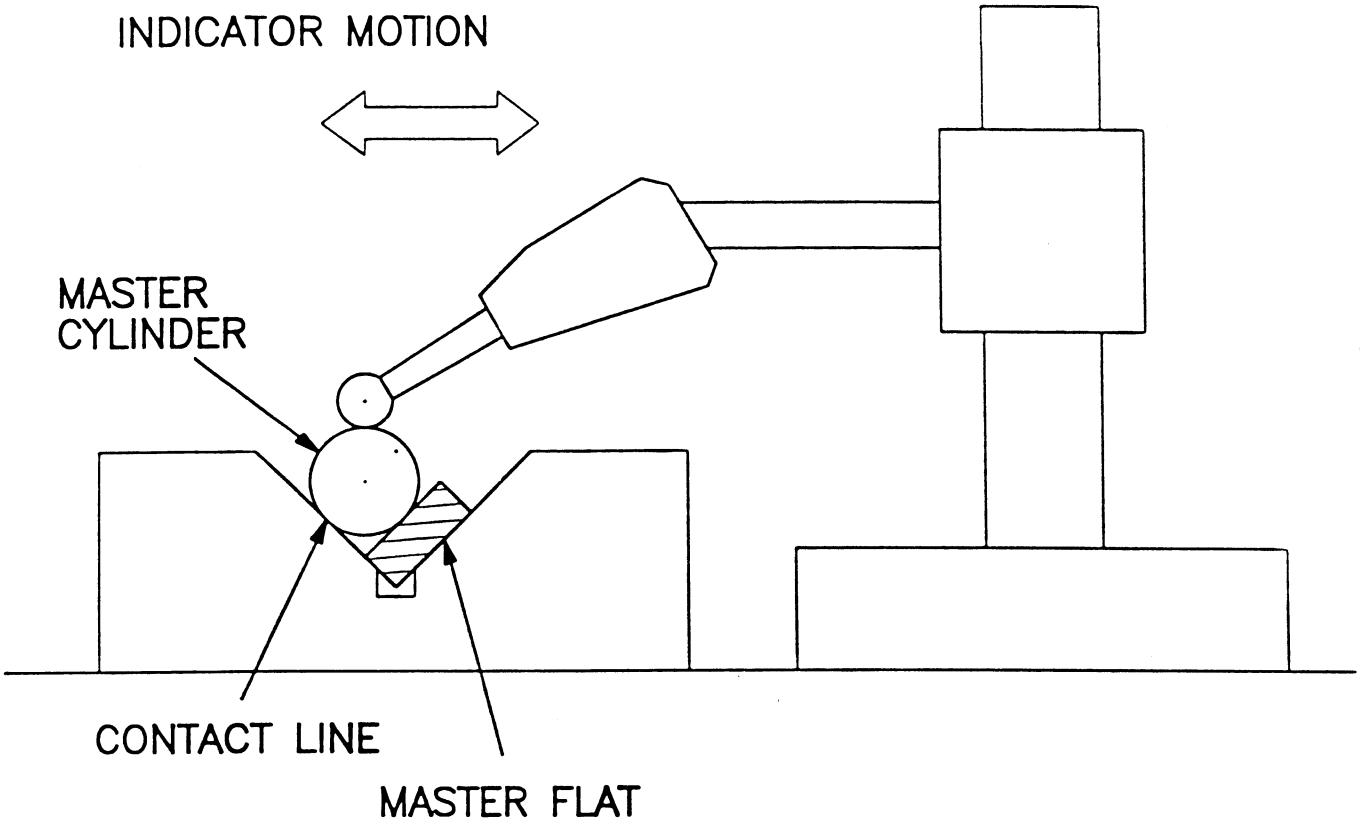
COMPARISON WITH A MASTER STRAIGHT EDGE

INDICATOR MOVED ALONG LENGTH OF V





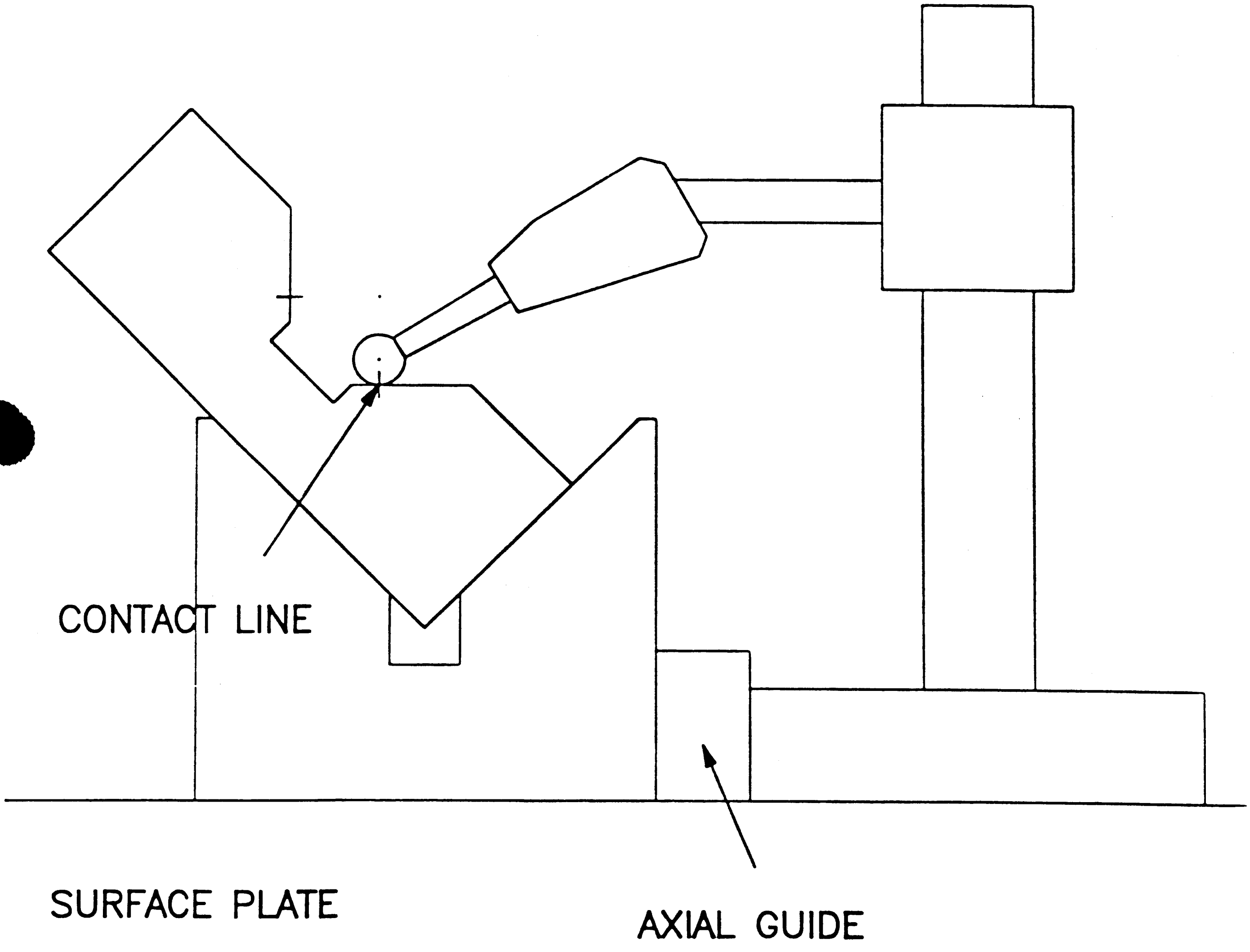
SEPARATION OF SIDES WITH A MASTER FLAT



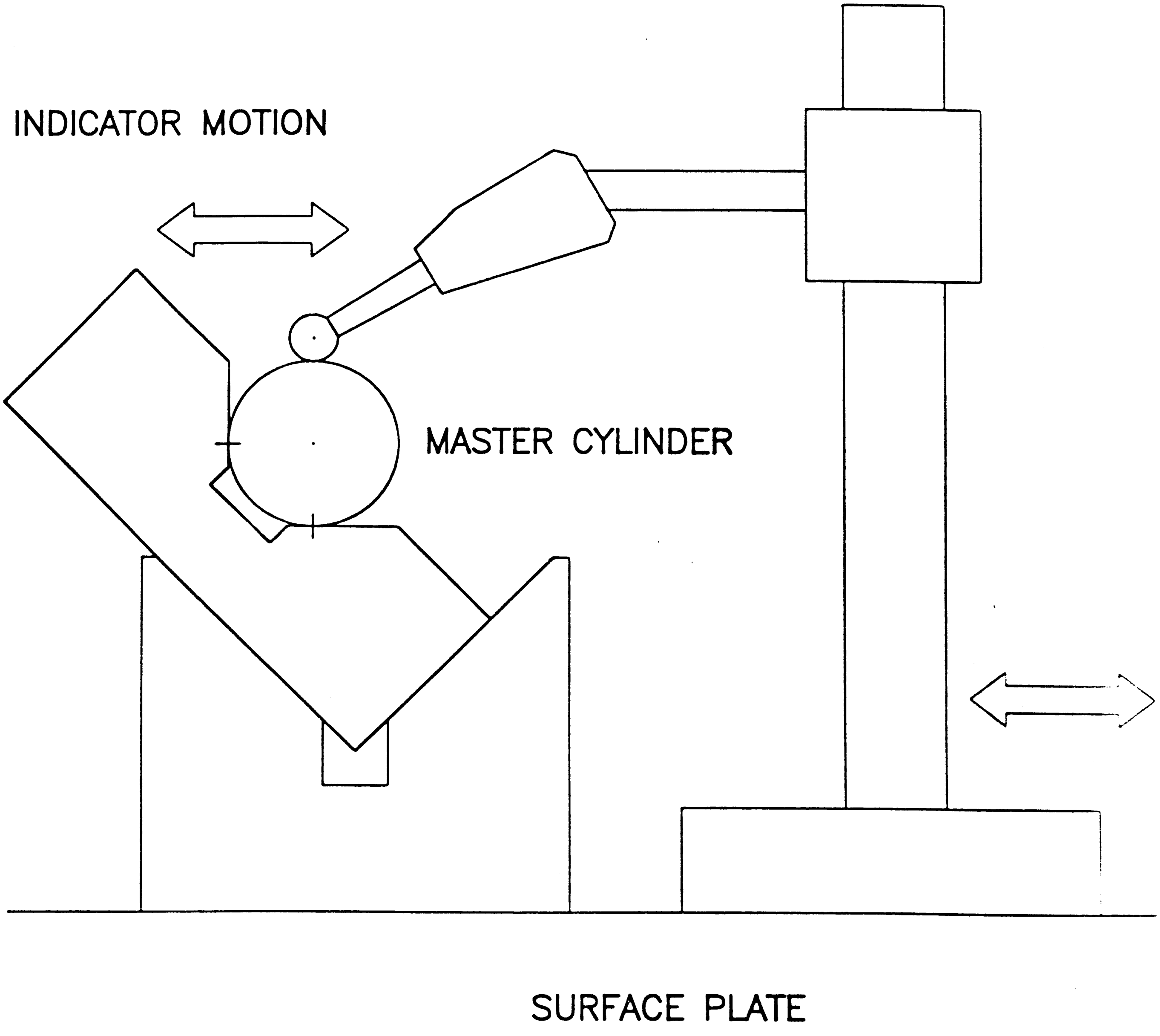
THE DIAMETER OF THE SMALL MASTER CYLINDER IS SUCH THAT IT TOUCHES THE CONTACT SURFACE ON THE REGULAR CONTACT LINE.
NON–FLATNESS OF THE CONTACT SURFACE DISPLACES THE SMALL CYLINDER AT 45°, AND THE VERTICAL COMPONENT OF THE DISPLACEMENT IS MEASURED.

CONTACT LINE STRAIGHTNESS

INDICATOR MOVES LENGTHWISE ALONG A CONTACT LINE



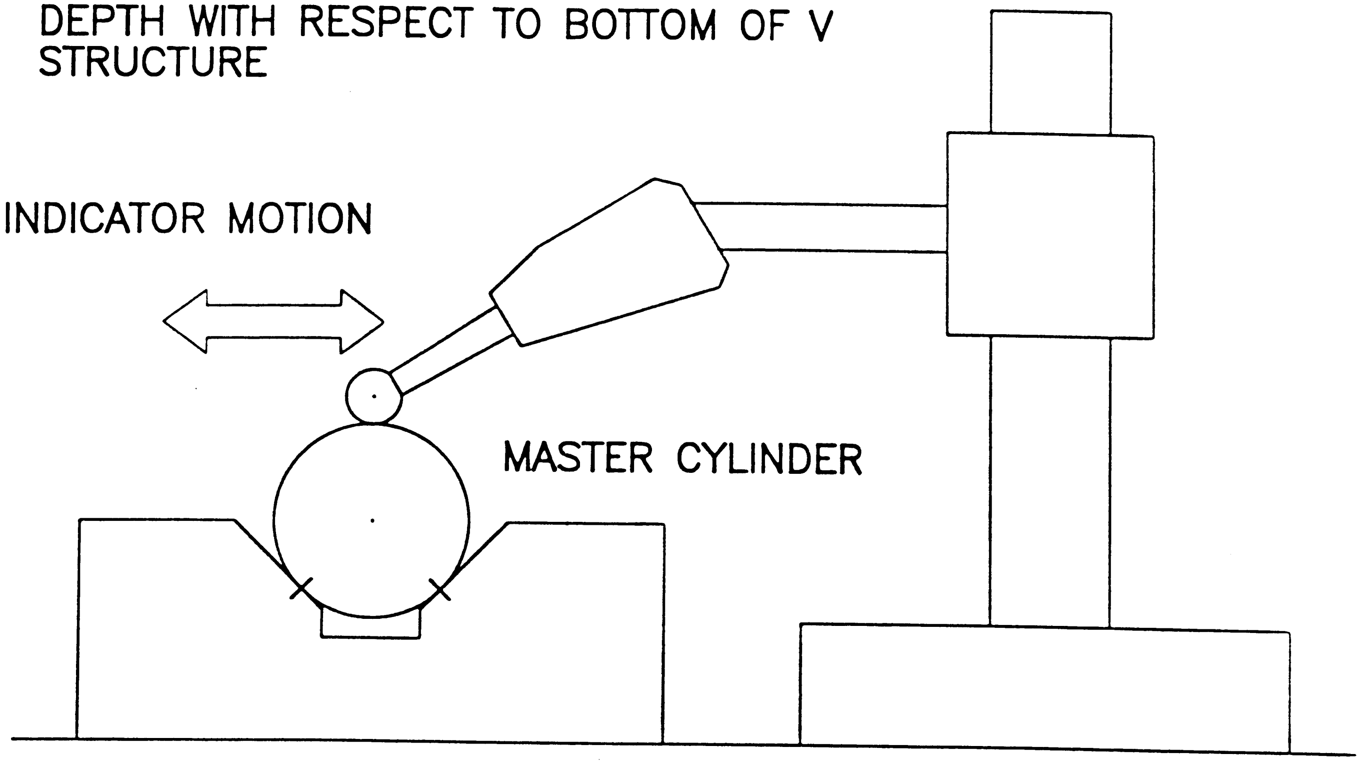
DISPLACMENT OF A CYLINDER RESULTING FROM CONTACT SURFACE IRREGULARITIES



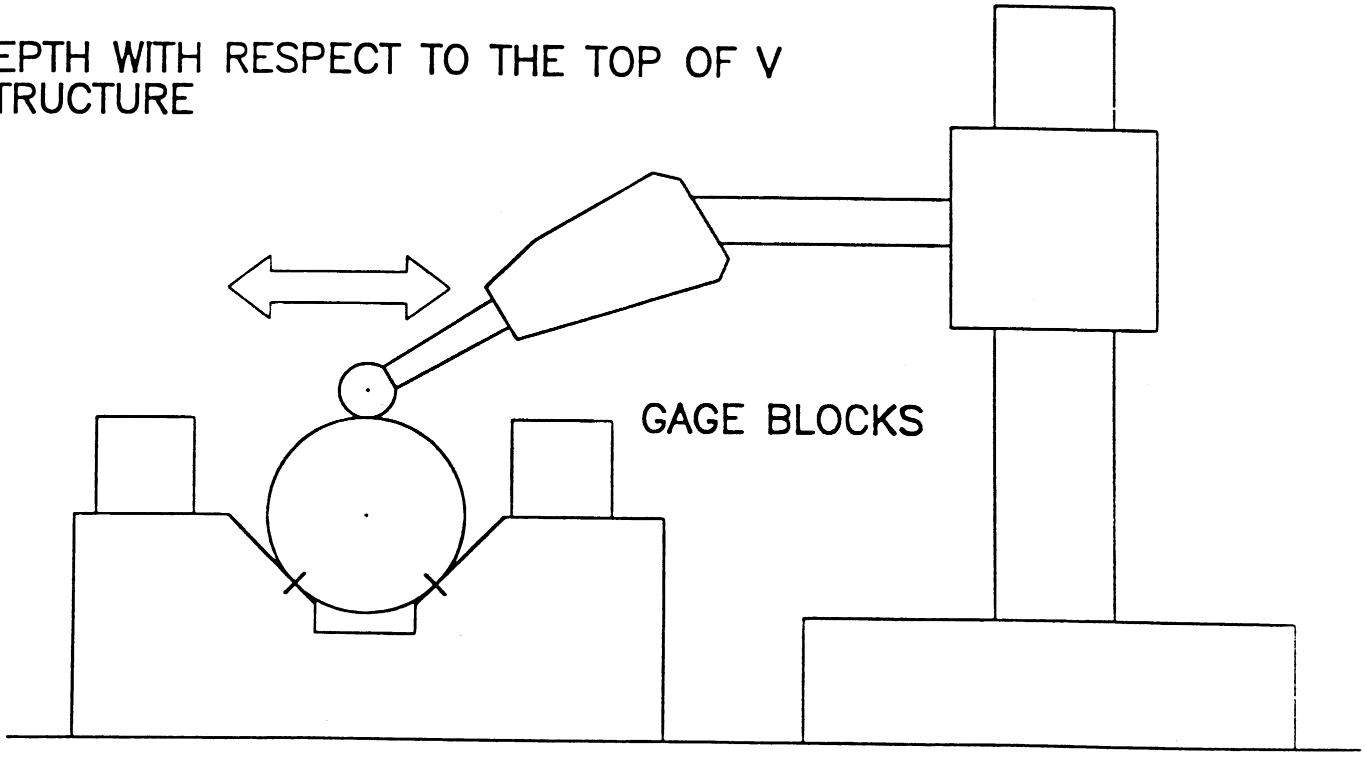
THE MEASUREMENT IS REPEATED AT A NUMBER OF AXIAL POSITIONS.

MEASURING V DEPTH

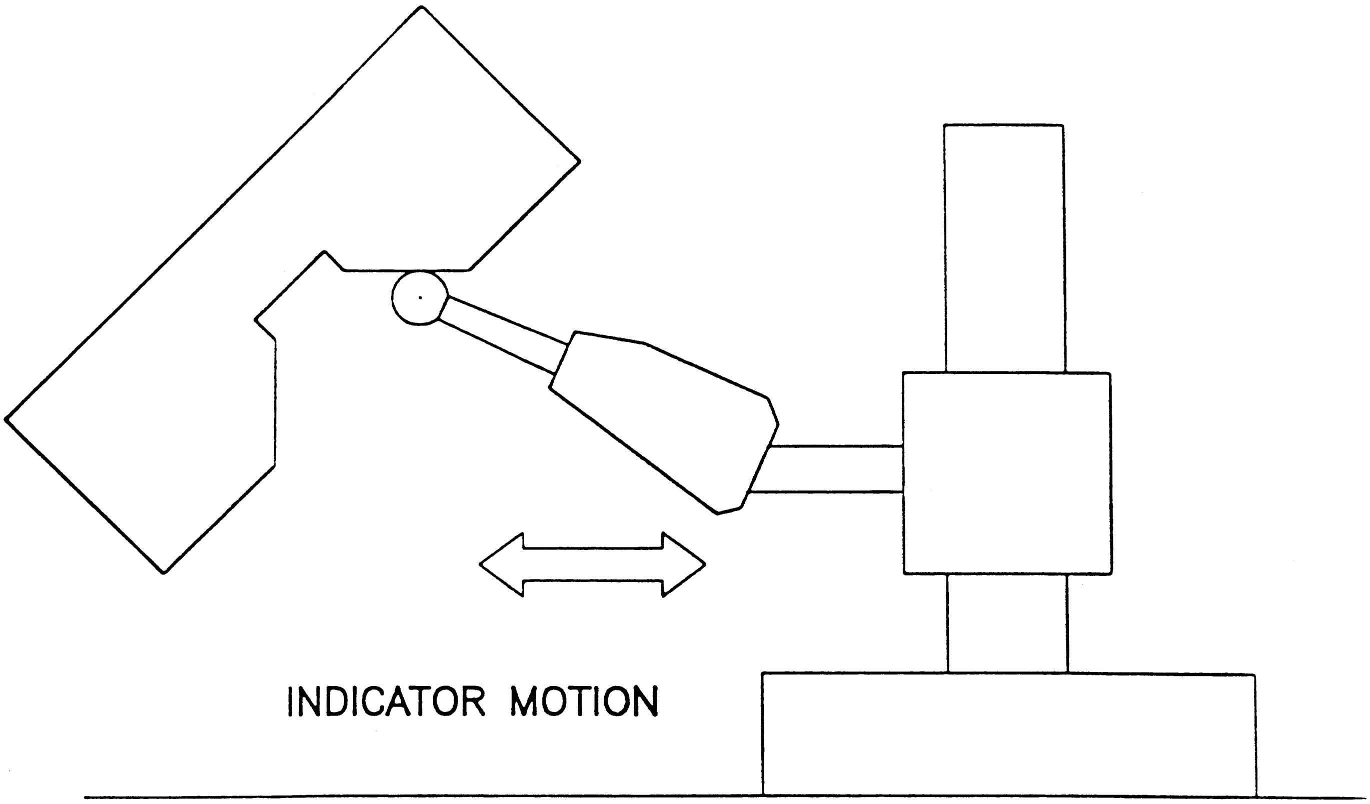
DEPTH WITH RESPECT TO BOTTOM OF V STRUCTURE



DEPTH WITH RESPECT TO THE TOP OF V STRUCTURE

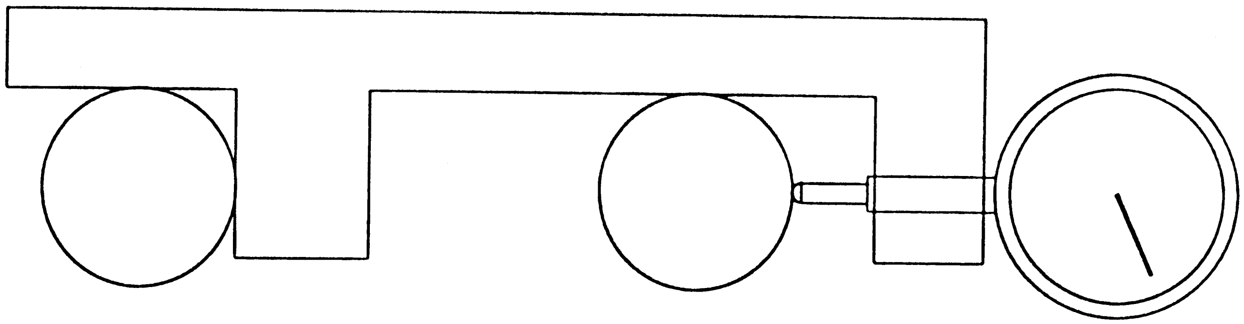


UPSIDE DOWN COMPARISON OF A CONTACT SURFACE WITH A SURFACE PLATE

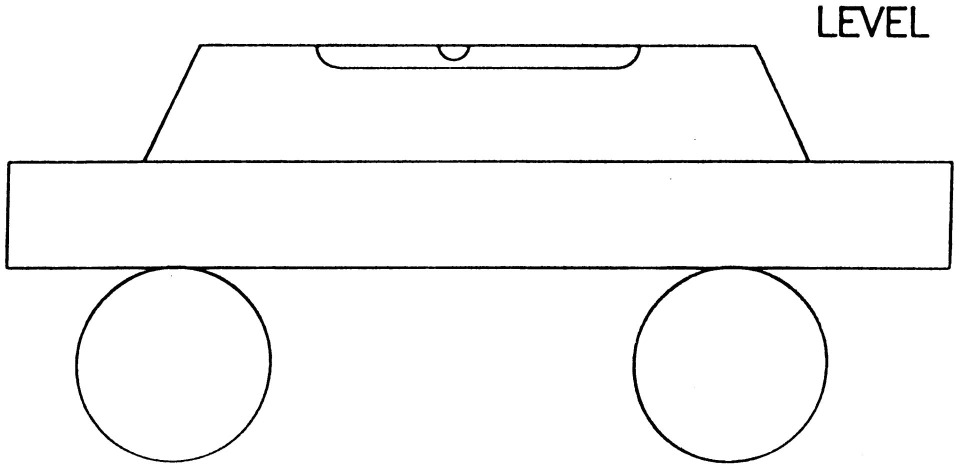


TESTING ROD VS

PARALLELNESS



COPLANARITY



CYLINDERS

ORIGINAL CONCEPT: ORDINARY ROUND CYLINDERS

GENERALIZED TO OTHER SHAPES

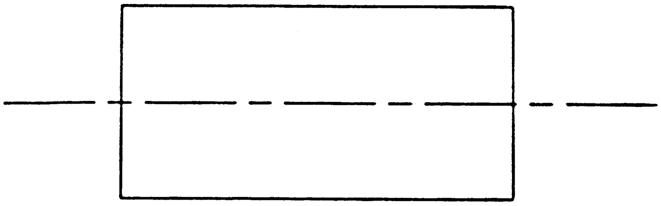
GENERAL DEFINITION: OBJECTS THAT HOLD OPTICAL ELEMENTS IN A V

SHAPE
  ROUND, NON ROUND

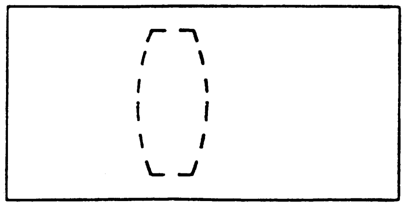
MACHINING

DIAMETER
LENGTH
MATERIAL
SURFACE TREATMENT

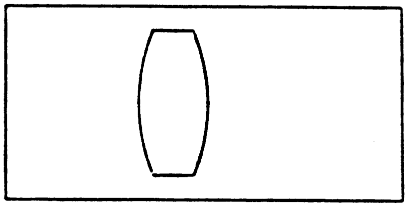
DIAGRAMS USUALLY SHOW SIMPLE SHAPE



INSIDE MACHINED AS NECESSARY TO HOLD ELEMENTS, SHOWN SCHEMATICALLY THUS:

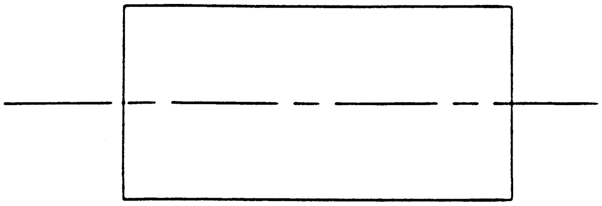


OR



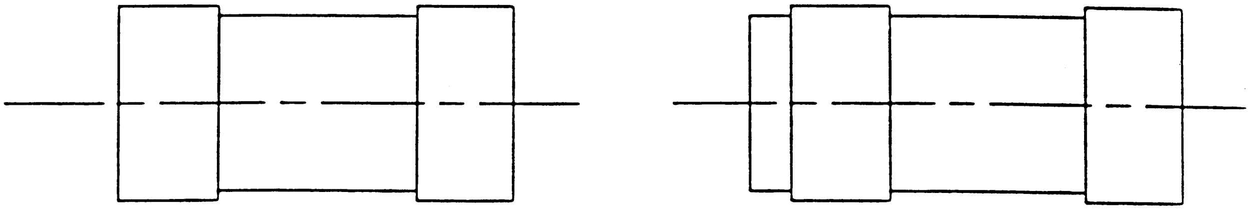
ROUND CYLINDERS

PLAIN

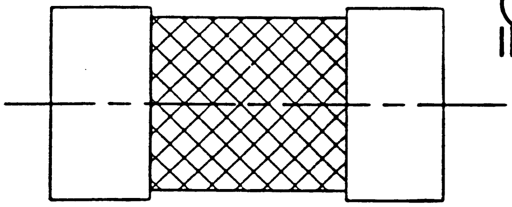


MAKES LINE CONTACT,
SEMI-KINEMATIC

UNDERCUT – MORE KINEMATIC, SHORTER LINE CONTACT
ALLOWS FOR CLAMPING MARKS

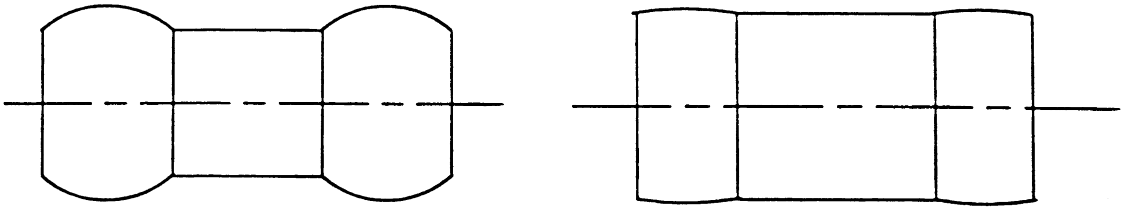


KNURLED

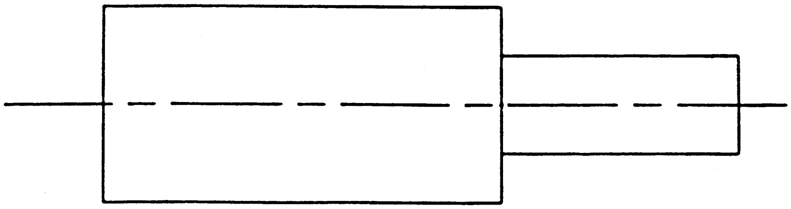


(CLEARANCE IS EXAGERRATED
IN THE FIGURES.)

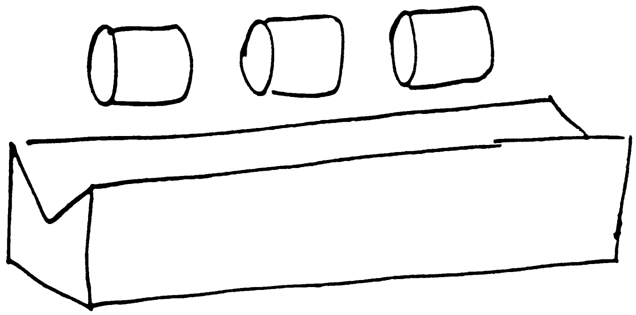
KINEMATIC "BONE" MAKES FOUR-POINT CONTACT WITH V.



WITH EXTENSION



MATCHING DIAMETERS



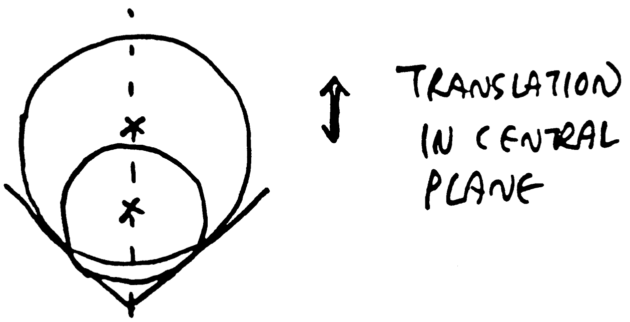
ABSOLUTE DIAMETER DOES NOT MATTER, BUT IDENTICALITY DOES.

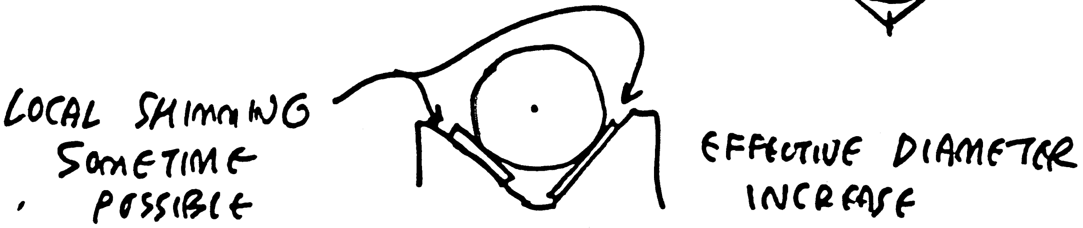
SPECIFY THIS WHEN ORDERING A NUMBER OF CYLINDERS.

FOR CRITICAL APPLICATIONS, NOMINALLY IDENTICAL CYLINDERS CAN BE SORTED TO FIND THOSE MOST ALIKE.

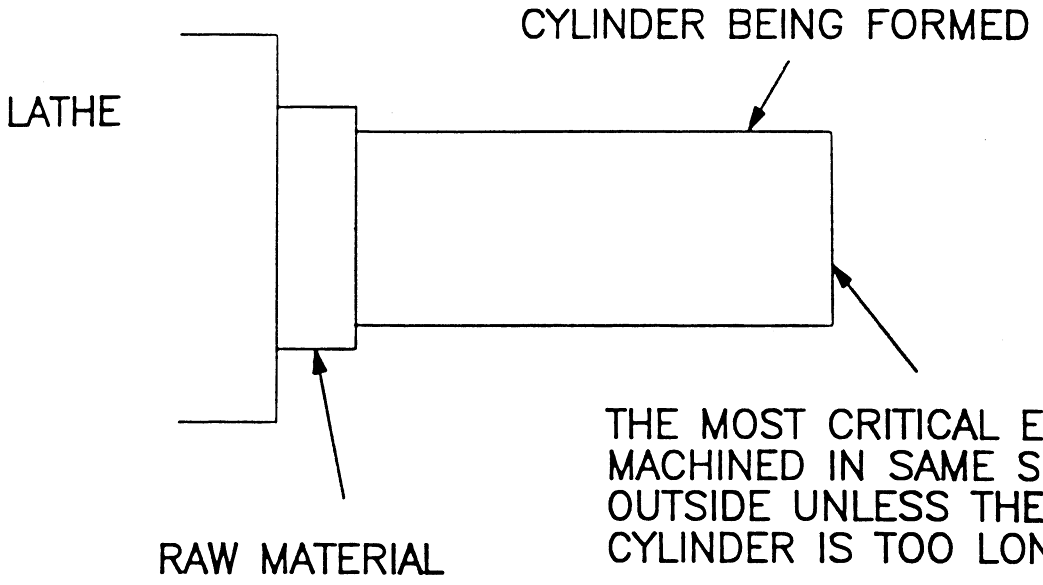
EFFECT OF DIAMETER ERROR IS DETERMINISTIC:

EFFECT OF DIAMETER DIFFERENCE (EXAGGERATED)





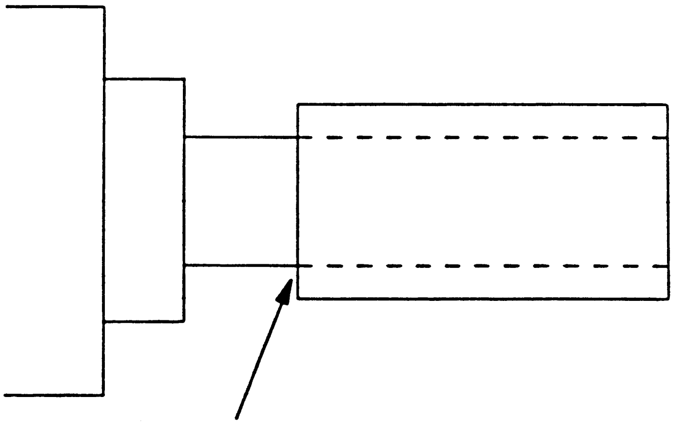
MACHINING ROUND CYLINDERS



THE MOST CRITICAL END IS MACHINED IN SAME SETUP AS OUTSIDE UNLESS THE CYLINDER IS TOO LONG.

CYLINDER IS HELD WITH A COLLET TO MACHINE OPPOSITE END.

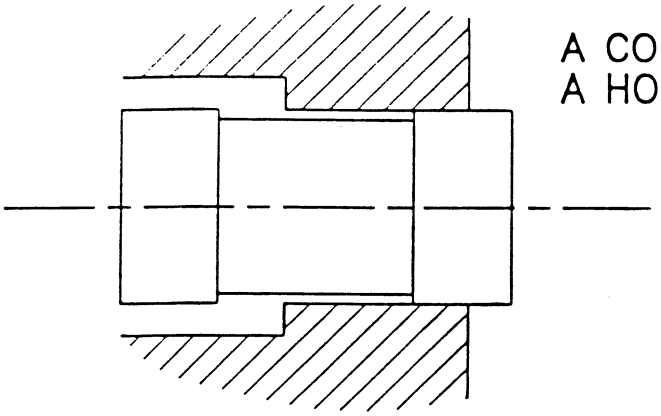
DOUBLE-ENDED MACHINING



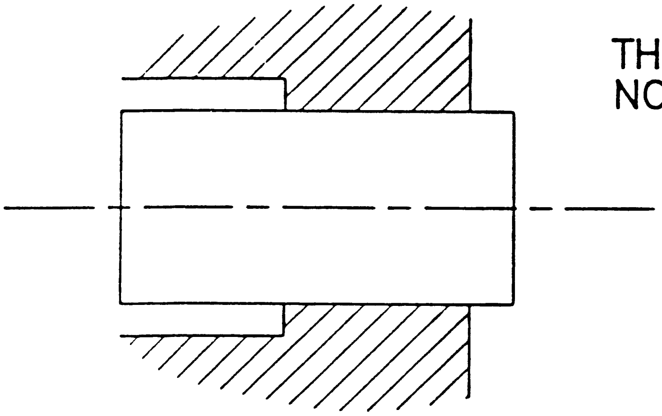
IT MAY BE POSSIBLE TO MACHINE THE INBOARD END WITHOUT REMOVING THE PART FROM THE LATHE, USING AS SUPPORT MATERIAL THAT IS REMOVED LATER WITH A LOOSE TOLERANCE FOR CLEARANCE.

END REVERSING AND UNDERCUT

BE SURE THAT HOLDING SURFACE OF THE COLLET IS LONG ENOUGH FOR A CYLINDER WITH UNDERCUT.

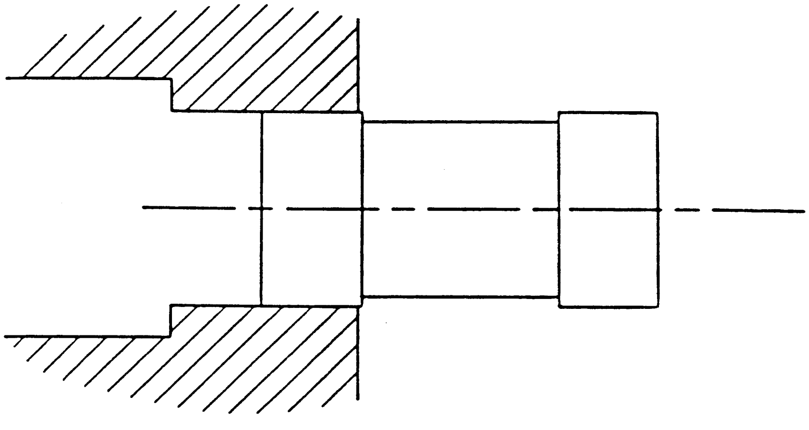


A COLLET WITH TOO SHORT A HOLDING SURFACE

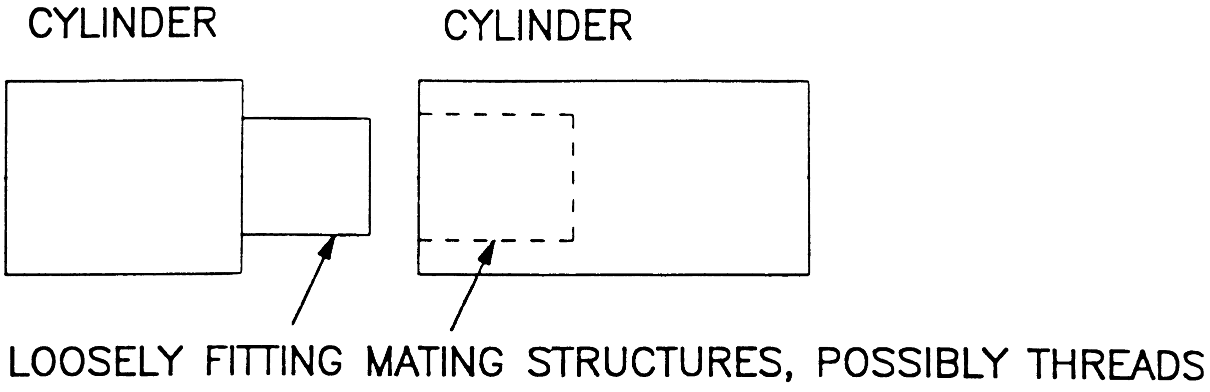


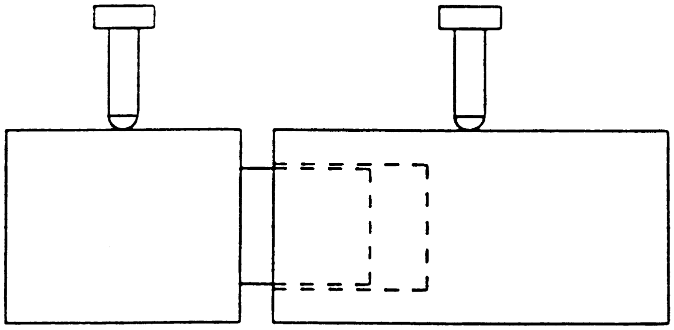
THE SAME COLLET WITH A NON–UNDERCUT CYLINDER

THE UNDERCUT, WHICH NEEDS NOT BE SO ACCURATE, CAN BE MACHINED LAST.



JOINING CYLINDERS AXIALLY





CYLINDERS SECURED IN ALIGNMENT IN A V

MATED PERMANENTLY WITH CEMENT OR VOFIMA

"VOFIMA" = VOLUME FILLING MATERIALS

HARDENS, BUT DOES NOT NECESSARILY ADHERE

AKA "LIQUID SHIM"

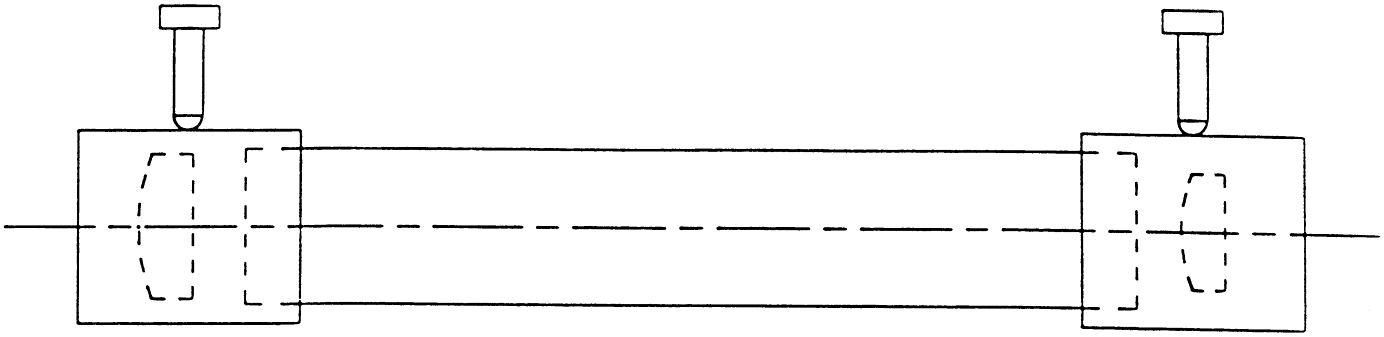
A V WORKS AS A FIXTURE TO MAKE APPARATUS FOR USE IN ITSELF.

JOINING CYLINDERS AXIALLY

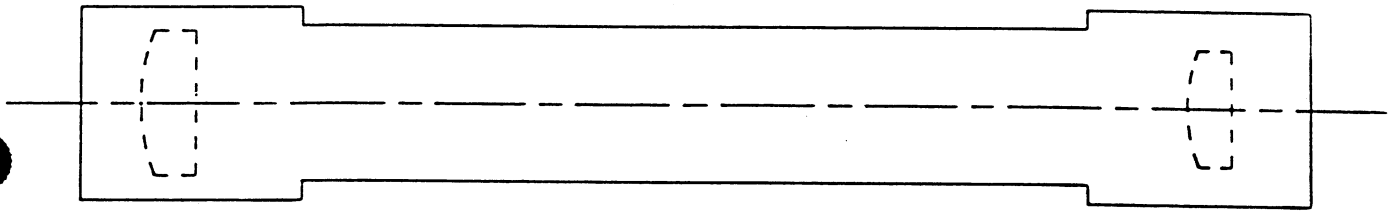
SEPARATED

- MORE EXAMPLES

END CYLINDERS CLAMPED IN A V WITH PROPER AXIAL SPACING

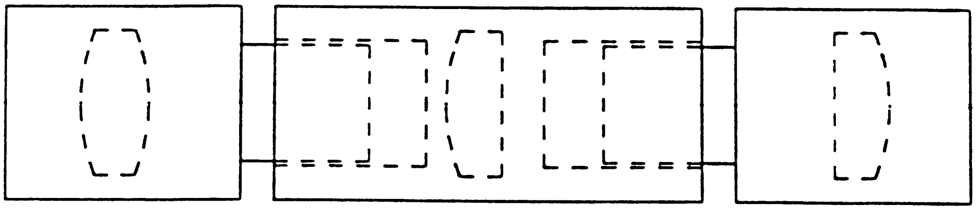


CENTRAL TUBE HELD AT BOTH ENDS WITH CLEARANCE
VOFIMA OR CEMENT ADDED

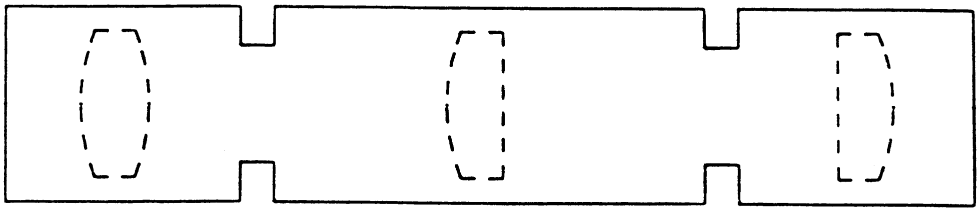


RESULTING STRUCTURE

THREE UNITS, EACH WITH A CENTERED LENS



FINAL OBJECT

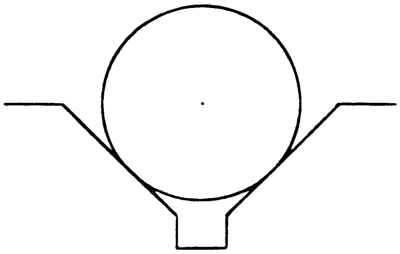


CYLINDERS IN CYLINDERS

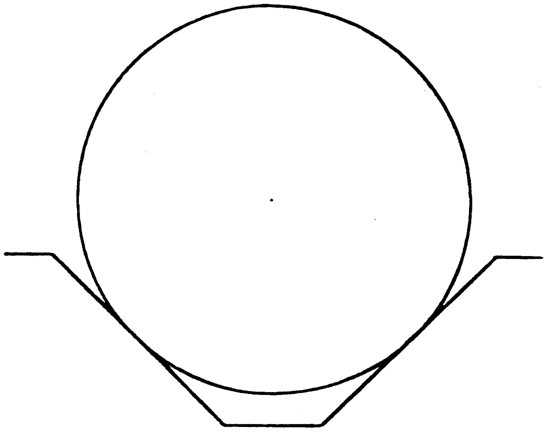
IF TWO OR MORE DIFFERENT CYLINDER SIZES ARE USED, SMALLER CYLINDERS CAN BE USED WITH LARGER ONES.

EXAMPLE:

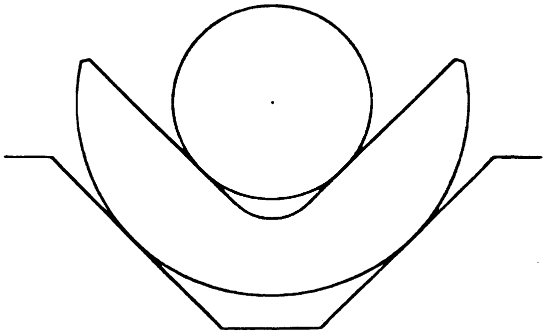
SMALLER CYLINDER AND V

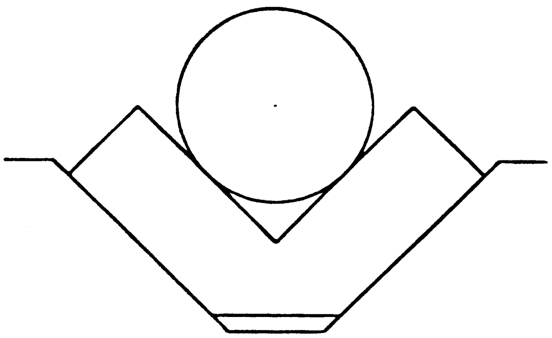


LARGER

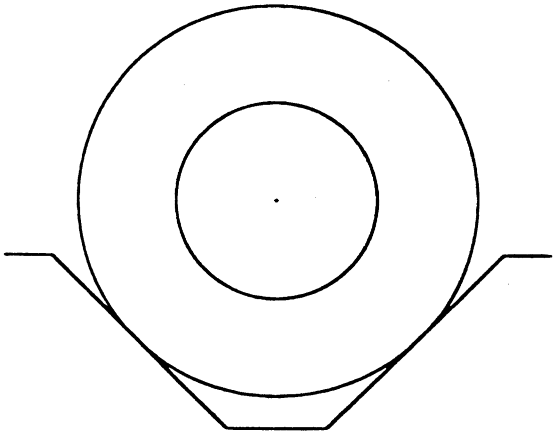


V ADAPTORS





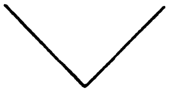
SLIP FIT



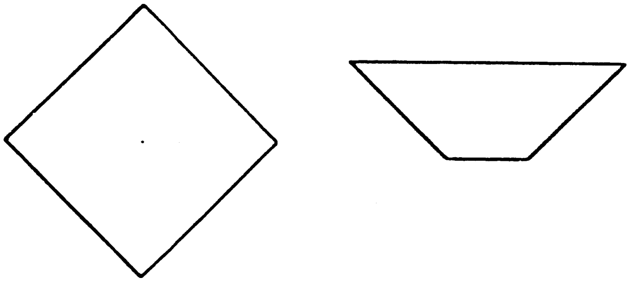
MISCELLANEOUS NON–ROUND CYLINDER SHAPES FOR 90° V

THESE RESTRAIN 5 DEGREES OF FREEDOM, ALLOWING ONLY AXIAL MOTION.

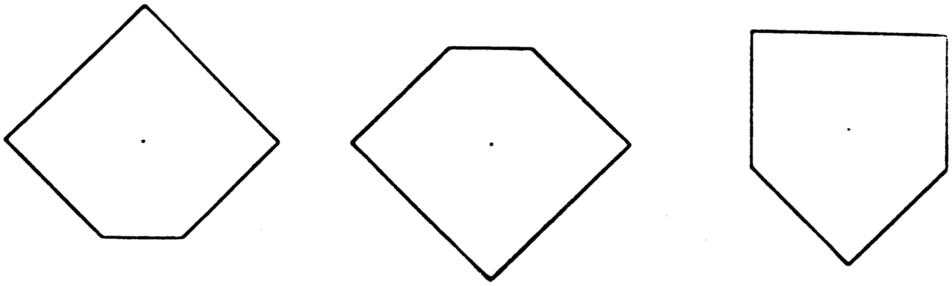
COMMON SIDES:



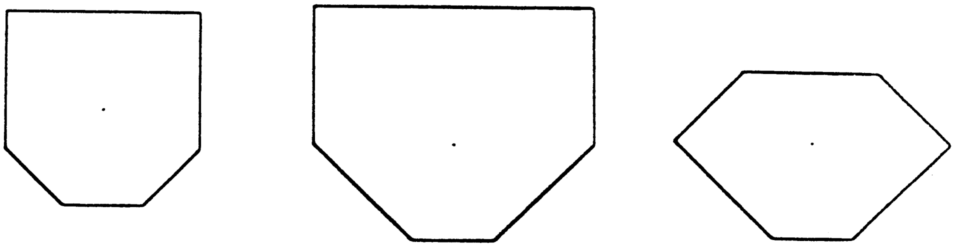
FOUR SIDED



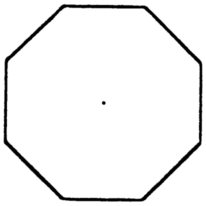
FIVE SIDED



SIX SIDED



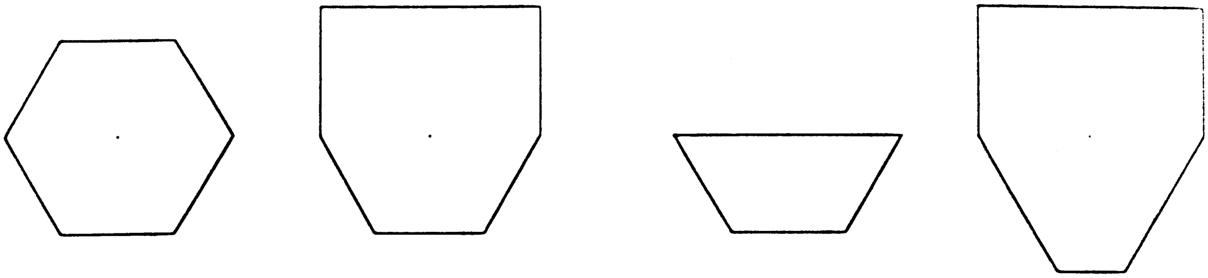
EIGHT SIDED



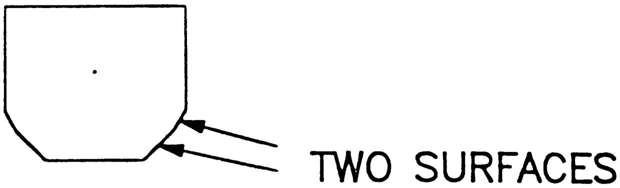
THESE SHAPES NOMINALLY MAKE PLANE–TO–PLANE CONTACT WITH A 90° V. THEY CAN BE MADE MORE KINEMATIC WITH ADDITIONAL FEATURES SHOWN LATER.

MISCELLANEOUS NON-ROUND CYLINDER SHAPES

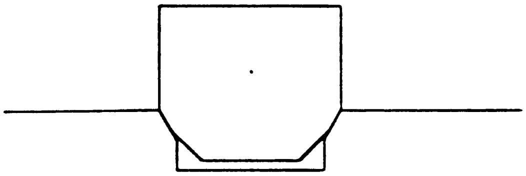
FOR 60° VS



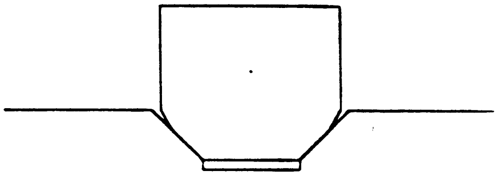
FOR 60° OR 90° V



IN A 60° V

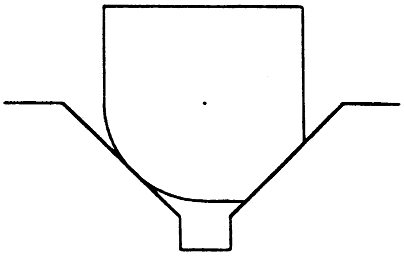


IN A 90° V



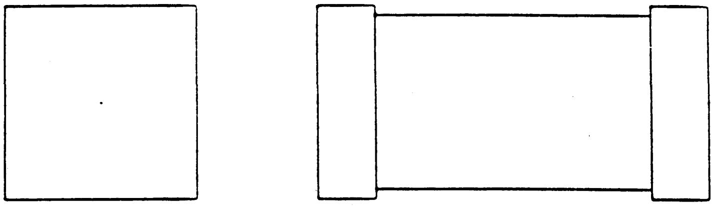
HALF ROUNDED

SEMI–KINEMATIC LINE CONTACT ON
ONE SIDE WITH ANTI–ROTATION
PLANE ON THE OTHER

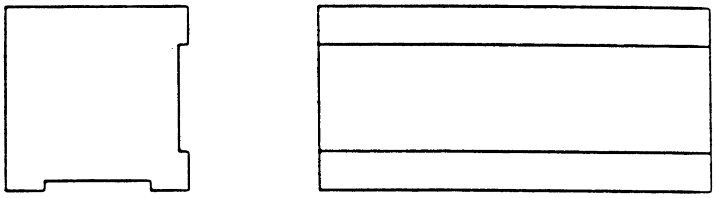


MODIFICATIONS TO PLANAR SURFACES FOR MORE KINEMATIC CONTACT

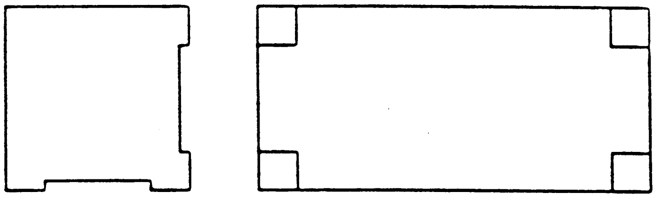
CENTRAL UNDERCUT



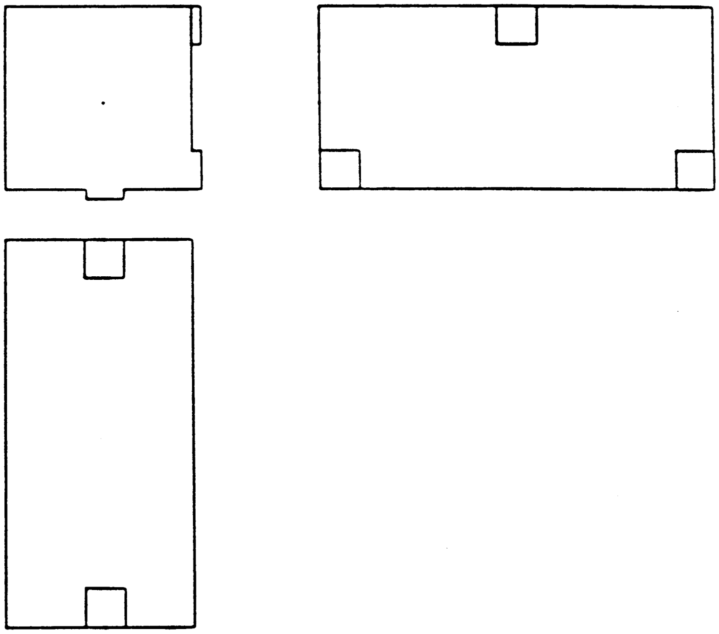
LONGITUDINAL UNDERCUT



FOUR FEET PER SIDE



SEMI–KINEMATIC WITH
FIVE PADS



SOME OF THESE FORMS WORK ONLY WITH A DEEP V.

ANALOGOUS SHAPES APPLY TO HEXAGONAL CYLINDERS.

CLAMPS AND RESTRAINTS

STRUCTURES THAT HOLD CYLINDERS IN PLACE IN VS

DIFFERENT DEGREES OF PERMANENCE

EASY IN AND OUT FOR LAB WORK TO FOREVER

POSITIVE RESTRAINT

FRICTION PRODUCED BY PRESSURE

COEFFICIENTS OF FRICTION
MACHINING MARKS

DEGREE OF INFLUENCE OF CLAMPING

SPRINGY

SYMMETRICAL FORCE IS USUALLY PREFERRED.

APPLYING RESTRAINT SHOULD NOT UPSET ALIGNMENT.

SMALL DAMAGE TO CYLINDERS MAY BE ACCEPTABLE, IF FUTURE ALIGNMENT IS NOT AFFECTED.

EXAMPLE: SET SCREW MARKS IN UNDERCUT REGION OF CYLINDER

SOMETIMES REPETITIVE REMOVAL AND REPLACEMENT ARE REQUIRED, E.G. IN PRODUCTION FIXTURES

THERMAL EFFECTS

TYPICAL LABORATORY ARRANGEMENT

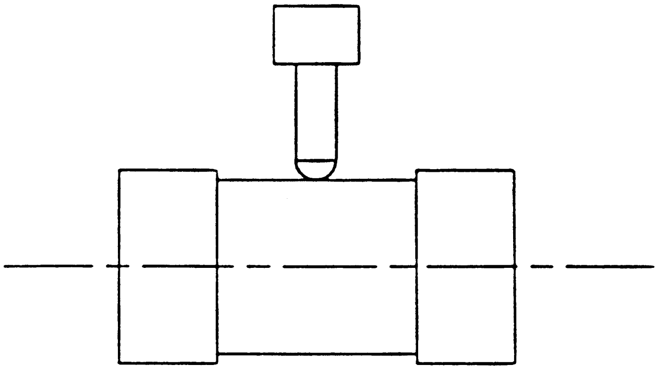
CLAMP NEAR CENTER

CLAMP ON UNDERCUT

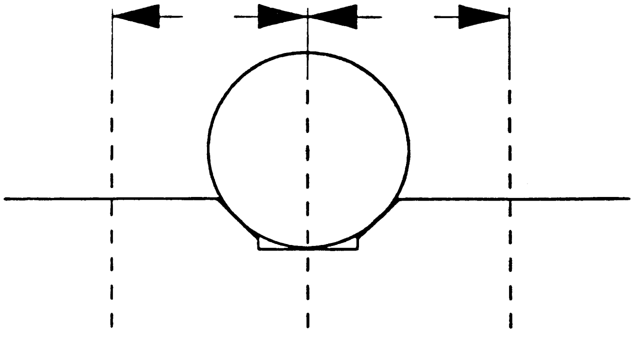
LOW FORCES

AXIAL RESTRAINT RESULTS FROM FRICTION BETWEEN CYLINDER AND V.

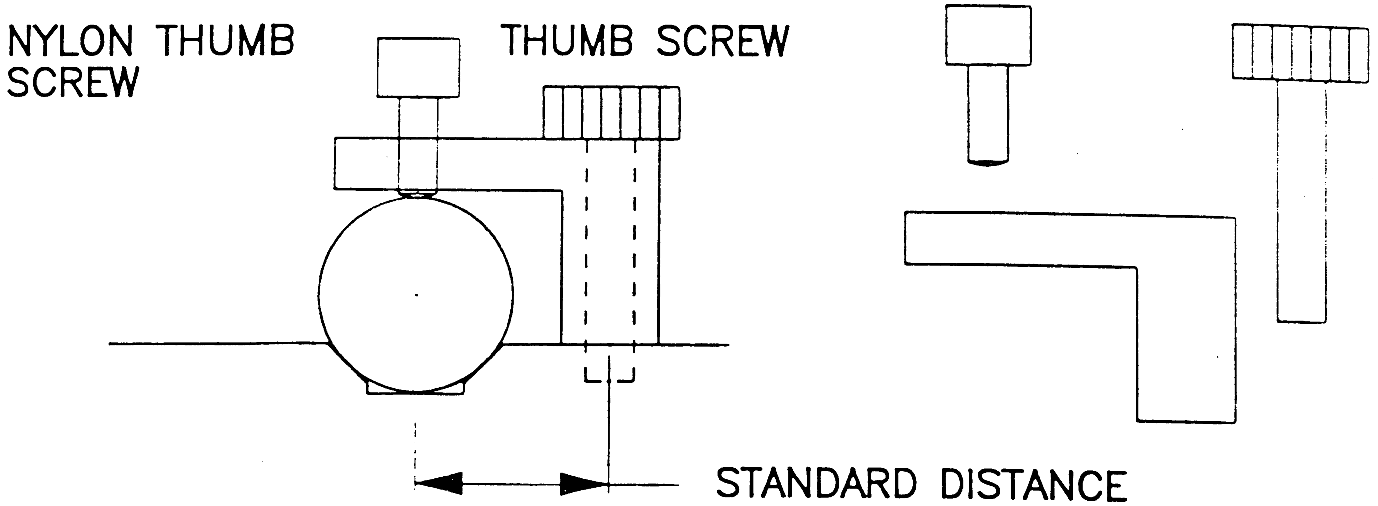
SCHEMATIC SIDE VIEW OF A CLAMPED CYLINDER

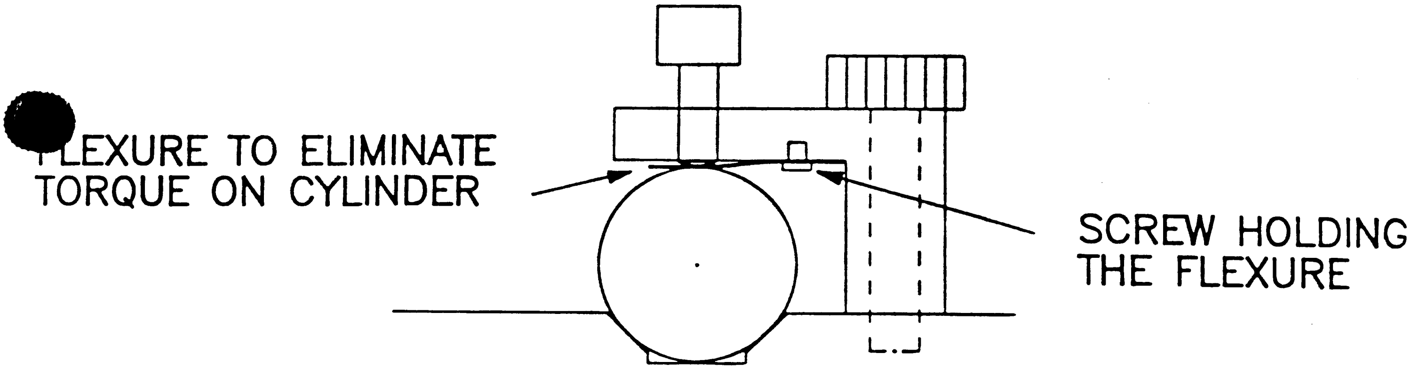


STANDARDIZE CLAMP SCREW LOCATIONS



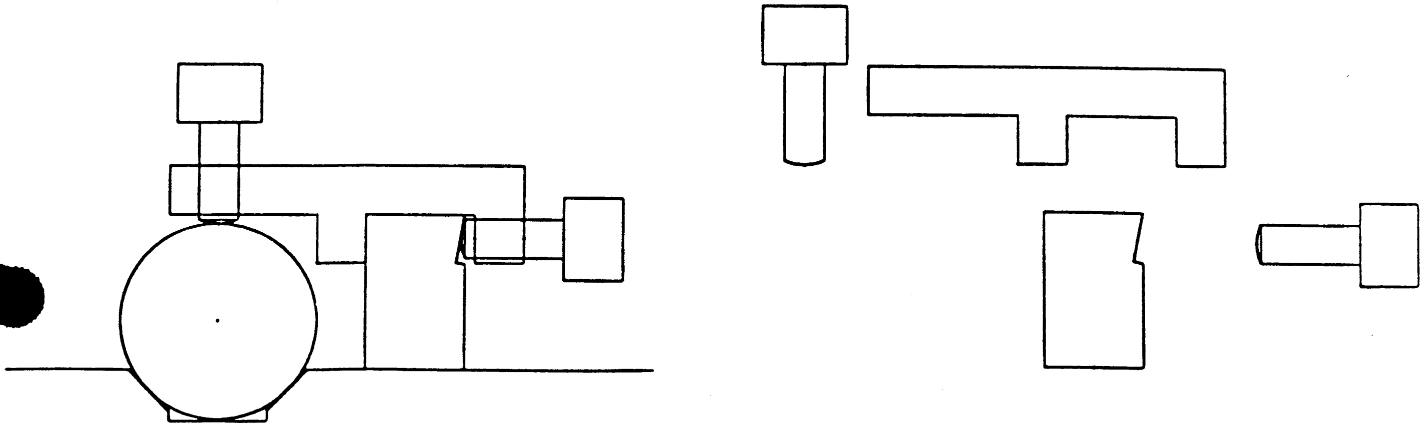
SIMPLE LABORATORY CLAMPS



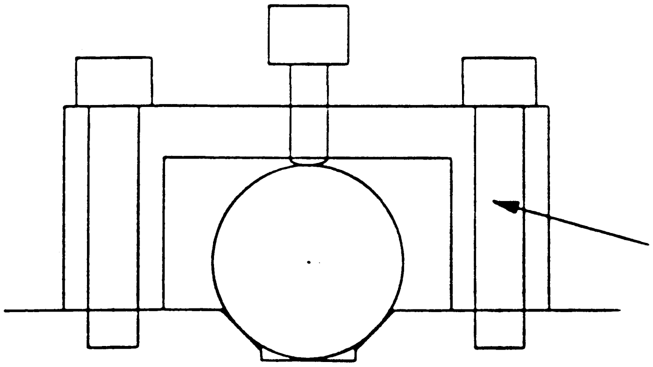


THE FLEXURE CAN BE MADE OF SHIM STOCK.

RAIL FOR CLAMPS ALLOWING ARBITRARY AXIAL POSITIONING

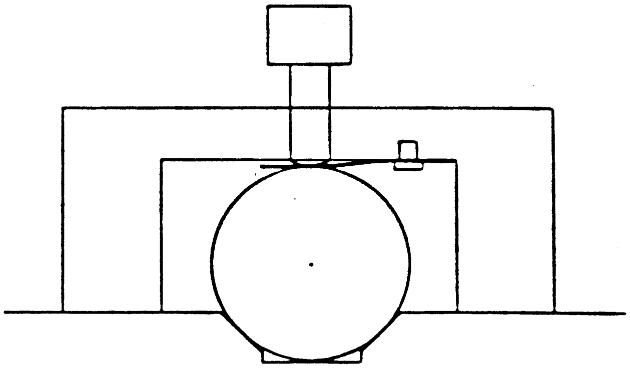


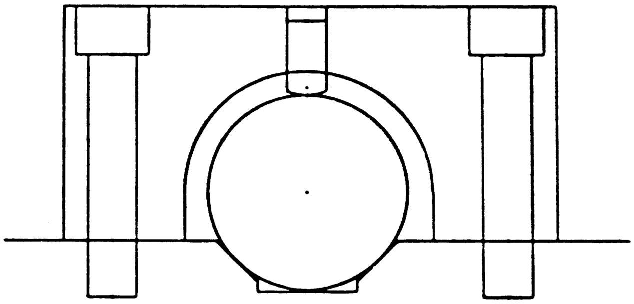
BRIDGE CLAMPS



THE BRIDGE SURFACE CAN FUNCTION AS AN AXIAL STOP

FLEXURE TO ELIMINATE TORQUE ON CYLINDER



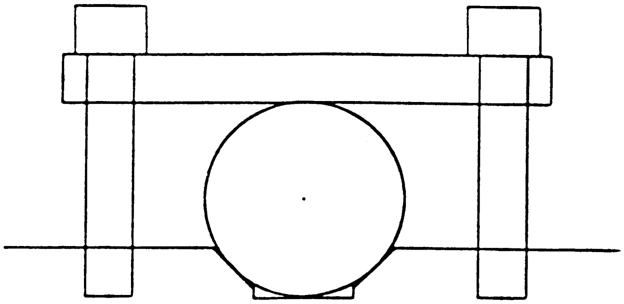


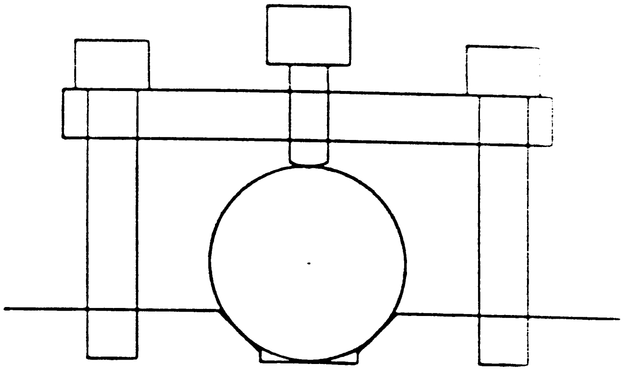
SUBMERGED SCREW HEADS SIMPLIFY LIGHT SHIELDING.

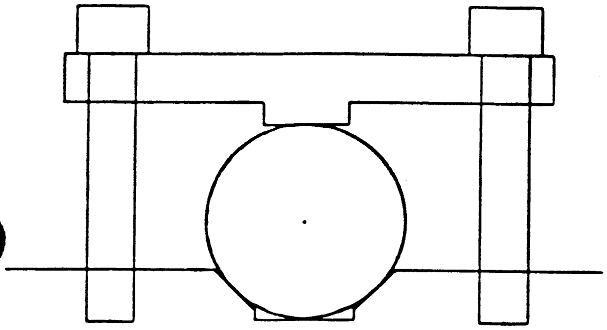
STRAPS

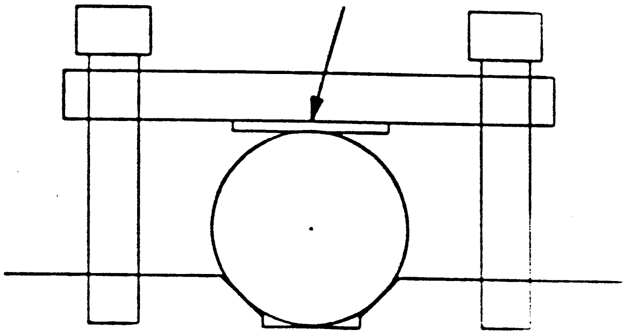
STRAPS CAN BE RIGID OR FLEXIBLE.

SCREWS, THUMB SCREWS, THREADED ROD AND NUTS



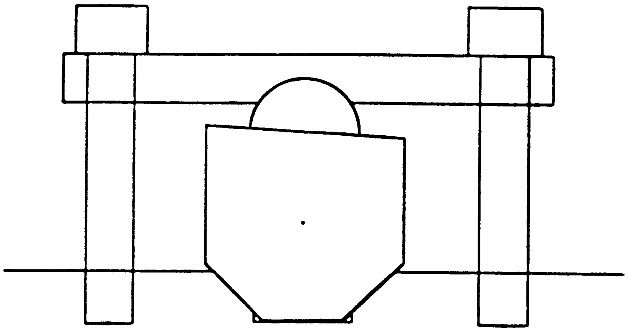


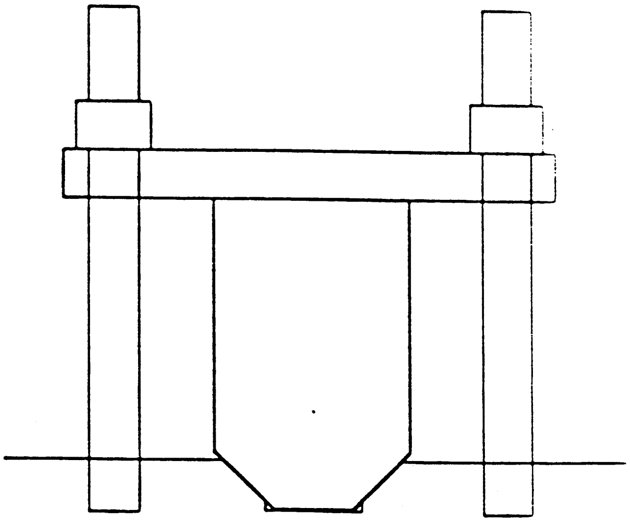




SOFT CONTACT AREA

SELF-ALIGNING STRUCTURE

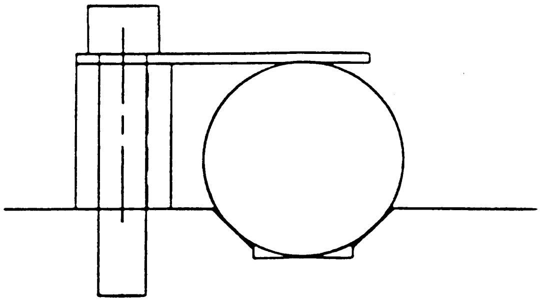


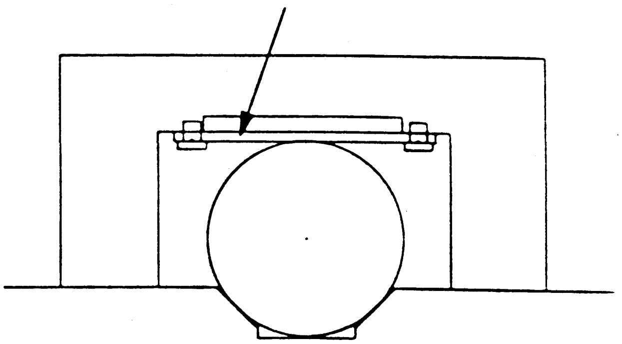


TALL OBJECTS

SPRINGY CLAMPS

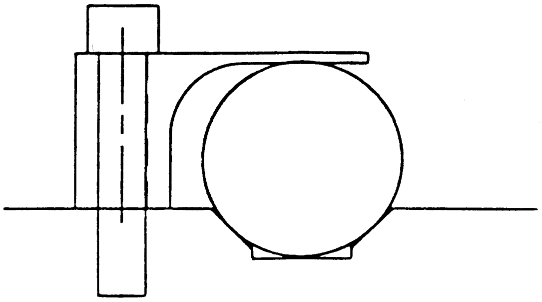
FABRICATED WITH FLAT SPRINGS, SINGLE OR MULTIPLE

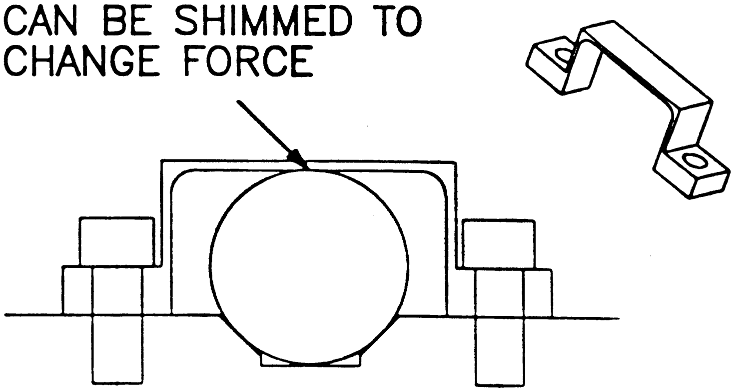




LOOSELY HELD

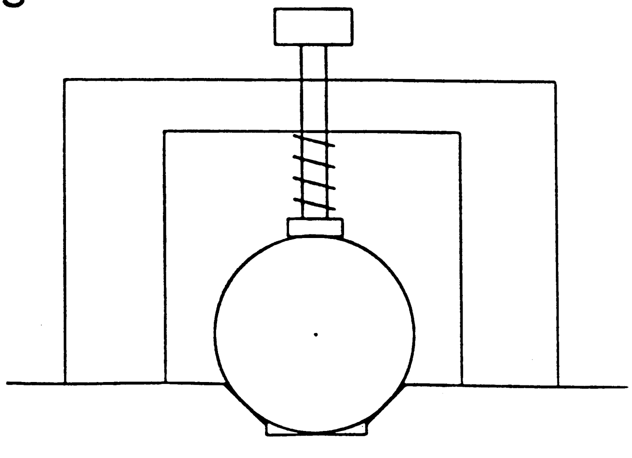
MONOLITHIC WITH SPRINGY SECTIONS





CAN BE SHIMMED TO CHANGE FORCE

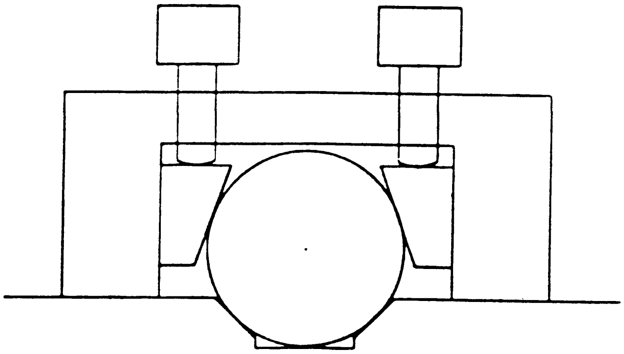
FABRICATED WITH HELICAL SPRINGS

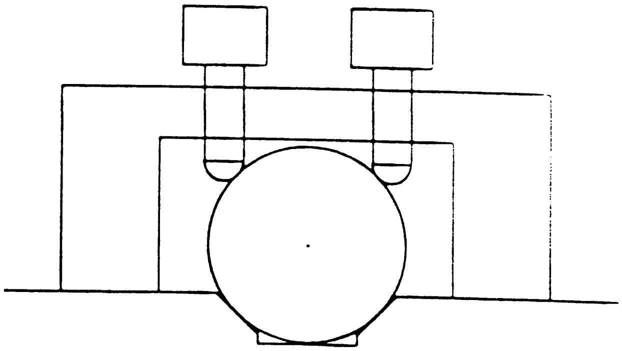


SPRING PLUNGER

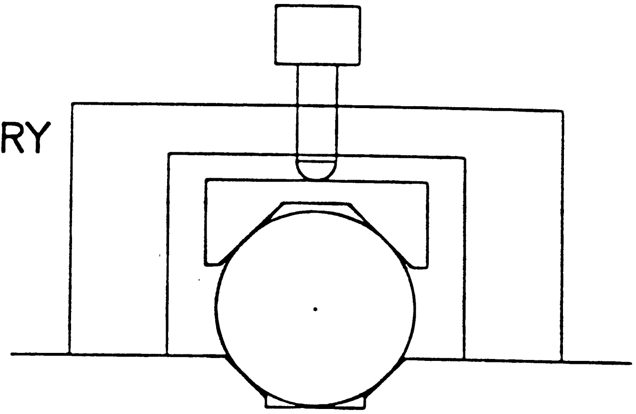
CONTROLLABLE FORCE THAT VARIES LITTLE WITH CYLINDER DIAMETER

MISCELLANEOUS CLAMPS

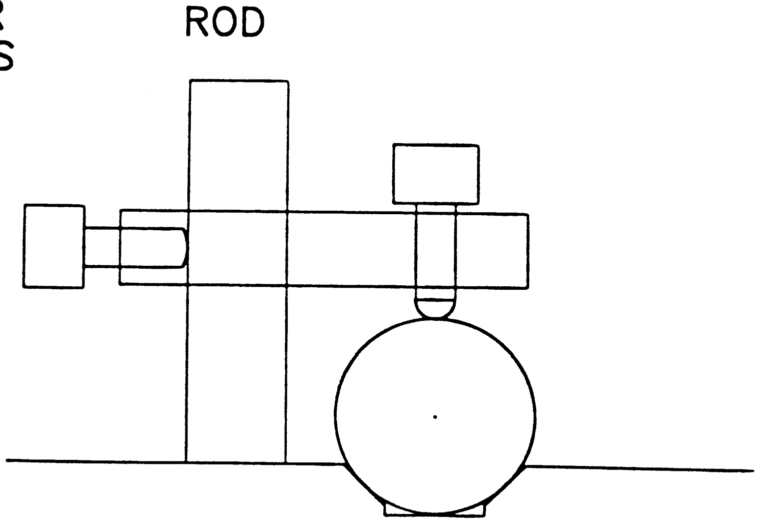




FOUR-FOLD CLAMPING SYMMETRY



ARRANGEMENT FOR DIFFERENT HEIGHTS

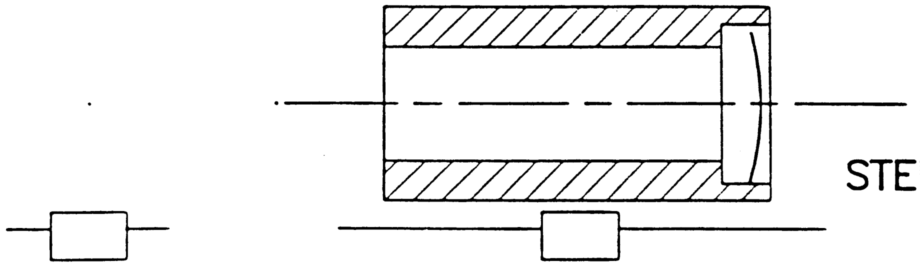


MAGNETIC FORCE

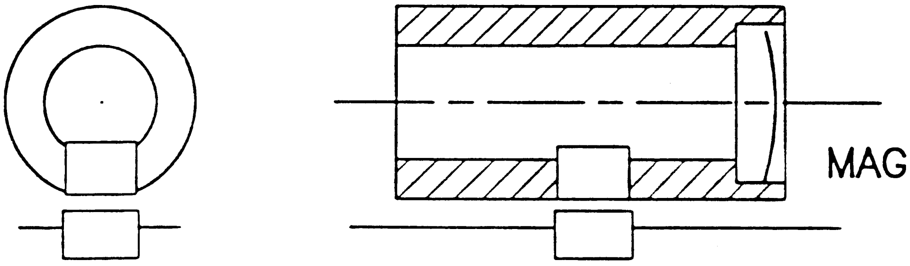
MAGNETISM CAN BE USED FOR
- CYLINDERS THAT MUST BE SWITCHED IN AND OUT
- TO HOLD CYLINDERS WHILE CEMENT OR VOFIMA DRIES

WATCH OUT FOR AXIAL FORCES.

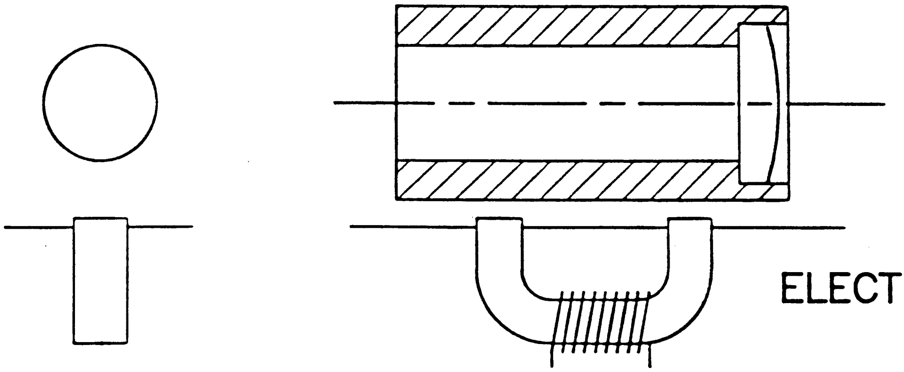
EXAMPLES:



MAGNET IN V STRUCTURE

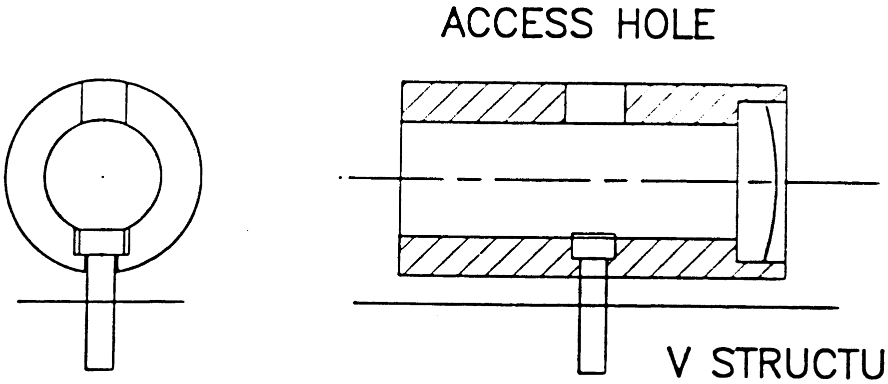


MAGNET IN CYLINDER

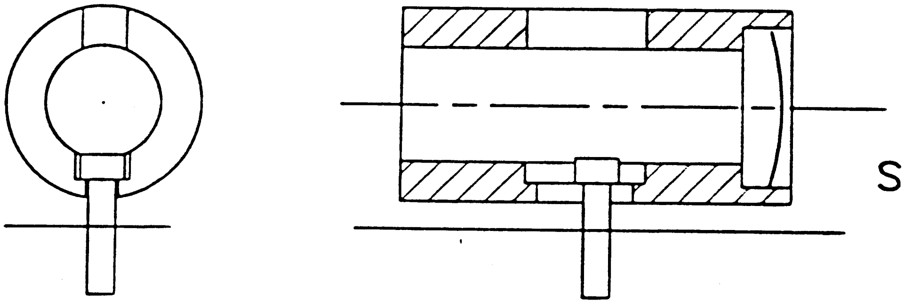


ELECTROMAGNET

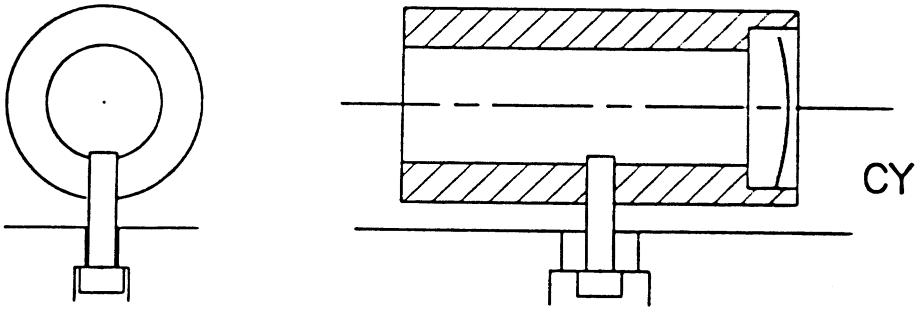
RESTRAINTS FROM THE BOTTOM OF THE V



V STRUCTURE TAPPED



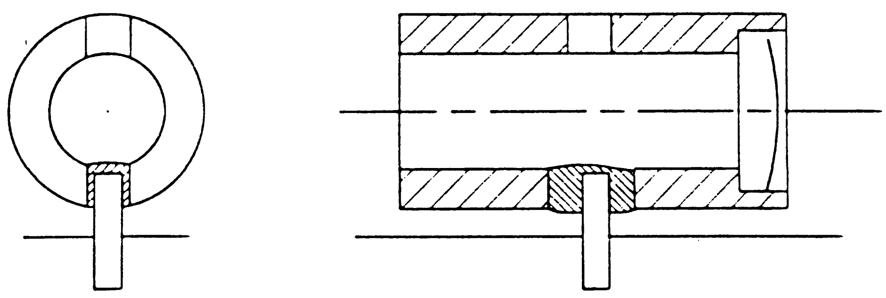
SLOT IN CYLINDER



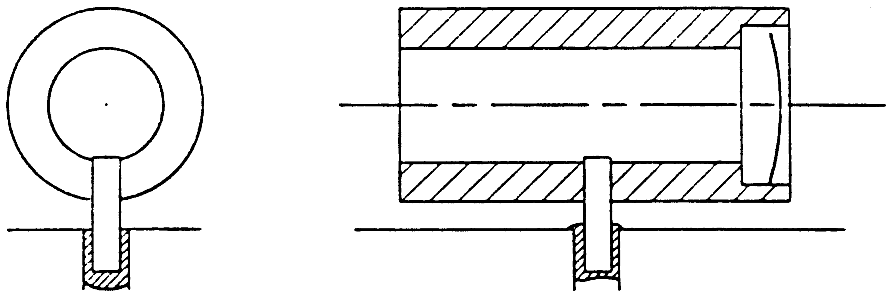
CYLINDER TAPPED

SLOT IN V STRUCTURE

VOFIMA RESTRAINTS

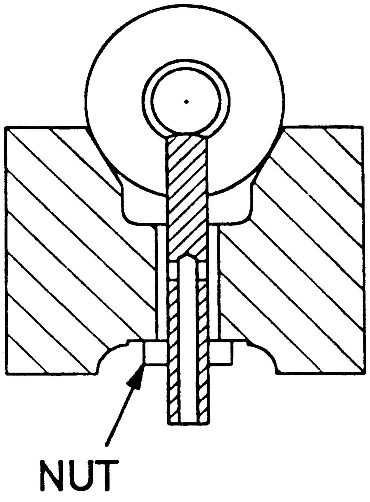


ROD SCREWED OR PRESSED INTO V STRUCTURE,
OVERSIZE OPENING IN CYLINDER



ROD SCREWED OR PRESSED INTO CYLINDER,
OVERSIZE OPENING IN V STRUCTURE

VOFIMA APPLIED THROUGH THREADED ROD



OBTAINING ROTATIONAL SYMMETRY

CENTERING METHODS

CENTERING CONES

TOROIDAL LENS MOUNTS

CENTERING METHODS

GOAL: POSITIONING AND SECURING ROTATIONALLY SYMMETRICAL OPTICAL ELEMENTS TO A CYLINDER LOCATED WRT A V AXIS.

THIS SECTION

MEASURING/QUALIFYING/TESTING THE DEGREE OF CENTRATION OF A ROTATIONAL ELEMENT RELATIVE TO THE AXIS OF A CYLINDER AND/OR THE V AXIS.

SOME OF THE METHODS WORK WITH NON-ROUND CYLINDERS.

SOME METHODS TEST CENTRATION RELATIVE TO THE CYLINDER AND NOT THE V. IN THIS CASE A CYLINDER SIZE ERROR RESULTS IN ERROR RELATIVE TO V.

THREE METHODS OF CENTERING

(1) CENTERING IN A ROUND CYLINDER BY ROTATING THE CYLINDER IN A V

(2) CENTERING IN A V WITHOUT ROTATION

(3) VIRTUAL CENTERING

(1) CENTERING IN A CYLINDER BY ROTATION IN A V

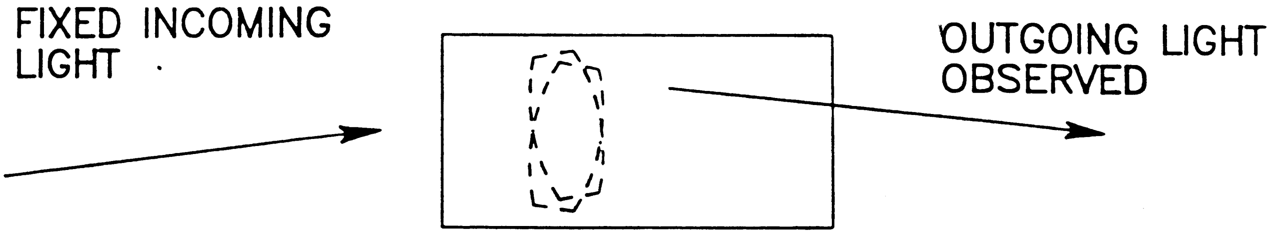
DEPENDS ON THE ROUNDNESS OF THE CYLINDER.

CENTERS TO THE AXIS OF CYLINDER, REGARDLESS OF ITS DIAMETER.

DOES NOT DEPEND ON PREVIOUSLY CENTERED OBJECTS.

PRINCIPLE

OPTICS IN A ROUND CYLINDER

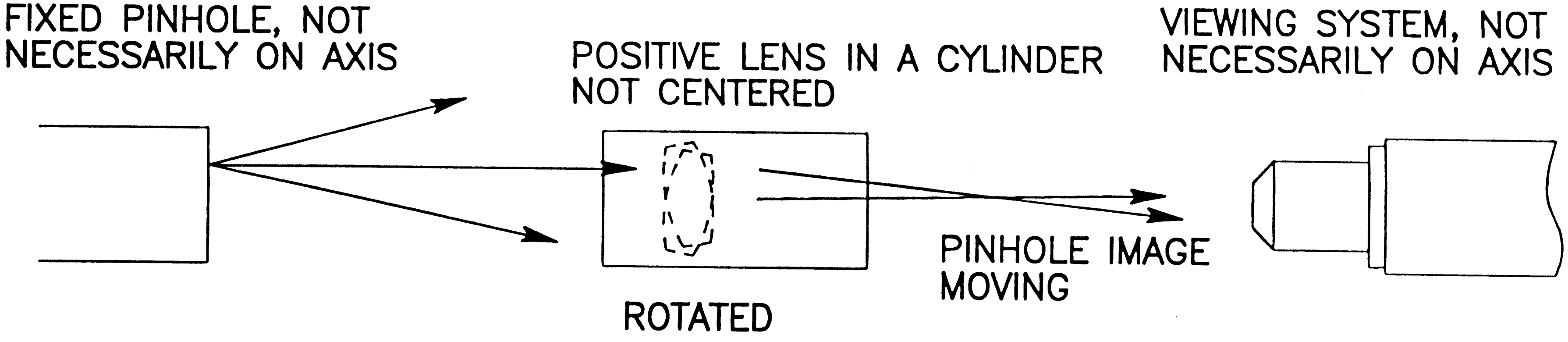


CYLINDER ROTATED IN A V

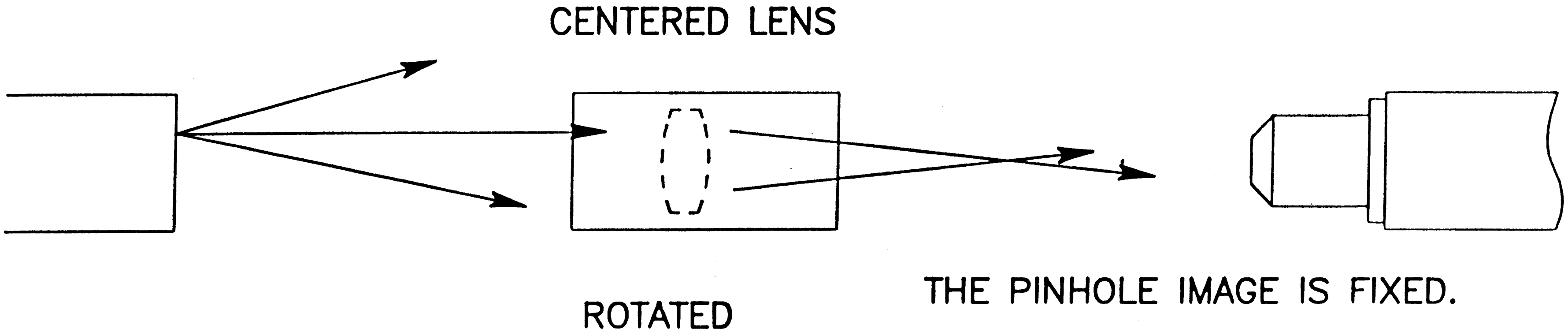
IF THE OPTICS IS CENTERED IN THE CYLINDER, THE OUTGOING LIGHT IS UNCHANGED BY ROTATION.

REGARDLESS OF CYLINDER DIAMETER

EXAMPLE

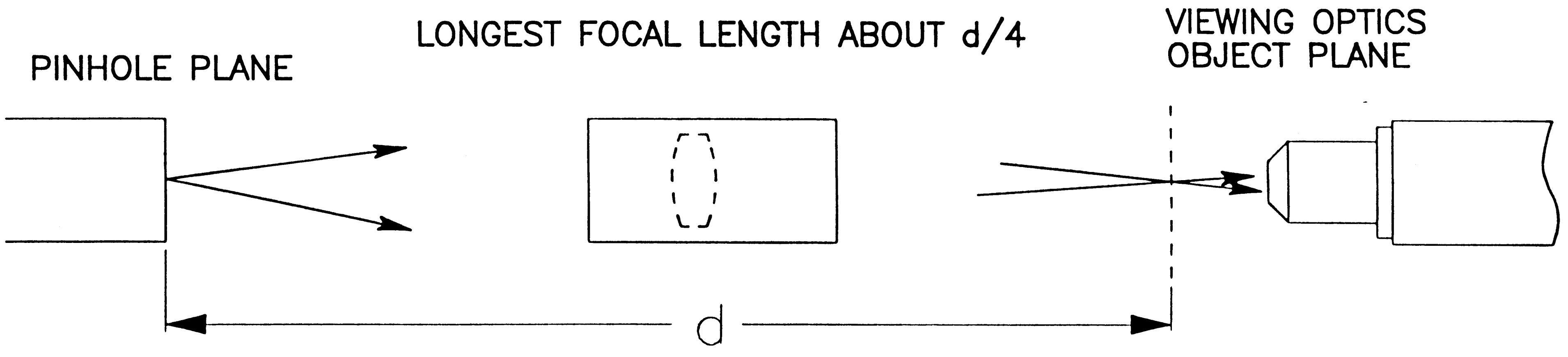


THE GREATEST SENSITIVITY TO MOTION IS OBTAINED BY OBSERVING A PINHOLE IMAGE.



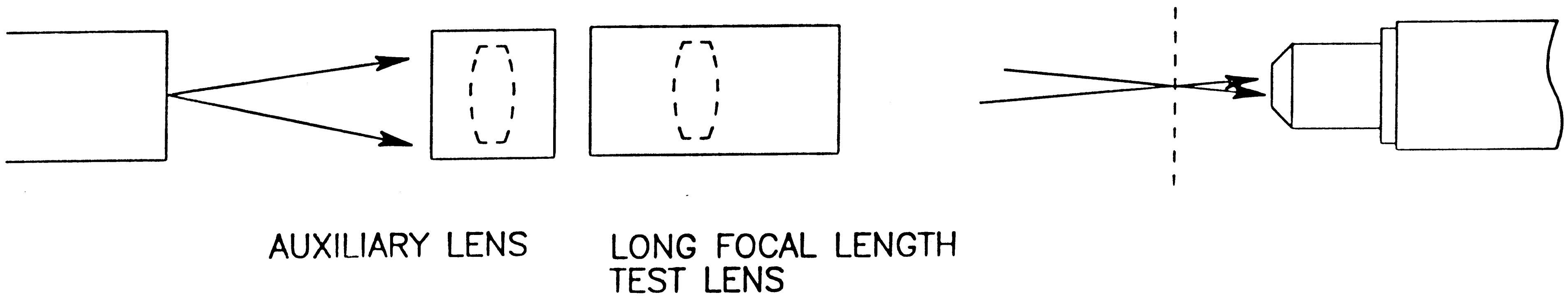
THE PINHOLE IMAGE IS FIXED.

THE CYLINDER DIAMETERS COULD DIFFER.

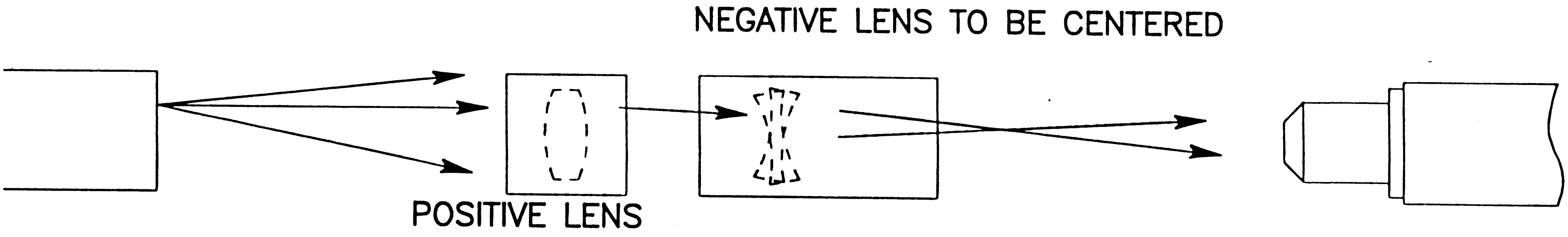


POSITIVE LENS ADDED TO FIXED PART OF APPARATUS.

IT NEED NOT BE ACCURATELY CENTERED.



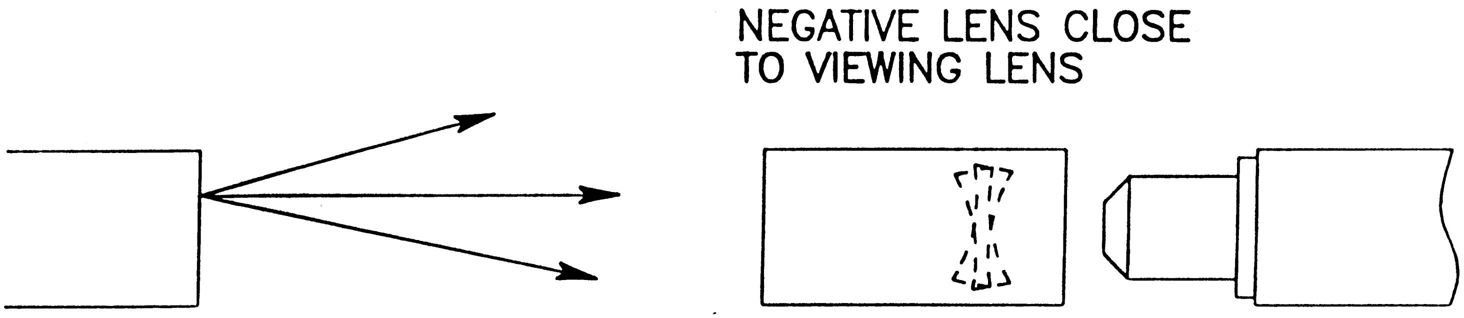
NEGATIVE LENSES



A FIXED POSITIVE LENS IS ADDED TO THE APPARATUS SO AN ACCESSIBLE PINHOLE IMAGE IS PRODUCED.

THIS LENS NEEDS NOT BE ACCURATELY CENTERED.

ANOTHER METHOD

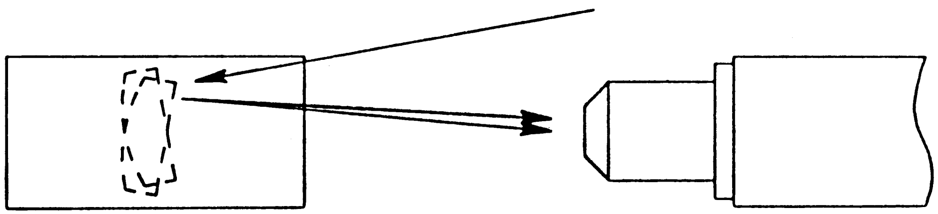


THE WORKING DISTANCE OF THE OBJECTIVE IS LONG ENOUGH TO REIMAGE THE VIRTUAL IMAGE OF THE PINHOLE FORMED BY THE NEGATIVE LENS.

REFLECTED LIGHT

THE SAME PRINCIPLES APPLY WITH REFLECTION.

REFLECTION CAN BE USED TO EXAMINE INDIVIDIUAL OUTER SURFACES.



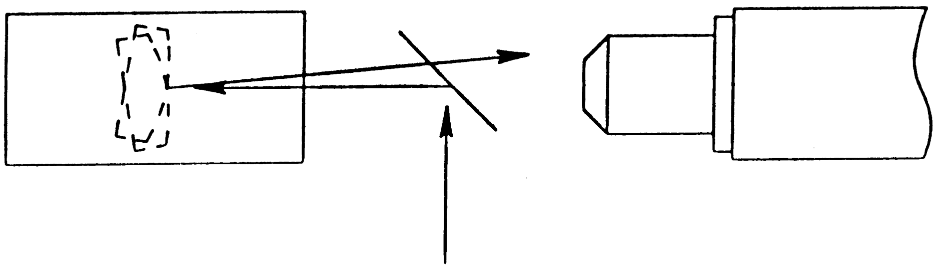
UNCENTERED OPTICAL
ELEMENT IN A CYLINDER

LIGHT SOURCE

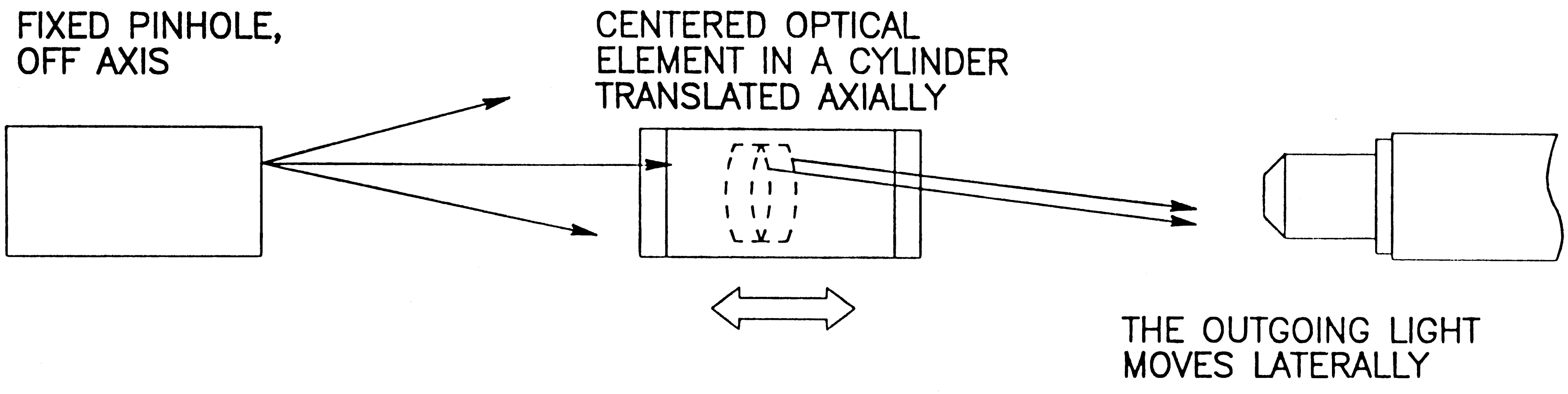
ROTATED

THE REFLECTED LIGHT MOVES.

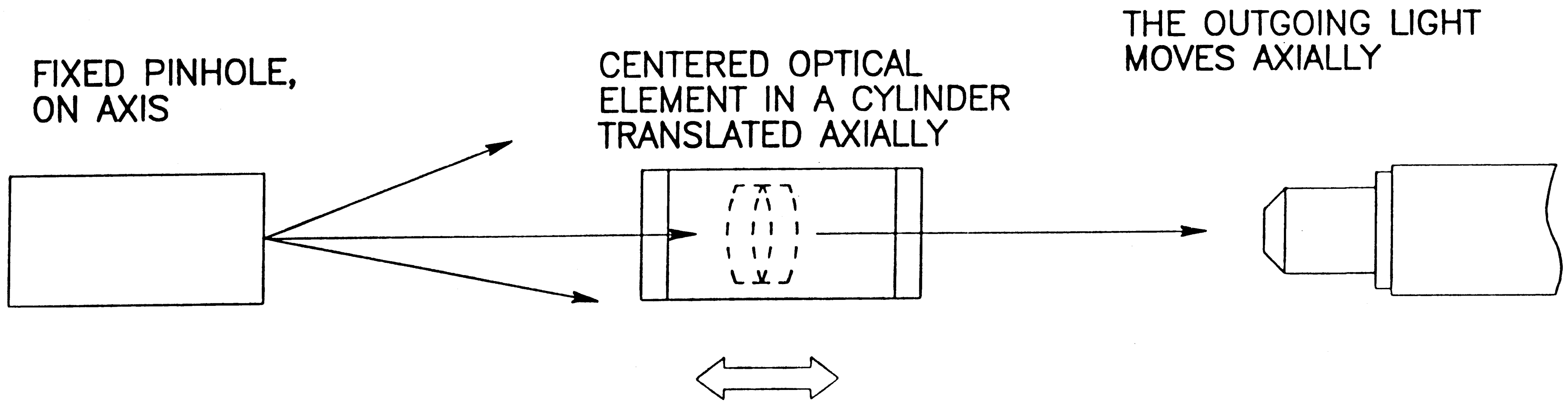
AXIAL ILLUMINATION BY BEAM SPLITTER



ERROR FROM PINHOLE DECENTRATION AND AXIAL LENS MOTION

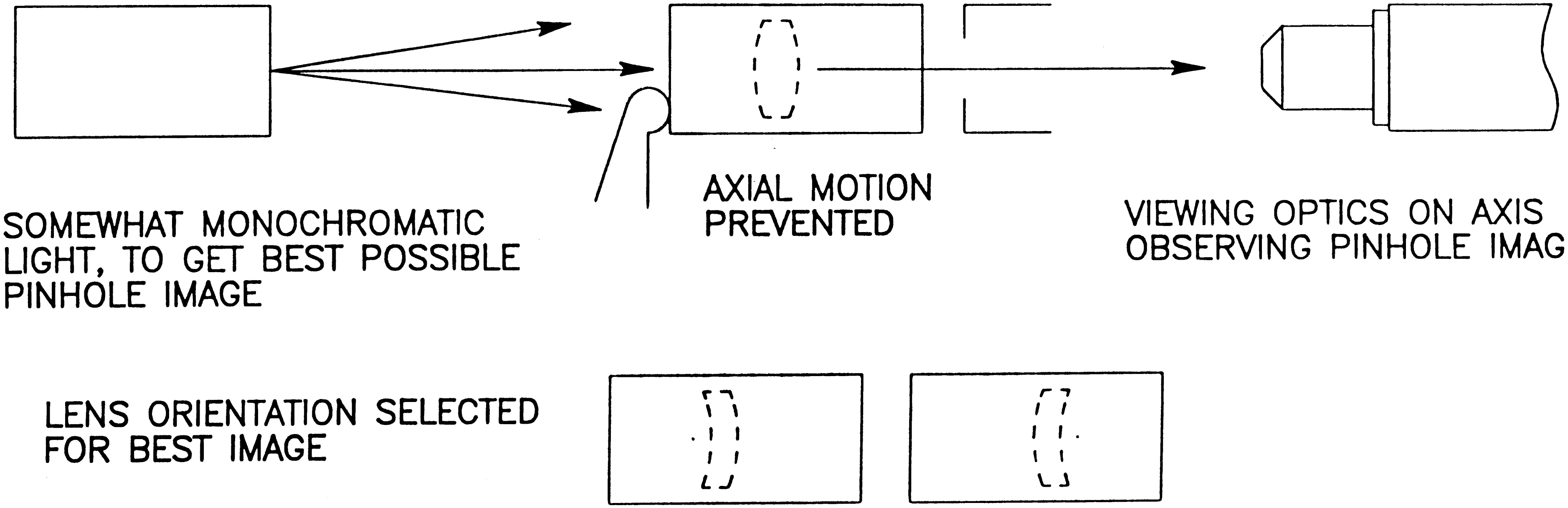


ERROR FROM AXIAL MOTION IS REDUCED BY PINHOLE CENTRATION.



PINHOLE CENTERING IS NOT REQUIRED, BUT IT IMPROVES MEASUREMENT ACCURACY.

SUMMARY OF BEST PRACTICE



PINHOLE ON AXIS

CENTERED ROUND
APERTURE

SOMEWHAT MONOCHROMATIC
LIGHT, TO GET BEST POSSIBLE
PINHOLE IMAGE

AXIAL MOTION
PREVENTED

VIEWING OPTICS ON AXIS
OBSERVING PINHOLE IMAGE

LENS ORIENTATION SELECTED
FOR BEST IMAGE

CENTERING A PINHOLE

A CENTERED PINHOLE IS A BUILDING BLOCK IN THE CYLINDER—IN—V SYSTEM.

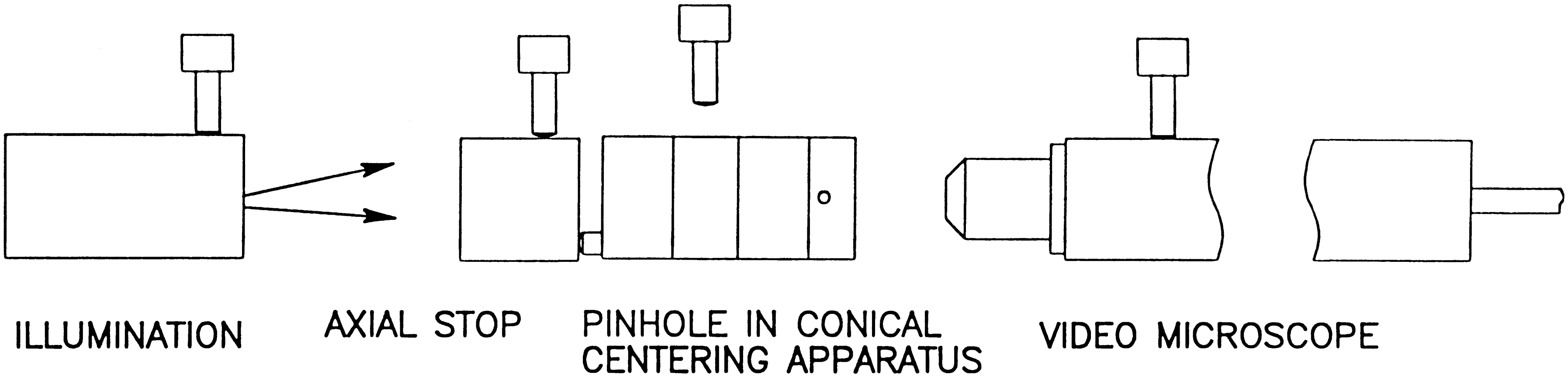
IT IS USED TO ALIGN AND TEST OTHER COMPONENTS.

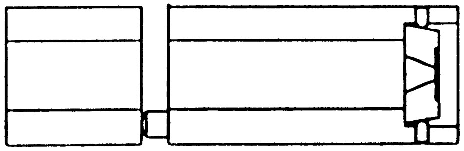
USE A HIGH QUALITY CYLINDER.

A CENTERING CONE WORKS WELL.

THE BEST PINHOLE SIZE VARIES WITH APPLICATION.
IT IS USEFL TO HAVE A SEVERAL DIFFERENT SIZES.

APPARATUS FOR CENTERING A PINHOLE

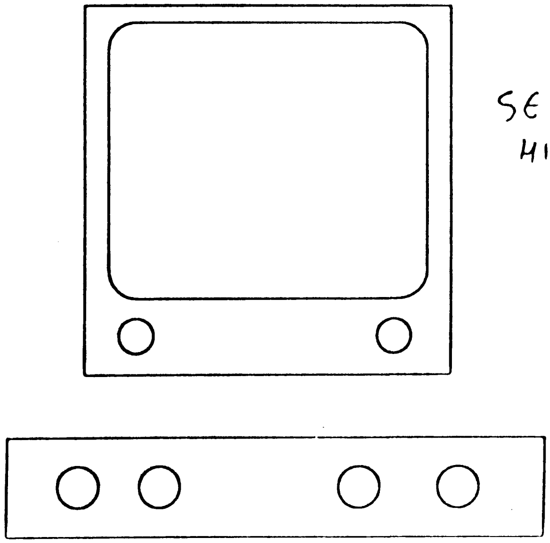




USE WHATEVER LIGHT SOURCE AND WAVELENGTH RANGE THAT GIVE THE BEST IMAGE.

ADJUST THE AZIMUTH OF THE CAMERA.

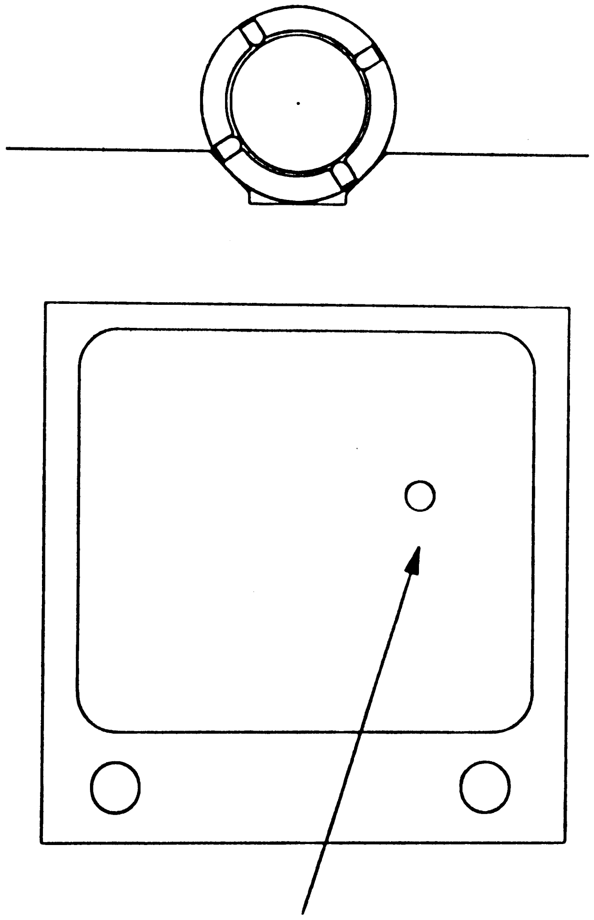
THE VIDEO SYSTEM CAN BE CALIBRATED BY OBSERVING A RONCHI RULING OR OTHER TARGET.



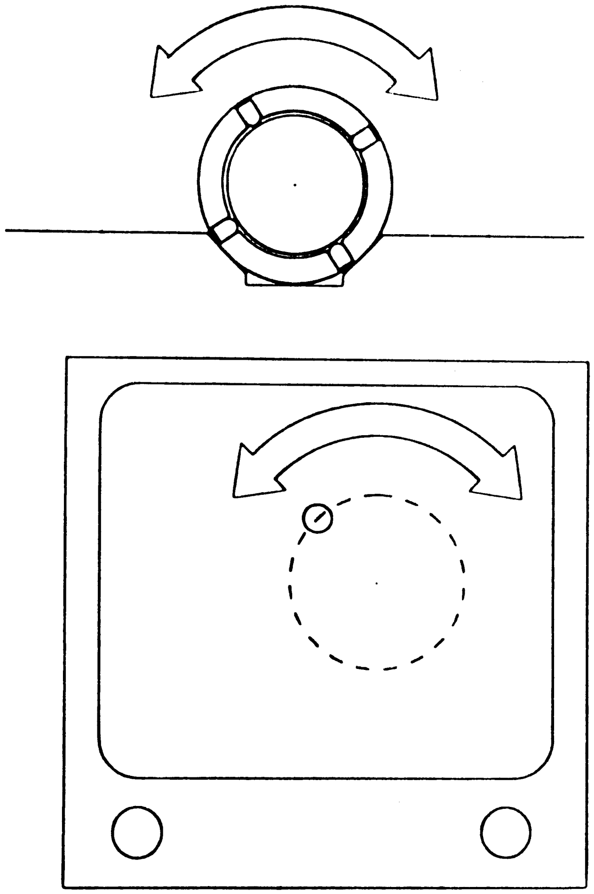
SET FOR HIGH GAMMA

ELECTRONIC RETICLE GENERATOR

CYLINDER

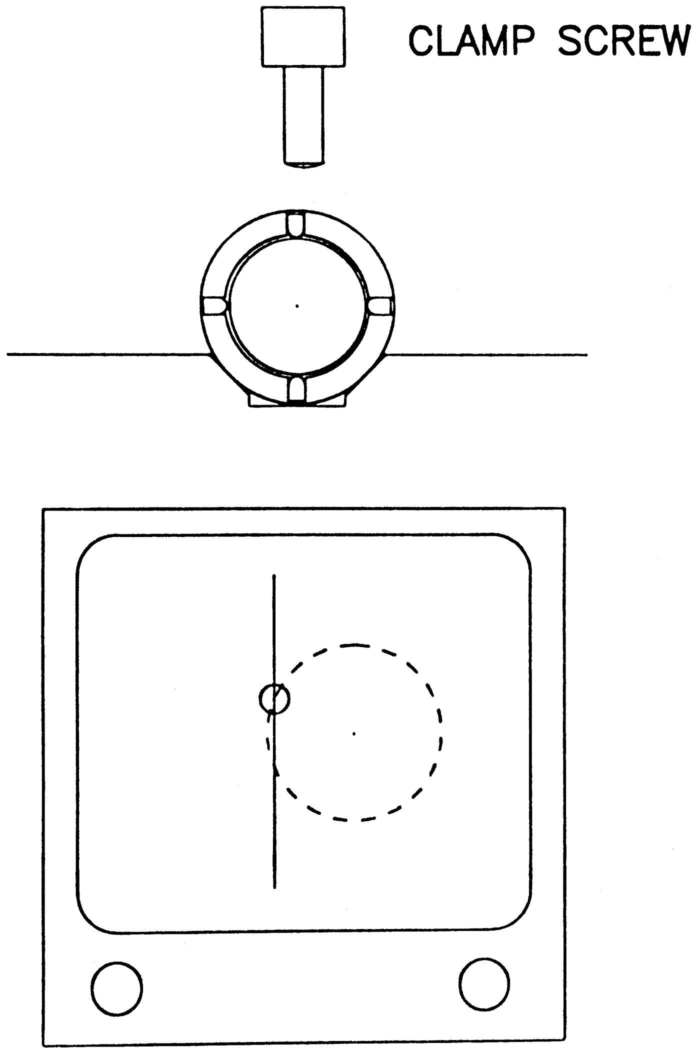


ROTATED CYLINDER



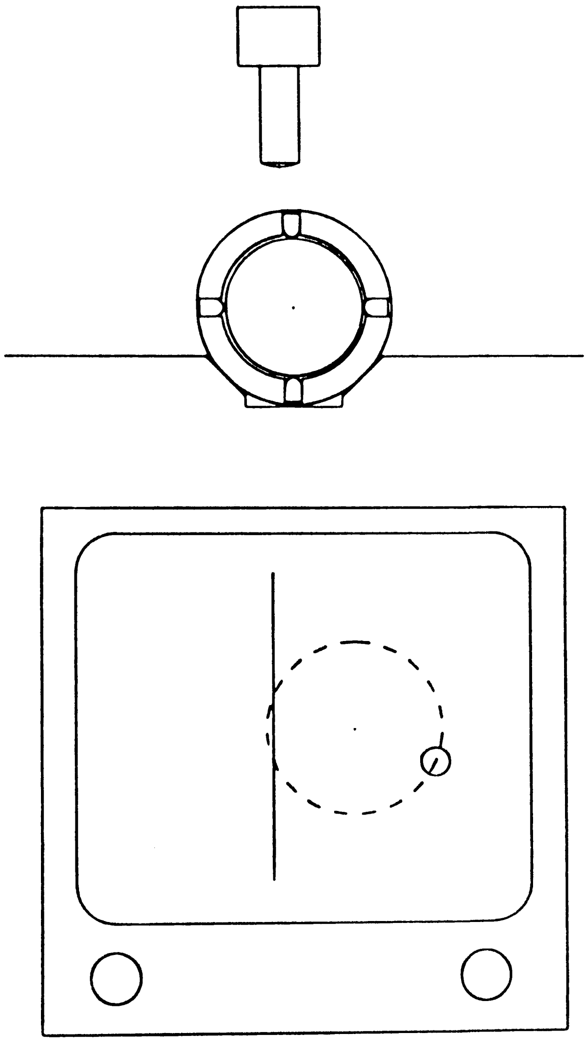
THE IMAGE OF AN UNCENTERED PINHOLE ON A ROTATING CYLINDER ROTATES.

USE CENTERING SCREWS FOR AZIMUTHAL MARKERS.

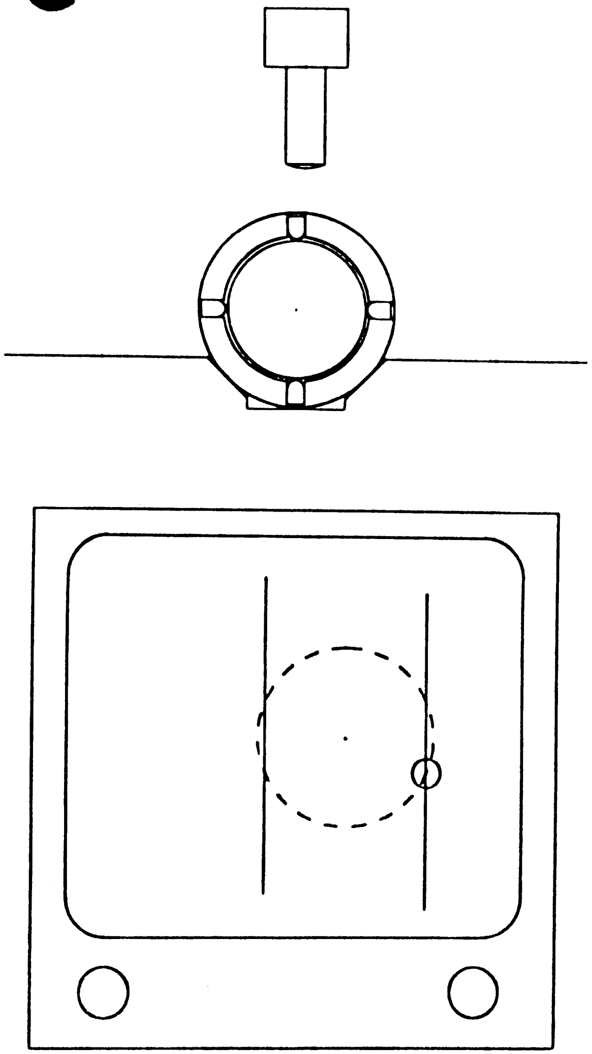


SET CYLINDER WITH ONE SCREW UP.

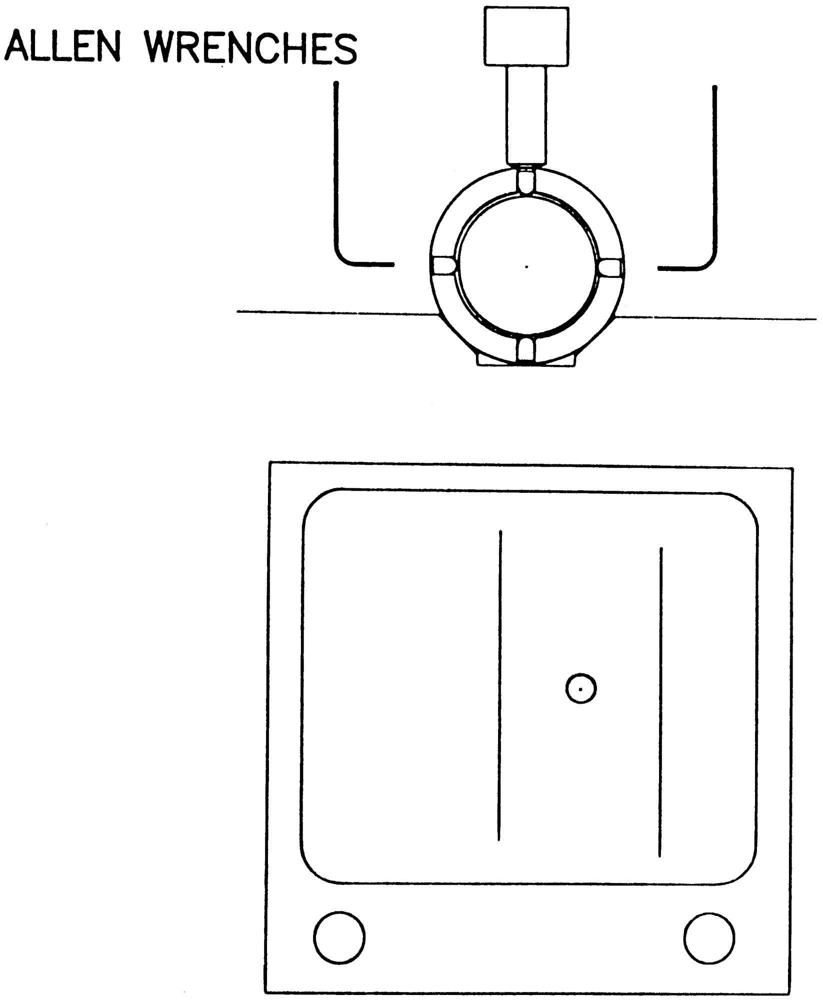
SET RETICLE ON THE PINHOLE IMAGE.



ROTATE THE CYLINDER 180°.



PUT A SECOND RETICLE ON
THE PINHOLE IMAGE.

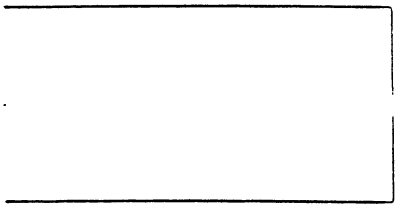


CLAMP THE CYLINDER.
ADJUST THE HORIZONTAL SCREWS TO
CENTER THE PINHOLE IMAGE BETWEEN
THE VIDEO LINES.
ITERATE AS NEEDED.
REPEAT FOR OTHER DIRECTION.

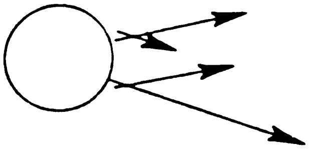
PINHOLE ILLUMINATION

SCHEMATICS:

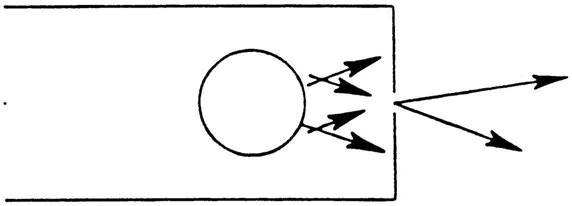
HOLLOW CYLINDER WITH A PINHOLE



SOURCE

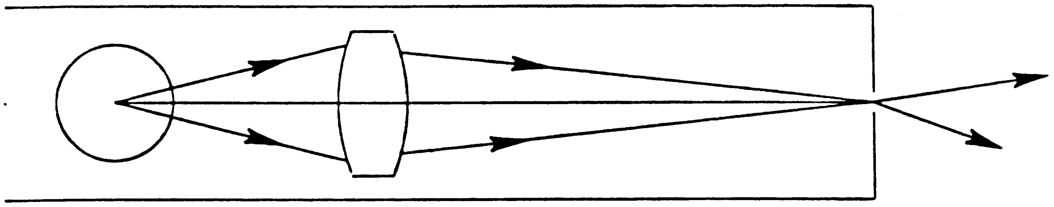


DIRECT ILLUMINATION BY SOURCE,
E.G. LED OR THERMAL

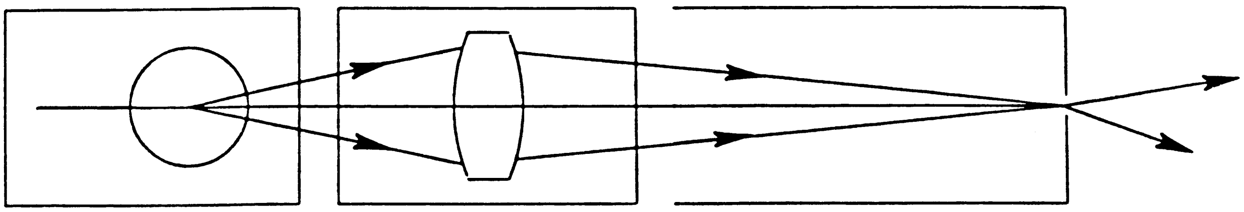


SOURCE IMAGED ON PINHOLE

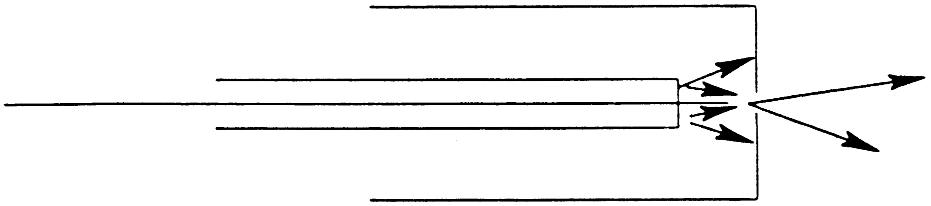
SELF CONTAINED



SEPARATE PARTS

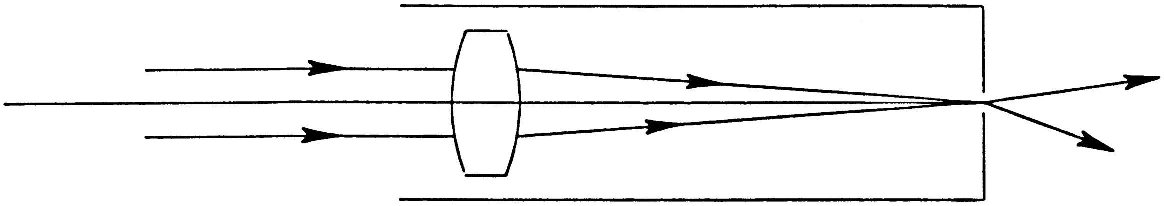


ILLUMINATED BY A FIBER BUNDLE

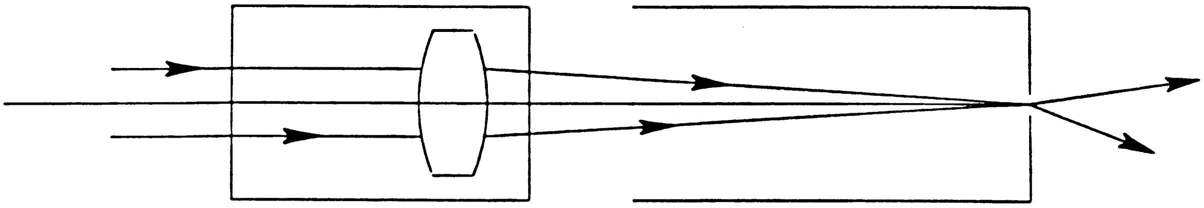


ILLUMINATED BY FOCUSED LASER BEAM

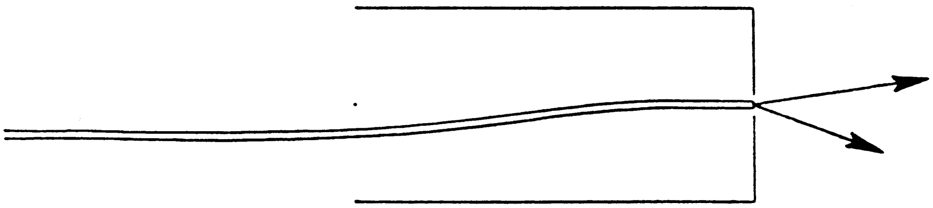
LENS IN PINHOLE CYLINDER



LENS SEPARATE

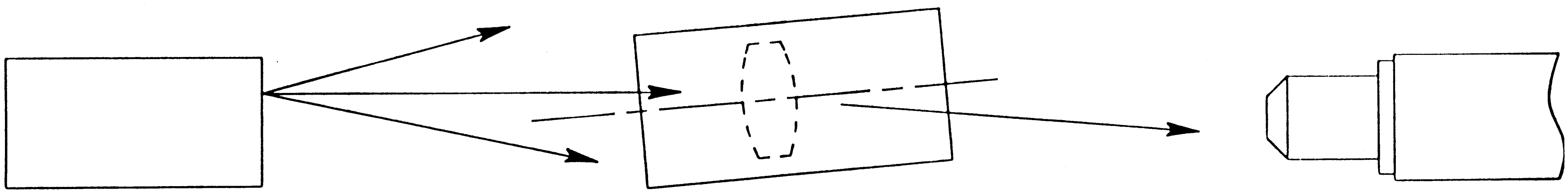


THE END OF SINGLE MODE FIBER ACTS AS A PINHOLE.



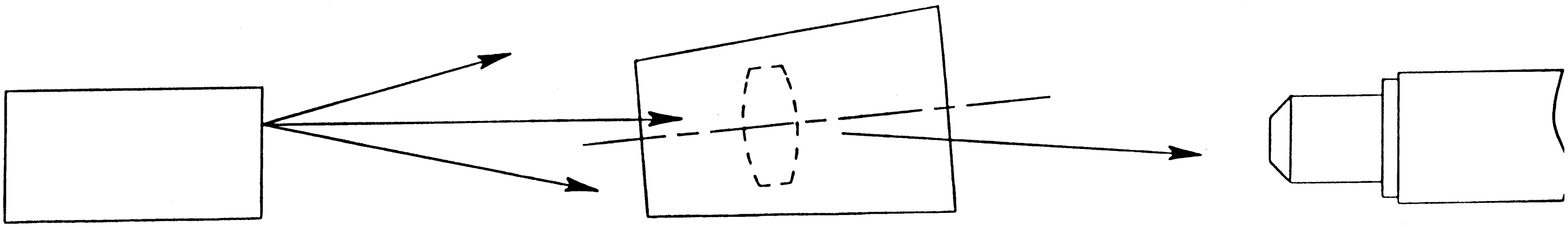
OTHER SITUATIONS

WITH A TILTED CYLINDER AXIS, ROTATION WITHOUT CHANGE IN OUTGOING LIGHT SHOWS CENTRATION WITH RESPECT TO THE CYLINDER AXIS.



THIS IS ALSO THE CASE FOR A CYLINDER OF ANY DIAMETER.

ROUND NON CYLINDER



ROTATION WITHOUT CHANGE IN OUTGOING LIGHT SHOWS CENTRATION OF A ROTATIONAL ELEMENT TO THE AXIS OF A ROUND NON—CYLINDRICAL OBJECT.

(2) CENTERING WITHOUT ROTATION

THE V AXIS IS DEFINED BY TWO CENTERED PHYSICAL ARTIFACTS, E.G., A PINHOLE AND A RETICLE.

TO CENTER AN OBJECT, THE SPOT OF LIGHT AT THE RETICLE IS ALIGNED TO THE RETICLE.

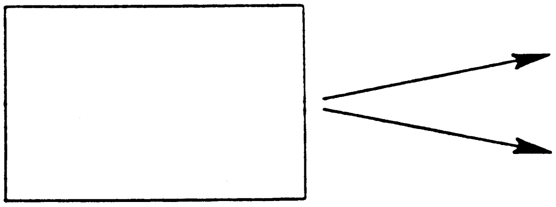
THE METHOD WORKS WITH CYLINDERS OF ANY SHAPE.

THE METHOD DEPENDS ON THE STRAIGHTNESS OF THE V.

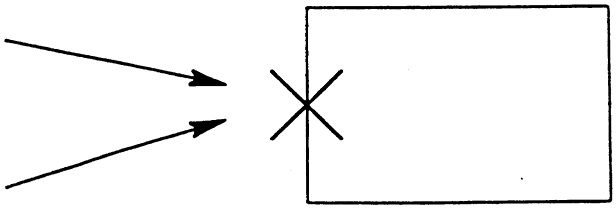
REDUNDANT MEASUREMENTS ARE RECOMMENDED.

SCHEMATIC

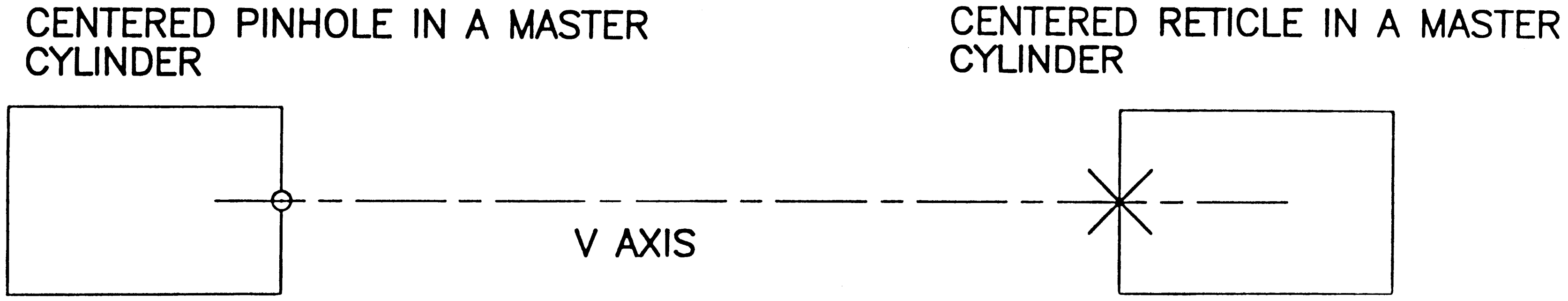
CENTERED PINHOLE IN A MASTER CYLINDER



CENTERED RETICLE IN A MASTER CYLINDER

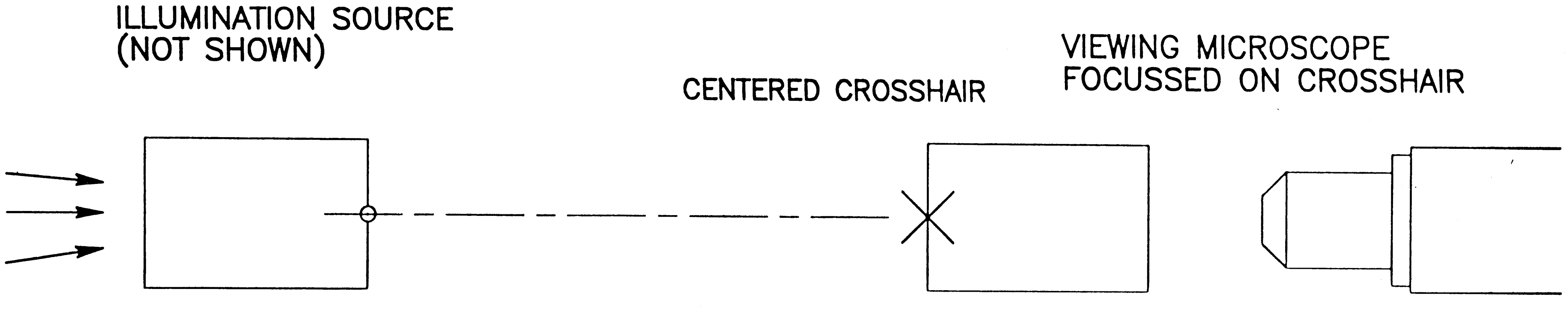


ESTABLISHING THE V AXIS

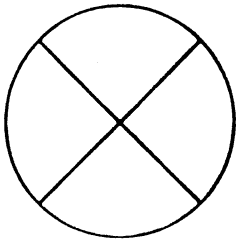


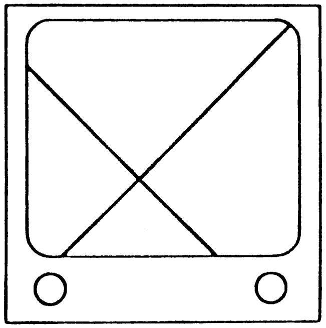
IF THE V IS NOT STRAIGHT, THERE IS ERROR.

OBSERVATION



METHODS OF VIEWING THE CROSSHAIR

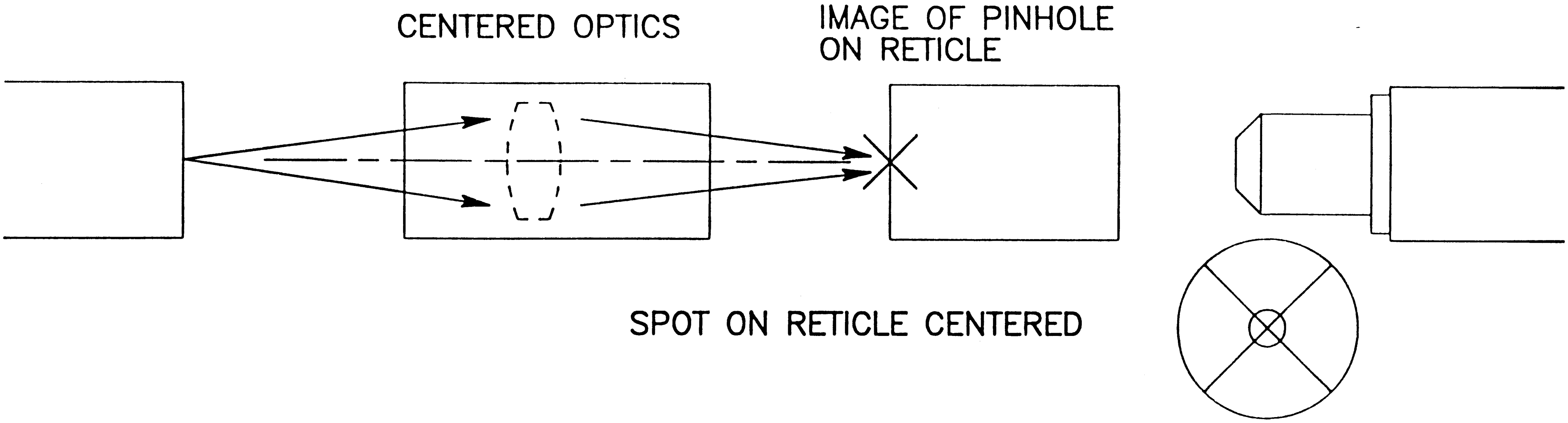

DIRECTLY BY EYE

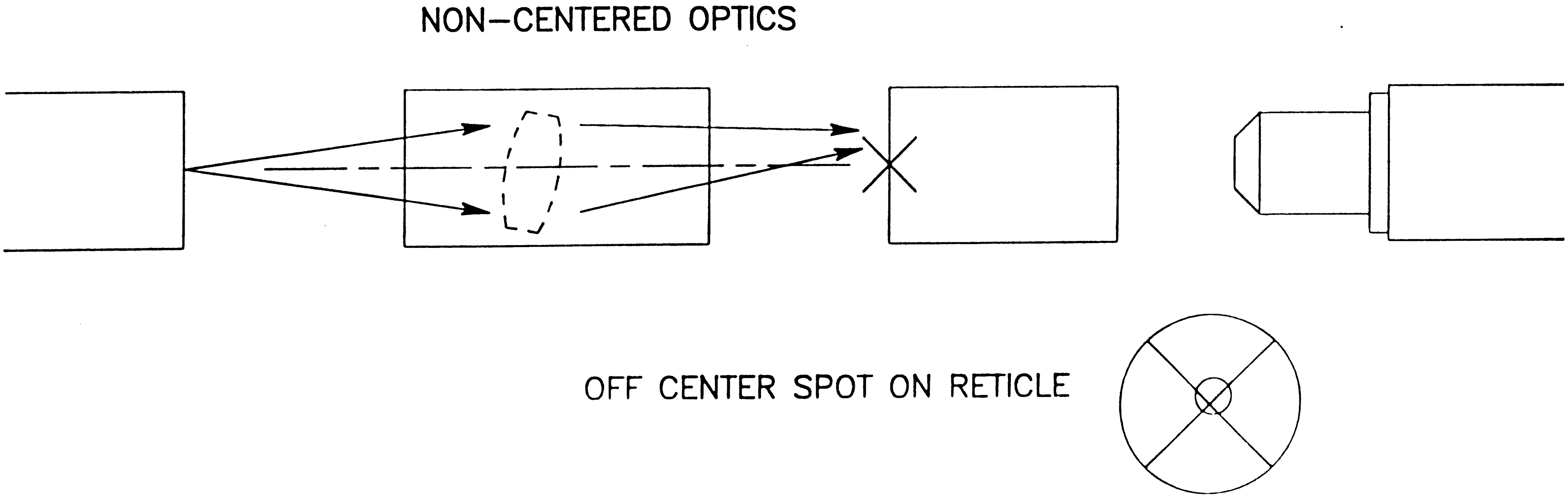

VIDEO IMAGE

THE RETICLE IMAGE NEEDS NOT BE CENTERED ON THE SCREEN.

THE POSITION AND CENTRATION OF THE MICROSCOPE ARE NOT CRITICAL.

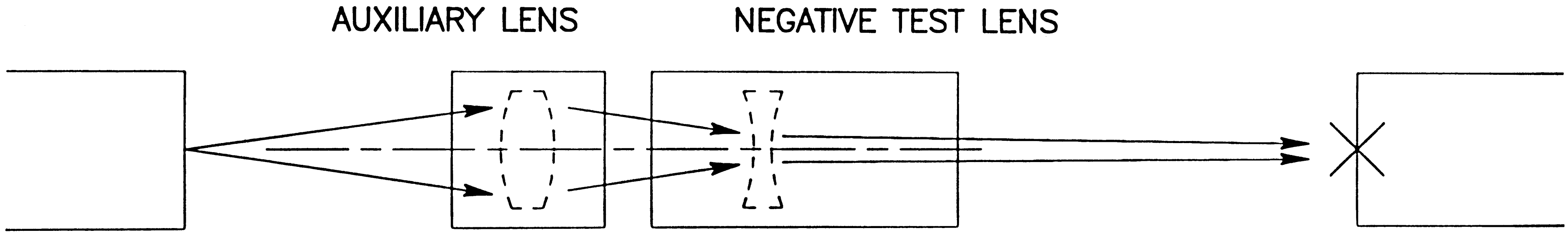
CENTERED AND UNCENTERED OPTICS

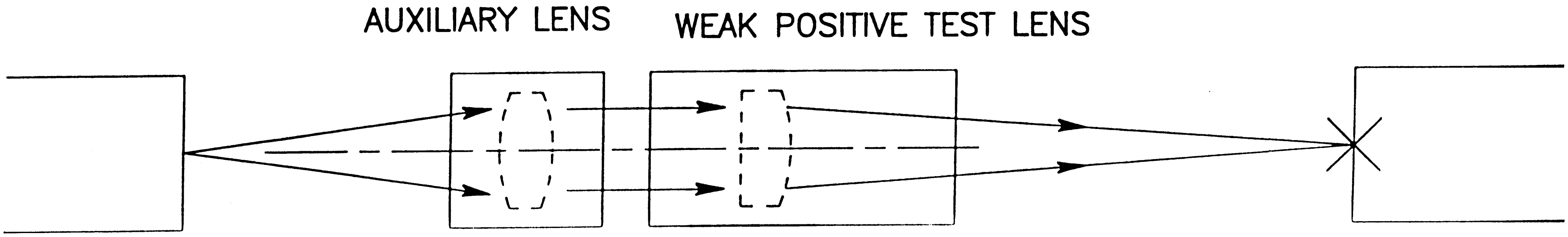




NEGATIVE OR WEAK POSITIVE LENS

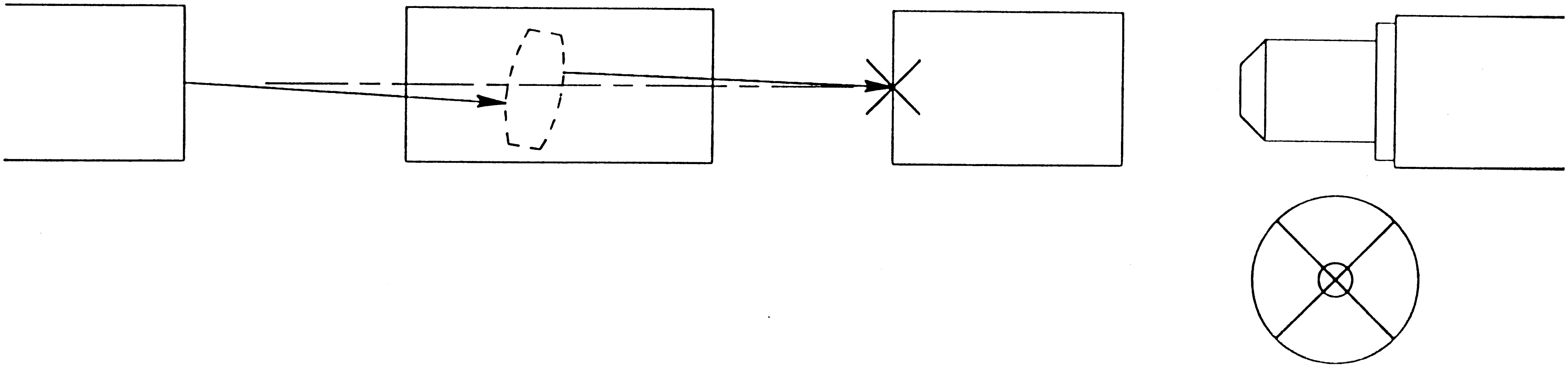
A CENTERED POSITIVE LENS MUST BE ADDED SO AN IMAGE OF THE PINHOLE CAN BE FORMED ON THE RETICLE.



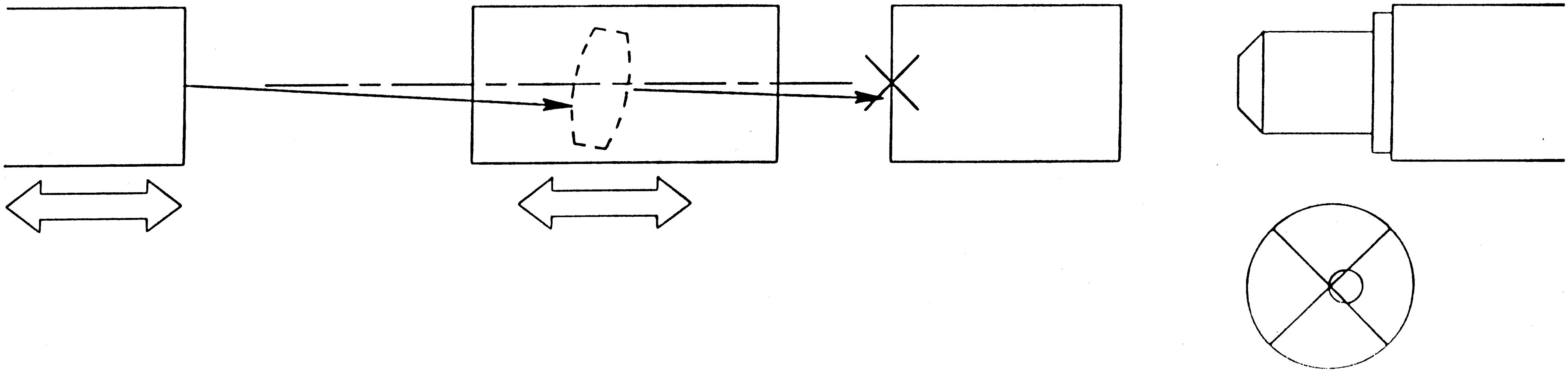


FALSE CENTERING

A CENTERED SPOT MAY BE PRODUCED AT ONE POINT ON AXIS BY COMPENSATORY OFFSETS AND TILTS.

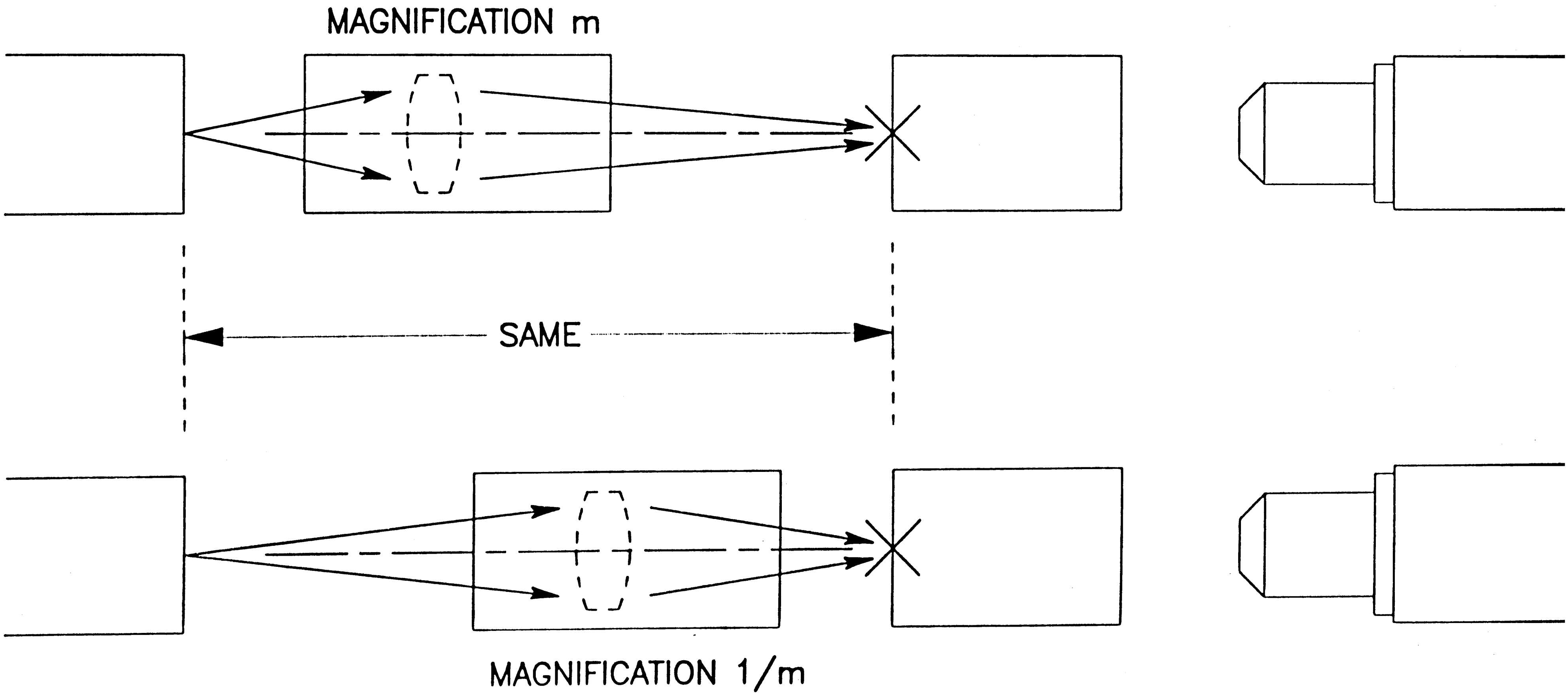


VERIFY CENTRATION BY CHANGING AXIAL POSITIONS OF TEST OPTICS AND/OR PINHOLE.



CONJUGATES WITH SAME OBJECT TO IMAGE DISTANCE

THERE ARE TWO MAGNIFICATIONS WITH SAME OBJECT–TO–IMAGE DISTANCES.
THE TEST LENS CAN THUS BE CHECKED TWICE WITHOUT MOVNG ANY OF THE
OTHER APPARATUS.



THE TEST LENS CAN ALSO BE FLIPPED END TO END AND RE–FOCUSSED WITH
THE SAME OBJECT–TO–IMAGE DISTANCE.

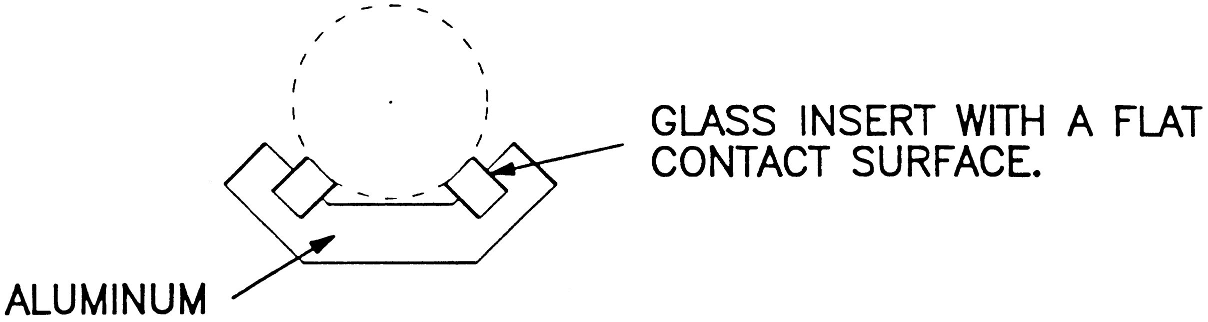
(3) VIRTUAL CENTERING

METHOD OF POSITIONING AN ELEMENT IN AN IMPERFECT CYLINDER SO THAT WHEN THE CYLINDER IS PLACED IN A V THE ELEMENT IS CENTERED RELATIVE TO THE AXIS OF THE V

REQUIRES:
- A MASTER CYLINDER
- A PRECISION SPINDLE WITH A TILT AND TRANSLATION STAGE
- A SHORT MASTER V

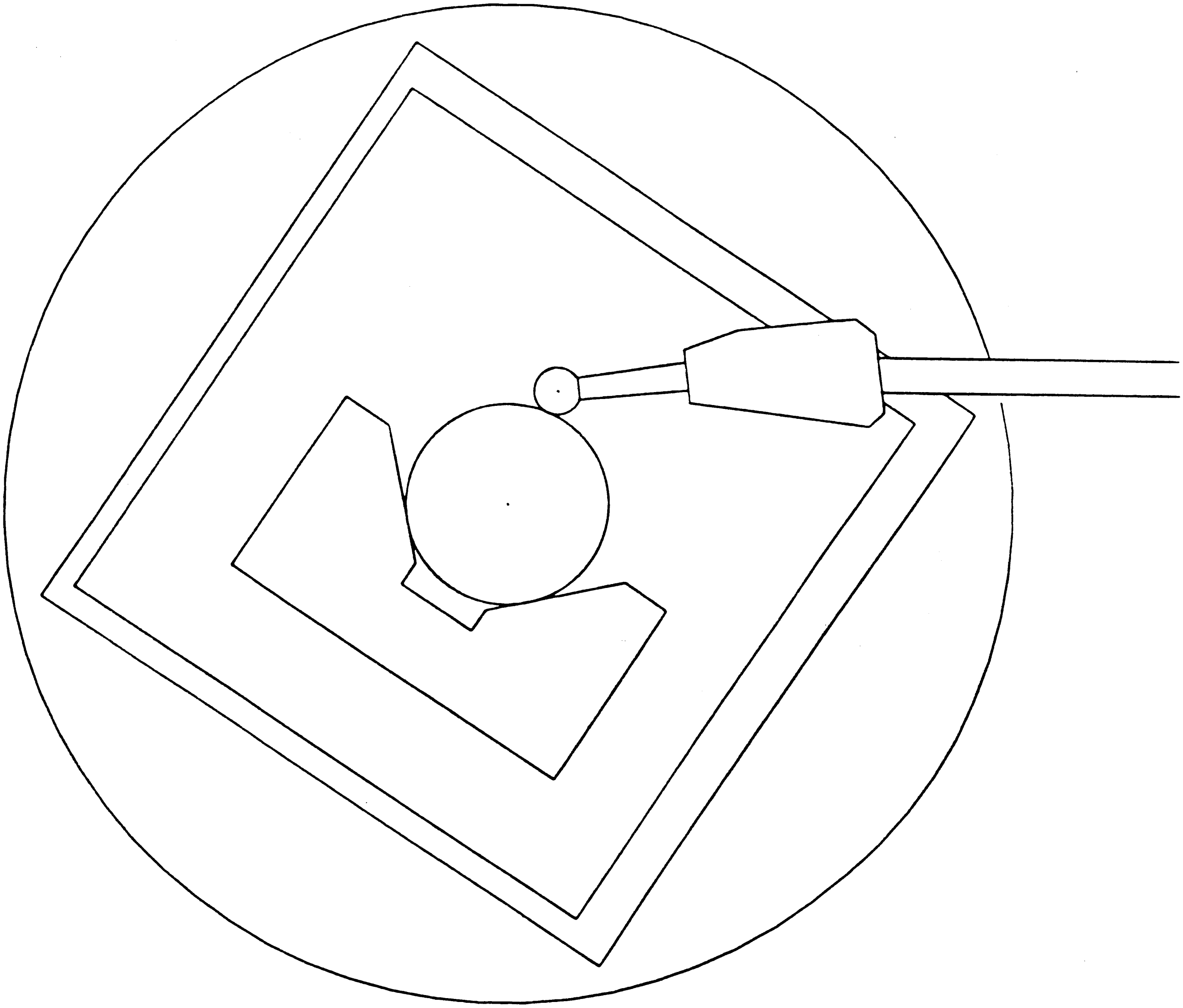
THE MASTER CYLINDER MIGHT BE MADE AT A GAGE HOUSE. (WE USE ONE THAT IS 1" DIAMETER, 4" LONG, ACCURATE TO 1 MICRON, STAINLESS STEEL.)

A MASTER V DESIGN



CLAMP NOT SHOWN

VIRTUAL CENTERING PROCEDURE

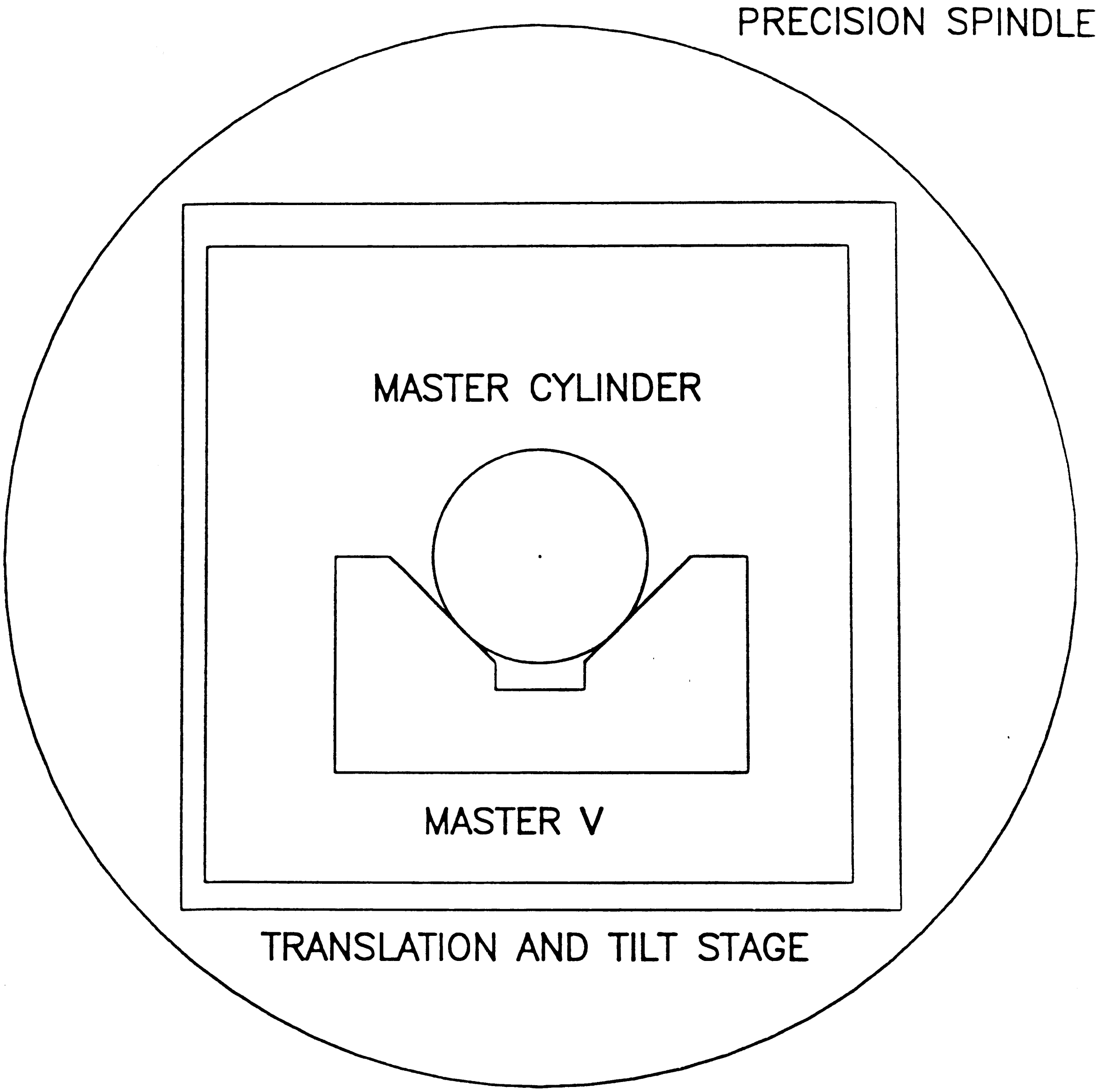


THE SPINDLE IS ROTATED AND THE RUNOUT OF THE CYLINDER IS MEASURED NEAR THE V AND AS FAR AS POSSIBLE FROM THE V.

THE STAGES ARE ADJUSTED SO THE AXIS OF THE CYLINDER LIES ALONG THAT OF THE SPINDLE.

THE MASTER CYLINDER IS THEN REMOVED.

VIRTUAL CENTERING APPARATUS

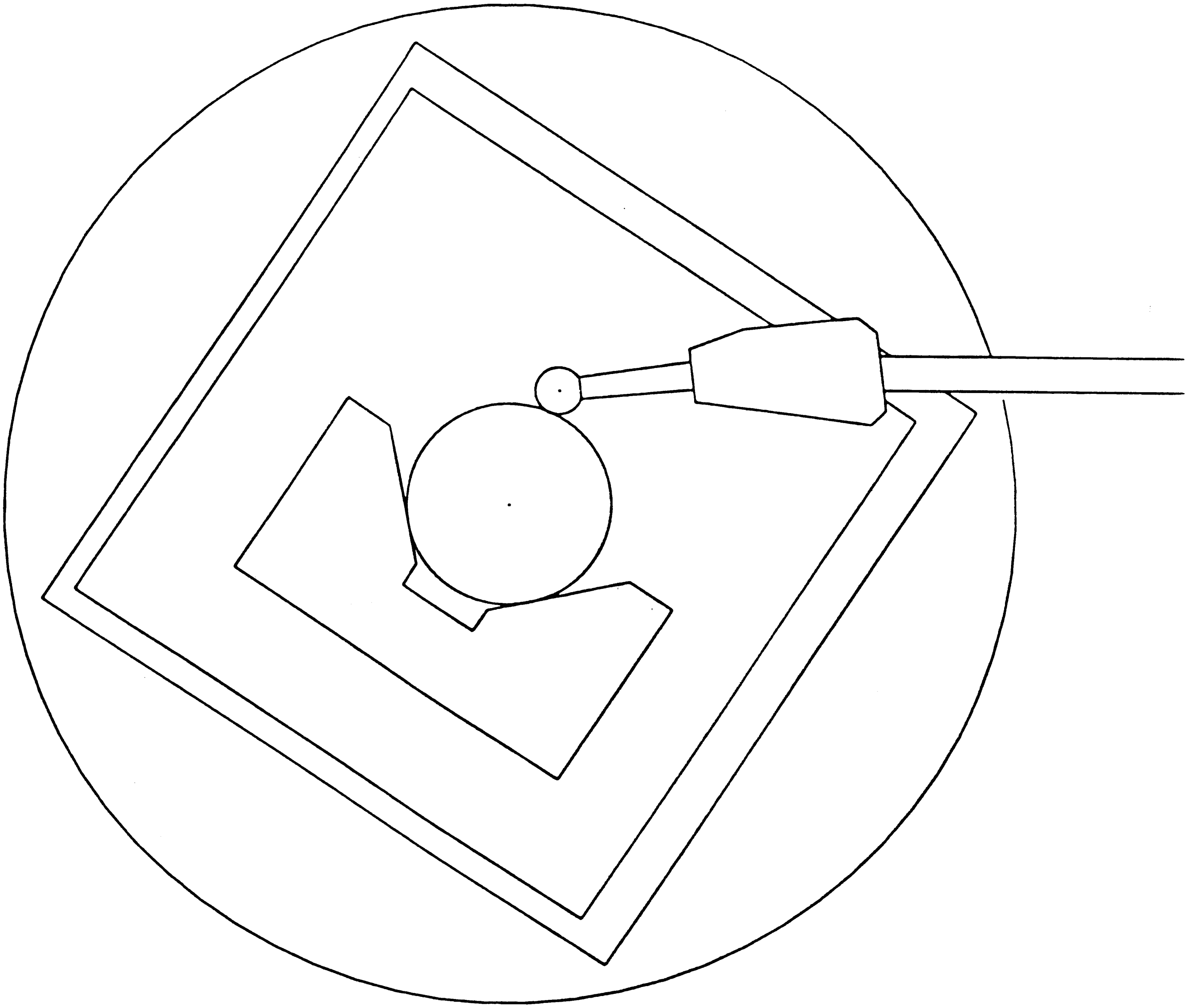


THE TWO DIMENSIONAL TRANSLATION STAGE AND TWO DIMENSIONAL TILT STAGE ARE ON THE AIR SPINDLE IN EITHER ORDER.

THE MASTER V SITS ON THE UPPER STAGE.

THE MASTER CYLINDER PROTRUDES FROM THE V.

VIRTUAL CENTERING PROCEDURE

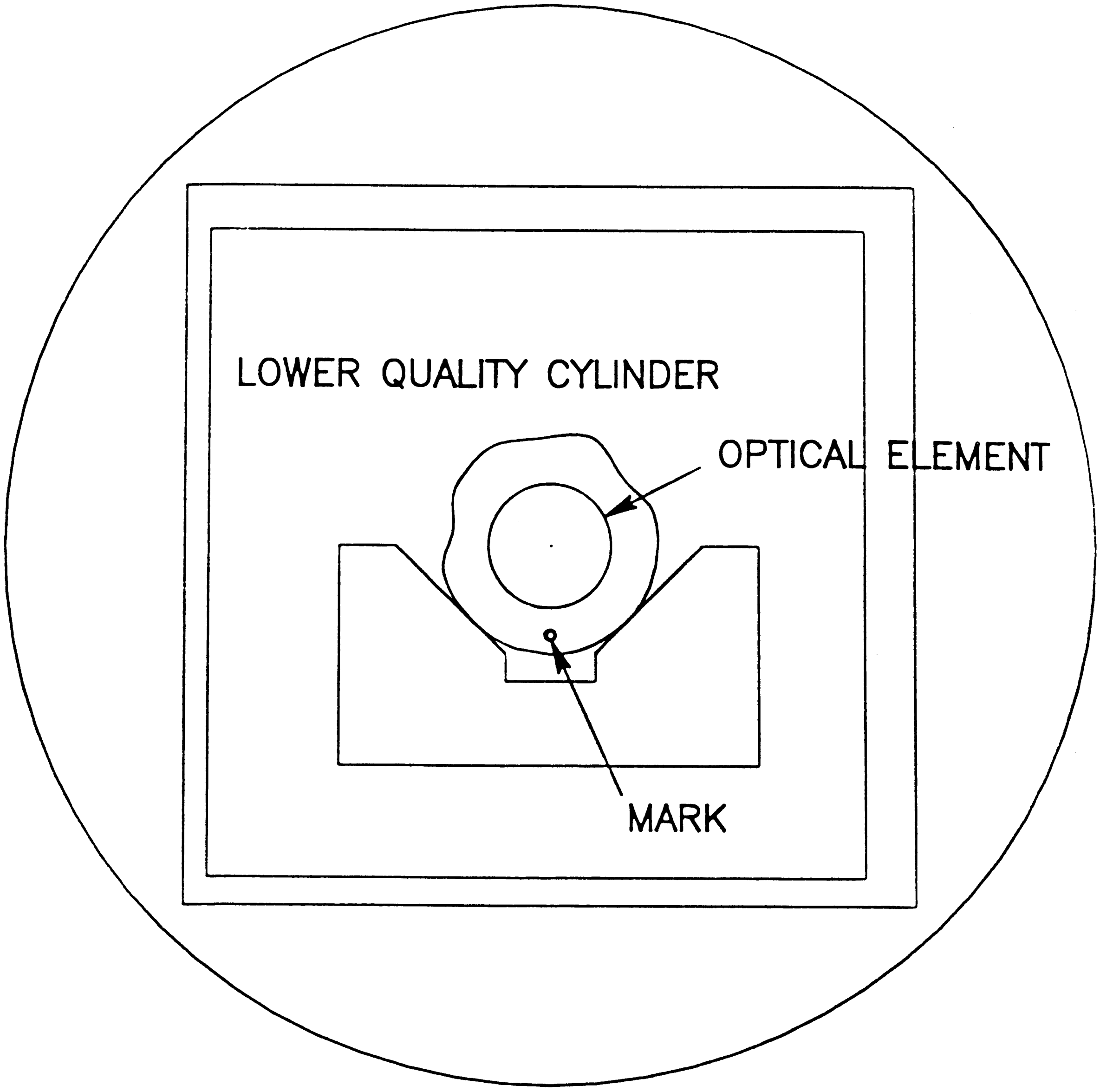


THE SPINDLE IS ROTATED AND THE RUNOUT OF THE CYLINDER IS MEASURED NEAR THE V AND AS FAR AS POSSIBLE FROM THE V.

THE STAGES ARE ADJUSTED SO THE AXIS OF THEO CYLINDER LIES ALONG THAT OF THE SPINDLE.

THE MASTER CYLINDER IS THEN REMOVED.

A CYLINDER IS PLACED IN THE V AND ITS ORIENTATION IS MARKED.
AN OPTICAL ELEMENT IS PLACED IN THE CYLINDER.

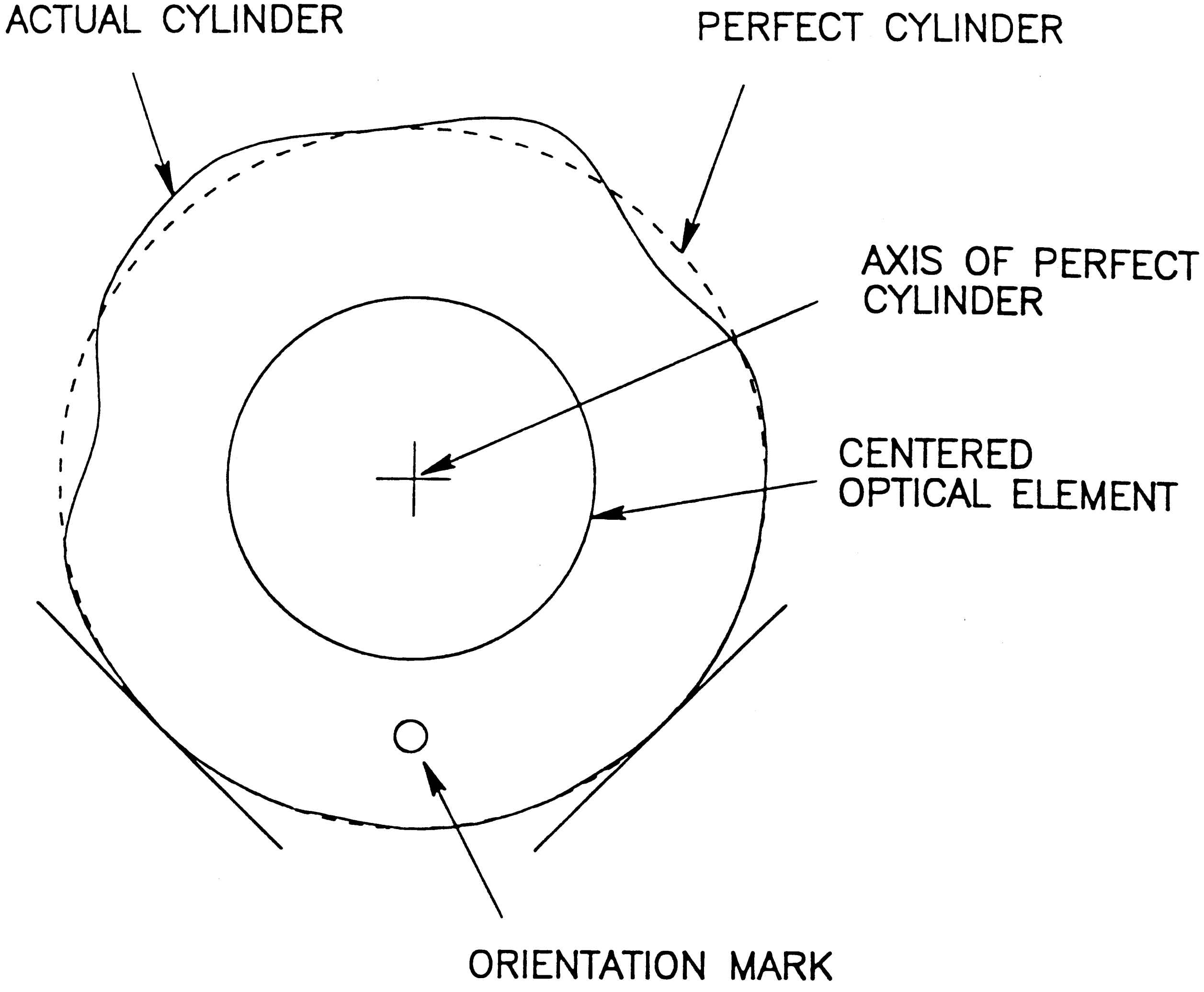


THE SPINDLE IS ROTATED AND THE RUNOUT OF THE ELEMENT IS OBSERVED.

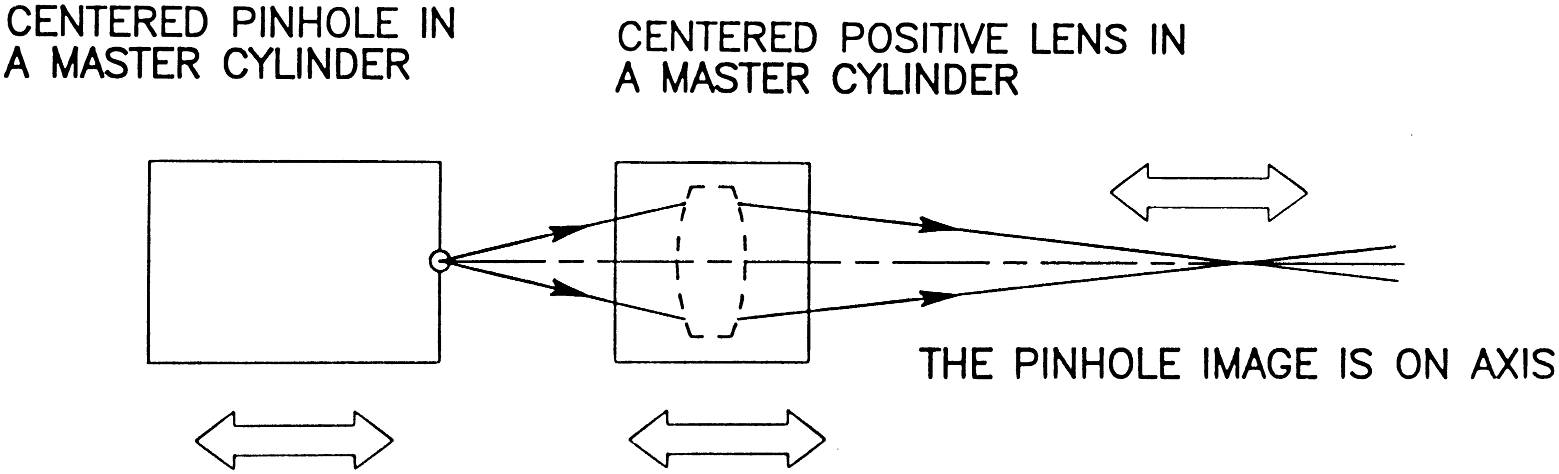
THE ELEMENT IS CENTERED RELATVE TO THE SPINDLE AXIS.

IT IS THEREBY CENTERED RELATIVE TO THE MASTER CYLINDER IN A V, SO LONG AS ITS AZIMUTHAL ORIENTATION DUPLICATES THAT WITH WHICH IT WAS ALIGNEDS.

IDEAL VIRTUAL CENTERING RESULT



CENTERED PINHOLE WITH CENTERED LENS



CENTERED PINHOLE IN
A MASTER CYLINDER

CENTERED POSITIVE LENS IN
A MASTER CYLINDER

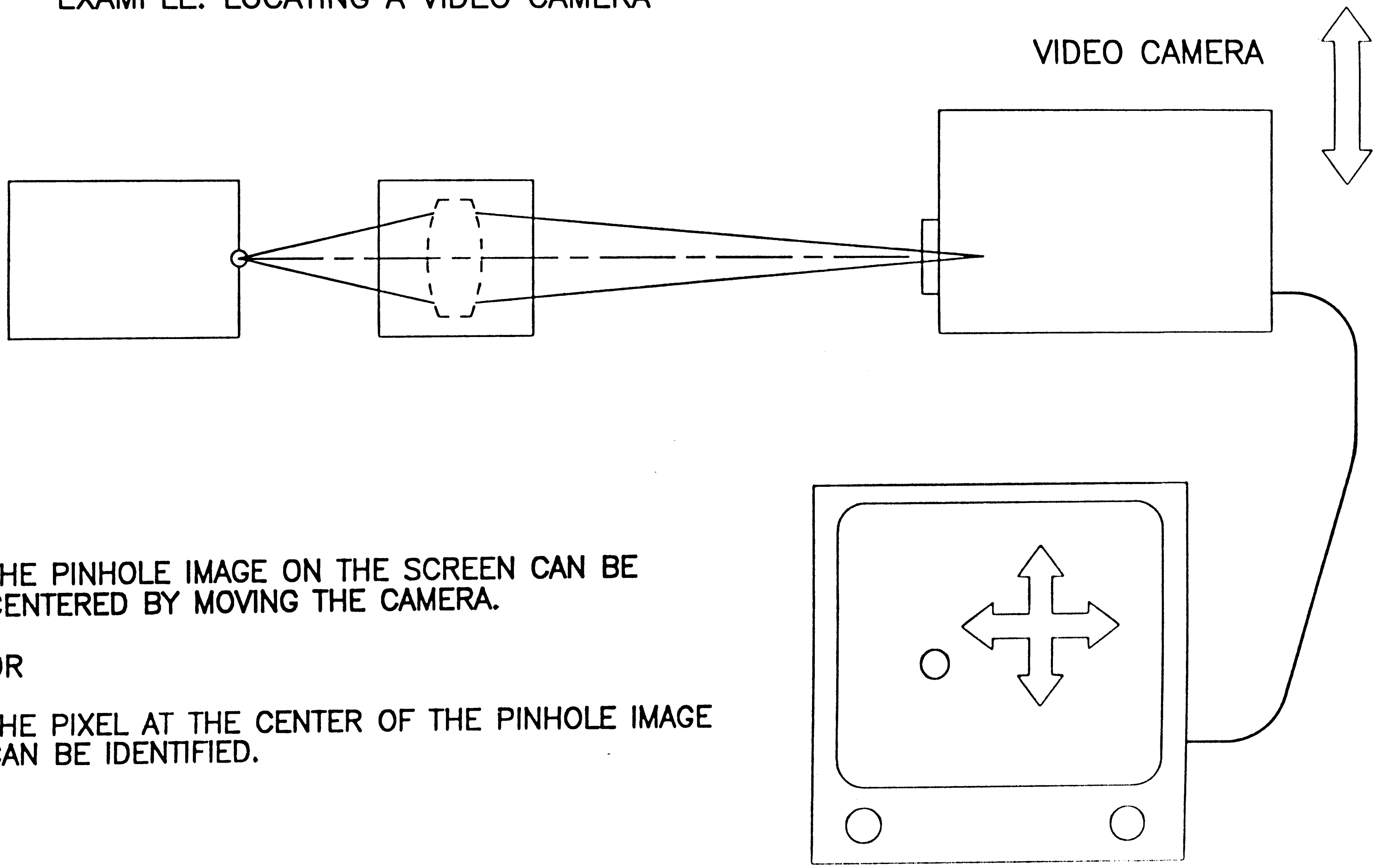
THE PINHOLE IMAGE IS ON AXIS

AXIAL TRANSLATIONS OF EITHER OR BOTH MOVES THE PINHOLE IMAGE AXIALLY.

THE CENTERED PINHOLE IMAGE CAN BE USED TO ALIGN VARIOUS ELEMENTS.

USING A CENTERED PINHOLE IMAGE

EXAMPLE: LOCATING A VIDEO CAMERA

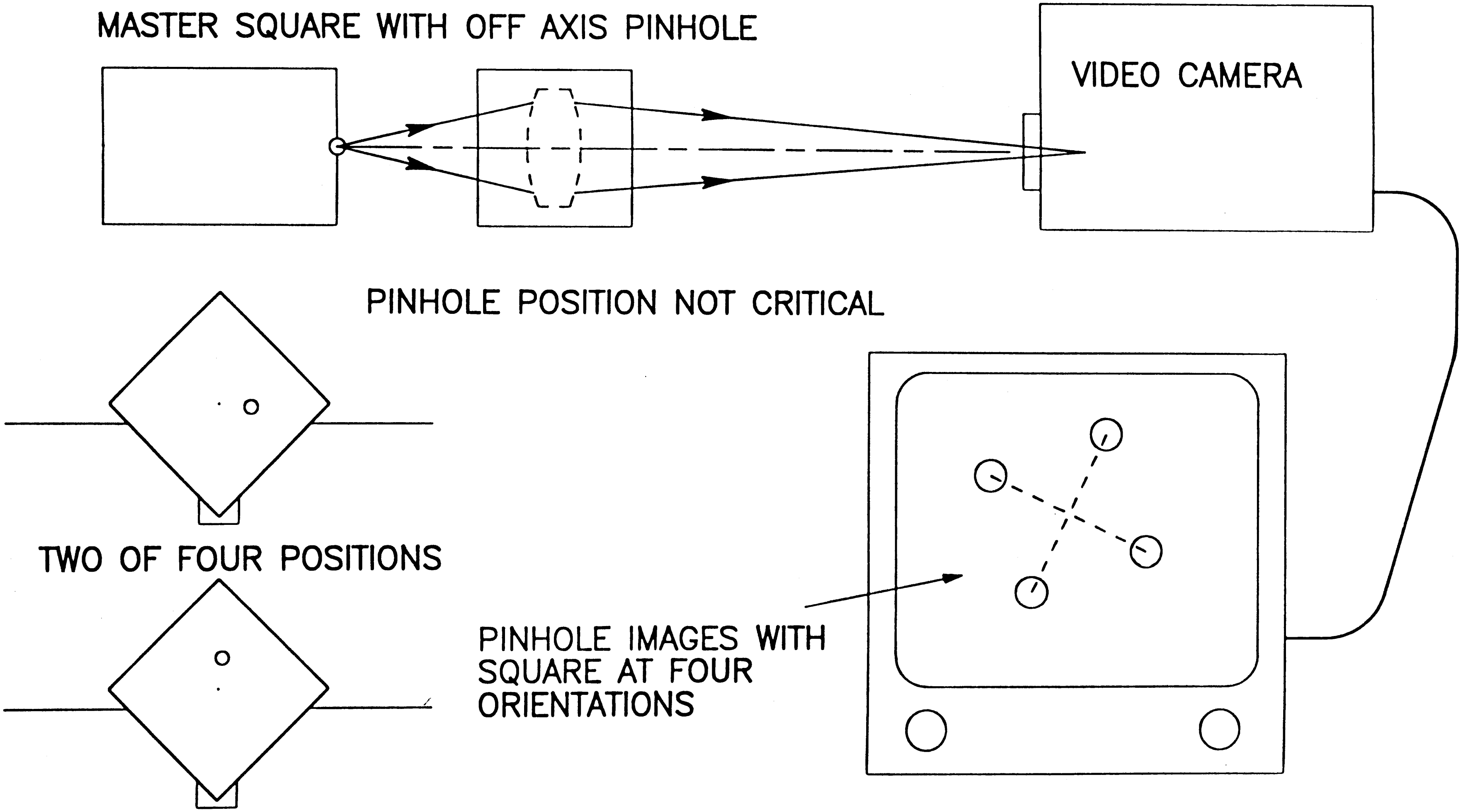


THE PINHOLE IMAGE ON THE SCREEN CAN BE CENTERED BY MOVING THE CAMERA.

OR

THE PIXEL AT THE CENTER OF THE PINHOLE IMAGE CAN BE IDENTIFIED.

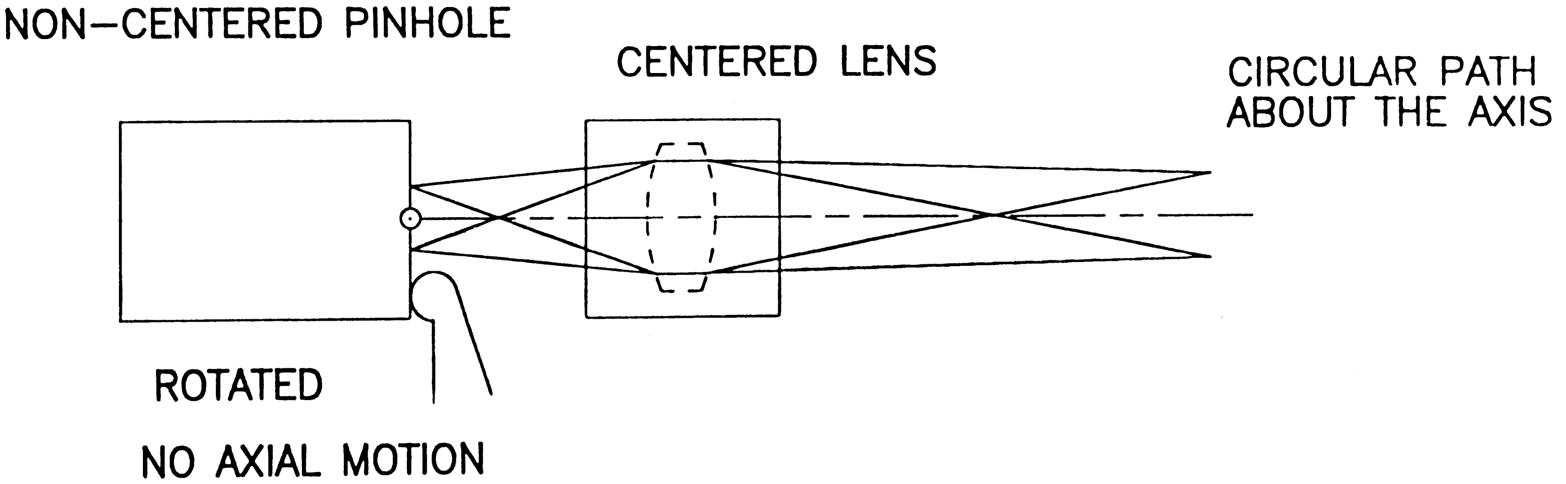
SQUARE CYLINDER WITH OFFSET PINHOLE

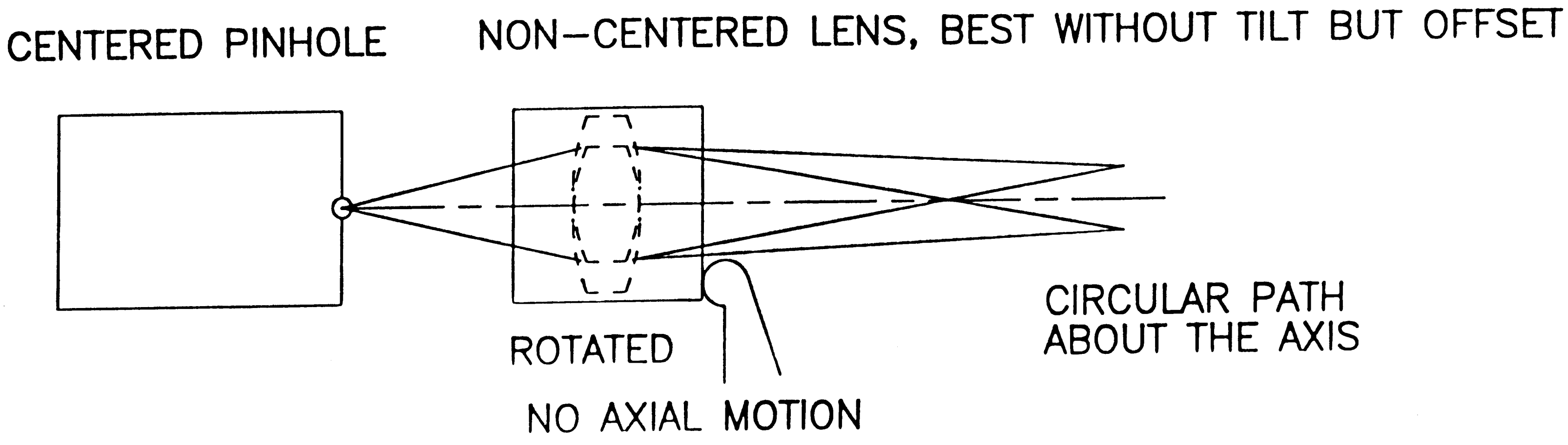


AZIMUTHAL POSITIONS 180° GIVE THE CENTER OF THE SQUARE.

SIMILAR FOR HEXAGON AND 60° V.

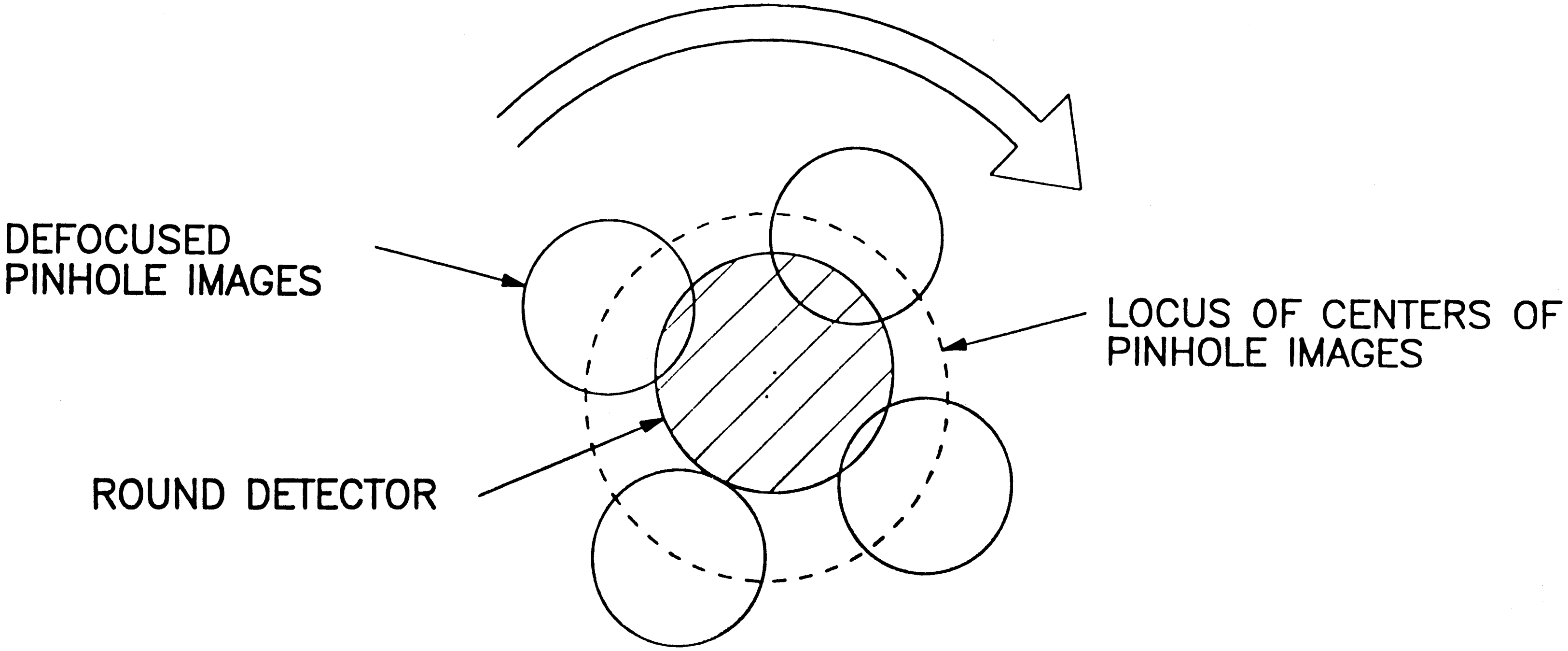
CENTERED CIRCLES



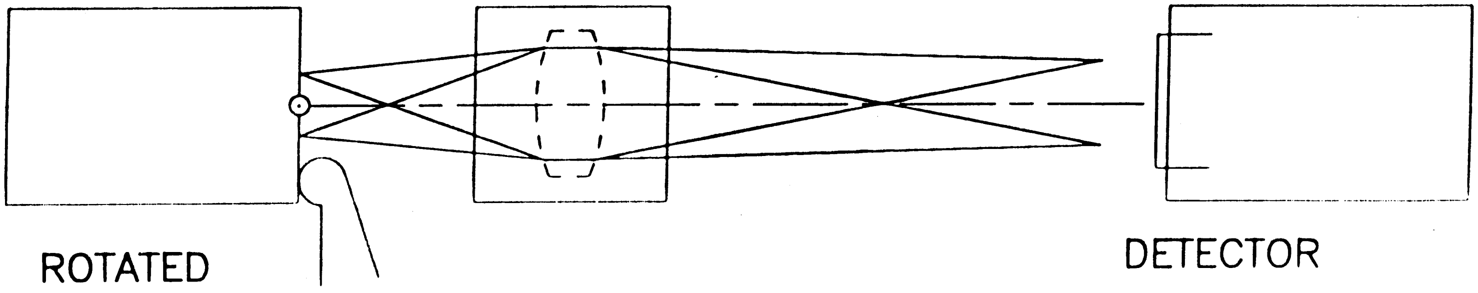


USING A CENTERED CIRCLE

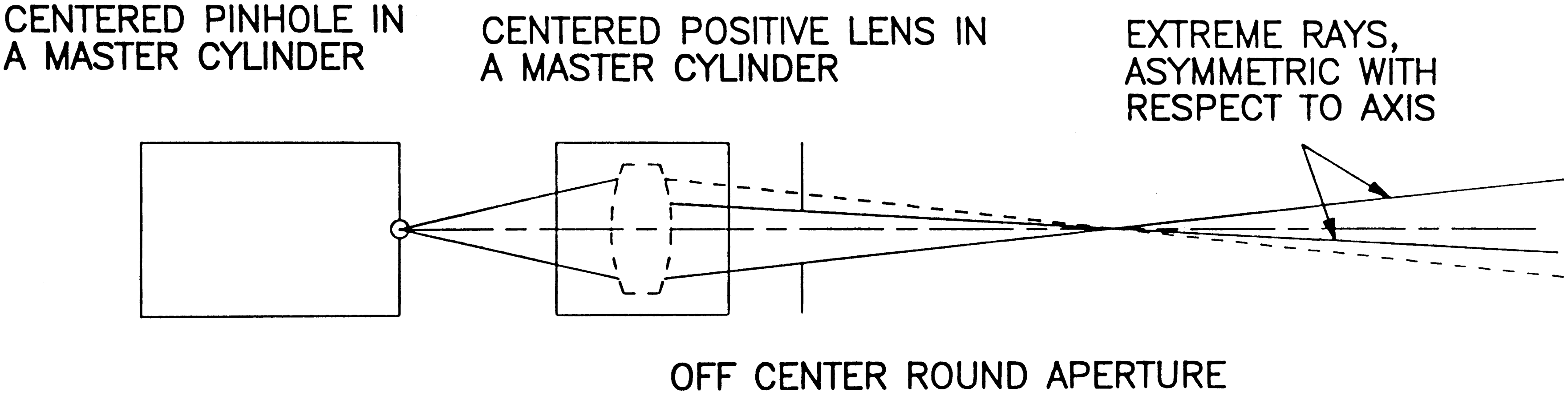
EXAMPLE: CENTERING A ROUND AREA DETECTOR

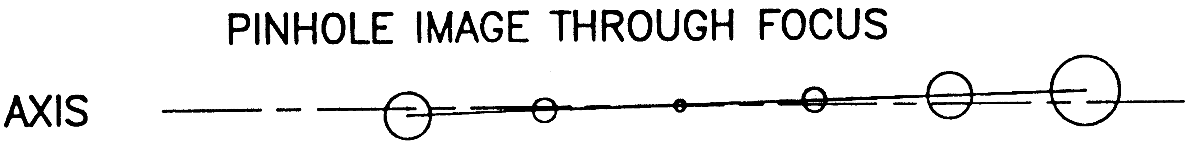


THE DETECTOR IS CENTERED WHEN IS OUTPUT IS THE SAME FOR PINHOLE IMAGE AZIMUTHS.



CENTERED LENS WITH APERTURE OFF CENTER





THE APERTURE SHOULD BE ROUND AND CENTERED.
OTHERWISE, DEFOCUS GIVES A PINHOLE IMAGE WHOSE CENTER IS OFF–AXIS.
TEST BY DEFOCUSING THE PINHOLE IMAGE AND ROTATING THE APERTURE.

IF THE LENS HAS AN UNSUITABLE APERTURE, IT CAN BE STOPPED
DOWN BY AN AUXILIARY APERTURE IN A CYLINDER.

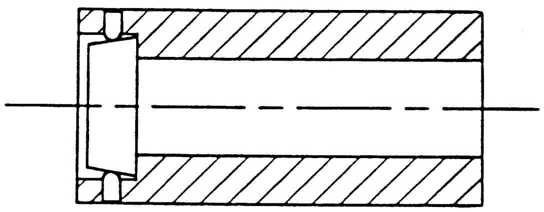
CENTERING CONE

A MECHANICAL DEVICE GENERALLY USEFUL FOR CENTERING OPTICAL ELEMENTS

A CONICAL PIECE HOLDS THE OPTICAL ELEMENT.
THE CONE IS ON A SEAT IN A CYLINDER.
SCREWS DETERMINE THE POSITION OF CONE AND APPLY SOME OR ALL OF LOCKING FORCE.

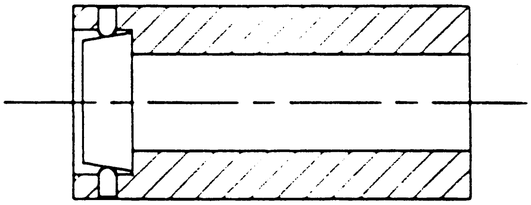
IN ONE VERSION ALIGNMENT AND CONSTRAINT ARE COMBINED BY USING PAIRS OF OPPOSING SCREWS.

THE CENTERING ACCURACY CAN FAR EXCEED THAT OF THE PARTS.

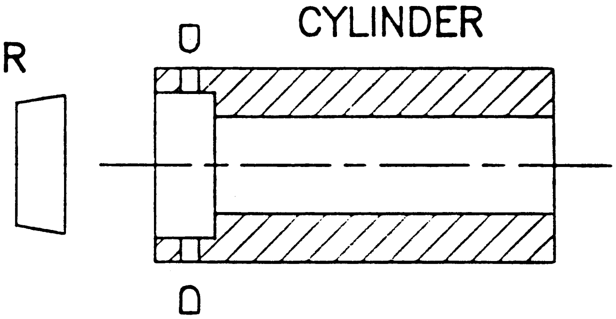


CYLINDER WITH CENTERING CONE

TYPICAL VERSION

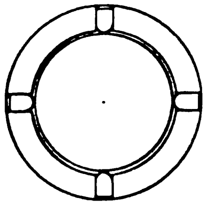


CONE WITH SEAT FOR
OPTICAL ELEMENT
(NOT SHOWN)



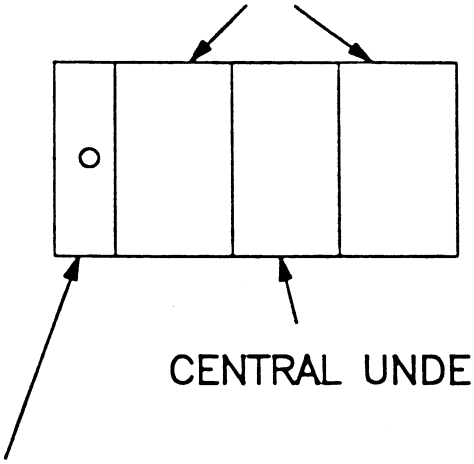
CENTERING/LOCKING SCREWS WITH ROUNDED OR SOFT TIPS

TYPICAL EXTERIOR



SECTION THROUGH
SCREWS

FULL CYLINDER

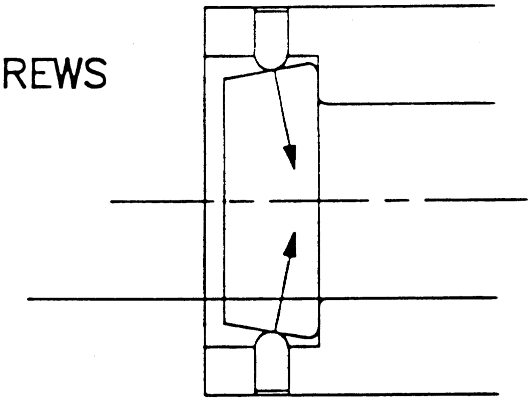


CENTRAL UNDERCUT

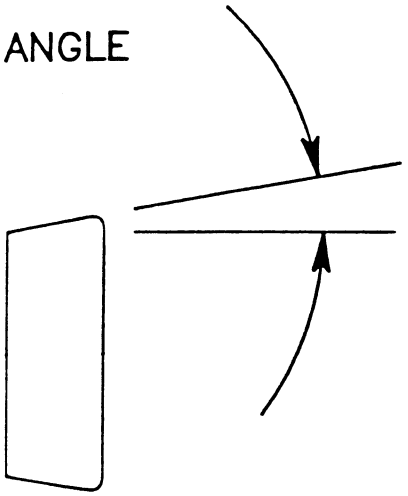
UNDERCUT, BECAUSE SCREWS DEFORM CYLINDER

CONE DETAILS

FORCES FROM SCREWS



CONE ANGLE



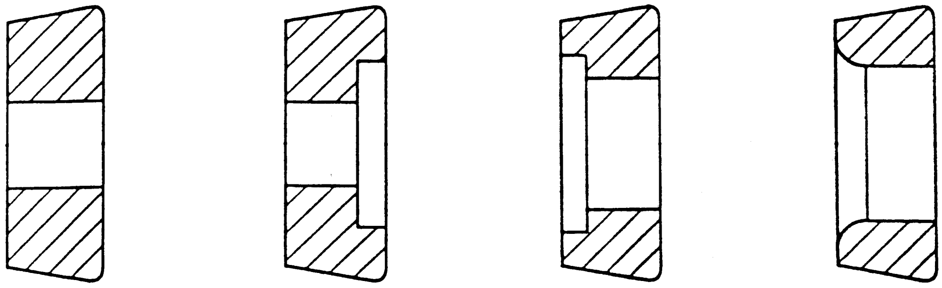
ANGLE NOT CRITICAL.

7°–10° WORKS

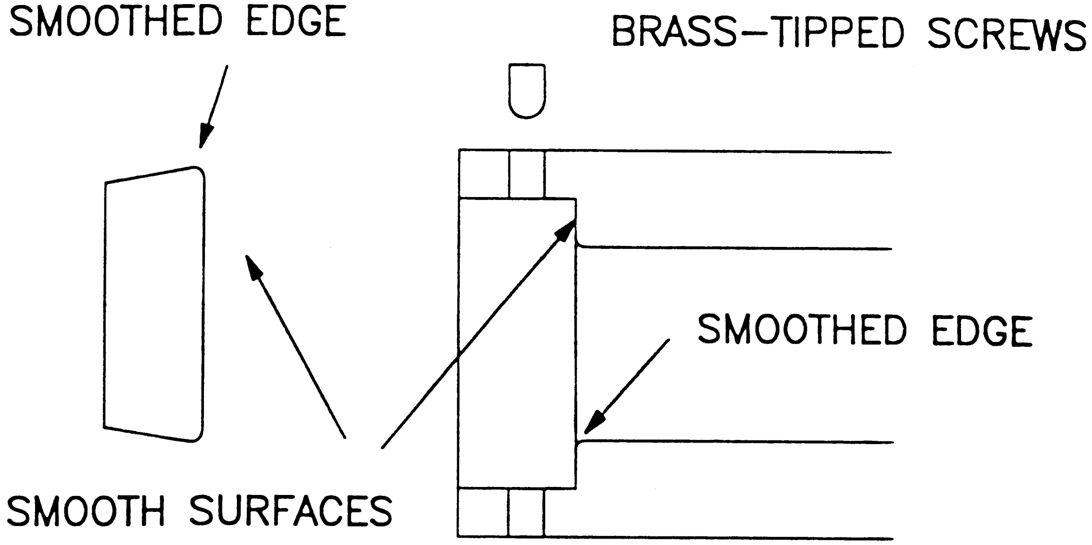
BEST ANGLE ?

THE CONE IS INTERNALLY MACHINED AS NEEDED.

EXAMPLES



FORM, FINISH AND FRICTION

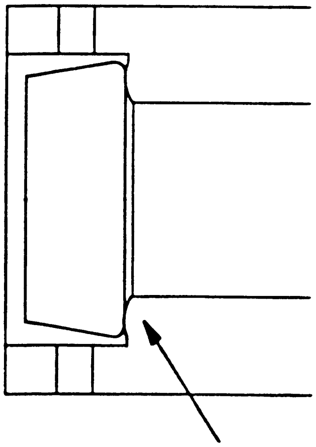


A LOW FRICTION COMBINATION OF MATERIALS IS DESIRABLE.

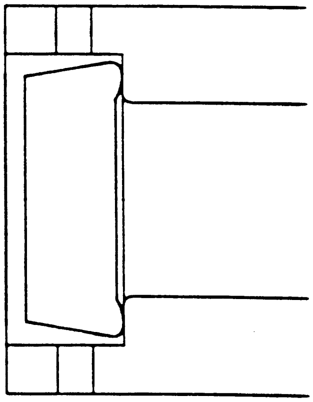
CONCENTRIC MACHINING MARKS INCREASE RESISTANCE.

A WASHER–SHAPED PLASTIC SHIM CAN REDUCE FRICTION.

CONTACT SURFACES THAT ARE MORE DETERMINISTIC THAN (NOMINAL) PLANE ON PLANE:



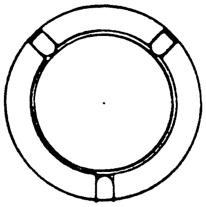
FLAT CONE SURFACE,
TOROIDAL CYLINDER SURFACE



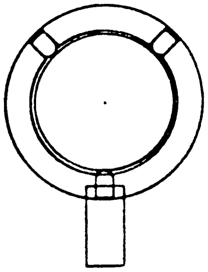
OPPOSITE

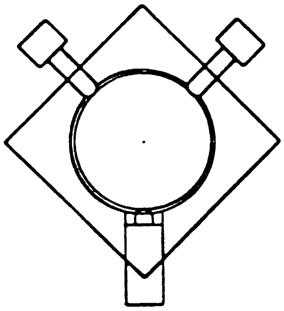
SPRING LOADED CENTERING CONE

BASIC DESIGN

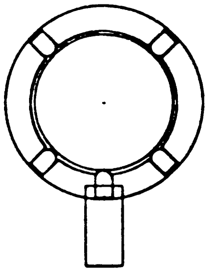


EXAMPLES



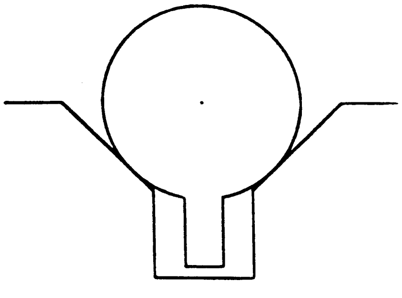


SQUARE CYLINDER PROVIDES MORE MATERIAL FOR PLUNGER.



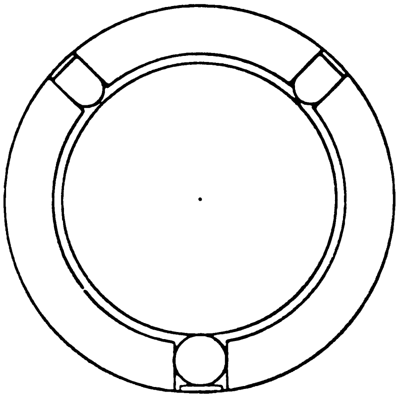
PLUNGER CAN BE REMOVED AFTER LOCKING.

SUFFICIENT TROUGH DEPTH IS REQUIRED FOR THE PLUNGER.

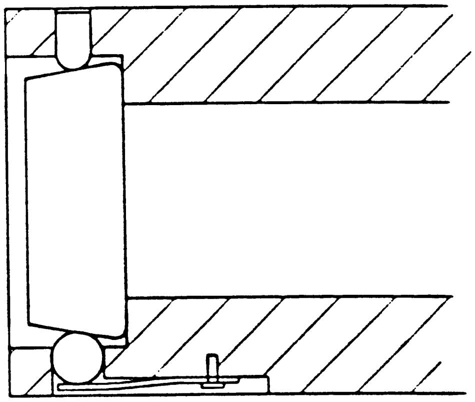


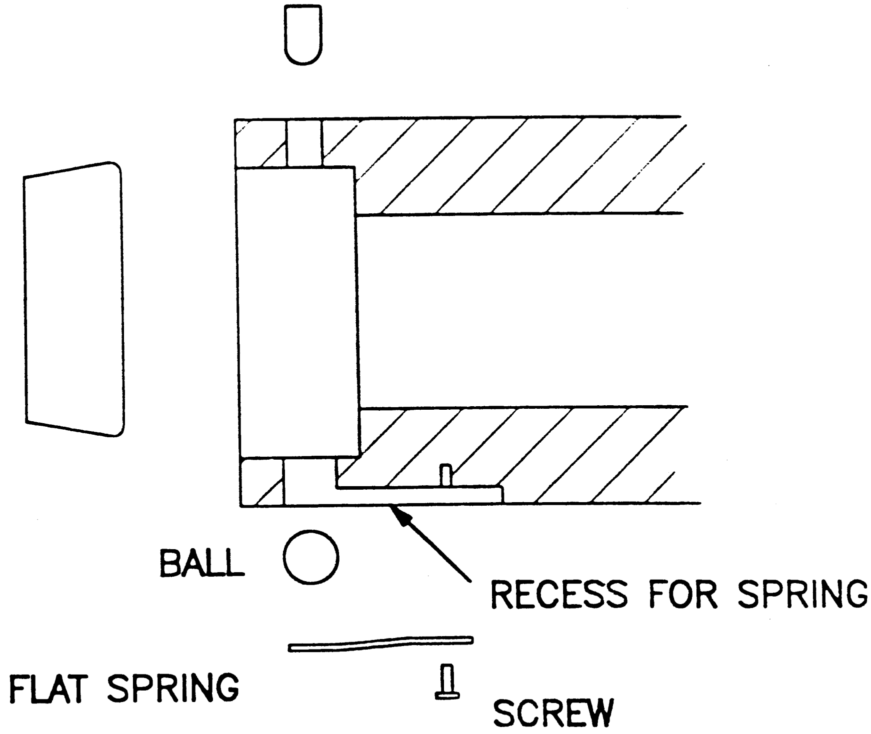
FLAT SPRING LOADING

NOTHING PROTRUDES BEYOND A CYLINDRICAL ENVELOPE.



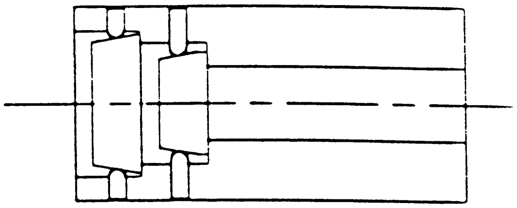
SECTION



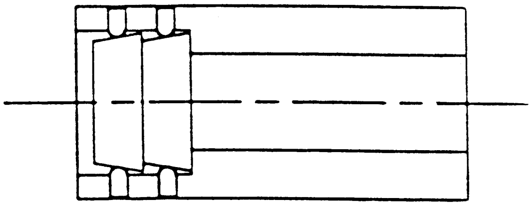


VARIETY OF CONE CONFIGURATIONS

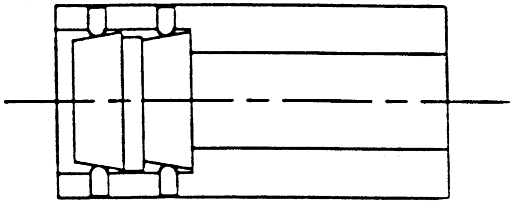
MULTIPLE CONES ON
SEPARATE SHOULDERS



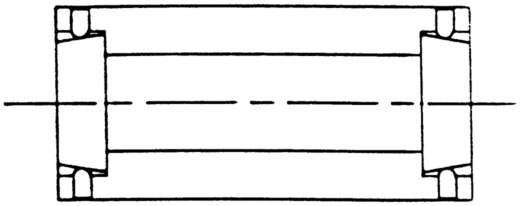
STACKED CONES



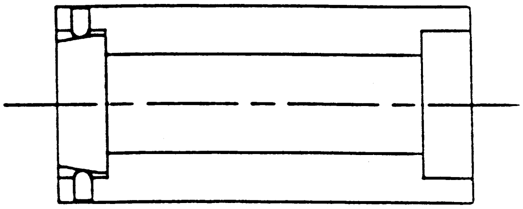
STACKED CONES SEPARATED
BY SPACERS



CYLINDER WITH CONES AT
BOTH ENDS

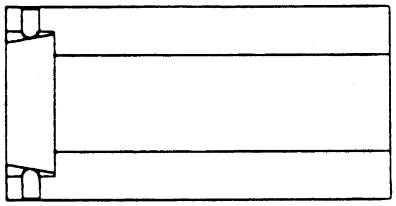


CONE AT ONE END, ANOTHER
TYPE OF SEAT AT THE OTHER

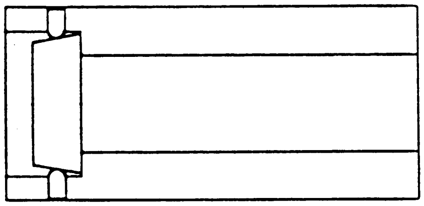


VARIETY OF CONE CONFIGURATIONS

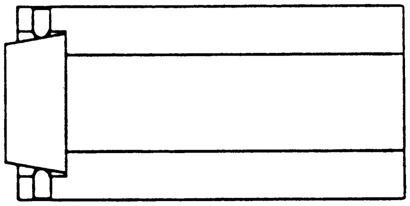
FLUSH END



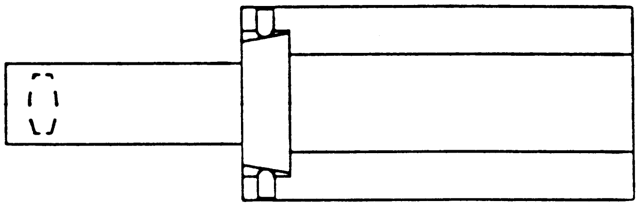
RECESSED



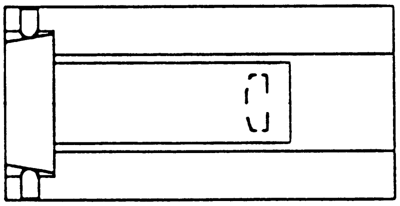
PROUD



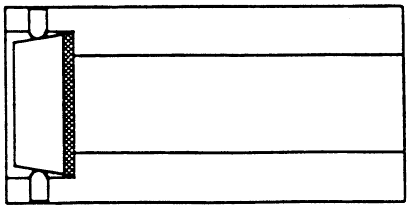
EXTROVERTED



INTROVERTED



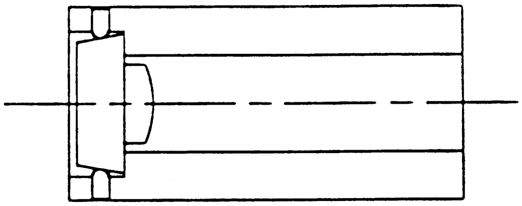
SHIMMED



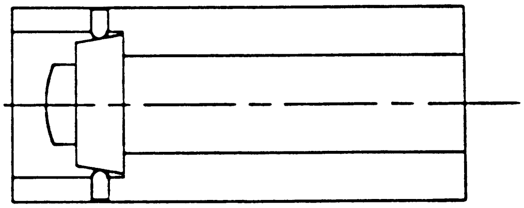
CONES WITH PLANO/X ELEMENTS

THE PLANO SURFACE OF THE ELEMENT IS MADE PARALLEL TO THE CYLINDER SHOULDER.

LENS INSIDE



LENS OUTSIDE

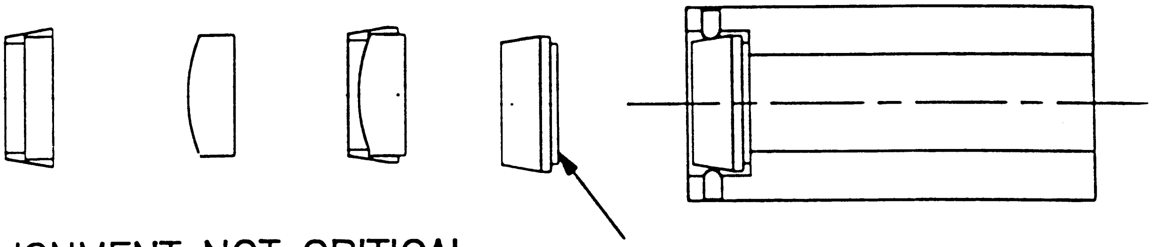


LENS CEMENTED IN CONICAL CAP

CAP

LENS

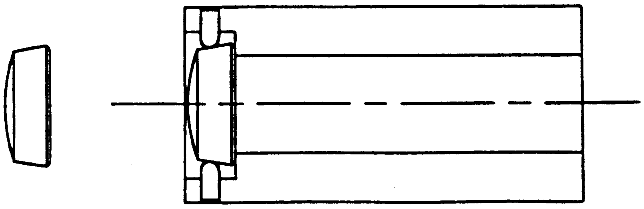
SCREWS BEAR ON CAP



ALIGNMENT NOT CRITICAL

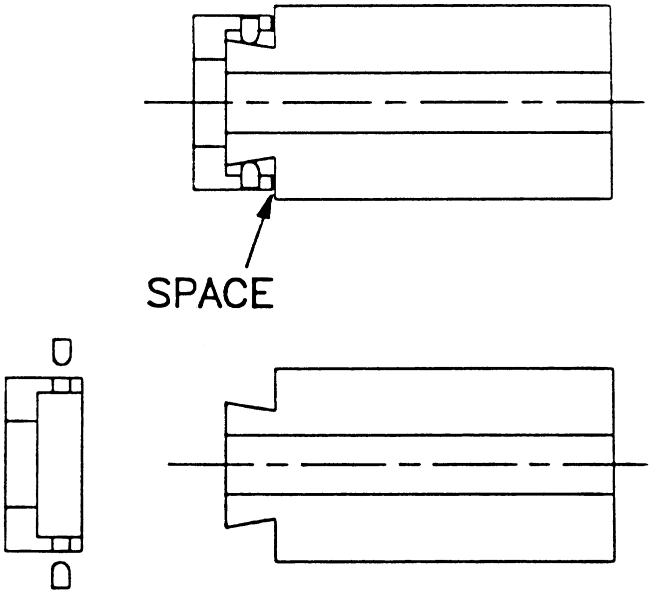
REFERENCE SURFACE

CONICALLY EDGED LENS USED DIRECTLY WITH SOFT-TIP SCREWS



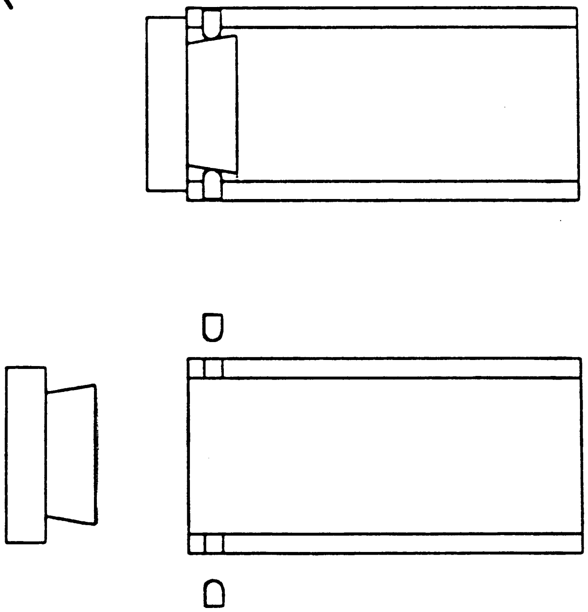
OTHER ARRANGEMENTS

FIXED CONE



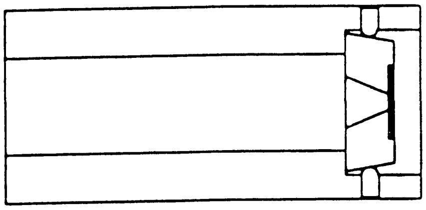
LARGER AREA FOR OPTICAL ELEMENT

END OF CYLINDER

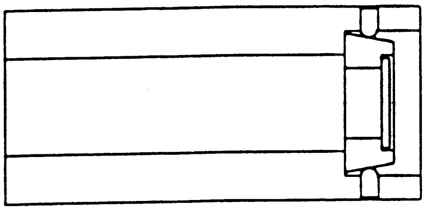


GREATER CLEAR APERTURE

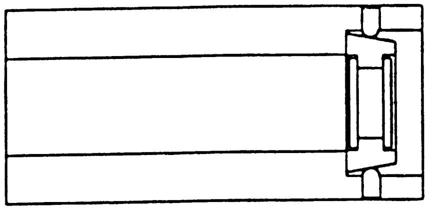
EXAMPLES OF APPLICATIONS



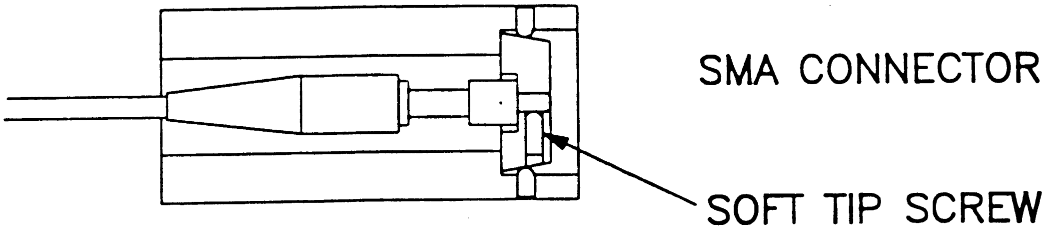
PINHOLE IN FOIL MOUNTED IN A SHALLOW RECESS



RETICLE

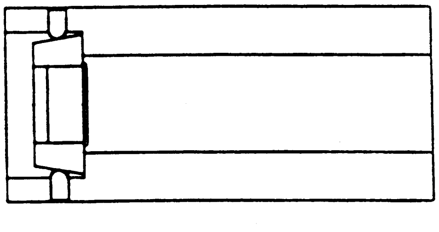


RETICLE WITH AXIALLY SEPARATED DIFFUSER



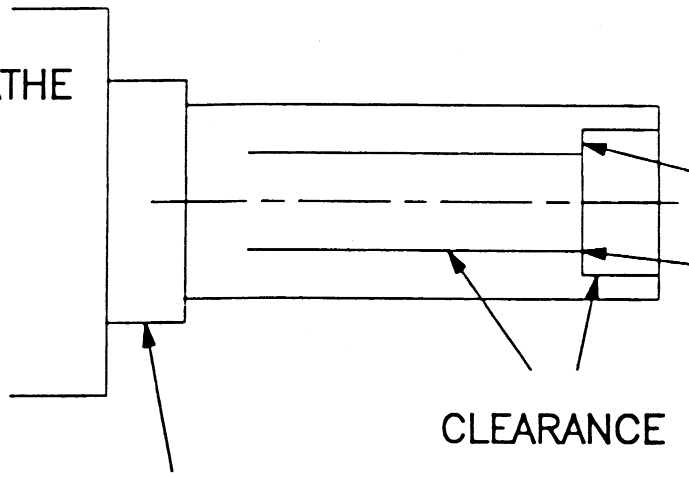
SMA CONNECTOR

POSITION SENSING DETECTOR

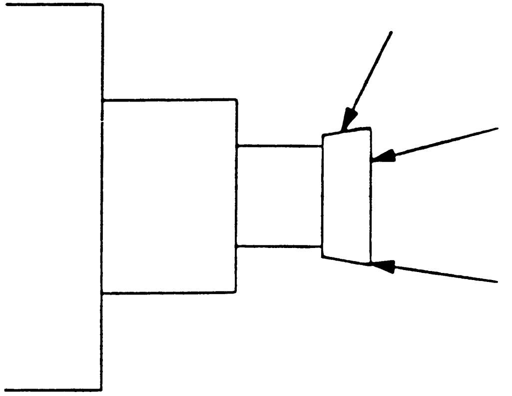


MACHINING

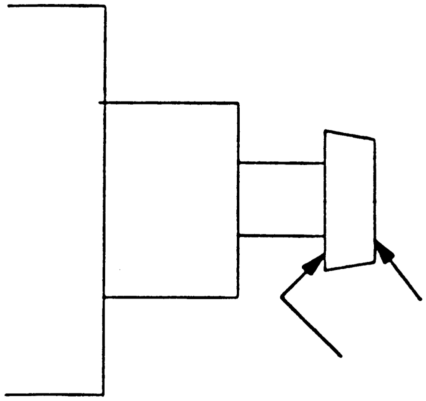
CYLINDER



CONE



TWO POSSIBLE ORIENTATIONS



TOROIDAL MOUNTING OF OPTICAL ELEMENTS

ROTATIONALLY SYMMETRIC OPTICAL ELEMENTS CAN BE MOUNTED ON TOROIDAL SURFACES MONOLITHIC WITH ROUND CYLINDERS.

ONE SUCH SURFACES ALIGNS ONE SURFACE (OR CENTER) OF A BI-SPHERICAL LENS

TWO CYLINDERS WITH TOROID COMPLETELY ALIGN A BI-SHERICAL LENS.

SURFACES OF A LENS CONTIGUOUS WITH OPTICAL SURFACES ARE USED.

LENS EDGES ARE IRRELEVANT EXCEPT FOR CLEARANCE.

LENSES ARE "OVERSIZED" IN THE SHOP.

SIDE BENEFIT: NO TURNED DOWN EDGES

TANGENTIAL LINE CONTACT

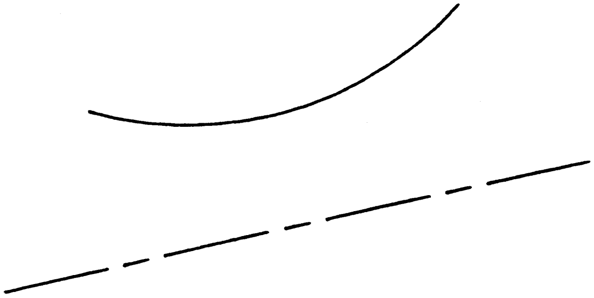
DEFINITION OF TOROID:
A SURFACE GENERATED BY THE ROTATION OF A PLANE CLOSED CURVE ABOUT AN AXIS LYING IN ITS PLANE

HERE "TOROID" IS PART OF A TOROID.

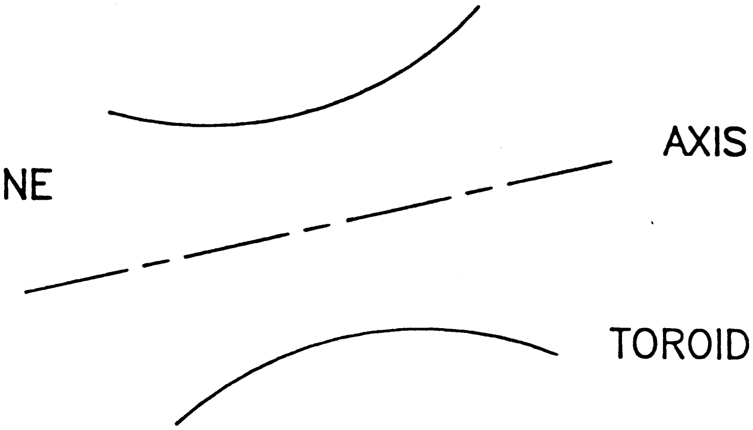
ROTATIONALLY SYMMETRIC ASPHERES CAN BE SO MOUNTED.
SUBTLETIES ?

TOROID AND SPHERE MATING

PLANE CURVE

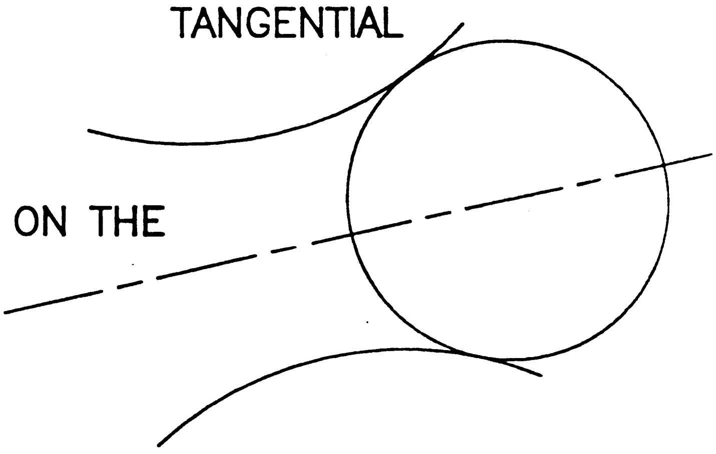


STRAIGHT LINE IN THE PLANE



REVOLUTION ABOUT THE LINE

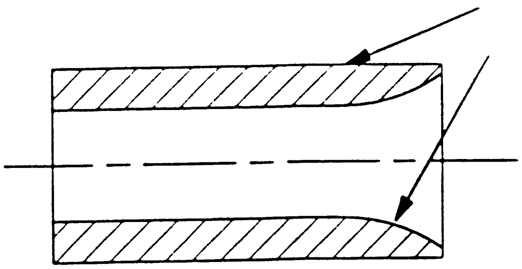
A SPHERE CONTACTING THE TOROID



CENTER OF THE SPHERE ON THE AXIS

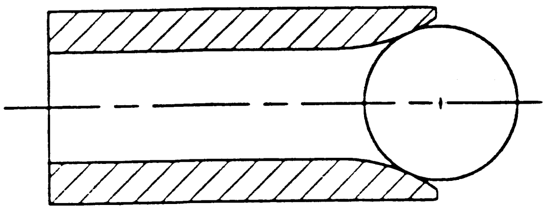
THREE DEGREES OF FREEDOM REMAIN

TOROIDAL MOUNTING SURFACES ON CYLINDERS

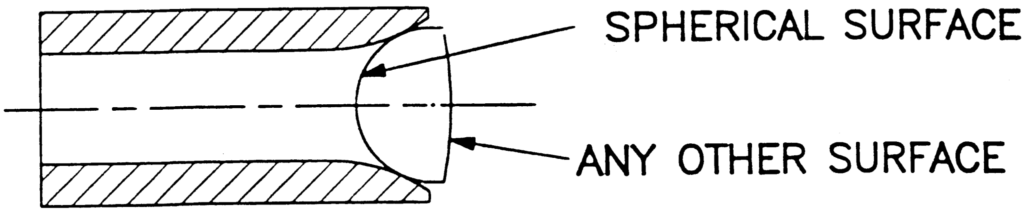


THE CYLINDRICAL OUTER SURFACE AND THE TOROIDAL SURFACE ARE MACHINED IN SAME LATHE SETUP FOR BEST ACCURACY.

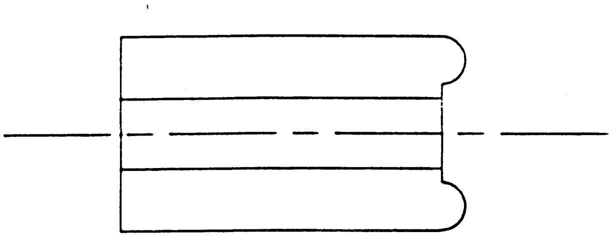
THE CENTER OF A SPHERE NESTED IN THE TOROID IS ON THE AXIS OF THE CYLINDER.

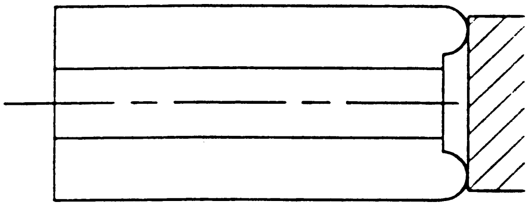


THE CENTER OF ONE SURFACE OF A SPHERICAL–X LENS IS ON THE CYLINDER AXIS.

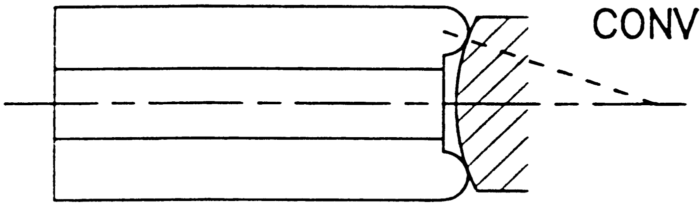


TOROIDAL MOUNTING

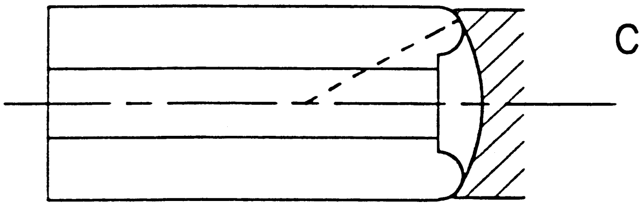




PLANE SURFACE



CONVEX SURFACE



CONCAVE SURFACE

SPECIAL CASES OF TOROID:
CONE
FLAT

CENTERING METHODS

ONE SPHERICAL SURFACE OF THE ELEMENT IS ALIGNED BY PHYSICAL CONTACT WITH A TOROIDAL SEAT.

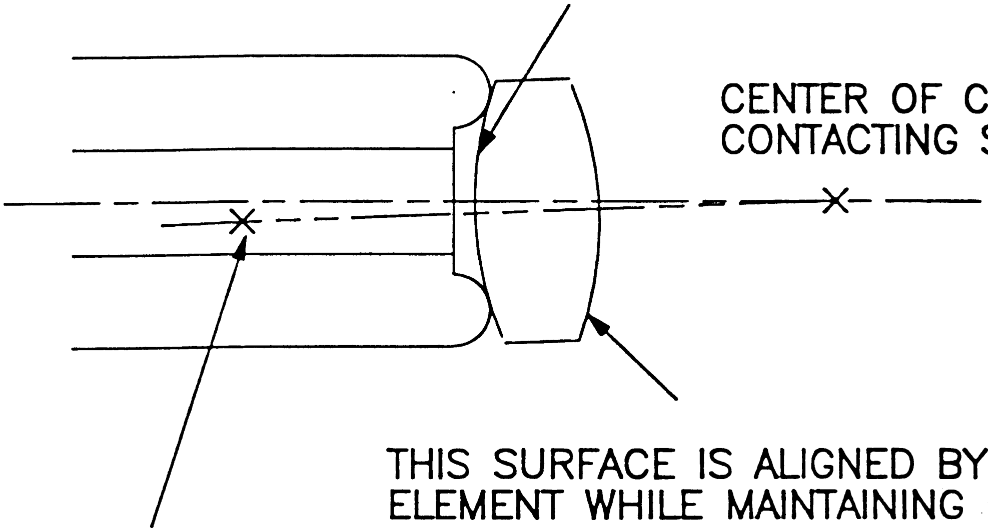
THE SECOND SIDE CAN BE ALIGNED IN SEVERAL WAYS:

- BY CONTACT WITH ANOTHER COAXIAL TOROID
  - PERMANENTLY
  - TEMPORARILY

- BY ADJUSTING WITH FEEDBACK, WHICH CAN BE
  - OPTICAL
  - MECHANICAL

CONTACT WITH TOROIDAL SEAT CAN BE MAINTAINED WITIH
- GRAVITY, USING A VERTICAL V
- VACUUM
- SPRING LOAD

CENTERING ON TOROIDAL SEATS



THIS SURFACE IS ALIGNED BY CONTACT

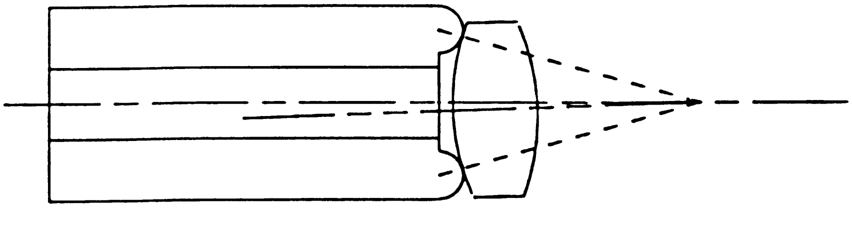
CENTER OF CURVATURE OF
CONTACTING SURFACE

AXIS

THIS SURFACE IS ALIGNED BY TILTING THE
ELEMENT WHILE MAINTAINING CONTACT

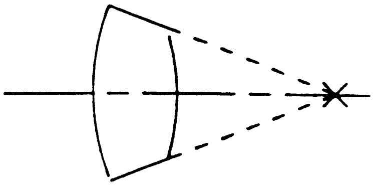
CENTER OF CURVATURE
OF NON–CONTACTING
SURFACE

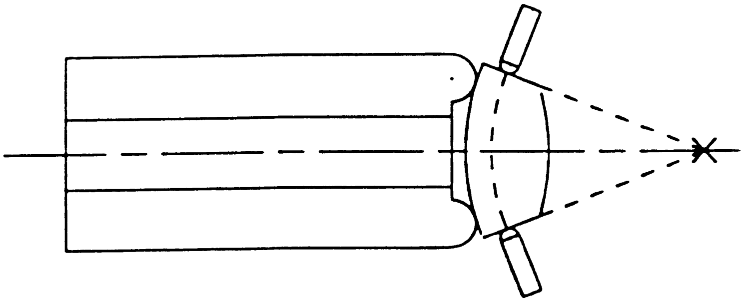
TWO DEGREES OF FREEDOM



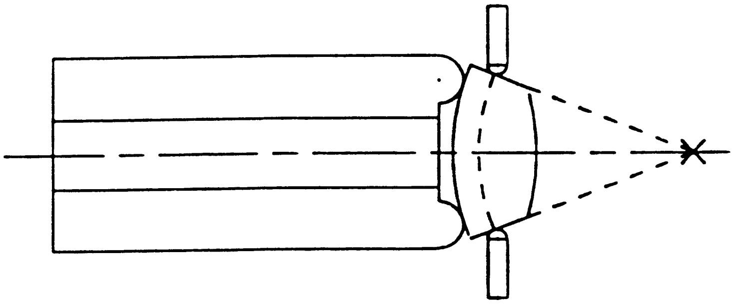
CONICAL ALIGNMENT

STARTING POINT: LENS EDGED TO PRODUCE A CONE WHOSE VERTEX IS AT THE CENTER OF CURVATURE OF THE SURFACE TO BE ON THE TOROID.



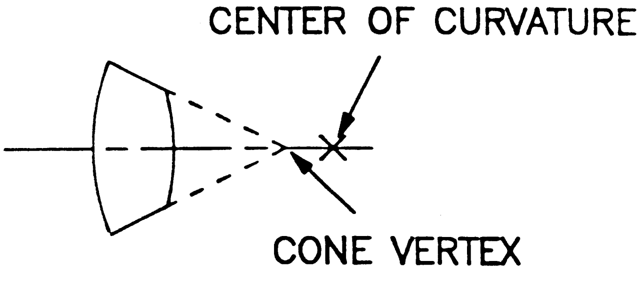


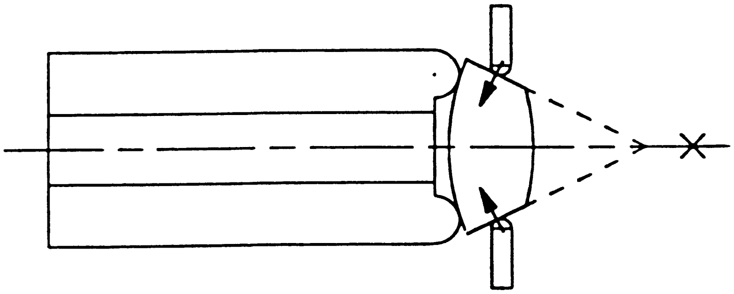
SCREWS NORMAL TO THE CONE PRODUCE PURE ROTATION ABOUT THE COMMON CENTER OF CURVATURE AND VERTEX..



SCREWS WITH A SPHERICAL TIP AT ANY ANGLE LIKEWISE PRODUCE PURE ROTATION.

LENS EDGED WITH CONE WHOSE VERTEX IS CLOSER TO THE LENS



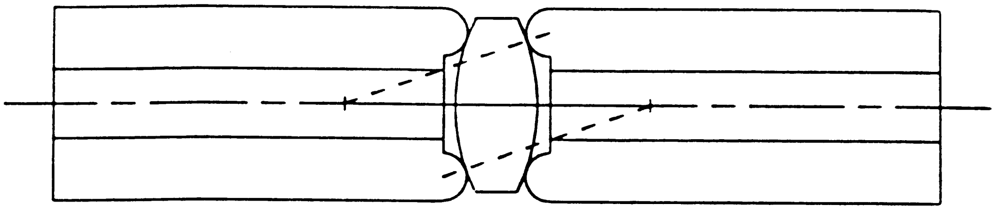


THERE IS AN AXIAL FORCE COMPONENT THAT HOLDS THE LENS AGAINST THE TOROID.

THIS IS A GENERALIZATION OF THE CENTERING CONE OF THE PREVIOUS SECTION.

DOUBLE TOROIDAL CENTERING

FOR ELEMENTS WITH TWO SPHERICAL SIDES,
INCLUDING PLANAR.



DIFFERENT VERSIONS:

THE ELEMENT CAN BE TEMPORARILY HELD.

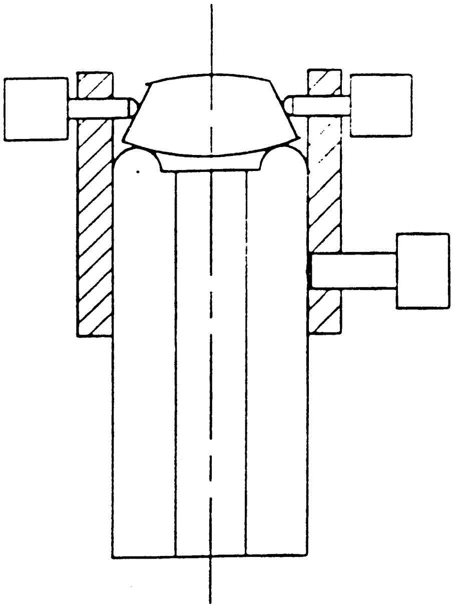
THE ELEMENT CAN BE CEMENTED TO ONE CYLINDER AND THE OTHER REMOVED.

THE ELEMENT CAN BE CEMENTED TO BOTH.

DIFFERENT CYLINDER DIAMETERS PRODUCE TILT.

REMOVABLE ALIGNMENT APPARATUS

COLLAR WITH ADJUSTMENT SCREWS

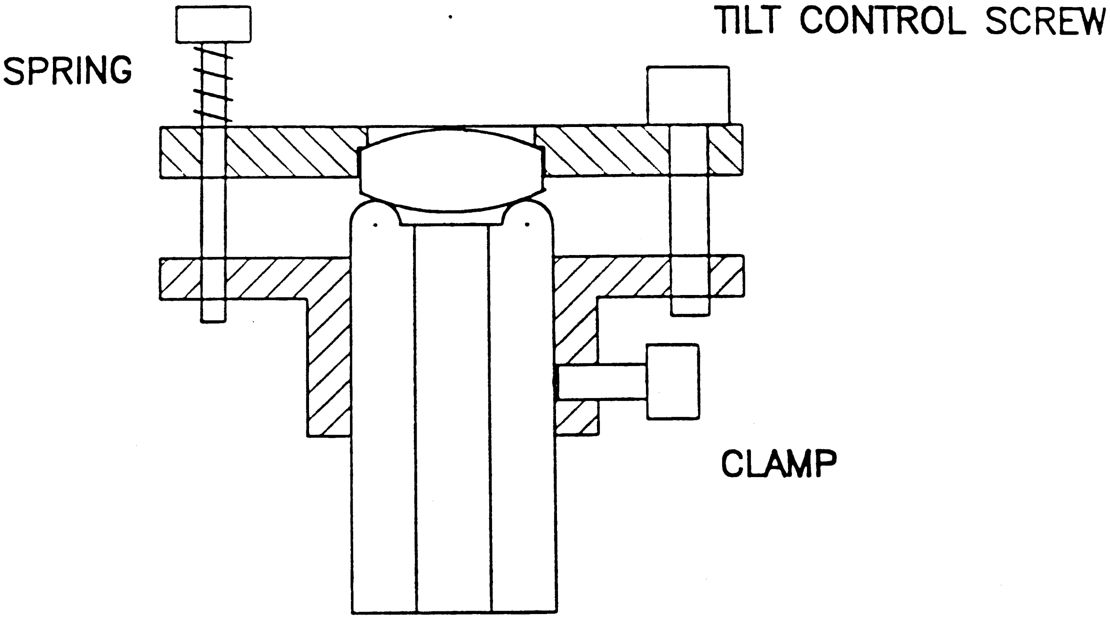


ADJUSTMENT SCREWS STAY WITH FIXTURE,
SO THEY CAN BE OF HIGH QUALITY.

CLAMP

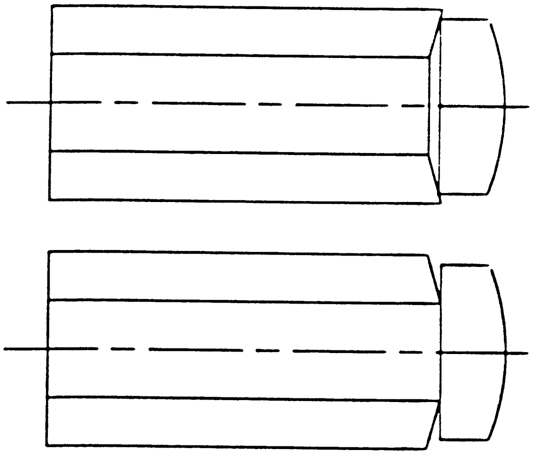
CAN ALSO BE USED WITH CONES.

COLLAR WITH TILT PIECE



IMPERFECTIONS IN PLANAR SEATS

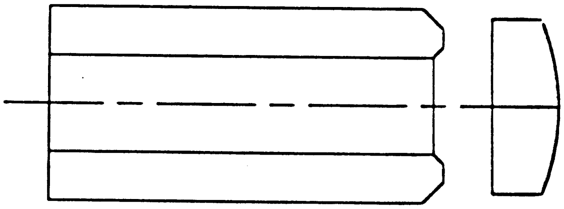
SLIGHTLY CONICAL SEAT (SHOWN EXAGGERRATED)



POORLY DEFINED
ALIGNMENT SURFACES

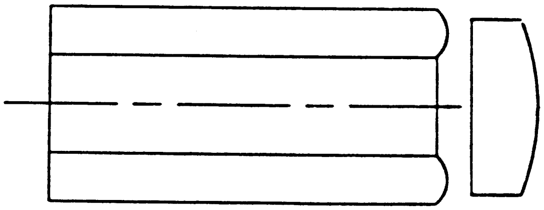
IMPROVEMENTS

NARROWER CONTACT RING WITH SMOOTHED EDGES

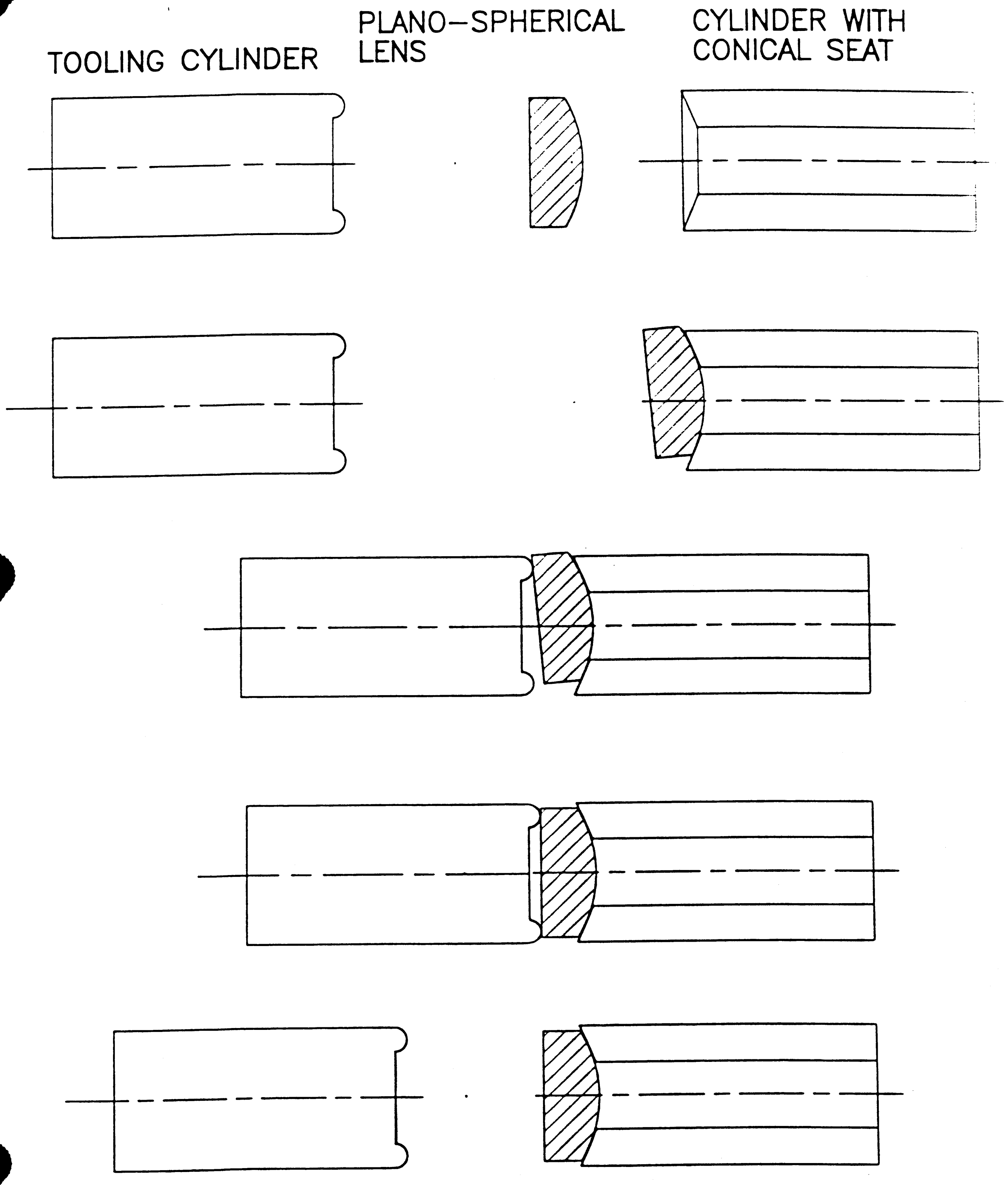


POOR MAN'S TOROID

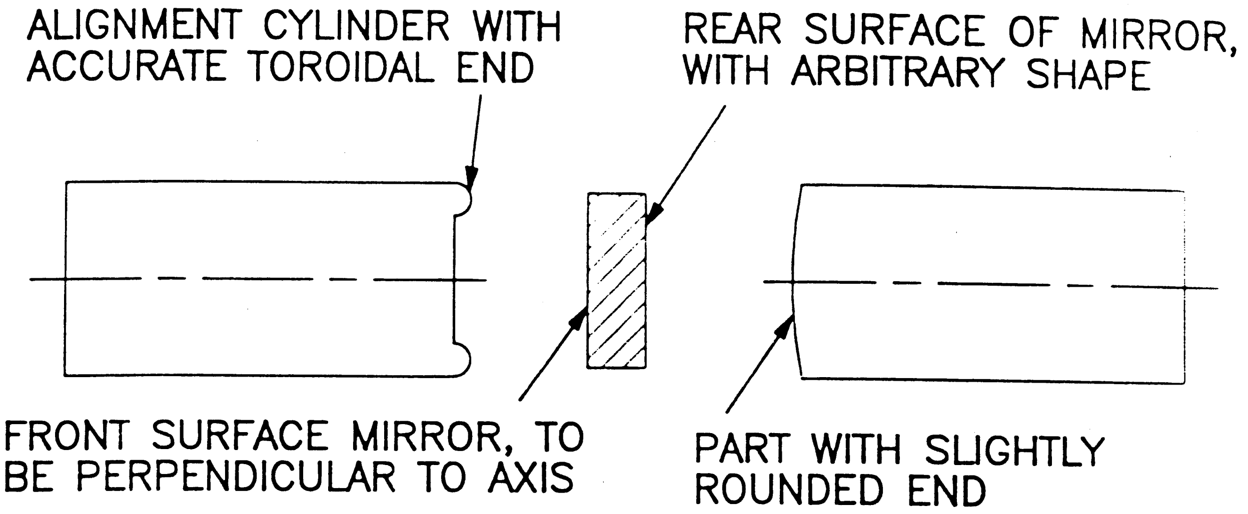
SLIGHT ROUNDING



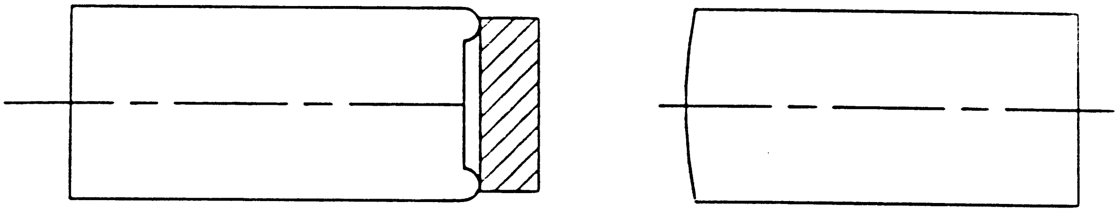
SQUARING BY TOOLING CYLINDER



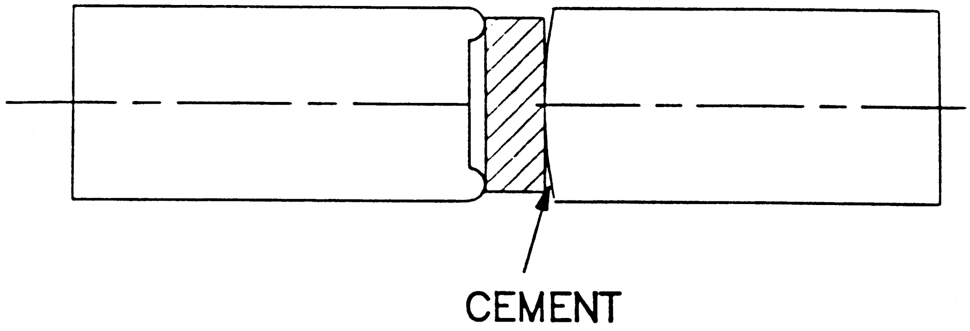
TRANSFER OF ALIGNMENT



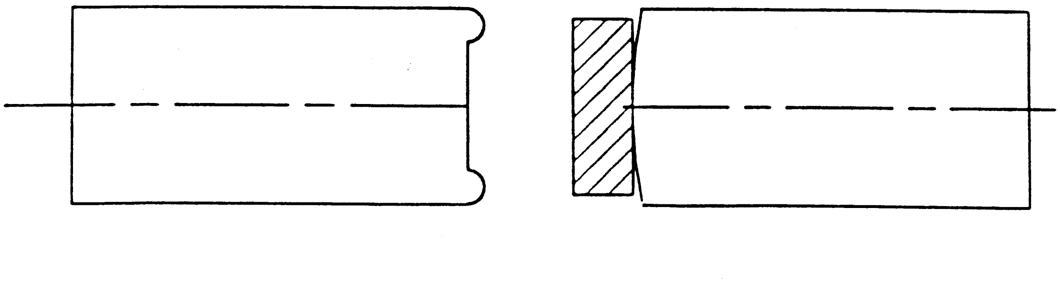
MIRROR SQUARED BY MASTER



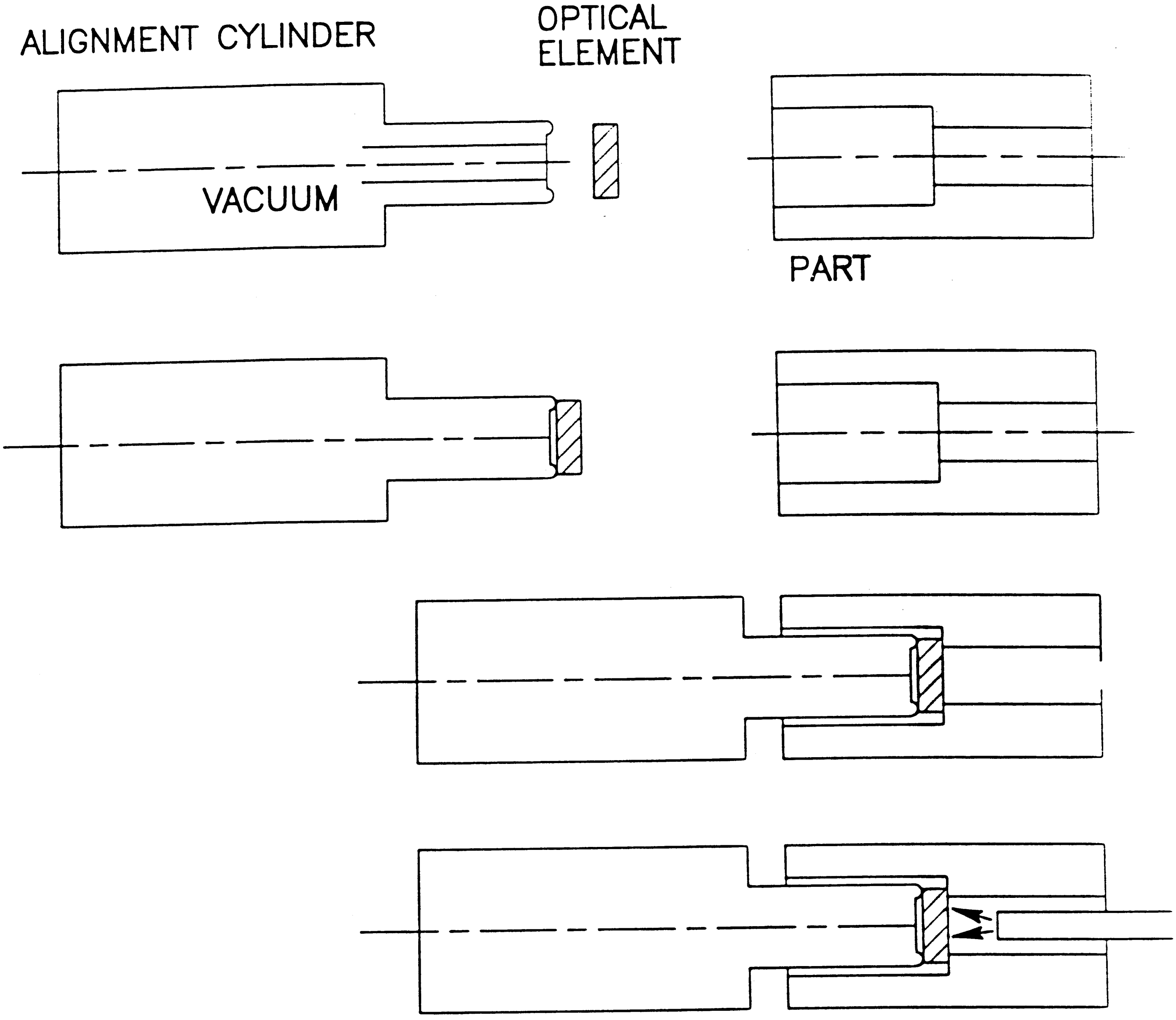
MIRROR TRANSFERRED TO PART



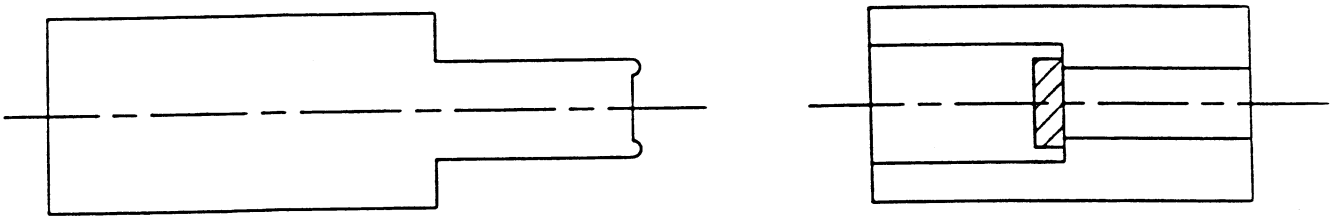
MASTER REMOVED



TRANSFER TO INACESSIBLE LOCATION

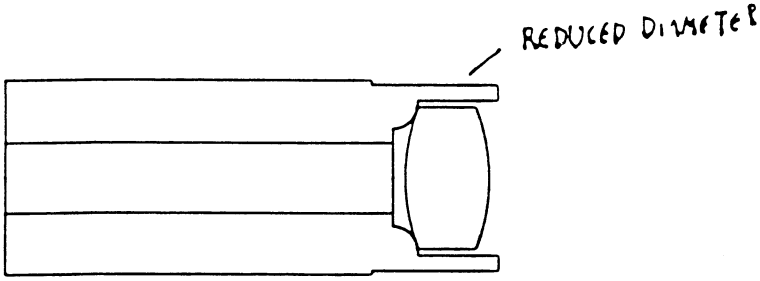


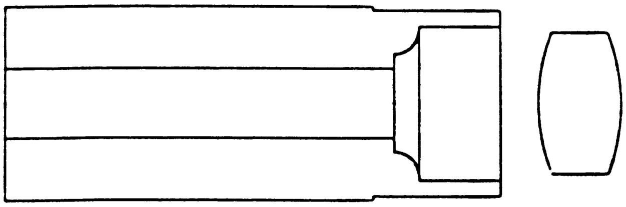
UV TO CURE CEMENT CAN BE DELIVERED BY A FIBER BUNDLE.



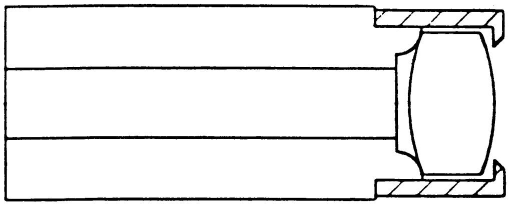
TOROIDAL SEATS WITH PROTECTIVE SHELL

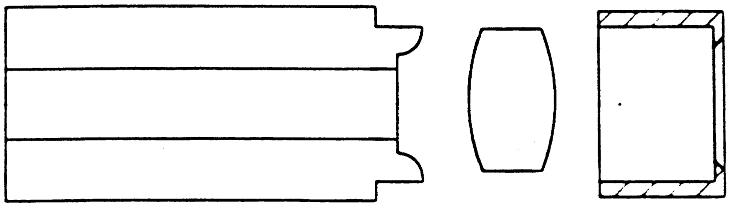
MONOLITHIC CYLINDER



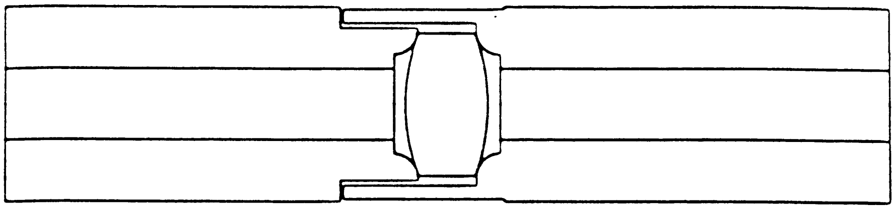


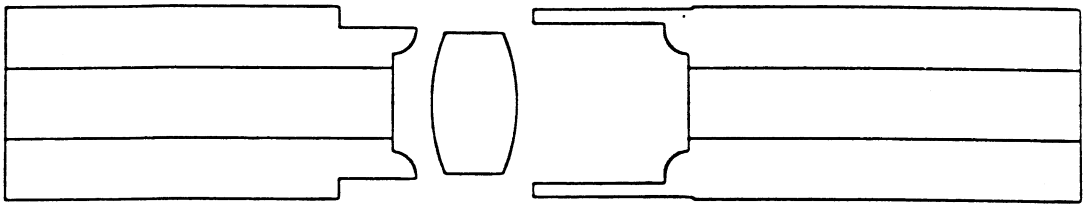
SEPARATE SHELL

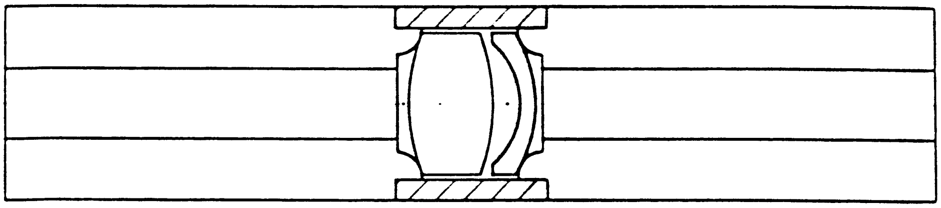


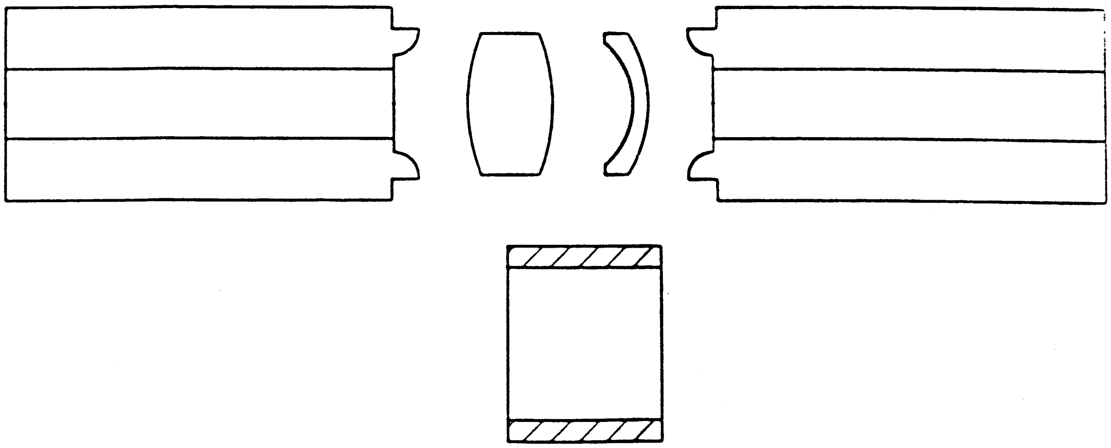


MATING CYLINDERS WITH A PROTECTIVE SHELL

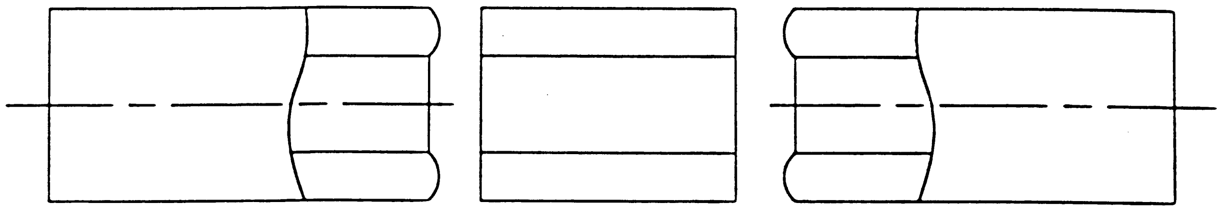








TOROIDS FOR AXIAL SPACING



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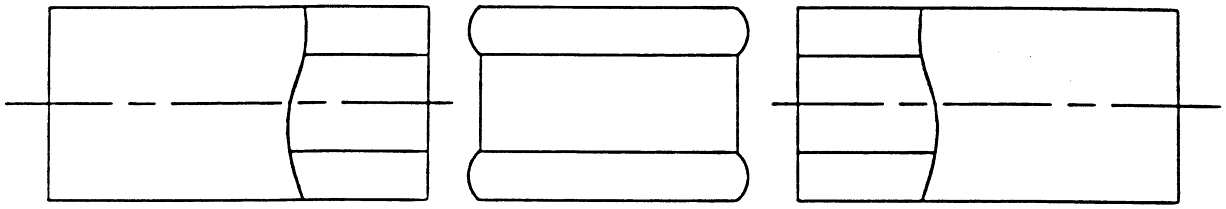
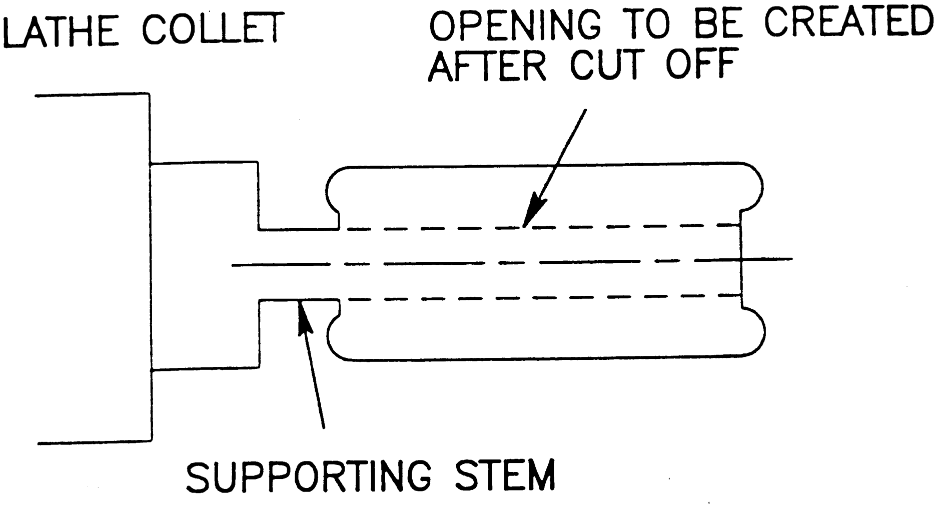


MORE DETERMINANT THAN FLAT TO FLAT.

SEATS MACHINED ON BOTH ENDS WITHOUT REMOVAL FROM THE LATHE



FOR IMPROVED CONCENTRICITY

AXIAL POSITIONING AND MOTION

DETERMINING AXIAL LOCATION OPTICALLY

DETERMINING SOME OPTICAL PROPERTIES

SETTING LENS SPACING MECHANICALLY

AXIAL STOPS

AXIAL MOTION OF CYLINDERS FOR FUNCTIONING

DRIVING CYLINDERS AXIALLY

AXIAL POSITIONING AND MOTION

VARIETIES OF AXIAL POSITIONING TASKS:

ASSEMBLING ELEMENTS

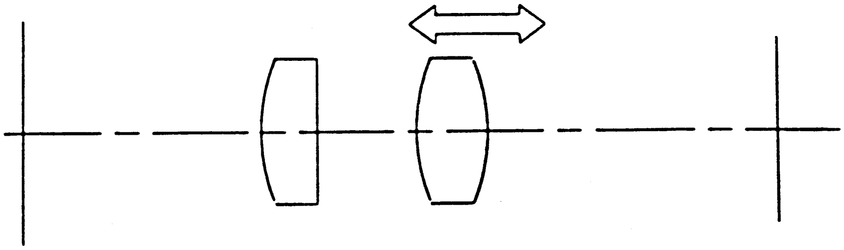
- SETUP POSITIONING
  - BY CALCULATION AND MEASUREMENT
    - MECHANICAL SETTING OF POSITIONS
  - BY OBSERVATION OF OPTICAL PROPERTIES

MEASURING OPTICAL PROPERTIES BY AXIAL MOTION

REMOVING CYLINDERS AND RETURNING THEM TO THE SAME AXIAL POSITION

MOVING ELEMENTS AXIALLY AS PART OF THE FUNCTION OF THE APPARATUS

EXAMPLES:
- FOCUS CHANGE
- INTERFEROMETER MOVEMENT
- ZOOM ACTION
- MAGNIFICATION CHANGE



DETERMINING AXIAL LOCATION OPTICALLY

THE OPTICAL SUBASSEMBLIES ARE ALREADY CENTERED IN CYLINDERS.

TO FIND THE PROPER AXIAL LOCATIONS, POSITIONS ARE VARIED WHILE AN OPTICAL PROPERTY IS MONITORED.

THE EVALUATION CAN BE
  DIRECT VISUAL
  VIDEO
  NON-IMAGING DETECTOR

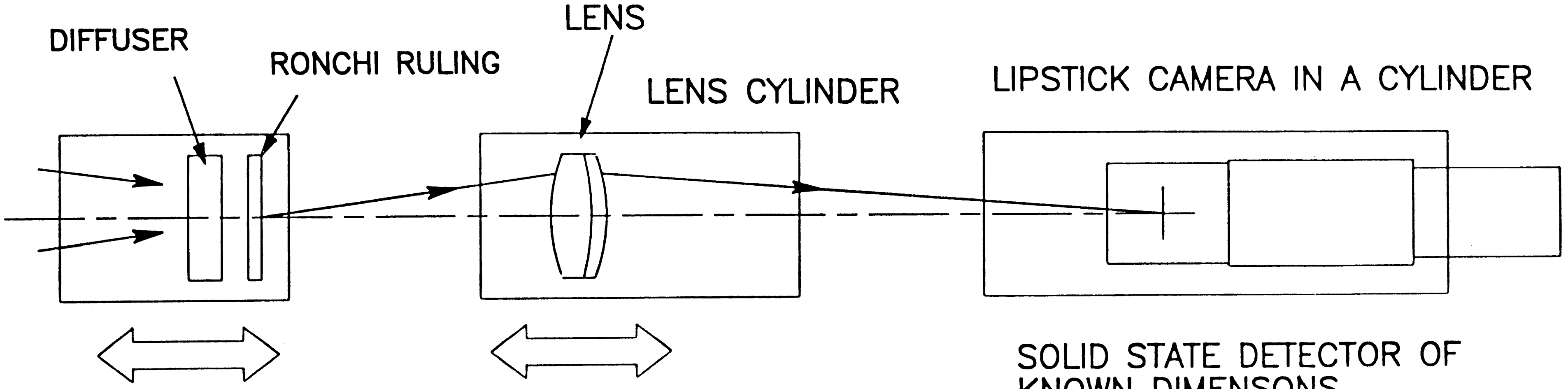
CRITERIA INCLUDE
  IMAGE SHARPNESS
  IMAGE SIZE
  POWER
  ETC

WHEN THE DESIRED POSITION IS FOUND:

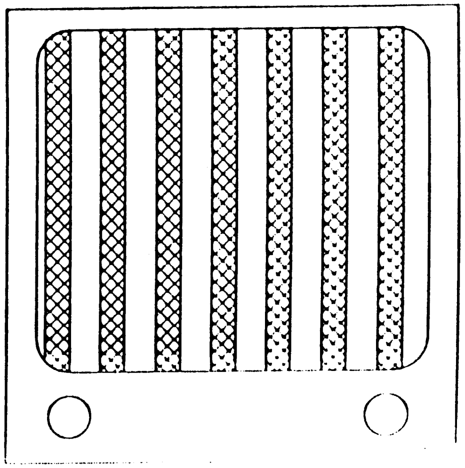
THE POSITION CAN BE MEASURED AND RECORDED FOR REPRODUCTION LATER.

THE POSITION MAY BE MADE PERMANENT.

SETTING A LENS AND VIDEO CAMERA FOR A PARTICULAR MAGNIFICATION



SOLID STATE DETECTOR OF
KNOWN DIMENSONS



THE AXIAL POSITIONS OF THE CYLINDERS ARE FOUND FOR WHICH THE IMAGE SIZE IS AS DESIRED.
(IT SUFFICES TO MOVE ANY TWO CYLINDERS.)

THE SEPARATION BETWEEN THE LENS CYLINDER AND CAMERA CYLINDER IS FOUND FOR WHICH THE IMAGE IS SHARP AND THE MAGNIFICATION CORRECT.

DETERMINING SOME OPTICAL PROPERTIES

USING METHODS INVOLVING AXIAL MOTION

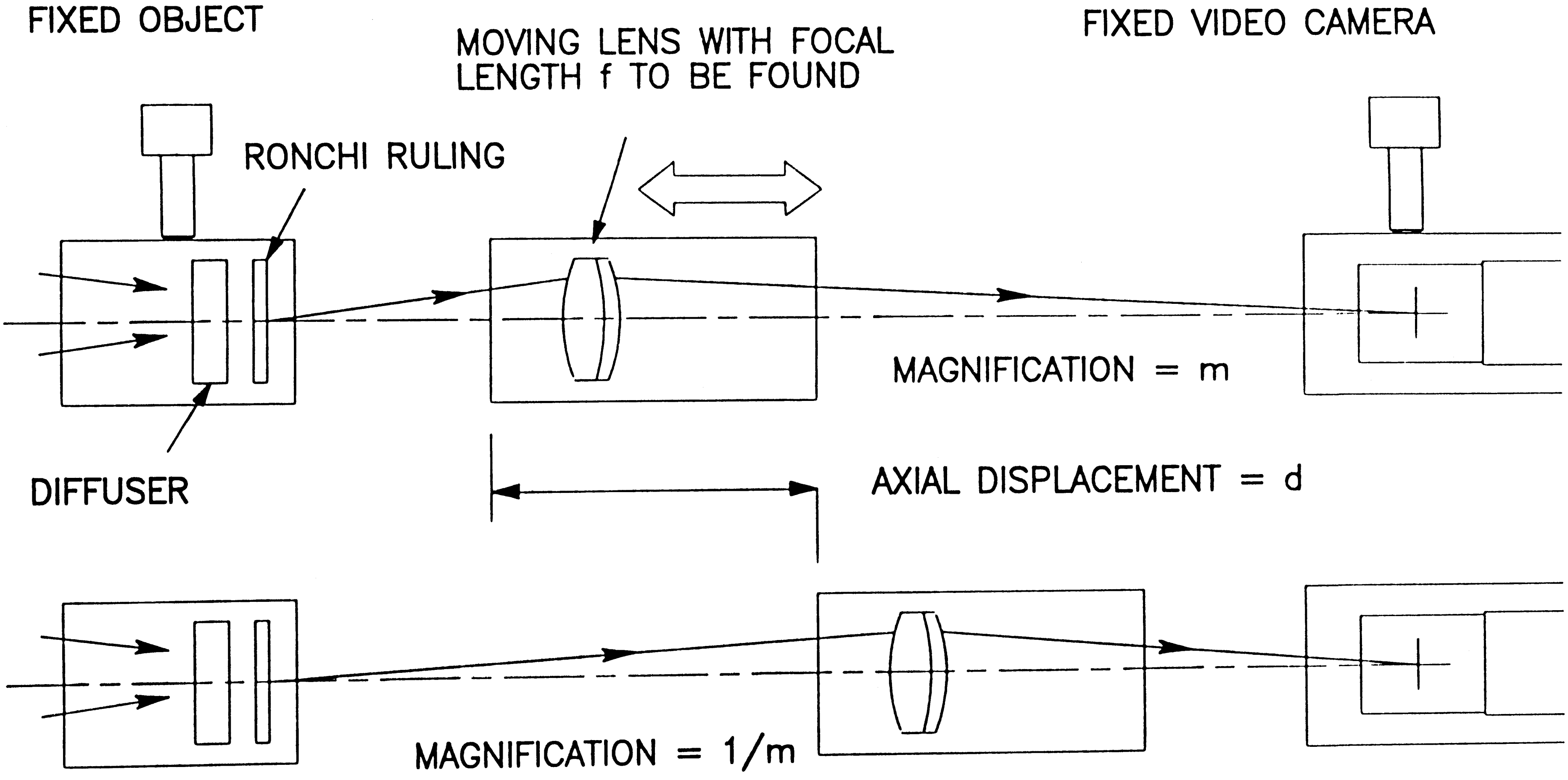
EXAMPLES:
LOCATIONS OF
  FOCAL POINTS
  PRINCIPAL POINTS
  PUPILS
VERTEX LOCATION AND
DISTANCE BETWEEN VERTICES

THE OPTICAL SUBASSEMBLIES ARE ALREADY CENTERED IN CYLINDERS.

TO FIND THE OPTICAL PROPERTIES, POSITIONS ARE VARIED WHILE AN OPTICAL EFFECT IS MONITORED.

THE EVALUATION CAN BE
  DIRECT VISUAL
  VIDEO
  NON-IMAGING DETECTOR

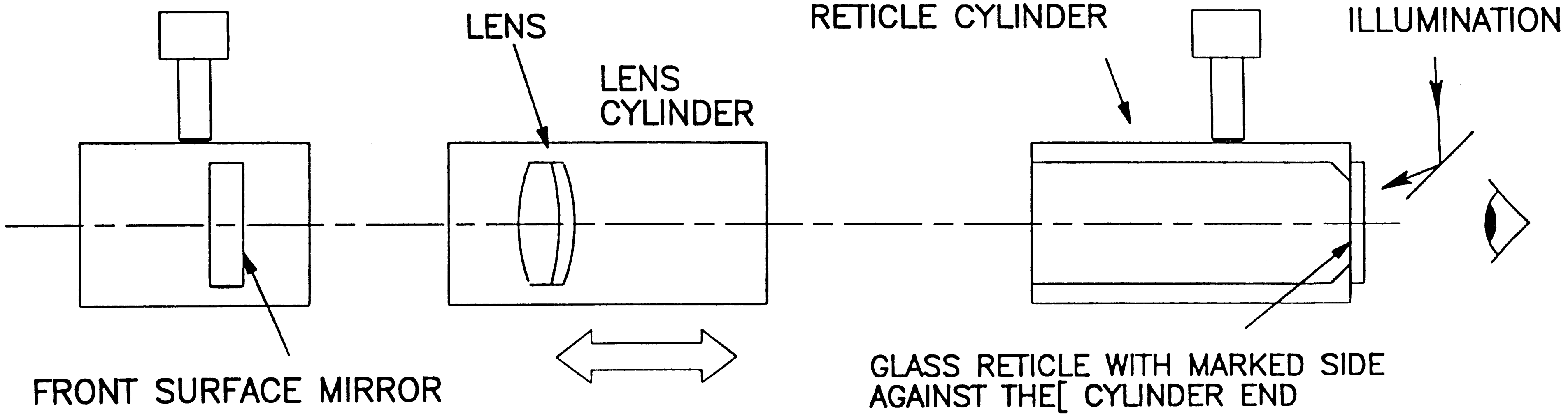
MEASURING FOCAL LENGTH



THE OBJECT AND IMAGE PLANES ARE FIXED FURTHER APART THAN 4 TIMES THE FOCAL LENGTH. THE TWO LENS POSITIONS ARE FOUND FOR WHICH THE IMAGES ARE SHARP. THEIR MAGNIFICATIONS ARE m AND 1/m. THE LENS MOVES d BETWEEN THESE TWO POSITIONS.

$$d = f\,(m - 1/m)$$

FINDING THE PRINCIPAL FOCAL PLANE OF A LENS



THE LENS IS PREVIOUSLY CENTERED.

THE RETICLE IS ILLUMINATED.

THE RETICLE IS OBSERVED ALONG WITH ITS IMAGE.

THE LENS IS MOVED AXIALLY TO MAKE THE IMAGE AS SHARP AS POSSIBLE.

THE SEPARATION OF THE LENS CYLINDER AND RETICLE CYLINDER IS EITHER FIXED OR RECORDED FOR FUTURE REPRODUCTION.

AN AUXILIARY VIDEO SYSTEM ELIMINATES THE EYE'S ACCOMODATION.

THE ANGLE OF THE MIRROR SURFACE IS NOT CRITICAL.

NOTE: THIS METHOD DOES NOT MEASURE THE FOCAL LENGTH.

SETTING LENS SPACING MECHANICALLY

IN THIS APPROACH, FOR PURPOSES OF SETTING AXIAL POSITIONS, LENSES ARE TREATED AS MECHANICAL OBJECTS.

PRIOR TO AXIAL POSITIONING, THE LENSES ARE CENTERED IN CYLINDERS.

THE OPTICAL DESIGN GIVES THE DESIRED VERTEX SEPARATIONS.

THE VERTICES CAN BE SET DIRECTLY.

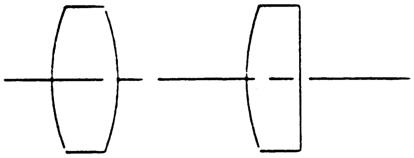
ALTERNATELY, THE VERTICES CAN BE LOCATED WITH RESPECT TO THE CYLINDER ENDS, WHICH ARE SET.

A FEW OF MANY POSSIBLE SETTING DEVICES ARE SHOWN.

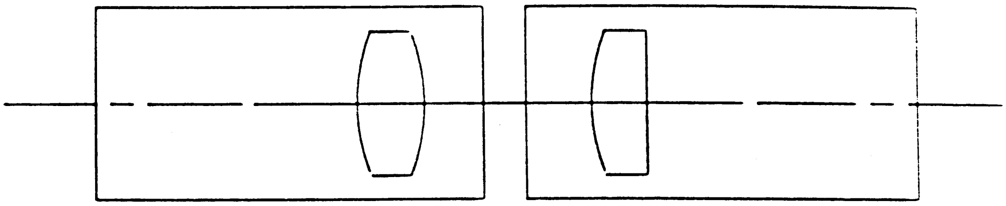
AXIAL POSITION ACCURACIES BETTER THAN TOLERANCE VALUES ARE OFTEN EASILY OBTAINED.

AN AXIAL SPACING PROCESS

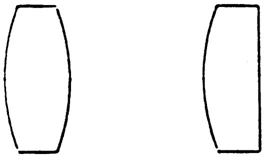
DESIGN THE OPTICS.



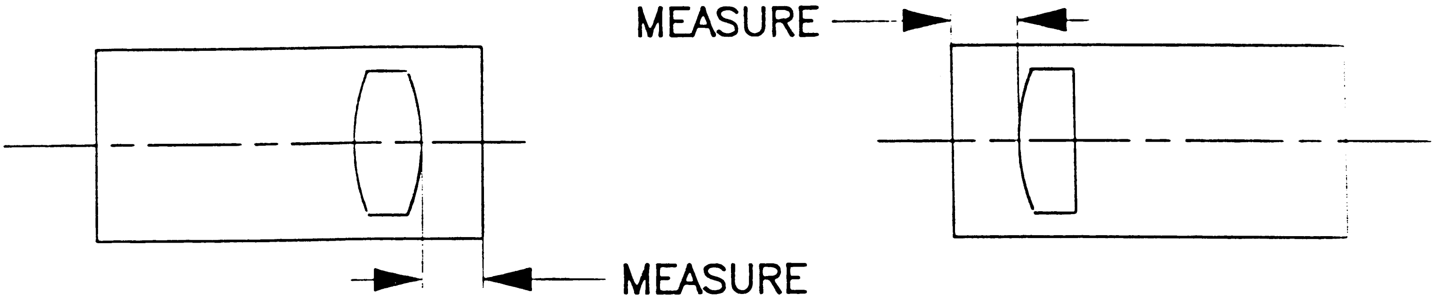
DESIGN THE LENS-HOLDING CYLINDERS, TAKING IN ACCOUNT THE REFERENCE ENDS.



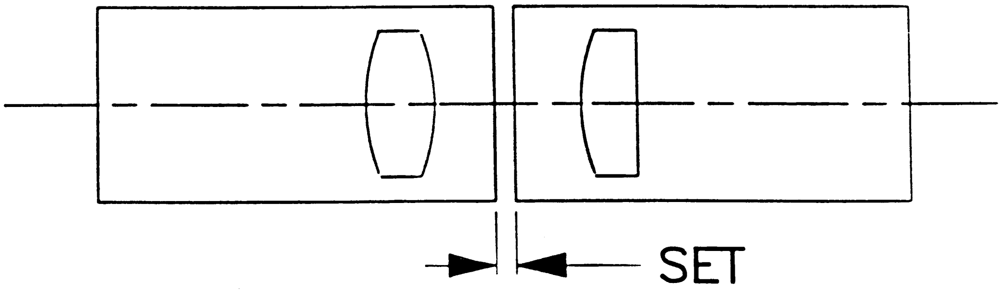
MEASURE ACTUAL LENSES AND CALCULATE THE AXIAL SPACINGS TO OPTIMIZE PERFORMANCE.



PUT THE LENSES IN THEIR CYLINDERS AND MEASURE THEIR VERTEX DISTANCES FROM THE CYLINDER ENDS.



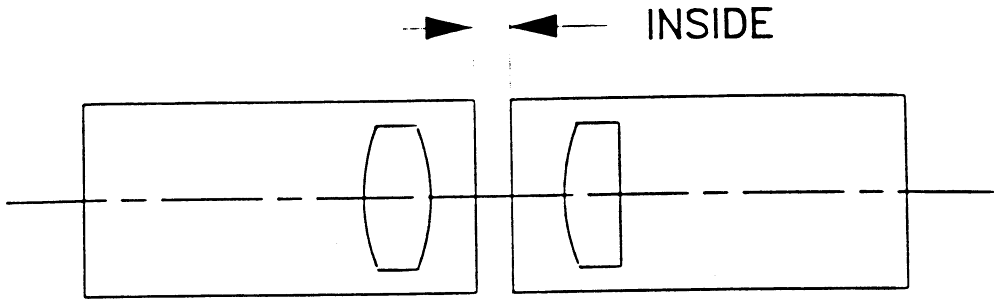
SPACE THE CYLINDERS OR VERTICES AS REQUIRED.

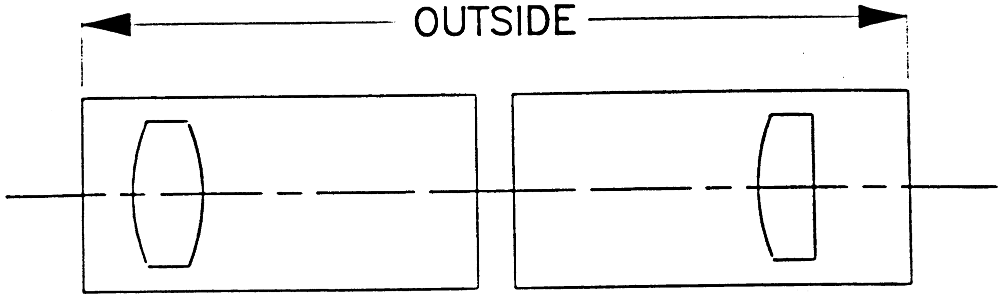


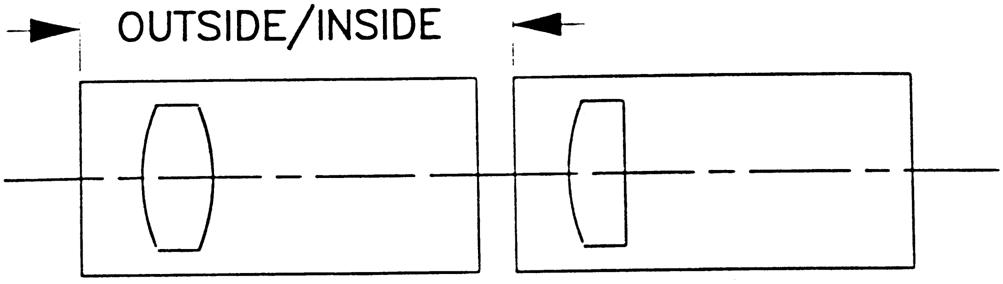
SPACING POSSIBILITIES

THERE MAY BE SEVERAL DIFFERENT SURFACES THAT CAN BE USED TO POSITION THE CYLINDERS.

EXAMPLES:





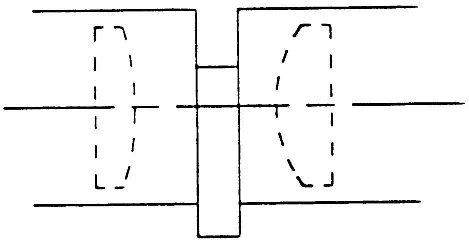


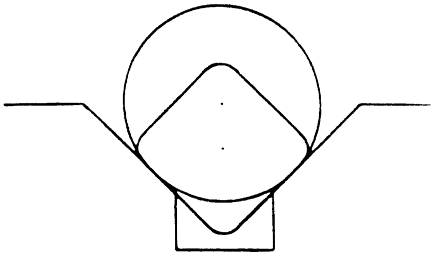
LIKEWISE, DIFFERENT COMBINATIONS OF LENS VERTICES CAN BE USED, OR COMBINATIONS OF VERTICES AND CYLINDER ENDS.

MECHANICALLY SPACING CYLINDERS

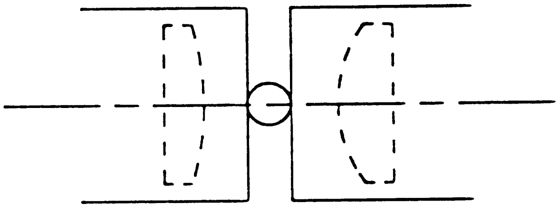
EXAMPLES

GAUGE BLOCK

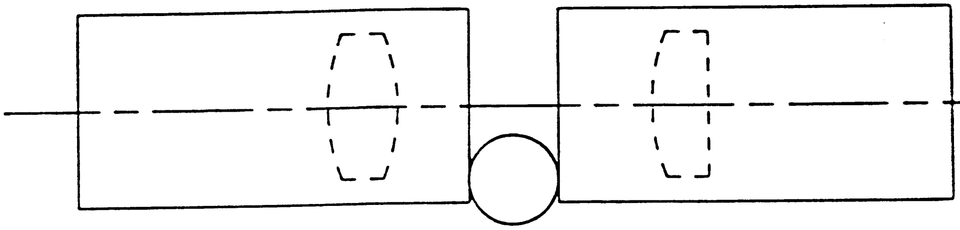


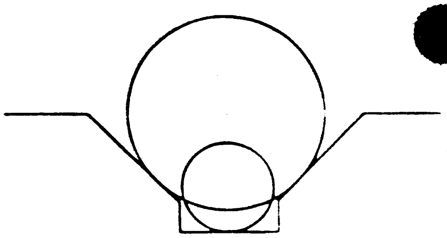


PIN

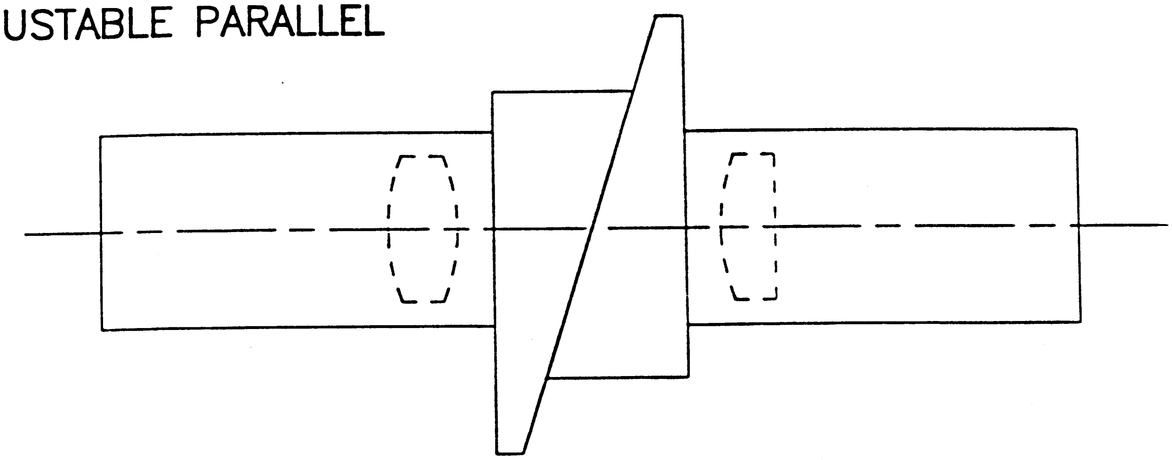


BALL IN TROUGH OF V





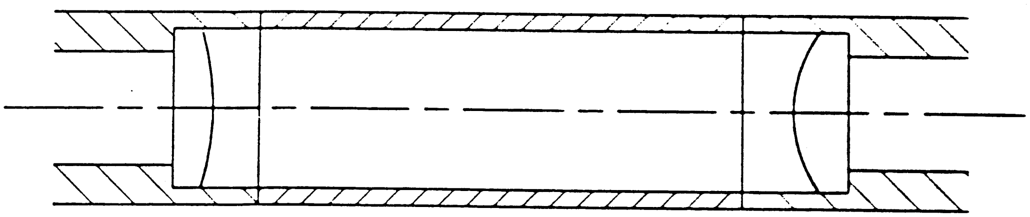
ADJUSTABLE PARALLEL



MECHANICAL SPACING CYLINDERS

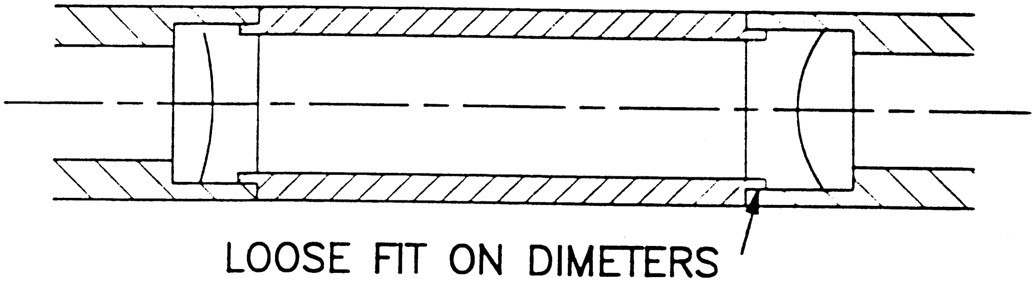
EXAMPLES:

CUSTOM MACHINED SPACING CYLINDER



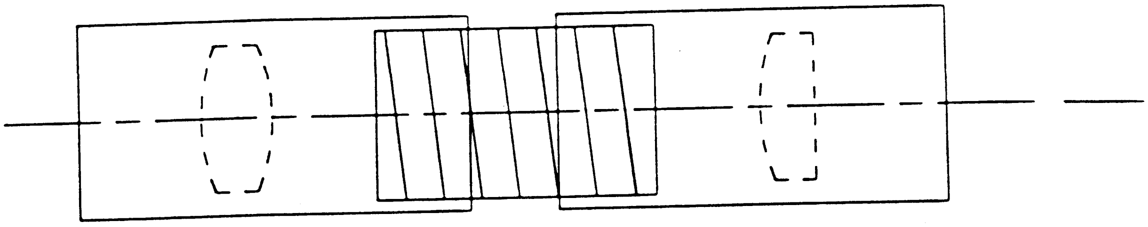
CAPTURED SPACING CYLINDER

CAPTURING MAKES A BETTER LIGHT SEAL AND
ELIMINATES A CLAMP.

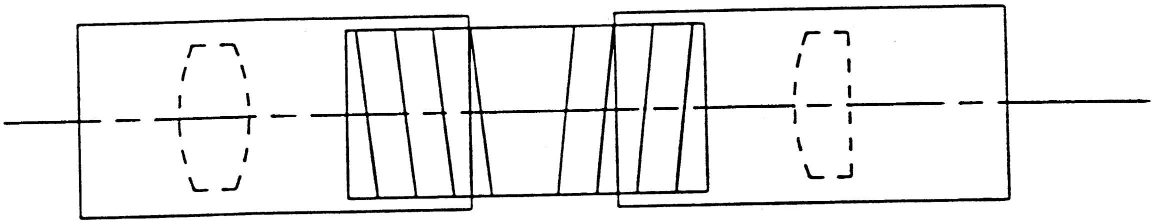


MECHANICALLY SPACING CYLINDERS

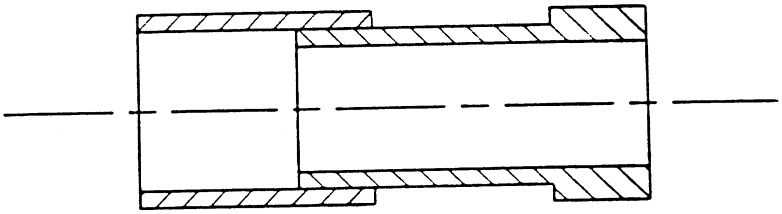
THREADED CYLINDERS AND CONNECTOR

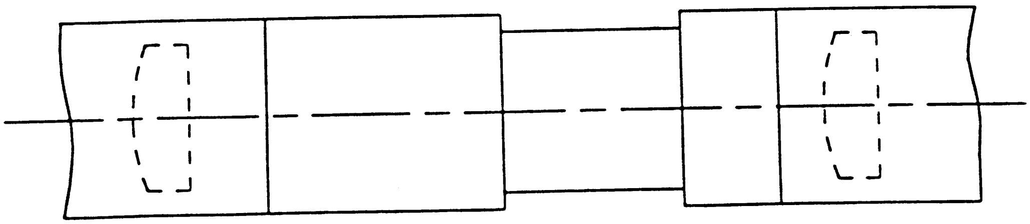


TURNBUCKLE STYLE FOR NON-ROTATING CYLINDERS



TELESCOPING TUBE PAIR WITH LOCK NUT OR THREADED





MECHANICALLY SPACING VERTICES

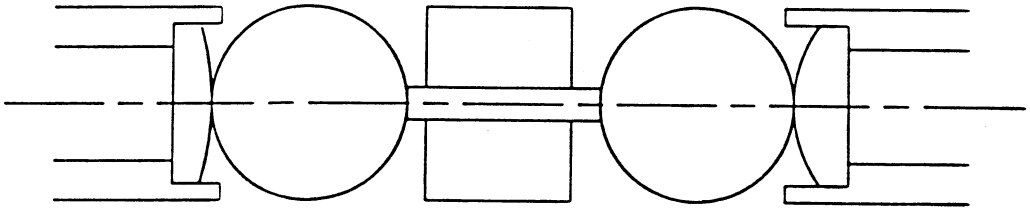
A DIRECT METHOD.
NO MEASUREMENT OF CYLINDER NEEDED.
END QUALITY OF CYLINDER NOT IMPORTANT.

THE CONTACT AREA AT THE VERTEX IS TINY.

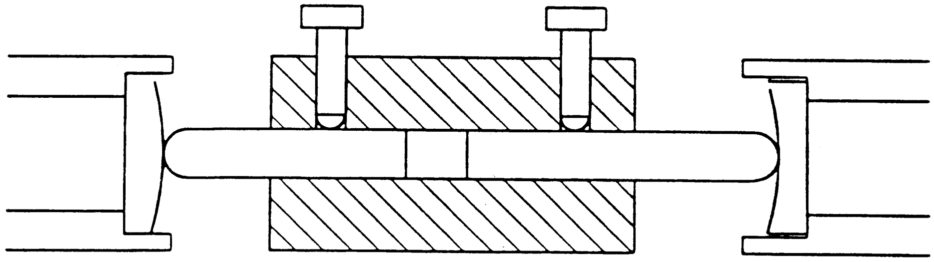
THE SPACER MUST BE REMOVABLE.

EXAMPLES

BALLS IN V WITH DIAMETER OF CYLINDER



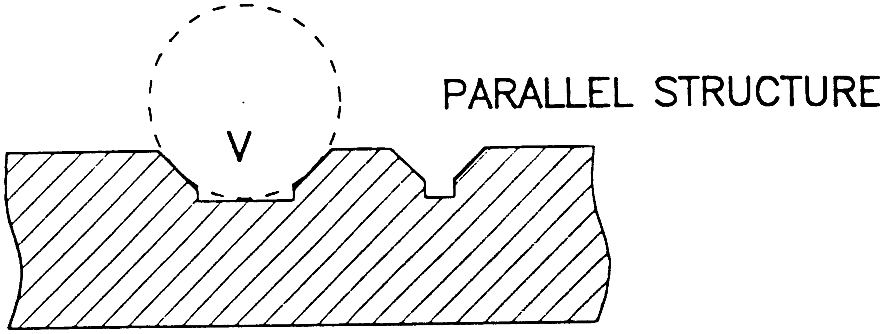
ADJUSTABLE SETTING TOOL



WORKS FOR CONCAVE AND CONVEX SURFACES.

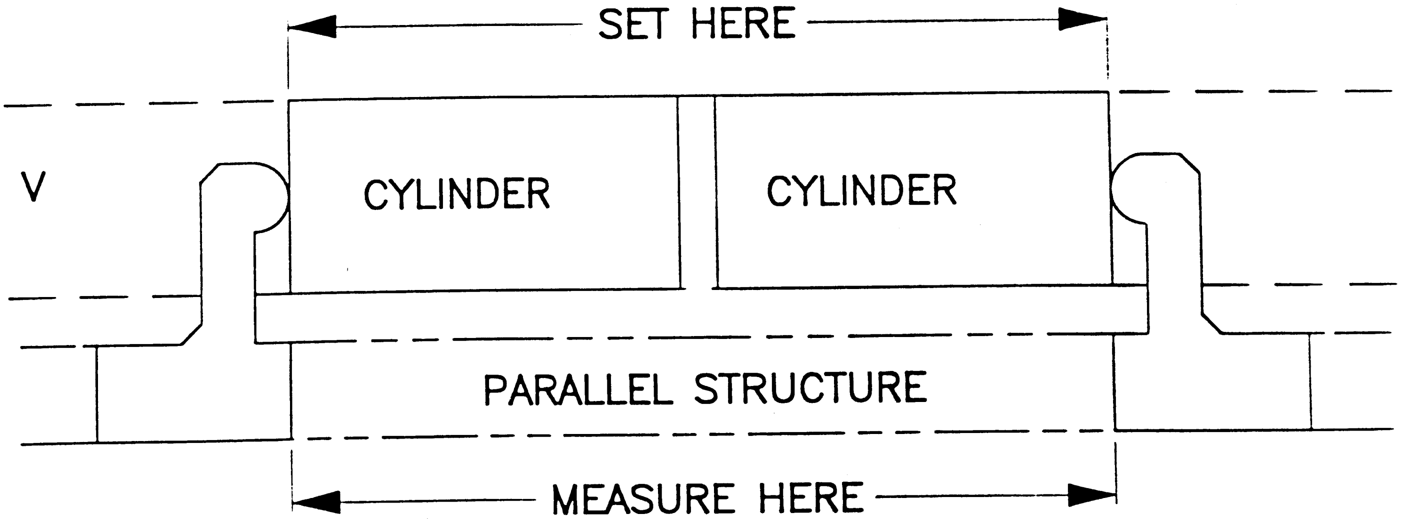
SPACING MECHANICALLY WITH PARALLEL AUXILIARY V STRUCTURE

EXAMPLE



SEE SECTION ABOUT VS

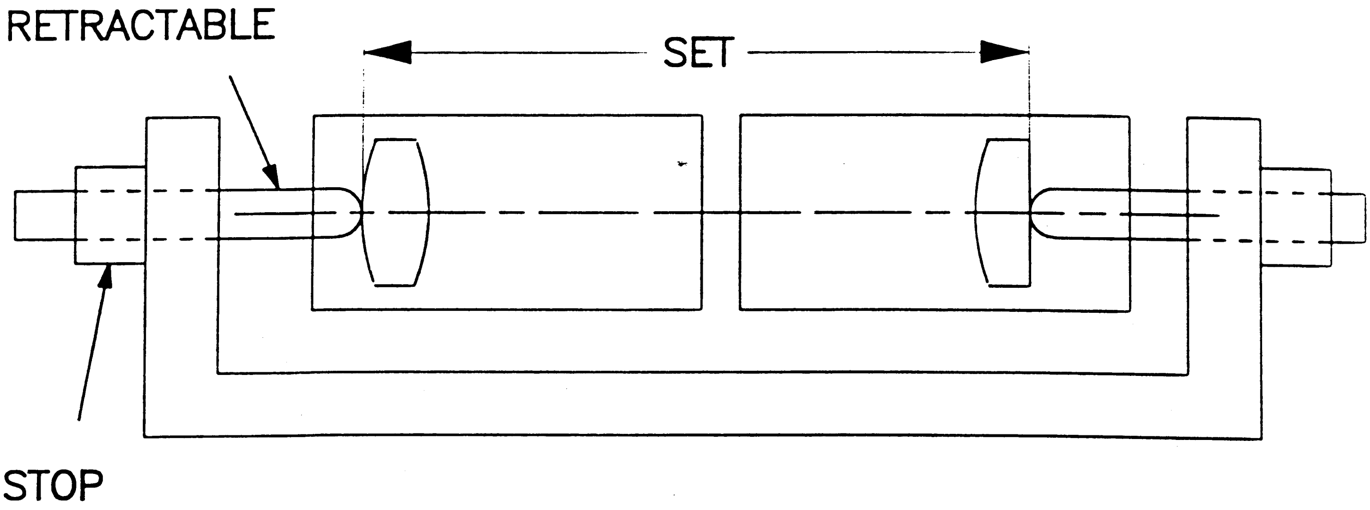
GENERAL SCHEME (PLAN VIEW)

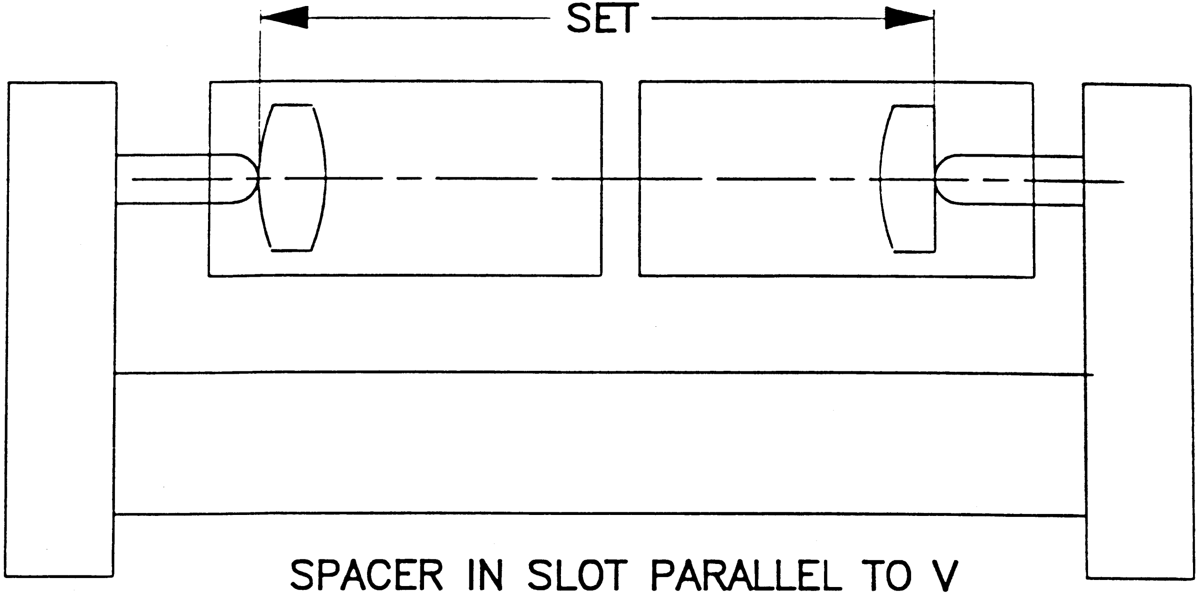


EXAMPLES FOLLOW, SHOWING A FEW OF MANY EMBODIMENTS.

AXIAL SETTING TOOLS FOR OUTSIDE

A FIXTURE SUITABLE FOR PRODUCTION WITH A FIXED SETTING DISTANCE

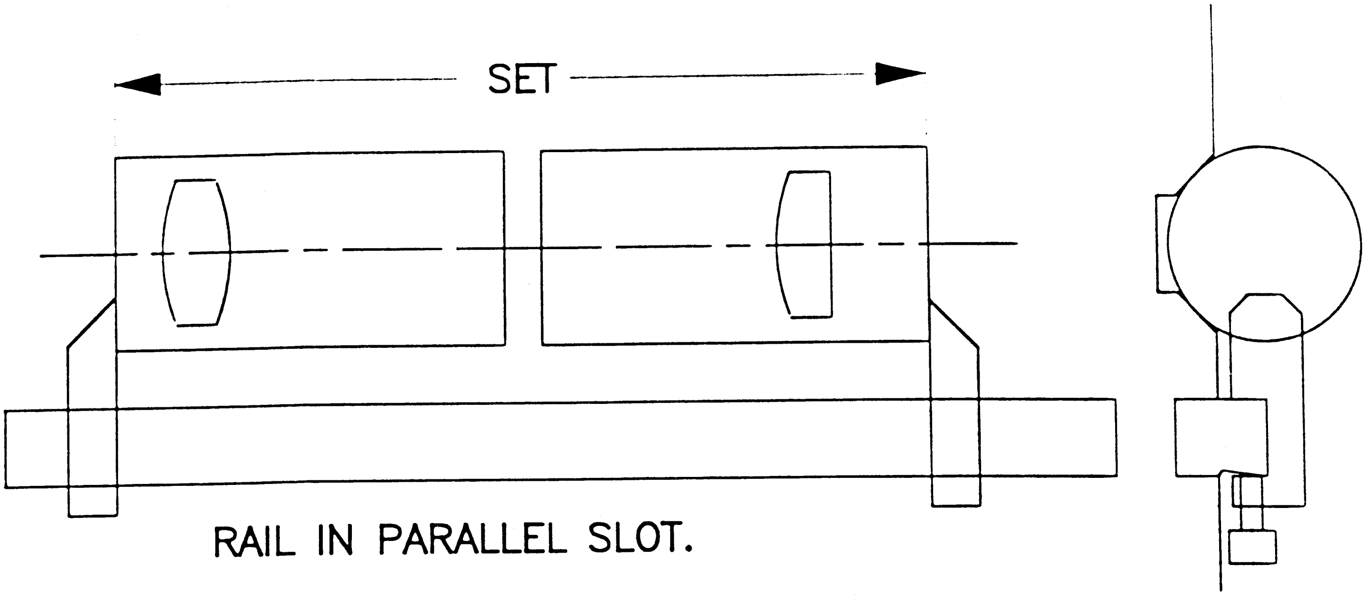




SPACER IN SLOT PARALLEL TO V

COULD BE A GAGE BLOCK STACK

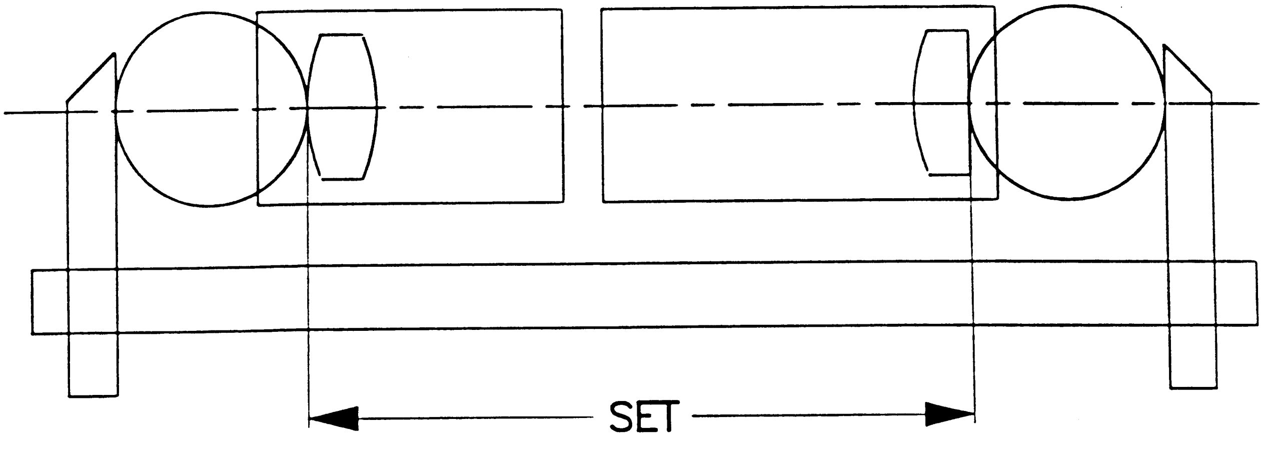
AXIAL SETTING TOOLS FOR OUTSIDE



RAIL IN PARALLEL SLOT.

USING LENS VERTICES

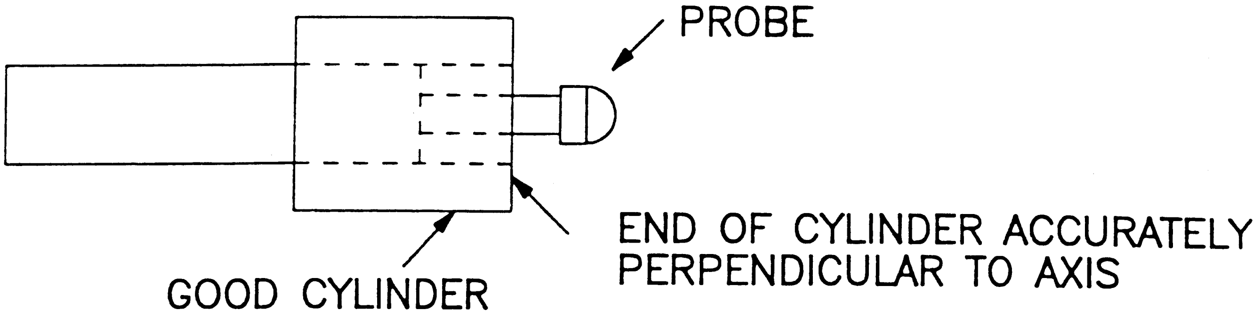
BALLS IN V WITH DIAMETER OF CYLINDER



VERTEX TO CYLINDER END GAGE

TO MEASURE DISTANCE FROM LENS VERTEX TO CYLINDER END.

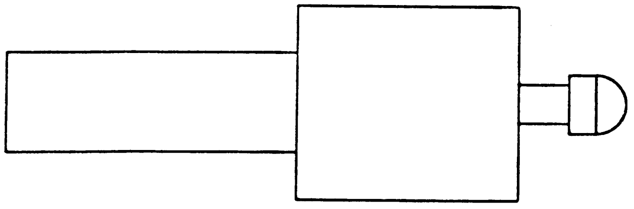
MEASUREMENT DEVICE WITH AXIS ALONG THE CYLINDER HOLDING IT

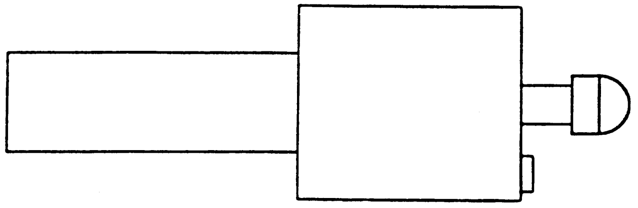


THE MEASUREMENT DEVICE COULD BE
- MICROMETER HEAD
- INDICATOR
- LVDT
- ETC

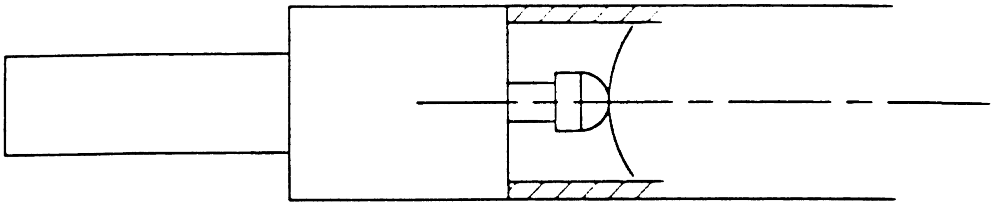
LIKE A DEPTH GAGE

TWO FORMS


SQUARE END


CONTACT PAD

MEASUREMENT OF DISTANCE FROM CYLINDER END TO LENS VERTEX



THE MEASUREMENT IS DONE IN A V.

CHECK THE GAGE AND LENS CENTRATION BY ROTATING THE GAGE AND REPEATING THE MEASUREMENT.

THIS IS A GOOD METROLOGY SETUP.

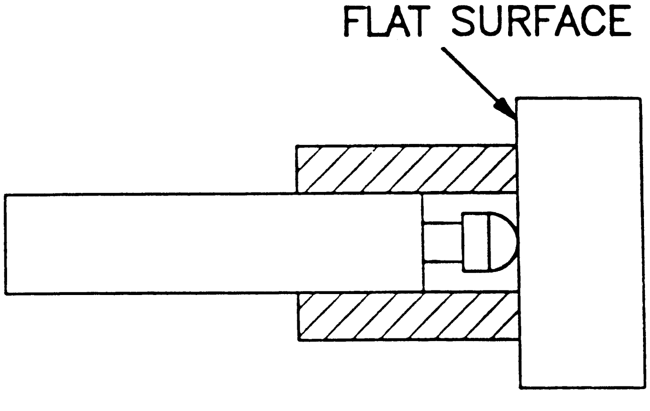
THE GAGE IS EASILY ZEROED.

THE GAGE IS EASILY CALIBRATED WITH GAGE BLOCKS.

THE GAGE CYLINDER EMULATES A SPACER.

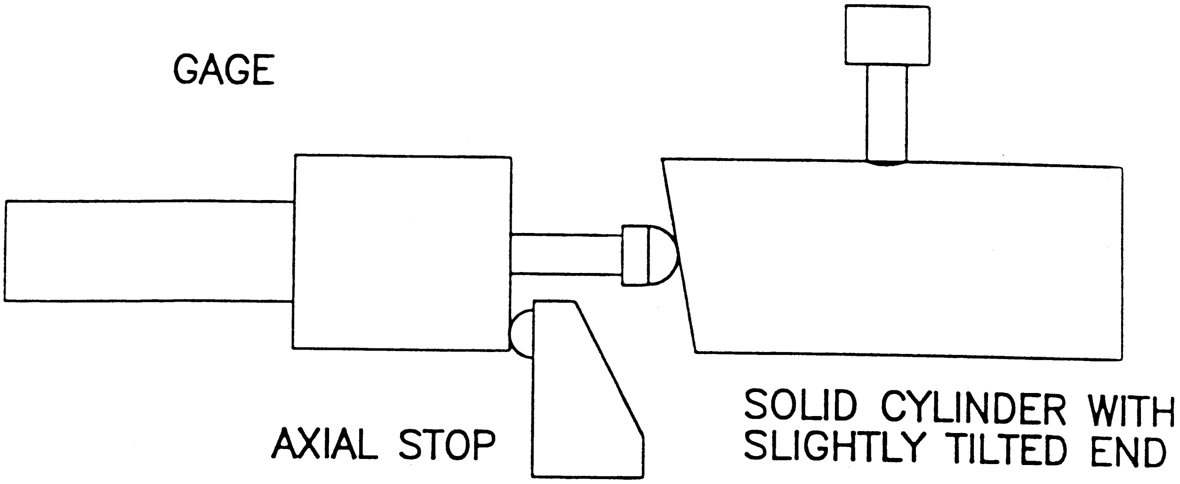
THE GAGE CAN BE TESTED FOR CENTRATION.

ZEROING



TESTING PROBE CENTRATION

FOR SPHERICAL PROBE TIP

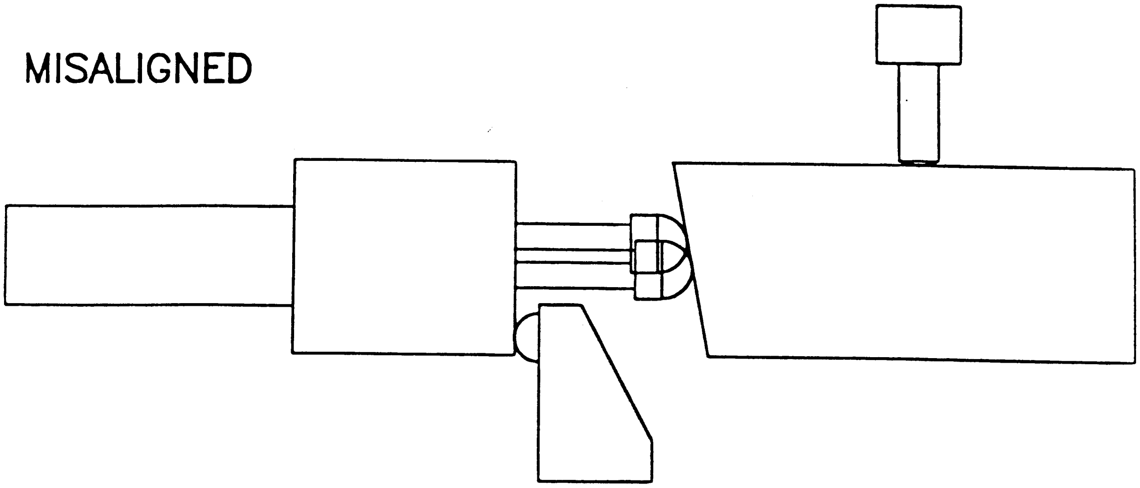


WITH THE GAGE AGAINST THE AXIAL STOP, TAKE A READING.

ROTATE THE GAGE, CONTACT THE STOP, AND REPEAT.

REPEAT FOR DIFFERENT EXTENSIONS OF THE PROBE.

MISALIGNED



AXIAL STOPS

USES:

AXIAL POSITIONINIG IN INITIAL SETUP

REMOVAL AND REPLACEMENT IN SAME POSITION

FOR DISCRETE AXIAL POSITIONS

STOP CONTACT LOCATIONS
- ON CYLINDER
  - END
  - ADDITIONAL STRUCTURE. E.G. AN ARM
- ON PLATE
  - TOP
  - TROUGH
  - CLAMP
- ANOTHER CYLINDER

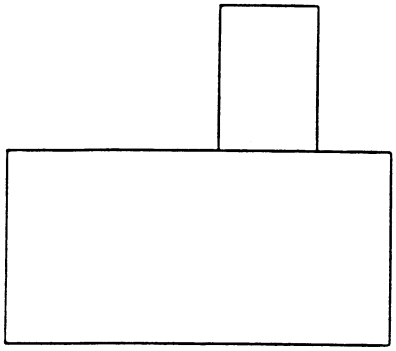
ONE TIME ADJUSTMENT
VS
REPEATABILITY, INTERCHANGEABILITY

STOP SCREWS HAVE ROUNDED ENDS.

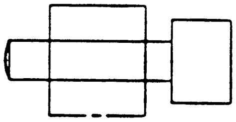
ADJUSTABLE STOPS

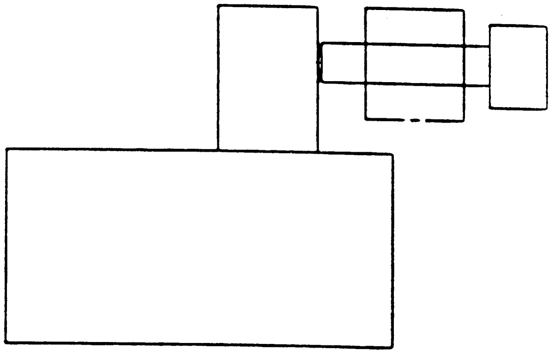
THE ADJUSTMENT ELEMENT CAN BE ON EITHER A FIXED OR A MOVING OBJECT.

CYLINDER WITH AN ARM



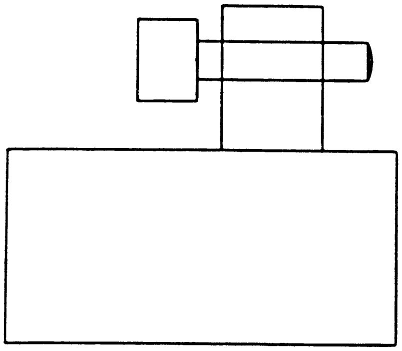
FIXED STRUCTURE WITH A SCREW

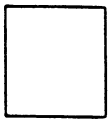




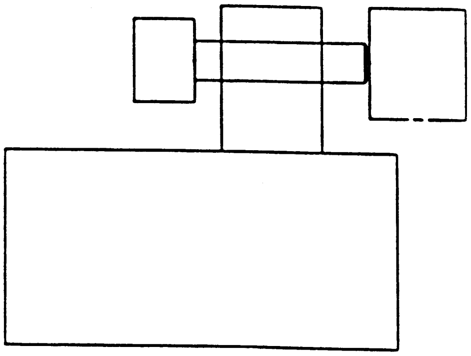
CYLINDER ARM AGAINST THE STOP SCREW

CYLINDER WITH AN ARM WITH A SCREW





SIMPLE FIXED STRUCTURE



CYLINDER SCREW AGAINST THE STOP

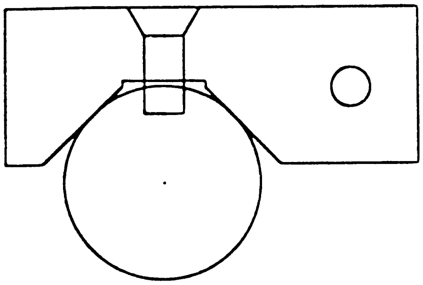
AXIAL STOP ARM

AN ARM IS ACCESSIBLE AND DOES NOT OBSTRUCT THE BEAM.

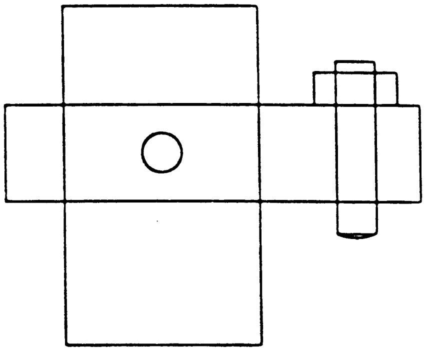
ARMS CAN BE PERMANENTLY OR TEMPORARILY ATTACHED.

PERMANENT EXAMPLE

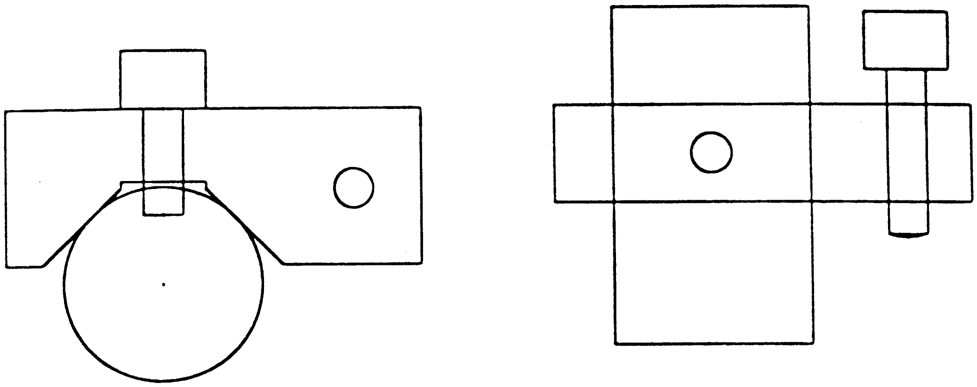
FLAT HEAD SCREW



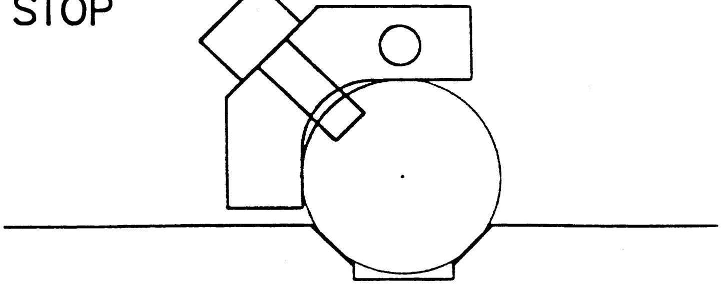
SET SCREW WITH
LOCK NUT



TEMPORARY EXAMPLE, USING THUMB SCREWS

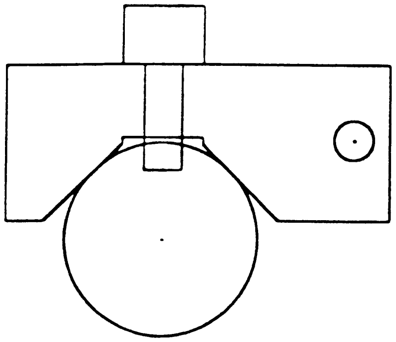


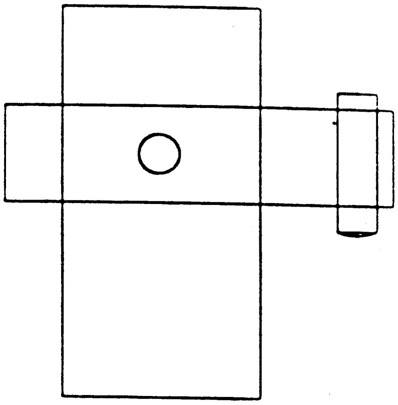
SYMMETRICALLY LOCATED STOP

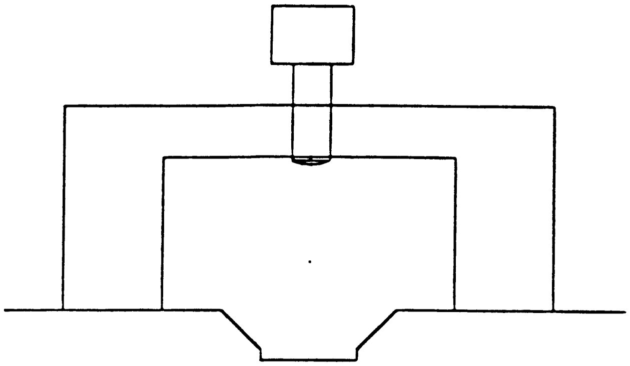


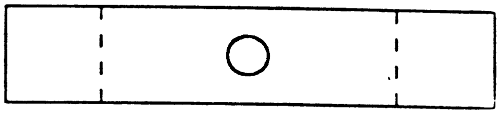
AXIAL STOP ARM AND CLAMPING BRIDGE AS STOP

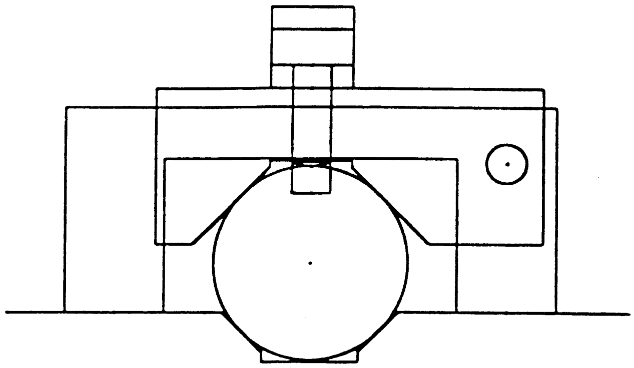
ADJUSTMENT ON CYLINDER ARM

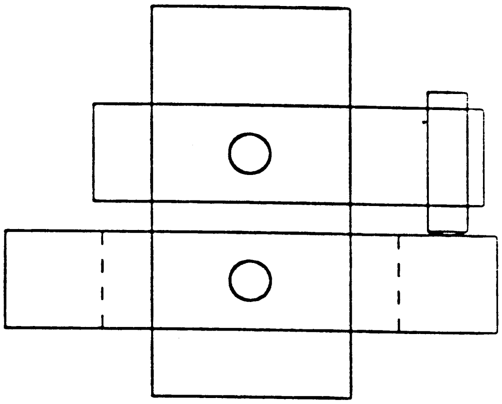




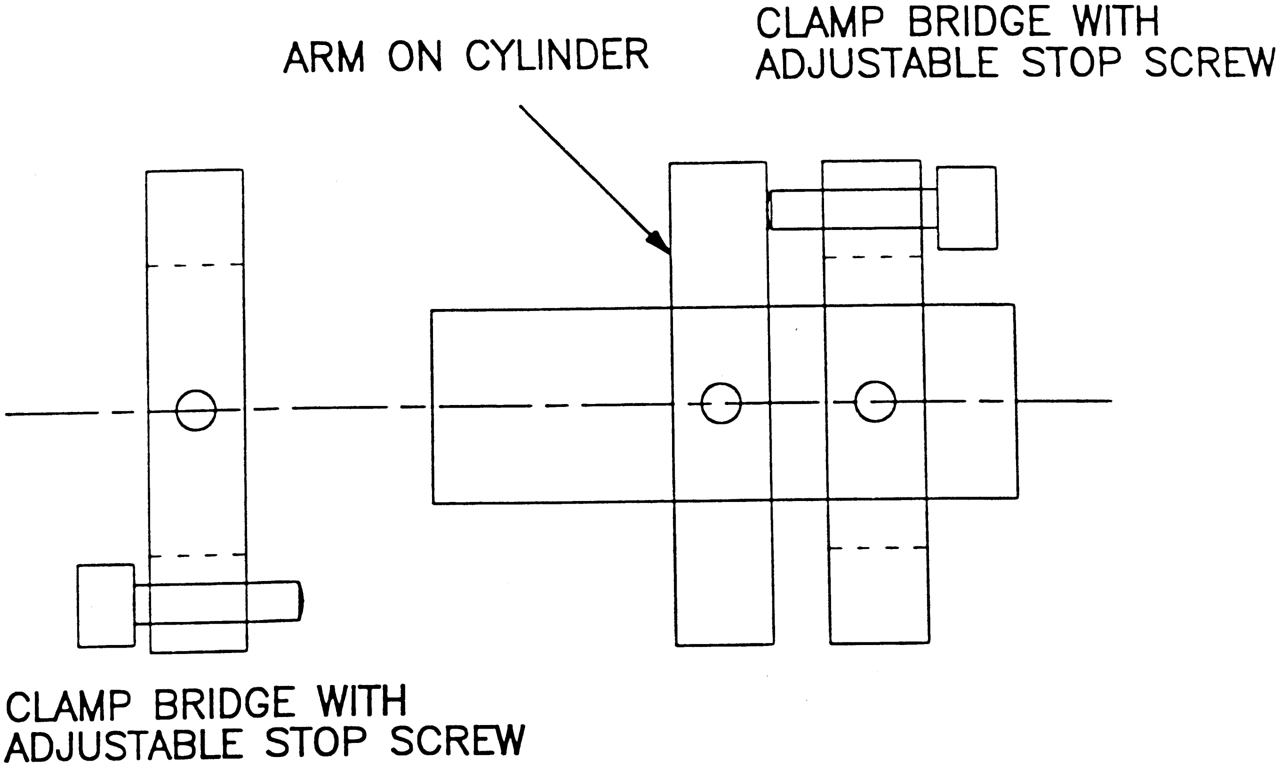


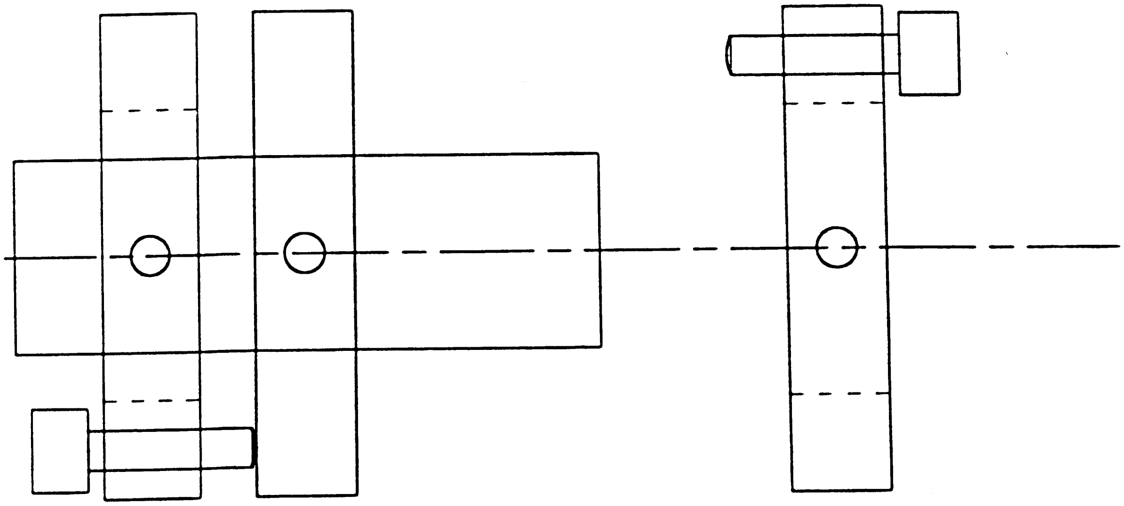






ARRANGEMENT FOR TWO POSITIONS

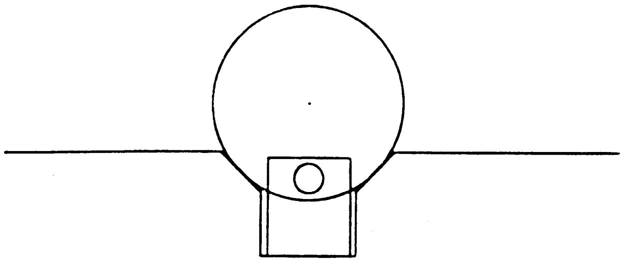




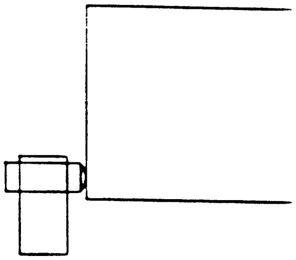
THERE ARE SEVERAL VARIATIONS.

SOME AXIAL STOP ARRANGEMENTS

STOP IN TROUGH OF V

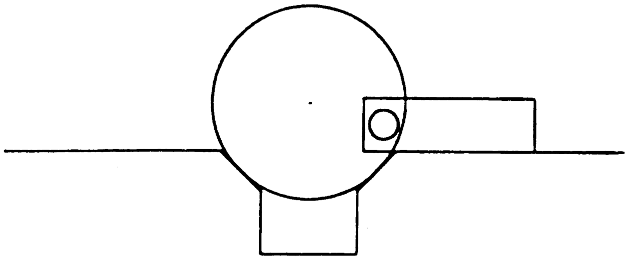


SIDE VIEW

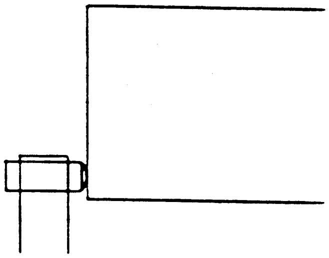


IDEALLY, CONTACT POINT AT CENTER OF FRICTION

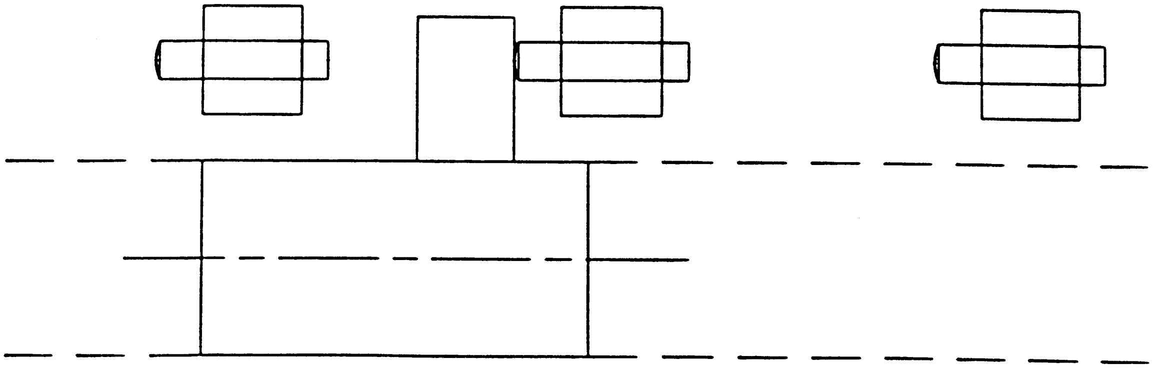
STOP ON V PLATE SURFACE



TOP VIEW



MULTIPLE STOPS ON THE V PLATE

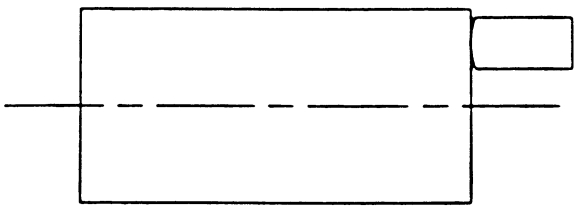


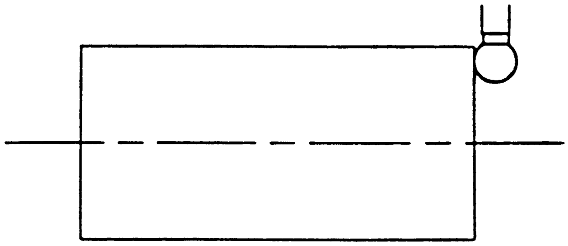
TOP VIEW

STOPS FOR CYLINDER ROTATION

THE END OF THE CYLINDER AGAINST THE STOP SHOULD BE SMOOTH AND PERPENDICULAR TO THE AXIS, SO ROTATION OF CYLINDER DOESN'T CHANGE AXIAL POSITION.

A CONVEX, SMOOTH STOP PERMITS CYLINDER ROTATION WITHOUT AXIAL MOTION, E.G. FOR CENTERING.



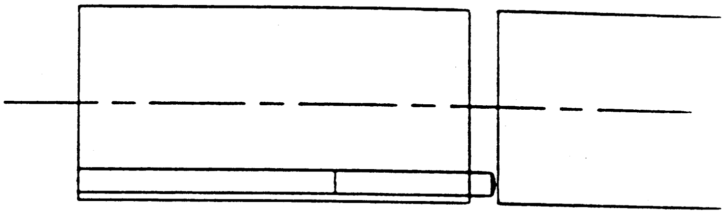


CYLINDER-TO-CYLINDER STOPS

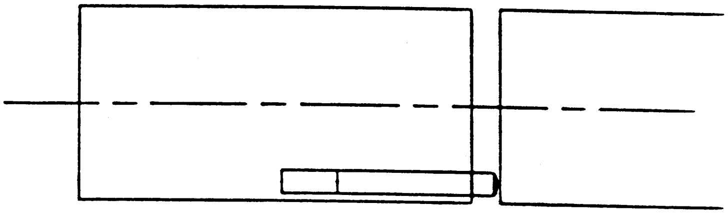
CONTROL RELATIVE CYLINDER SPACING

EXAMPLES

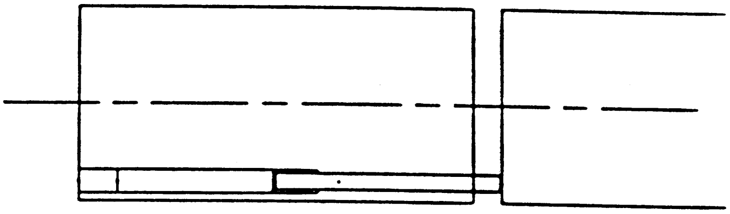
SCREW IN A THROUGH HOLE



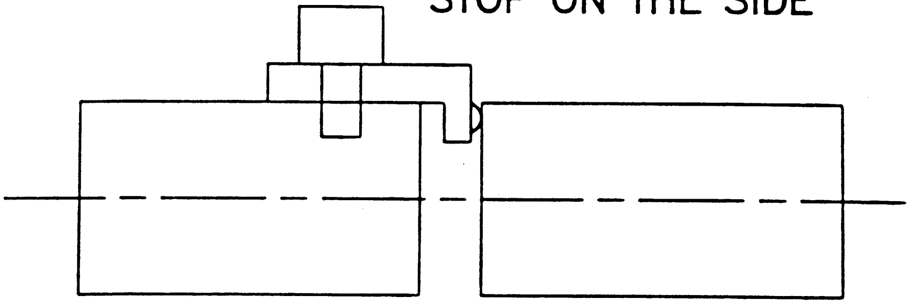
STOP SCREWED BACKWARDS
INTO BLIND HOLE

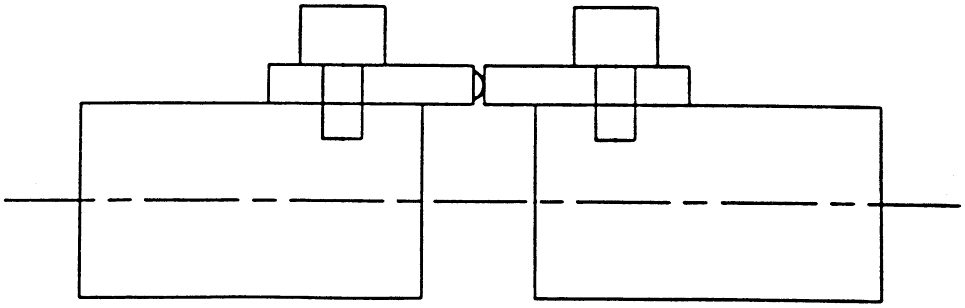


SCREW AND ROD



STOP ON THE SIDE





AXIAL MOTION OF CYLINDERS FOR FUNCTIONING

EXAMPLES: FOCUS CONTROL, MAGNIFICATION CHANGE

FOR FUNCTIONING
  FUNCTIONING AT REST ONLY
  FUNCTIONING DURING MOTION

MAIN PROBLEM: MAINTAINING ALIGNMENT DURING MOTION

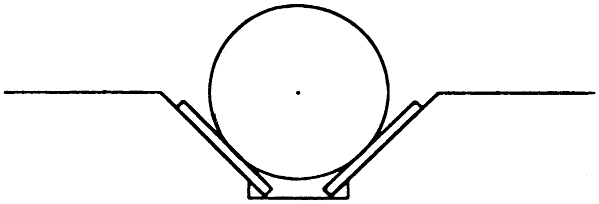
REQUIRES CONTACT BETWEEN CYLINDER AND V

NO LIFT BY MOTION SYSTEM

DOWNWARD FORCE IS DESIRABLE TO MAINTAIN CONTACT, BUT THIS INCREASES FRICTION

WITH LINE AND POINT CONTACT, MACHINING MARKS GREATLY INFLUENCE FRICTION.

SLIPPERY INSERT WITH SMALLER DIAMETER CYLINDER TO REDUCE FRICTION



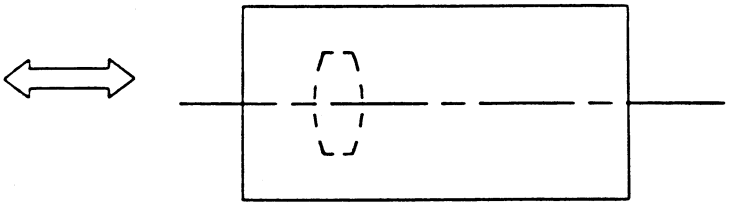
GLASS INSERT AND BRASS CYLINDER WORK WELL IN THE LABORATORY.

SLIDING
ROLLING

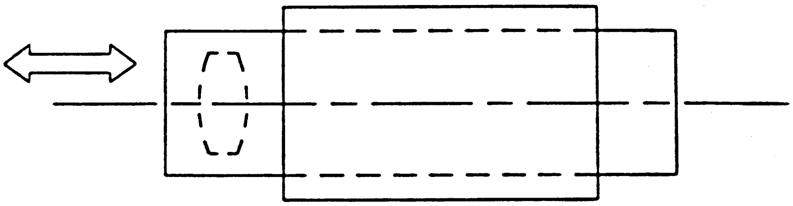
FACTORS INCLUDE
MAINTAINING ALIGNMENT
POSITION FEEDBACK

TYPES OF AXIAL MOTION

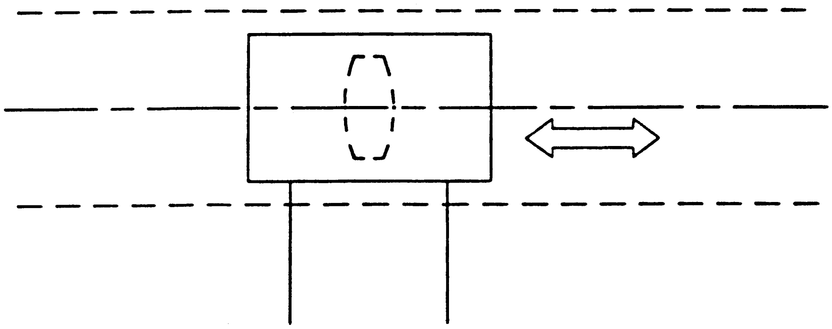
MOTION OF A CYLINDER IN A V



MOTION OF A UNIT WITHIN A STATIONARY CYLINDER IN A V

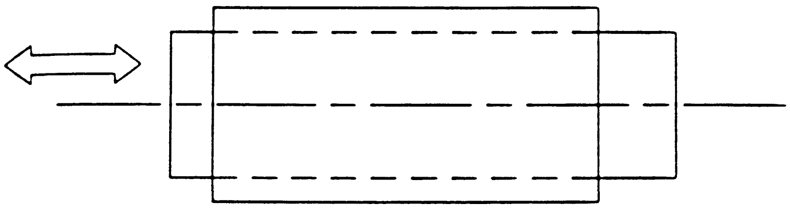


MOTION OF AN OBJECT OUT OF THE V THAT HOLDS AN OPTICAL ELEMENT IN ALIGNMENT WITH THE V



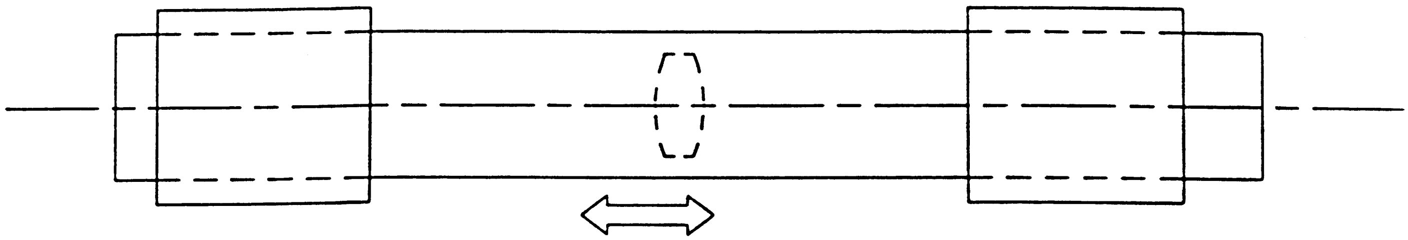
THE MOTION CAN USE AUXILIARY PARALLEL STRUCTURES.

MOTION WITHIN A FIXED CYLINDER



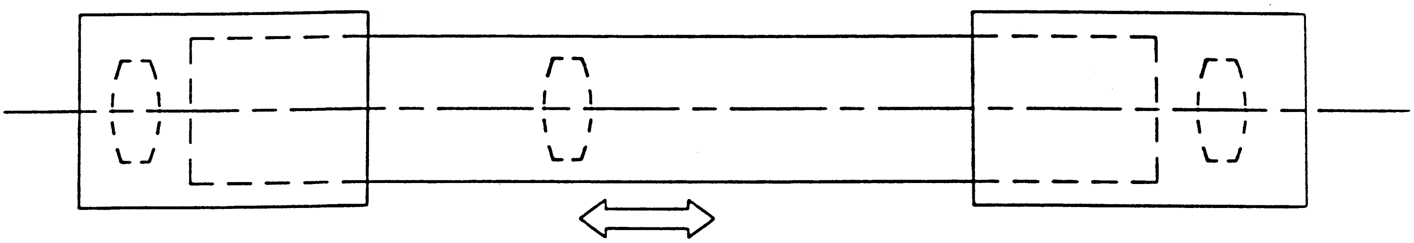
EXAMPLES
BUSHING, LINEAR BALL BEARING, AIR BEARINGS,
FLEXURES: MEMBRANE, PARALLEL REED, SPOKED

LONG MOVING PIECE

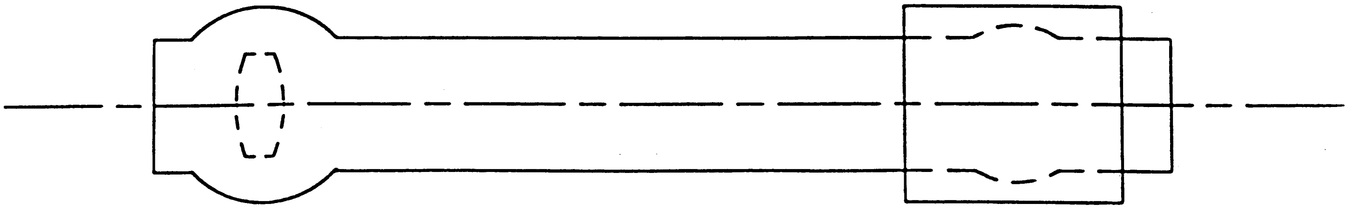


GOOD FOR OFF AXIS POSITIONING FORCES.

COMBINATION BUSHING/LENS HOLDING CYLINDERS



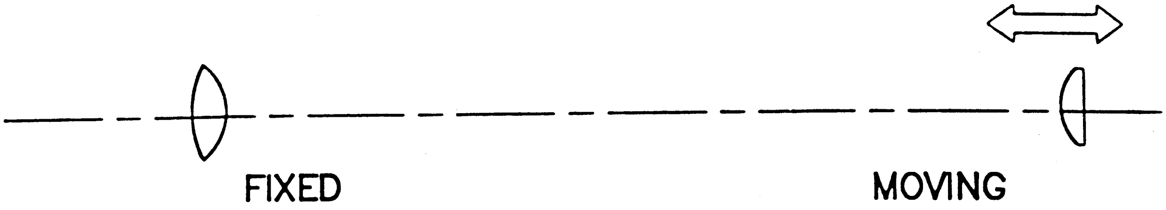
ONE END IN V AND ONE IN A BUSHING

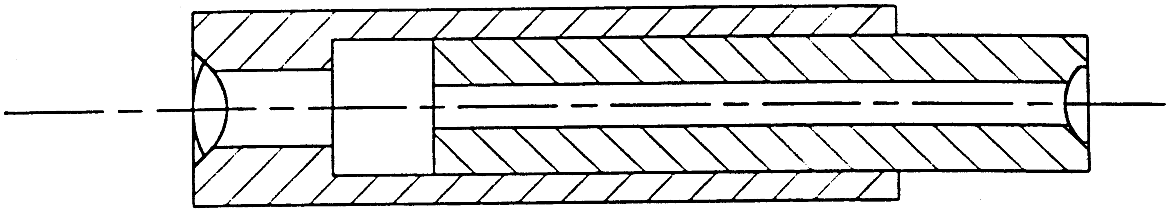


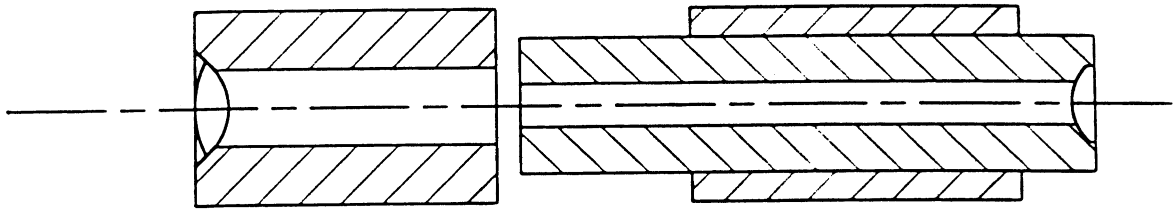
EXAMPLE

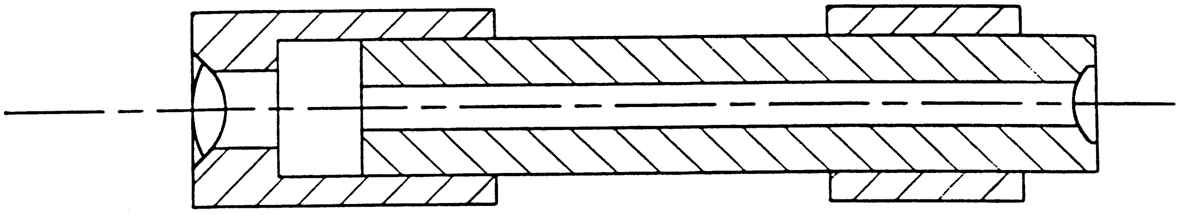
A FIXED AND A MOVING LENS

THEIR MECHANICS CAN BE COMBINED IN A NUMBER OF WAYS.



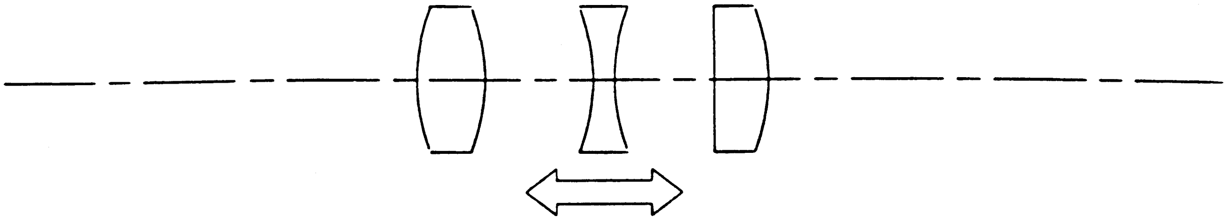




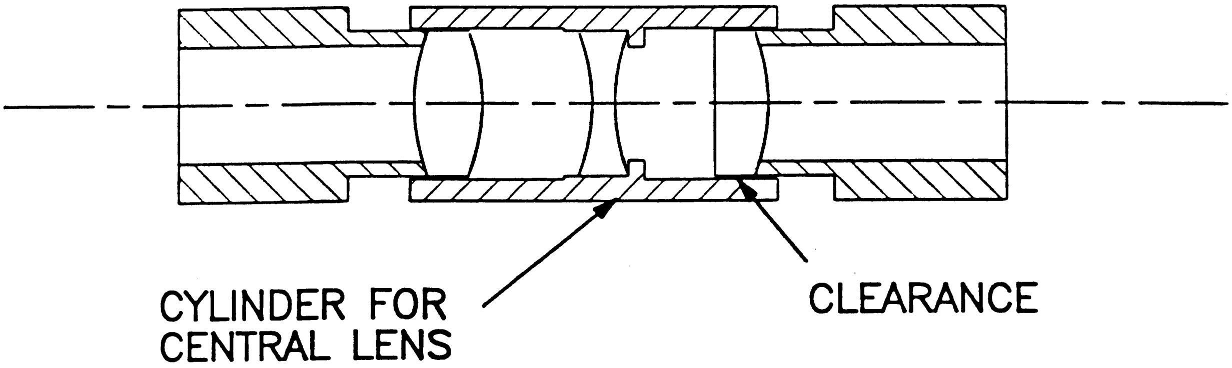


AXIAL MOTION IN A TIGHT SPACE

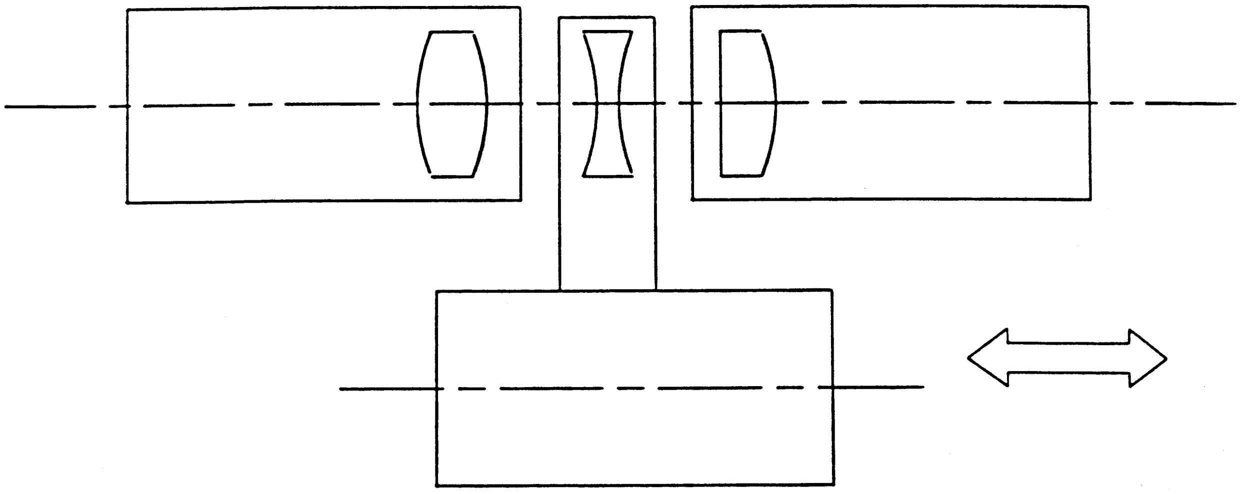
REQUIRED: AXIAL MOTION OF CENTRAL ELEMENT WITH NEAR NEIGHBORS



CENTRAL CYLINDER EXTENDED AROUND NEIGHBORING LENSES



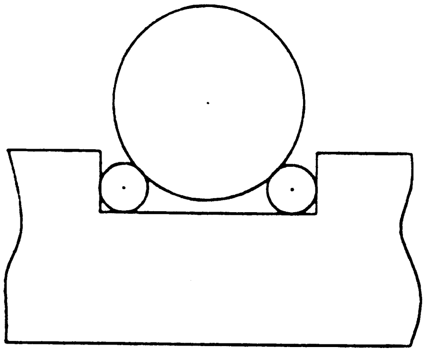
CENTRAL LENS MOVED BY APPARATUS OUTSIDE THE V

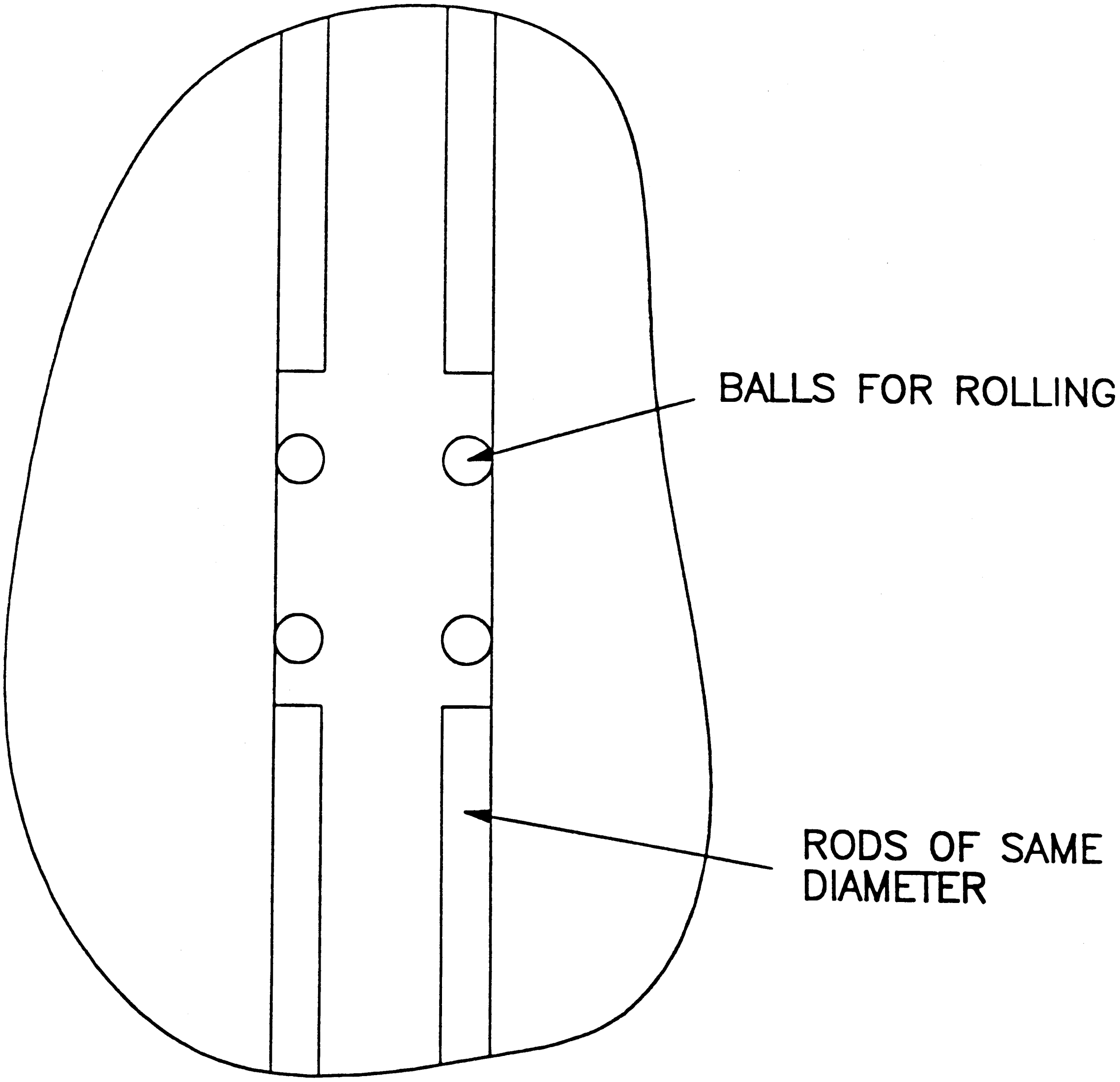


MOTION ALONG STRUCTURE PARALLEL TO THE V

V COMPRISED OF RODS AND BALLS

V COMPRISED OF RODS UNDER STATIONARY CYLINDERS
AND BALLS UNDER MOVING CYLINDER(S)

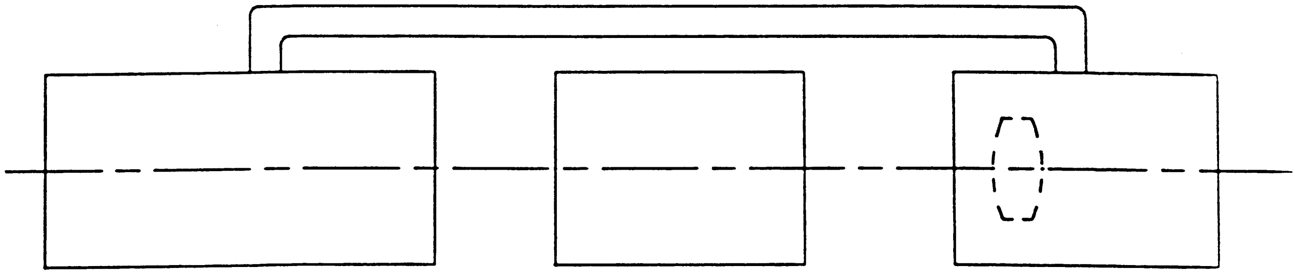




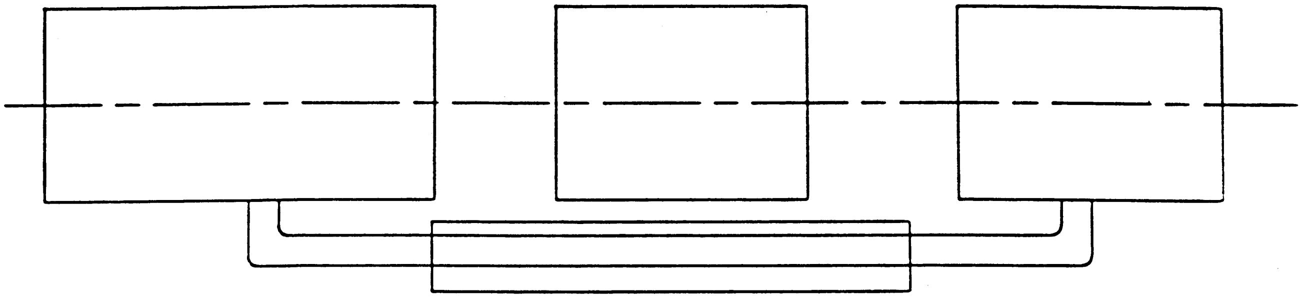
JOINING SEPARATED CYLINDERS FOR JOINT MOTION

EXAMPLES SHOWN IN SIDE VIEW

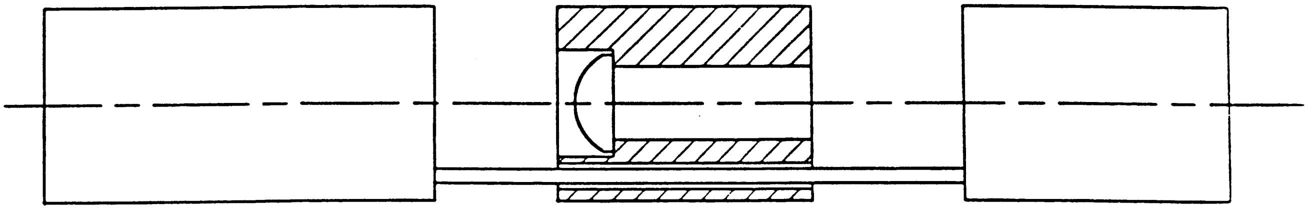
OVER THE TOP



UNDERNEATH IN A TROUGH



THROUGH, IF CLEAR APERTURE PERMITS



THE CONNECTOR, SHOW SCHEMATICALLY, NEEDS ONLY BE AXIALLY STIFF.

DRIVING CYLINDERS AXIALLY

WAYS TO APPLY FORCE TO A CYLINDER TO MOVE IT AXIALLY, WHILE KEEPING IT IN ALIGNMENT.

SOME CONSIDERATIONS:

MAINTAINING CENTRATION DURING MOTION

LOCATION OF DRIVE POINT

LENGTH OF MOTION

SPEED OF MOTION

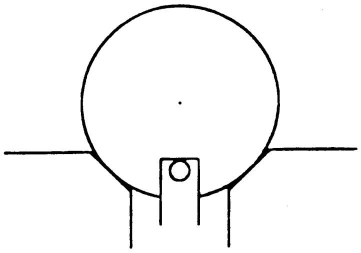
ROTATION OF CYLINDER

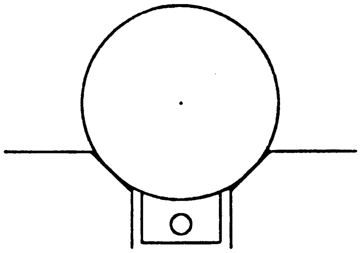
BACKLASH

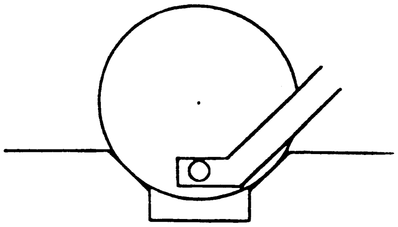
FEEDBACK
  FROM CYLINDER
  FROM DRIVE
  FROM POSITION SENSOR
  OPTICAL

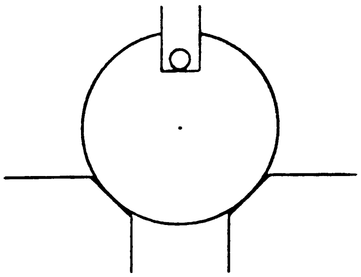
END DRIVE AZIMUTH POSSIBILITIES

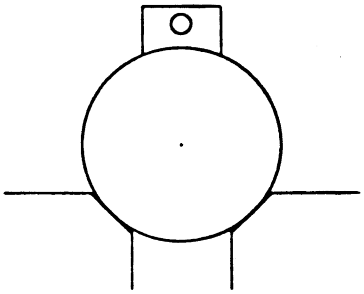
ARRANGEMENTS WITH BILATERAL SYMMETRY

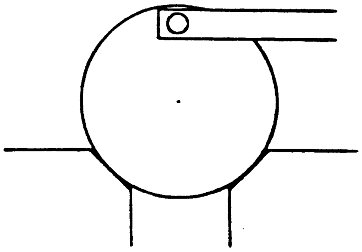




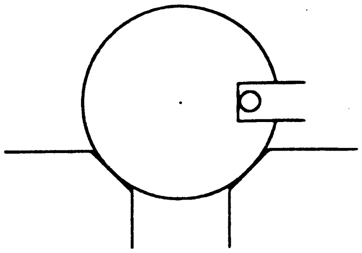


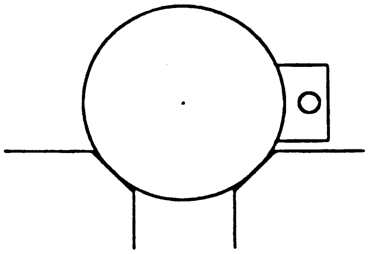






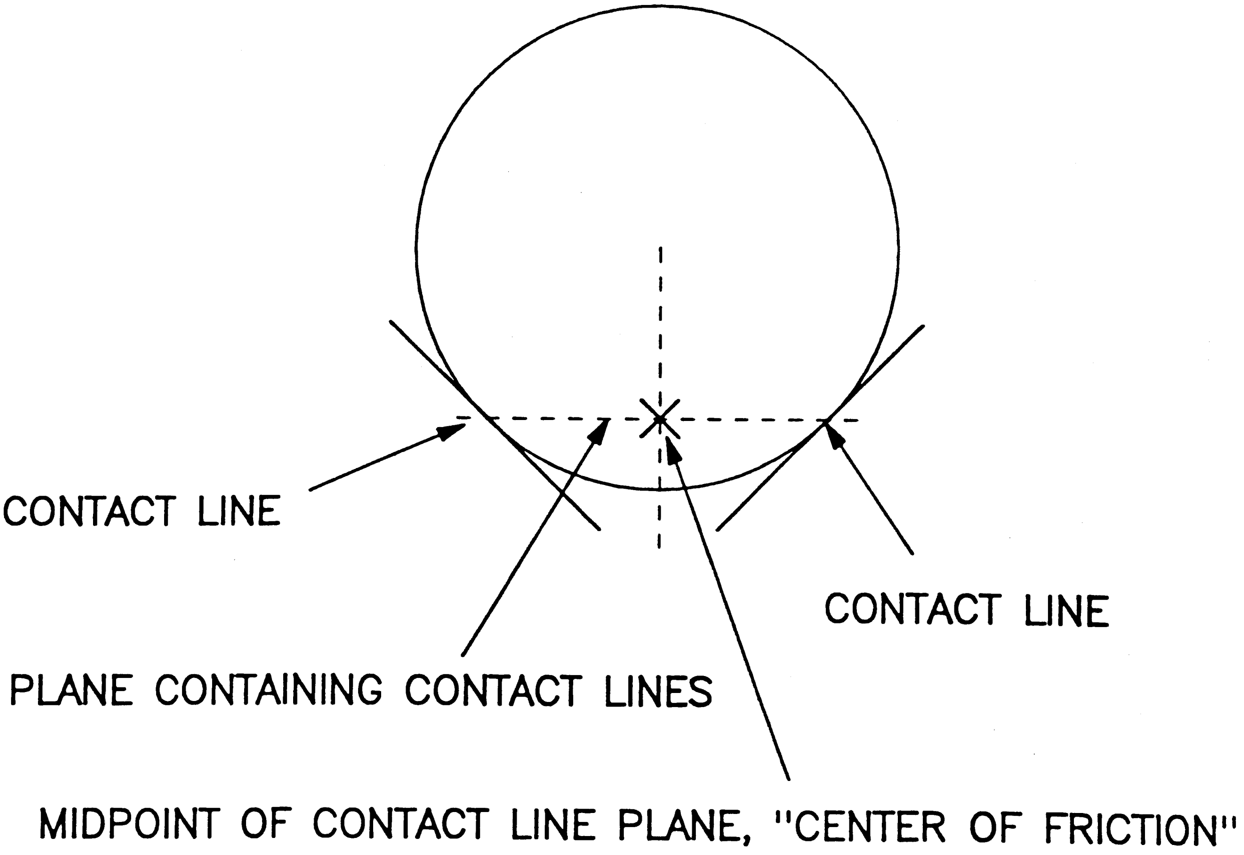
ARRANGEMENTS WITHOUT BILATERAL SYMMETRY





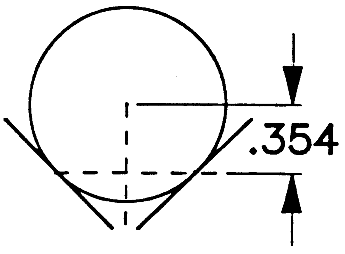
GOOD DRIVE POINT

DRIVING A CYLINDER AT THE CENTER OF FRICTION REDUCES THE TENDENCY OF CYLINDER TO TIP BECAUSE OF FRICTION.

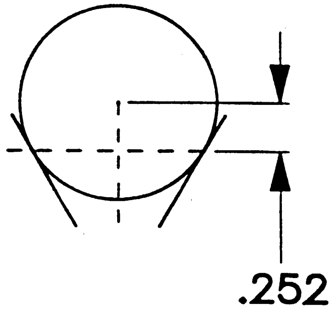


POINT LOCATIONS

90° V

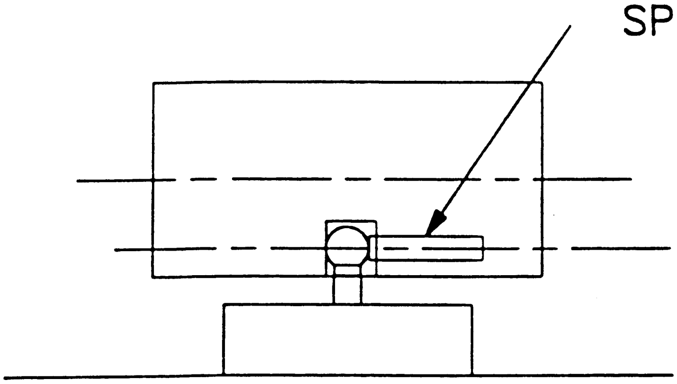


60° V

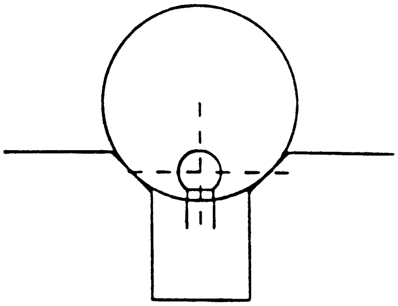


DRIVE POINT INSIDE CYLINDER

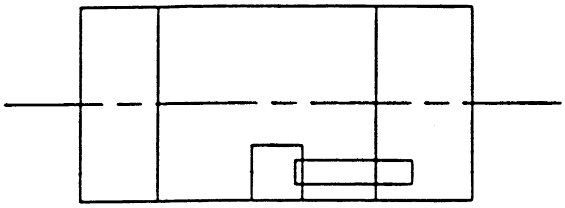
BALL ON STAGE AT CENTER OF FRICTION AND MIDDLE OF CYLINDER

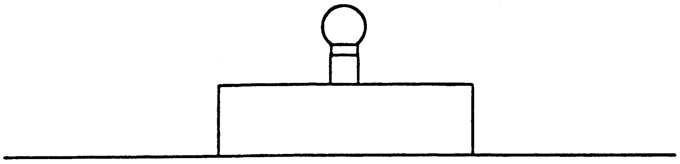


STAGE IN TROUGH



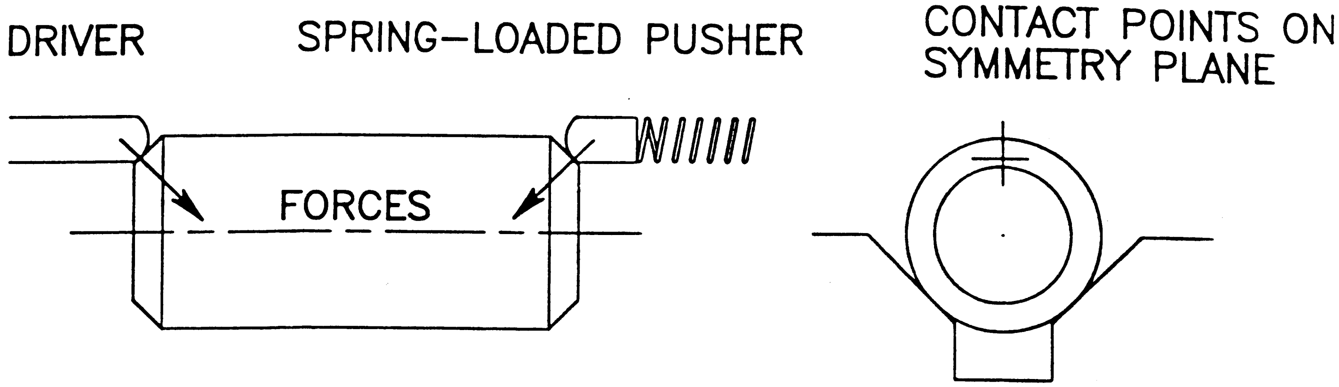
CENTER OF FRICTION



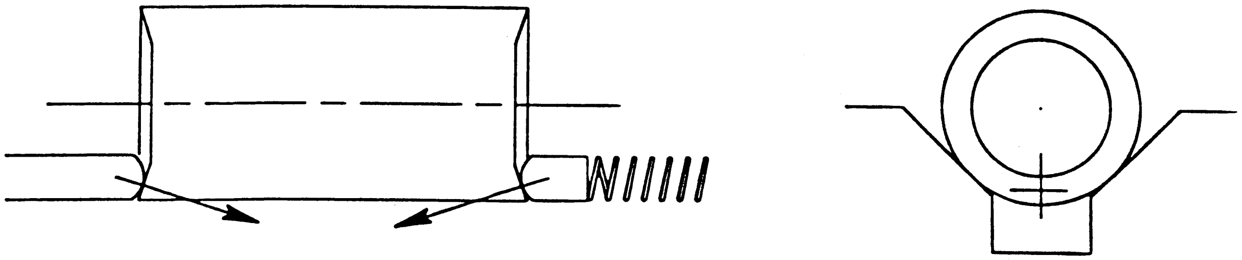


DRIVNG WITHOUT BACKLASH

SIDE VIEW



"INSIDE OUT" VERSION



A FORCE COMPONENT OF KEEPS THE CYLINDER AGAINST THE V.

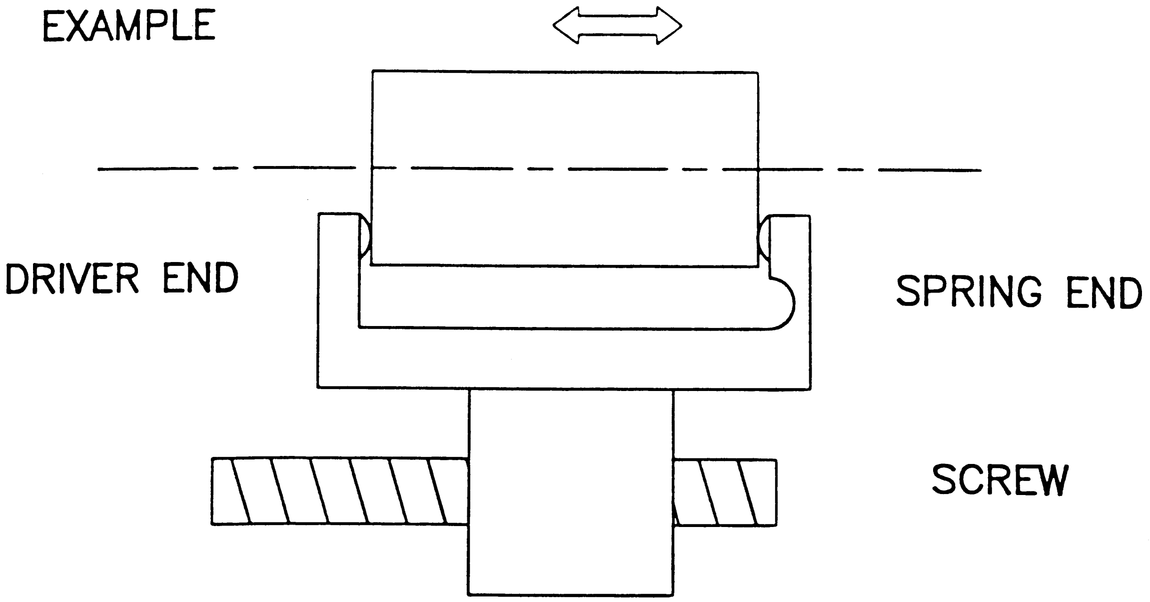
THIS ALSO PRODUCES FRICTION

BEST IF THE DRIVER DOES NOT ROTATE.

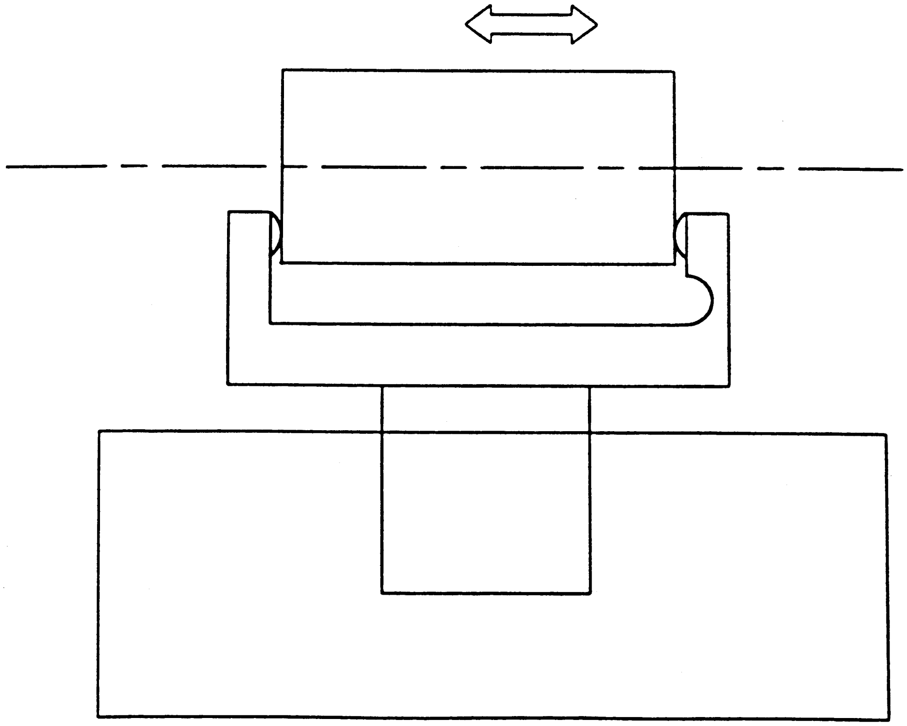
BEST IF THE SPRING LOAD IS LATERALLY STIFF.

DRIVER AND SPRING COMBINED

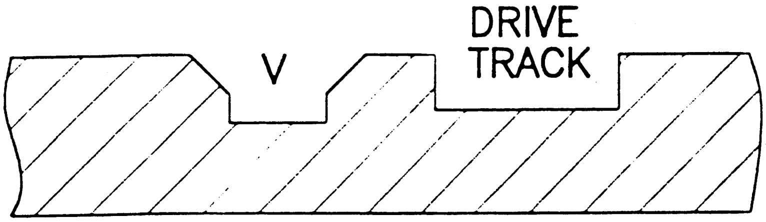
EXAMPLE



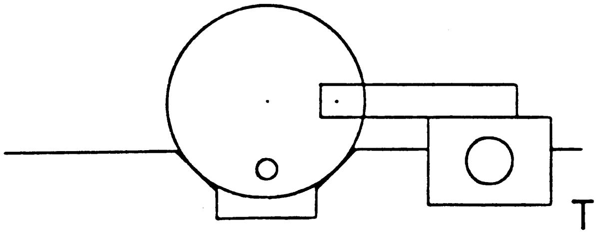
CAN BE ABOVE, BENEATH, TO THE SIDE



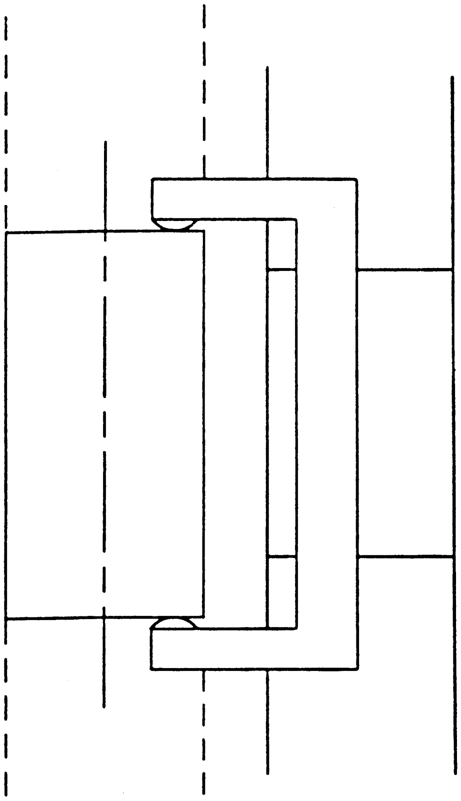
DRIVE TRACK PARALLEL TO V



THE CYLINDER IS MOVED BY ARMS ATTACHED TO THE SLIDE.



THE SLIDE IS MOVED BY A SCREW.

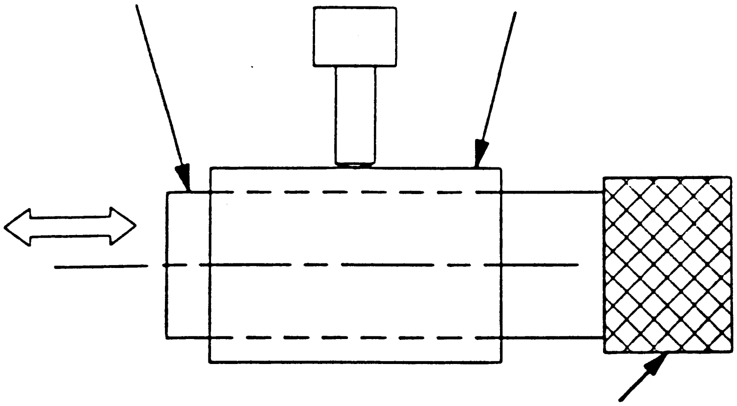


THE SLIDE MOVED IS CONSTRAINED TO MOVE PARALLEL TO THE V.

THE DRIVE TRACK IS MACHINED IN THE SAME SETUP AS THE V.

HOLLOW SCREW

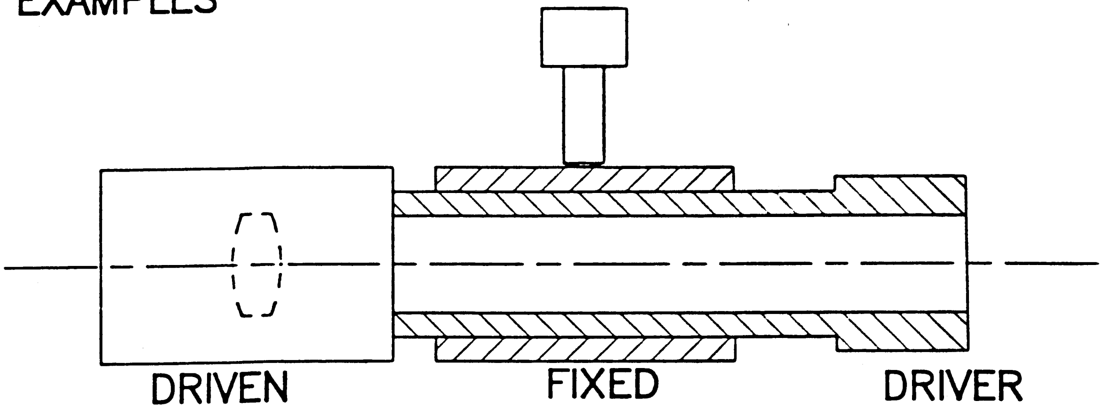
THREADED PIECE IN THREADED CYLINDER

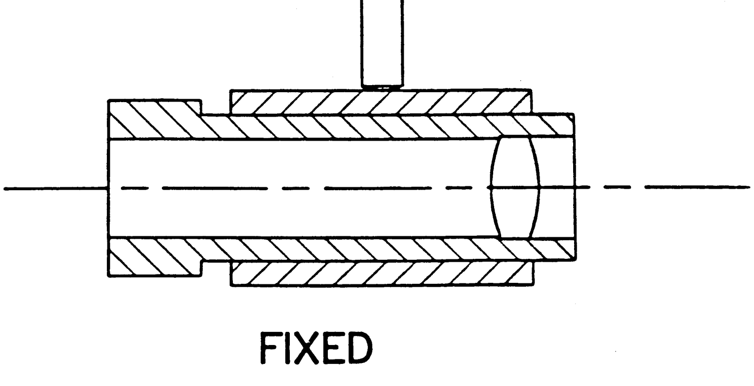


KNURLED WITH DIAMETER LESS THAN THAT OF CYLINDER

MOVES ITSELF OR SOMETHING ELSE, WITH CYLINDER CLAMPED

EXAMPLES



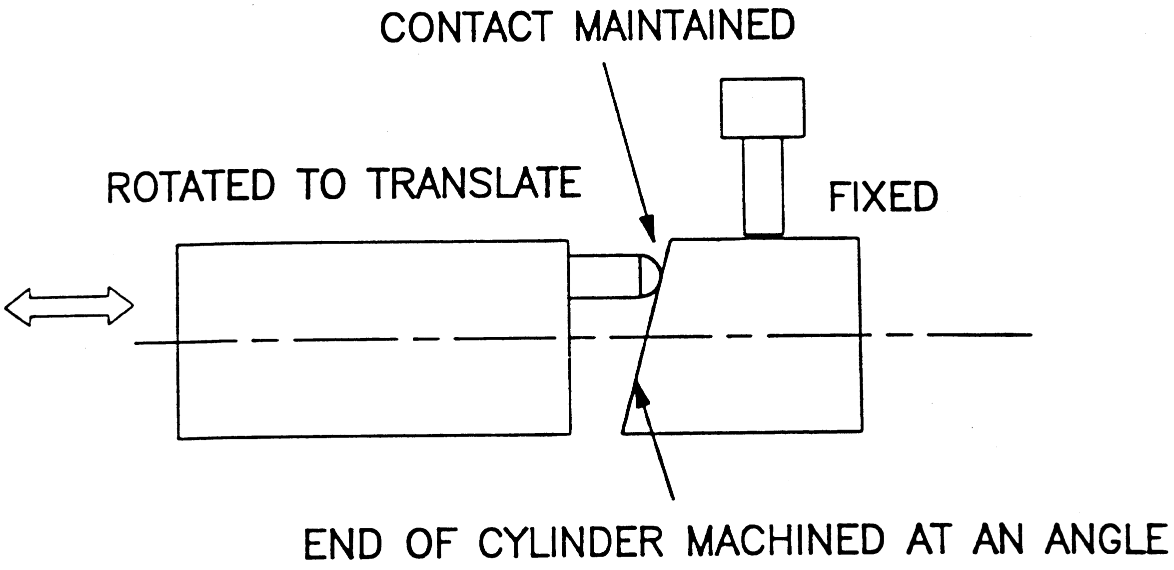


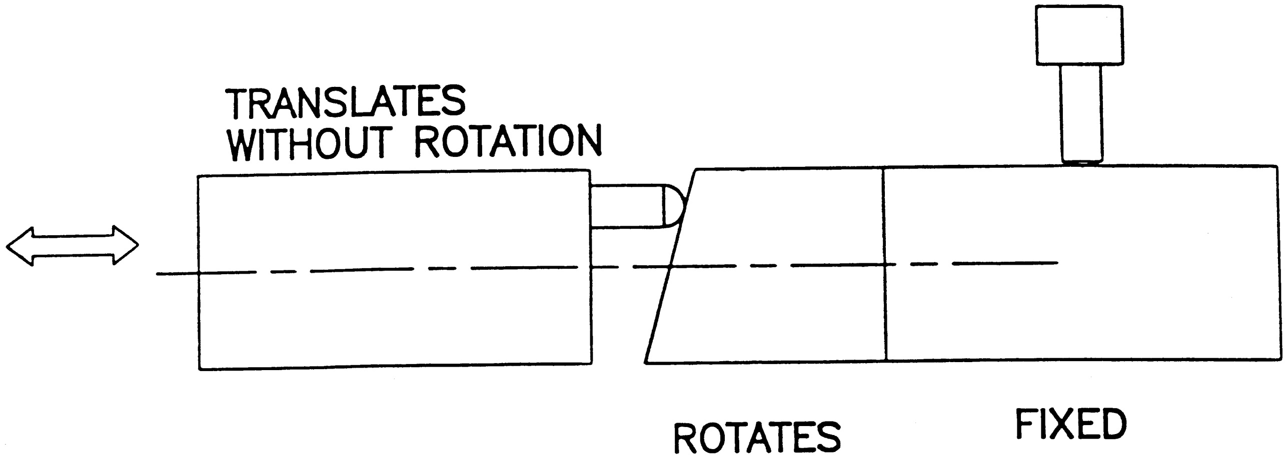
AXIAL CAM

"ROTATIONAL INCLINED PLANE"

GENERAL PROPERTIES
- REPEATABLE, NO BACKLASH
- SENSITIVITY CUSTOMIZED BY ANGLE
- LIMITED RANGE

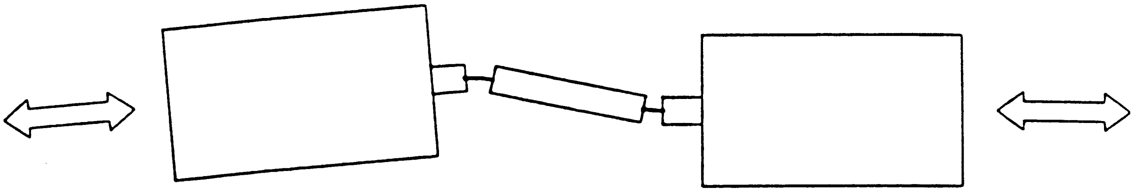
EXAMPLES





WOBBLE PIN

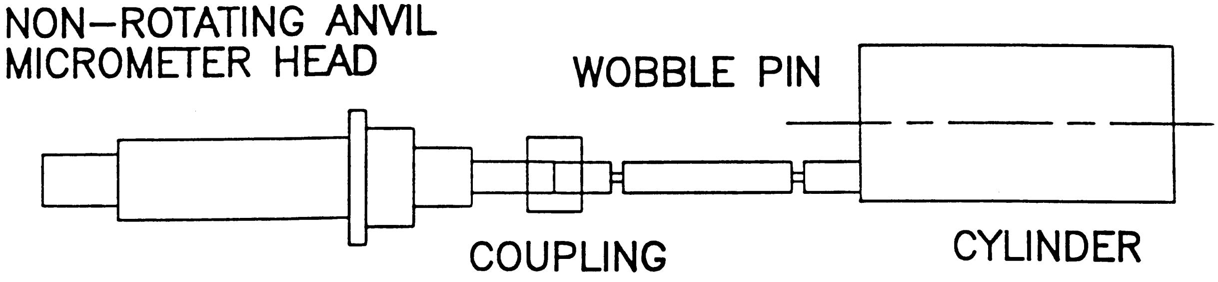
ALLOWS MISALIGNMENT BETWEEN DRIVER AND DRIVEN



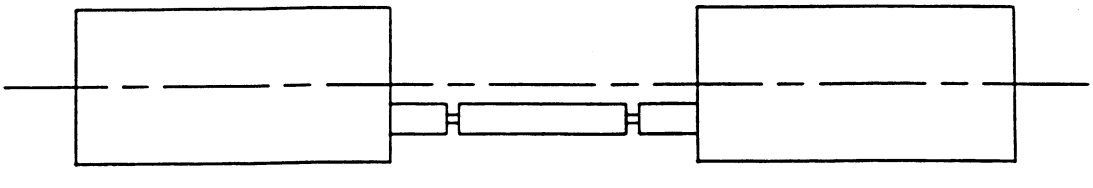
WOBBLE PIN EXAMPLE

MACHINED FROM ABS PLASTIC

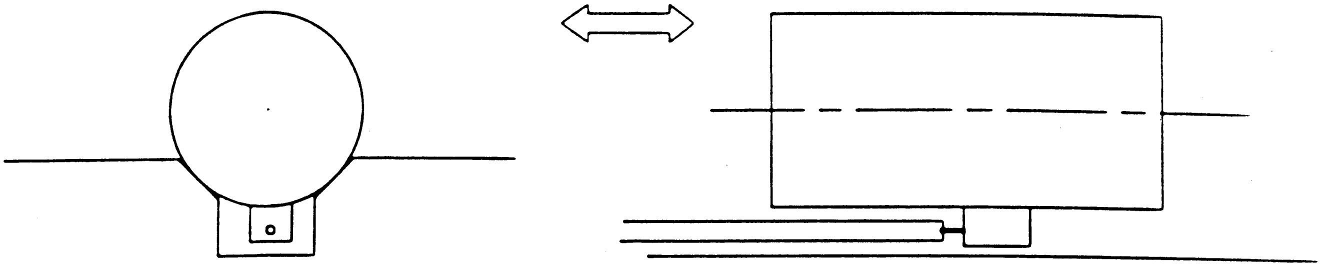
EXAMPLES



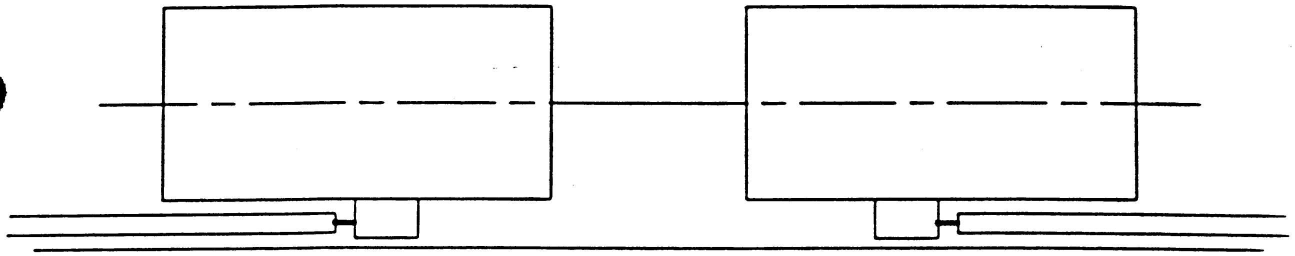
JOINED CYLINDERS

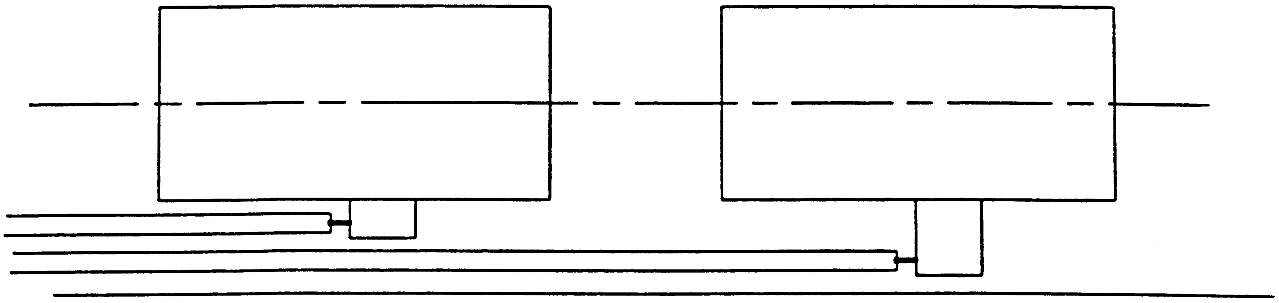


DRIVE PIN IN THE TROUGH



TWO MOVING CYLINDERS

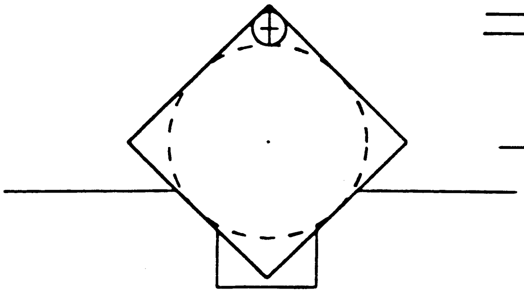


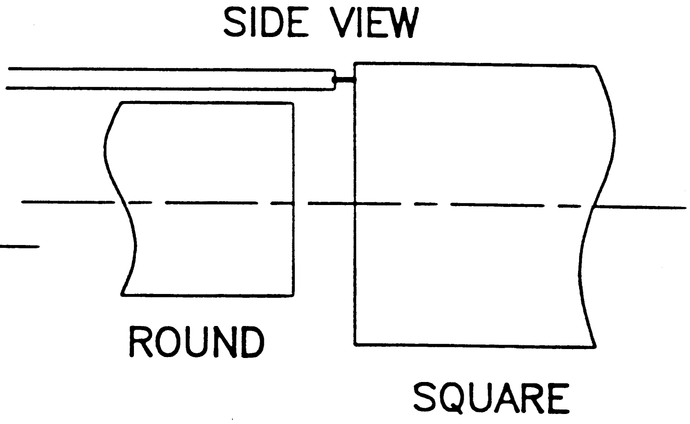


SQUARE CYLINDERS

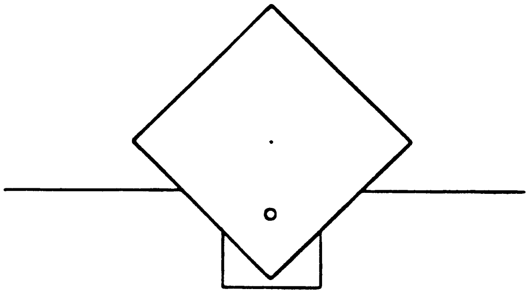
NO ROTATION WITH AXIAL TRAVEL

DRIVE ABOVE THE ROUND CYLINDER





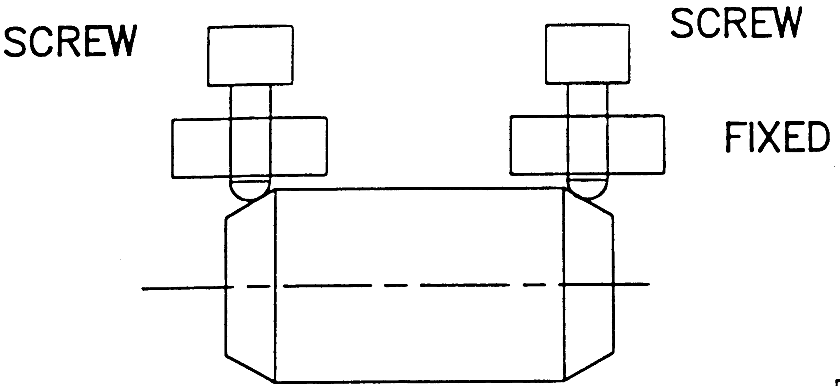
MORE ROOM FOR DRIVE CONTACT WITH ADJACENT ROUND CYLINDER



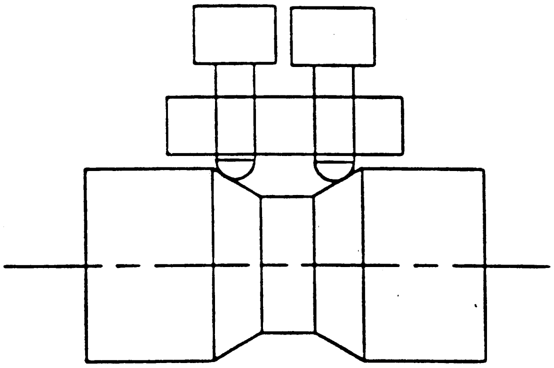
BEST DRIVE POINT ?

CLAMPS WITH AXIAL ADJUSTMENT BY OPPOSING SCREWS

SIDE VIEW

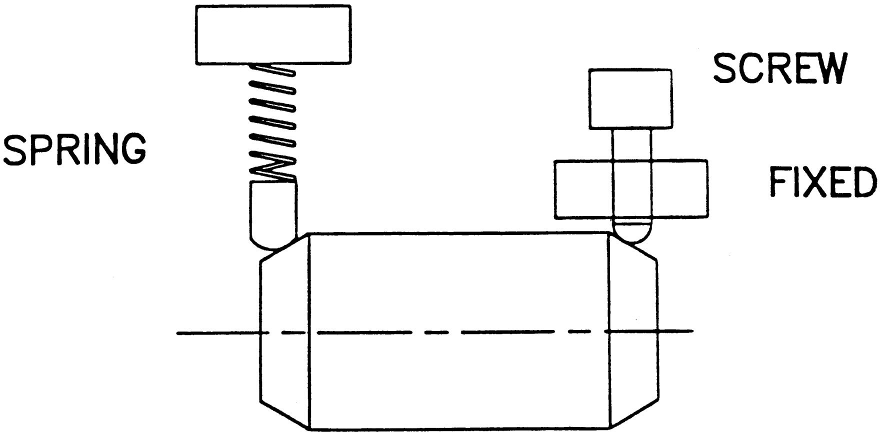


INSIDE OUT

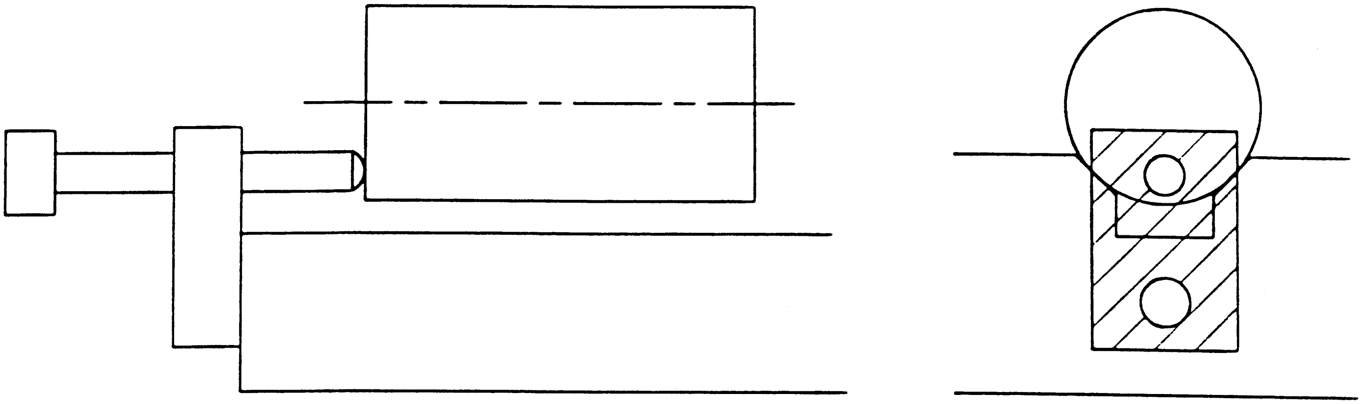


FOR FINE MOTION AND SIMULTANEOUS LOCKING.

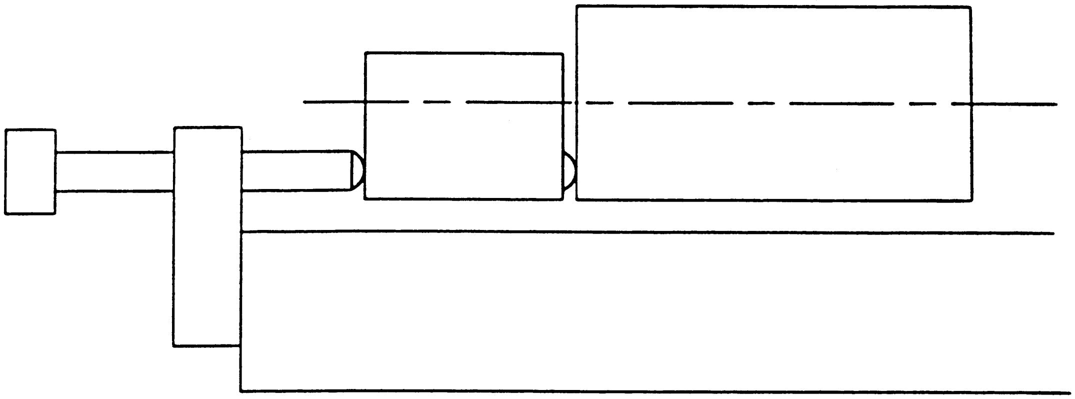
POSSIBLE PROBLEMS WITH FRICTION.



AXIAL ADJUSTMENT AT END OF V

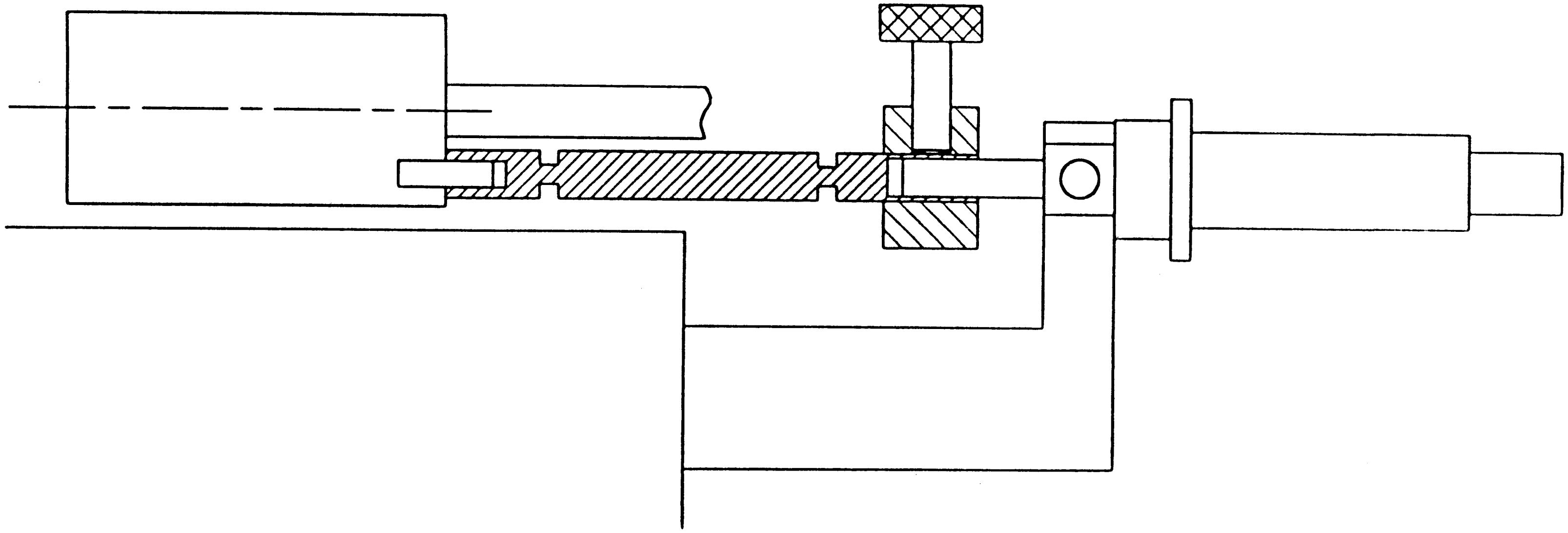


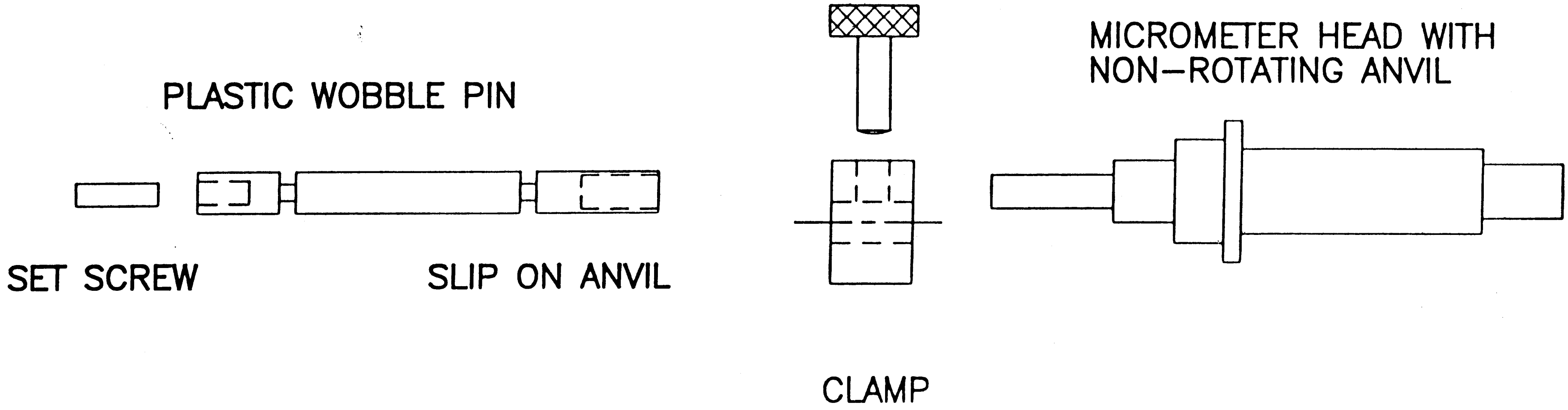
NON–ROUND INTERMEDIATE PART



AXIAL ADJUSTMENT AT END OF V

WOBBLE PIN ATTACHED AT CENTER OF FRICTION





USED WITH FIBER PUMP

METHODS FOR NON-ROTATIONAL SYMMETRY

AZIMUTHAL ADJUSTMENT AND MOTION

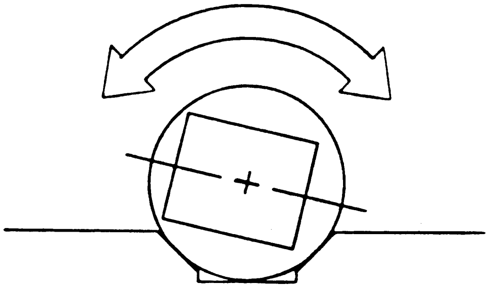
FLIPPING

LEVELLING

TILT

TILT AND TRANSLATION

AZIMUTHAL ADJUSTMENT AND MOTION



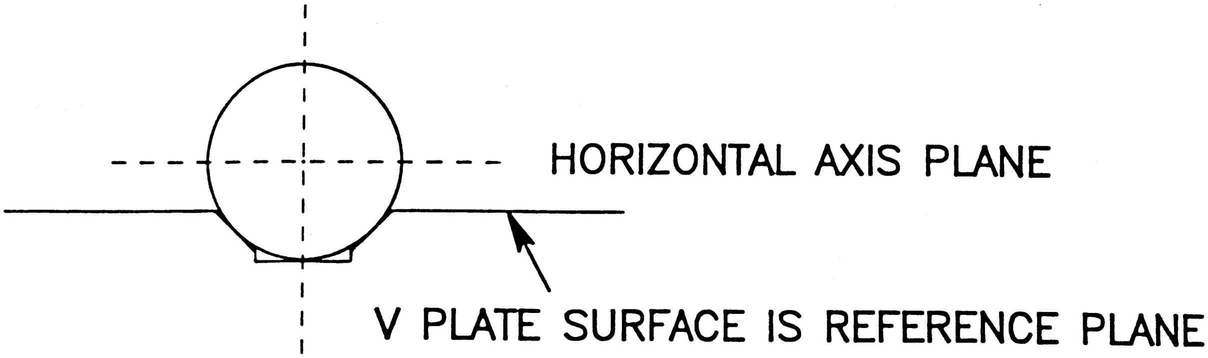
APPLICABLE TO NON-ROTATIONALLY SYMMETRIC ELEMENTS MOUNTED IN ROUND CYLINDERS OR ROTATIONAL INSERTS IN NON-ROUND CYLINDERS.

CLASSES
- ADJUSTMENT IN SETUP
- ROTATION IN PERFORMANCE OF INSTRUMENT FUNCTION
  - CONTINUOUS ROTATION
  - INTERMITTENT ROTATION
    - TO REPEATED ORIENTATIONS
    - TO ARBITRARY ORIENTATIONS

ALSO REMOVAL OF CYLINDER AND REPLACEMENT TO SAME ANGLE

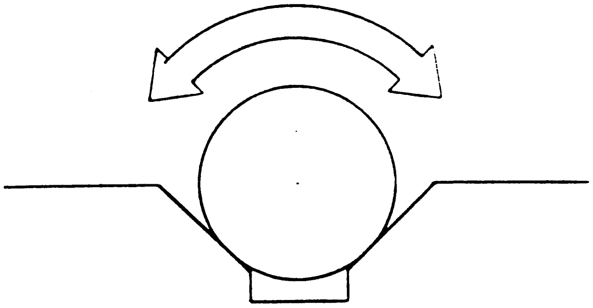
TERMINOLOGY

VERTICAL AXIS PLANE

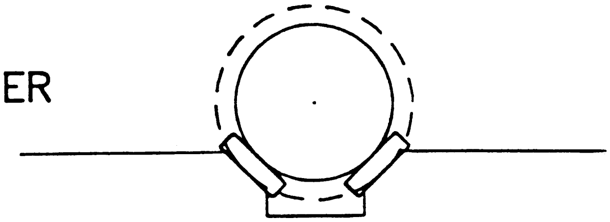


ROTATION OF AN OPTICAL ELEMENT ABOUT THE AXIS

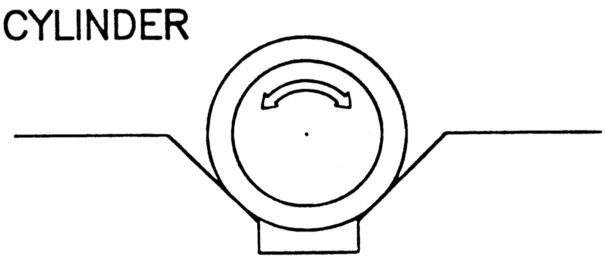
ROTATION OF THE CYLINDER
DIRECTLY AGAINST THE V



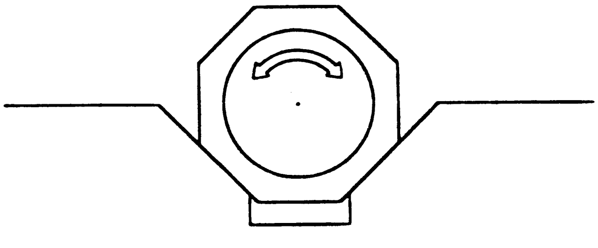
LOW FRICTION INSERT AND
REDUCED DIAMETER CYLINDER



ROTATION INSIDE THE CYLINDER



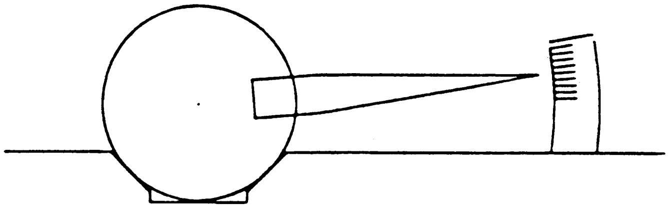
THE CYLINDER CAN BE NON–ROUND.

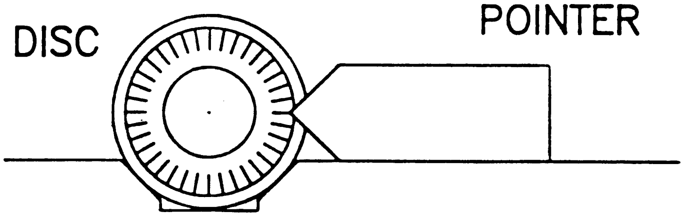


SOME ELEMENTS THAT ARE ROTATED NEED NOT BE CENTERED,
E.G. SHEET POLARIZER.

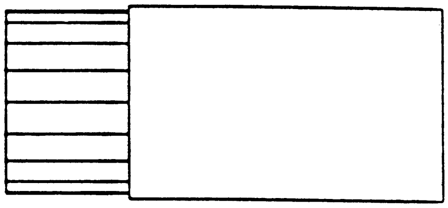
MEASURING AZIMUTHAL ANGLE

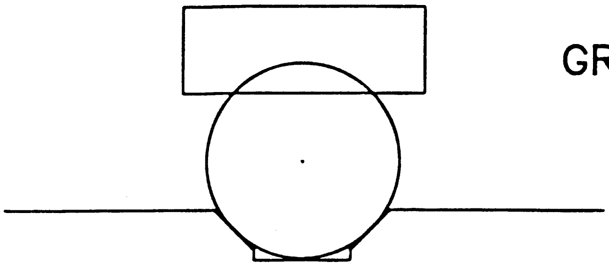
- EXAMPLES





GRADUATED DRUM ON CYLINDER





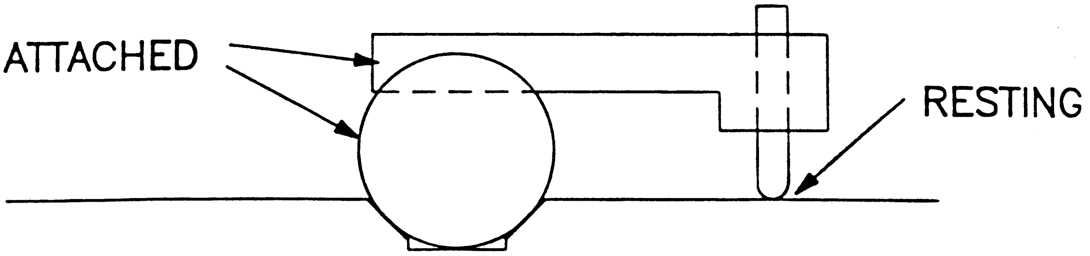
GRAVITY SENSING TILTOMETER

"AZIMUTH ARM"

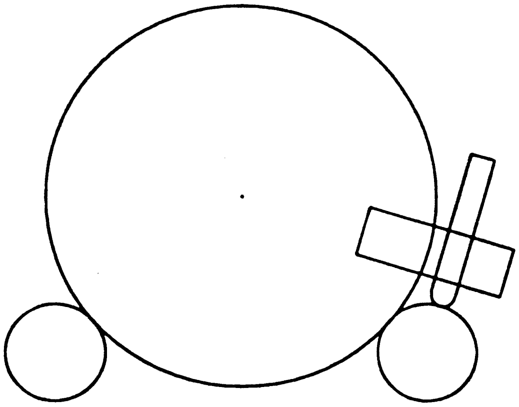
STRUCTURE THAT DETERMINES AZIMUTH.
ATTACHED TO CYLINDER AND RESTING ON SOMETHING
FIXED RELATIVE TO THE V PLATE SURFACE OR ELSEWHERE

EXAMPLES

TANGENT SCREW



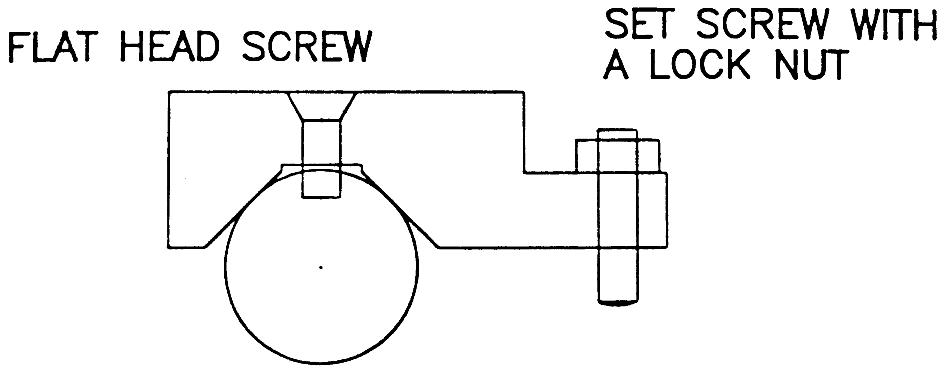
"ROD V" USED AS AZIMUTHAL REFERENCE



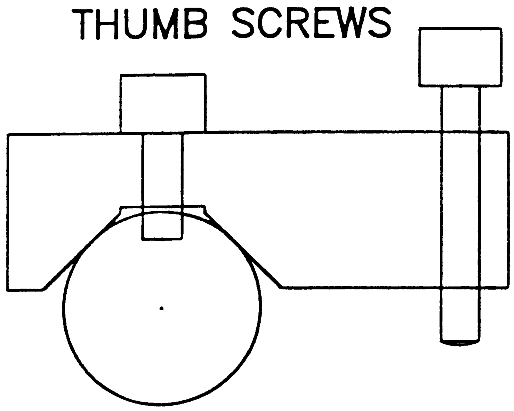
AZIMUTH ARM EXAMPLES

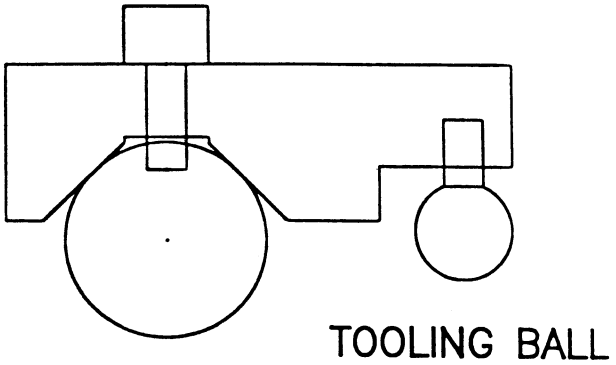
AN ARM FOR AZIMUTH CONTROL CAN BE PERMANENTLY OR TEMPORARILY ATTACHED TO A CYLINDER.

PERMANENT

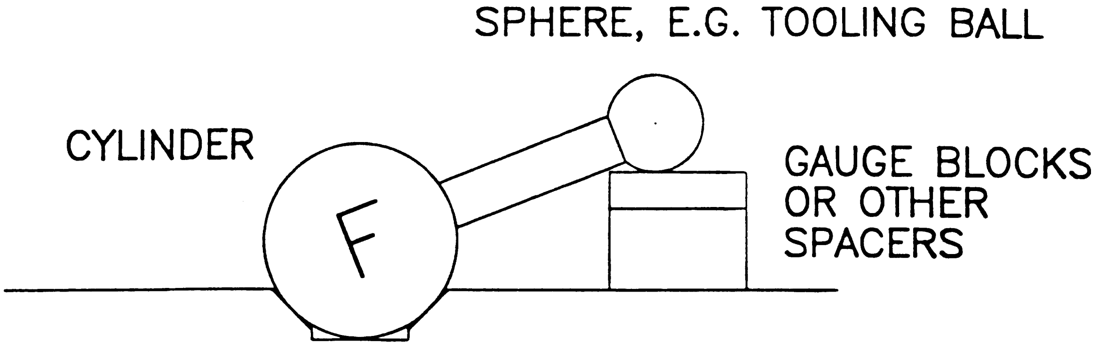


TEMPORARY

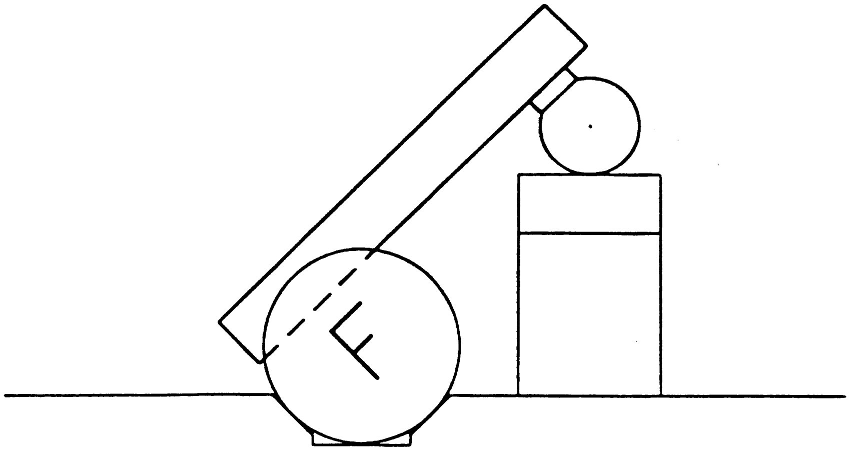




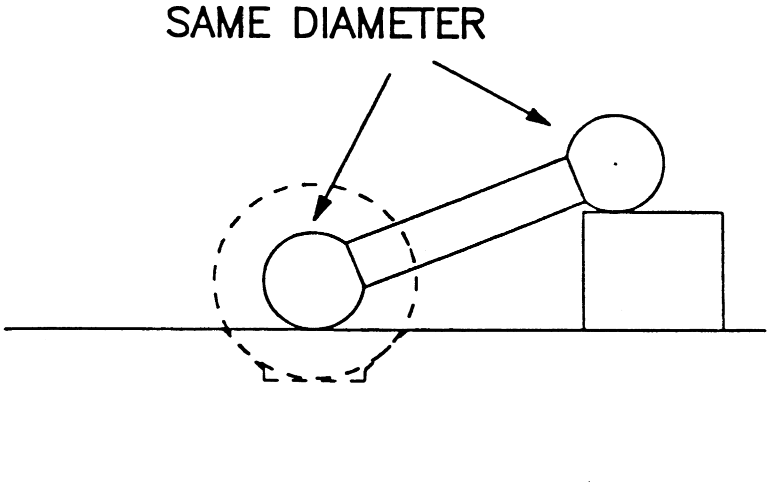
SINE BAR METHODS



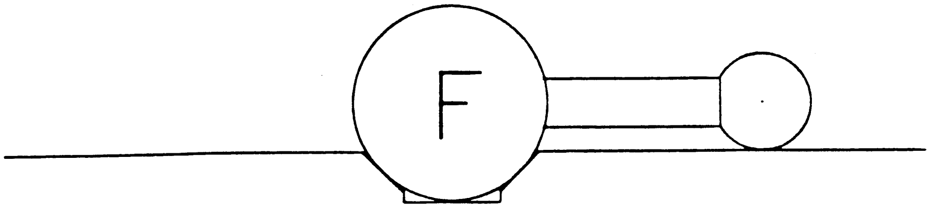
DESIGN FOR GREATER ANGLES

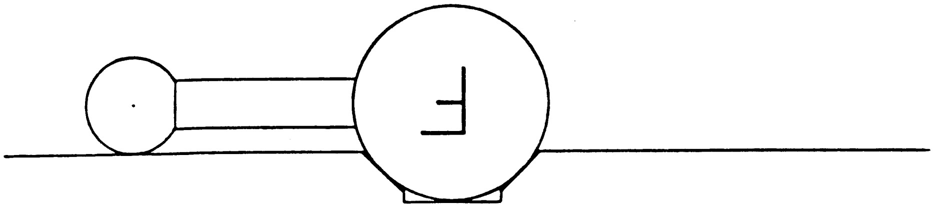


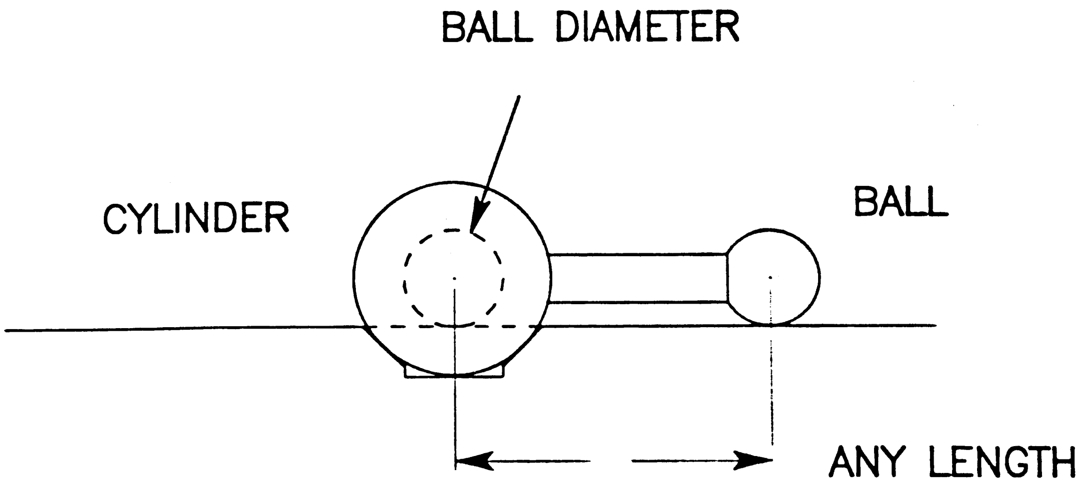
EQUIVALENT



180 DEGREE ROTATION

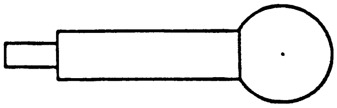






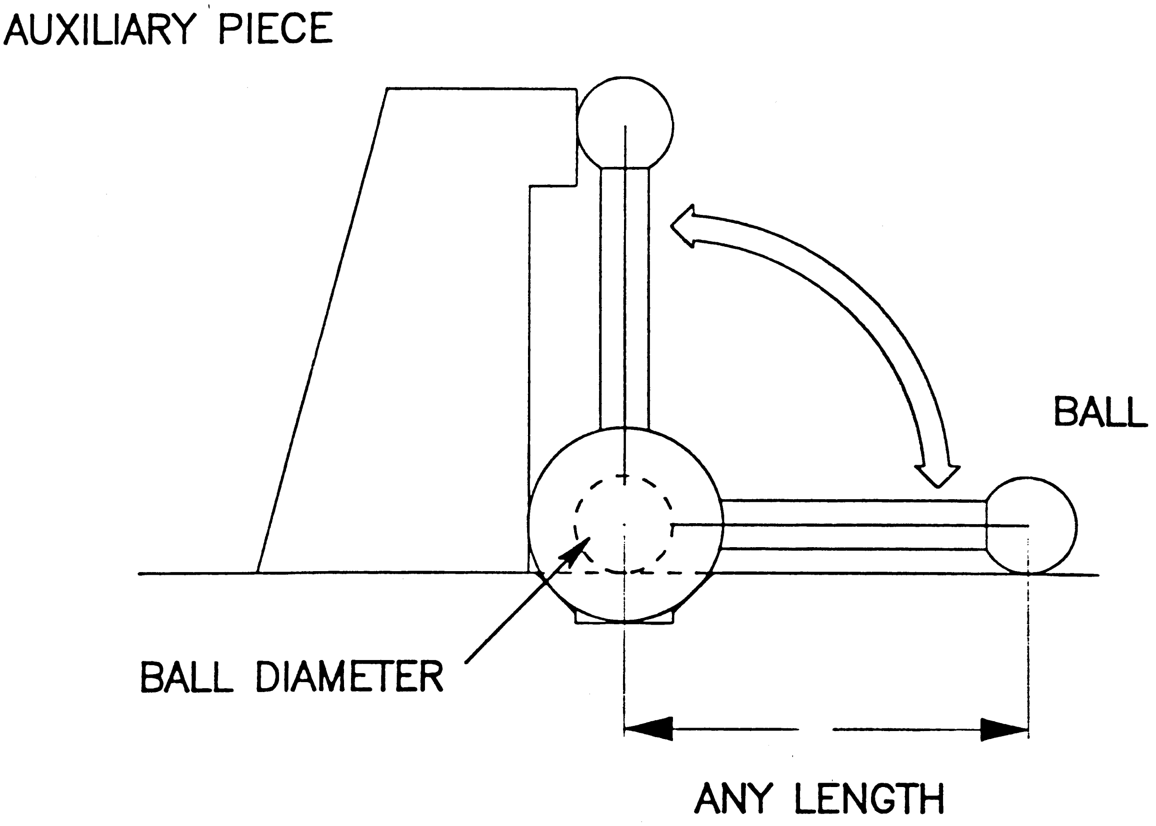
THIS WORKS ONLY FOR SHALLOW VS.

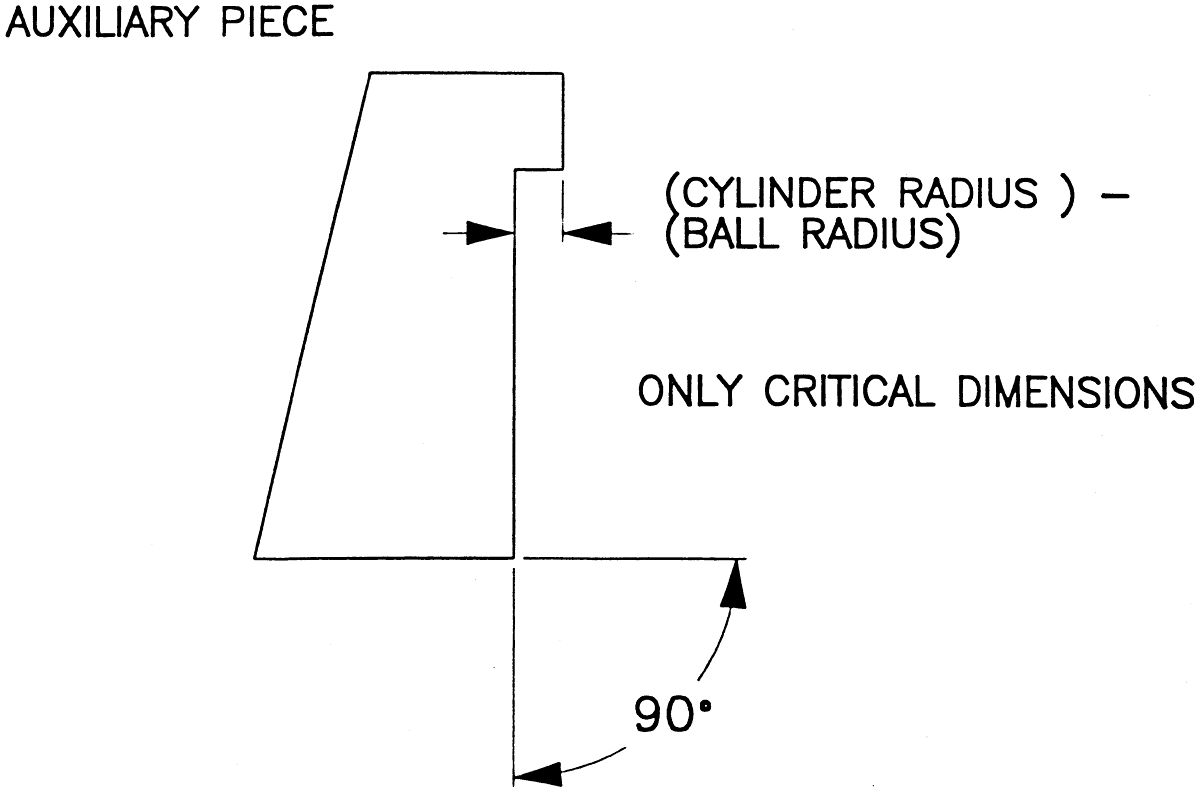
THE ARM CAN BE TEMPORARILY ATTACHED FOR SETUP.



180° ROTATION IS USED IN CENTERING.

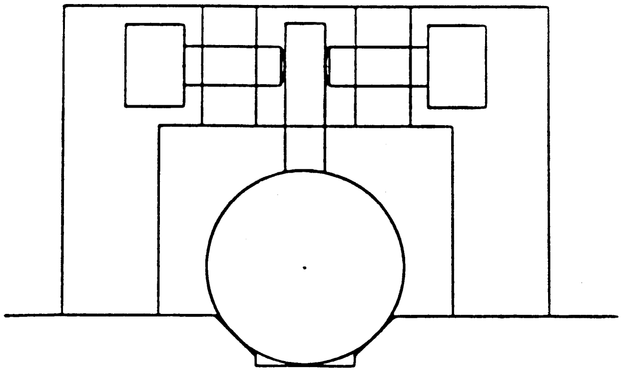
90 DEGREE ROTATION



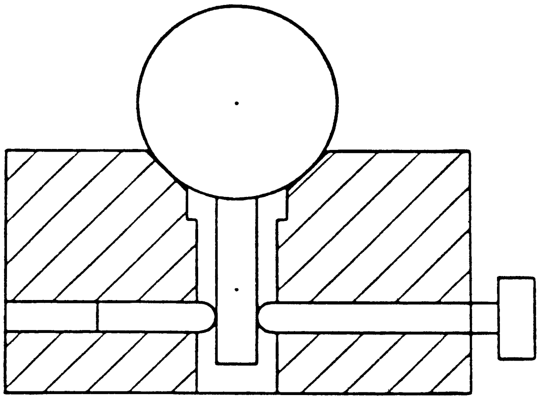


VERTICAL ROTATION ARM

OPPOSING TANGENT SCREWS OR
SCREW AND A SPRING ON A BRIDGE



ARM AND TANGENT SCREW INSIDE THE V BODY



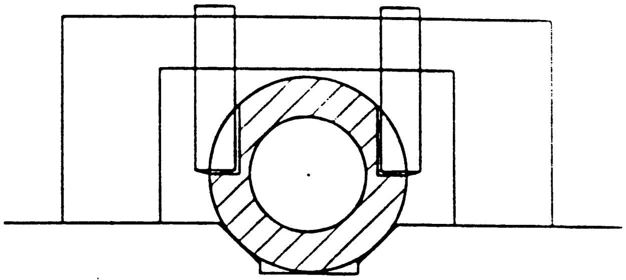
DO NOT DISPLACE CYLINDER FROM V.

A SPRING LOAD MAY BE NEEDED.

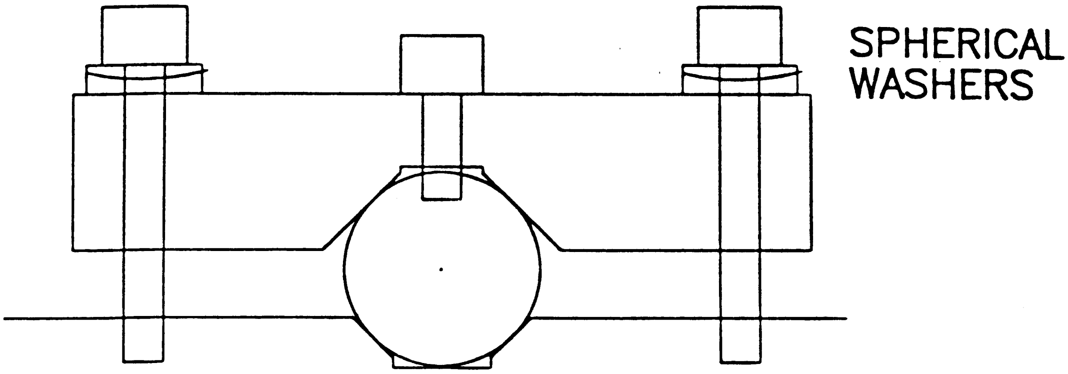
ADJUSTMENT CLAMPS

THE CYLINDER IS AZIMUTHALLY ADJUSTED AND THEN RESTRAINED BY THE SAME APPARATUS.

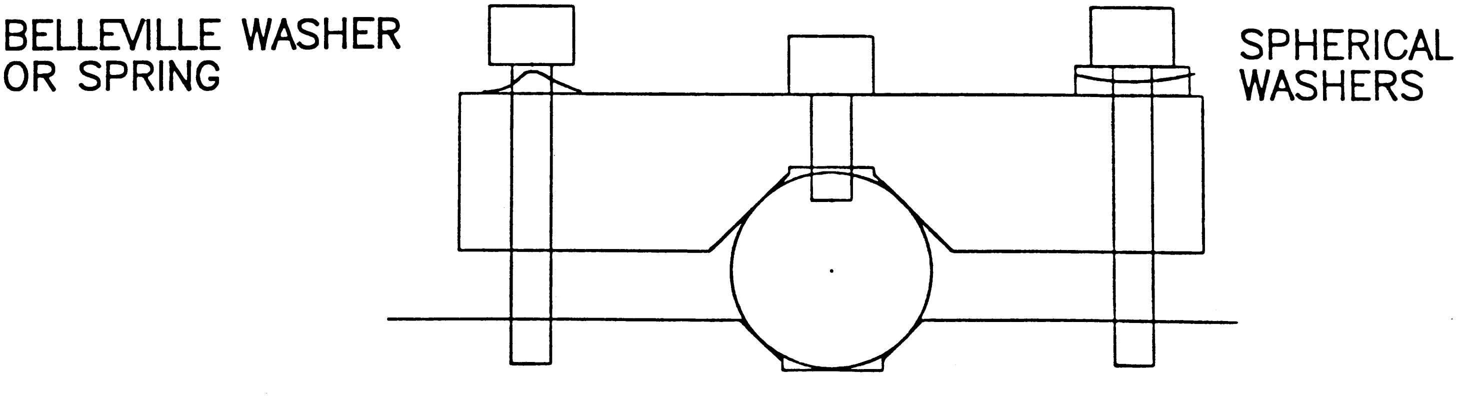
AZIMUTHAL ANGLE ADJUSTED WITH OPPOSING SCREWS AND OPPOSITE FLATS ON THE CYLINDER



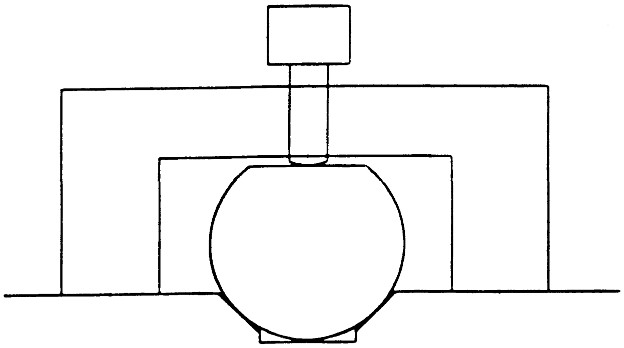
AZIMUTH ADJUST ARM WITH OPPOSING SCREWS



AZIMUTH ADJUST ARM WITH SCREW AND OPPOSING SPRING

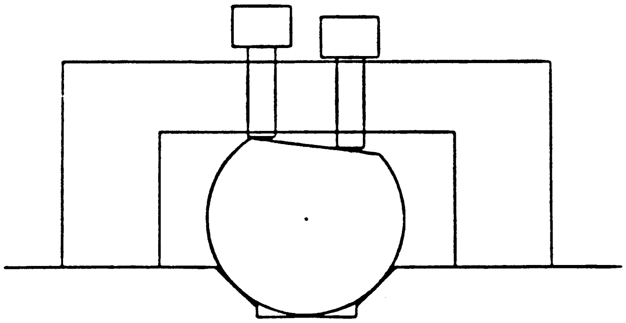


AZIMUTH LIMITING CLAMPS

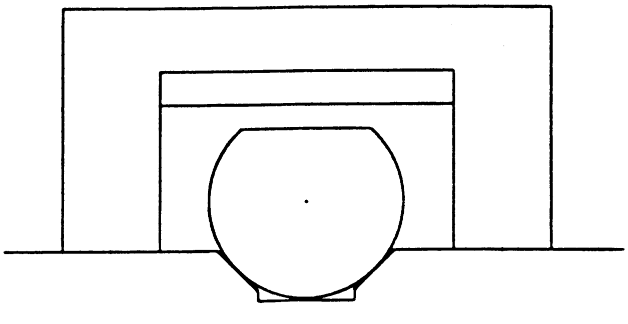


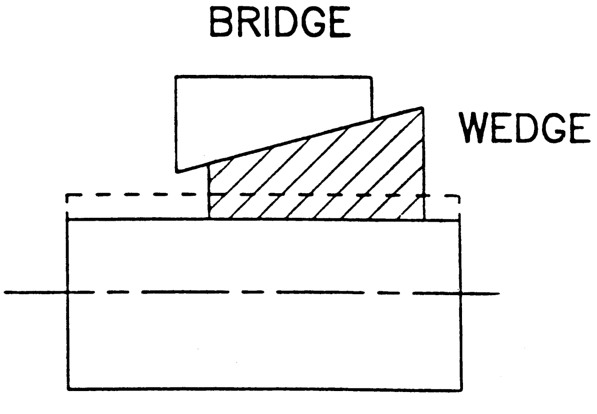
TIGHT FIT UNDER BRIDGE AND CYLINDER WITH FLAT

ONE SCREW ADJUSTED AND LEFT FIXED, THE OTHER CLAMPED



BRIDGE WITH SLOPED UNDERSIDE

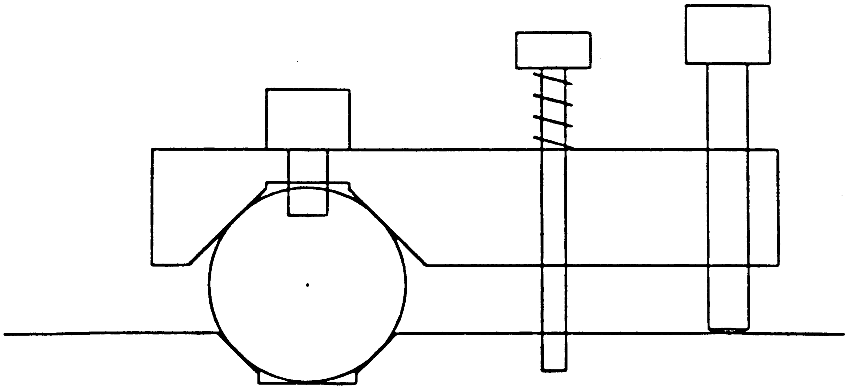




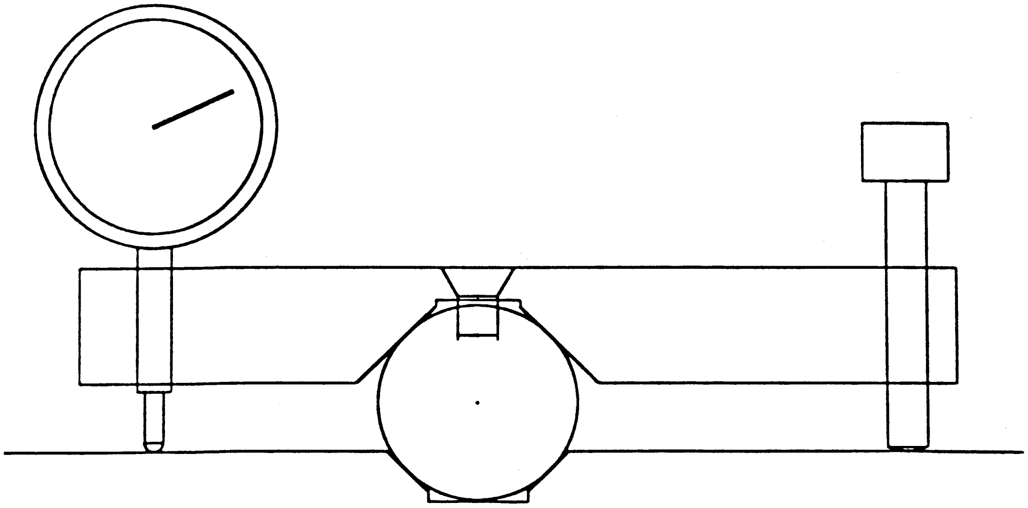
CYLINDER WITH A FLAT

MISCELLANEOUS

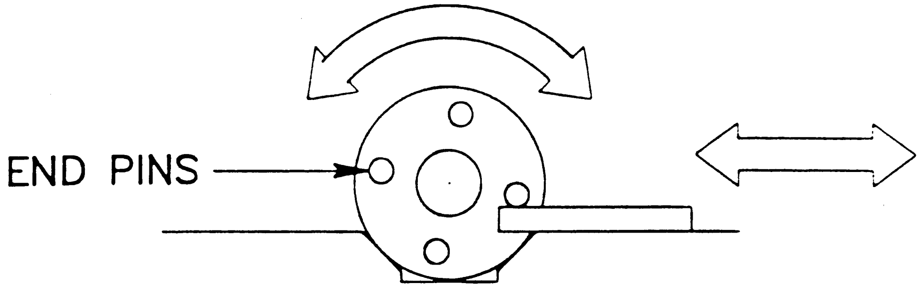
SPRING FOR BOTH CLAMPING AND AZIMUTHAL ADJUSTMENT RESISTANCE



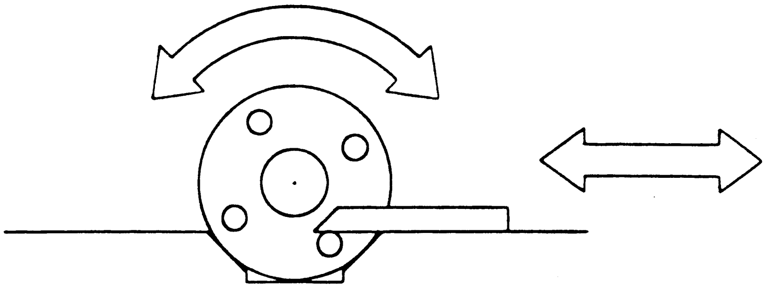
ANGLE MEASURED BY INDICATOR

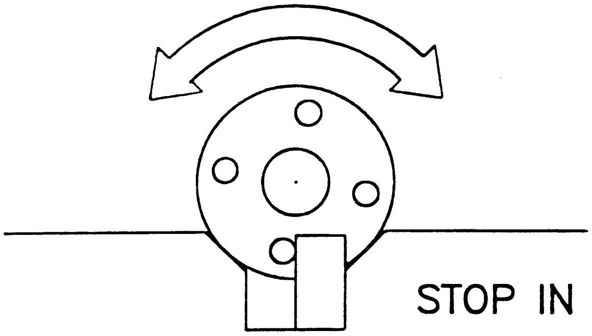


ANGLE INDEXING



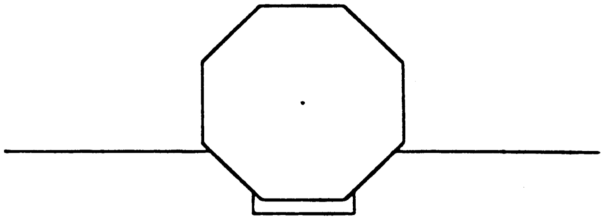
STOPS ON THE V PLATE





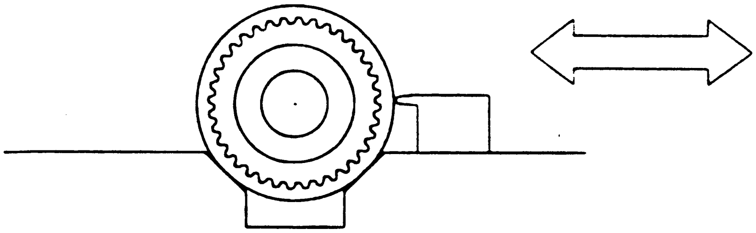
STOP IN THE TROUGH

POLYGONAL CYLINDERS INDEX THEMSELVES

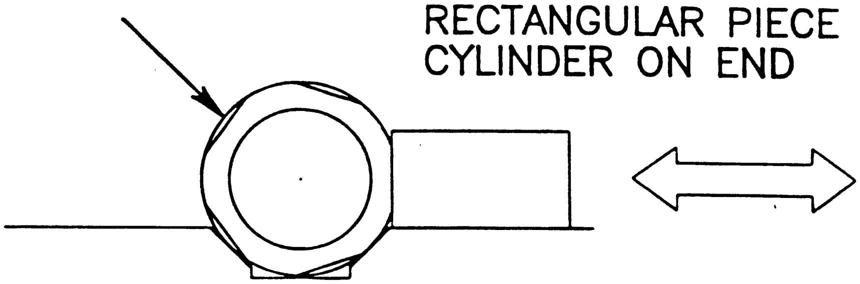


ANGLE INDEXING

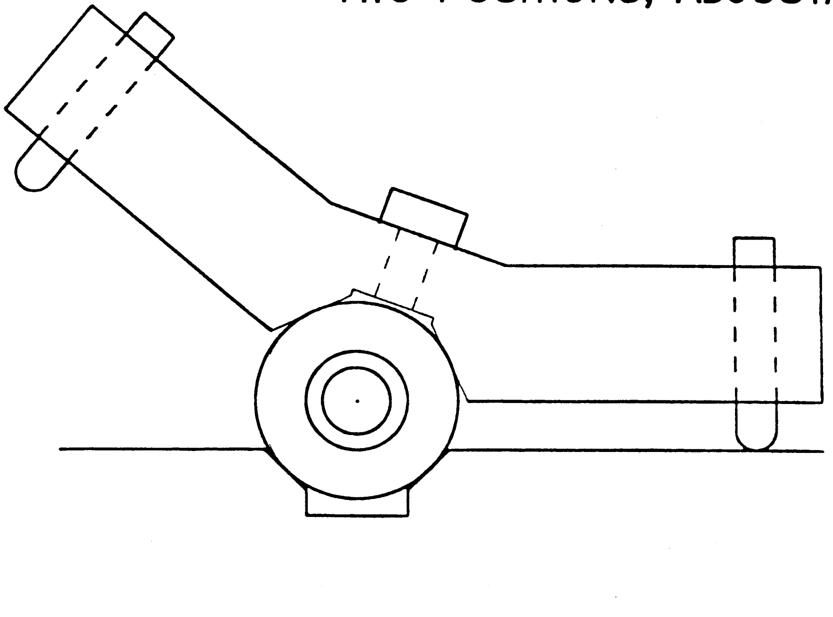
GEAR ATTACHED TO END OF CYLINDER



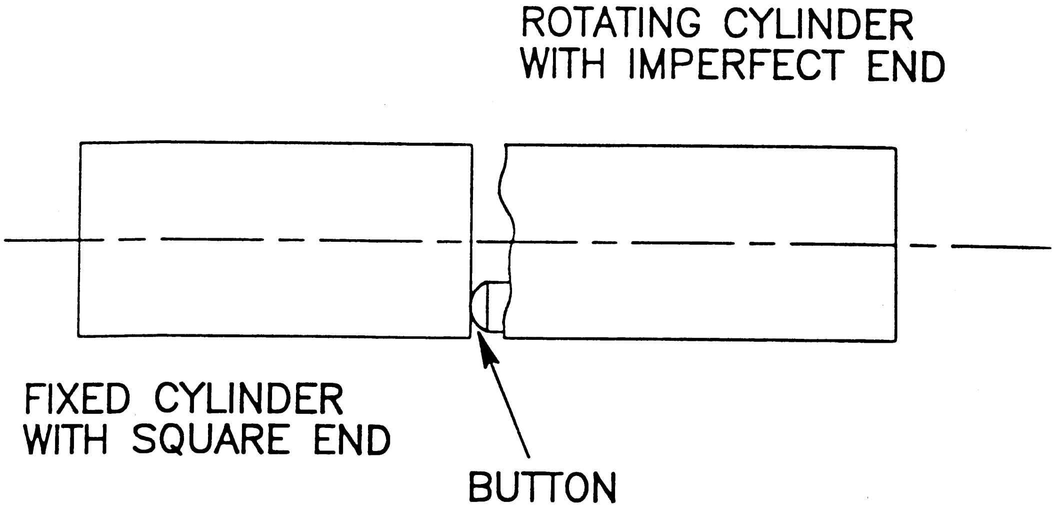
FLATS ON CYLINDER



TWO POSITIONS, ADJUSTABLE



AVOIDING AXIAL MOTION WHILE ROTATING A CYLINDER



FLIPPING

FLIPPING IS AN OPERATION PERFORMED ON CYLINDERS WITH AN AZIMUTHAL STOP.
SUCH A CYLINDER LOCATED BY A STOP IS LIFTED FROM THE V, ROTATED 180° ABOUT THE BISECTION PLANE OF THE V, THEN REPLACED IN THE V WITH THE AZIMUTHAL STOP ENGAGED.
AN EFFECT OF THE ELEMENT IN THE CYLINDER IS COMPARED FOR THE TWO POSITIONS.

SIMILAR OPERATIONS CAN BE PERFORMED WITH NON-ROUND CYLINDERS USING THE V TO DETERMINE THE AZIMUTHS.

AXIAL POSITION IS NOT CONSTRAINED IN FLIPPING, AND MOTION FOR REFOCUS MAY BE NEEDED.

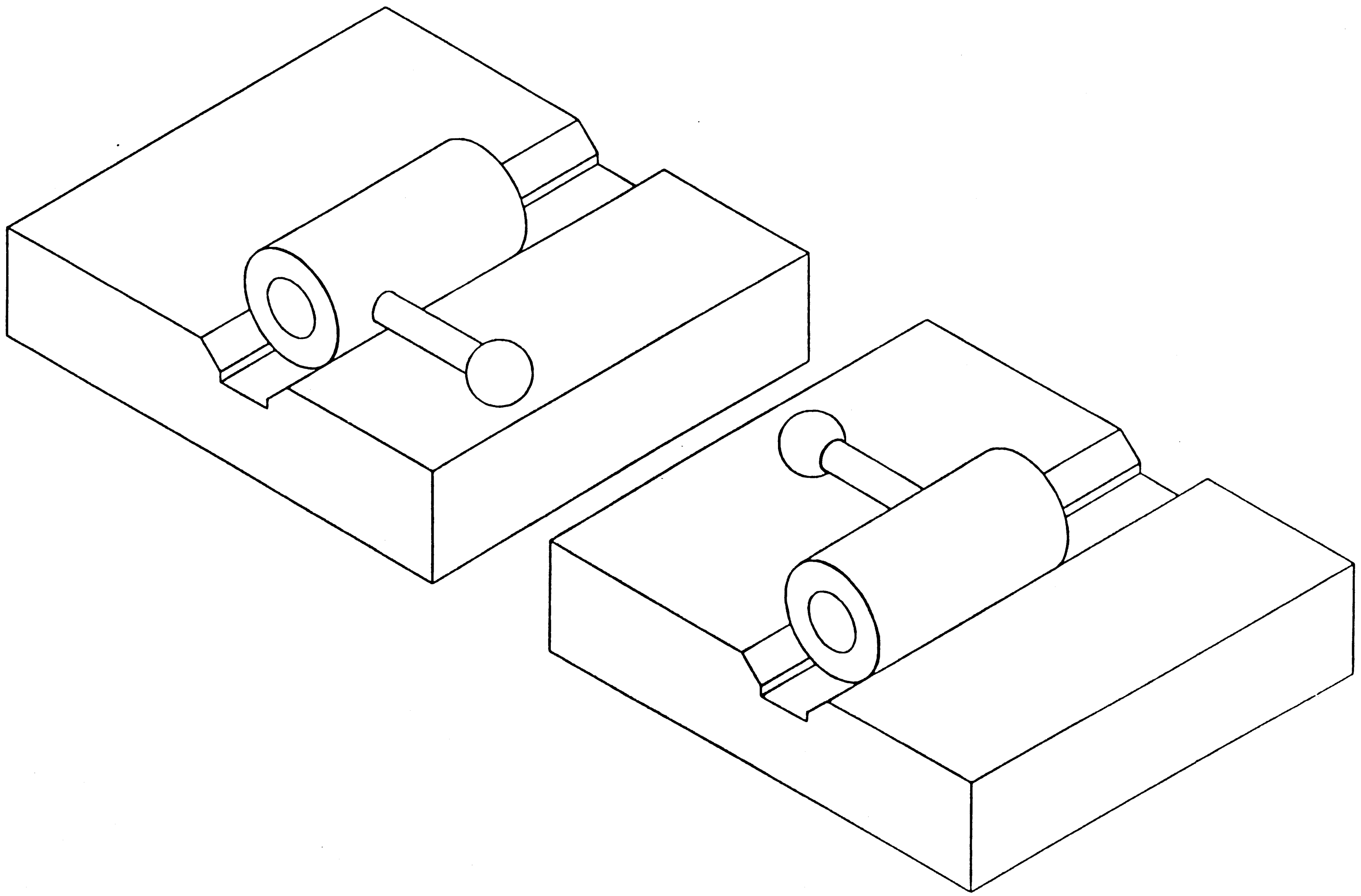
THIS PROCEDURE CAN BE USED TO FIND AZIMUTHAL ORIENTATIONS

- RELATIVE TO V PLATE SURFACE OR OTHER AZIMUTHAL REFERENCE FOR ROUND CYLINDERS

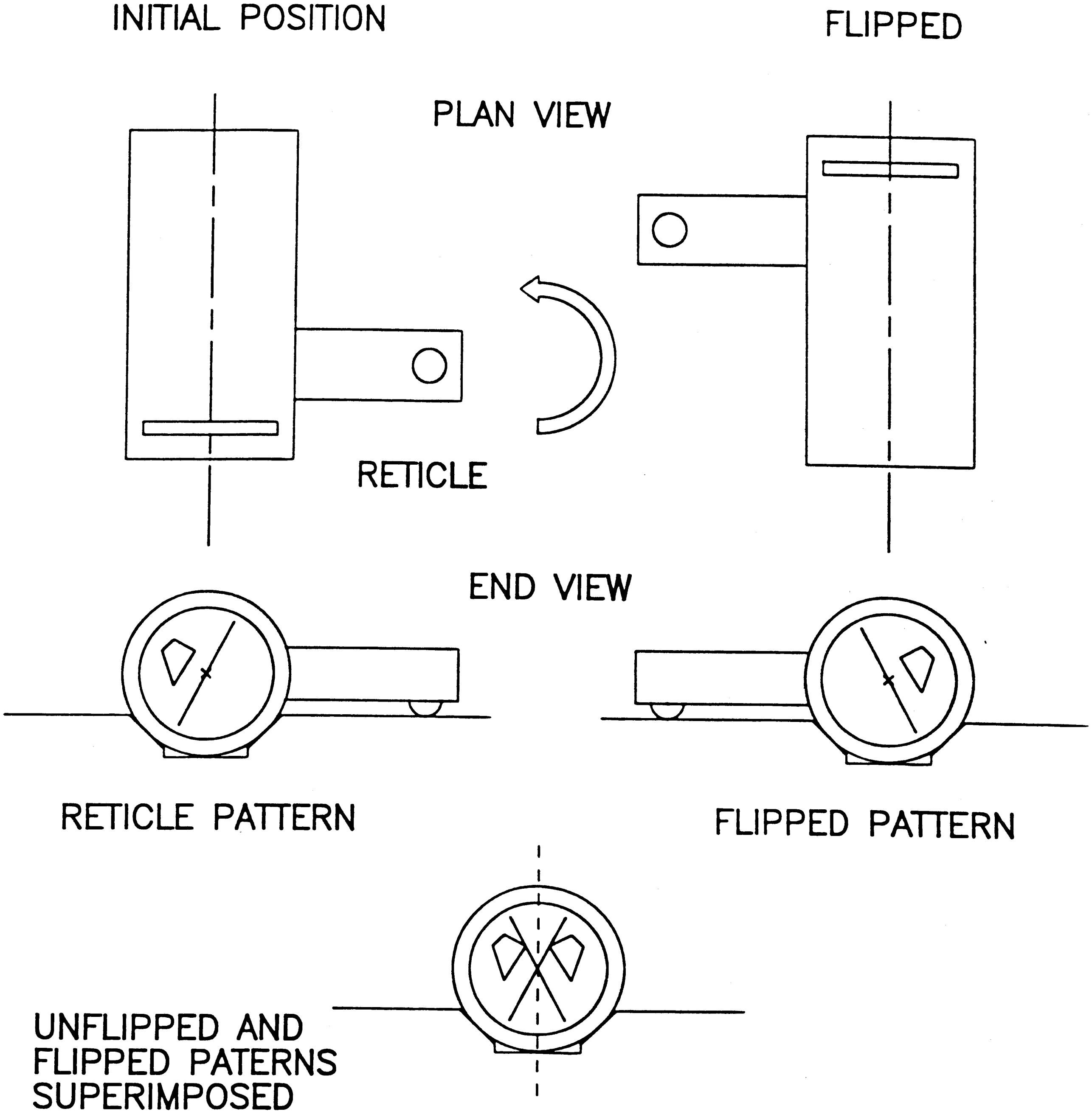
- RELATIVE TO THE V FOR NONROUND CYLINDERS

FLIPPING CAN BE USE TO AZIMUTHALLY ORIENT SUCH ELEMENTS AS:
CYLINDRICAL LENSES
POLARIZATION COMPONENTS
RECTANGULAR APERTURES
SLITS
RETICLES

FLIPPING



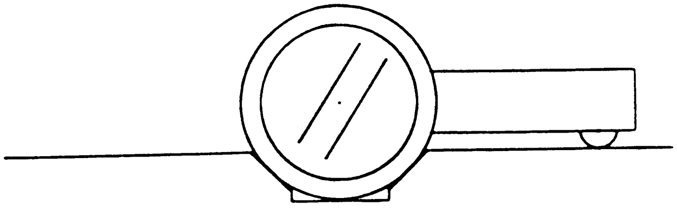
FLIPPING A ROUND CYLINDER WITH AN AZIMUTH ARM



MIRROR IMAGES ABOUT VERTICAL AXIAL PLANE, I.E. PLANE THROUGH AXIS THAT IS PERPENDICULAR TO THE V PLATE SURFACE

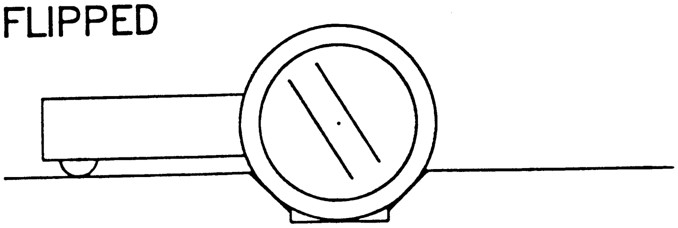
FINDING VERTICAL AXIAL PLANE BY FLIPPING

A RETICLE WITH TWO LINES IS ORIENTED ROUGHLY AS SHOWN.

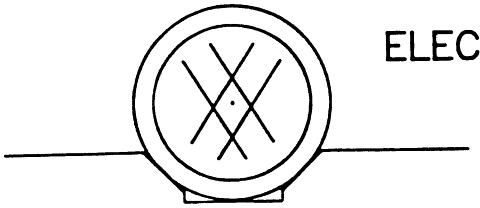


THE IMAGE OF THE RETICLE IS CAPTURED BY A VIDEO SYSTEM.

FLIPPED

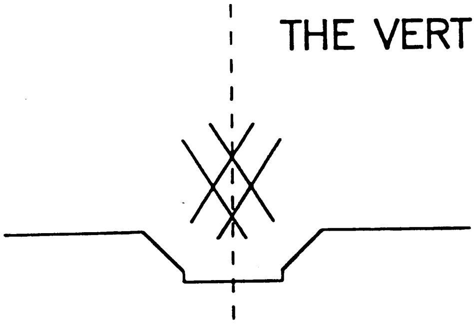


A SECOND IMAGE IS CAPTURED.

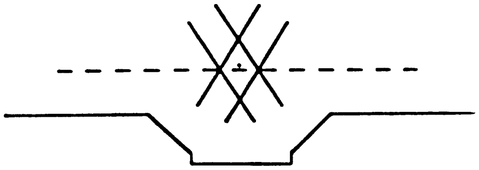


ELECTRONICALLY COMBINED IMAGES

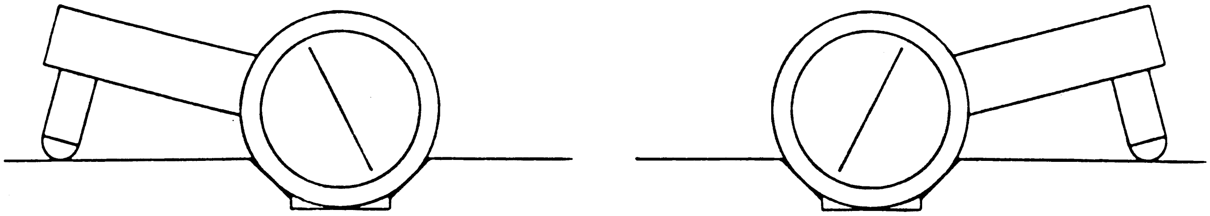
THE VERTICAL AXIAL PLANE



LIKEWISE, A HORIZONTAL PLANE CAN BE FOUND, BUT ITS HEIGHT IS UNKNOWN.



FLIPPING PROPERTIES



THE AZIMUTH ARM SETTING IS IRRELEVANT.

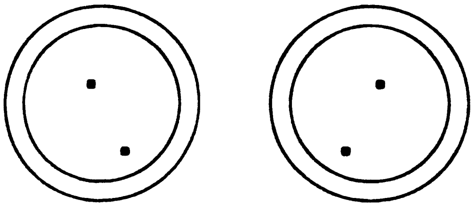
A PARTICULAR ARM LENGTH IS NOT REQUIRED.

THE CENTER POINT IS NOT FOUND.

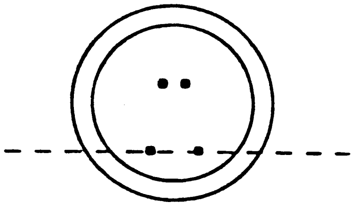
AXIAL POSITION IS LOST.

CYLINDER DIAMETER DOES NOT MATTER FOR FINDING THE AXIAL VERTICAL PLANE.

HORIZONTAL PLANES CAN BE FOUND, BUT THE AXIAL HORIZONTAL PLANE CANNOT BE IDENTIFIED.



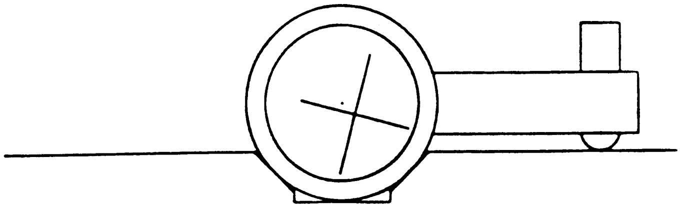
FLIPPED

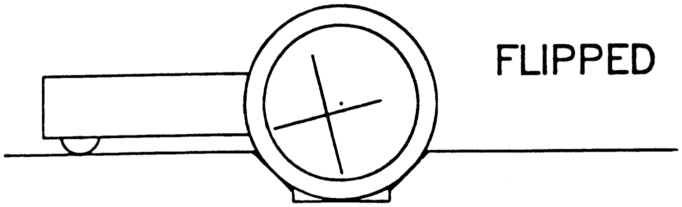


SUPERIMPOSED

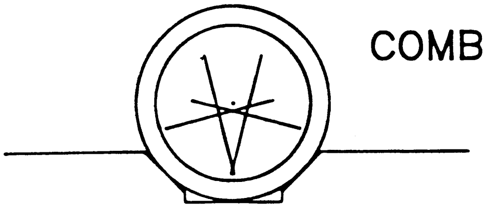
MAKING A HORIZONTAL/VERTICAL MASTER

RETICLE WITH PERPENDICULAR LINES



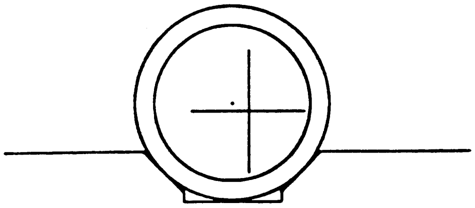


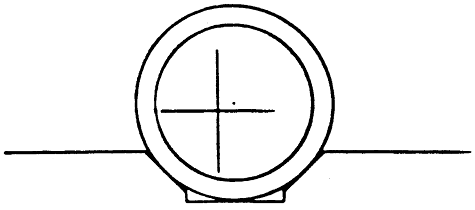
FLIPPED



COMBINED IMAGES

THE TANGENT SCREW IS ADJUSTED UNTIL BOTH IMAGES HAVE SAME ORIENTATION UPON FLIPPING.

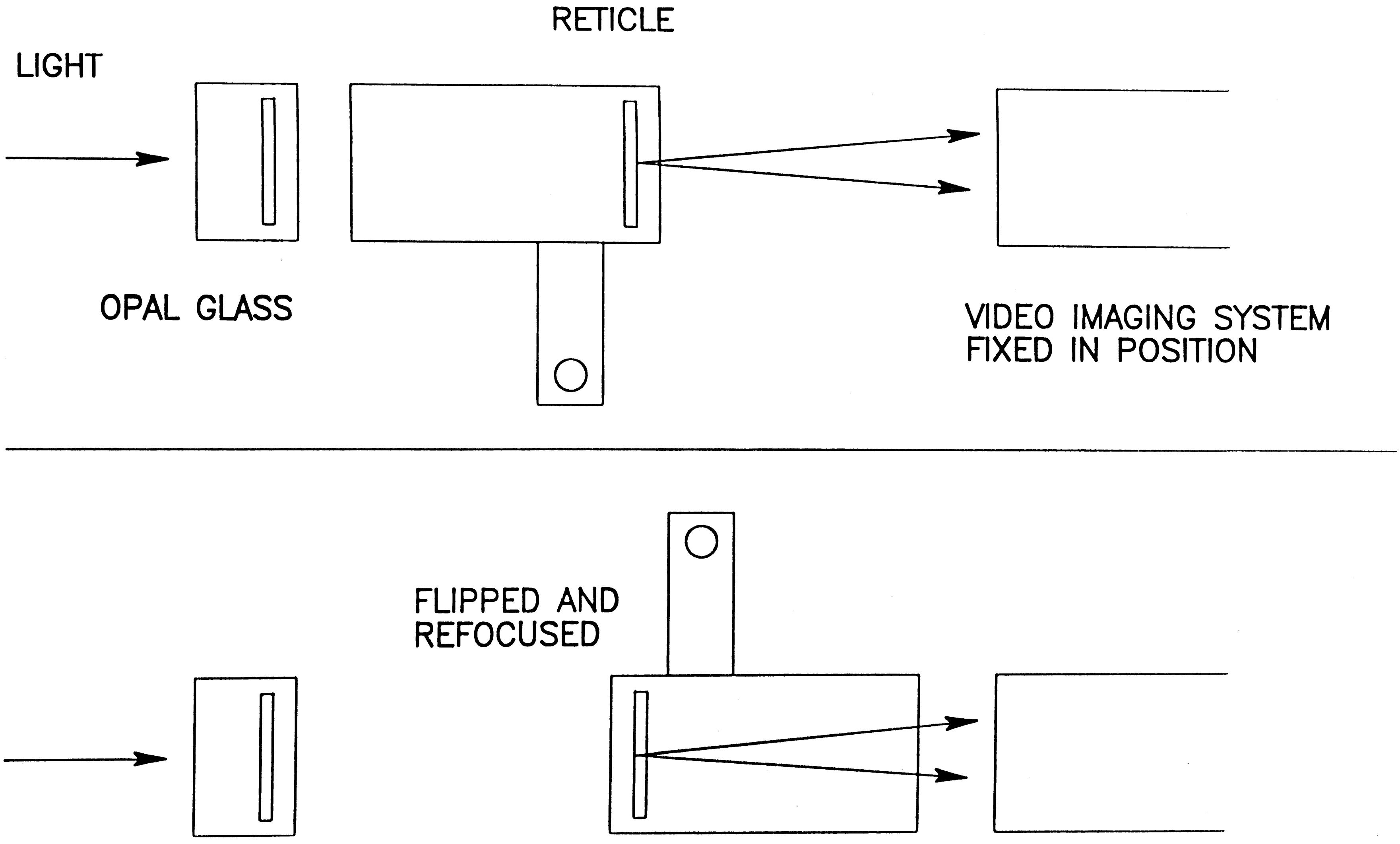




THE CROSS HAIRS ARE NOW HORIZONTAL AND VERTICAL.

THE RETICLE CAN ALSO BE CENTERED.
CENTERING IS DONE BEFORE LEVELLING.

OIENTATION BY FLIPPING SETUP

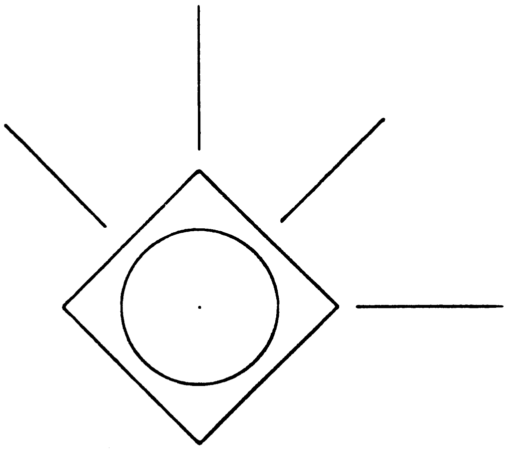


USE SEMI-MONOCHROMATIC LIGHT FOR SHARPEST IMAGES

FLIPPING SQUARE CYLINDERS

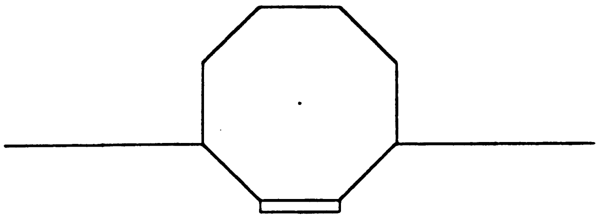
FLIPPING INVOLVES THE V ONLY, NOT THE V PLATE.

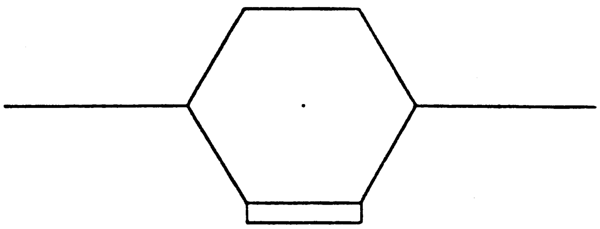
THERE ARE FOUR DIFFERENT FLIP AXES.



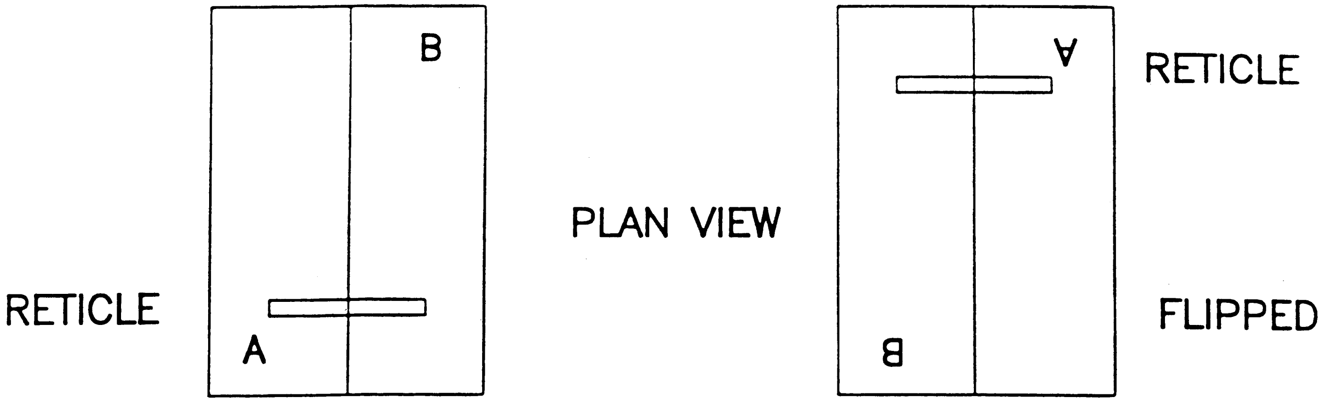
EACH ALLOWS A DIFFERENT ORIENTATION TO BE FOUND.
THERE ARE COMPLICATIONS INVOLVING SIZE AND SHAPE.

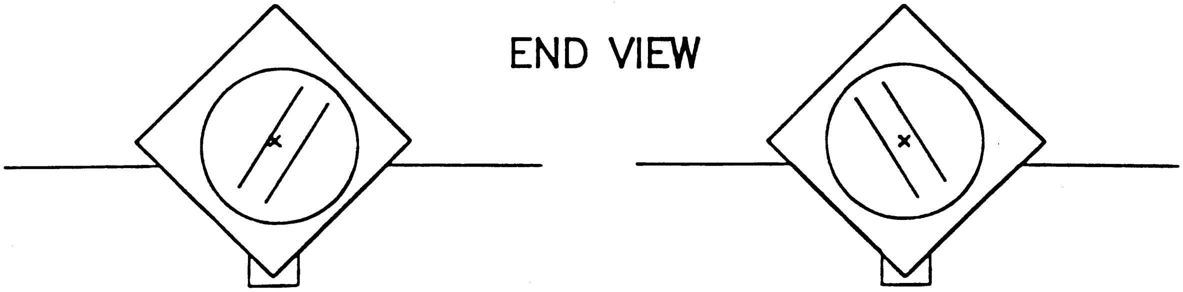
OCTAGONS AND HEXAGONS HAVE ANALOGOUS PROPERTIES.





FINDING THE BISECTION PLANE BY FLIPPING WITH A SQUARE CLINDER

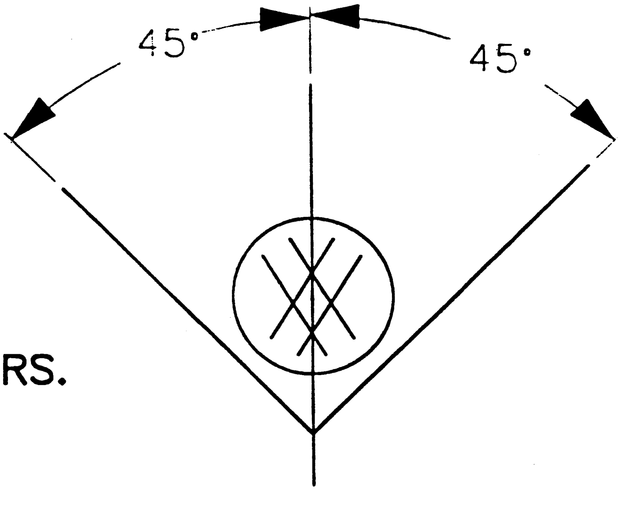




THE PLANE FOUND BY SUPERIMPOSING THE IMAGES BISECTS THE V ANGLE.

THE V PLATE SURFACE IS NOT INVOLVED.

SAME WITH HEXAGONAL CYLINDERS.

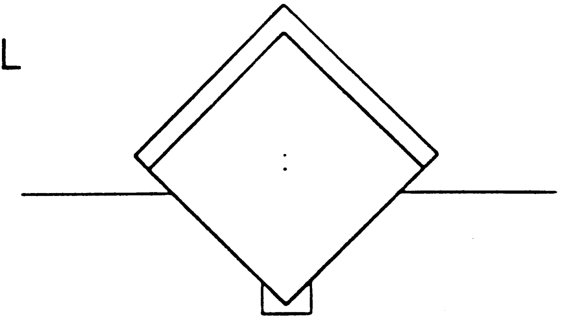


ONLY SHAPE COUNTS FOR BISECTOR ORIENTATION

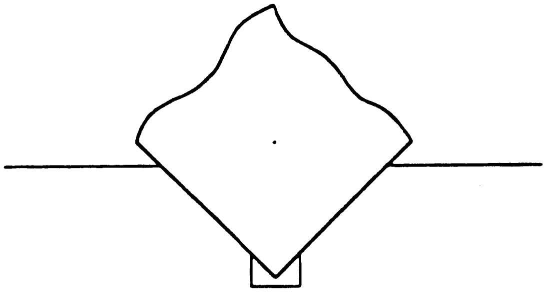
ONLY SHAPES MATTER

SIZES ARE NOT CRITICAL

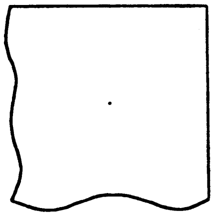
EXAMPLES:



TWO IRRELEVANT SIDES

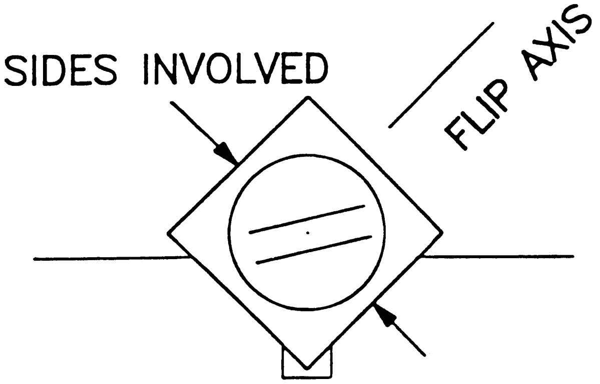


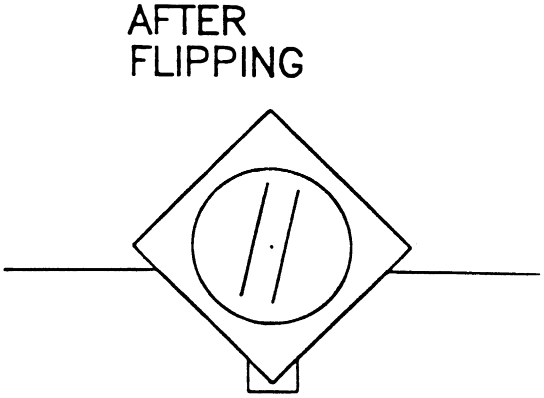
TWO ADJACENT SIDES CAN BE MACHINED IN THE SAME SETUP.



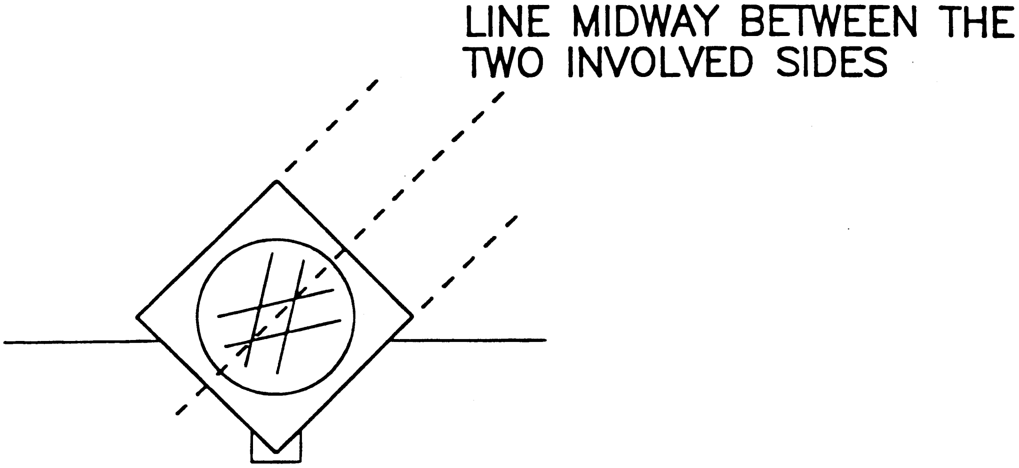
DIAGONAL FLIP AXIS

EXAMPLE



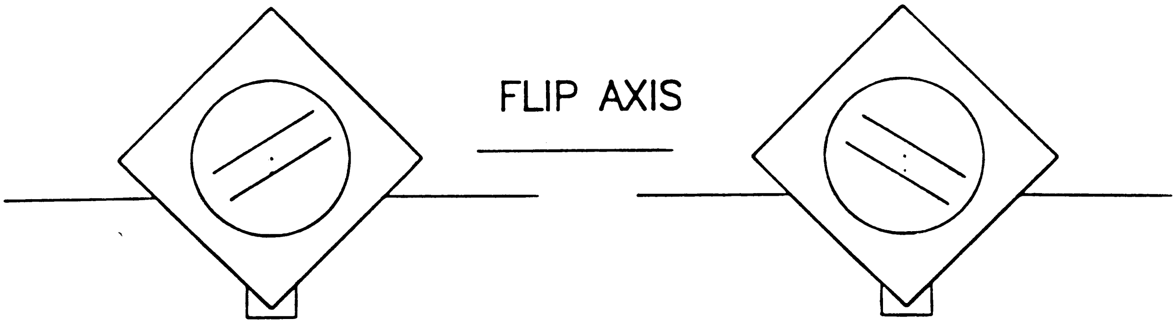


COMBINED IMAGES

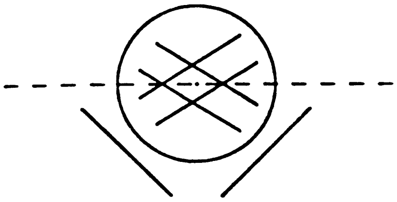


THE LINE DOES NOT PASS THROUGH THE AXIS IF THE SIZE OF THE SQUARE IS OFF.

HORIZONTAL FLIP AXIS



COMBINED IMAGES



ALL FOUR SIDES ARE INVOLVED.

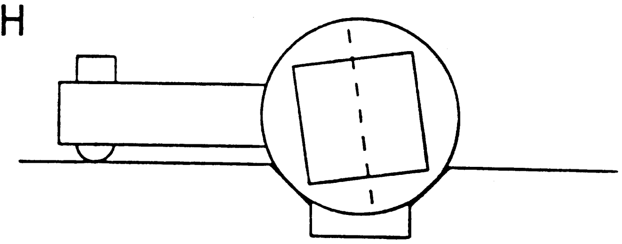
LEVELING

LEVELING IS THE ADJUSTMENT OF THE AZIMUTH OF AN OBJECT (WITHOUT ROTATIONAL SYMMETRY) SO THAT A DIRECTION IS VERTICAL OR HORIZONTAL WITH RESPECT TO EITHER THE V SURFACE PLANE OR THE BISECTOR OF THE V.

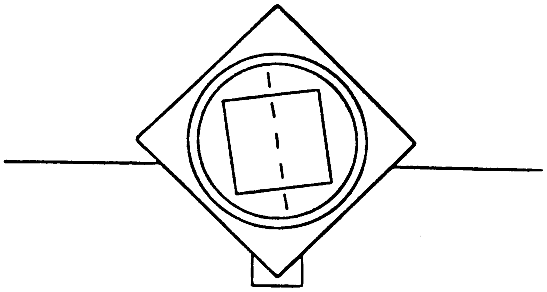
TWO ASPECTS: MEASUREMENT AND MOTION

EXAMPLES OF MECHANICS TO ENABLE LEVELING

ROUND CYLINDER WITH AZIMUTH ARM AND ADJUSTABLE SCREW



SQUARE CYLINDER WITH ROTATABLE ELEMENT HOLDER

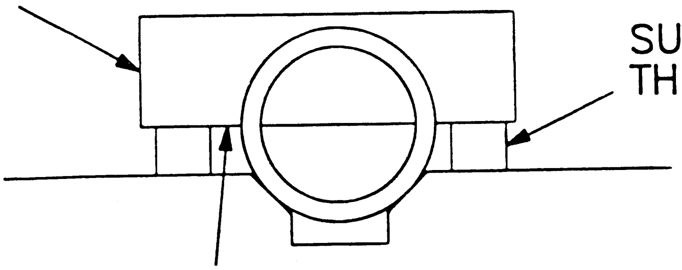


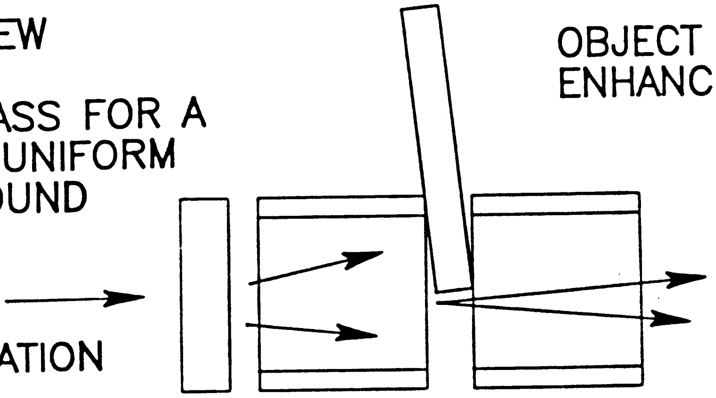
SEVERAL METHODS OF LEVELING MEASUREMENT:
- COMPARISON TO AN OPTICAL MASTER
- MECHANICAL
- SELF-TESTING BY FLIPPING

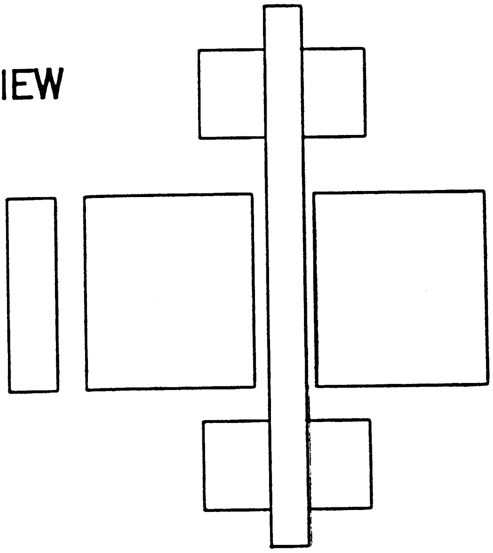
EXAMPLES OF APPLICABLE COMPONENTS:
- CYLINDRICAL LENSES
- PRISMS
- GRATINGS
- RETICLES
- POLARIZATION ELEMENTS

NOTE: LEVELING DOES NOT IMPLY CENTERING.

AN OPTICAL LEVELING REFERENCE







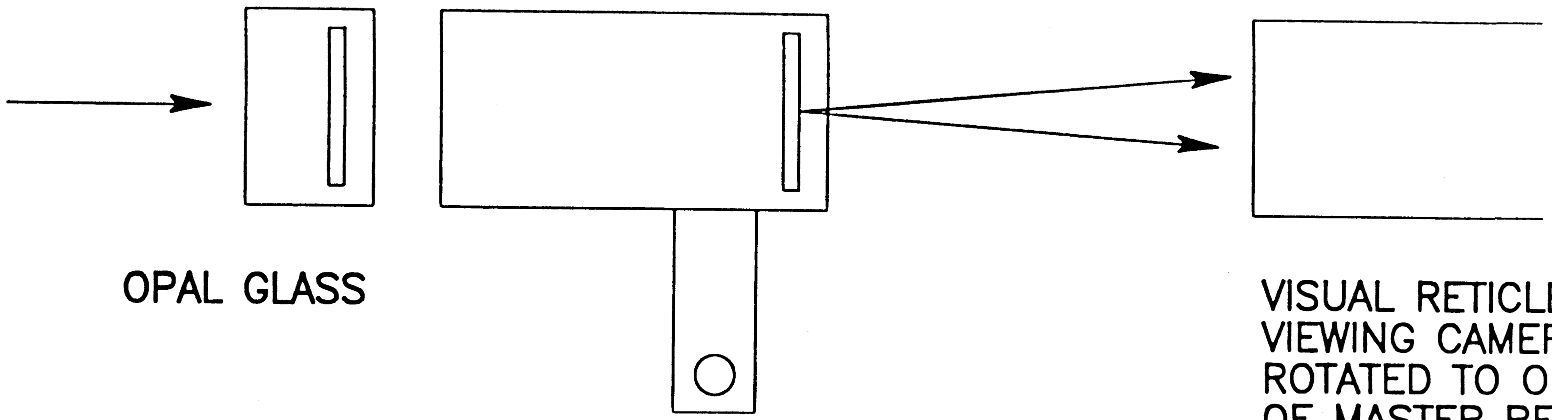
GOOD OBJECTS:

–CLEAVED SILICON WAFER

– RAZOR BLADE, SOME BETTER THAN OTHERS

OPTICAL LEVELING – METHOD 1

STEP 1



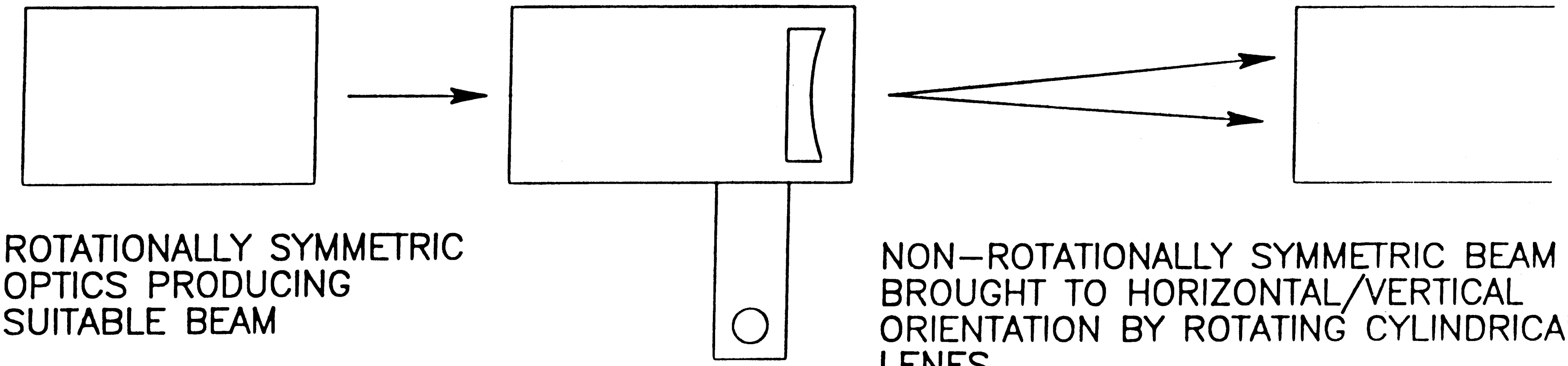
MASTER HORIZONTAL/VERTICAL
RETICLE IN FOCUS

IMAGING SYSTEM FIXED
IN POSITION

OPAL GLASS

VISUAL RETICLE OR
VIEWING CAMERA
ROTATED TO ORIENTATION
OF MASTER RETICLE

STEP 2



CYLINDRICAL LENS OR OTHER ELEMENT,
MOUNTED FOR AZIMUTHAL ADJUSTMENT

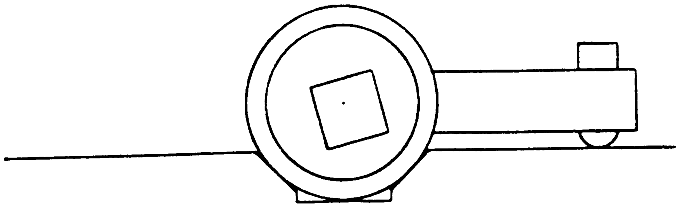
ROTATIONALLY SYMMETRIC
OPTICS PRODUCING
SUITABLE BEAM

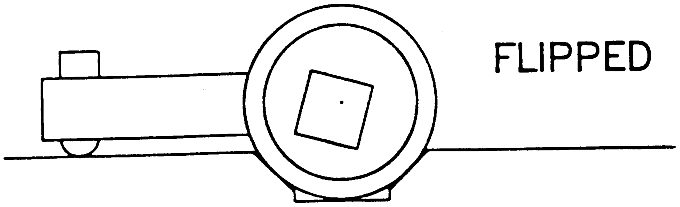
NON–ROTATIONALLY SYMMETRIC BEAM
BROUGHT TO HORIZONTAL/VERTICAL
ORIENTATION BY ROTATING CYLINDRICAL
LENES

LEVELING BY FLIPPING

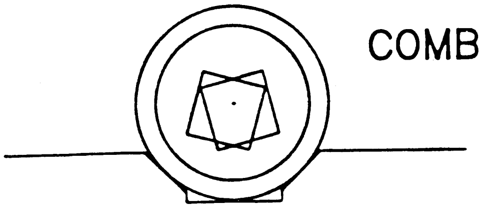
EXAMPLE: A RECTANGULAR APERTURE

INITIAL ORIENTATION



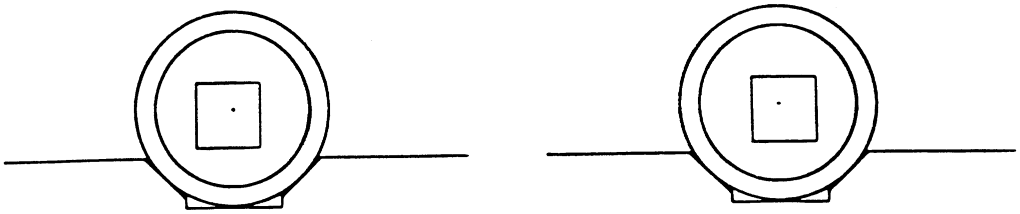


FLIPPED

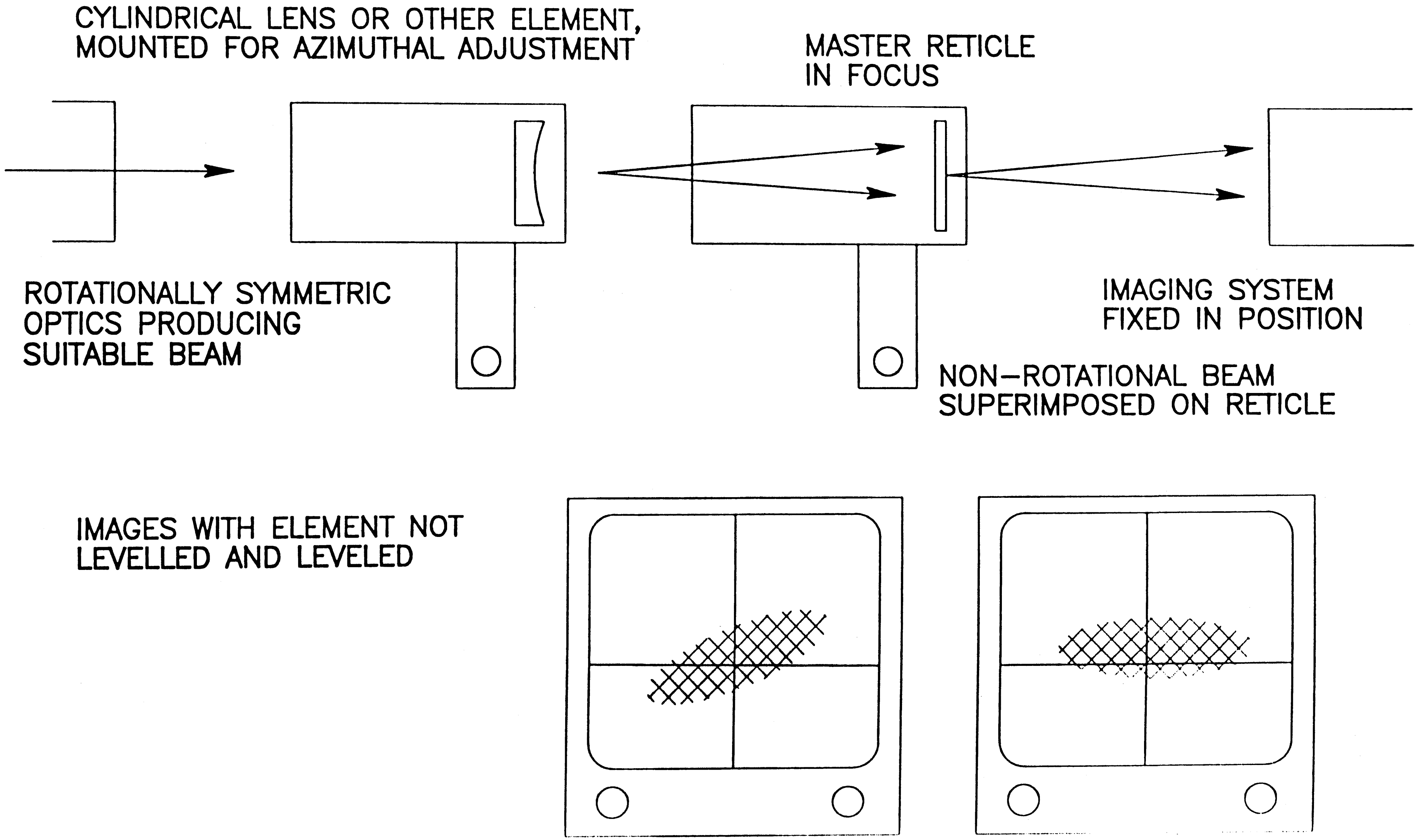


COMBINED IMAGES

THE TANGENT SCREW IS ADJUSTED UNTIL BOTH IMAGES HAVE SAME ORIENTATION

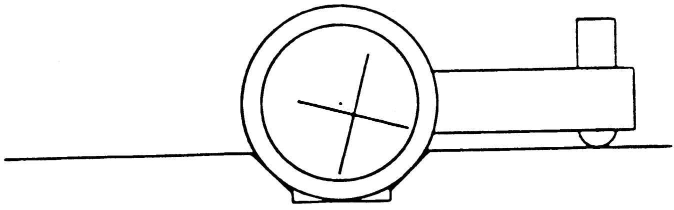


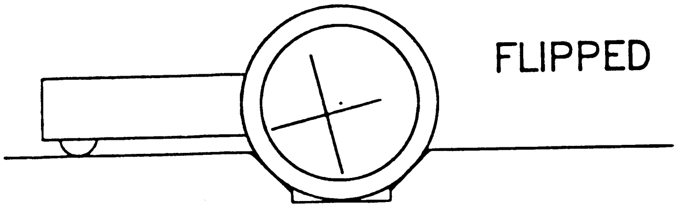
OPTICAL LEVELING – METHOD 2

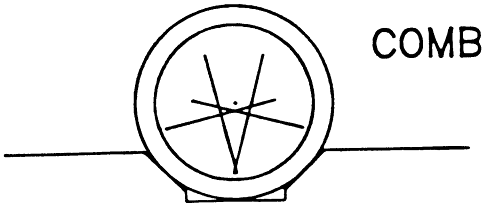


MAKING A HORIZONTAL/VERTICAL MASTER

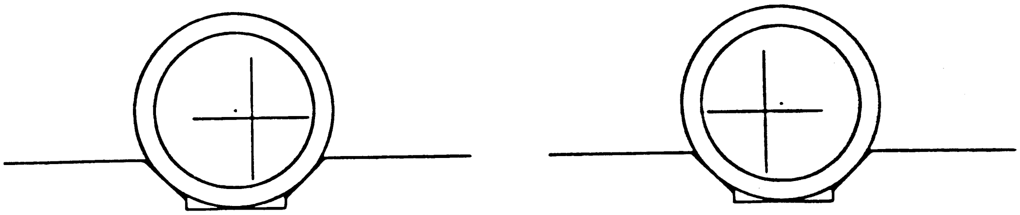
RETICLE WITH PERPENDICULAR LINES







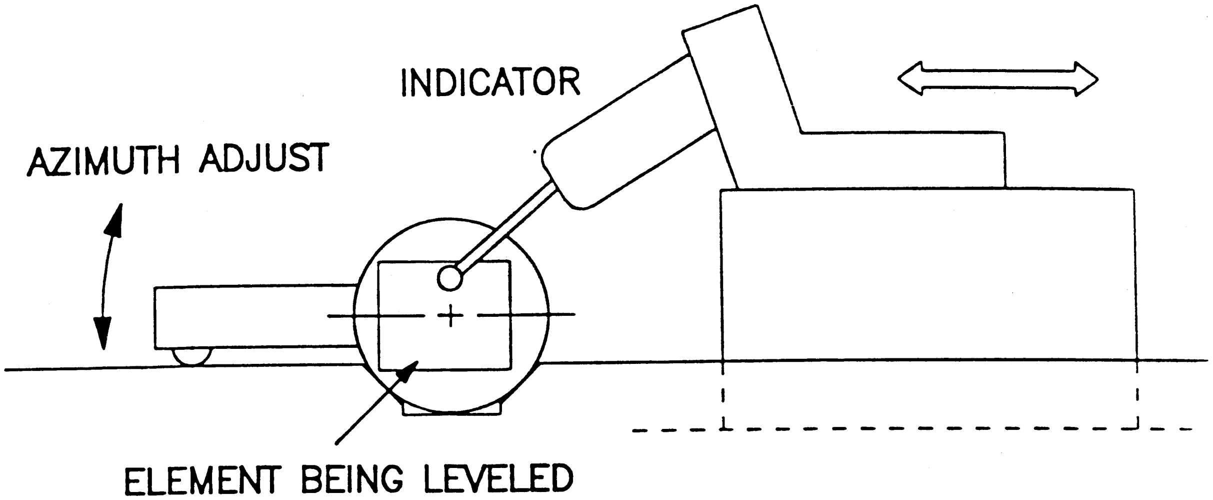
THE TANGENT SCREW IS ADJUSTED UNTIL BOTH IMAGES HAVE SAME ORIENTATION UPON FLIPPING.



THE CROSS HAIRS ARE NOW HORIZONTAL AND VERTICAL.

THE RETICLE CAN ALSO BE CENTERED.
CENTERING IS DONE BEFORE LEVELING.

MECHANICAL LEVELING

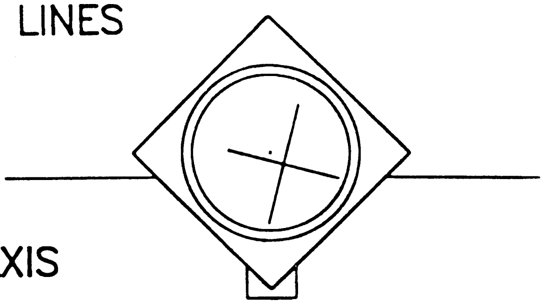


THE DIRECTION OF MOTION IS PERPENDICULAR TO THE V.

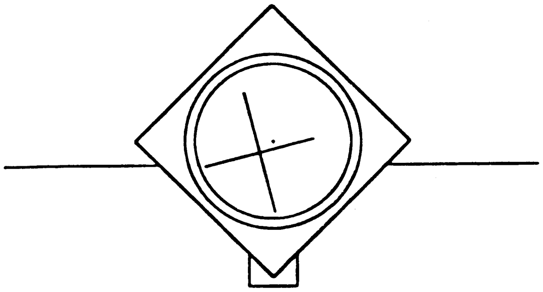
THIS METHOD CAN BE APPLIED TO CYLINDRICAL LENSES AND TO PRISMS.

SETTING CROSSHAIRS TO A V BY FLIPPING A SQUARE CYLINDER

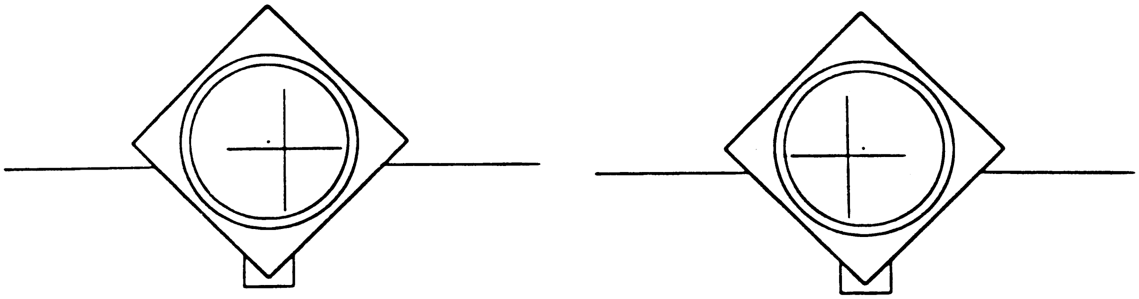
RETICLE WITH PERPENDICULAR LINES



FLIPPED ABOUT A VERTICAL AXIS



THE RETICLE AZIMUTH IS ADJUSTED UNTIL BOTH IMAGES HAVE SAME ORIENTATION.



ONE CROSS HAIRS IS NOW PARALLEL TO THE BISECTOR OF THE V AND THE OTHER IS PERPENDICULAR.

THE CROSS HAIRS CAN BE CENTERED ALSO, BY DOING SO BEFORE LEVELING.

TILT

TERMINOLOGY: ORIENTATION OF ELEMENT SYMMETRY AXIS OR SPECIAL DIRECTION RELATIVE TO CYLINDER/V AXIS

TWO ANGULAR DEGREES OF FREEDOM

ADJUSTMENT OF TILT
OFTEN REMOVAL BY MAKING ELEMENT AXIS PARALLEL TO AXIS

INTENTIONAL TILTS
- BEAMSPLITTERS
- MIRRORS

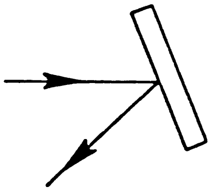
VARIABLE TILT
CONTROLLED CHANGE OF TILT IN OPERATION

REMOVAL OF TILT
ALIGNING ROTATIONALLY SYMMETRIC ELEMENTS

EXAMPLES OF INTENTIONAL TILT

COMPONENT NORMAL NOT PARALLEL TO AXIS

MIRROR



PLANE PARALLEL PLATE

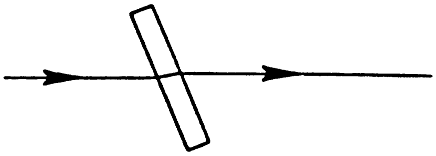
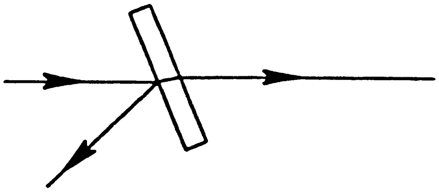
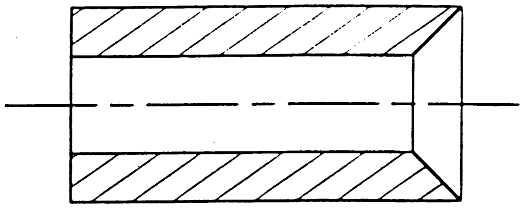


PLATE BEAMSPLITTER

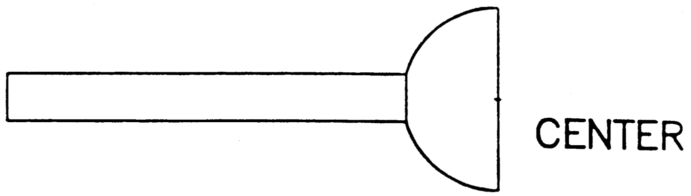


SPHERE-IN-TOROID TILT ADJUSTMENT

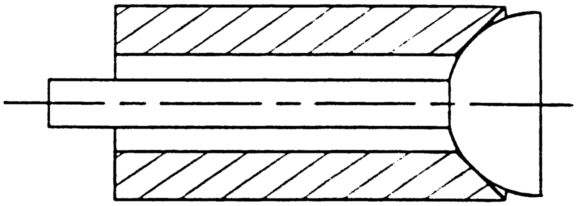
TOROIDAL SEAT



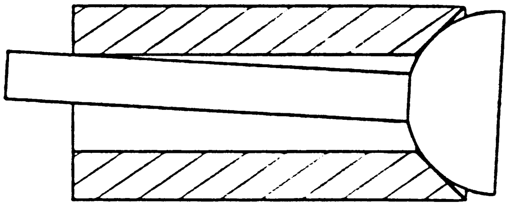
PARTIAL SPHERE WITH A STEM



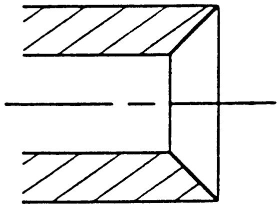
ASSEMBLY



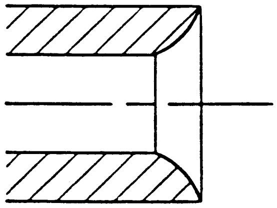
TILTED



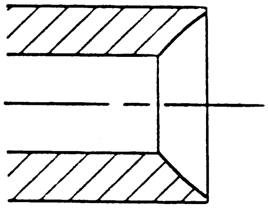
TOROIDAL SEATS



CONICAL

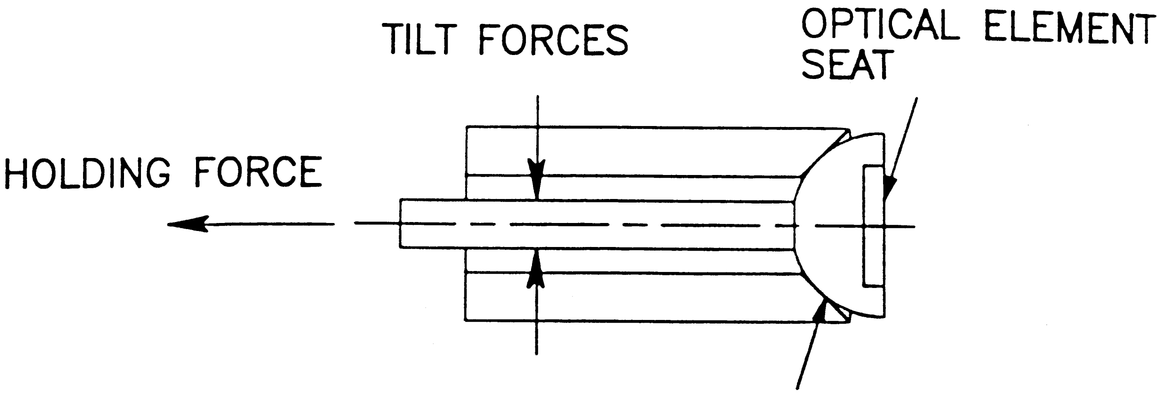


CONVEX



CONCAVE

SPHERE–IN–TOROID



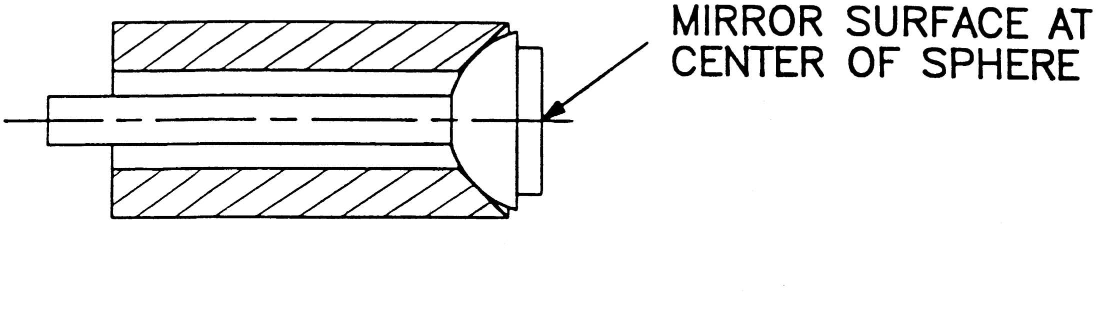
CONCENTRIC MACHINING MARKS CAN RESULT IN BUMPY MOTION.

THE HOLDING FORCE CAN BE INCREASED TO LOCK WHEN ADJUSTMENT IS COMPLETE.

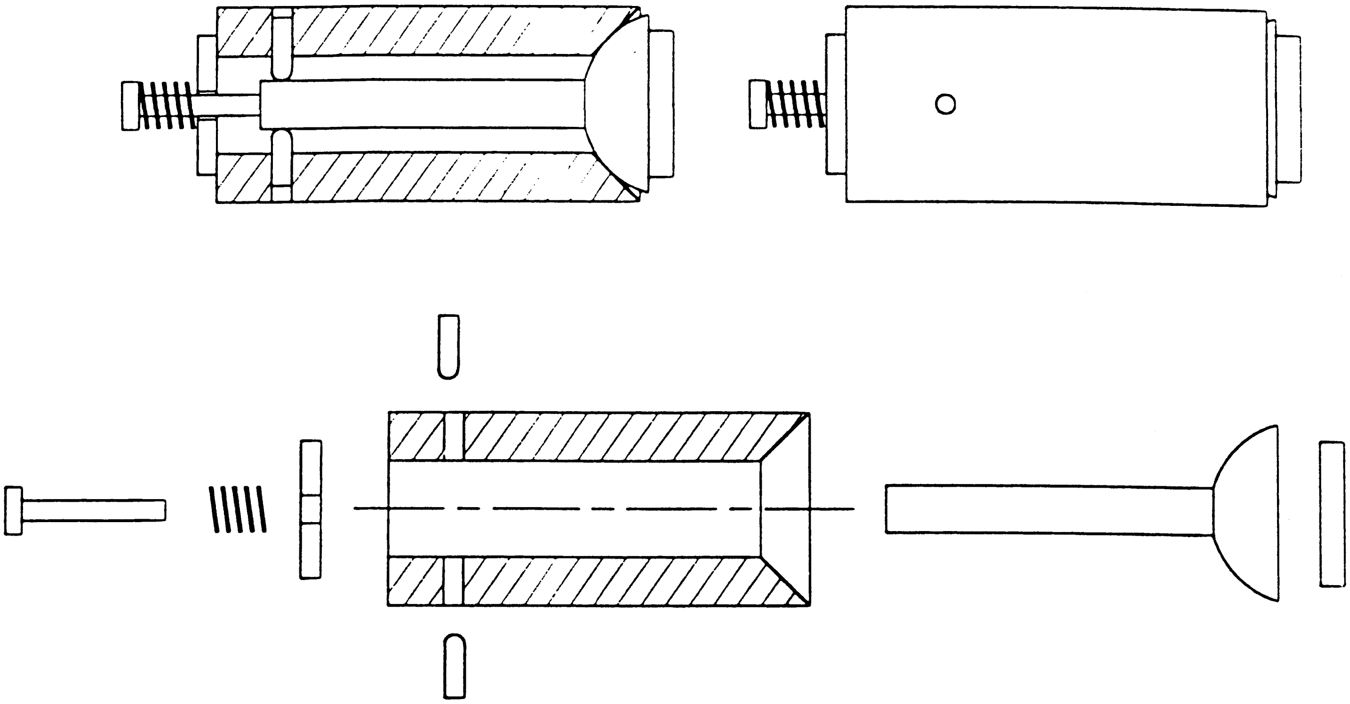
STICK SLIP CAN OCCUR IF THE STEM IS FLEXIBLE RELATIVE TO THE FRICTIONAL FORCES BETWEEN THE SPHERE AND SEAT.

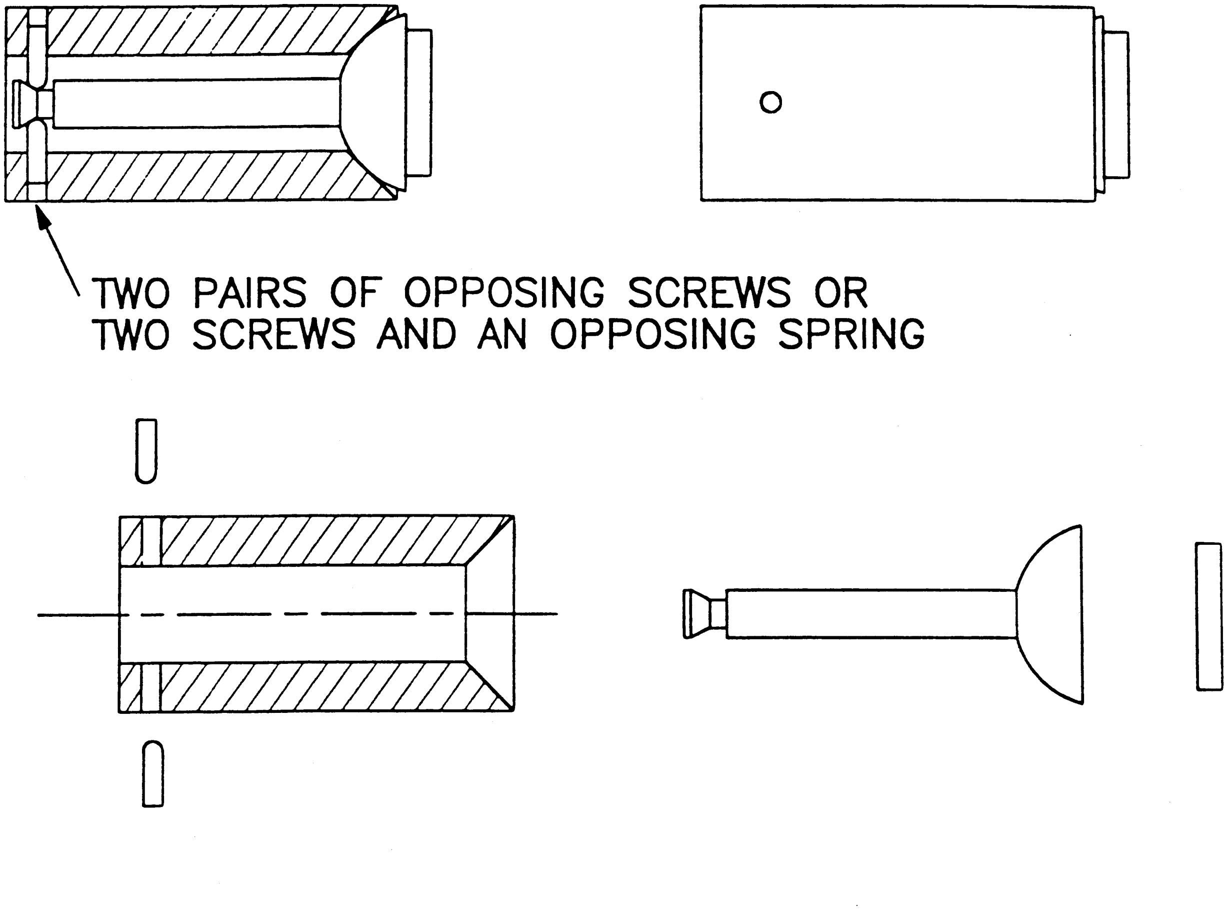
THE STEM CAN BE SOLID IF LIGHT DOES NOT PASS ALONG THE CYLINDER'S AXIS.

MIRROR PLACEMENT FOR PURE TILT OF REFLECTED BEAM



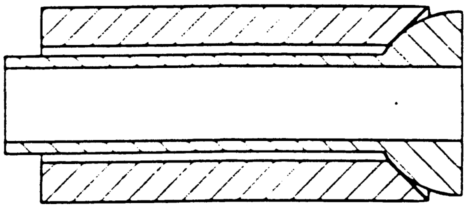
TWO EMBODIMENTS

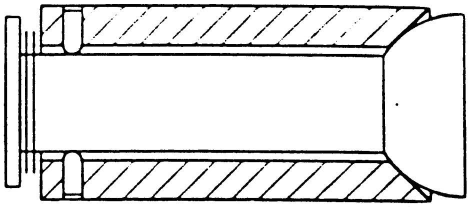


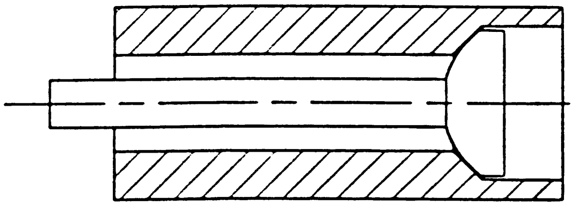


VARIATIONS

- LARGE HOLLOW STEM FOR TRANSMITTED LIGHT

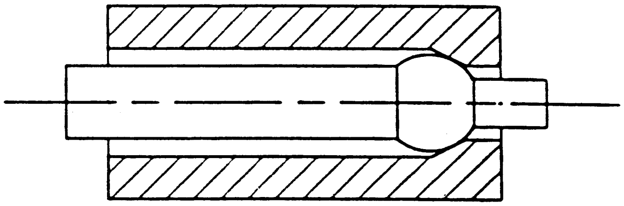




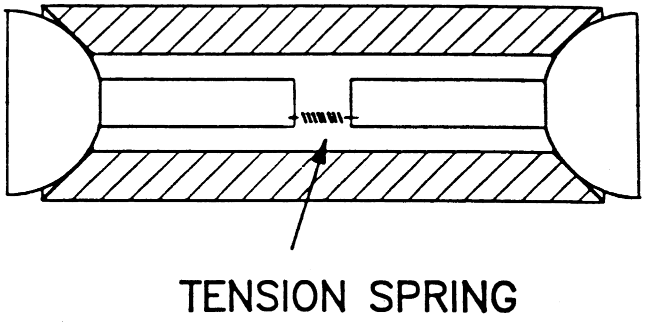


RECESSED

SPHERE INSIDE

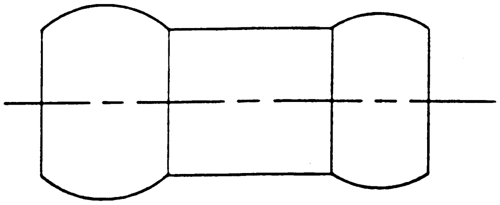


DOUBLE

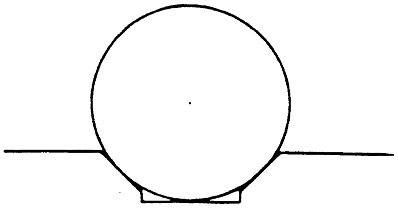


SINE BONE SHIMMED AT ONE END

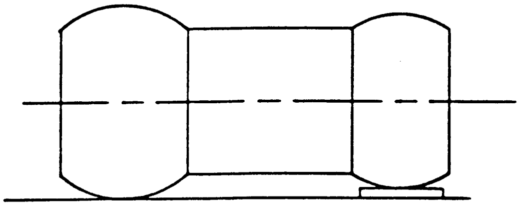
LARGE SPHERE SMALL SPHERE



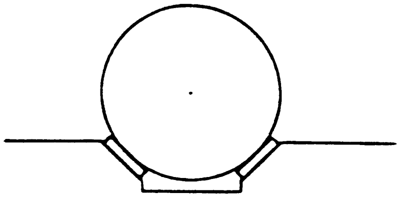
LARGE SPHERE IN V



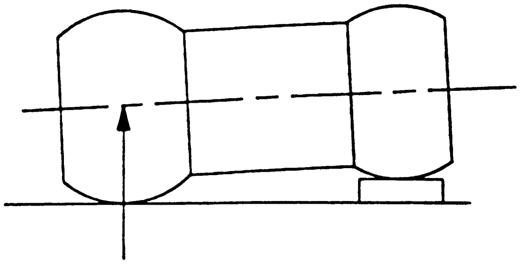
SMALL SPHERE SHIMMED
FOR NO TILT



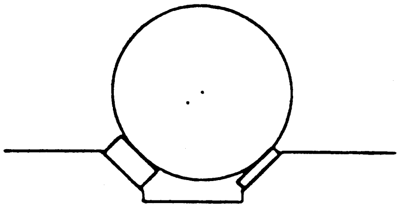
SMALL SPHERE IN V



SMALL SPHERE SHIMMED
FOR TILT



SMALL SPHERE IN V



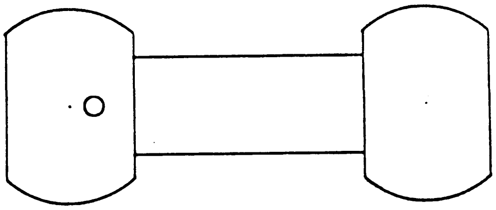
THE SPHERES CAN BE THE SAME SIZE IF THERE NEED NOT BE TILT ABOUT A POINT WITH NO TRANSLATION, AS WITH A PLANE PARALLEL PLATE.

AN AXIAL STOP CAN BE ADDED AT THE LARGE SPHERE.

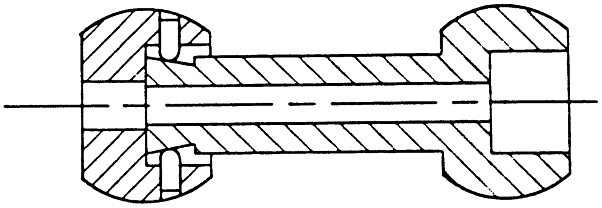
THE TERM "SINE BONE" IS BY ANALOGY TO THE SINE BAR.

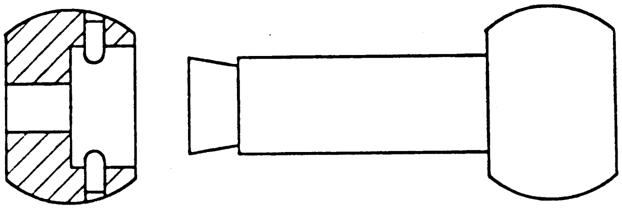
OFFSET BALL BONE

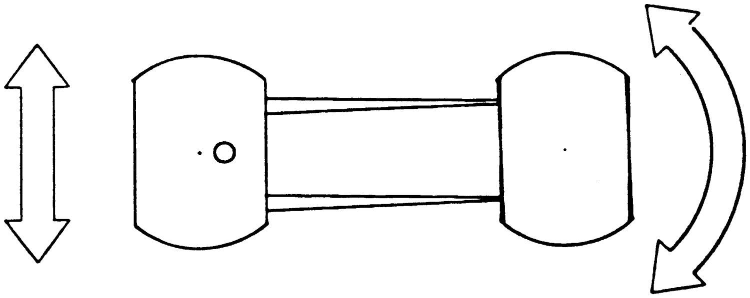
SPHERICAL SURFACES WITH SAME DIAMETERS



TRANSLATING MECHANISM LIKE A
CENTERING CONE

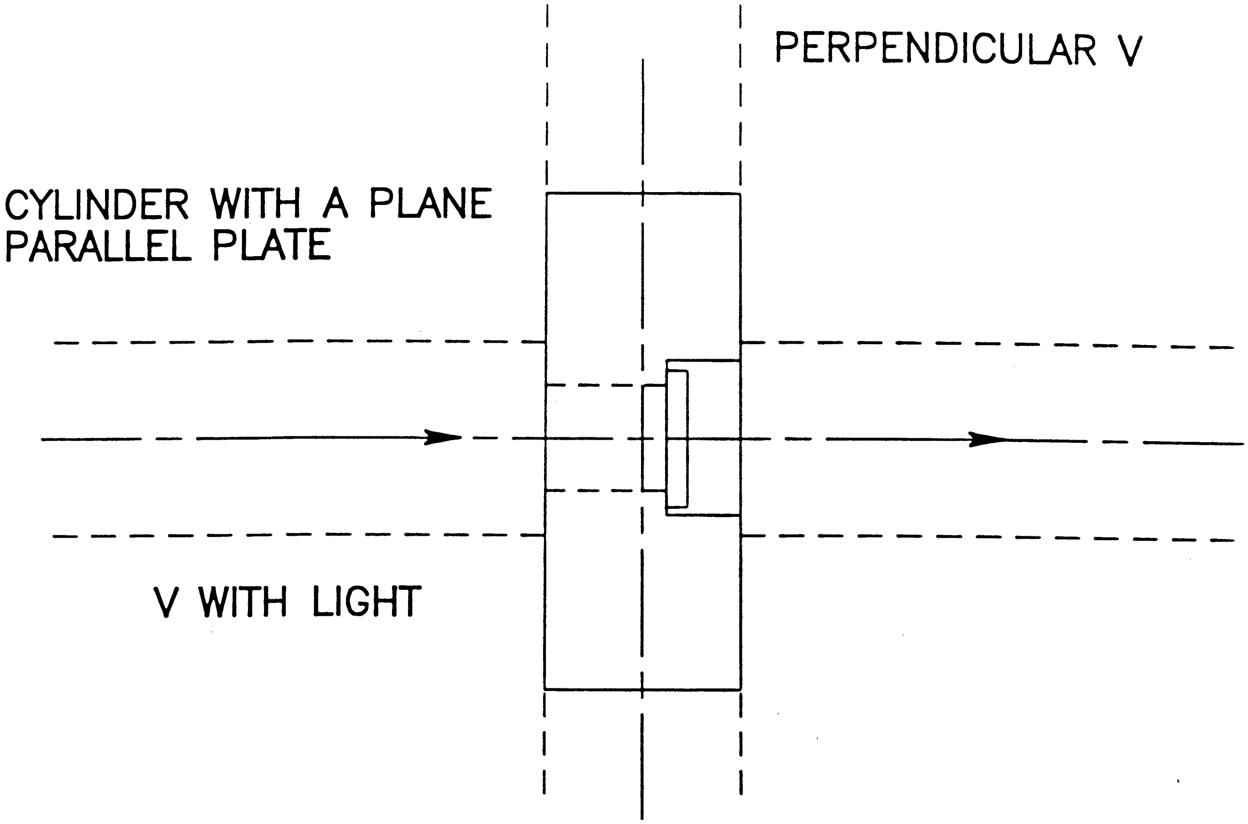


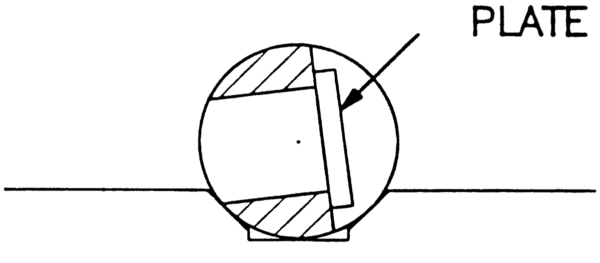




TRANSLATION OF THE MOVEABLE BALL PRODUCES TILT
ABOUT THE CENTER OF THE FIXED BALL.

CYLINDER IN PERPENDICULAR V

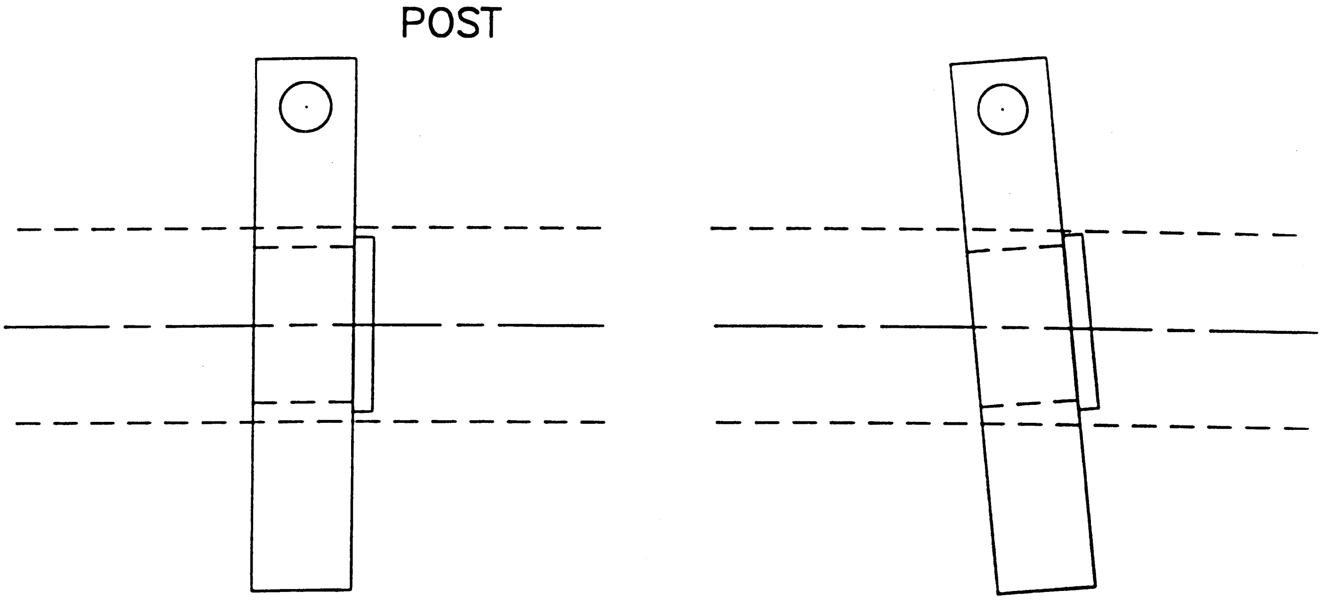




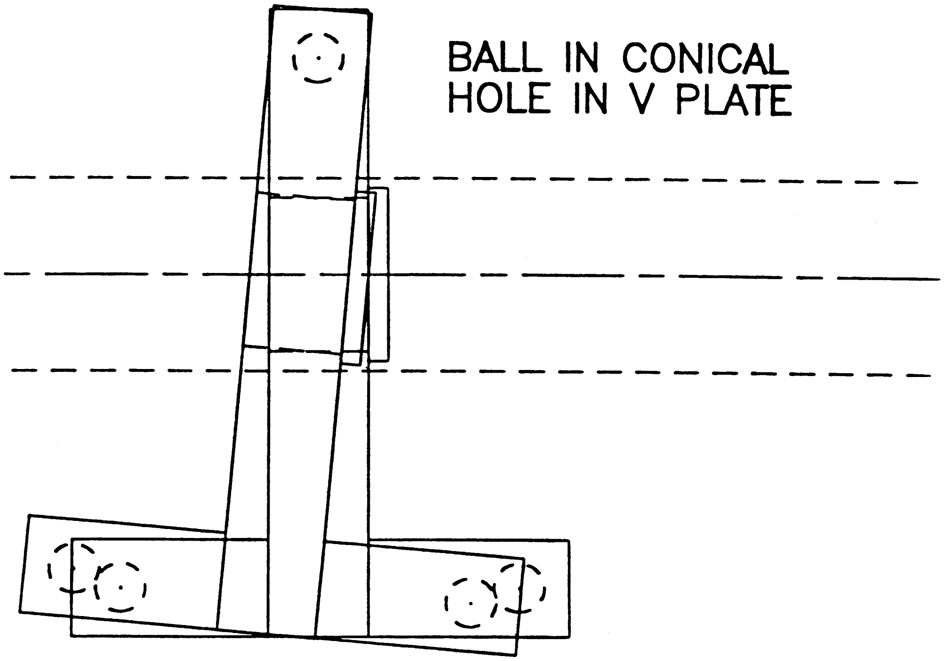
THE CYLINDER CAN BE ROTATED BY METHODS SHOWN IN THE AZIMUTH SECTION.

TILT USING STRUCTURES ON V PLATE

- ROTATION ABOUT NORMAL TO V PLATE



- KINEMATIC STRUCTURE WITH THREE FEET



- BALLS ON FLAT SURFACE

TILT AND LATERAL TRANSLATION

FOUR DEGREES OF FREEDOM.

NECESSARY AND SUFFICIENT TO CENTER A ROTATIONALLY SYMMETRIC OPTICAL ELEMENT.

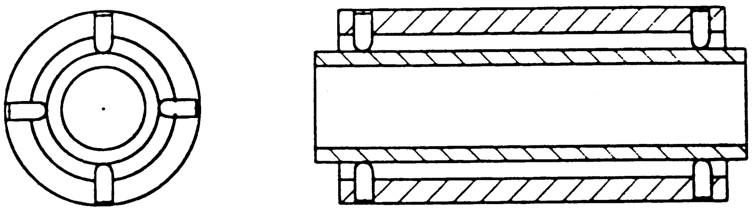
ONE APPROACH IS BY COMBINATIONS OF TILT AND CENTERNG MECHANISMS.

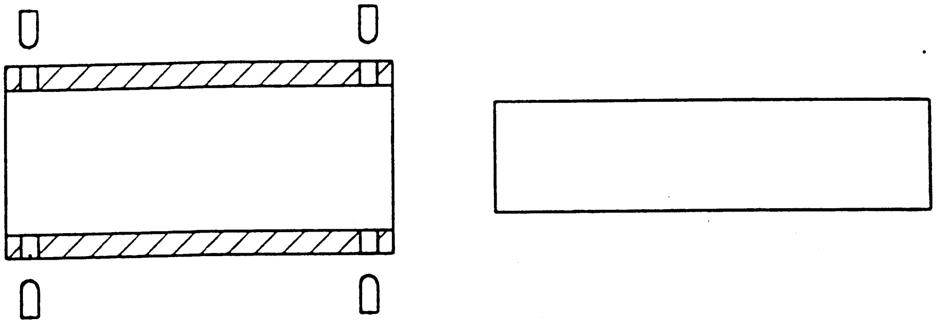
THE ORDER OF ADJUSTMENT MATTERS.

DECOUPLING OF TILT AND TRANSLATION IS OFTEN ADVANTAGEOUS.

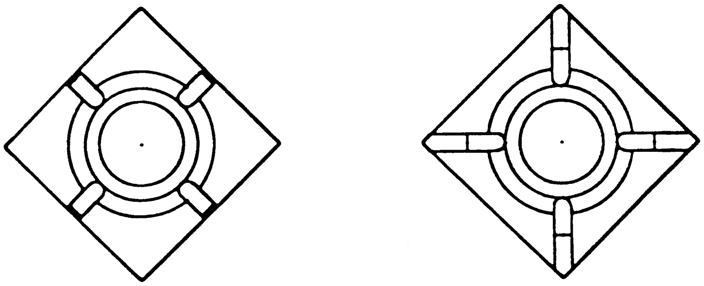
CYLINDER IN A CYLINDER

FOUR PAIRS OF SCREWS PROVIDE FOUR DEGREES OF FREEDOM.



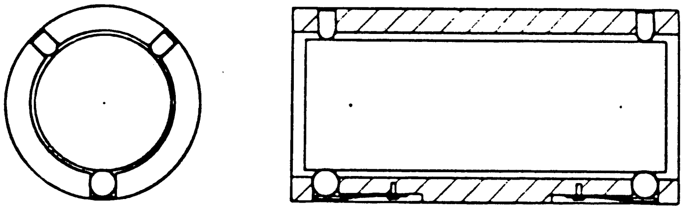


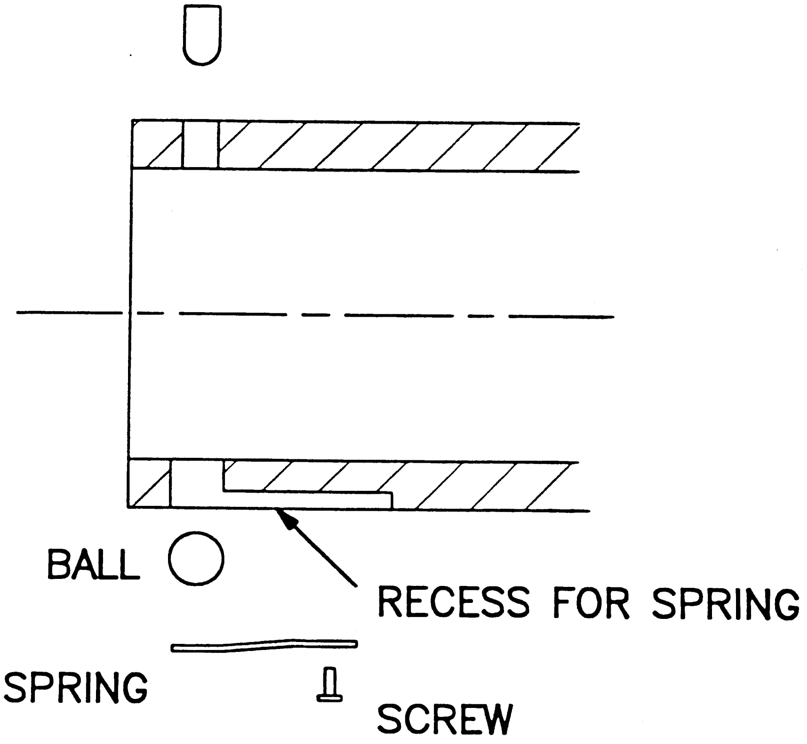
SQUARE VERSIONS



VARIATIONS INCLUDE: THUMB SCREWS, SPRING LOADING

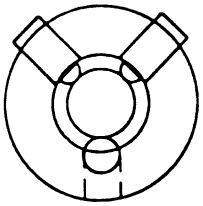
TWO PAIRS OF ADJUSTMENT SCREWS WITH LOADING BY FLAT SPRINGS





NOTHING PROTRUDES BEYOND A CYLINDRICAL ENVELOPE.

FIBER LASER INPUT



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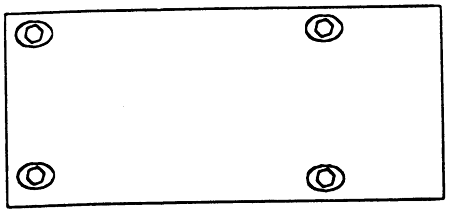
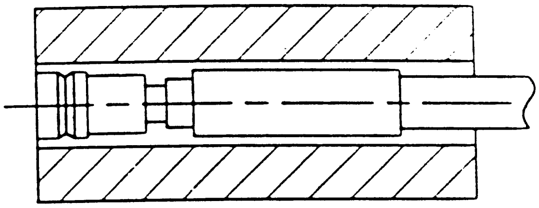


HORIZONTAL SECTION



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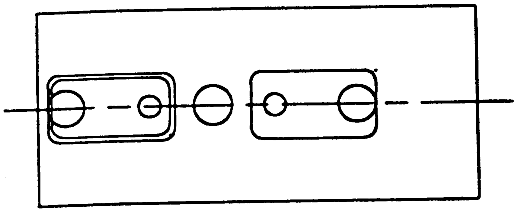
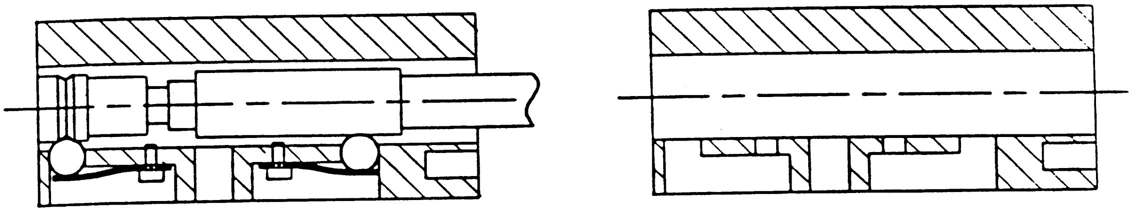


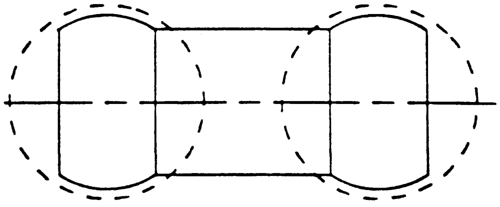
VERTICAL SECTION



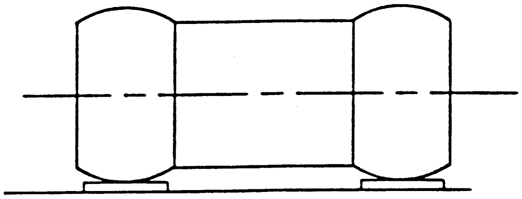
SET SCREWS 100 TPI

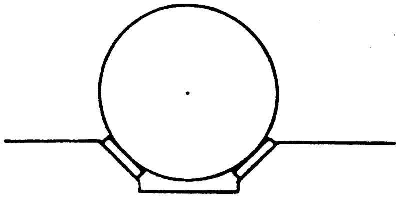
SINE BONE

BOTH SPHERE DIAMETERS
LESS THAN STANDARD

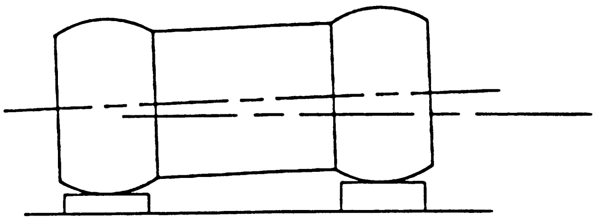


SPHERES SHIMMED FOR
CENTRATION AND NO TILT

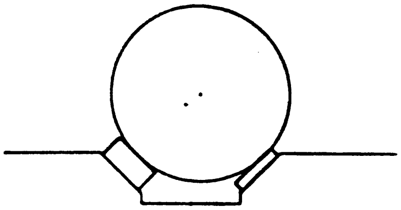


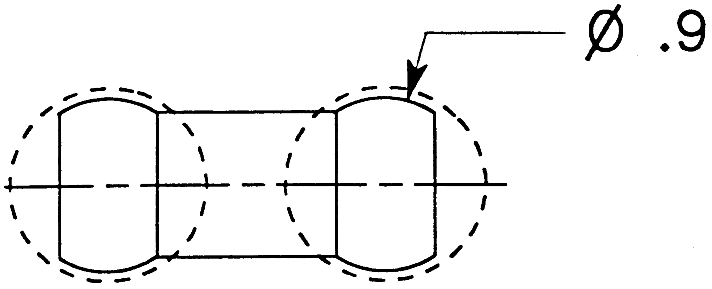


SHIMMED FOR
DECENTRATION AND TILT

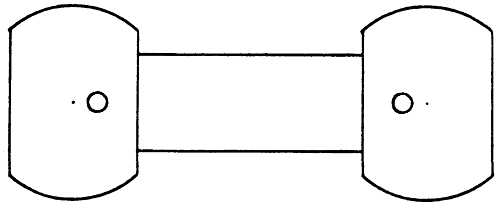


EXAMPLE

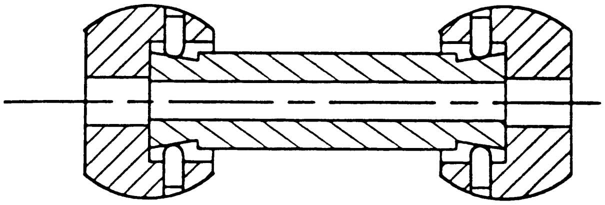


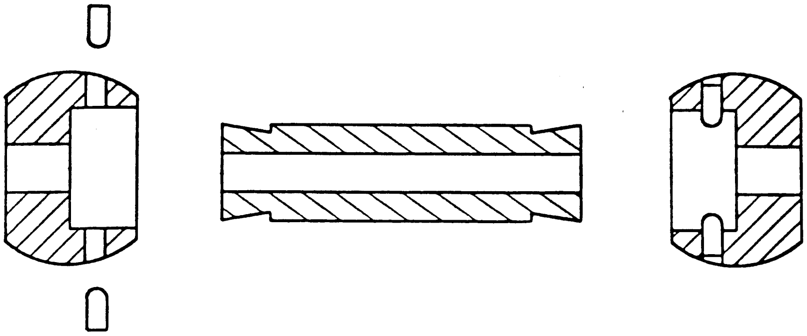


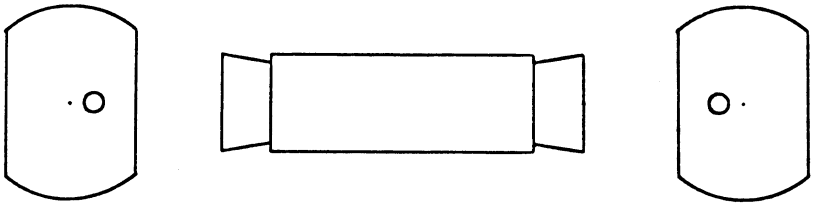
OFFSET BALL BONE



TWO TRANSLATING MECHANISMS LIKE CENTERING CONE

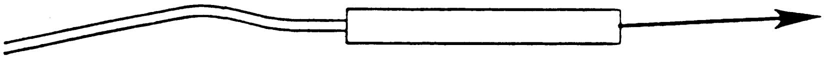




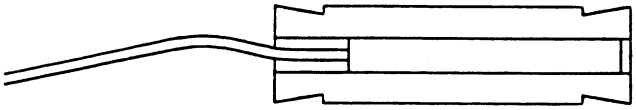


TRANSLATION OF ONE BALL PRODUCES TILT ABOUT THE CENTER OF THE OTHER.

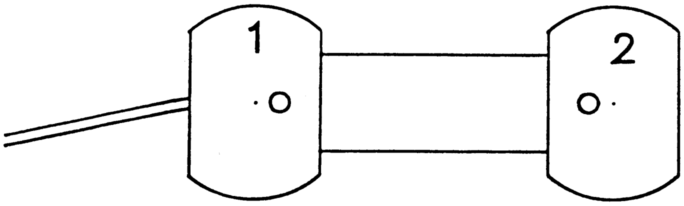
EXAMPLE: A FIBER LASER OUTPUT



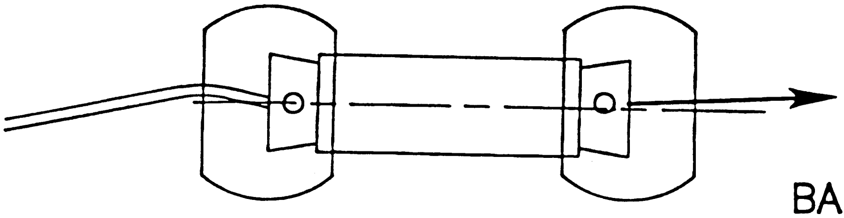
OUTPUT POSITION AND DIRECTION IMPERFECTLY CONTROLLED



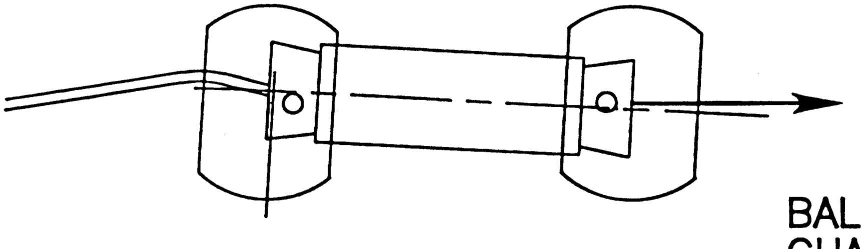
ASSEMBLY WITH FIBER LASER OUTPUT



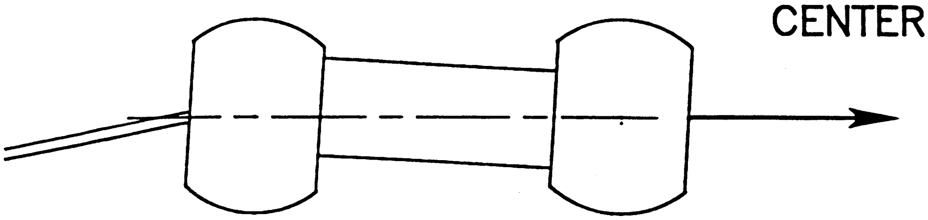
INITUAL ARRANGEMENT



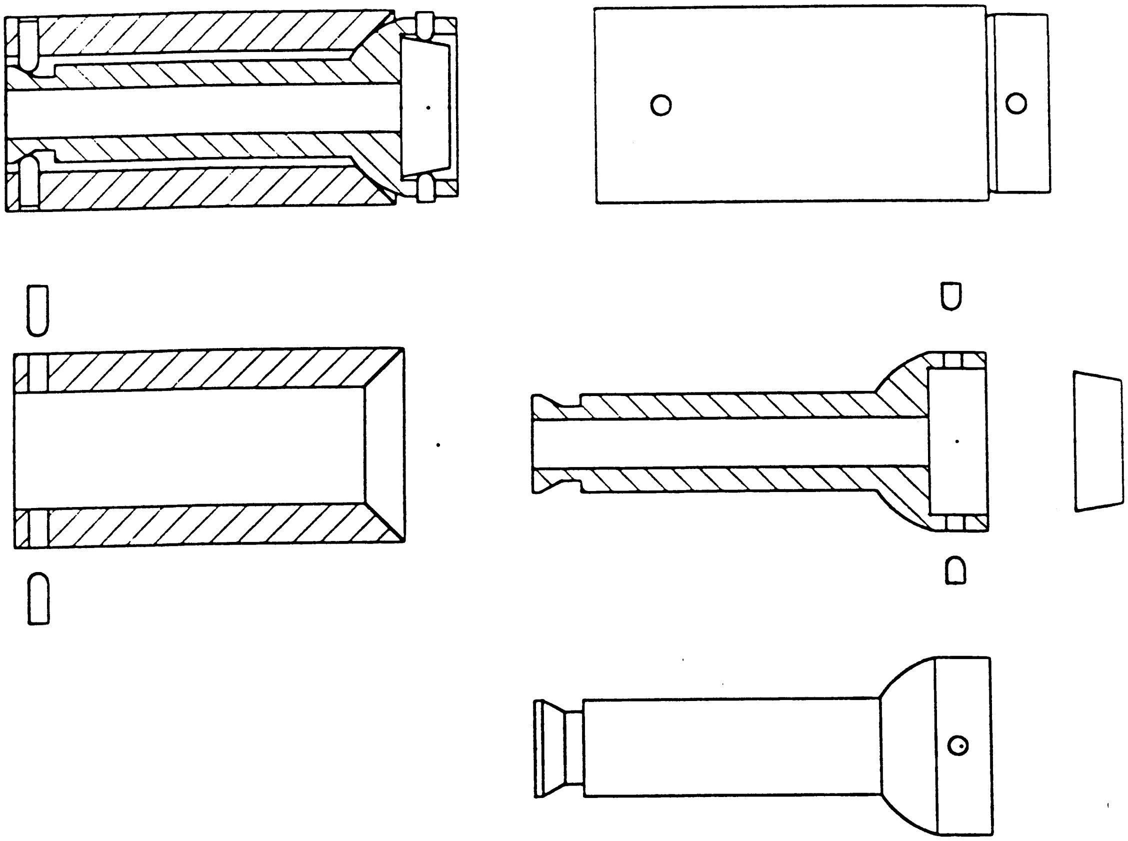
BALL 2 ADJUSTED TO MAKE THE BEAM PASS THROUGH ITS CENTER

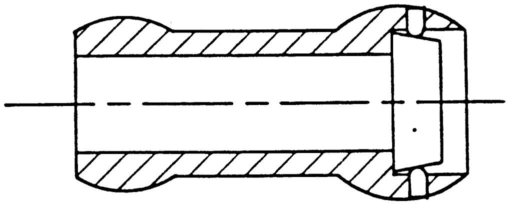


BALL 1 ADJUSTED TO CHANGE BEAM ANGLE, PIVOTING THROUGH CENTER OF BALL 2

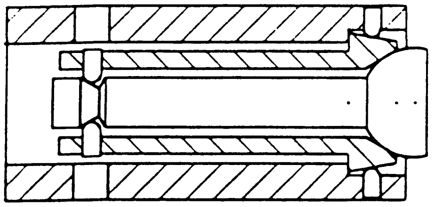


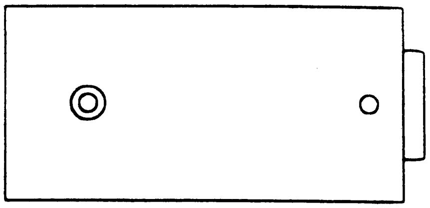
TRANSLATING CONE ON A TILTING DEVICE

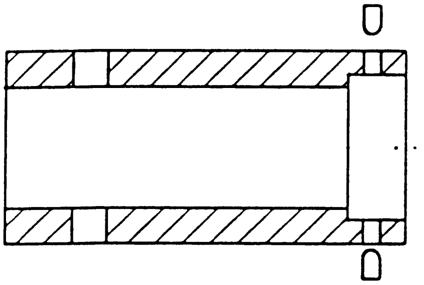


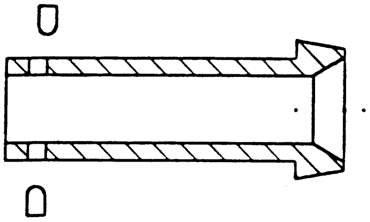


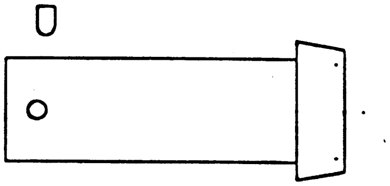
TILTING SPHERE ON A TRANSLATING CONE

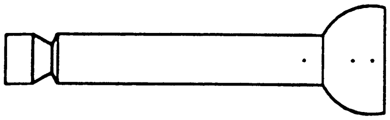




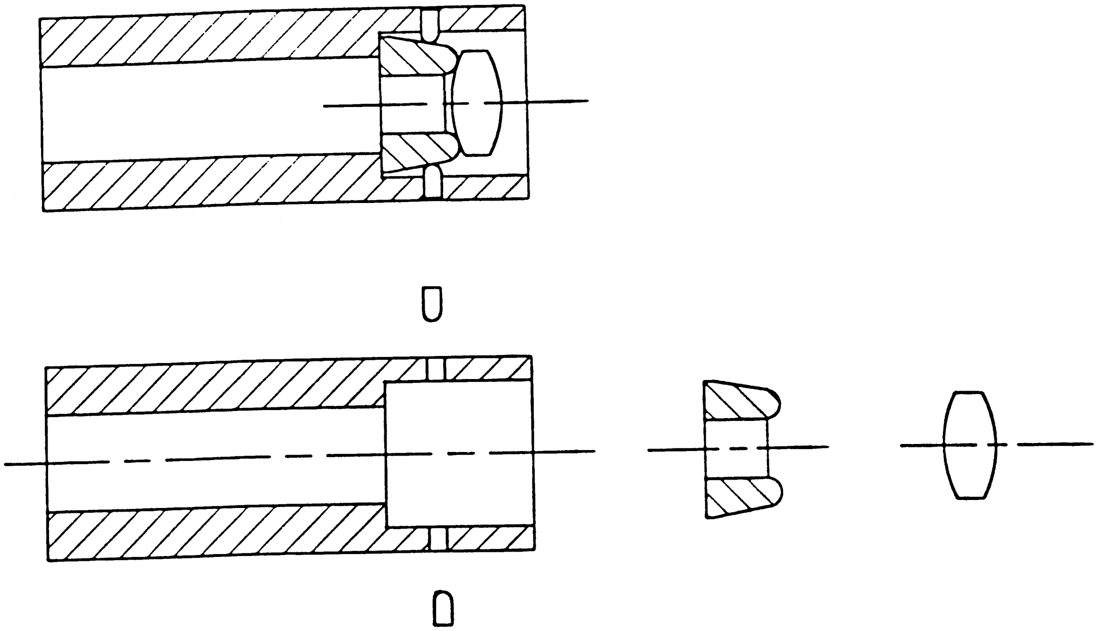








TOROID ON A CENTERING CONE



THE LENS TILTS IN THE TOROID, WHICH TRANSLATES WITH THE CONE.

INSTRUMENTAL METHODS

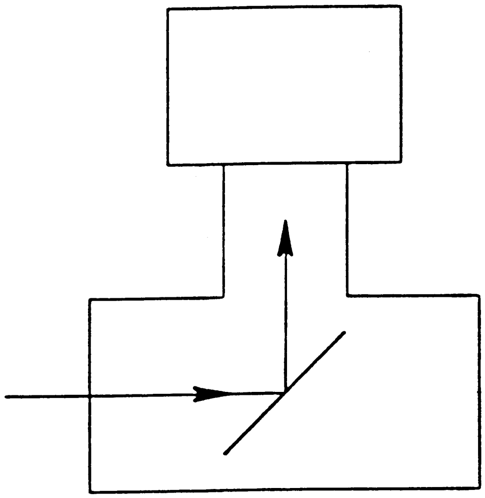
- BENT CYLINDERS
- DETECTOR MOUNTS
- USING VIDEO CAMERAS
- MICROSCOPE OBJECTIVES
- ILLUMINATION
- PLANAR POLARIZATION COMPONENTS
- SUPPRESSING UNWANTED LIGHT
- BEAM POSITION AND DIRECTION CONTROL
- GETTING LIGHT INTO AND OUT OF VS
- THERMAL MATTERS

"BENT CYLINDERS"

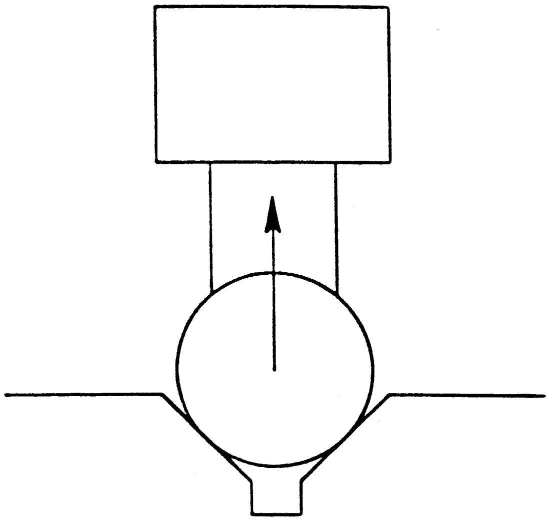
- CYLINDERS WITH MIRRORS OR BEAMSPLITTERS THAT DIRECT LIGHT FROM AXIS, USUALLY INTO THE VERTICAL PLANE

EXAMPLES:

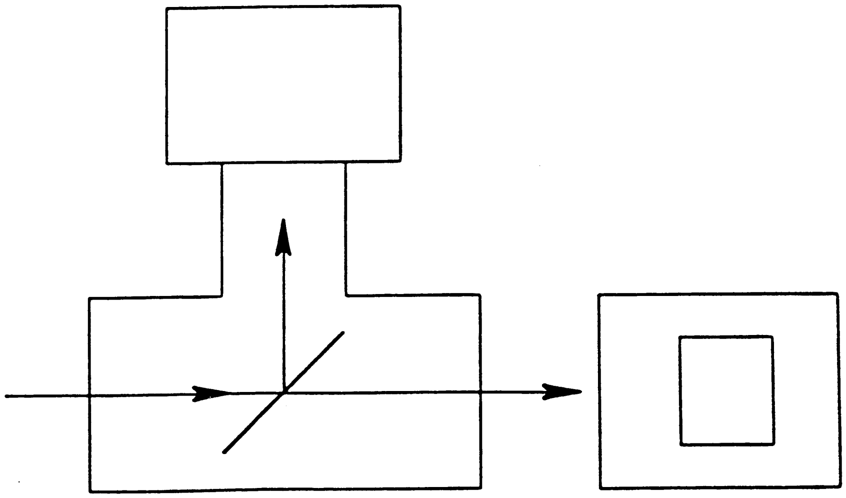
DETECTOR TOO LARGE TO FIT IN V



MIRROR



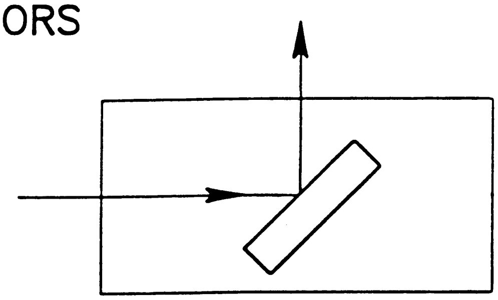
TWO DETECTORS



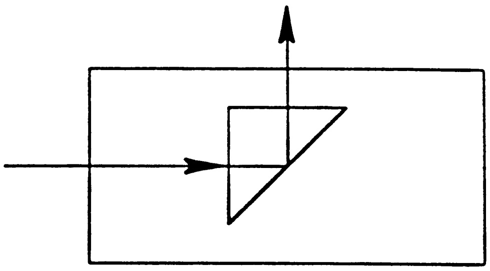
BEAMSPLITTER

COMMON MIRROR AND BEAMSPLITTER TYPES

MIRRORS

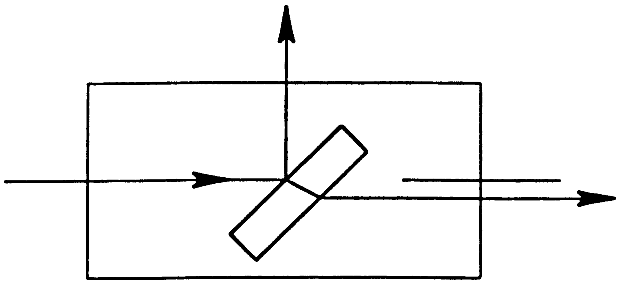


FRONT SURFACE PLATE

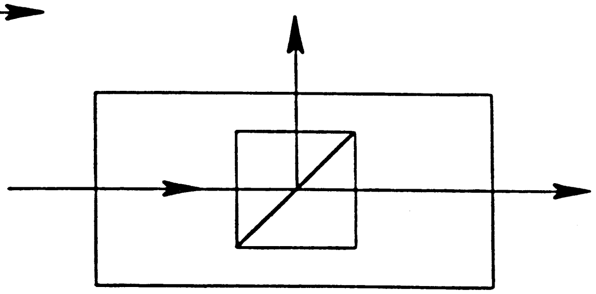


PRISM USING TIR OR COATED

BEAMSPLITTERS



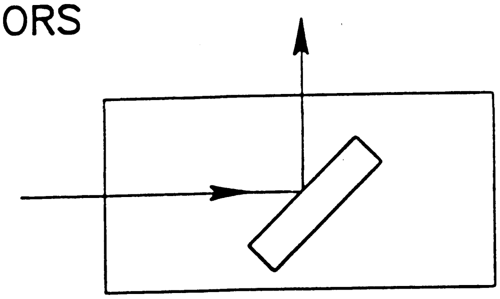
PLATE



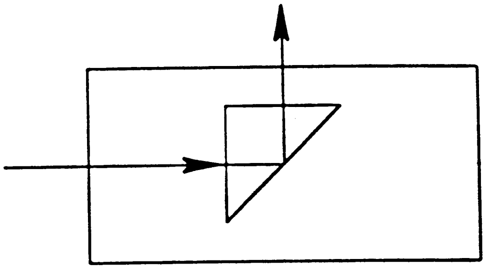
CUBE

COMMON MIRROR AND BEAMSPLITTER TYPES

MIRRORS

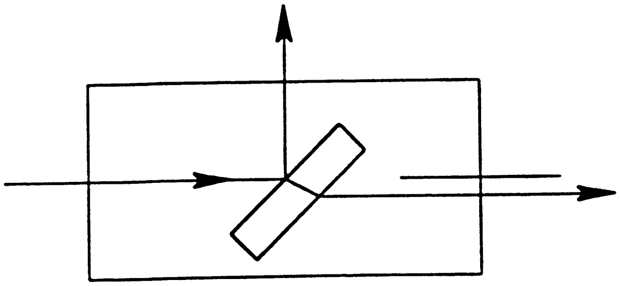


FRONT SURFACE PLATE

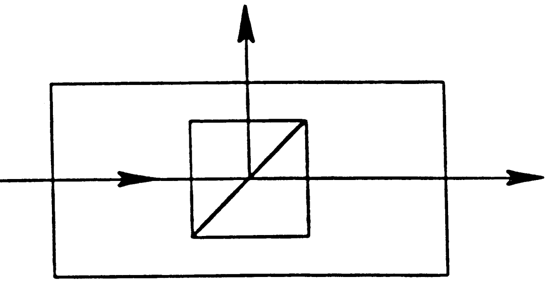


PRISM USING TIR OR COATED

BEAMSPLITTERS



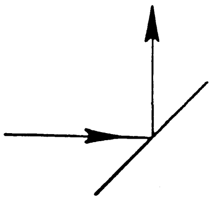
PLATE



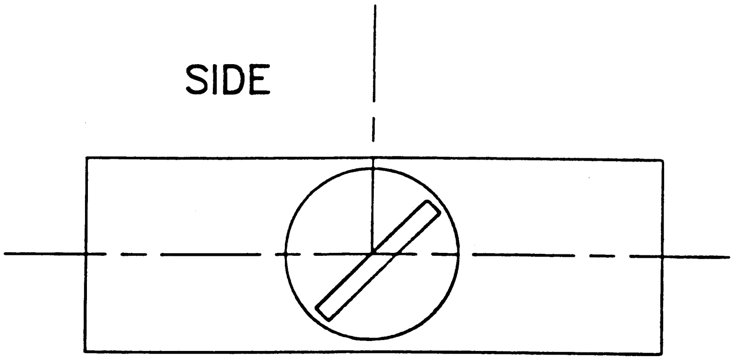
CUBE

WAYS TO HOLD A MIRROR OR PLATE BEAMSPLITTER

SIDE VIEW



SIDE



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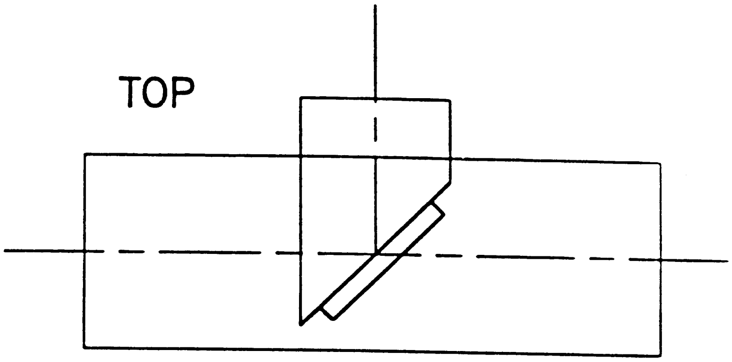
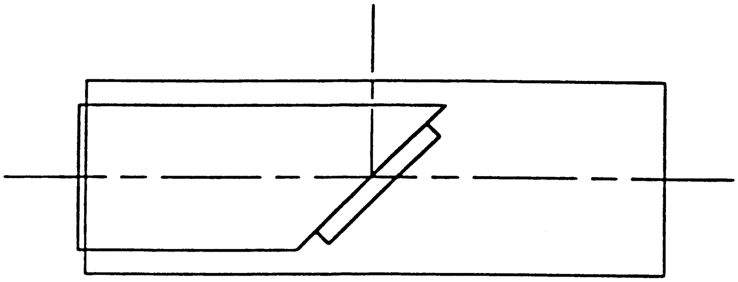


FRONT



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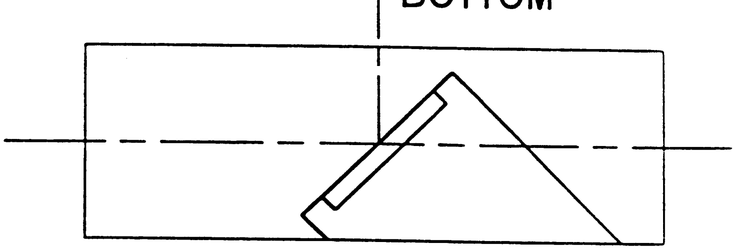
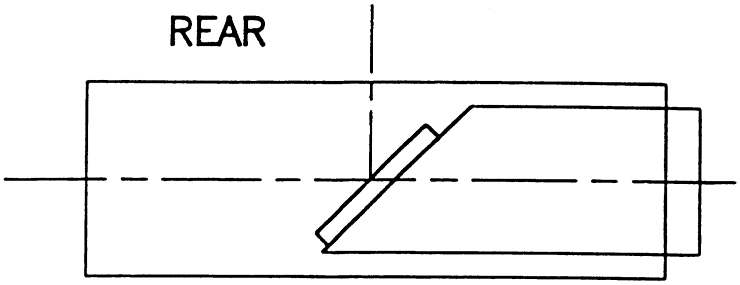


REAR



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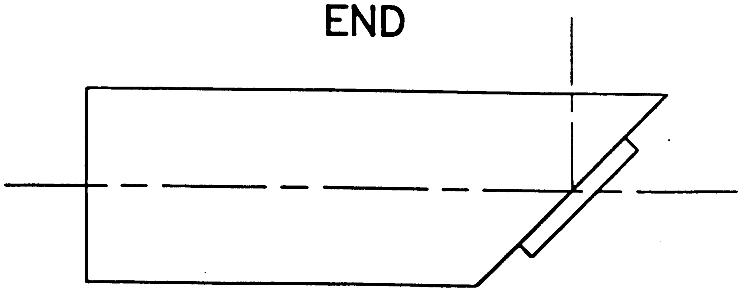
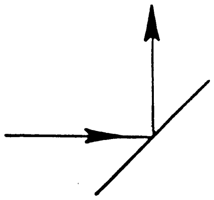
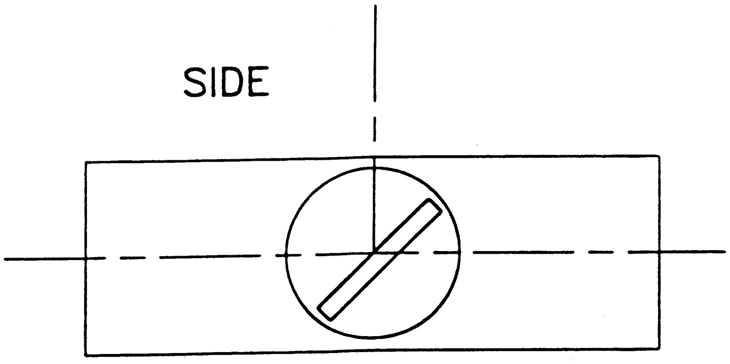


WAYS TO HOLD A MIRROR OR PLATE BEAMSPLITTER

SIDE VIEW



SIDE



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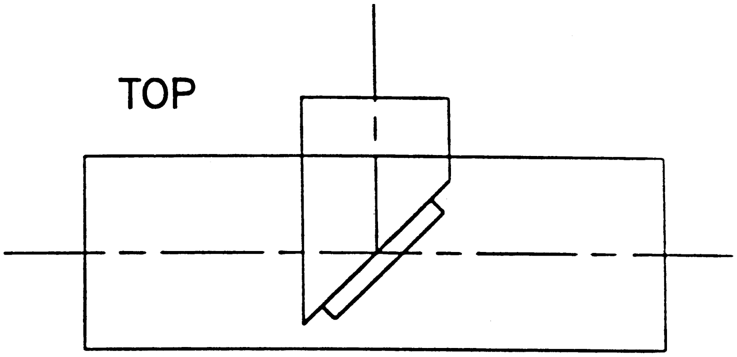

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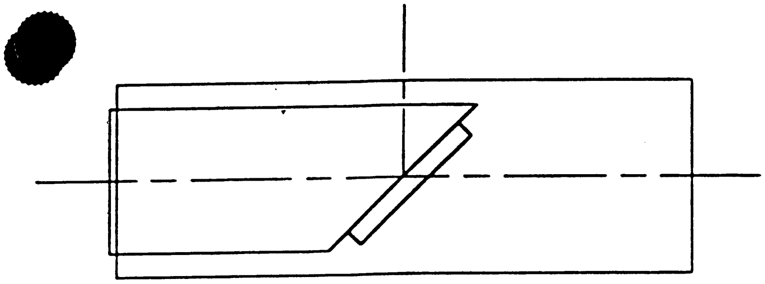

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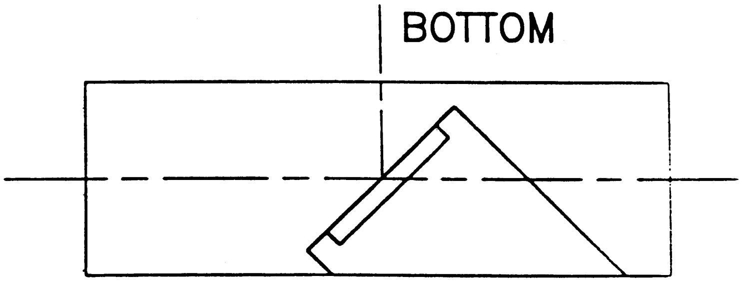

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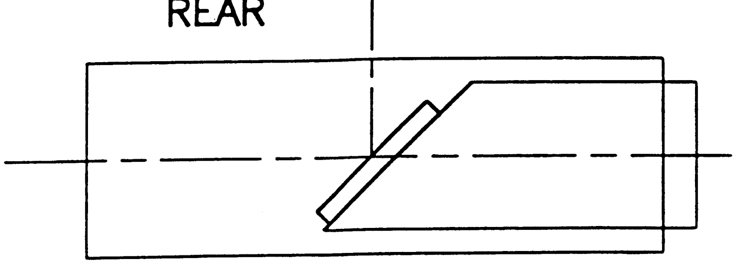
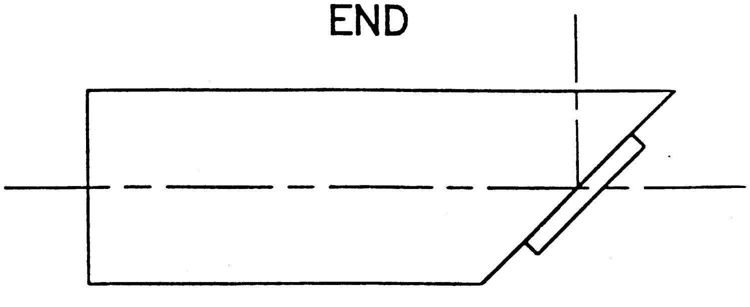
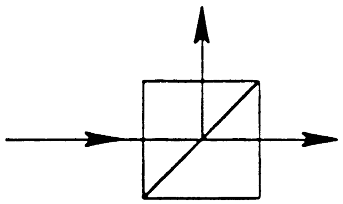


END

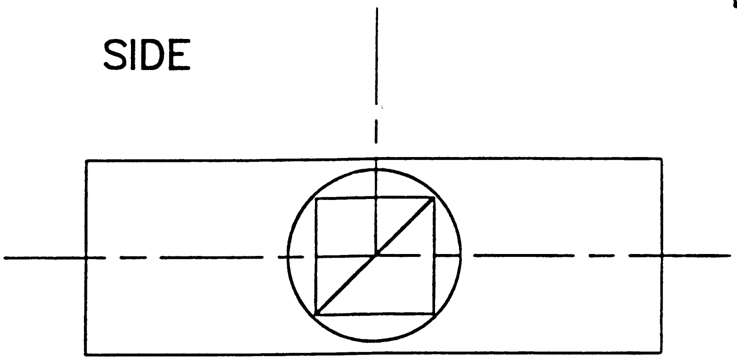


WAYS TO HOLD A CUBE BEAMSPLITTER

SIDE VIEW



SIDE



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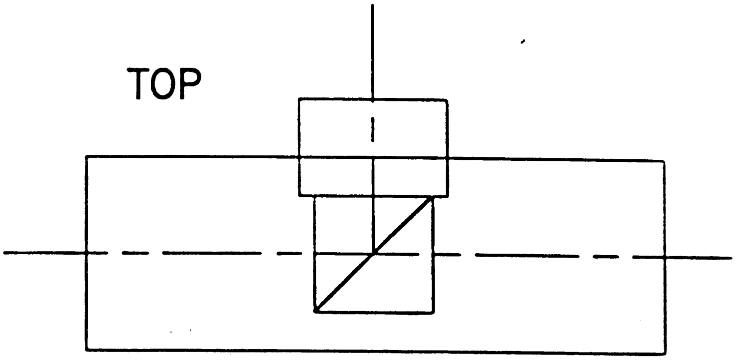
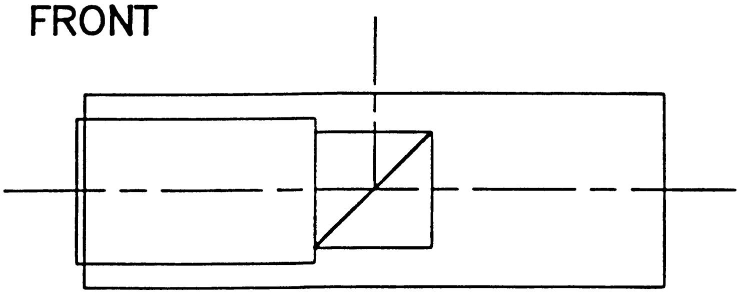
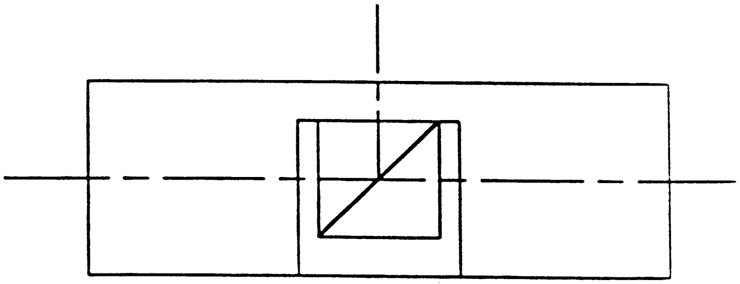


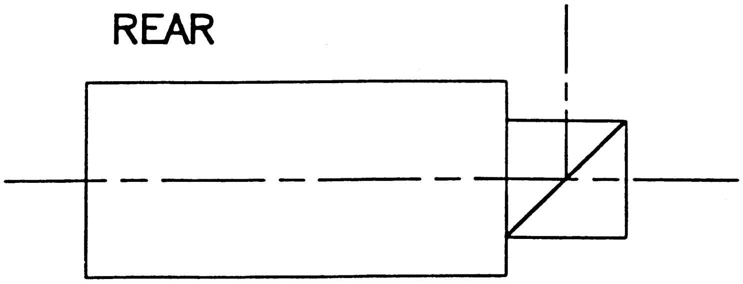
FRONT



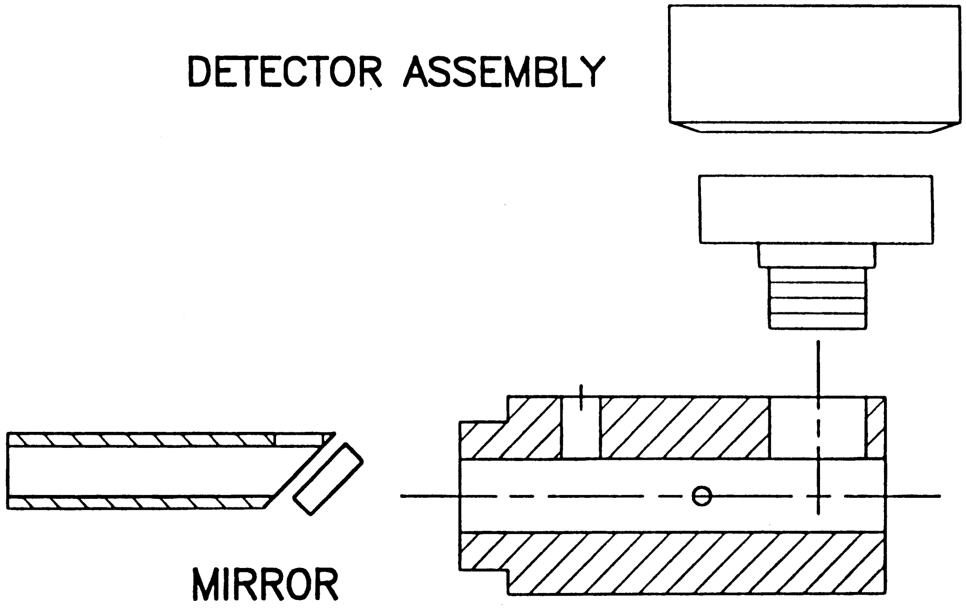
BOTTOM

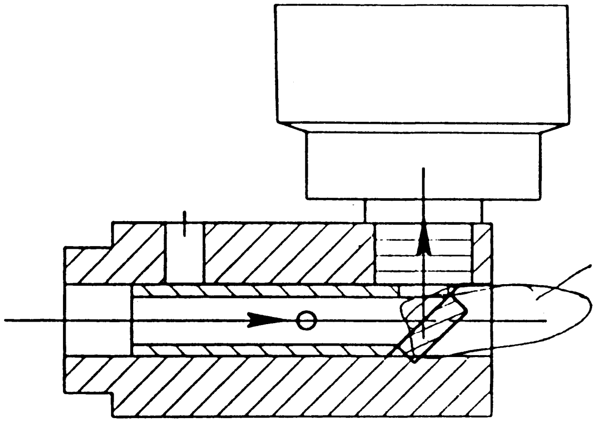


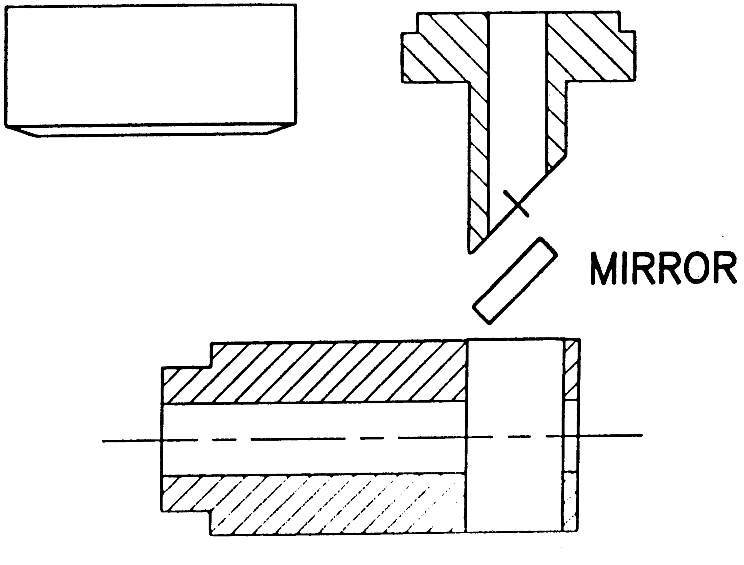
REAR

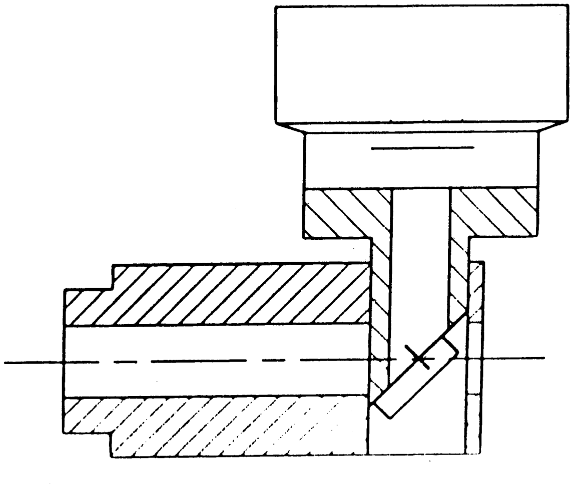


EXAMPLE



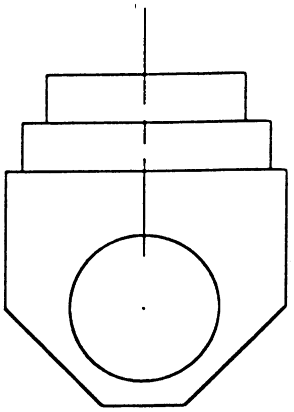




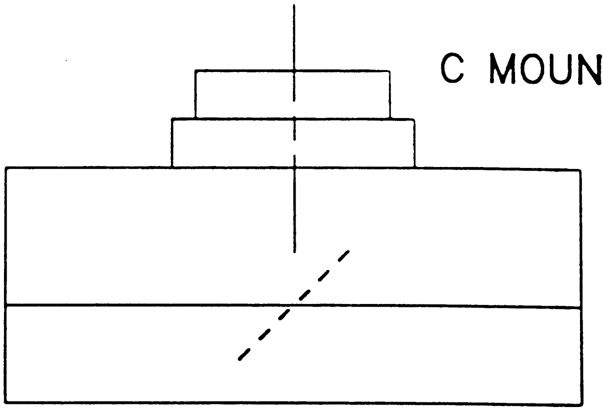


USING NON-ROUND CYLINDERS

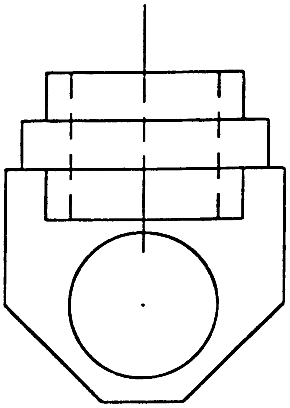
EXAMPLE

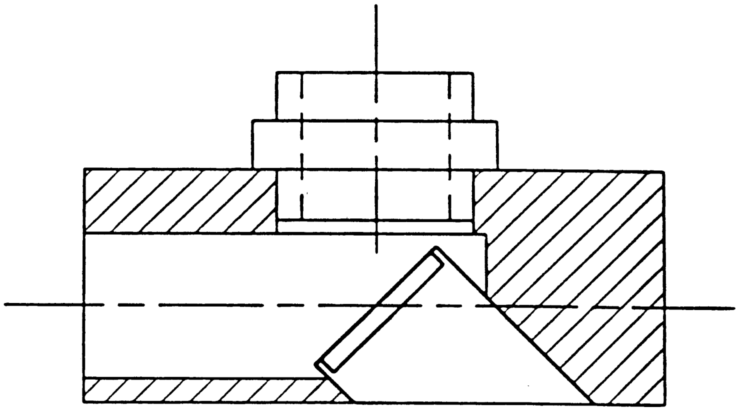


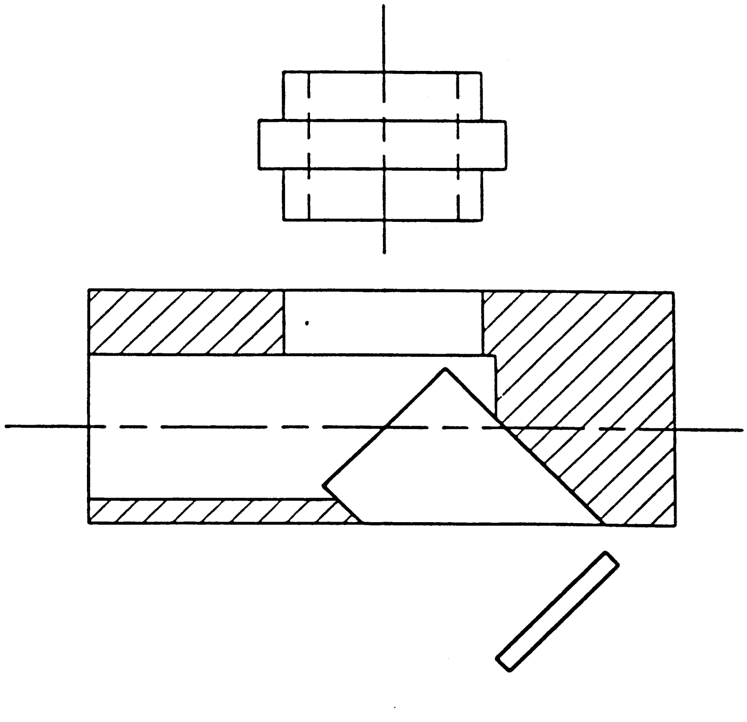
LARGE PLANAR AREAS TO RESIST TIPPING

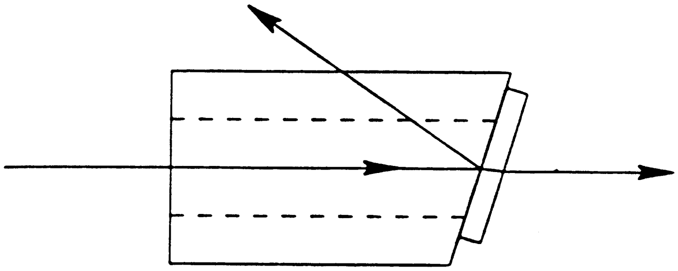


LENGTHENED FOR WEIGHT

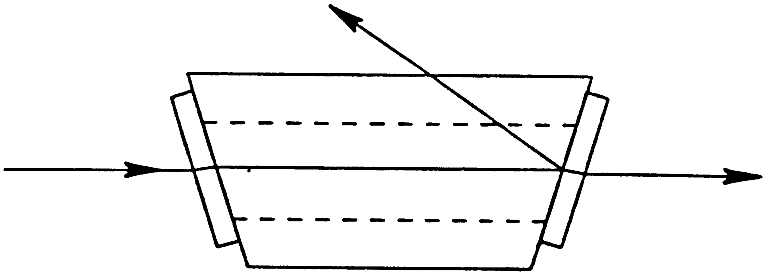


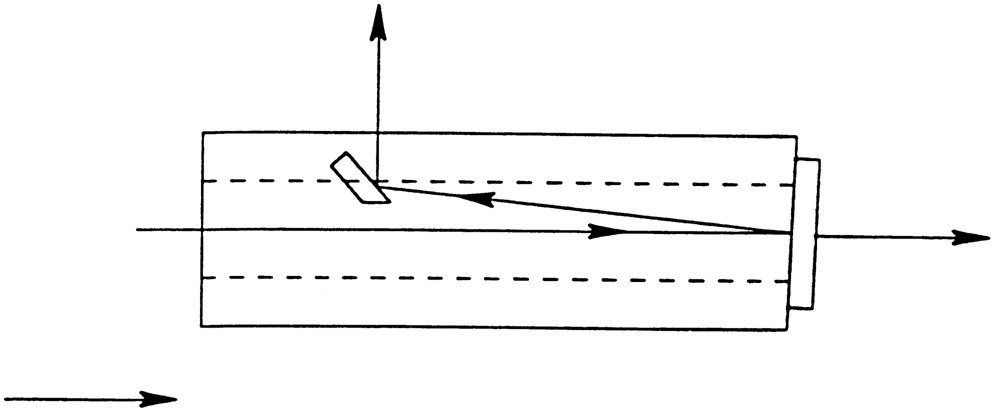


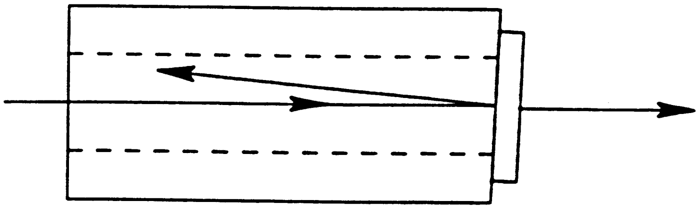




COMPENSATING PLATE TO ELIMINAGE BEAM OFFSET







DETECTOR MOUNTS

ON CYLINDER IN V

ON A BENT CYLINDER

AT END OF CYLINDER

ABOVE V

AT ANGLE TO V

REMOTE WITH FIBER

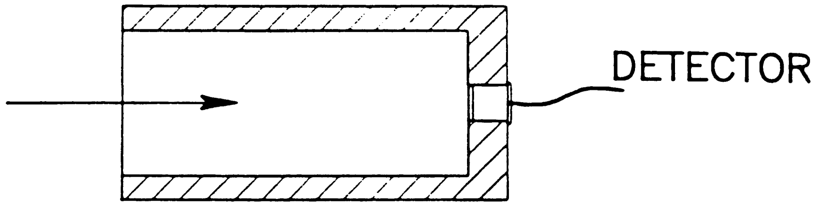
ROUGHLY ALIGNED

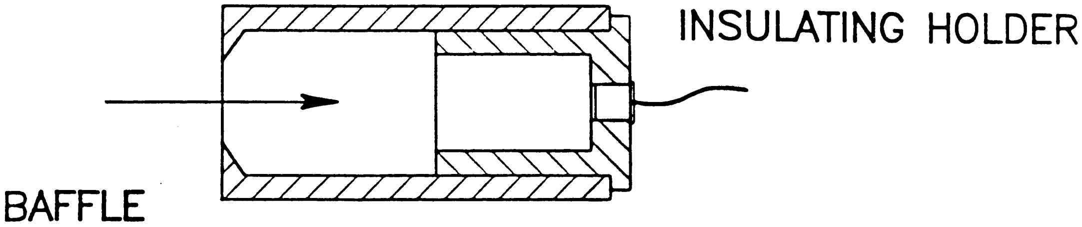
WITH CENTERING MECHANISM

WITH AZIMUTHAL CONTROL

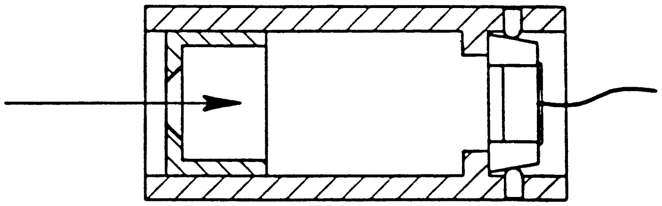
SOME DETECTOR MOUNTS

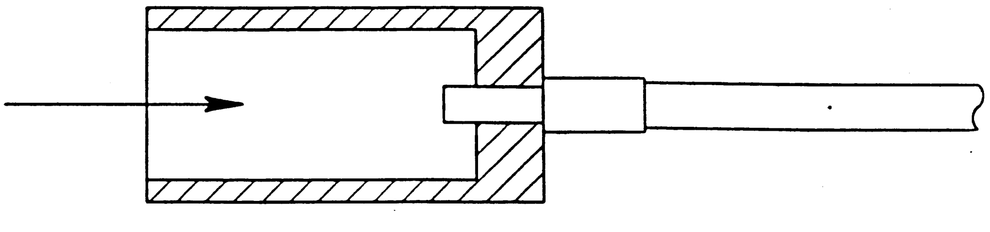
STRAY LIGHT SHIELD





DETECTOR IN CENTERING CONE





FIBER BUNDLE TO DETECTOR

USING VIDEO CAMERAS

PRINCIPAL MOUNTING POSSIBILITIES

IN A CYLINDER THAT IS IN THE V

ON A CYLINDER THAT IS IN THE V
  SEE BENT CYLINDERS

ON A CYLINDER HANGING FROM THE END OF THE V

NOT ATTACHED TO A CYLINDER

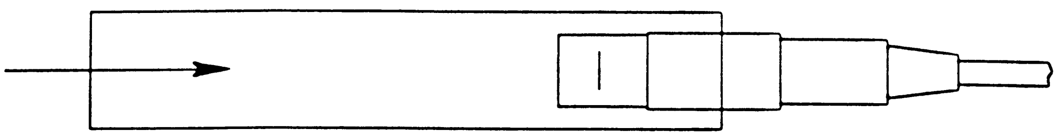
- ABOVE THE V
- AT THE END OF THE V

THE MOUNTING METHOD DEPENDS LARGELY ON THE SIZE OF THE CAMERA.

VIDEO CAMERA ARRANGEMENTS

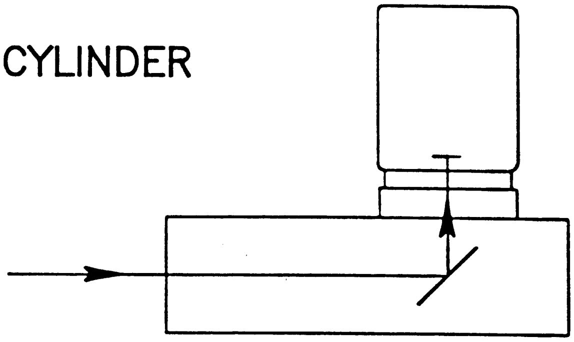
EXAMPLES

CAMERA IN A CYLINDER IN A V

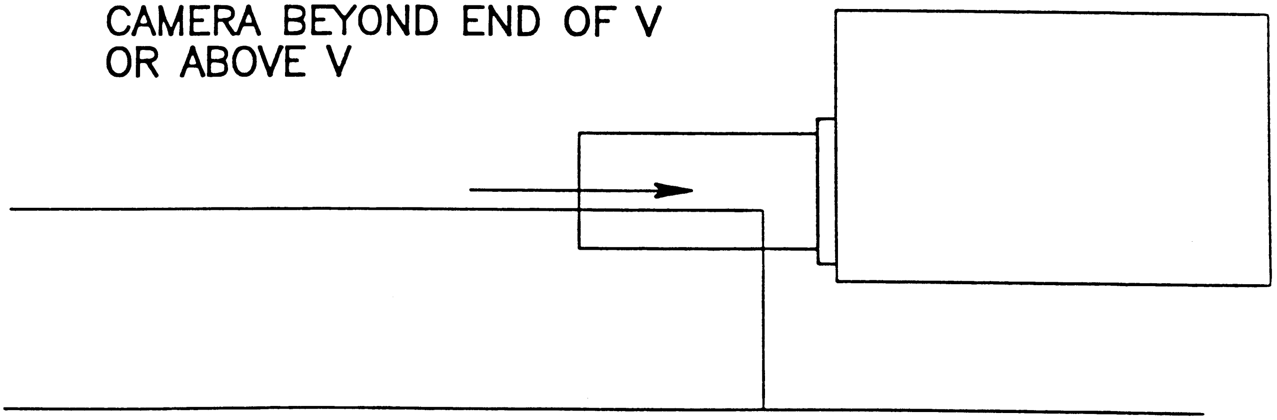


A LIPSTICK CAMERA

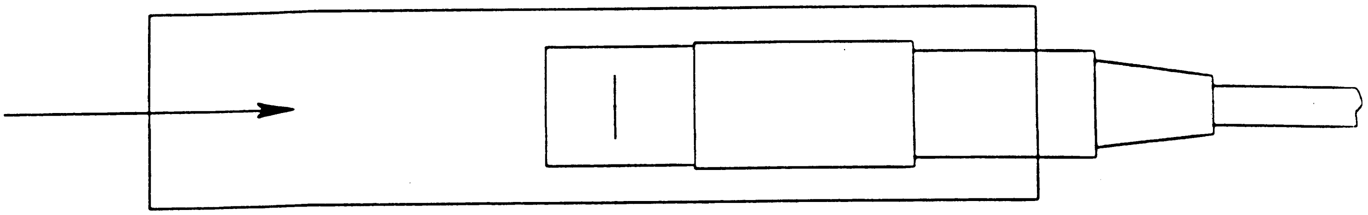
CAMERA ON A BENT CYLINDER



CAMERA BEYOND END OF V
OR ABOVE V



CAMERA IN A CYLINDER



A LIPSTICK CAMERA

SIMPLE.

EASY TO FOCUS.

EASY TO ADJUST AZIMUTH.

ONE CAMERA CAN BE SHARED BETWEEN SETUPS.

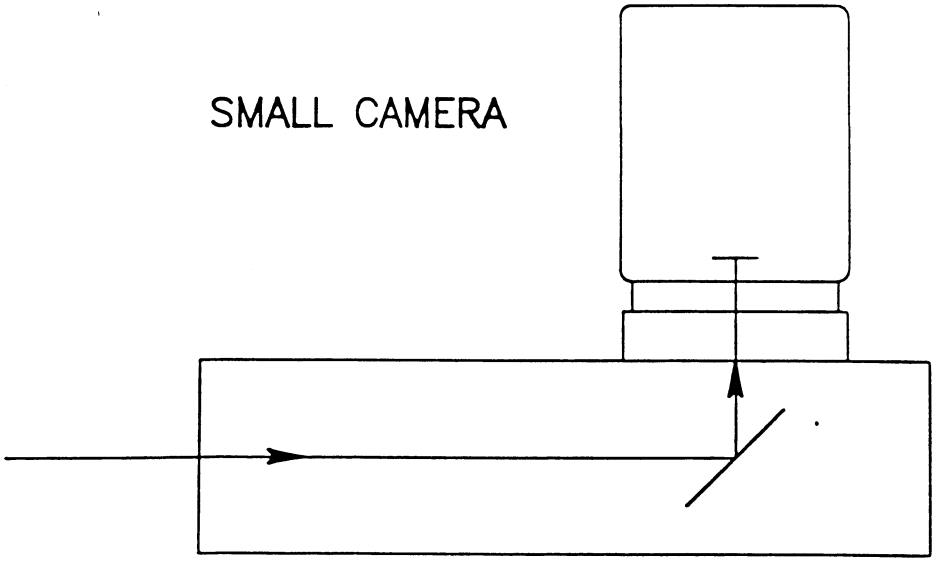
CAN BE ROBUST AND STABLE, WITH THE ENTIRE CAMERA INSIDE A CYLINDER.

LIPSTICK CAMERAS AS SMALL AS 1/4" DIAMETER

TOSHIBA MAKES A MONOCHROME ONE, WITH
DIAMETER = 17MM (ABOUT 2/3 INCH)
IT IS SHOWN ABOVE.

THE HIGH PRICE OF LIPSTICK CAMERAS IS MADE UP FOR IN DESIGN AND MACHINING SIMPLIFICATION AND THE ABOVE CHARACTERISTICS.

CAMERA IN A BENT CYLINDER



EASY TO FOCUS.

IMAGE AZIMUTH ADJUSTED BY ROTATING CAMERA.

ONE CAMERA CAN BE SHARED BETWEEN SETUPS

IMAGE PARITY IS SWITCHED BY A SINGLE REFLECTION.

CAN BE USED WITH A MIRROR OR A BEAMSPLITTER.

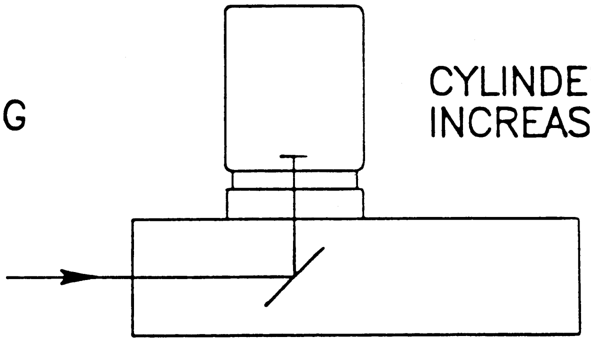
CAN BE TOP HEAVY.
NON–ROUND AND HEAVY CYLINDERS HELP STABILITY.

SEE THE SECTION ON BENT CYLINDERS.

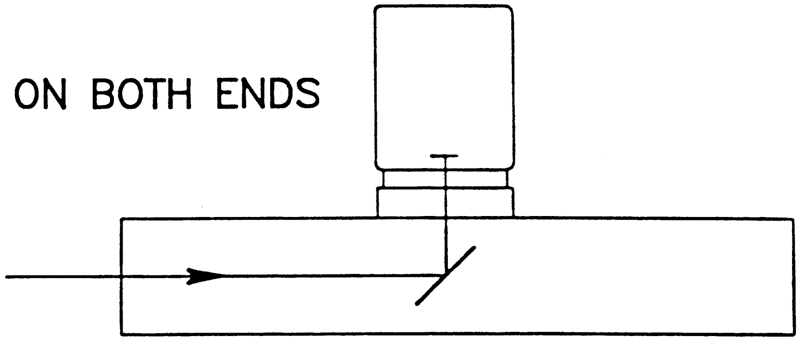
BENT CYLINDER VARIATIONS

REDUCED WORKING
DISTANCE

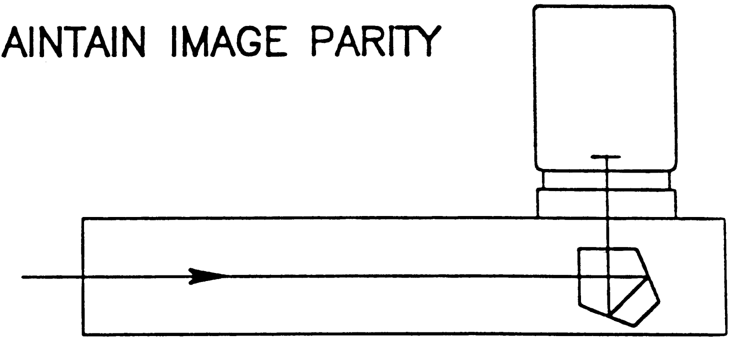
CYLINDER LENGTH
INCREASED FOR STABILITY



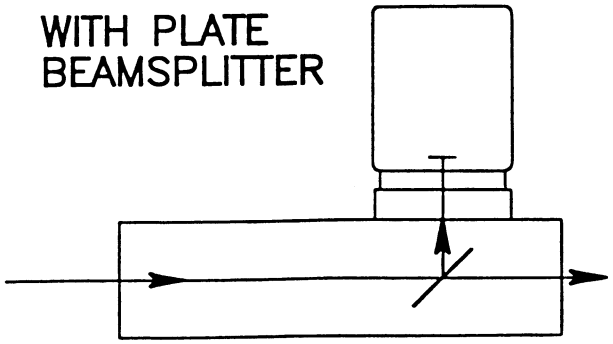
ELONGATED CYLINDER ON BOTH ENDS



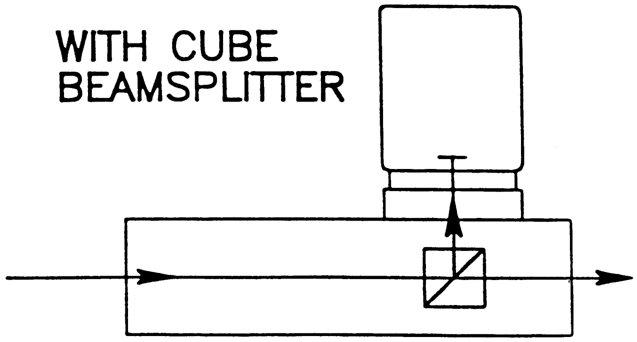
TWO REFLECTIONS TO MAINTAIN IMAGE PARITY



WITH PLATE
BEAMSPLITTER



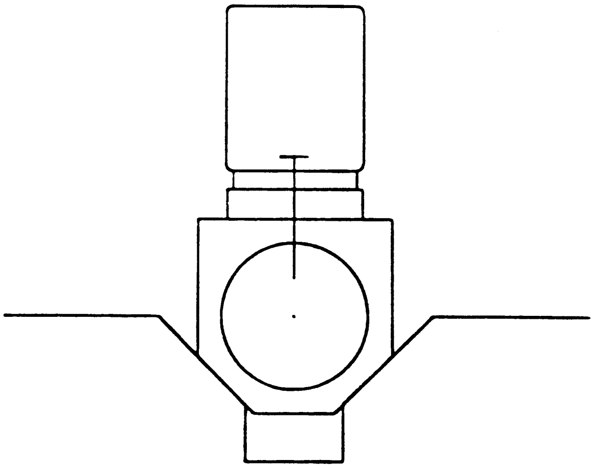
WITH CUBE
BEAMSPLITTER



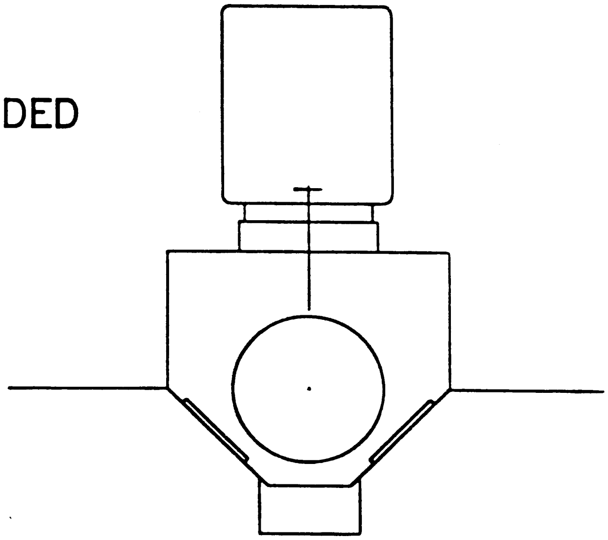
CAMERA IN A BENT CYLINDER

EXAMPLES

DEEP V AND NON-ROUND CYLINDER



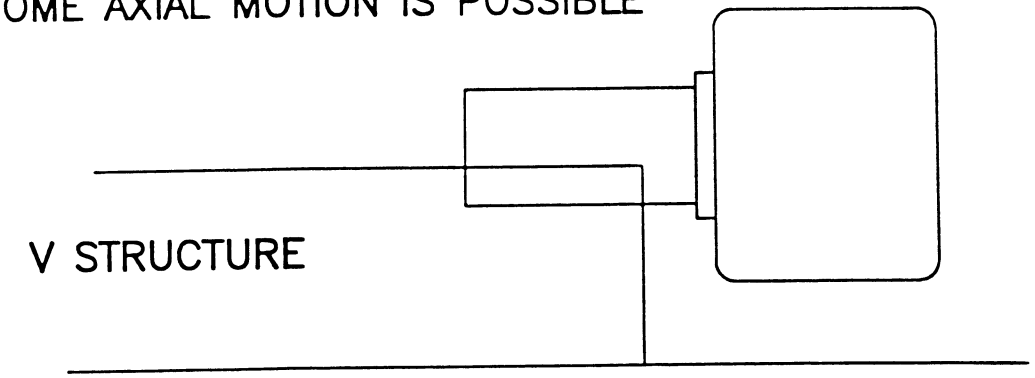
CONTACT AREA AND MASS ADDED
TO CYLINDER FOR STABILITY



VIDEO CAMERA BEYOND THE V

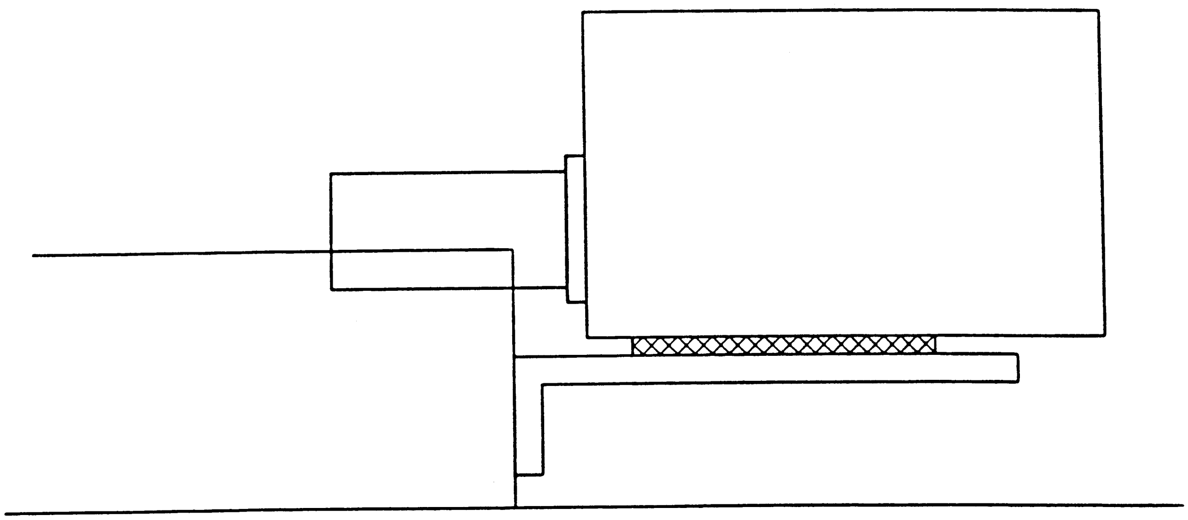
CAMERA SMALL ENOUGH TO BE SUPPORTED BY A TUBE

SOME AXIAL MOTION IS POSSIBLE



AZIMUTH ADJUST BY ROTATION

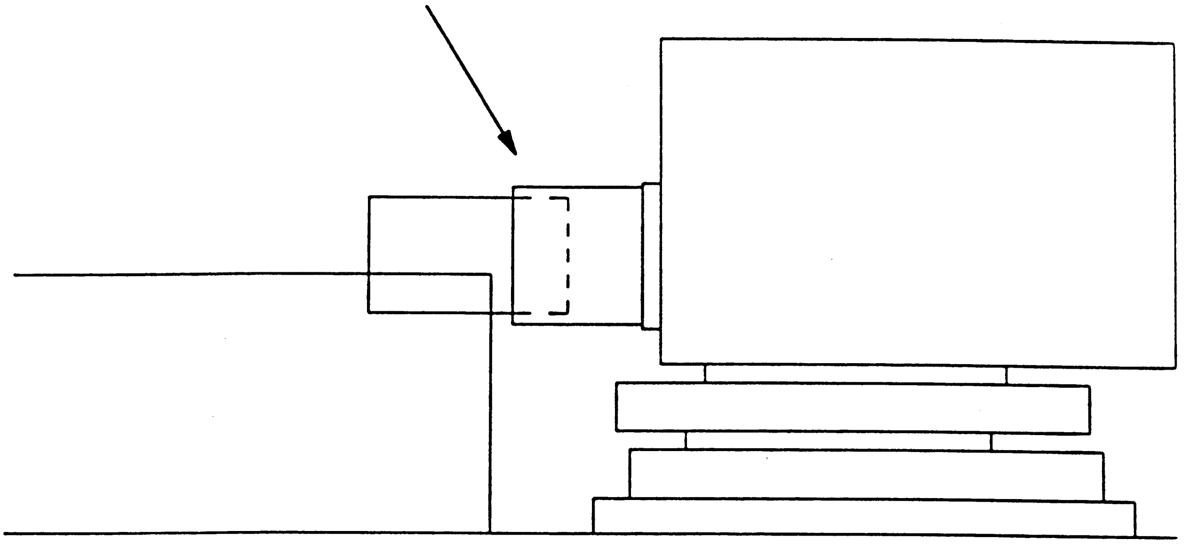
CAMERA TOO LARGE TO BE FULLY SUPPORTED BY TUBE



ELASTIC SUPPORT OF MOST OF THE WEIGHT PERMITS ALIGNMENT BY THE TUBE.

VIDEO CAMERA BEYOND THE V

CAMERA TOO LARGE TO BE SUPPORTED BY A TUBE IN THE V.

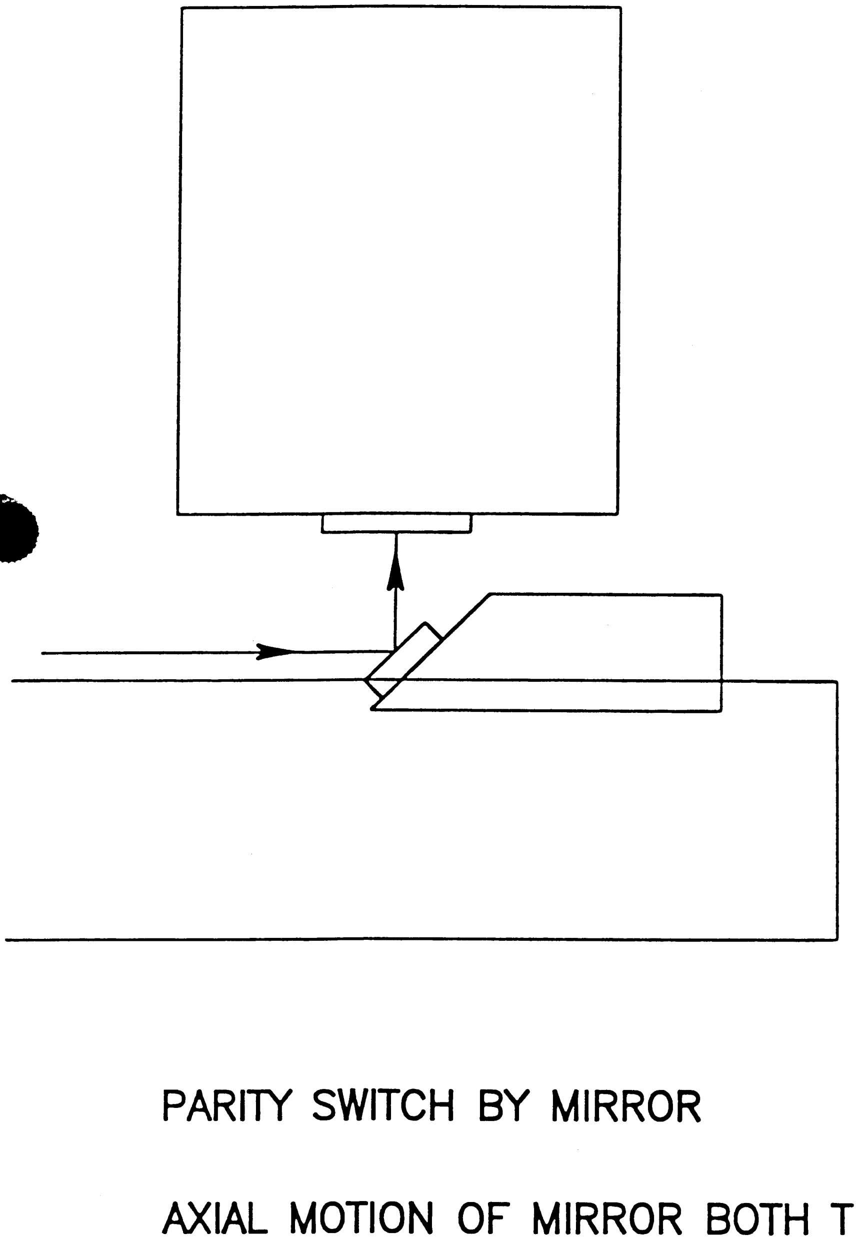


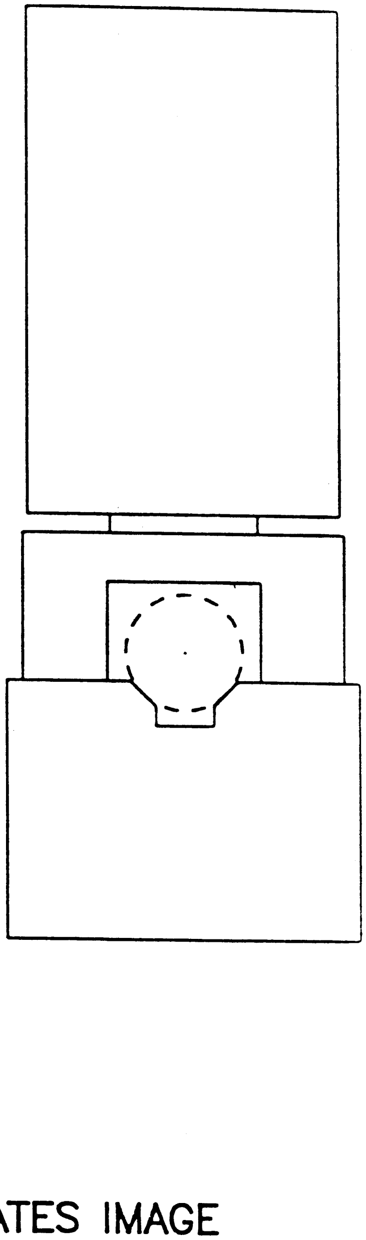
FLEXIBLE OR NON-CONTACTING LIGHT SEAL

STAGES AND STANDS AS NEEDED

VIDEO CAMERA ABOVE THE V

LARGE CAMERA SUPPORTED ABOVE V, POSSIBLY BY A BRIDGE.



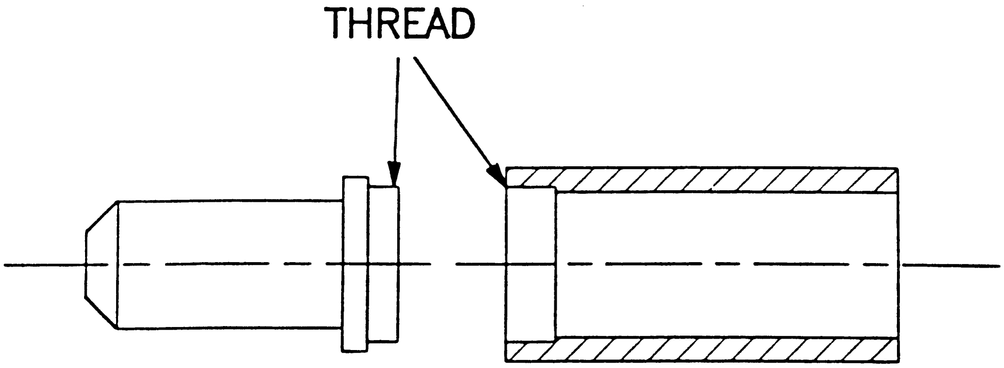


PARITY SWITCH BY MIRROR

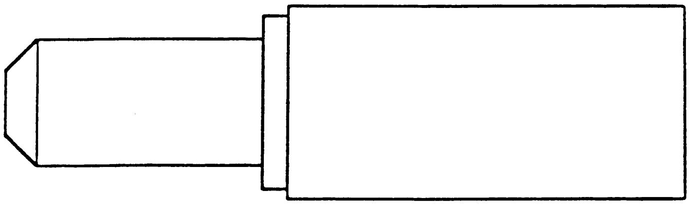
AXIAL MOTION OF MIRROR BOTH TRANSLATES IMAGE AND CHANGES FOCUS.

MICROSCOPE OBJECTIVES

TYPICAL CYLINDER FOR AN OBJECTIVE

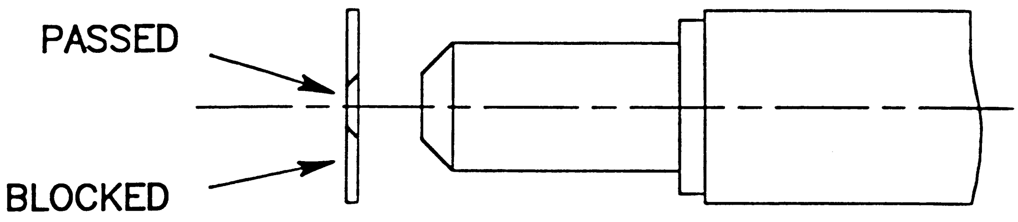


LONG ENOUGH AND HEAVY ENOUGH TO RESIST TIPPING

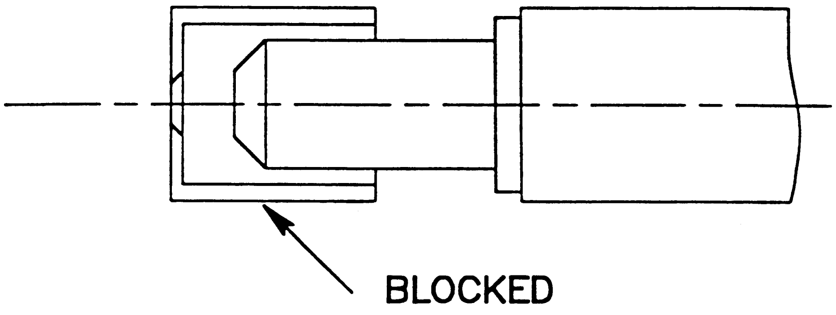


FIELD STOP

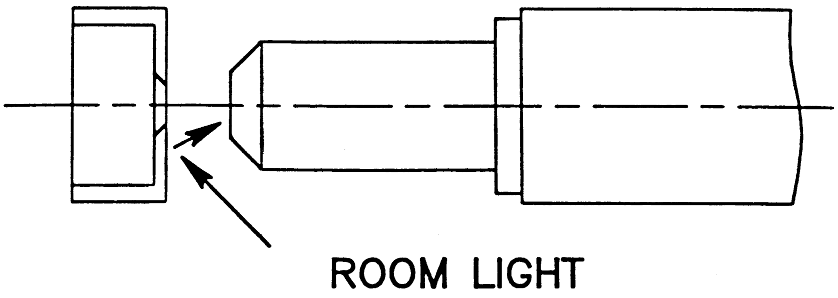
STRAY LIGHT CAN BE REDUCED WITH A FIELD STOP IN THE OBJECT AND/OR IMAGE PLANE OF A MICROSCOPE OBJECTIVE.



SELF-STANDING FIELD STOPS

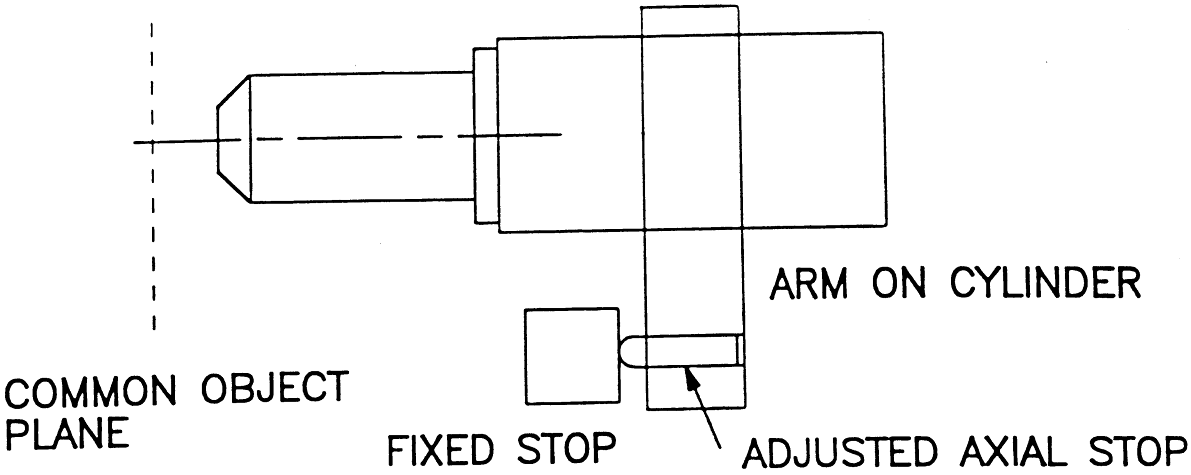


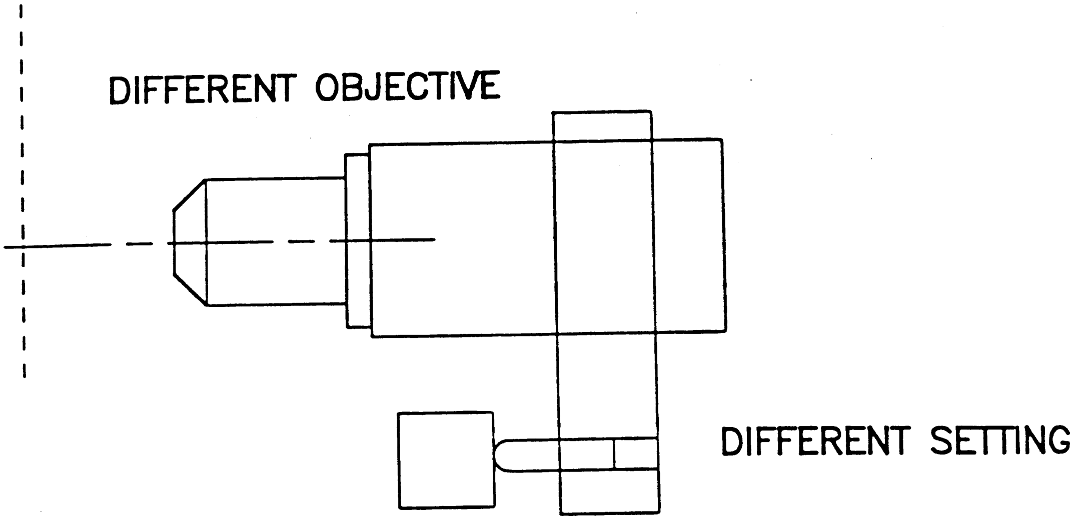
NOT AS GOOD

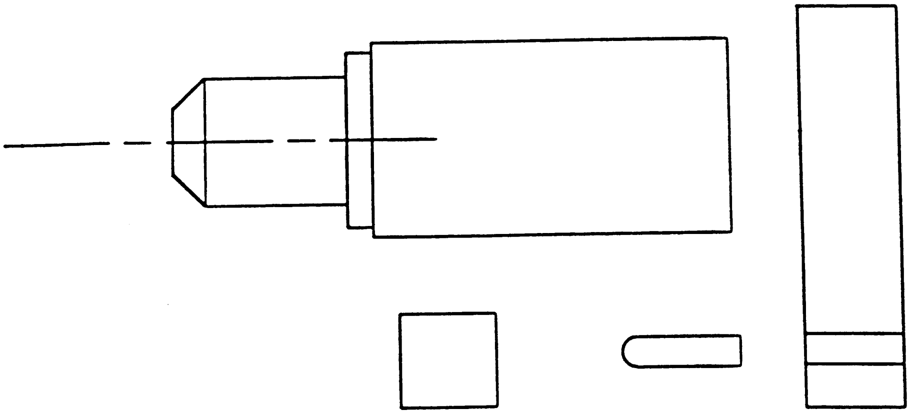


PARFOCAL OBJECTIVES

DIFFERENT OBJECTIVES CAN BE INDIVIDUALLY ADJUSTED TO A FIXED STOP SO THAT THEY FOCUS AT COMMON OBJECT AND IMAGE PLANES AND CAN BE SWITCHED WITHOUT FOCUSSING.

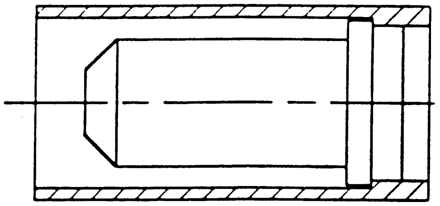






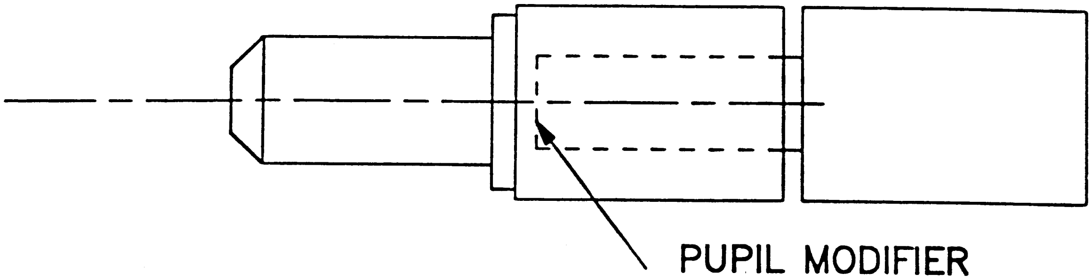
ACCESSING OBJECTIVE PUPIL

OBJECTIVE HELD BY A CYLINDER AROUND IT

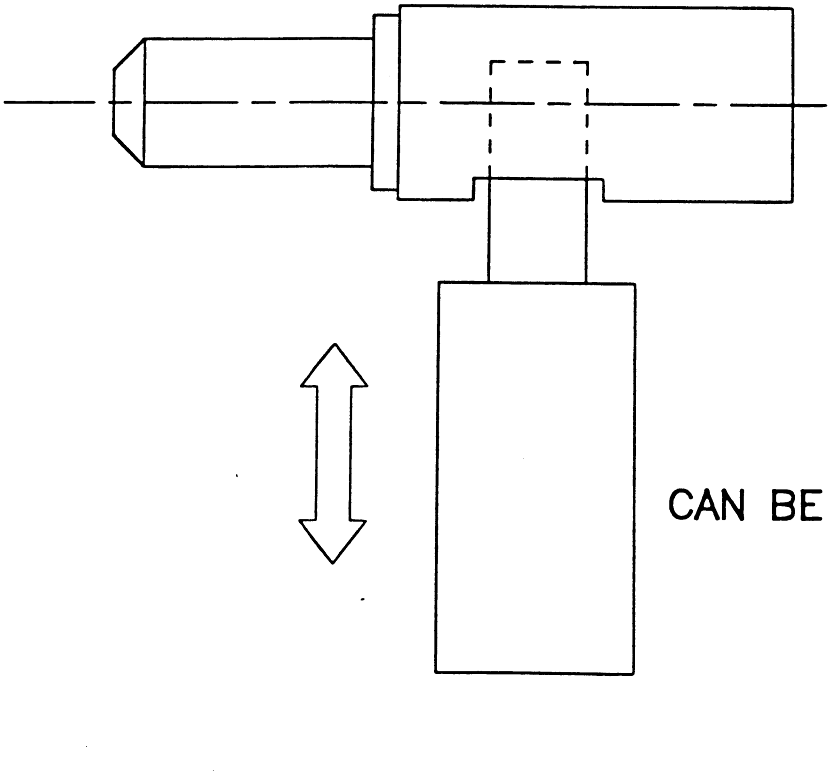


THIS WORKS IF CYLINDER DIAMETER IS LARGE ENOUGH RELATIVE TO THE OBJECTIVE.

REACHING IN

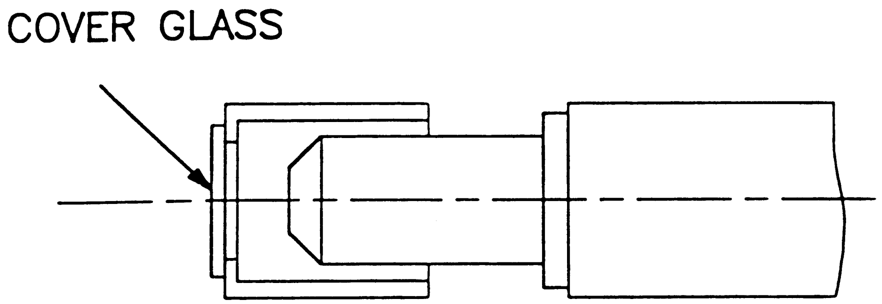


TRANSVERSE ACCESS THROUGH OPENING IN CYLINDER SUPPORTING OBJECTIVE

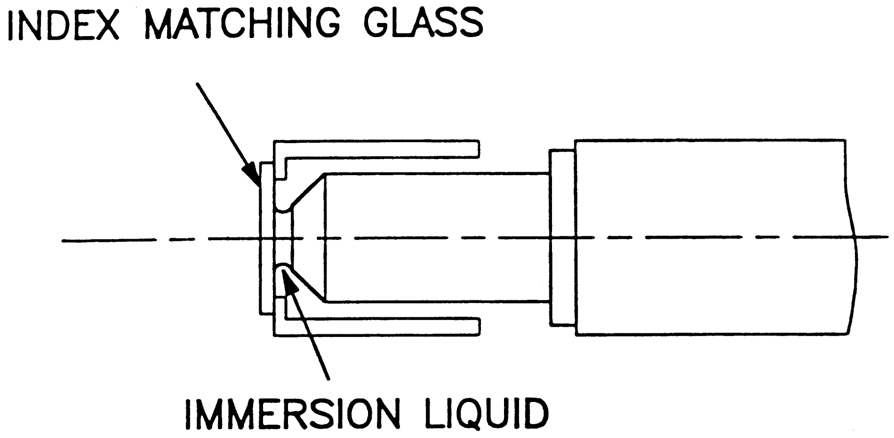


CAN BE IN A PERPENDICULAR V

COVER GLASS AND IMMERSION OBJECTIVES



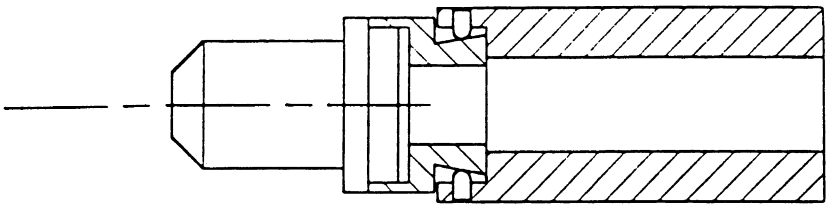
OBJECTIVES DESIGNED FOR COVER GLASS CAN BE USED IN AIR BY HOLDING A COVER GLASS WITH A CYLINDER.

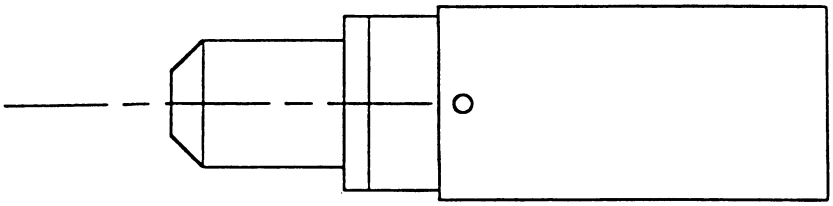


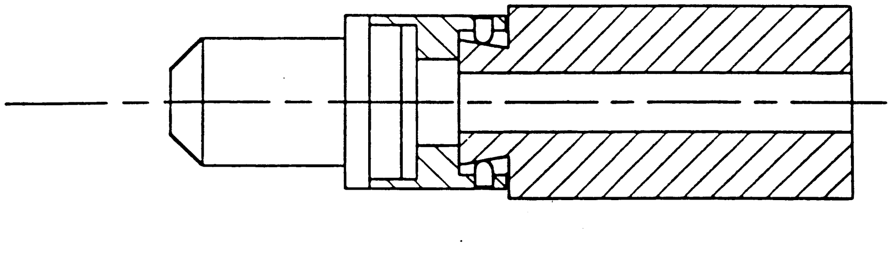
OBJECTIVES DESIGNED FOR IMMERSION CAN BE USED IN AIR BY HOLDING A COVER GLASS WITH A CYLINDER.

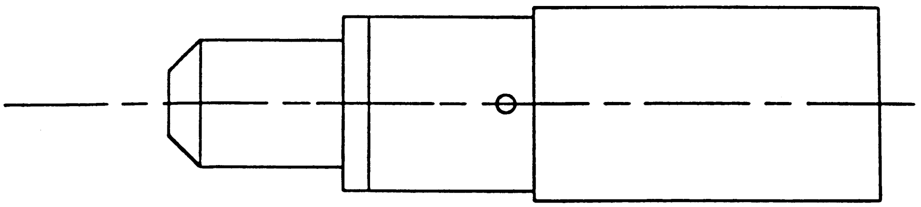
A FIELD STOP CAN BE INCORPORATED.

OBJECTIVES WITH CENTERING CONES





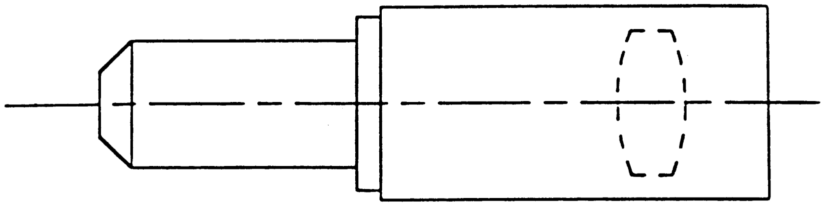




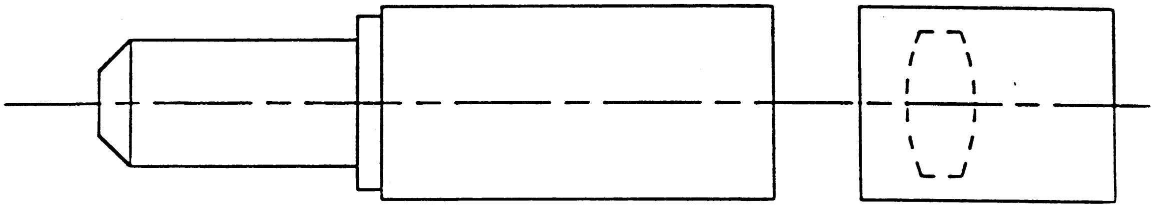
INFINITY OBJECTIVES

INFINITY OBJECTIVES USE A "TUBE LENS" TO PRODUCE A REAL IMAGE.
THE TUBE LENS CAN BE MOVED AXIALLY TO MOVE THE IMAGE WITH NO CHANGE IN MAGNIFICATION.

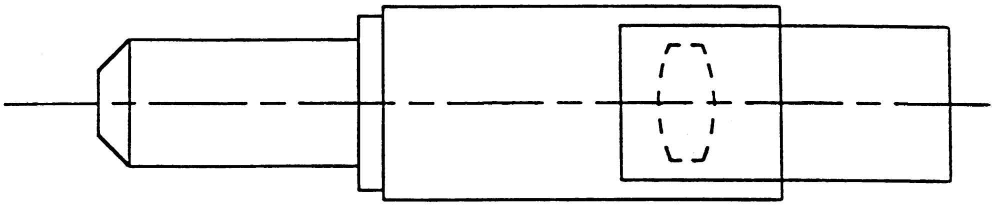
TUBE LENS FIXED IN OBJECTIVE CYLINDER



TUBE LENS IN A SEPARATE CYLINDER



TUBE LENS IN A MOVEABLE STRUCTURE WITHIN THE OBJECTIVE CYLINDER



ILLUMINATION

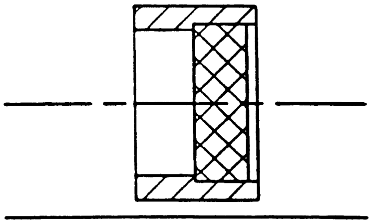
SOURCE LOCATION
- IN V
- OUT OF V
  - LIGHT BROUGHT TO V IN FREE SPACE
  - LIGHT BROUGHT BY FIBER

SOURCE TYPE
- THERMAL
- LASER
- LED

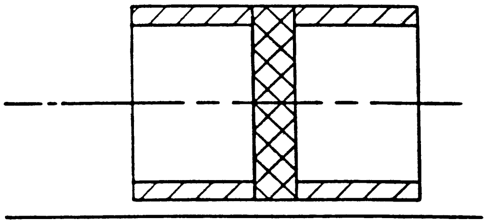
APPARATUS ASSOCIATED WITH ILLUMINATION
- DIFFUSERS
- NEUTRAL DENSITY FILTERS
- COLOR FILTERS
- HOT AND COLD MIRRORS

FOR LABORATORY USE, FILTERS CAN BE MOUNTED IN SHORT CYLINDERS.
FILTERS CAN SOMETIMES BE USED WITHOUT MOUNTING, SUPPORTED ON BOTH SIDES BY CYLINDERS

A SHORT FILTER CYLINDER



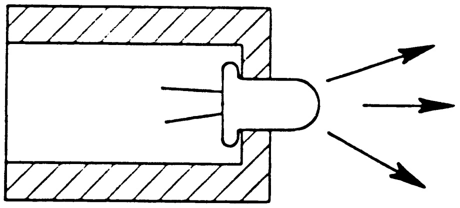
A FILTER SUPPORTED BY TWO HOLLOW CYLINDERS

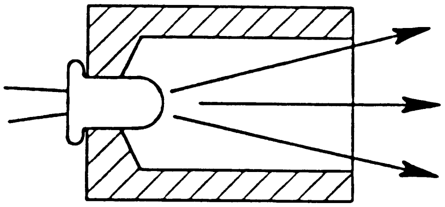


SOURCES MOUNTED ON CYLINDERS

EXAMPLES

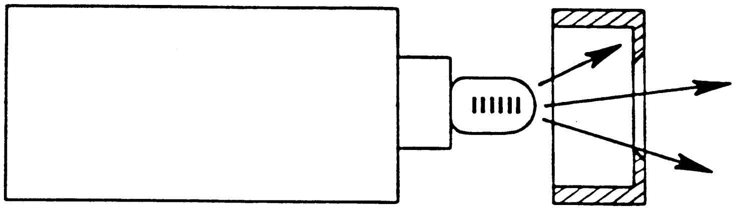
LED





AN LED CAN BE HELD A IN CYLINDER BY PRESSURE,
CEMENT, OR SET SCREW

TUNGSTEN LAMP



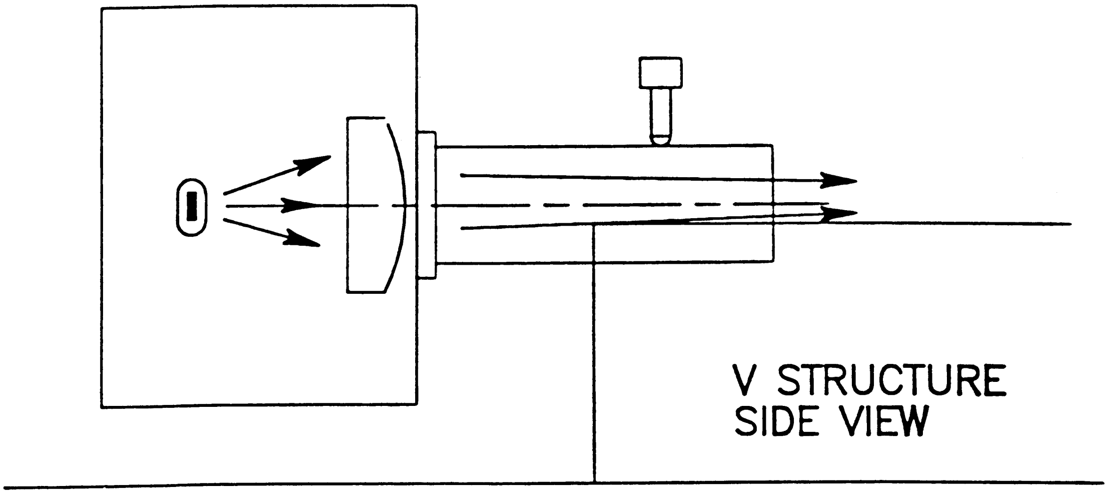
A LAMP SOCKET IS MOUNTED
ON THE CYLINDER.

THE SOURCES CAN BE CENTERED AND TILTED AS DESCRIBED
ELSEWHERE.

SEE ALSO SECTIONS
  THERMAL
  SUPPRESSING UNWANTED LIGHT

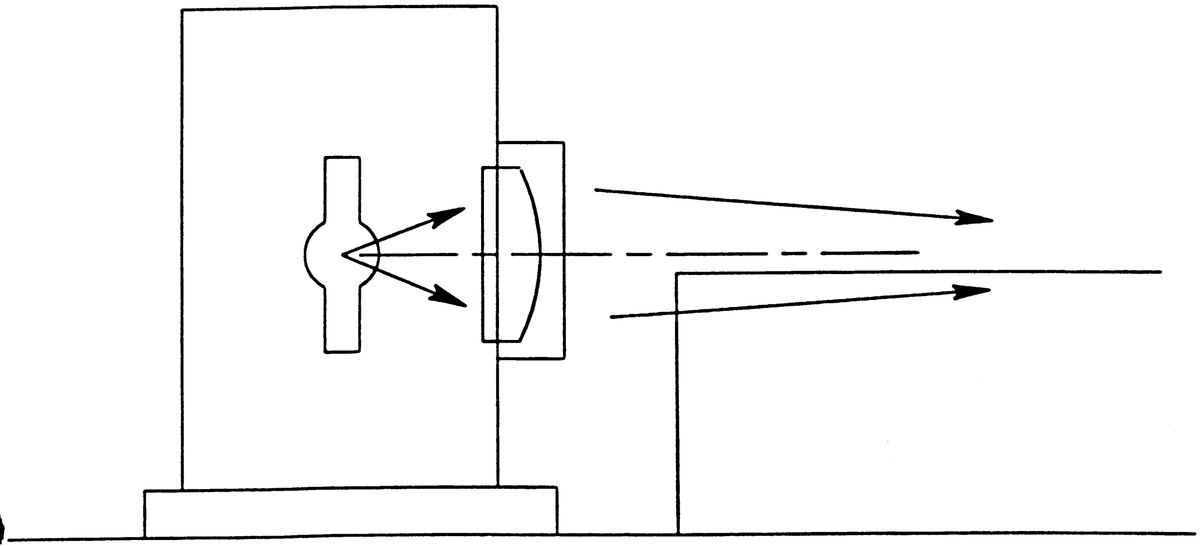
LAMP IN HOUSING OUTSIDE OF THE V

LAMP HOUSING SMALL ENOUGH TO BE SUPPORTED BY A TUBE CLAMPED IN THE CYLINDER



ALIGNMENT OF THE LAMP TO THE TUBE MAKES A MODULAR UNIT.

SELF–STANDING LAMP HOUSING



ILLUMINATION DELIVERY BY FIBER

MERITS:

THE SOURCE IS OUT OF THE WAY.

HEAT AND FAN VIBRATION ARE SEPARATED FROM THE INSTRUMENT.

THE SOURCE NEEDS NOT BE ALIGNED TO THE V.

THE ALIGNMENT OF THE SOURCE TO A FIBER OR FIBER BUNDLE AND A FIBER TO THE V MAY BE EASIER THAN ALIGNMENT OF THE SOURCE TO A V.

THE OUTPUT END OF THE FIBER CAN BE HELD BY A CYLINDER AND IT CAN BE CENTERED.

FILTERS THAT WOULD BE DAMAGED AT THE SOURCE CAN BE USED AT OUTPUT END OF A FIBER BUNDLE.

THE FIBER'S OUTPUT LOCATION CAN BE SWITCHED, SO ONE SOURCE CAN BE USED WITH SEVERAL SETUPS WITH QUICK CHANGEOVER.

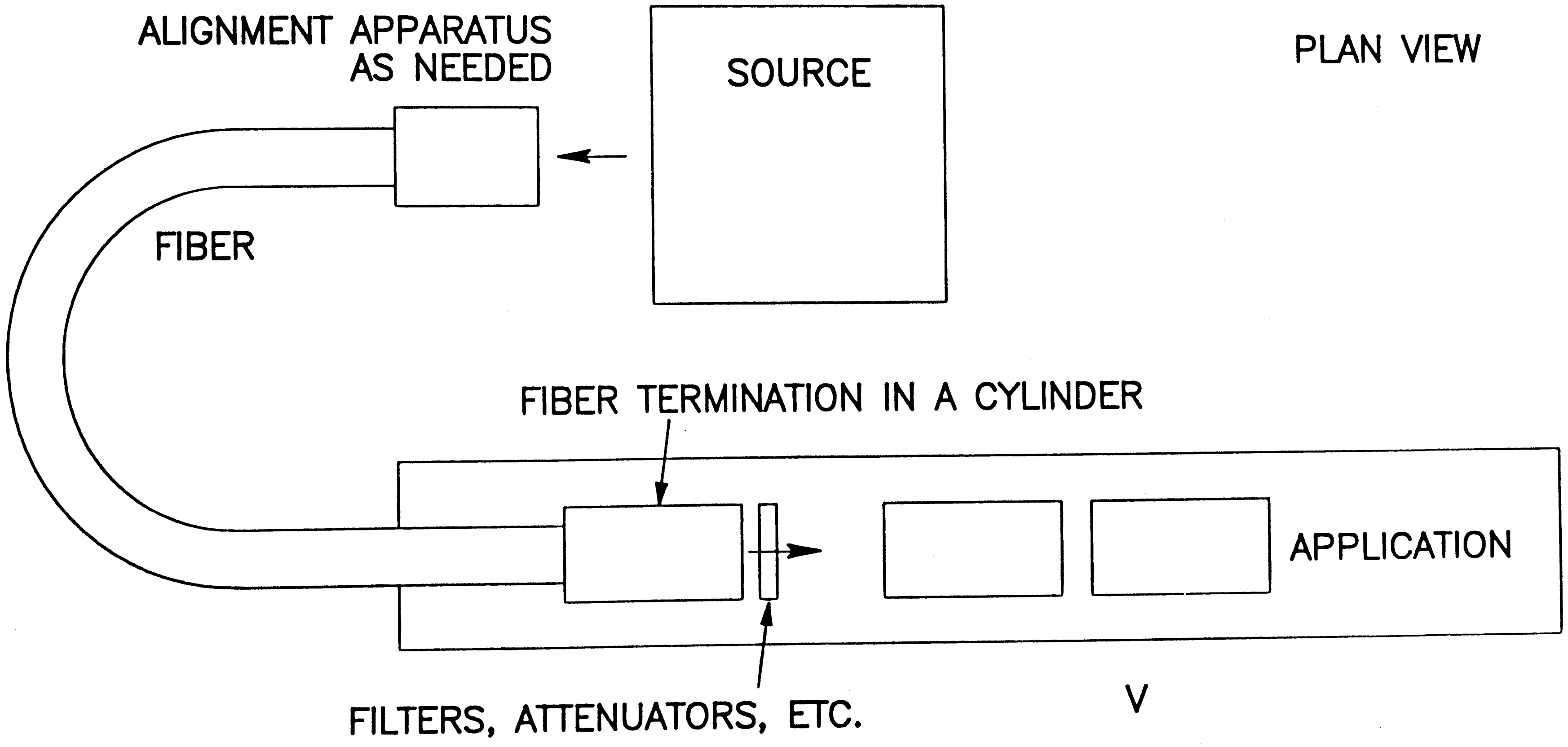
THE INPUT OF THE FIBER CAN BE MOVED TO CHANGE THE SOURCE.

A FAILED SOURCE CAN BE CHANGED WITHOUT AFFECTING THE POSITION OF THE OUTPUT END OF THE FIBER.

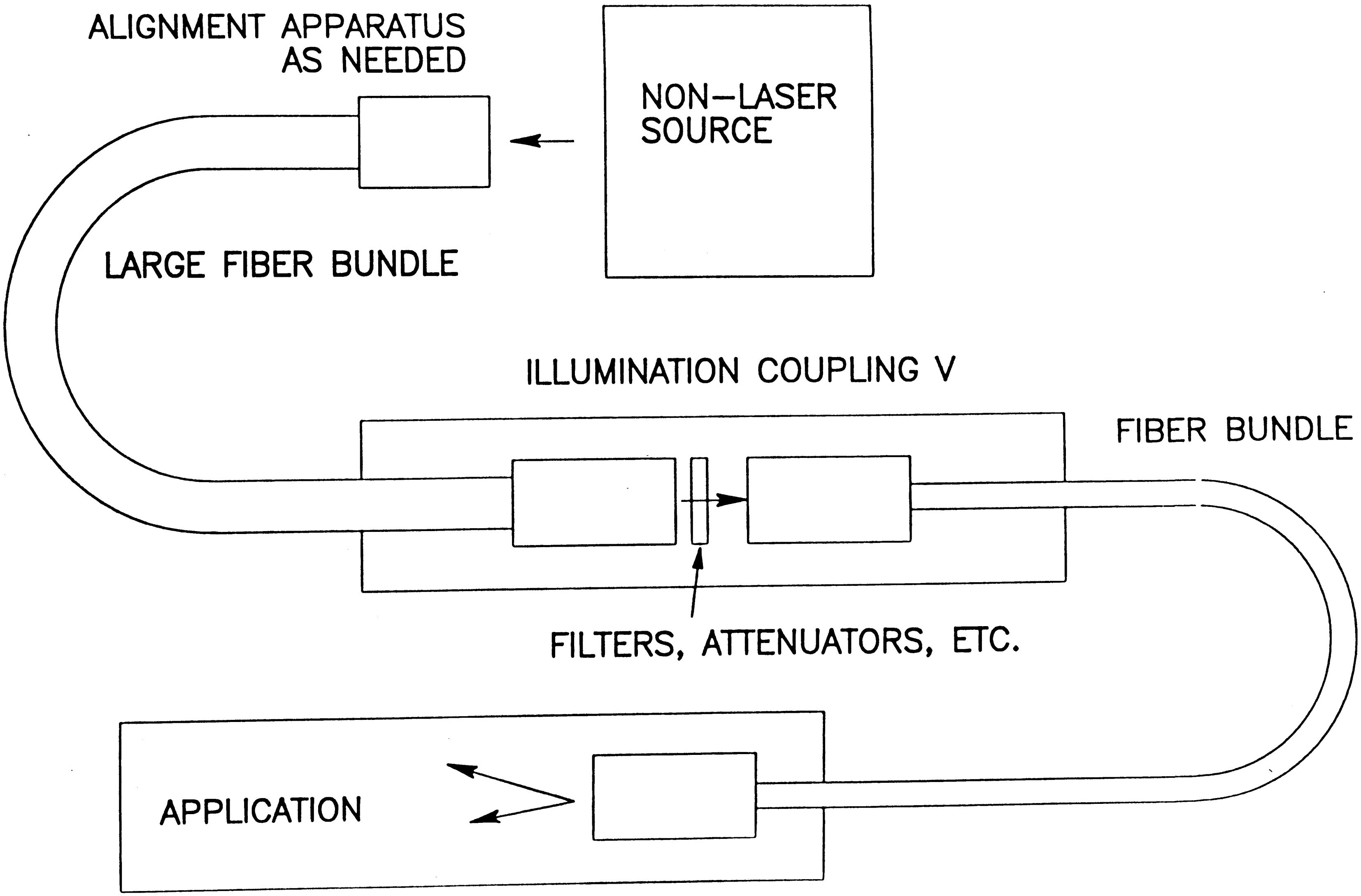
THESE ADVANTAGES APPLY TO:
- SINGLE MODE FIBERS
- MULTI–MODE FIBERS
- FIBER BUNDLES

DISADVANTAGES:
LOSS OF POWER AND BRIGHTNESS
POSSIBLY, THE STRUCTURE OF A FIBER BUNDLE

ILLUMINATION DELIVERED BY A FIBER BUNDLE FROM THE SOURCE TO THE V

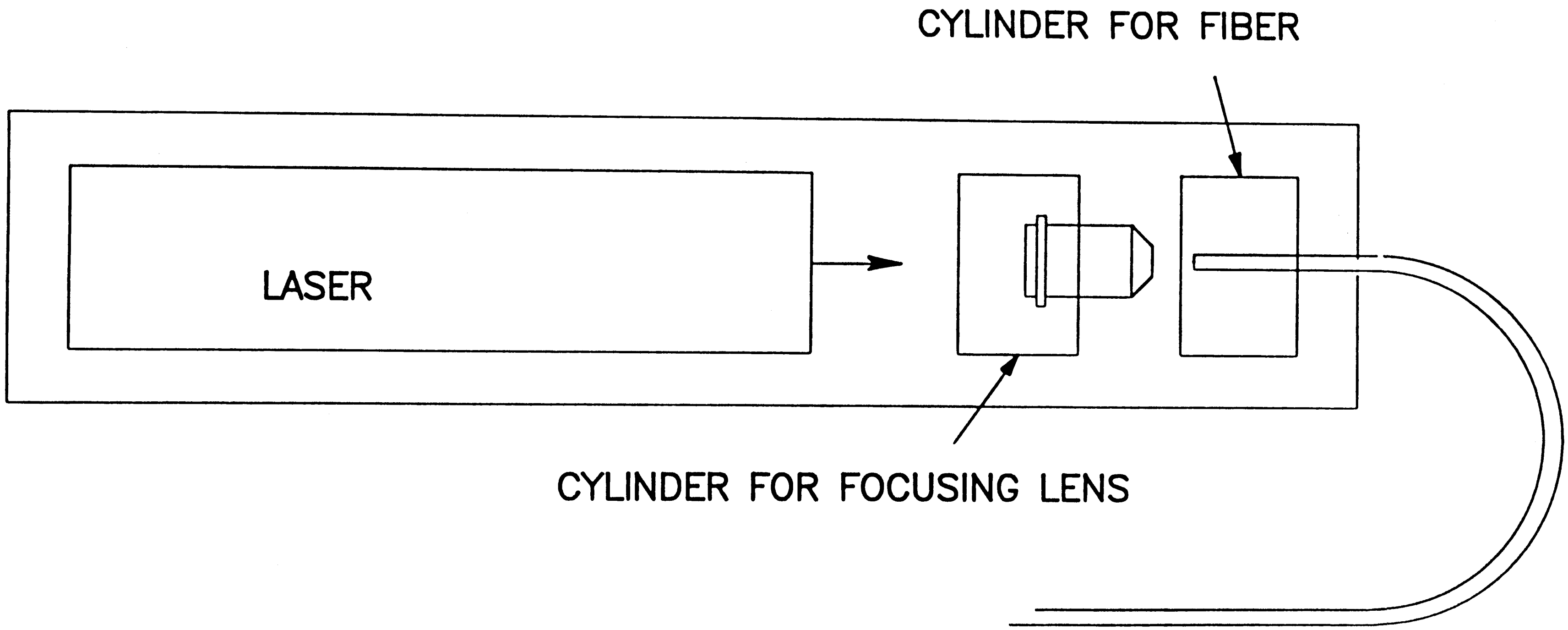


ILLUMINATION ARRANGEMENT WITH FIBER BUNDLE COUPLING ON A V



AUXILIARY V FOR ROUND LASERS

PLAN VIEW

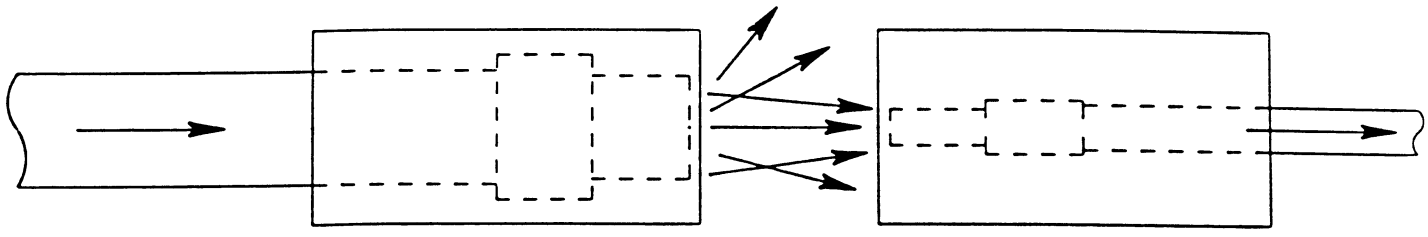


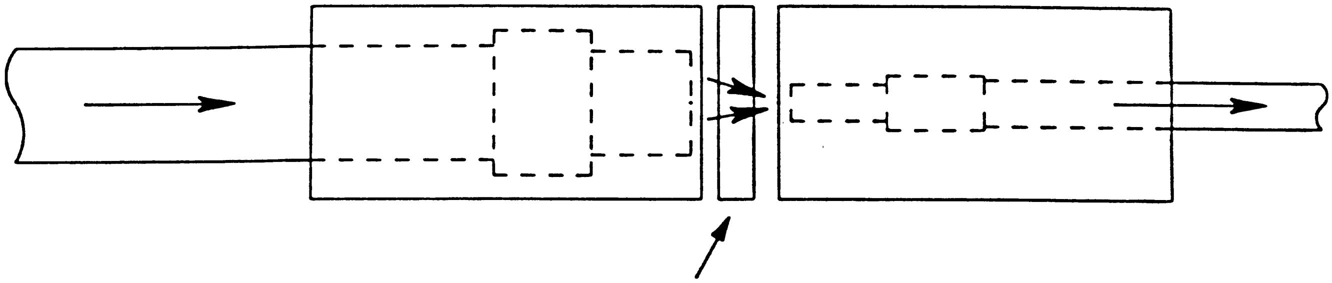
THE OUTSIDE DIAMETERS OF THE CYLINDERS ARE THAT OF THE LASER.

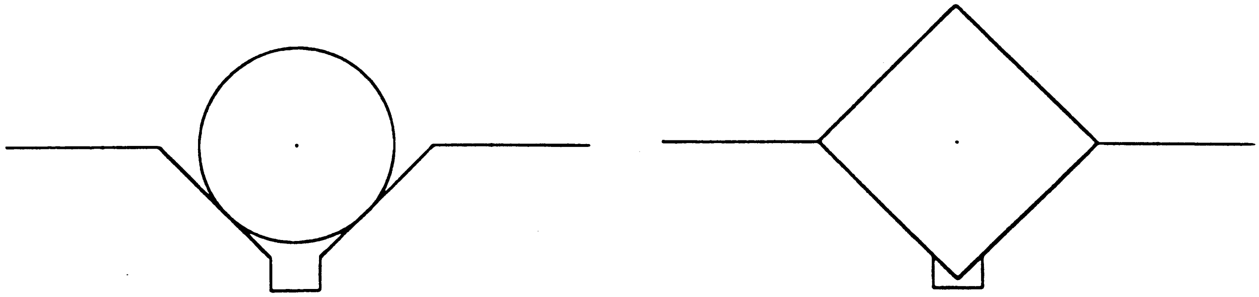
AT LEAST ONE OF THE CYLINDERS HAS A LATERAL POSITION ADJUSTMENT

COUPLED FIBER BUNDLES

COUPLING BY FIBERS IN CYLINDERS IN A V



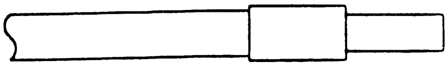




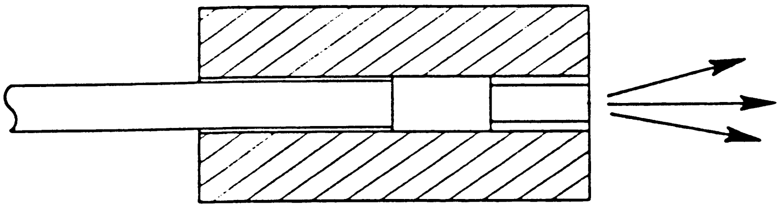
A DEEP 90° V WITH A TROUGH IS GOOD FOR BOTH ROUND AND SQUARE FILTERS.

THE V CAN BE SIZED FOR STANDARD FILTER SIZE, E.G. 1" ROUND AND 1" SQUARE.

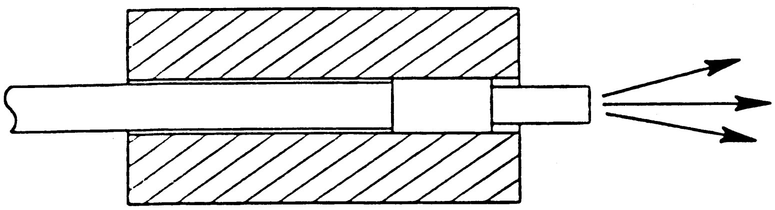
FIBER BUNDLE TERMINATION CYLINDERS



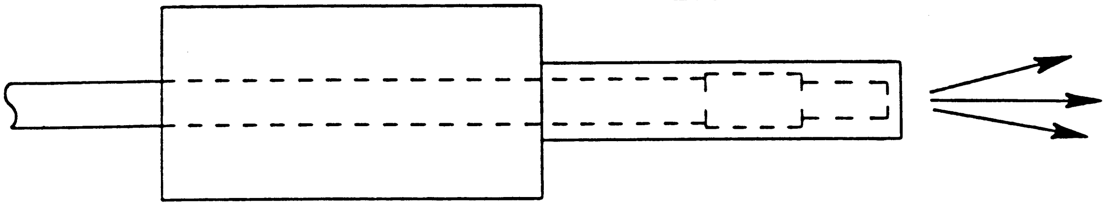
COMMON BUNDLE



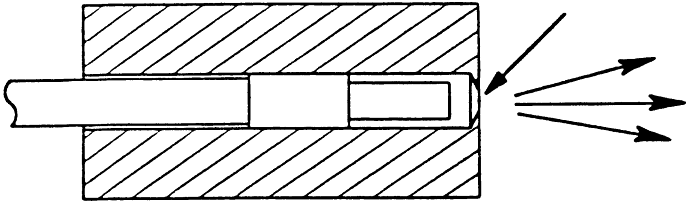
FLUSH



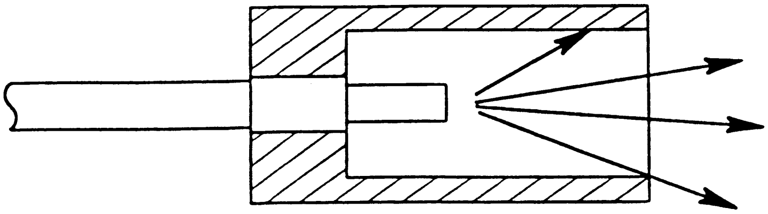
PROTRUDING



EXTENDED



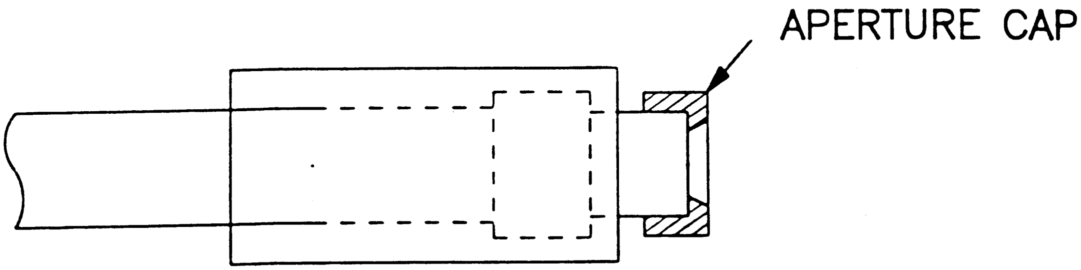
MACHINED APERTURE

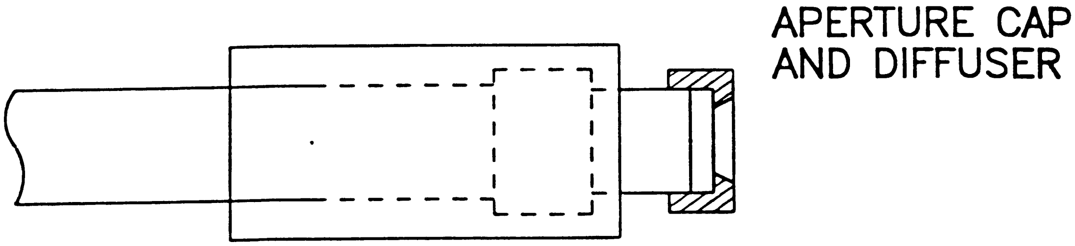


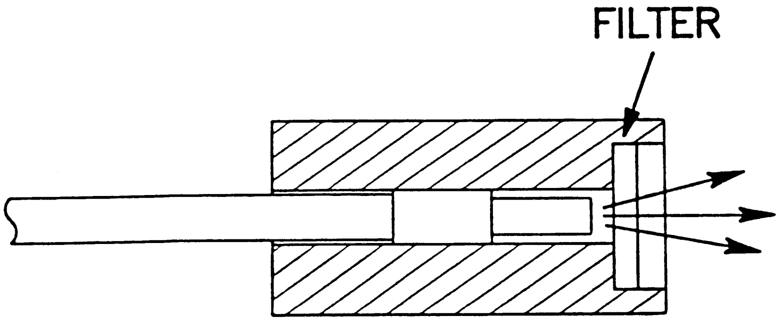
CUP

OUTGOING RAY ANGLES LIMITED

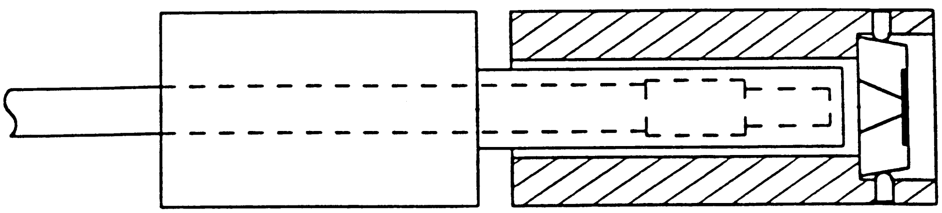
SOME FIBER BUNDLE TERMINATION CYLINDERS





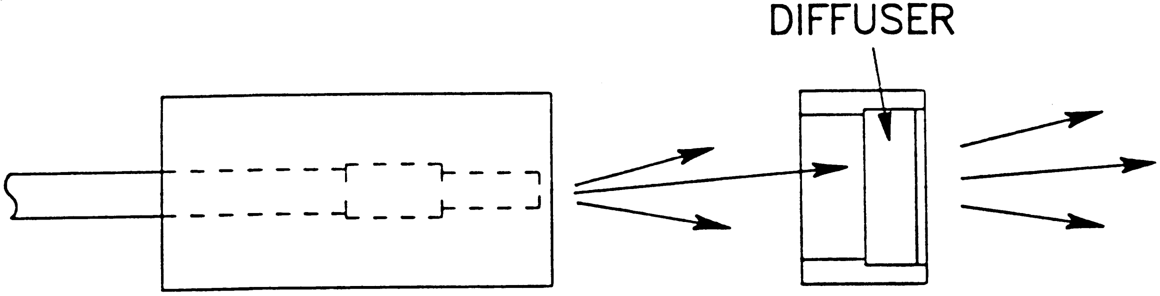


ILLUMINATION OF A CONE-CENTERED OBJECT

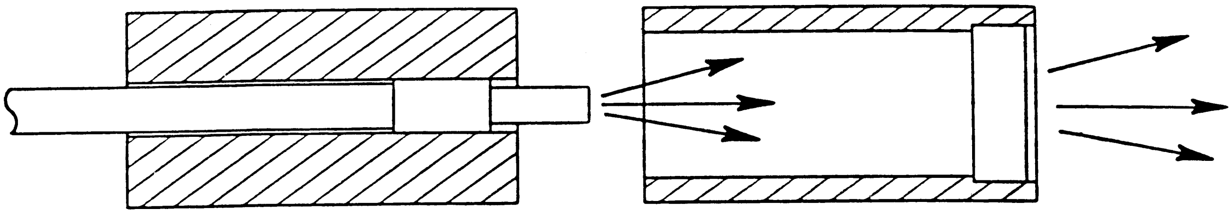


APPARATUS WITH DIFFUSERS

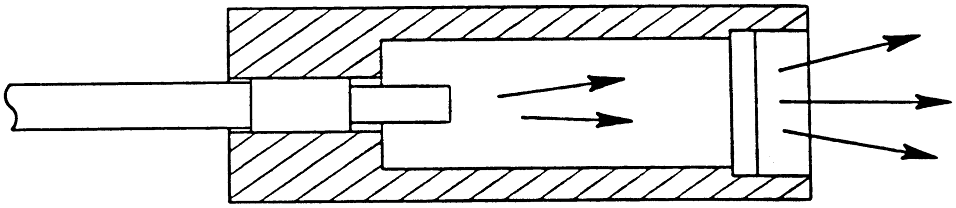
EXAMPLES

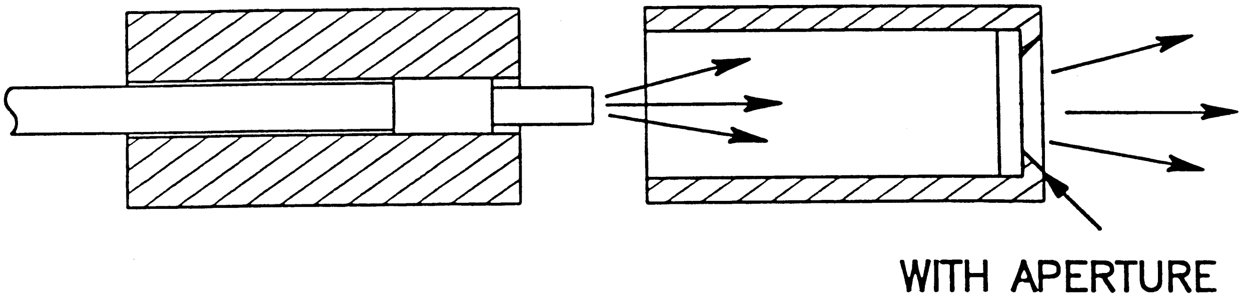


LESS STRAY LIGHT

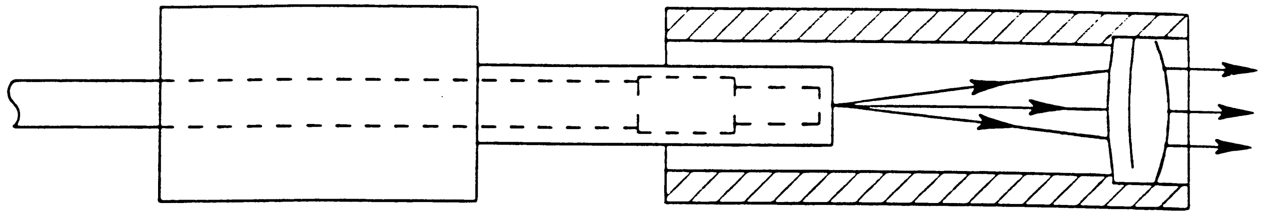


ONE-PIECE

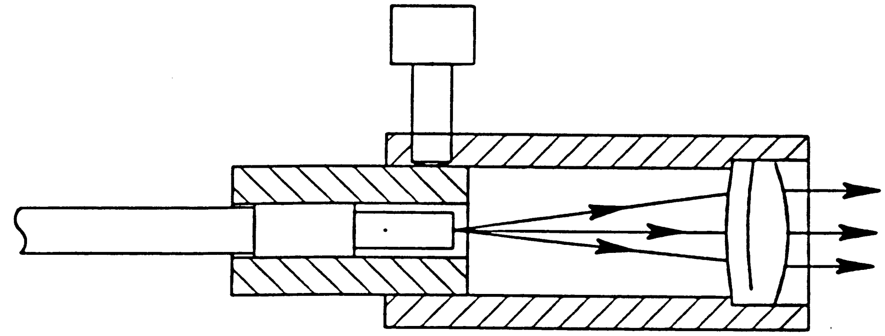




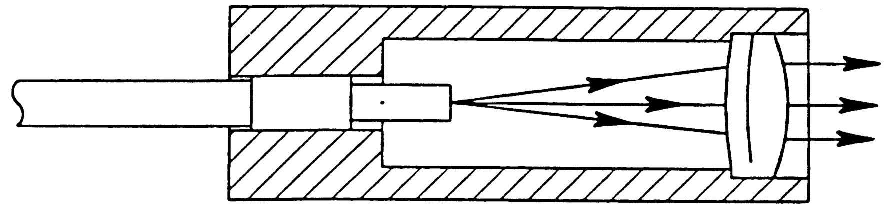
ILLUMINATION APPARATUS WITH A LENS



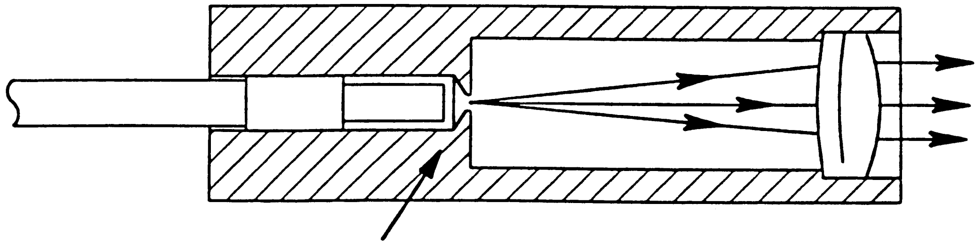
FIBER BUNDLE AND LENS IN SEPARATE CYLINDERS



FIBER BUNDLE FOCUSABLE IN LENS CYLINDER



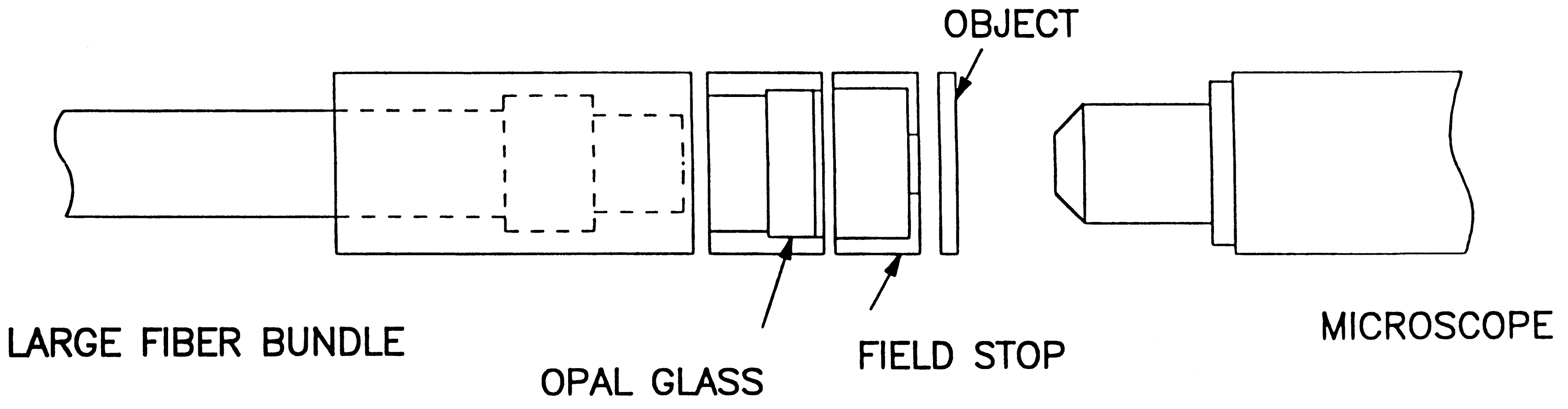
FIBER BUNDLE FIXED IN LENS CYLINDER



WTH MACHINED APERTURE

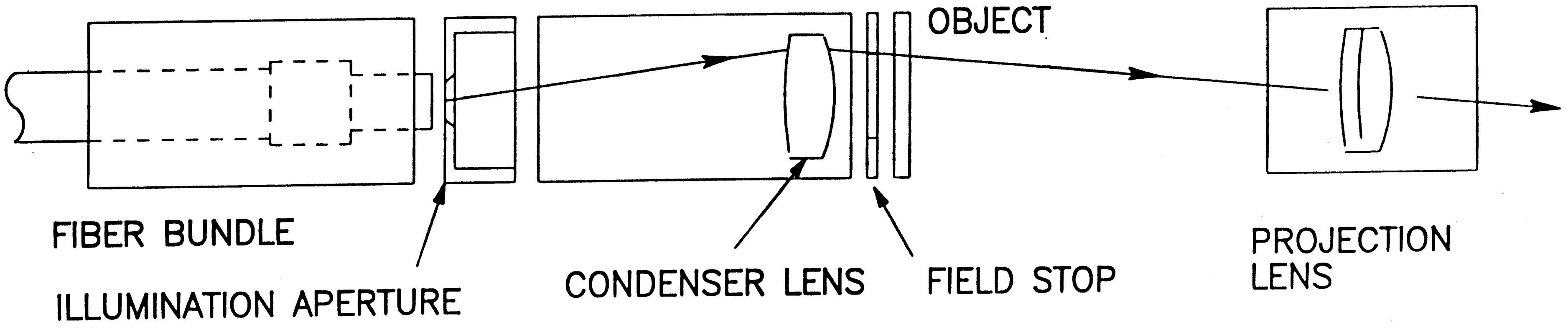
SOME ILLUMINATION EXAMPLES

DIFFUSE ILLUMINATION FOR A MIICROSCOPE



ILLUMINATION FOR PROJECTION

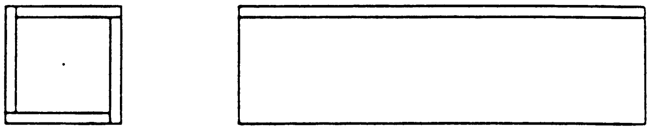
THE END OF BUNDLE IS IMAGED INTO THE PROJECTION LENS.



LIGHT TUNNEL UNIFORMIZERS

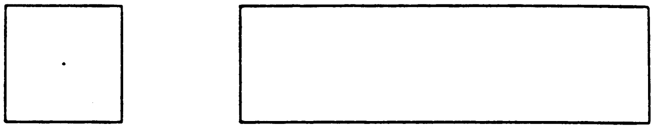
EXAMPLES

HOLLOW



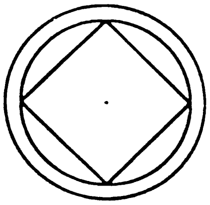
FOUR PIECES OF FRONT SURFACE MIRROR CEMENTED TOGETHER, REFLECTIVE SIDES INSIDE

SOLID
USING TIR

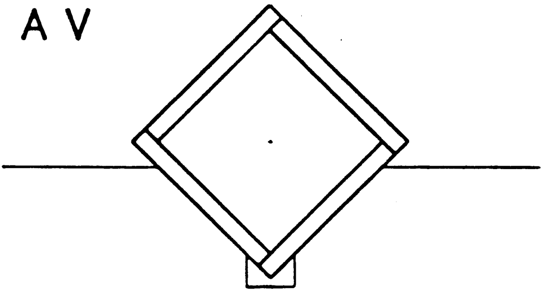


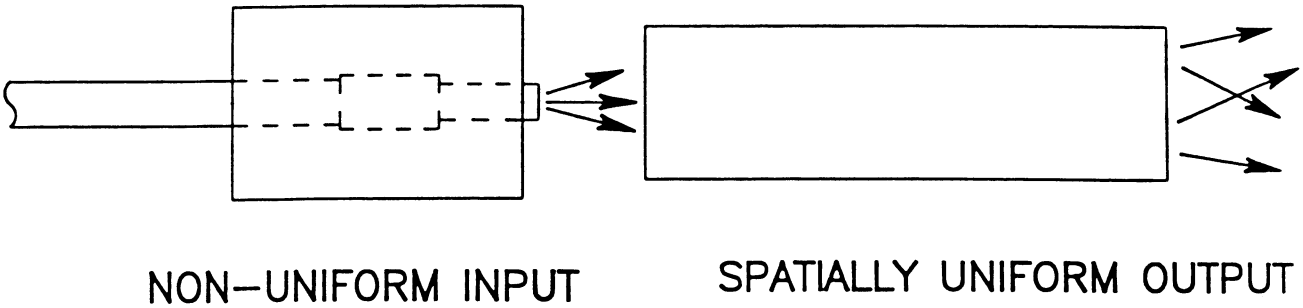
TUNNELS CAN BE SQUARE, RECTANGULAR, HEXAGONAL.

SOLID LIGHT TUNNEL IN A CYLINDER WITH MINIMAL EDGE CONTACT



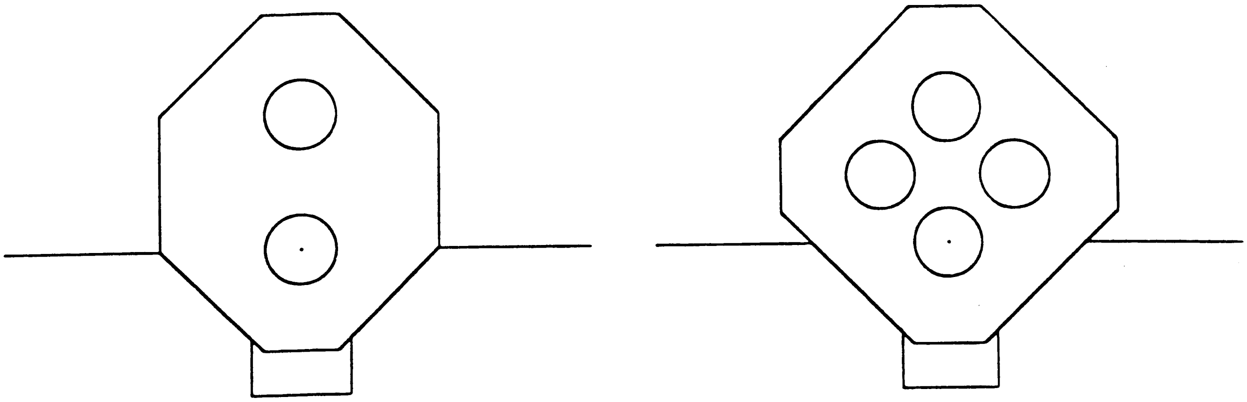
HOLLOW TUNNEL IN A V



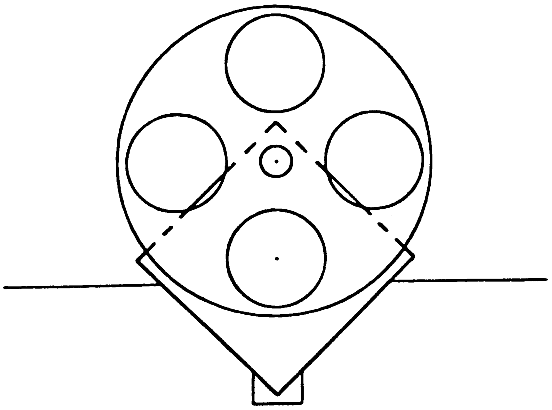


ILLUMINATION GADGETS

MULTI–POSITION FILTER HOLDERS



TURRET MOUNTED ON A SQUARE CYLINDER

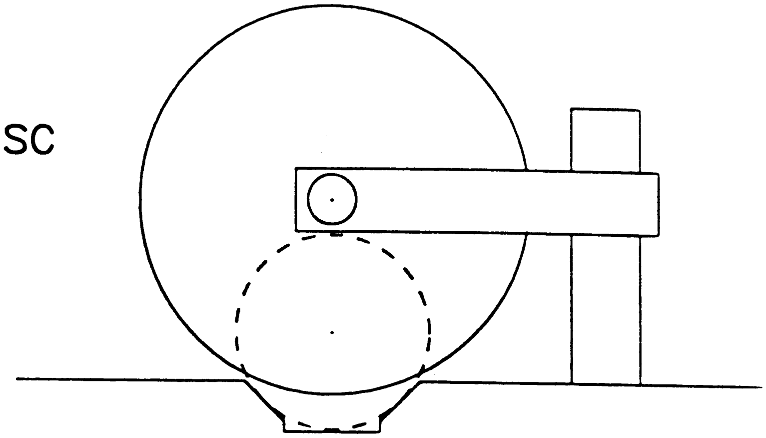


SUCH MULTI–POSITION DEVICES ARE ALSO USEFUL FOR POLARIZATION COMPONENTS.

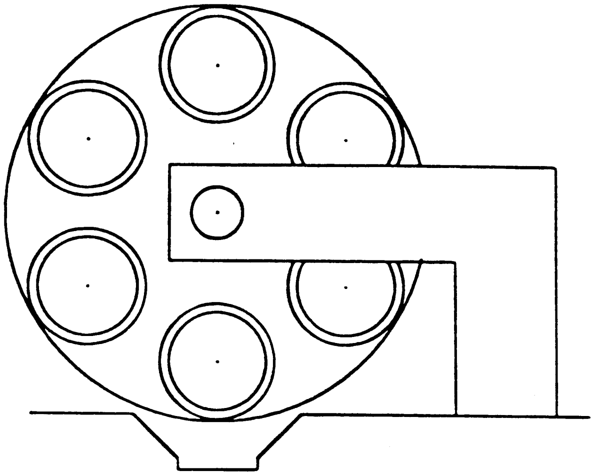
ILLUMINATION GADGETS

SUCH DEVICES CAN BE CONVENIENTLY MOUNTED ON A COUPLING V.

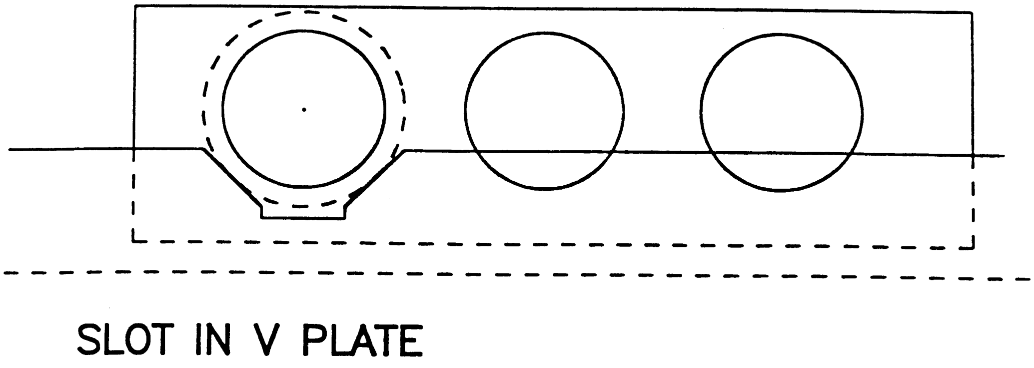
VARIABLE DENSITY DISC



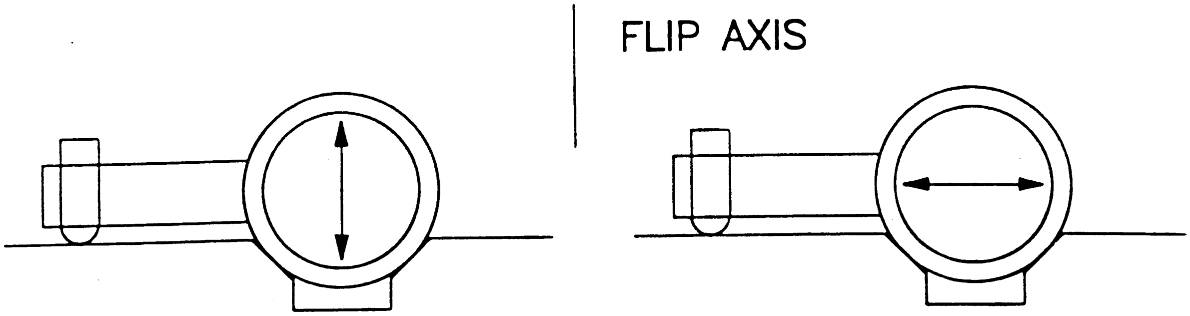
TURRET WITH FILTERS

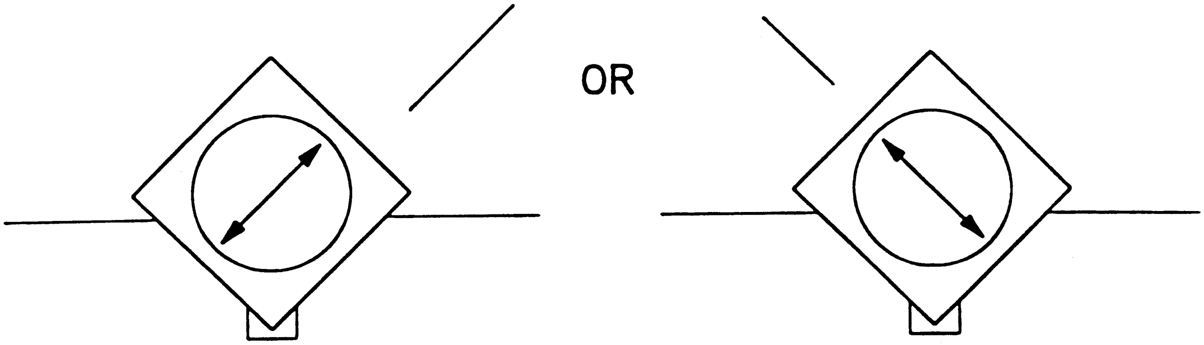


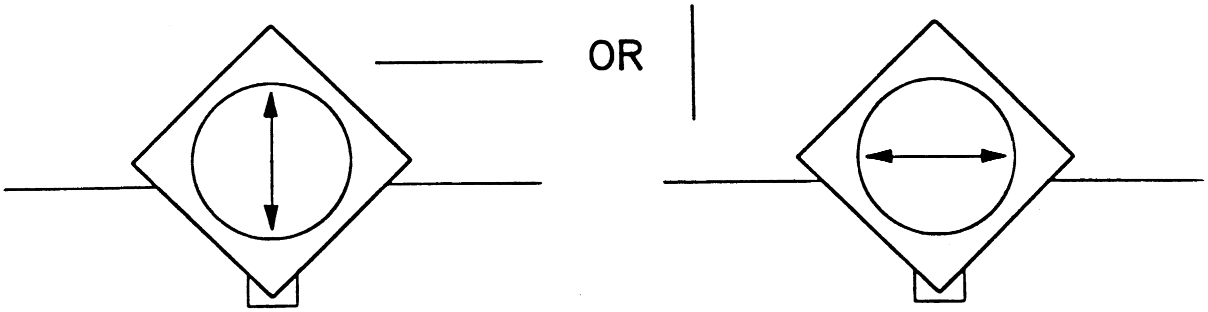
SLIDE WITH FILTERS

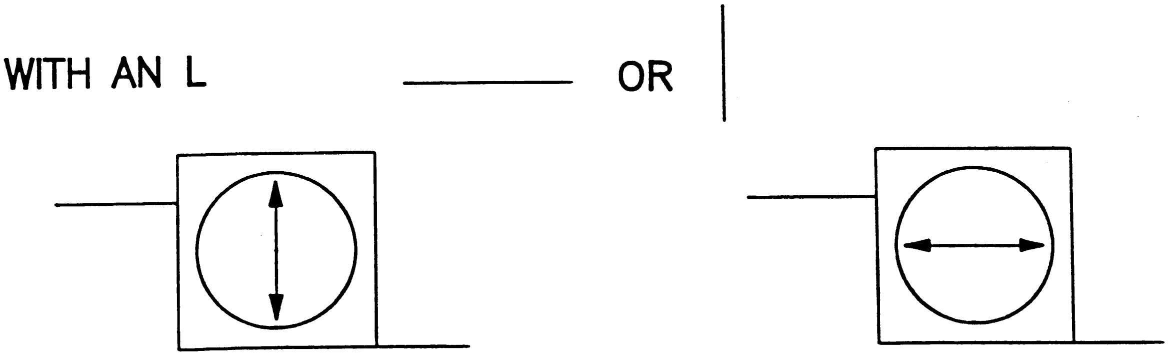


CONVENIENT PRINCIPAL DIRECTIONS AND FLIP AXES TO LOCATE THEM









PLANAR POLARIZATION COMPONENTS

CONSIDERED HERE:
SHEET POLARIZER
PLATE AND SHEET RETARDERS

SYMMETRIES:
TWO PRINCIPAL DIRECTIONS 90° APART
NO CENTER
HOMOGENEOUS, ANISOTROPIC
UNCHANGED BY 180° ROTATION

AZIMUTHAL ANGLE CONTROLLED

MOST IMPORTANT RELATIVE ANGLES: 0° AND 90°

SOMETIMES 45°

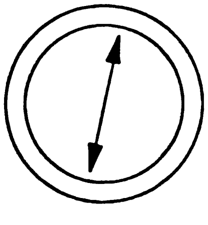
THE V PLATE SURFACE IS A CONVENIENT REFERENCE FOR ANGLE, AS IS THE V ITSELF

NON-ROUND CYLINDERS ARE USEFUL
SQUARE CYLINDERS GIVE 0° AND 90°
OCTAGONAL CYLINDERS ALSO GIVE 45°

ROUND CYLINDERS NEED AZIMUTH ARMS.

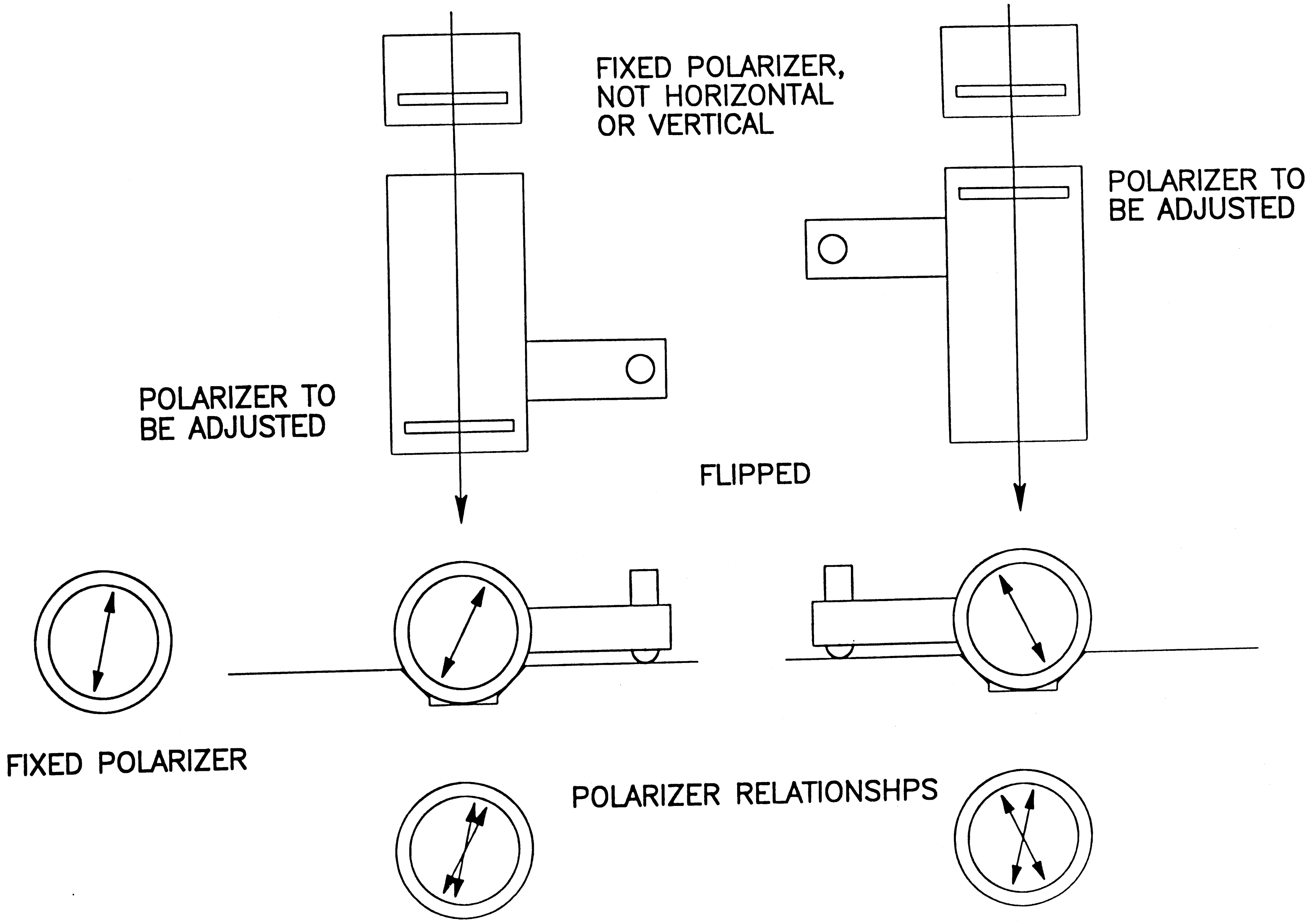
FLIPPING IS USED FOR ORIENTATION.
(180° ROTATION GIVES NO INFORMATION.)

SCHEMATIC

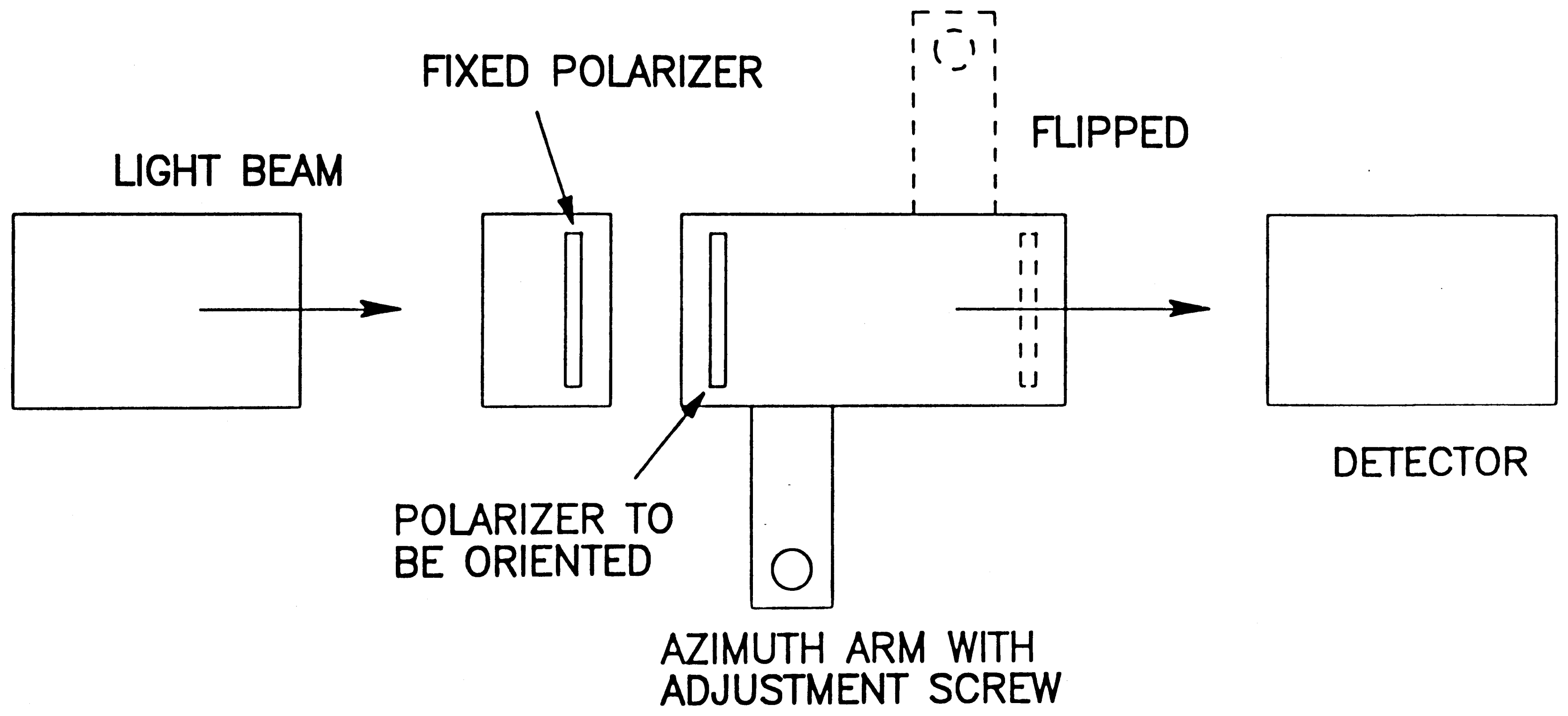


ONE PRINCIPAL DIRECTION OF A POLARIZATION ELEMENT IS INDICATED BY A DOUBLE-ENDED ARROW.
THE ORTHOGONAL DIRECTION IS NOT SHOWN.

SHEET POLARIZER ORIENTATION BY FLIPPING



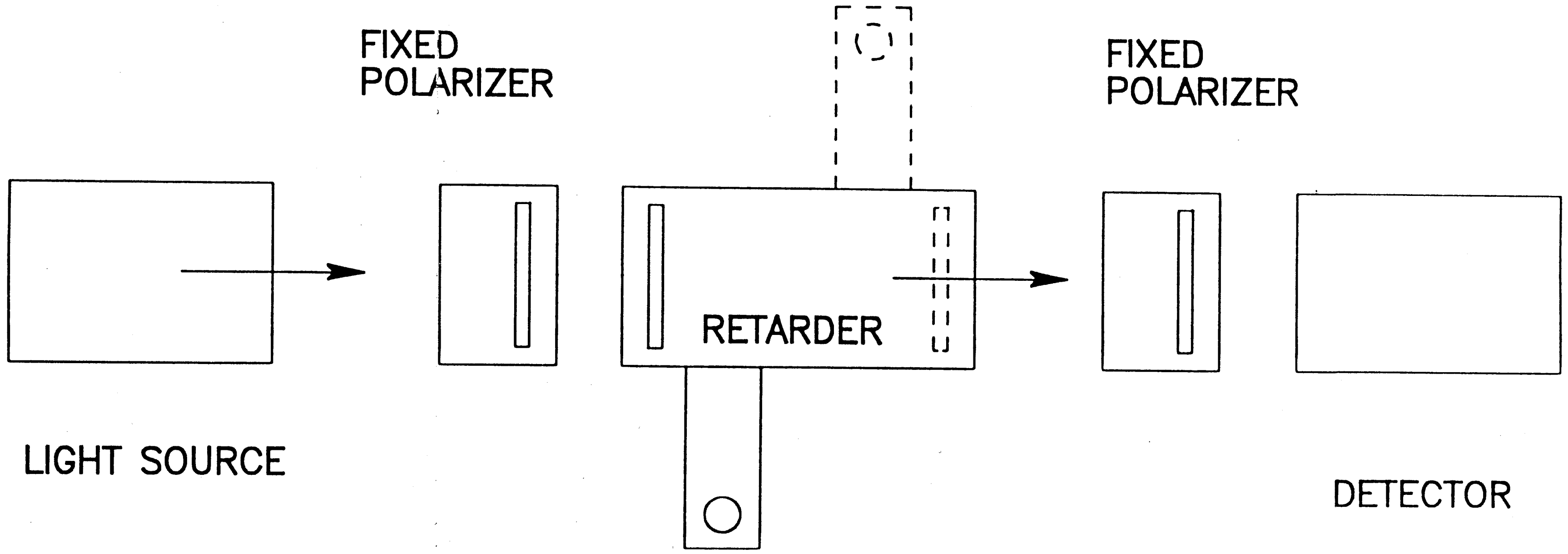
SHEET POLARIZER ORIENTATION BY FLIPPING A ROUND CYLINDER WITH AN AZIMUTH ARM



THE TANGENT SCREW OF THE ARM IS ADJUSTED TO EQUALIZE THE
DETECTED POWER FOR THE FLIPPED POSITIONS.
THE POLARIZER IS THEN EITHER HORIZONTAL OR VERTICAL.

RETARDER ORIENTATION BY FLIPPING

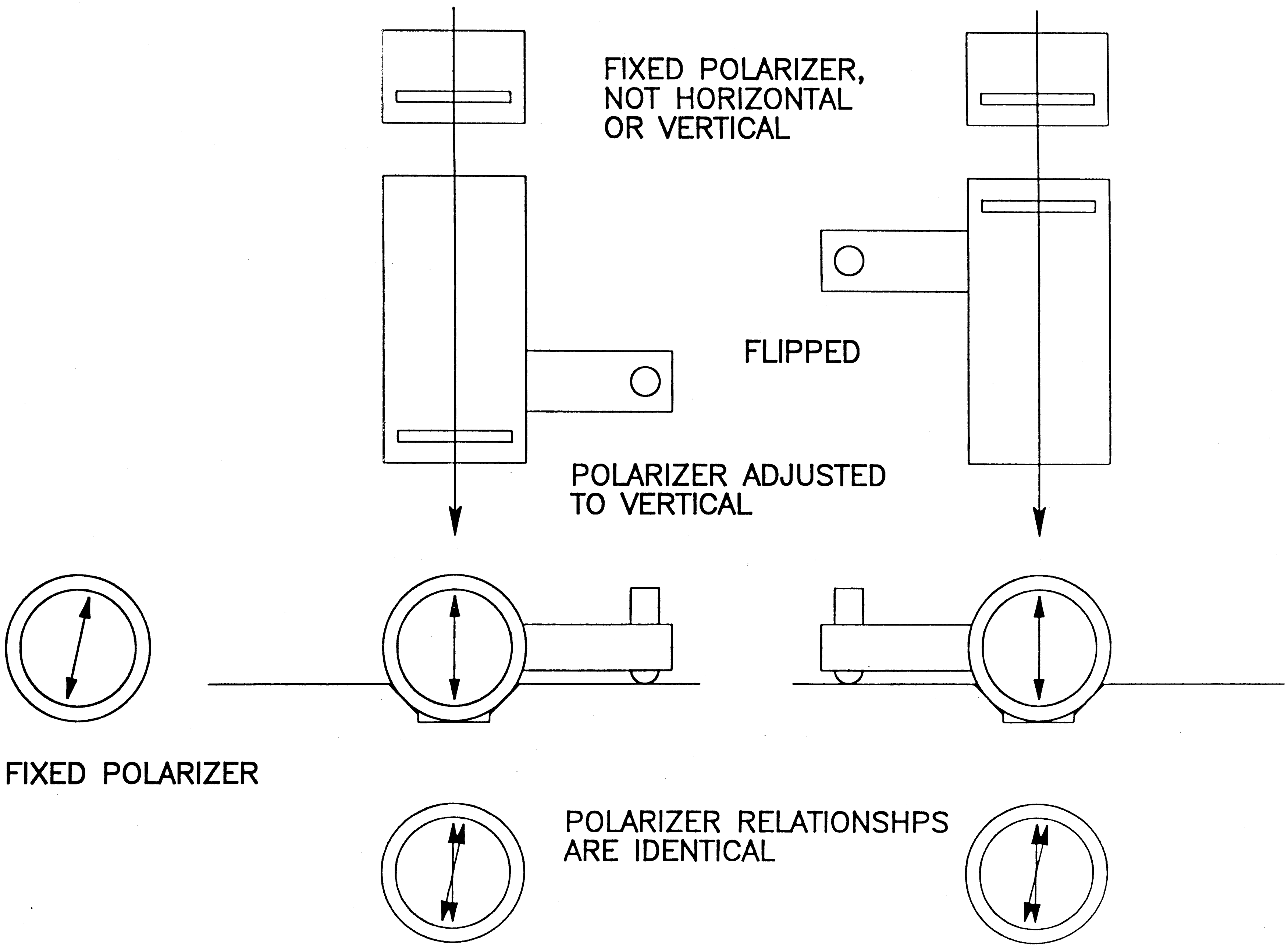
THE RETARDER IS FLIPPED BETWEEN FIXED POLARIZERS.



THE TANGENT SCREW OF THE ARM IS ADJUSTED TO EQUALIZE THE DETECTED POWER FOR THE FLIPPED POSITIONS.

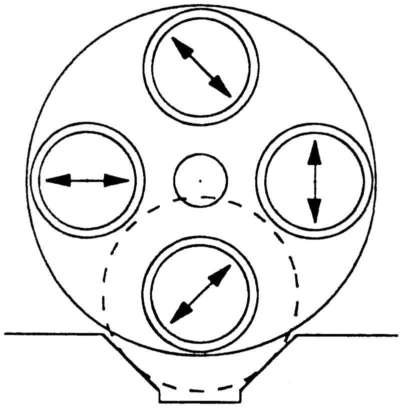
THE FIXED POLARIZER ANGLES ARE NOT CRITICAL, BUT THEY SHOULD NOT BOTH BE HORIZONTAL OR VERTICAL.
APPROXIMATELY +45 DEG AND −45 DEG IS GOOD.

VERTICALLY ORIENTED SHEET POLARIZER

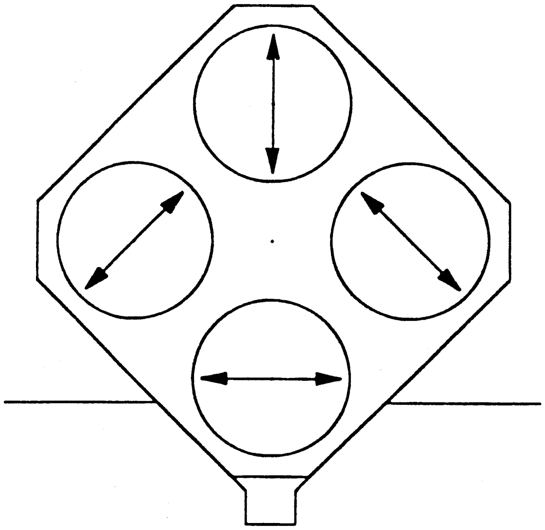


FOUR ORIENTATIONS

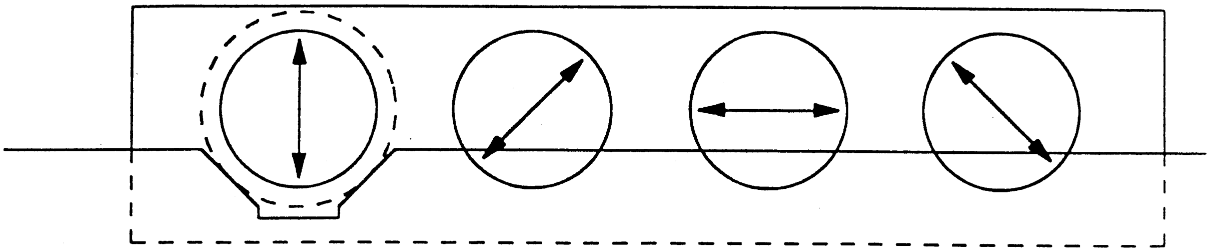
ROTATING TURRET



INDEXING SQUARE

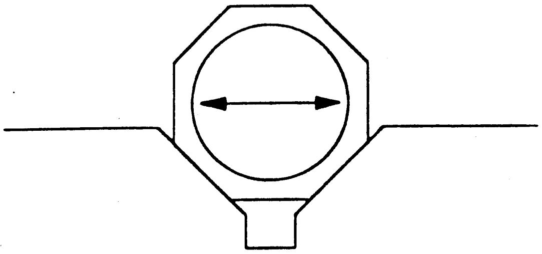


INDEXING SLIDE

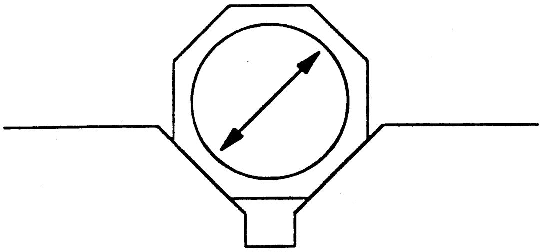


OCTAGONAL CYLINDERS FOR 45° STEPS

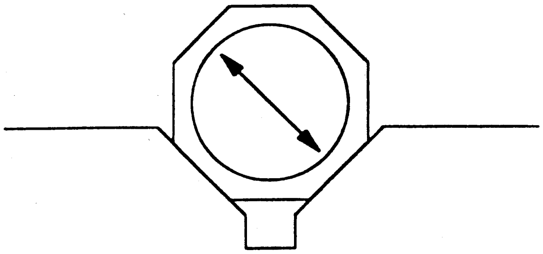
THE OCTAGON CAN BE ALIGNED HORIZONTALLY OR VERTICALLY AND THEN USED AT +/– 45°.



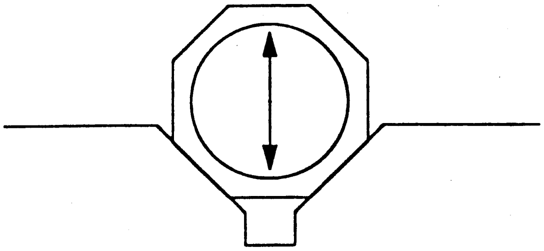
0°



+45°

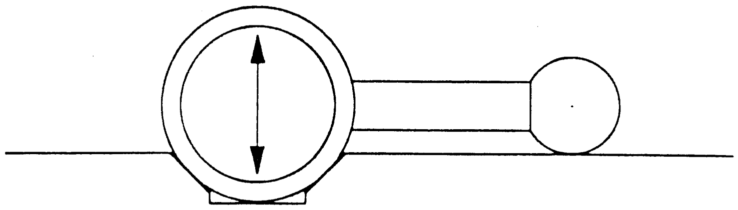


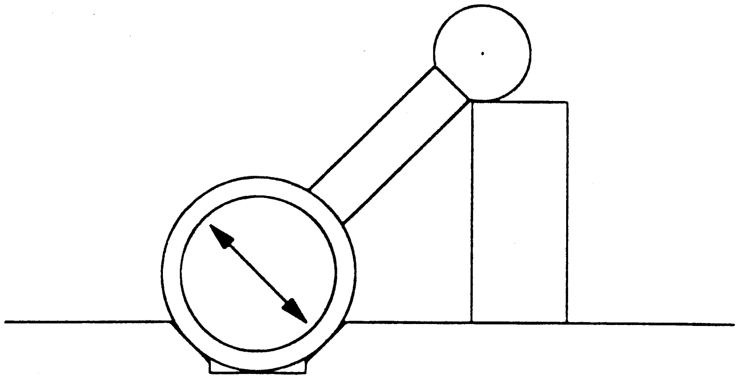
–45°

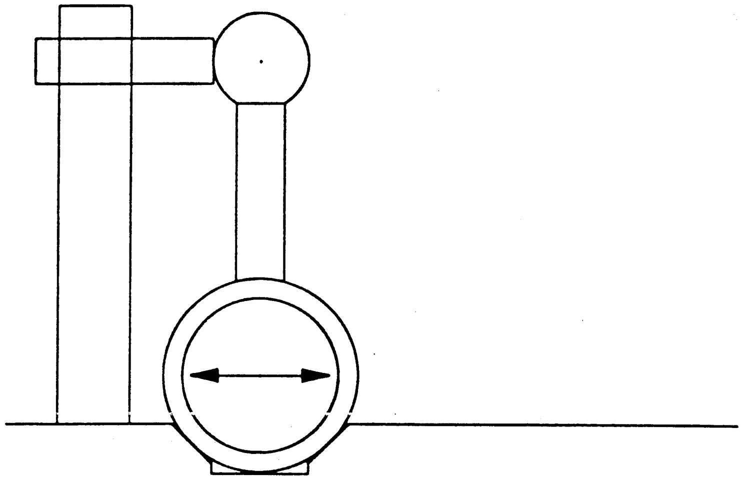


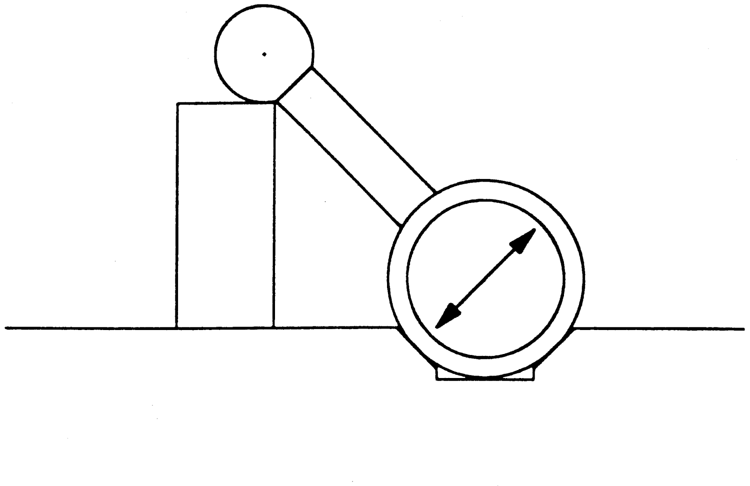
90°

FOUR ORIENTATIONS





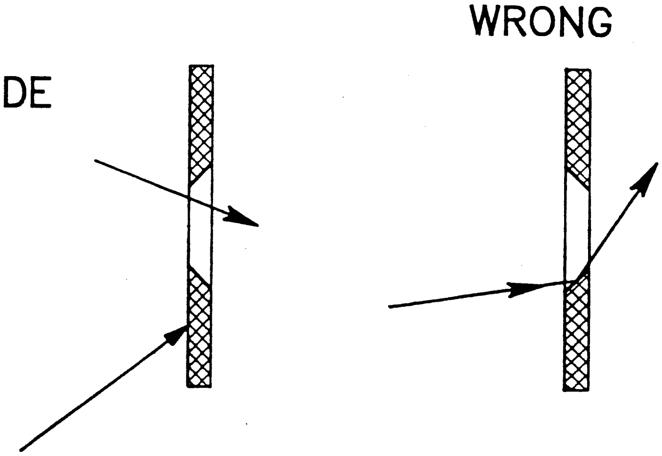




BLOCKING LIGHT

ALL STRUCTURES THAT BLOCK LIGHT ARE REFERRED TO HERE AS 'APERTURES.' THESE INCLUDE:
- APERTURE STOPS
- FIELD STOPS
- BAFFLES

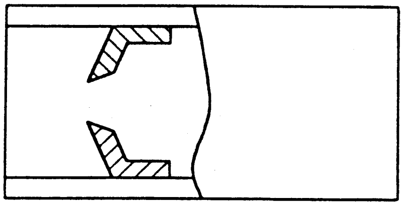
APERTURE CONSTRUCTION



SHARP EDGE ON SIDE OF INCIDENT LIGHT

BLACK SURFACE, EITHER SMOOTH OR ROUGH, DEPENDING ON CIRCUMATANCES

APERTURES CAN BE NON-PLANAR.



SUPPRESSING UNWANTED LIGHT

TASKS

DELIMIT FIELDS AND ANGLES

KEEP UNWANTED LIGHT OUT

KEEP DANGEROUS LIGHT IN

SUPPRESS UNWANTED LIGHT PRODUCED INTERNALLY

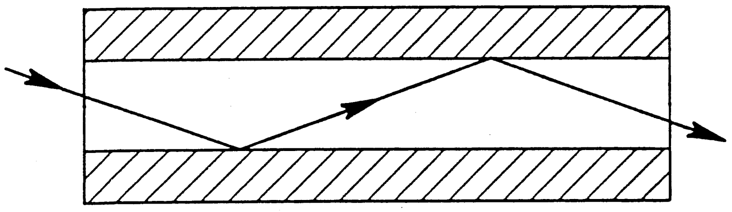
DONE BY BLOCKING AND ABSORBING LIGHT AND BY SEALING

DESIGN IN LIGHT CONTROL FROM THE BEGINNING.

ELIMINATE UNWANTED LIGHT AS FAR UPSTREAM AS POSSIBLE, INCLUDING LIGHT OF UNWANTED WAVELENGTHS.

A CYLINDER IN V PROBLEM:

STRAY LIGHT IS CHANNELED BY BOTH CYLINDERS AND VS.

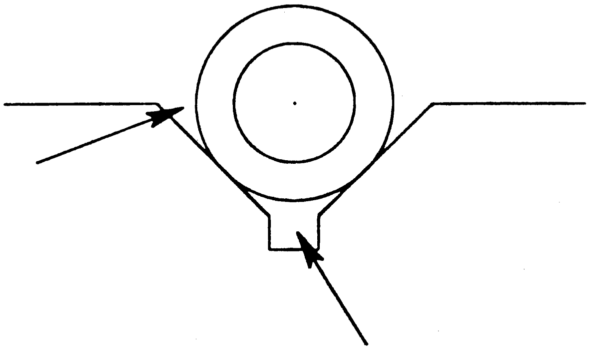


ABSORPTION IS DIMINISHED AT OBLIQUE ANGLES.

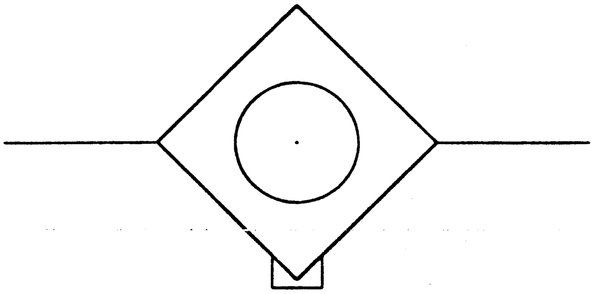
APERTURES WITH NON-ROUND OUTER SHAPES

EXAMPLE:

LIGHT CAN PASS OUTSIDE OF THIS APERTURE.

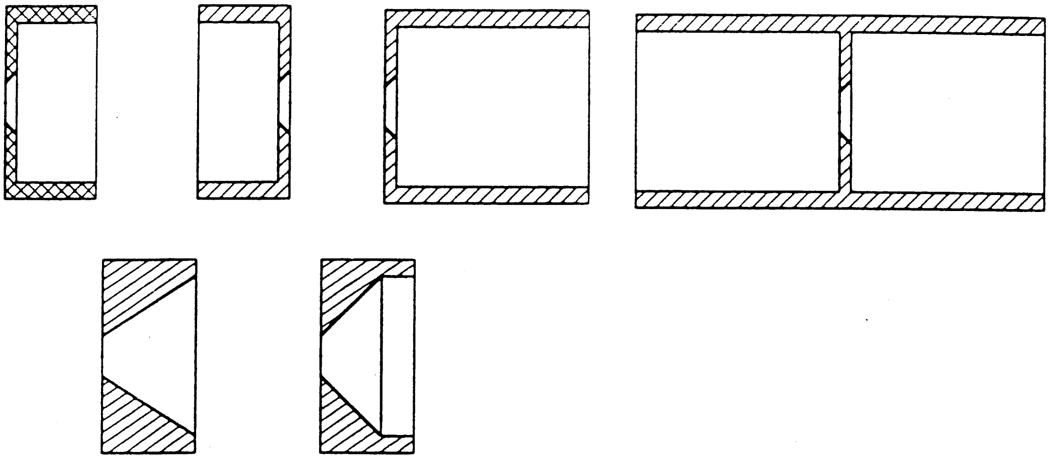


THIS IS BETTER.

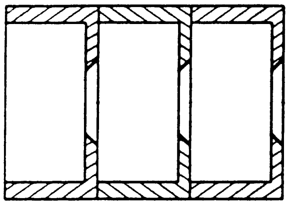


SELF STANDING APERTURES

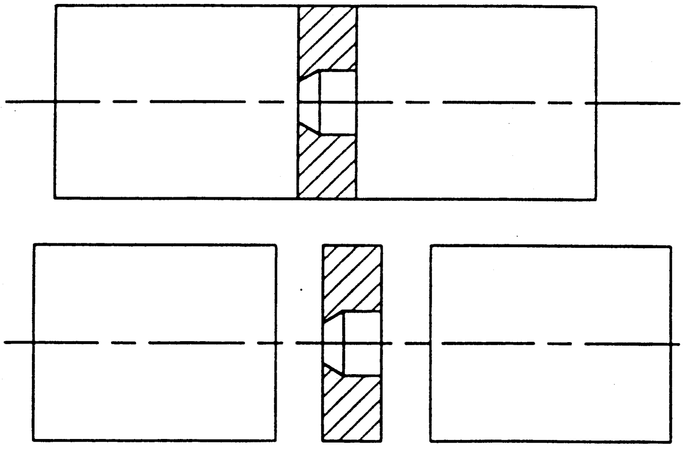
CAN BE USED IN A V.
MAY BE ROUND OR NON-ROUND.



STACKED

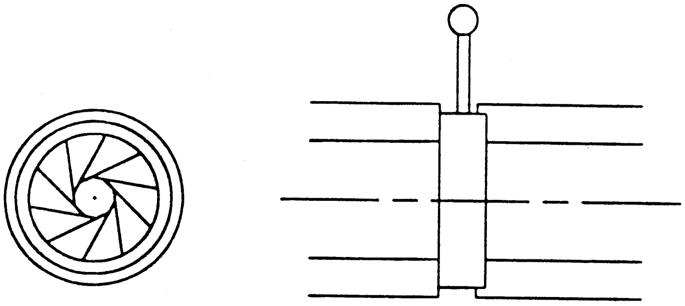


AXIAL SPACER COMBINED WITH BAFFLE

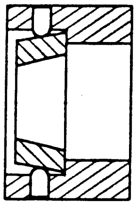


MISCELLANEOUS

IRISES CAN BE HELD BY CYLINDERS OR SELF–STANDING



FOR EXTREME ACCURACY OR ADJUSTABILITY, APERTURES CAN BE MOUNTED ON OR INTEGRAL WITH CENTERING CONES.

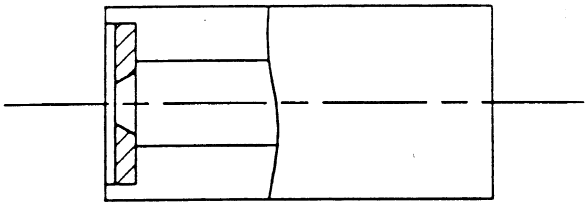


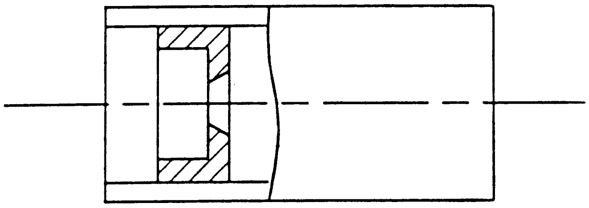
SHUTTERS CAN SOMETIMES BE MOUNTED ON CYLINDERS.

EDM CAN CREATE NON–ROUND HOLES AND HOLES IN THIN MATERIAL

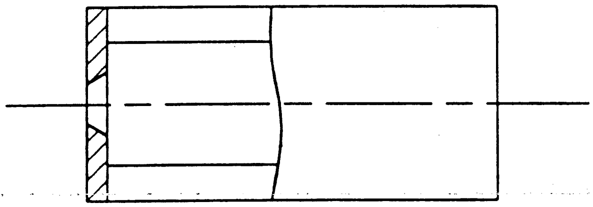
APERTURES ADDED TO CYLINDERS

APERTURE PRESSED INTO, CEMENTED TO, OR
THREADED IN CYLINDER





FULL DIAMETER APERTURE CEMENTED OR SCREWED
ONTO THE CYLINDER END



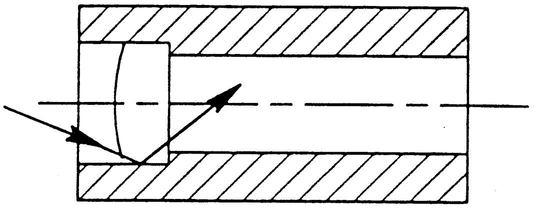
BEWARE OF DISTORTING CYLINDER BY PRESSING IN
AN APERTURE.

PRESSED IN APERTURES CAN BE BLACK PLASTIC TO
REDUCE FORCE AND EASE TOLERANCES.

INCREASED LIGHT BLOCKING WITH LARGER LENS

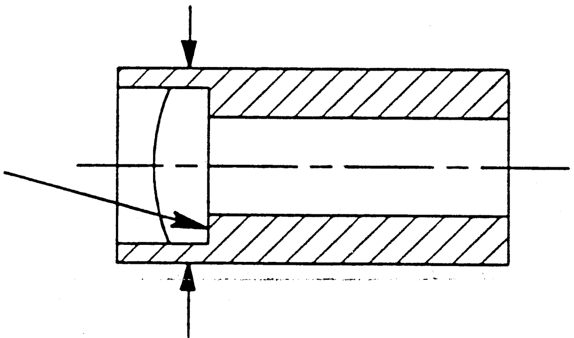
EXAMPLE

LENS JUST LARGE ENOUGH TO PASS WANTED LIGHT



A STRAY LIGHT PATH

OVERSIZE LENS AND BLOCKING SURFACE



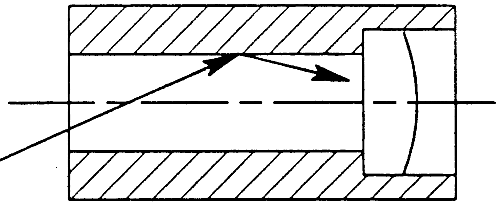
THE SAME RAY NOW
HITS THE LENS SEAT

LARGER

BUILT IN BAFFLES

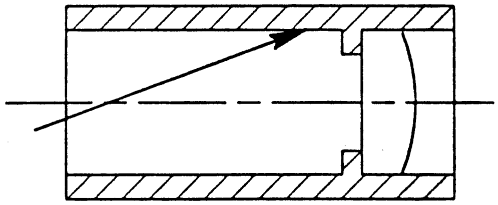
EXAMPLE

HOLE JUST LARGE ENOUGH FOR CLEAR APERTURE



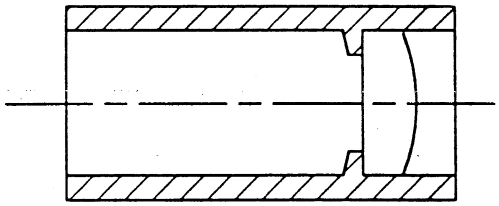
A STRAY LIGHT PATH

OVERSIZE HOLE WITH LENS SEAT ACTING AS BAFFLE



A STRAY LIGHT PATH

END OF DRILL USED, INSTEAD OF BORING TOOL



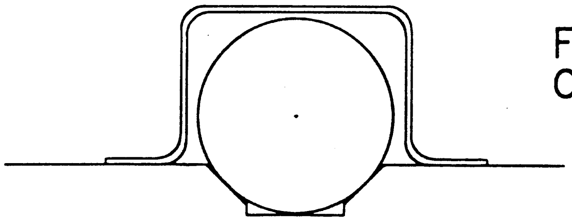
MACHINING BAFFLE SIDES DOES NOT REQUIRE ACCURACY.

ROOFS

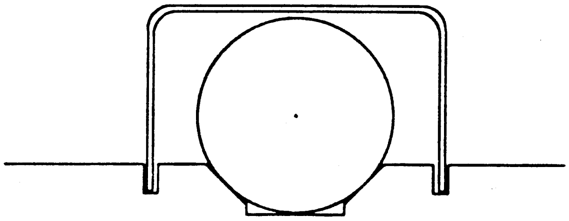
MOUNTED ON V PLATE

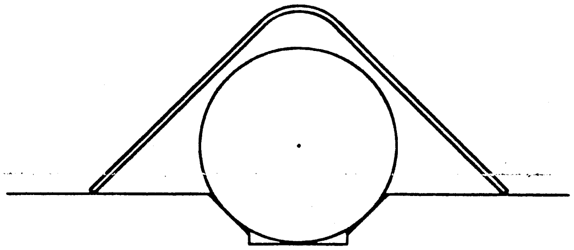
ROOFS CAN BE MADE WITH SHEET METAL, ALUMINUM FOIL, ETC.

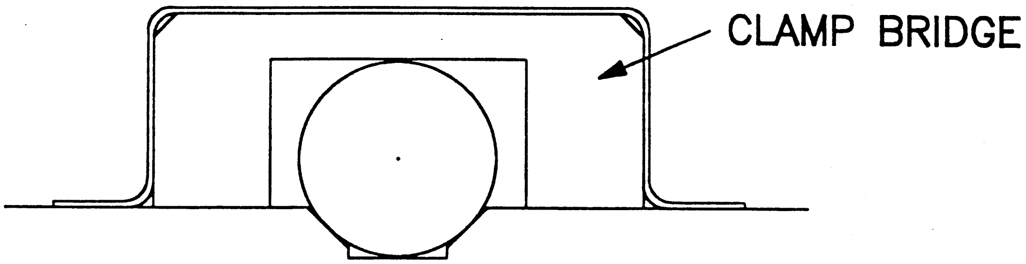
EXAMPLES



FREE STANDING
OR SECURED

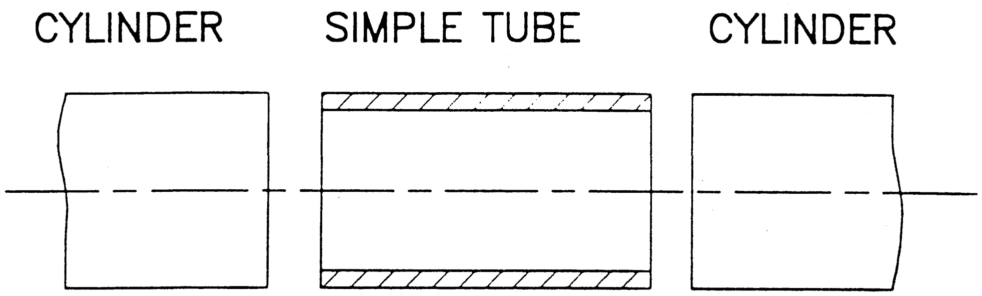






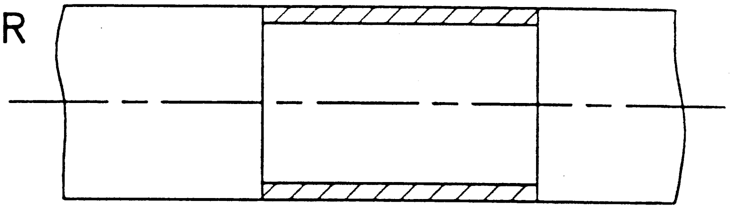
TUBES

TUBES BETWEEN CYLINDERS KEEP LIGHT OUT OR IN

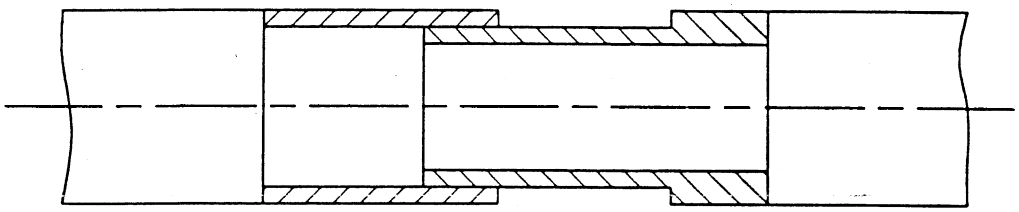


INEXPENSIVE THIN—WALLED TUBING MAY WORK.
SHAPE AND SIZE ARE NOT CRITICAL

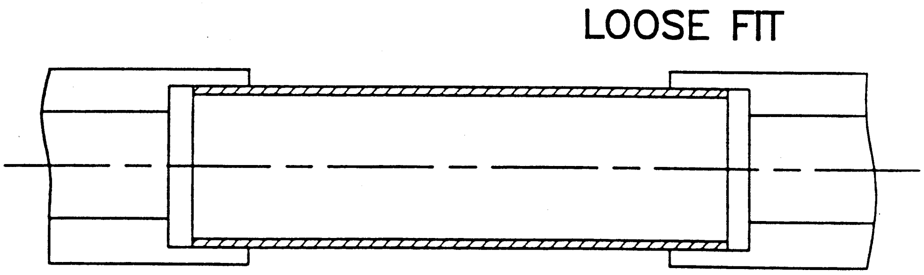
TUBE DOUBLING AS SPACER



TELESCOPING TUBE PAIR
CAN ALSO BE THREADED FOR ADJUSTABLE SPACING



CAPTURED TUBE

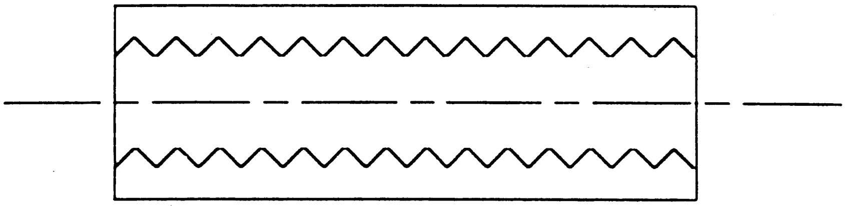


TUBES CAN HAVE BAFFLES, ANTIGLARE THREAD, CONTAIN FLOCKING

MISCELLANEOUS

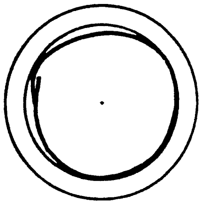
ANTI–GLARE THREAD WITH SHARP TOPS

(MECHANICAL MATING IS NOT REQUIRED.)

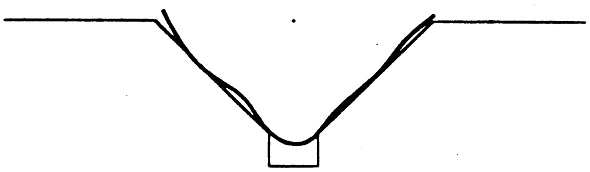


BLACK FLOCKING IS GOOD FOR LABORATORY USE:

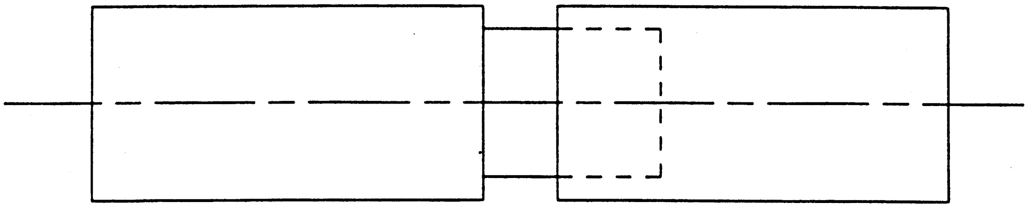
INSIDE CYLINDERS
AND TUBES



ON VS WHERE NO CYLINDERS SIT

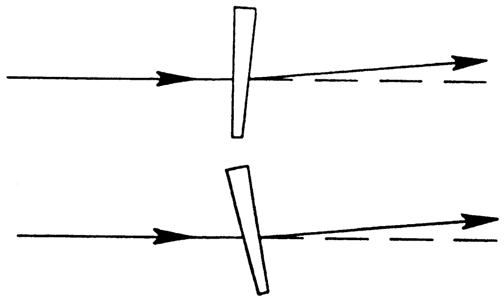


INTERPENETRATING CYLINDERS MAKE A LIGHT SEAL.



THE THIN PRISM

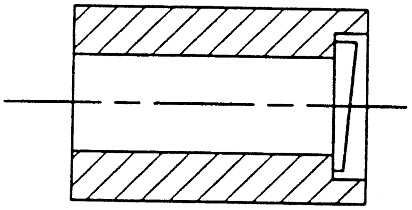
THIN PRISM

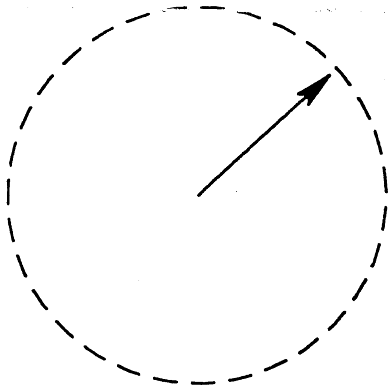


ANGULAR DEVIATION IS NEARLY INDEPENDENT OF PRISM ANGLE.

(DEVIATION IS EXAGERRATED IN THESE DIAGRAMS.)

THIN PRISM IN A ROUND CYLINDER





DIRECTION VECTORS SEEN END ON FOR A ROTATING CYLINDER

BEAM POSITION AND DIRECTION CONTROL

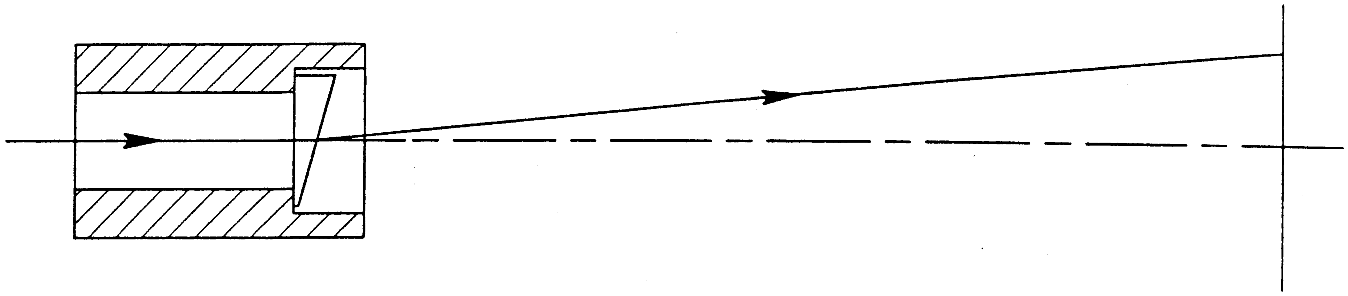
APPLIES TO BEAMS MORE OR LESS ALONG THE AXIS.

MAKES USE OF THIN PRISMS AND PLANE PARALLEL PLATES IN CYLINDERS THAT ARE ROTATED AND TRANSLATED.

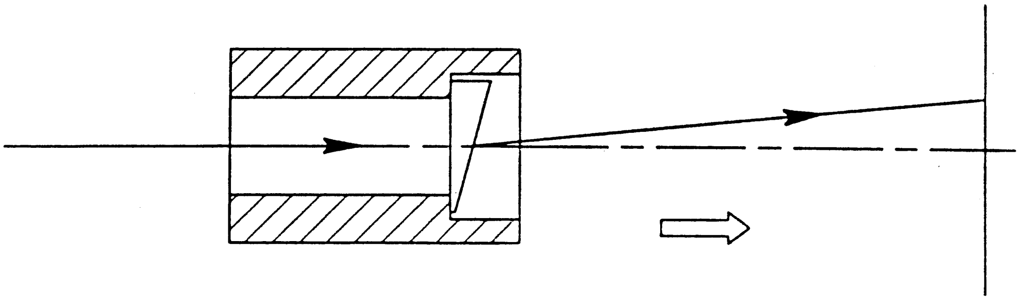
ABERRATIONS MAY RESULT, ESPECIALLY ASTIGMATISM.

PRISM FOR SPOT POSITION CONTROL

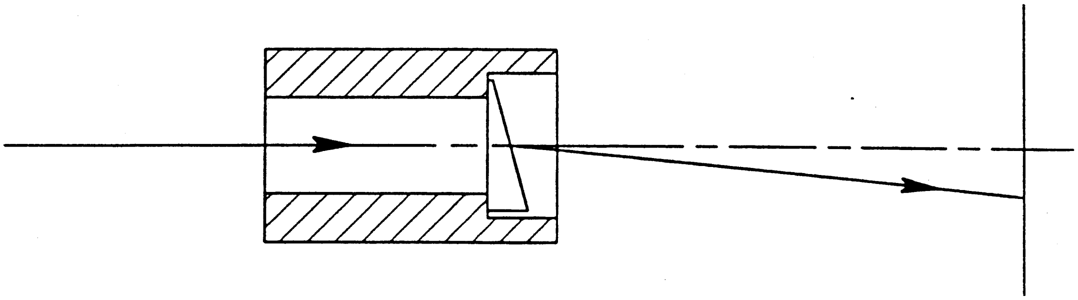
A CYLINDER WITH A PRISM IS ROTATED AND MOVED AXIALLY TO CONTROL THE BEAM INTERSECTION POSITION IN A PLANE.
A DIRECTION CHANGE RESULTS.



PRISM TRANSLATED TOWARD RECEIVING PLANE

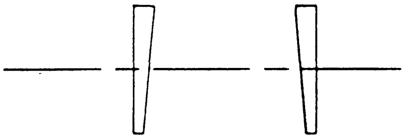


PRISM ROTATED 180°



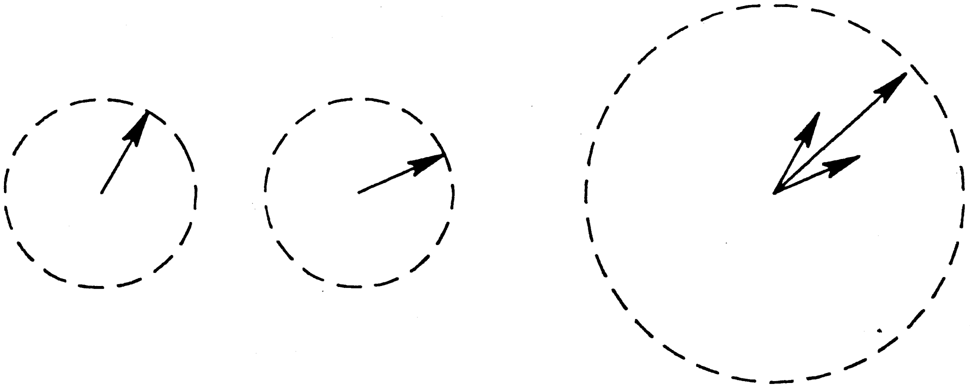
RISLEY PRISM

TWO NEARBY THIN PRISMS IN SERIES ABLE TO ROTATE ABOUT A COMMON AXIS



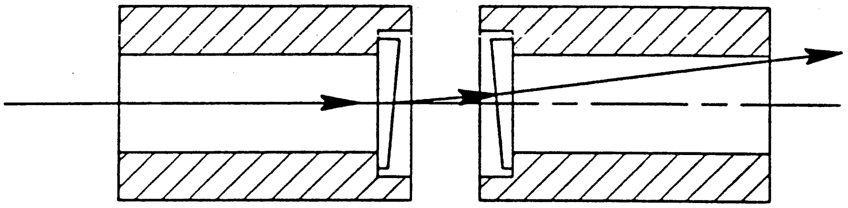
THEIR ANGULAR DEVIATIONS ADD VECTORIALLY.

INDIVIDUAL DEVIATION VECTORS AND THEIR SUM SEEN END ON

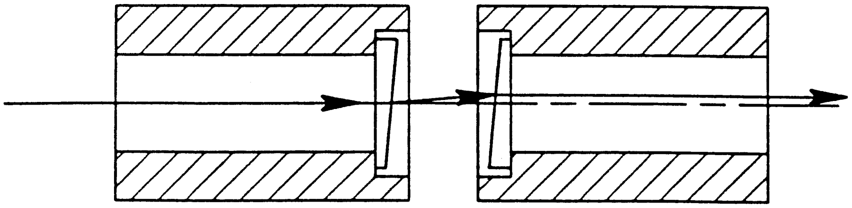


A CYLINDRICAL EMBODIMENT

ADDING

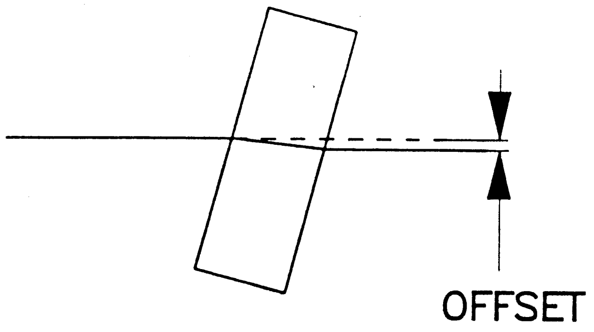


CANCELLING



TILTED PLANE PARALLEL PLATE

MOVES BEAM LATERALLY.



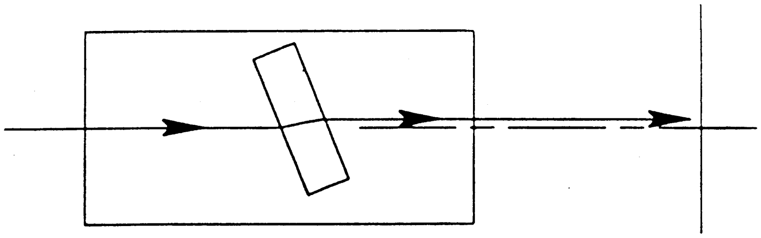
OFFSET DEPENDS ON
- PLATE THICKNESS
- PLATE ORIENTATION
- PLATE INDEX

THE MECHANICAL ROTATION AXIS IS IRRELEVANT.

ANY OF THE TILT MECHODS DESCRIBED ELSEWHERE CAN BE USED.

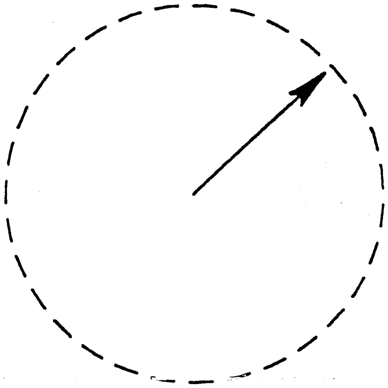
THE TILT MECHANISM NEEDS NOT BE ASSOCIATED WITH THE V.

PLATE WITH FIXED TILT IN A ROTATING CYLINDER

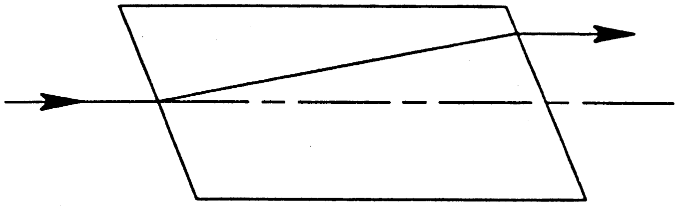


INTERSECTION POINT DESCRIBES A CIRCLE

DISPLACEMENT VECTOR SEEN END ON



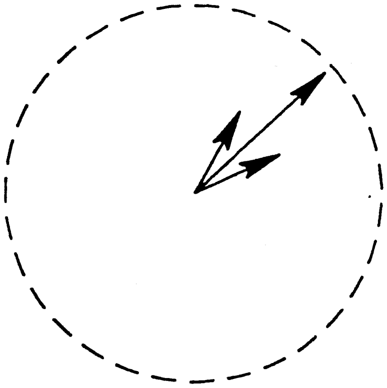
ALL–GLASS



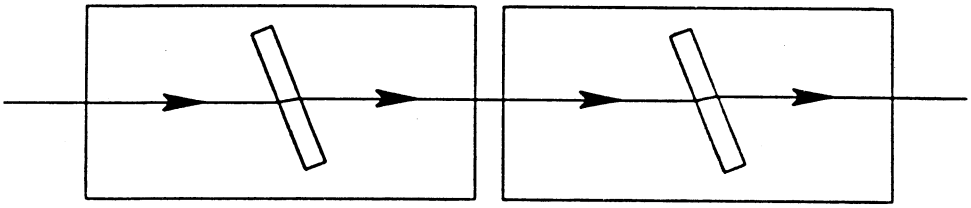
"RISLEY PLATES" FOR OFFSET ADJUSTABLE BY ROTATION

PAIR OF MATCHED TILTED PLATES IN ROUND CYLINDERS

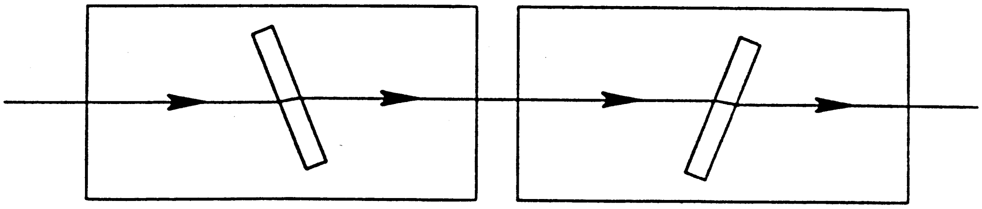
DISPLACEMENT VECTORS SEEN END ON



SET FOR MAXIMUM OFFSET

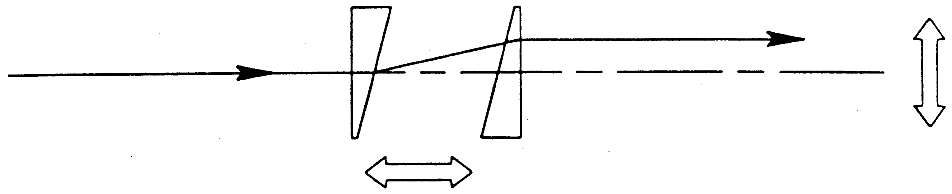


SET FOR ZERO OFFSET



VARIABLE OFFSET WITHOUT DIRECTION CHANGE

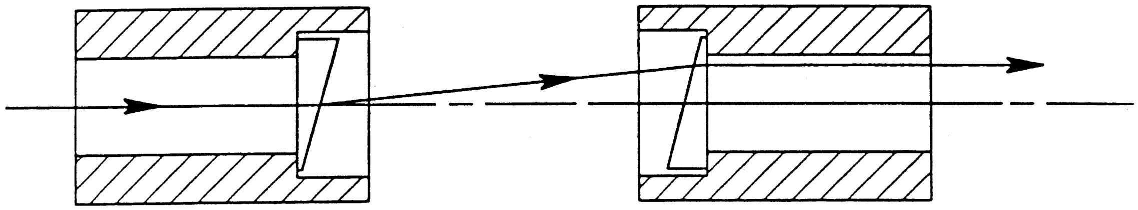
PRINCIPLE



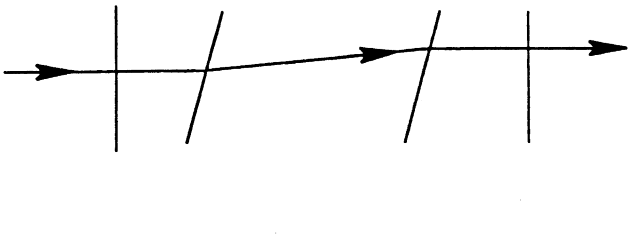
MATCHING PRISMS

PRODUCES OFFSET AND ANGLE CHANGE

RESTORES ANGLE

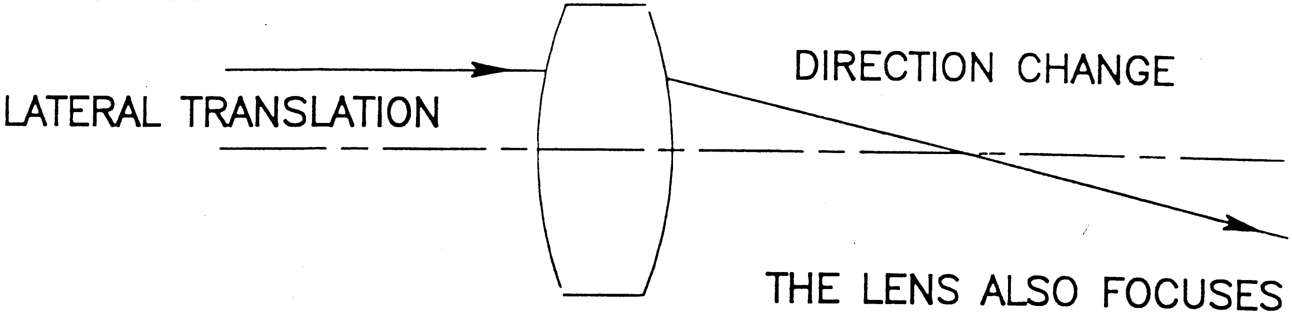


THIS IS EQUIVALENT TO A VARIABLE THICKNESS TILTED PLANE PARALLEL PLATE OF AIR WITHIN GLASS.

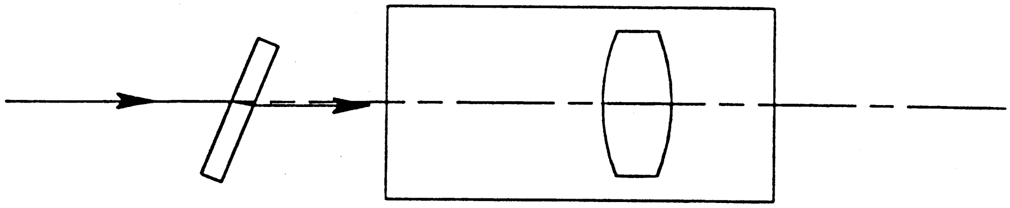


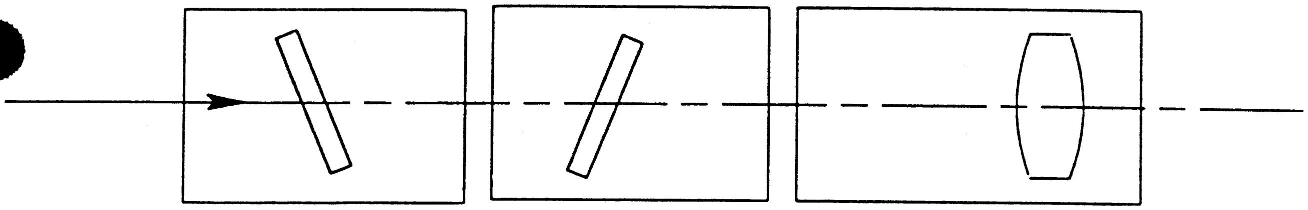
DIRECTION CONTROL BY TRANSLATION

PRINCIPLE

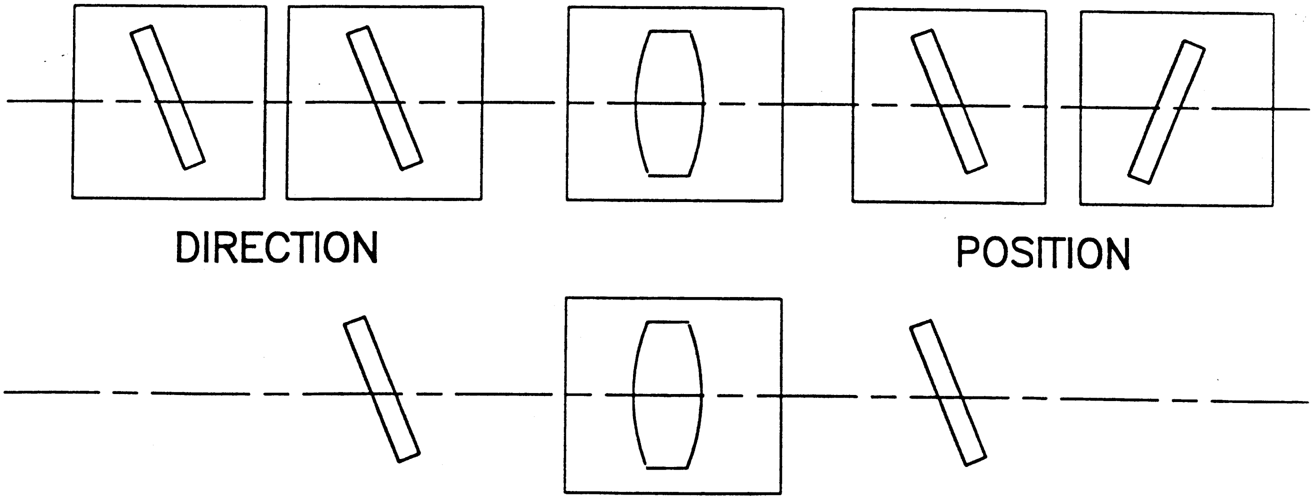


EMBODIMENTS



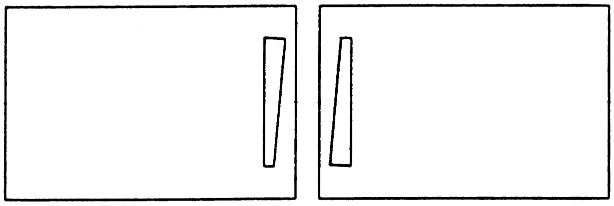


DIRECTION AND POSITION CONTROL WITH PLATES AND A LENS

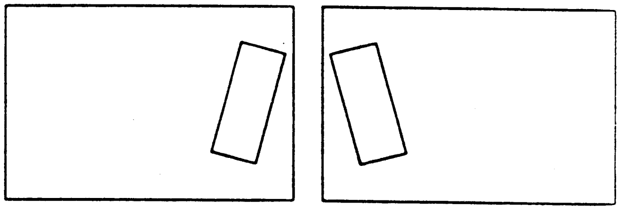


DIRECTION AND POSITION BEAM CONTROL

RISLEY PRISMS PLUS TILTED PLATES PERMIT CONTROL OF BOTH POSITION AND DIRECTION.



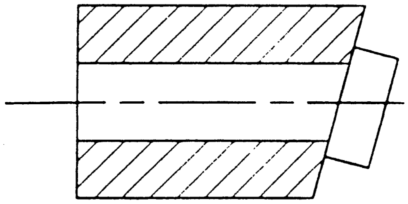
DIRECTION

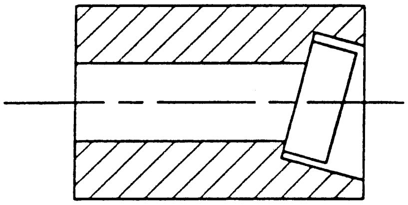


POSITION

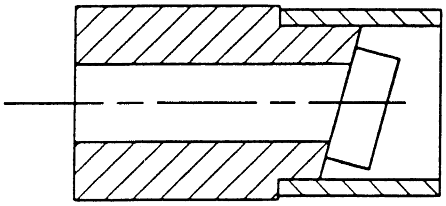
DIRECTION IS ADJUSTED BEFORE POSITION.

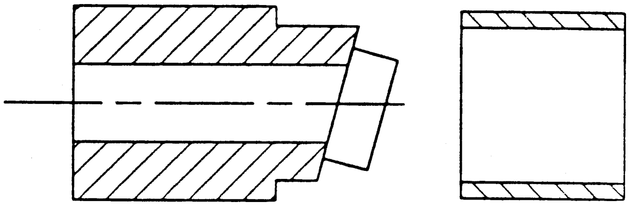
SOME WAYS TO MOUNT TILTED PLATES

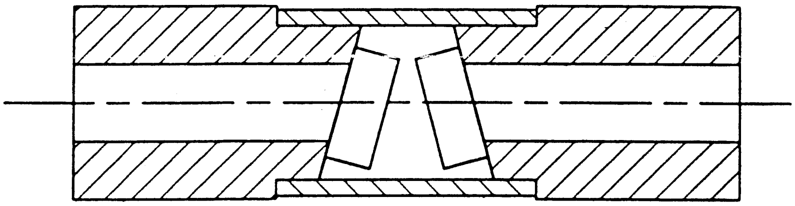




PROTECTIVE TUBE





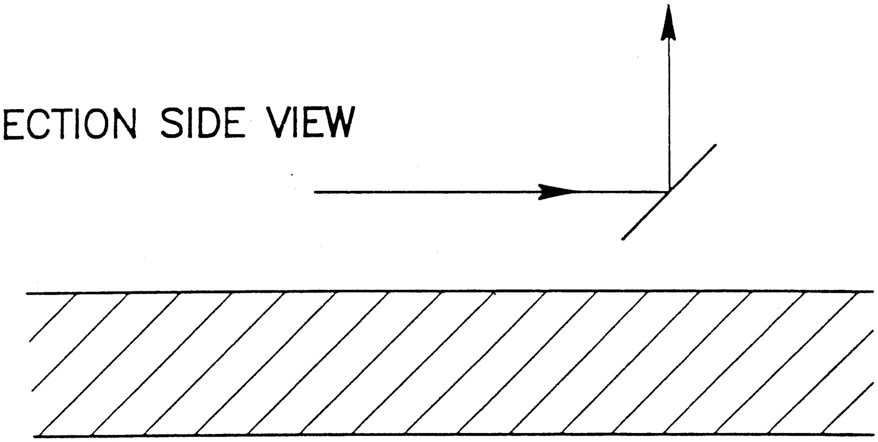


SHARED TUBE

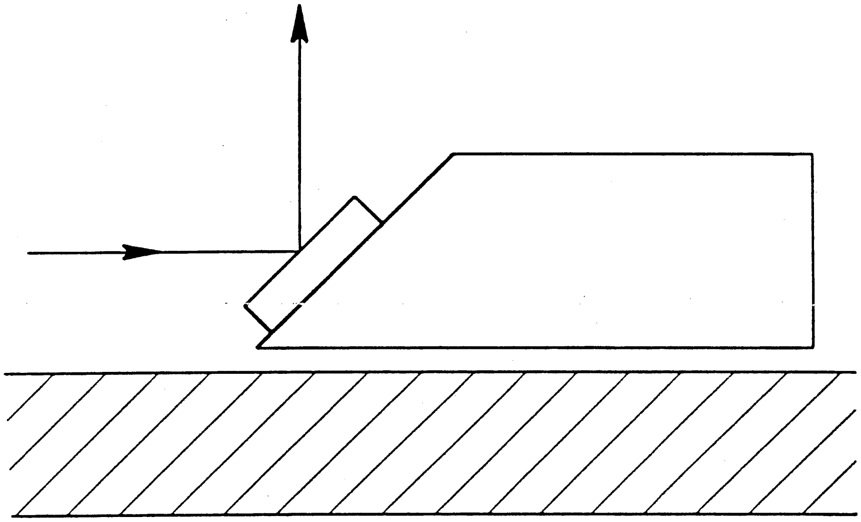
FOR BEST MATCHING:
- THE CYLINDERS CAN BE MACHINED AS A MATCHED PAIR.
- PIECES OF THE SAME PLATE CAN BE USED.

TO OR FROM ABOVE

SECTION SIDE VIEW



EXAMPLE



GETTING LIGHT INTO AND OUT OF VS

AT THE BEGINNING/END OF THE V

TO/FROM ABOVE THE V

TO OR FROM BELOW THE V

LATERALLY, ACROSS THE V PLATE

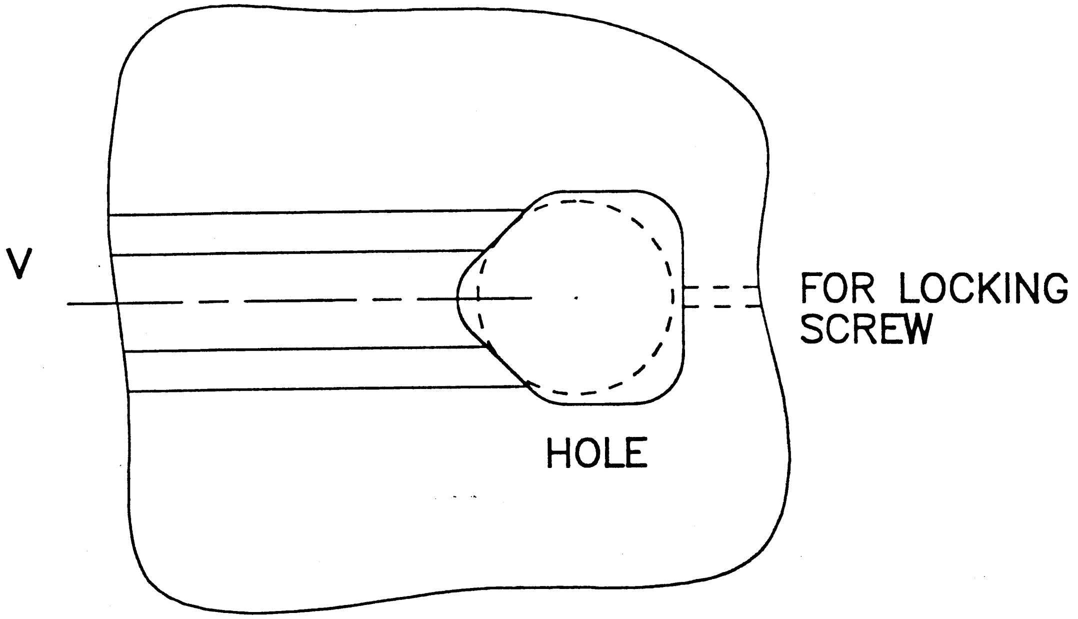
EXAMPLES OF FREE SPACE COUPLING FOLLOW.

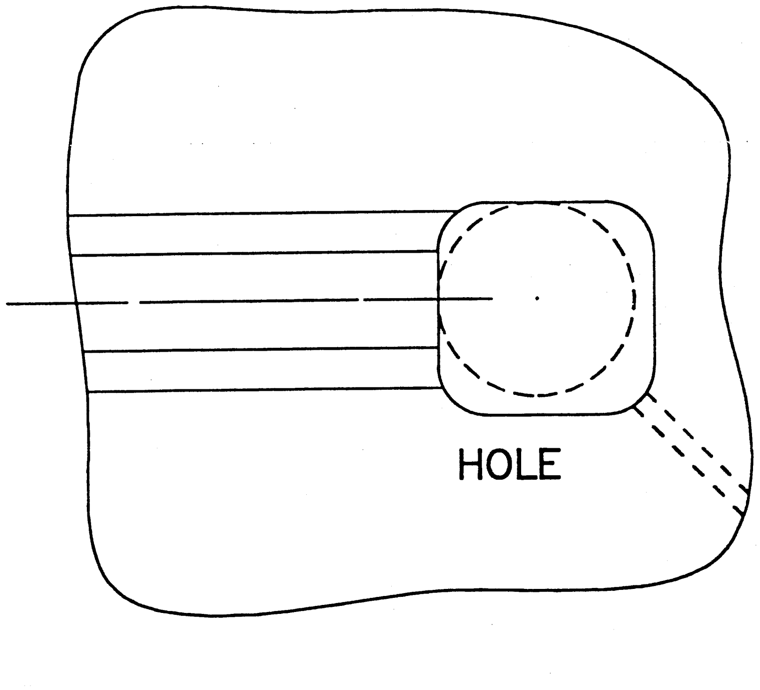
ALL BEAM DIRECTIONS CAN BE REVERSED.

THE SECTION ON ILLUMINATION TREATS FIBER COUPLING.

THROUGH HOLES ALIGNED WITH V

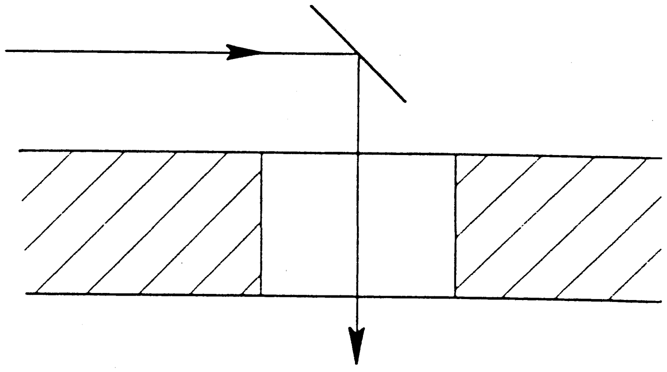
PORTION OF V PLATE SEEN FROM ABOVE



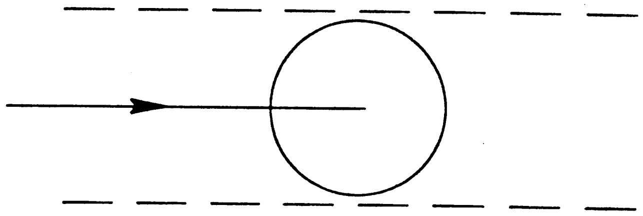


TO OR FROM BELOW

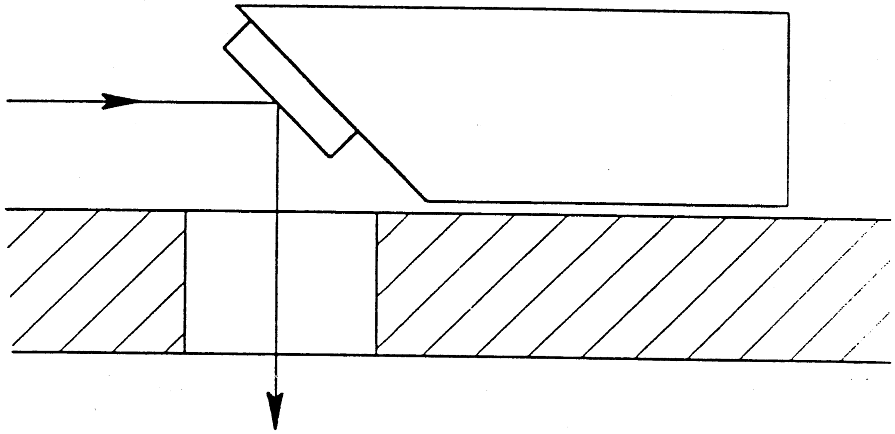
SECTION SIDE VIEW

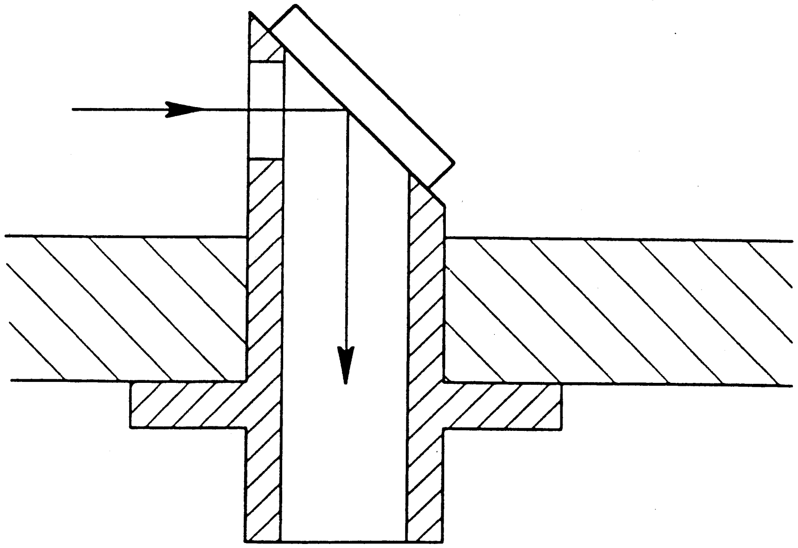


PLAN VIEW

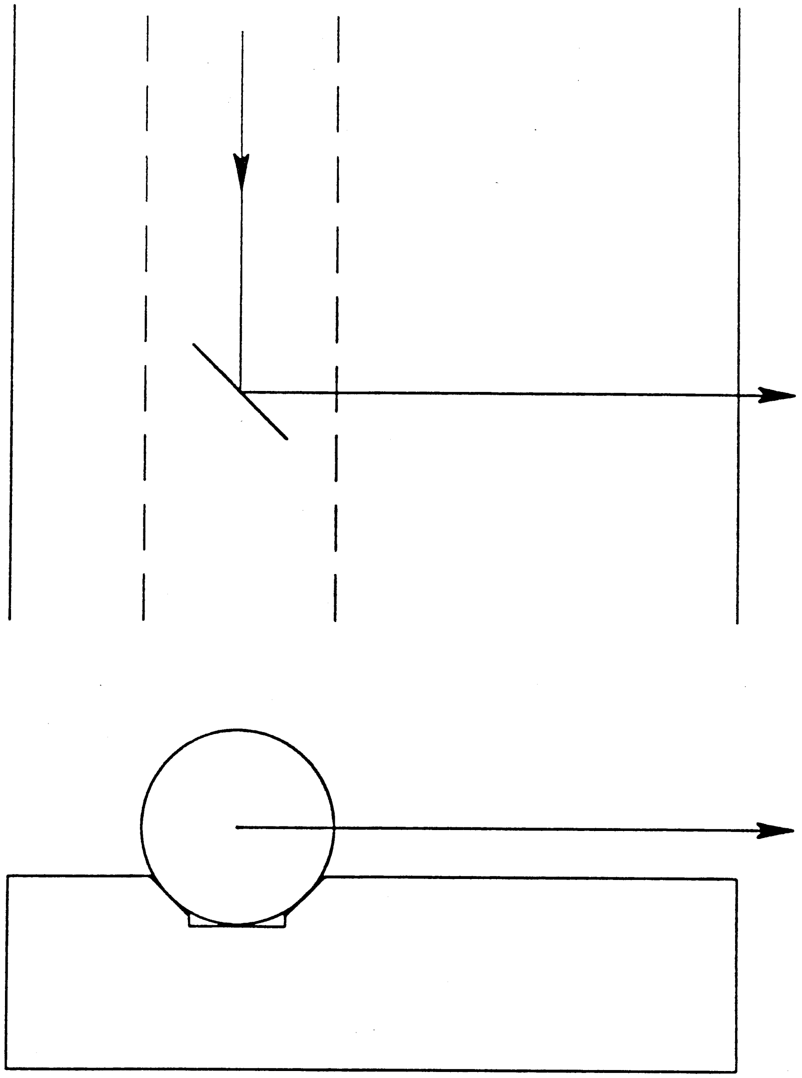


EXAMPLES



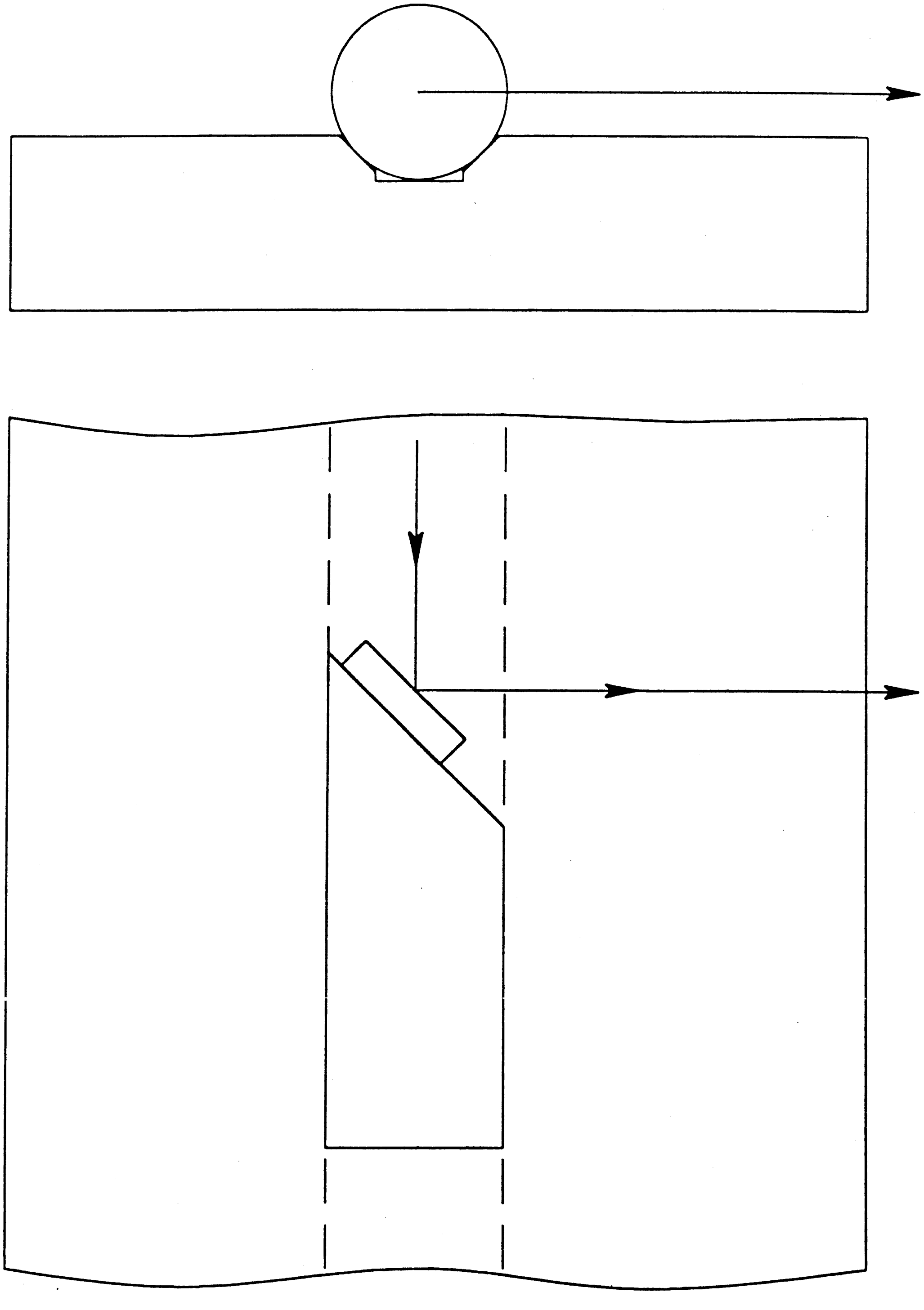


LATERALLY



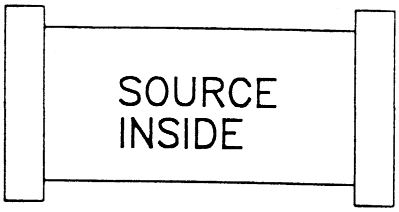
A CLEARANCE TROUGH FOR THE BEAM MAY BE NECESSARY.

LATERAL EXAMPLE

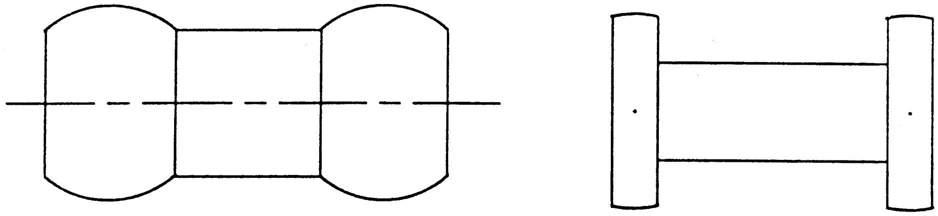


HEAT SOURCE ISOLATION

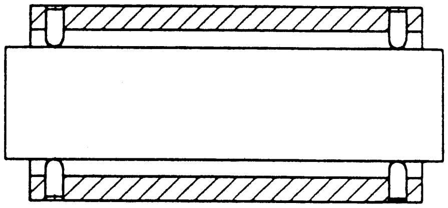
REDUCED CONTACT LENGTH
BETWEEN CYLINDER AND V



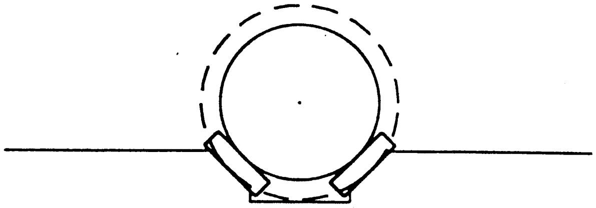
TOROIDAL STRUCTURE TO REDUCE CONTACT AREA TO
FOUR POINTS



SUSPENDED SOURCE



INSULATING SHIM ON V



THERMAL MATTERS

TOPICS

ISOLATION OF HEAT SOURCES

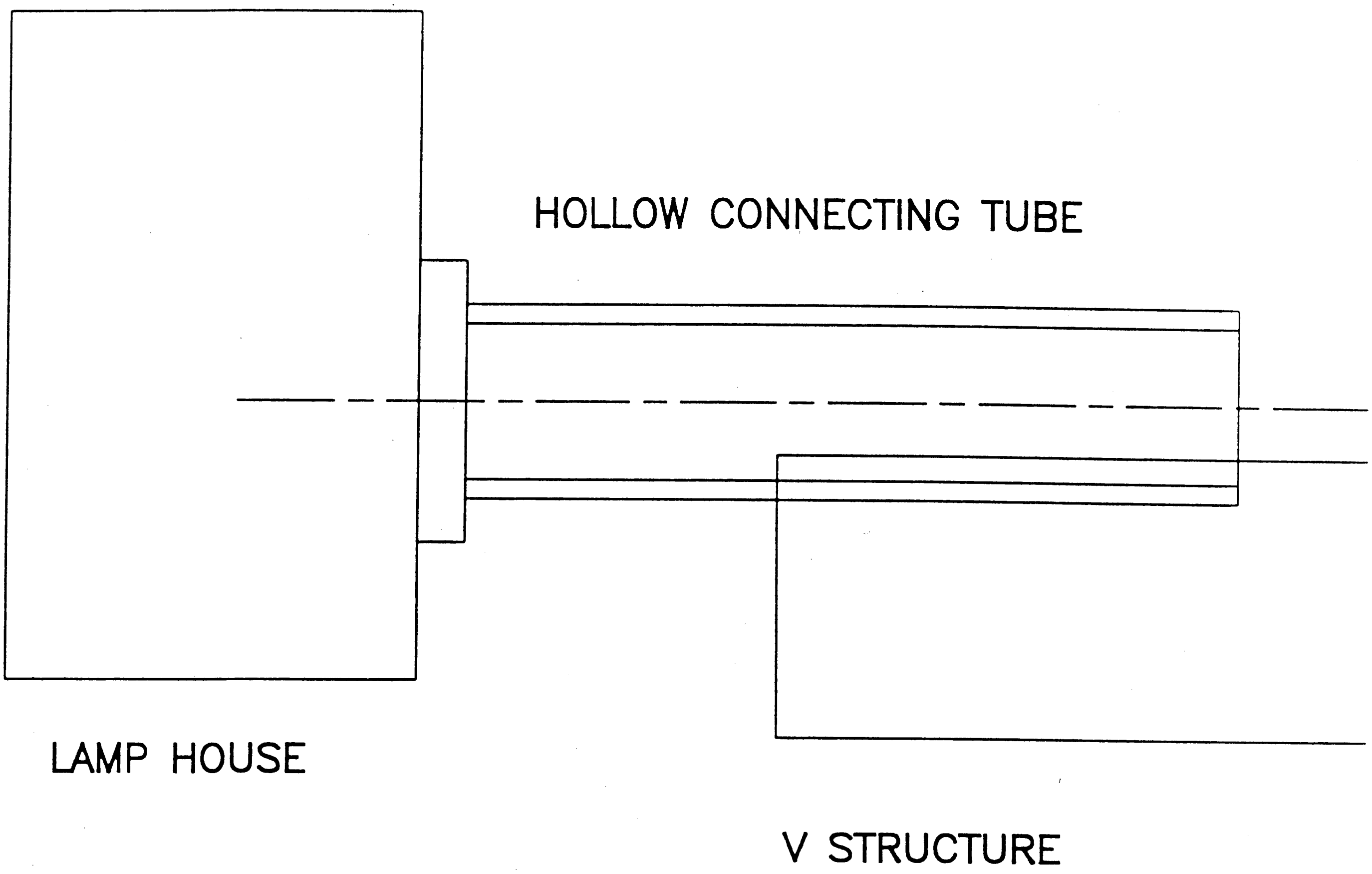
KEEPING HEAT FROM UNITS IN CYLINDERS FROM GETTING IN THE V PLATE

ALREADY HELPED BY LINE CONTACT OF ROUND CYLINDERS

OPTICAL SYSTEM ATHERMALIZATION

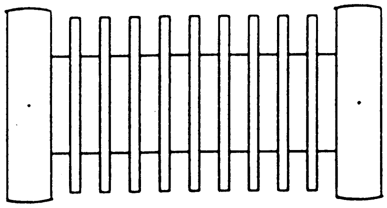
FACILITATED BY THE ABILITY OF CYLINDERS TO MOVE AXIALLY WITHOUT TILT OR LATERAL MOTION

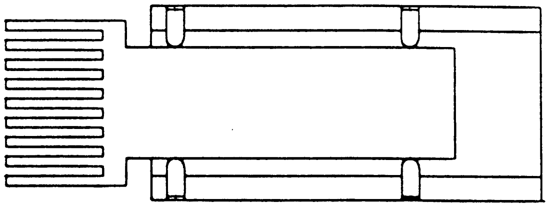
SOURCE HANGING OFF THE END OF V OR SUSPENDED ABOVE V



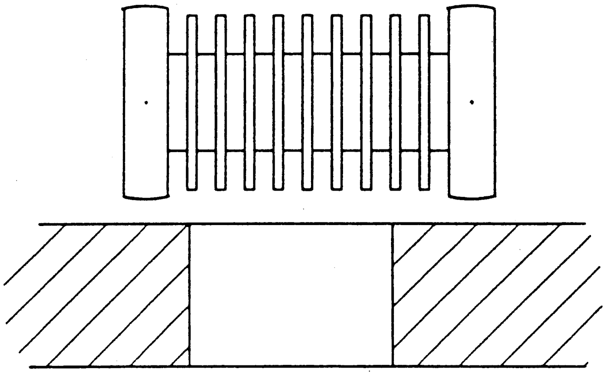
COOLING FINS AND CONVECTION VENTS

COOLING FINS

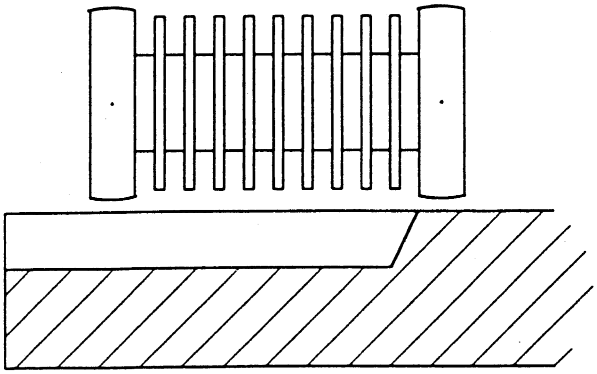


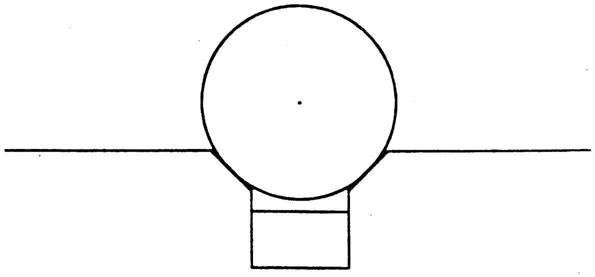


CONVECTION OPENING IN V STRUCTURE



CONVECTION TROUGH

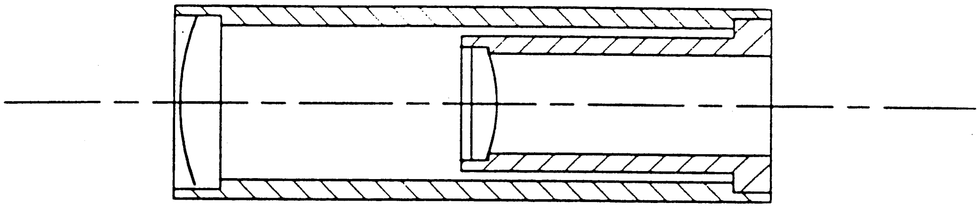




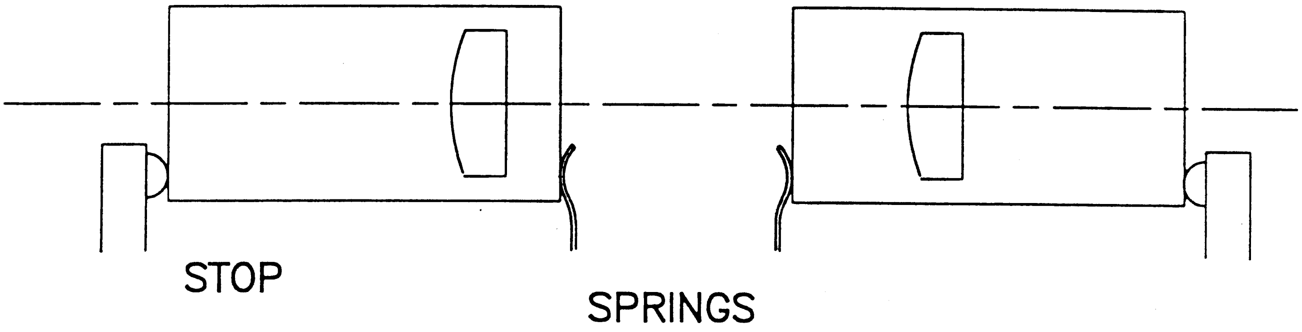
ATHERMALIZATION

EXAMPLES OF COMPENSATORY MOTIONS WITH TEMPERATURE CHANGE

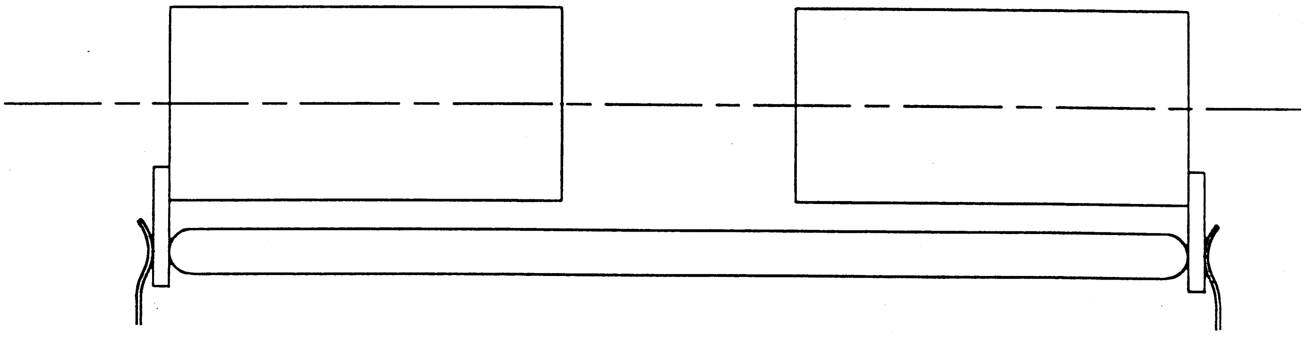
CYLINDER WITHIN CYLINDER IN WITH DISSIMILAR MATERIALS



CYLINDER(S) FIXED AT ONE END AGAINST STOP



CYLINDERS SPACED BY A METERING ROD



TWO DIMENSIONAL V ARRANGEMENT

TERMINOLOGY

"ONE DIMENSIONAL" – A SINGLE AXIS

"TWO DIMENSIONAL" – TWO OR MORE V AXES IN A COMMON PLANE PLANE

THE ANGLES BETWEEN INTERSECTING VS ARE MOST OFTEN 90°, BUT NOT EXCLUSIVELY SO.

THE MAIN ADDITIONAL REQUIREMENT IS GOING AROUND CORNERS WITH MIRRORS AND BEAMSPLITTERS, WHICH MUST BE ALIGNED WITH RESPECT TO TWO AXES.

THIS MATERIAL EMPHASIZES THE MECHANICAL ALIGNMENT OF OPTICAL ELEMENTS

MOST TWO DIMENSIONAL STRUCTURES WILL BE MONOLITHIC AND BASED ON PLATES. OTHER POSSIBILITIES ARE NOT DISCUSSED HERE.

SHALLOW VS ARE BETTER FOR INTERSECTIONS AND FOR PLATE STIFFNESS AND PLATE THICKNESS TO MAINTAIN THERMAL EQUILIBRIUM.

SEE SECTIONS:
BENT CYLINDERS
IN AND OUT OF VS

TWO DIMENSIONAL V ARRANGEMENT

INTRODUCTION

MIRRORS

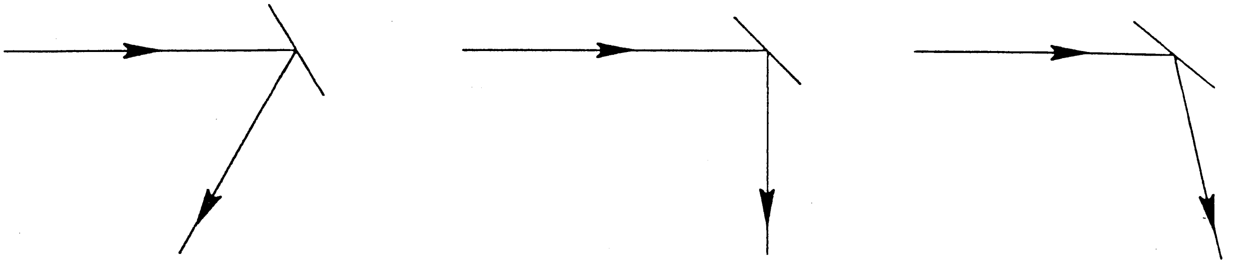
BEAMSPLITTERS

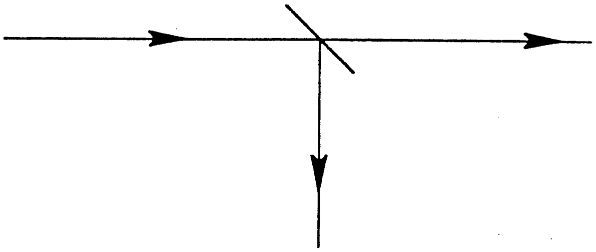
SWITCHES

MISCELLANEOUS

BASIC 2D MOVES

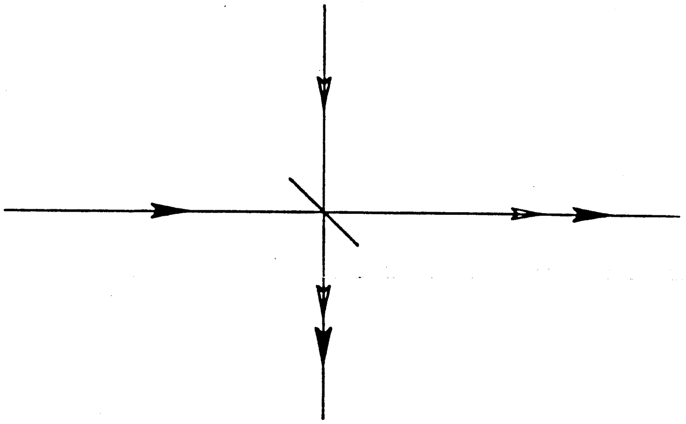
GOING AROUND CORNERS BY REFLECTION





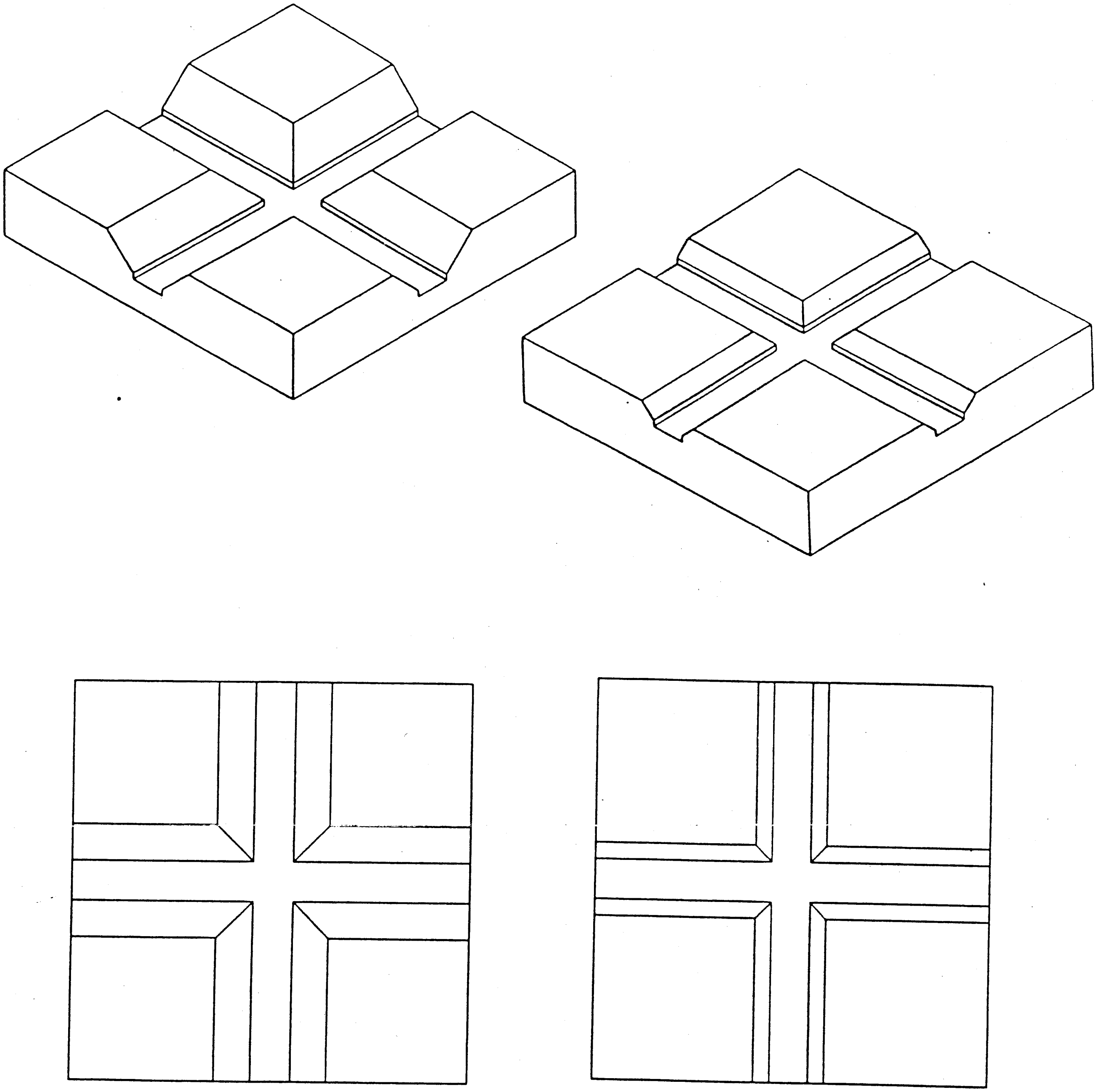
BEAM SPLITTING

BEAM COMBINING



SIMILAR WITH PRISMS, GRATINGS

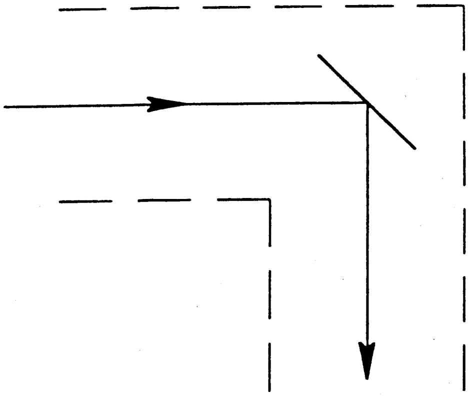
ADVANTAGE OF SHALLOW VS FOR TWO DIMENSIONAL ARRANGEMENTS



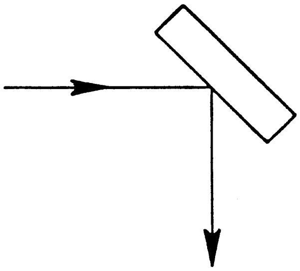
THE MIRROR

"MIRROR" INCLUDES SOME PRISM TYPES.

THE 90° TURN IS THE MOST COMMON OPERATION.
THE SAME PRINCIPLES APPLY TO OTHER ANGLES.

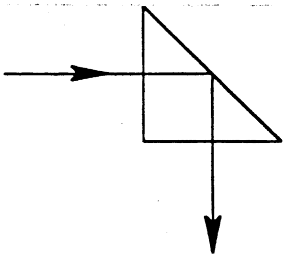


THERE ARE MANY WAYS TO DO THE SAME THING



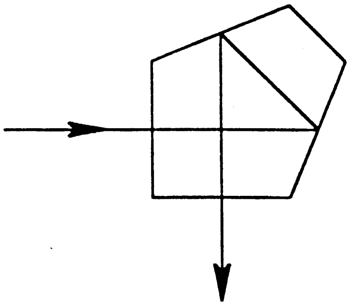
MIRRORS ON CYLINDER
  END ANGLED
  CYLINDER ANGLED

MIRROR ON V PLATE

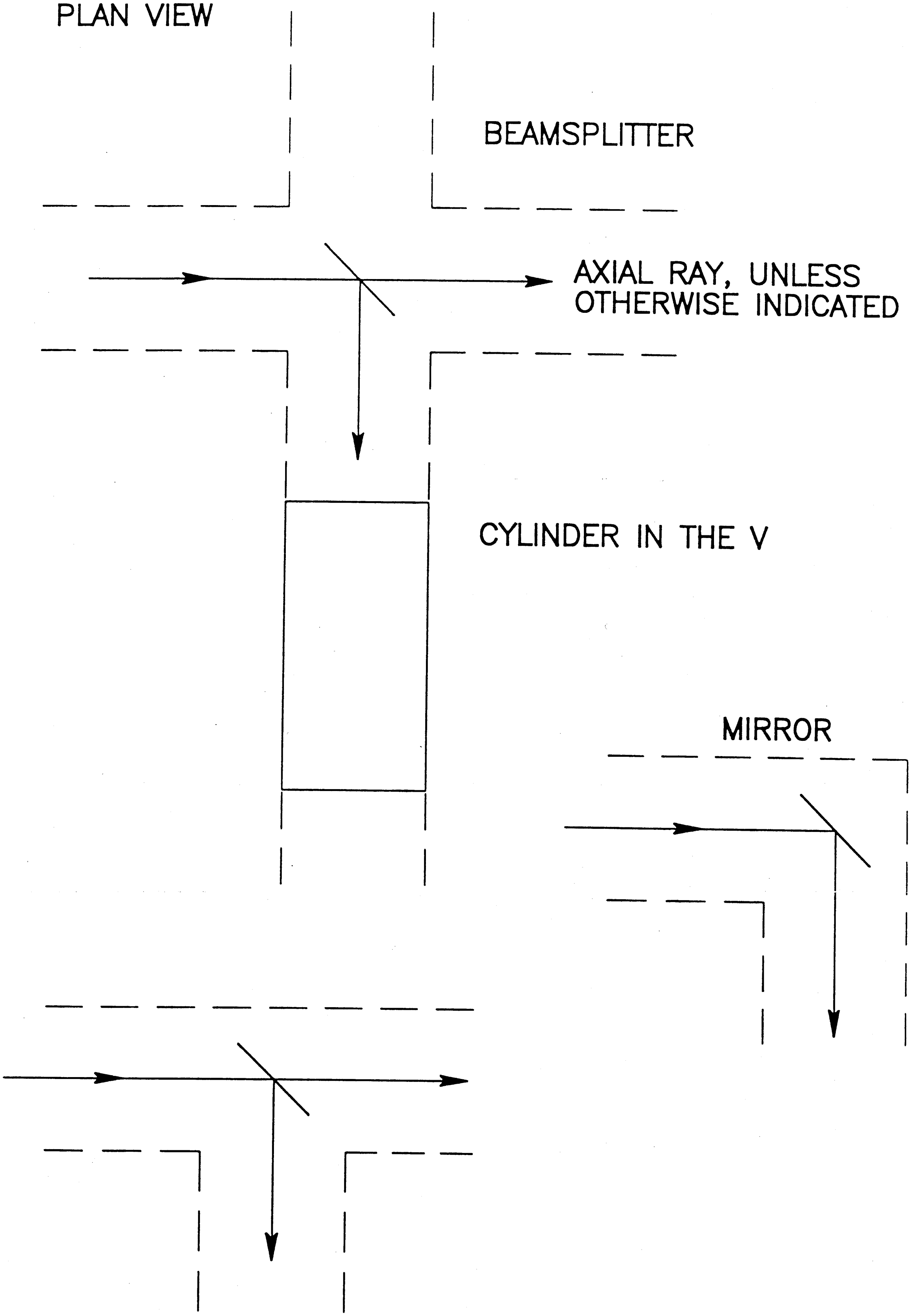


FIXED MIRROR
SWITCH ABLE

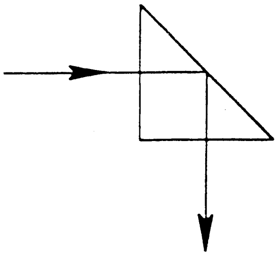
MECHANICAL ALIGNMENT
OPTICAL ALIGNMENT
MIXED

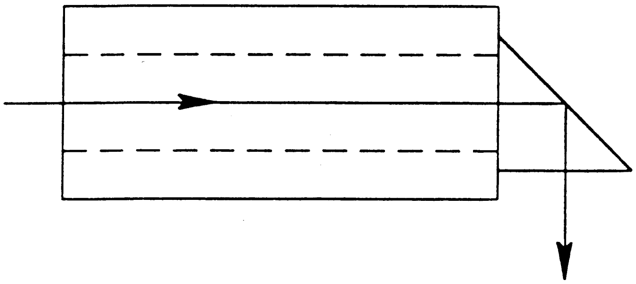


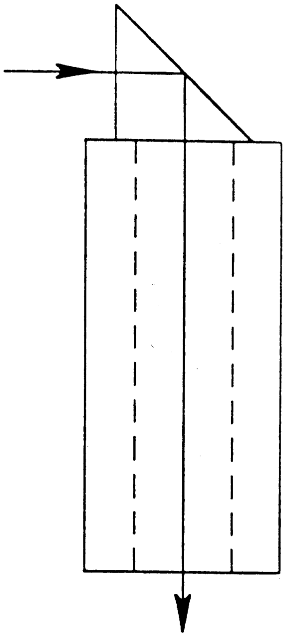
DRAWINGS

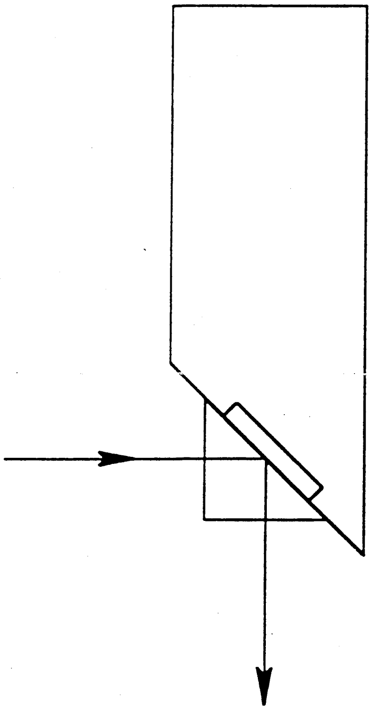

PLAN VIEW
BEAMSPLITTER
AXIAL RAY, UNLESS OTHERWISE INDICATED
CYLINDER IN THE V
MIRROR

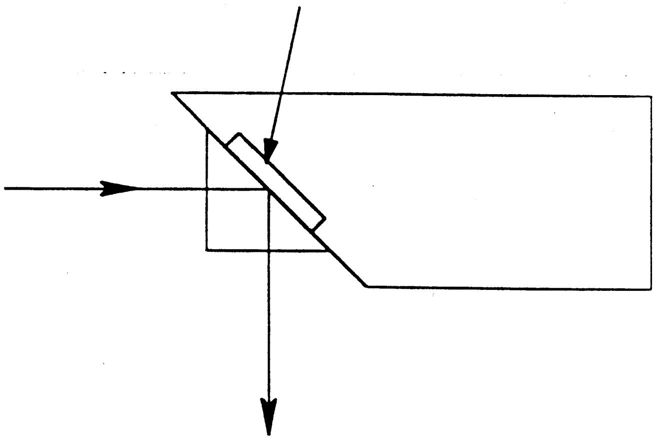
SOME WAYS TO MAKE A 90° TURN WITH A REFLECTING PRISM



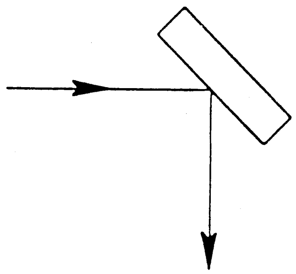




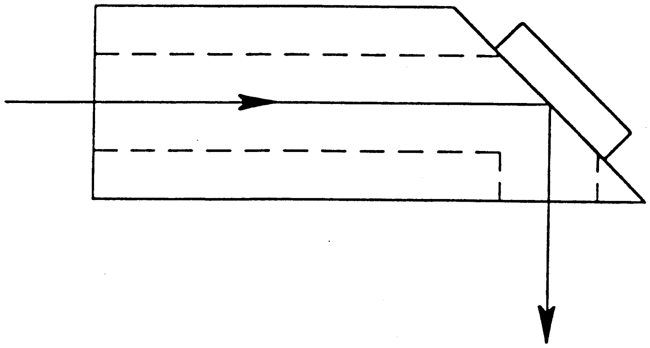


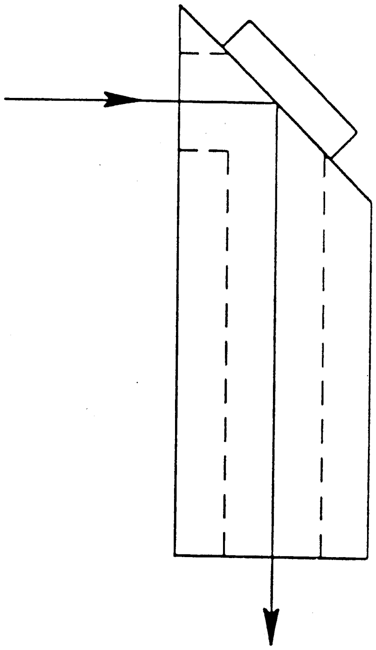


SOME WAYS TO MAKE A 90° TURN WITH A FRONT SURFACE MIRROR

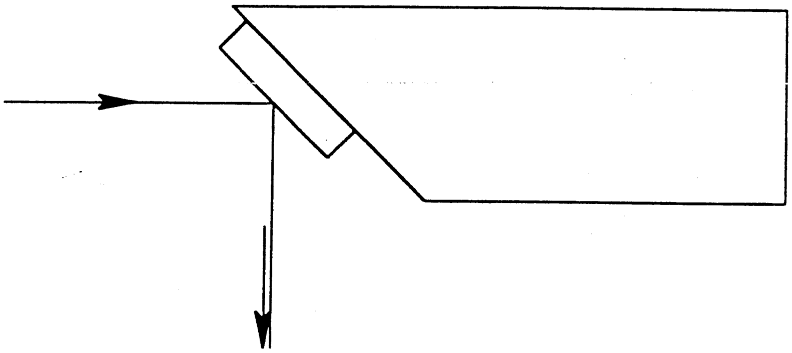


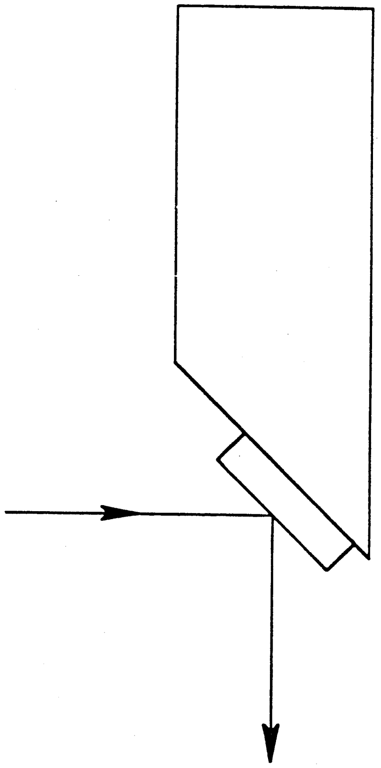
FRONT MOUNT



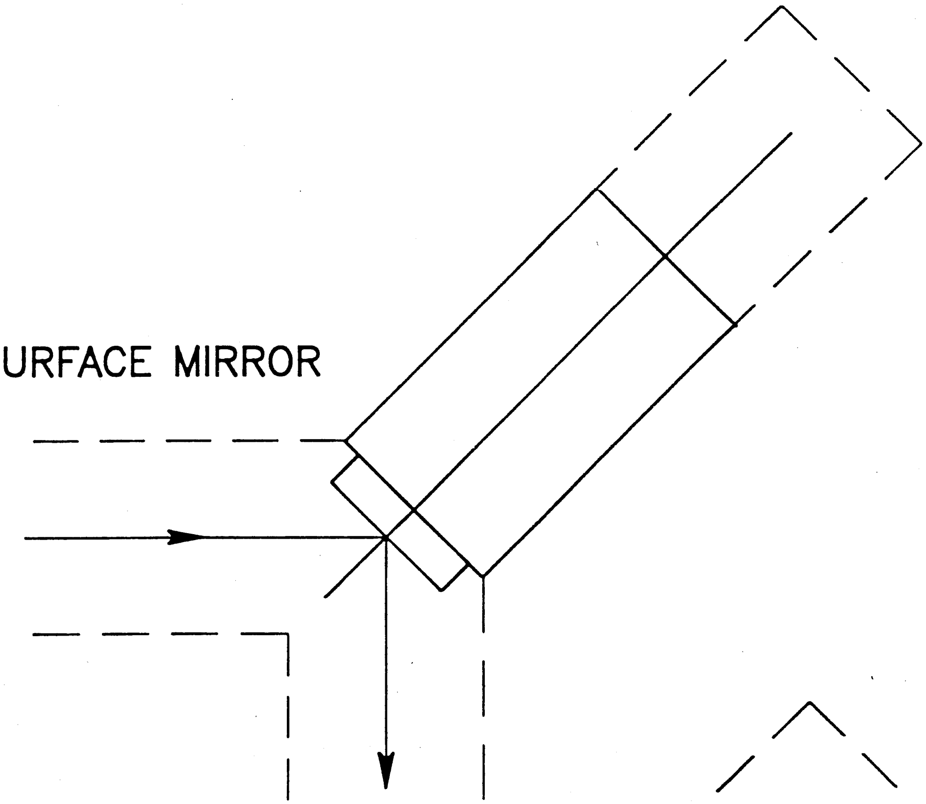


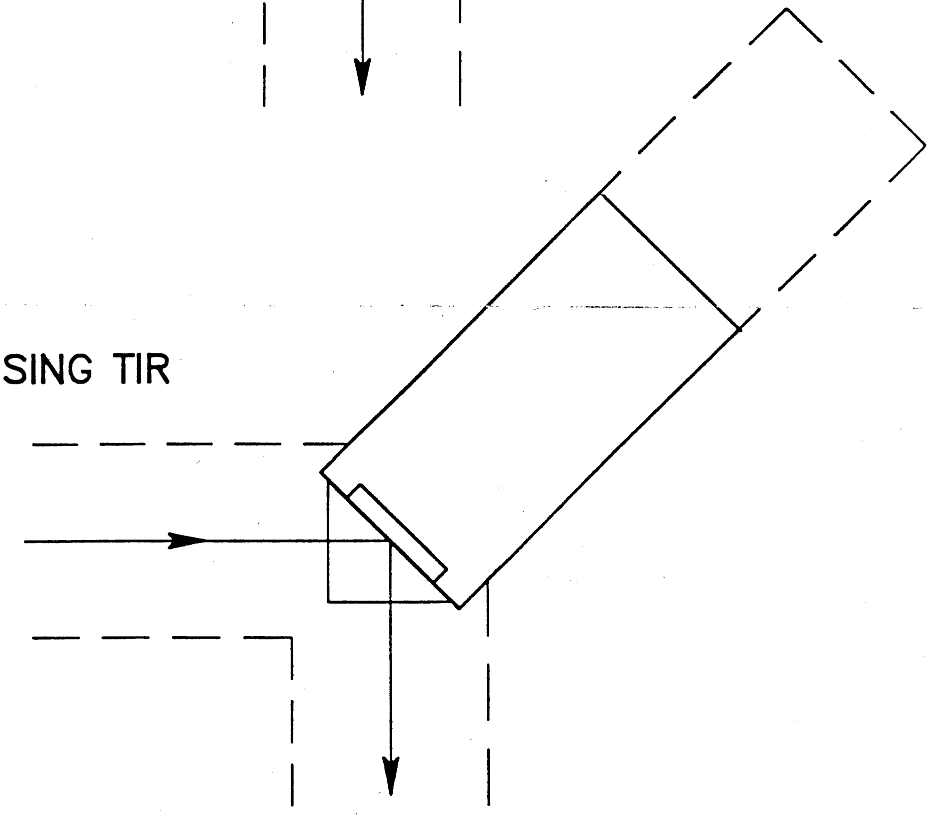
REAR MOUNT



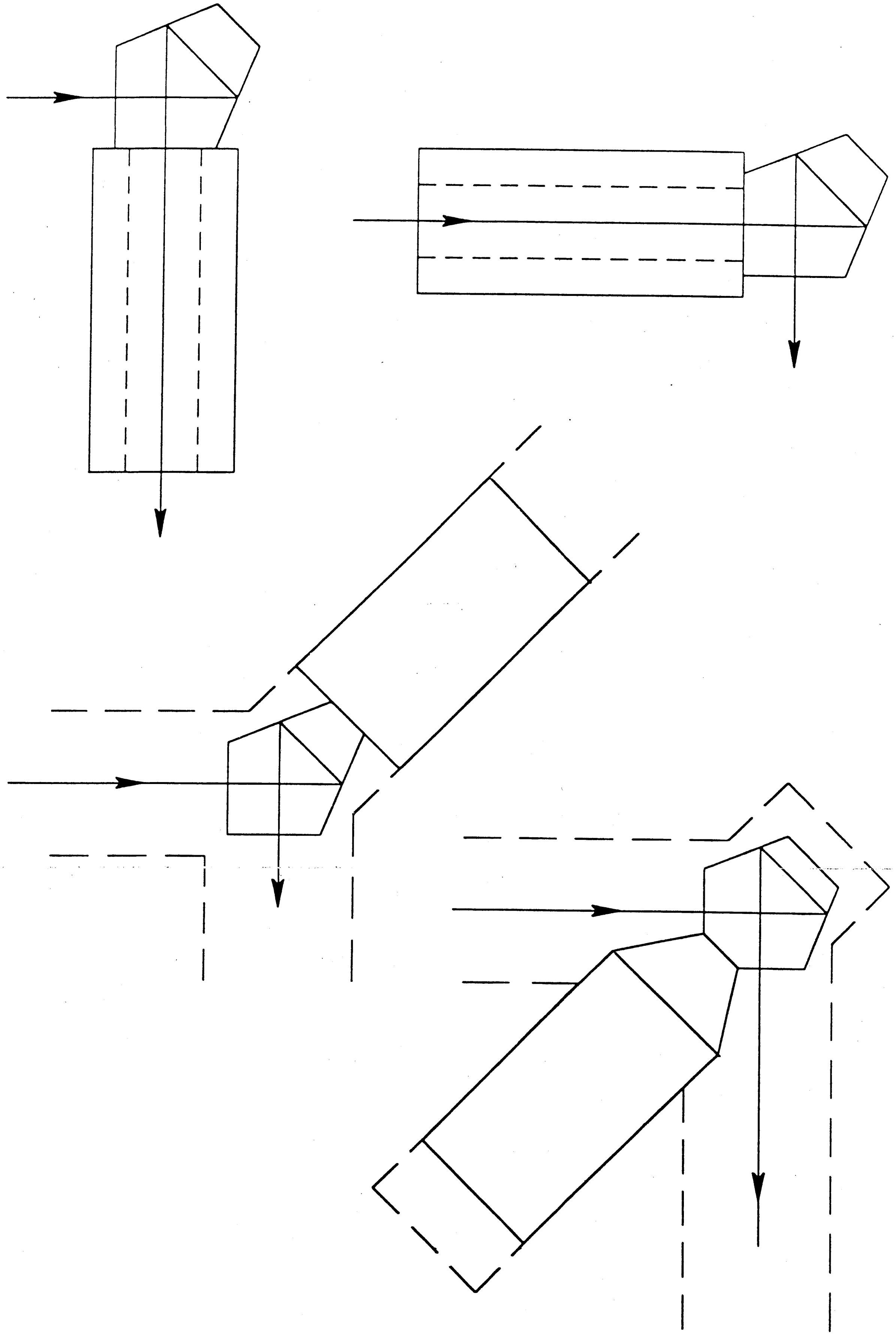


SOME WAYS TO MAKE A 90° TURN WITH A MIRROR HELD BY A CYLINDER AT 45°

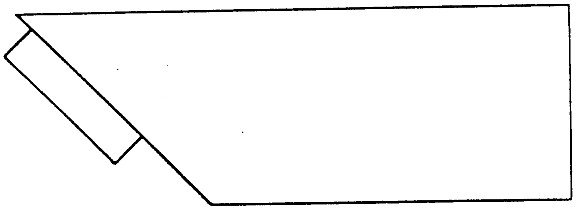

FRONT SURFACE MIRROR


PRISM USING TIR

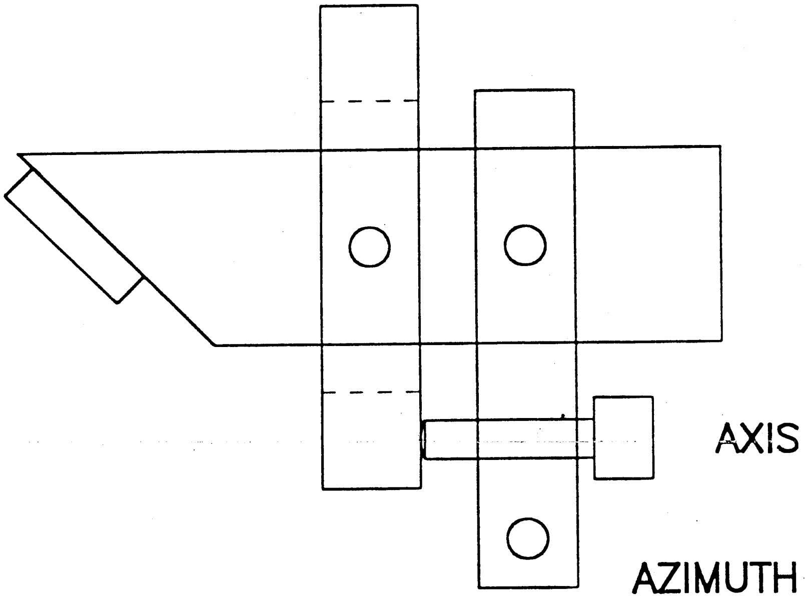
SOME WAYS TO MAKE A 90° TURN WITH A PENTA PRISM



ADJUSTMENT OF A MIRROR HARD MOUNTED TO A CYLINDER



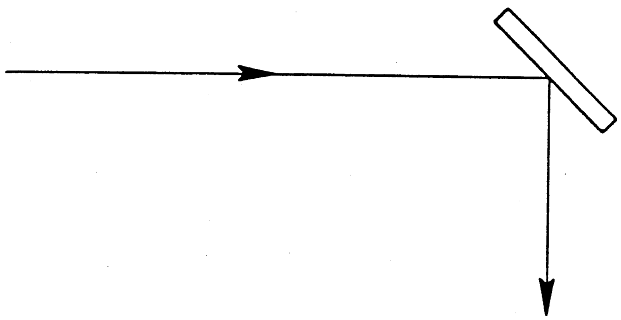
TWO DEGREES OF FREEDOM REMAIN:
AXIAL AND AZIMUTHAL



AN AXIAL AND AZIMUTHAL ADJUSTMENT ARRANGEMENT

MIRROR ADJUSTMENT

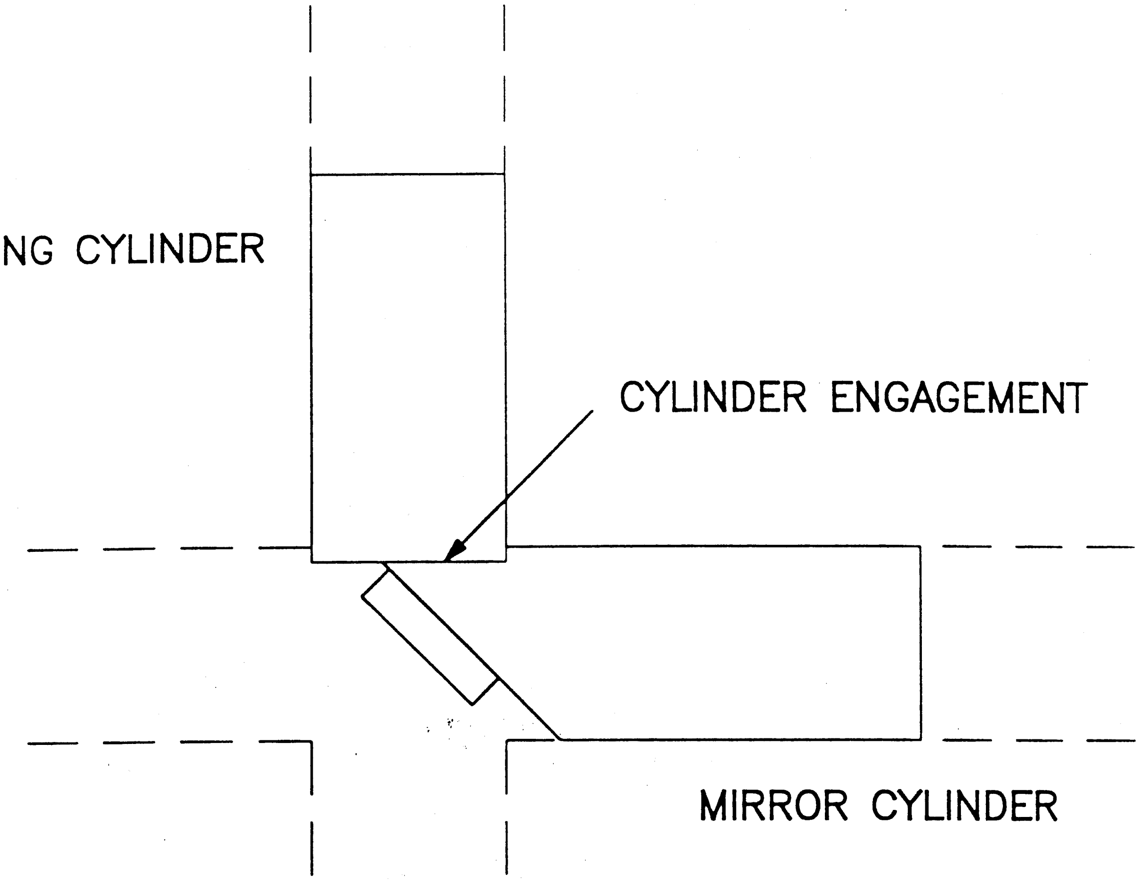
DEGREES OF FREEDOM



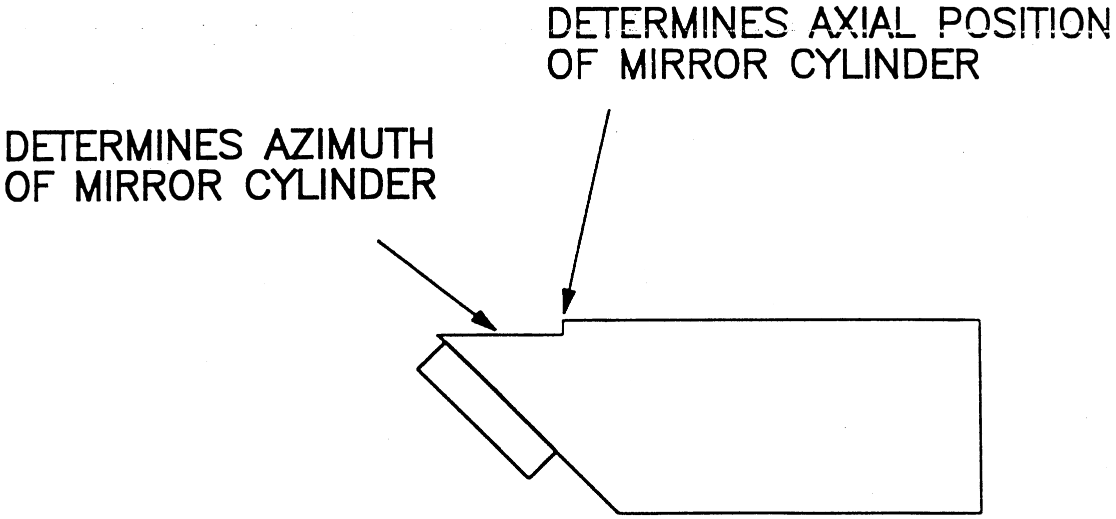
RELEVANT:
DIRECTION OF NORMAL, TWO ANGLES
AXIAL POSITION
3 DEGREES OF FREEDOM

NON–CRITICAL OR IRRELEVANT:
ROTATION ABOUT SURFACE NORMAL
TRANSLATION IN SURFACE PLANE
2 DEGREES OF FREEDOM

SETTING A MIRROR MECHANICALLY

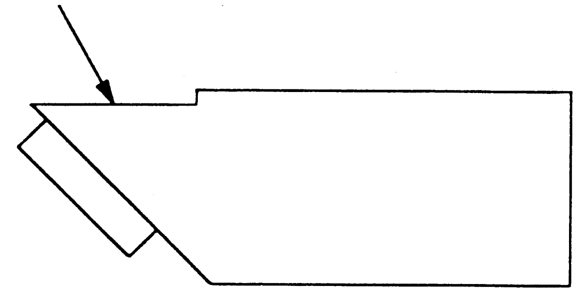


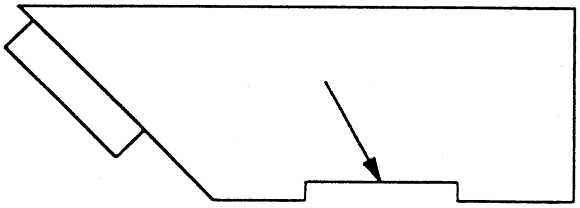
MIRROR CYLINDER ALIGNMENT FEATURES



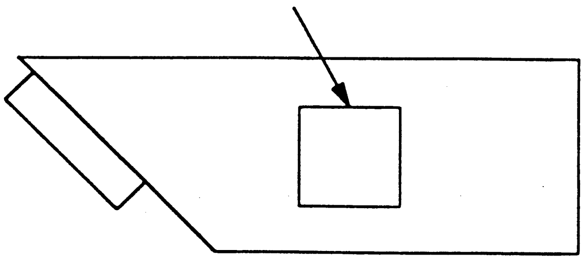
ALIGNMENT FEATURES MACHINED ON CYLINDERS

FLATS PERPENDICULAR TO V PLATE SURFACE



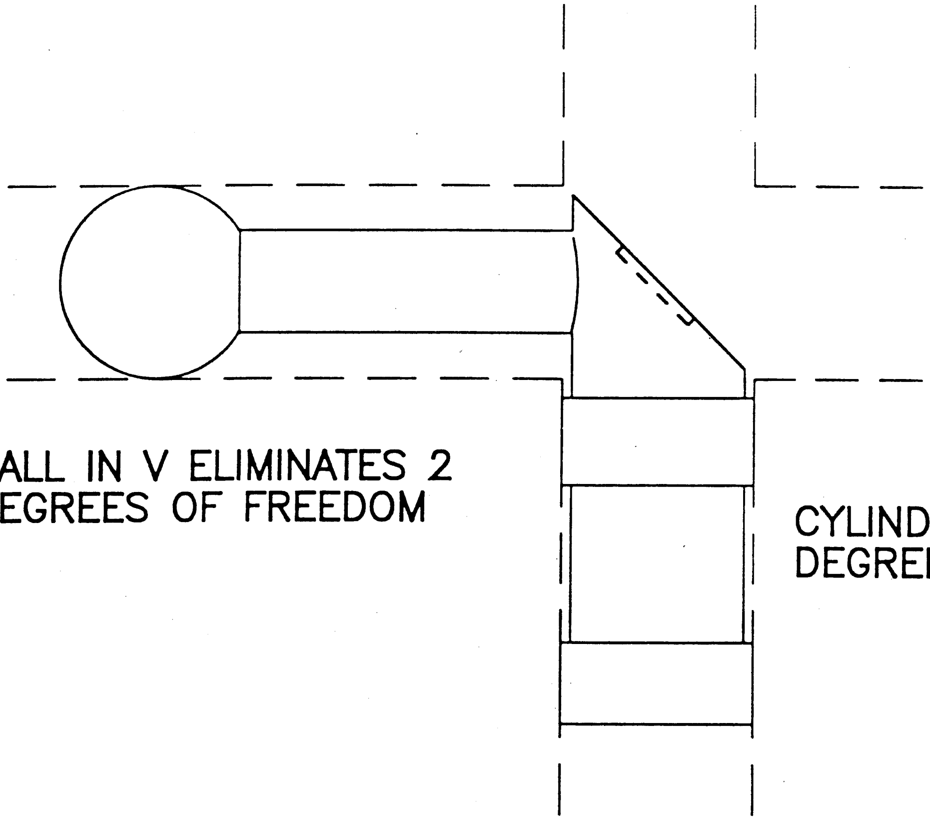


FLAT PARALELL TO V PLATE SURFACE



SEMI-KINEMATIC FIXTURE

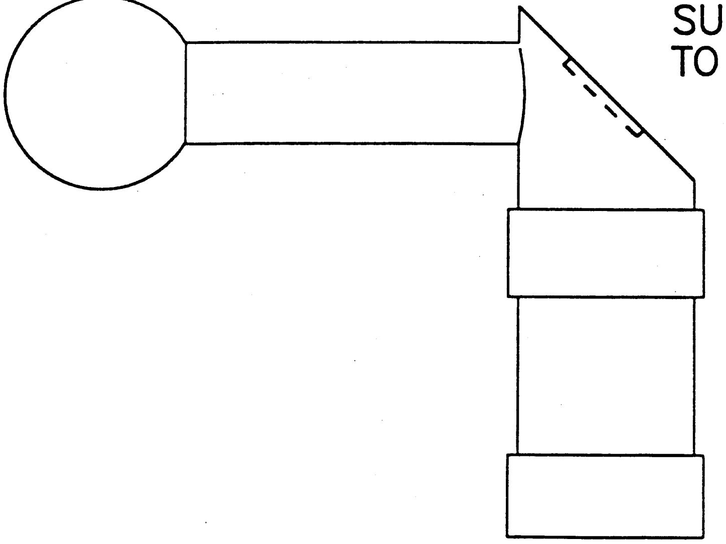
USEFUL FOR REPEATED MIRROR ALIGNMENT



BALL IN V ELIMINATES 2 DEGREES OF FREEDOM

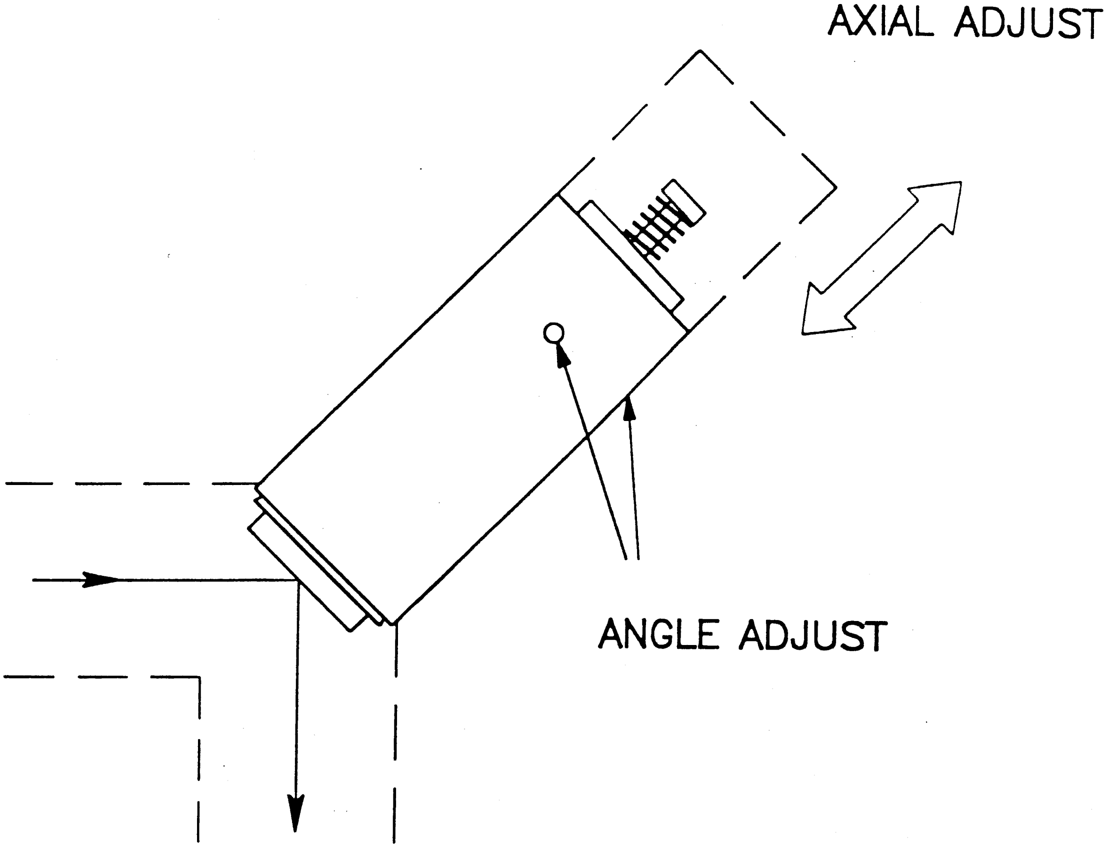
CYLINDER ELIMINATES 4 DEGREES OF FREEDOM.

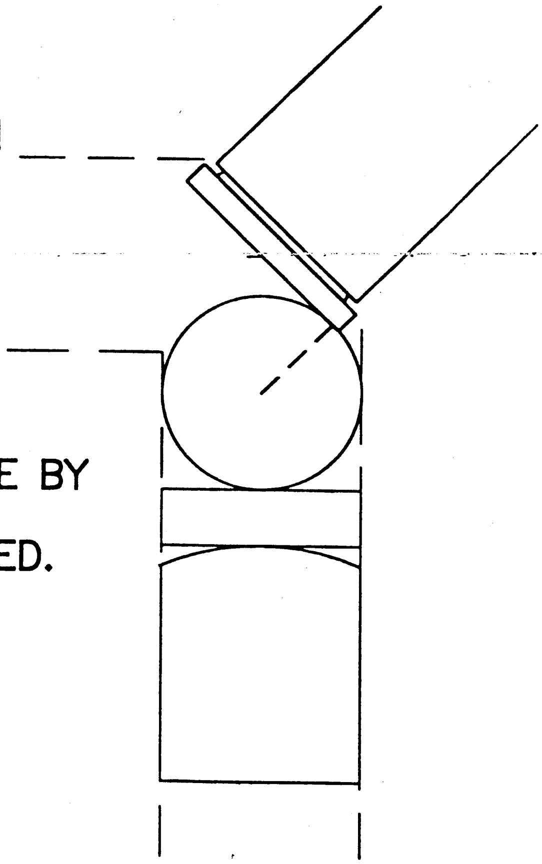
CAN BE ARRANGED FOUR WAYS



PLANE OF REFLECTING SURFACE WITH UNDERCUT TO PREVENT DAMAGE

TILTABLE MIRROR IN 45° V



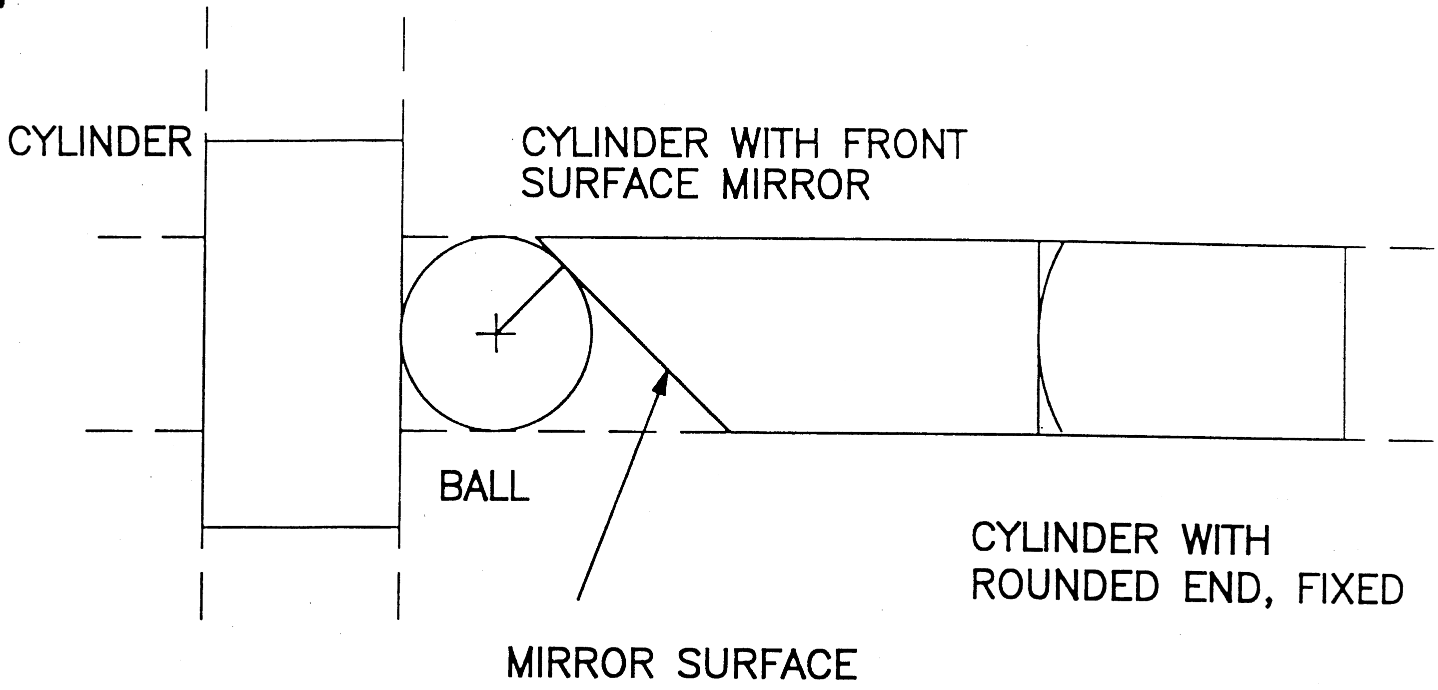


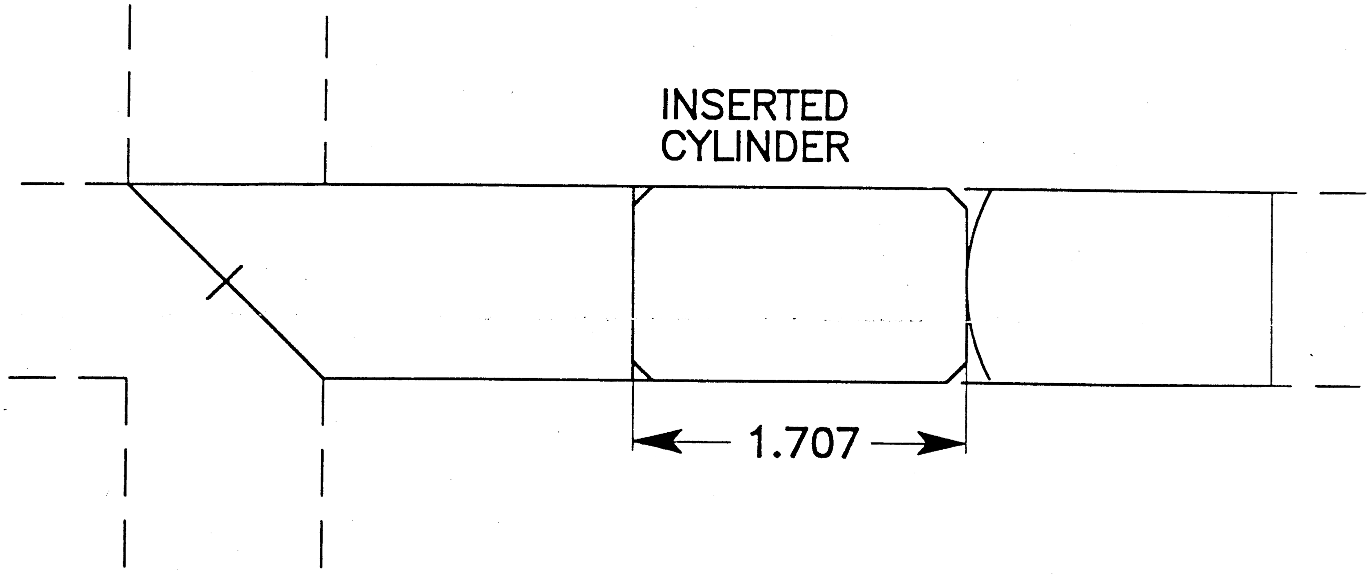
THE ANGULAR ADJUSTMENT OF THE MIRROR TO THE CYLINDER AXIS CAN BE DONE BY CENTERING METHODS.

AXIAL ALIGNMENT CAN BE DONE BY ONE OF THE METHODS BELOW.
AN OVERSIZE MIRROR IS NEEDED.

AXIAL SETTING METHOD FOR MIRROR

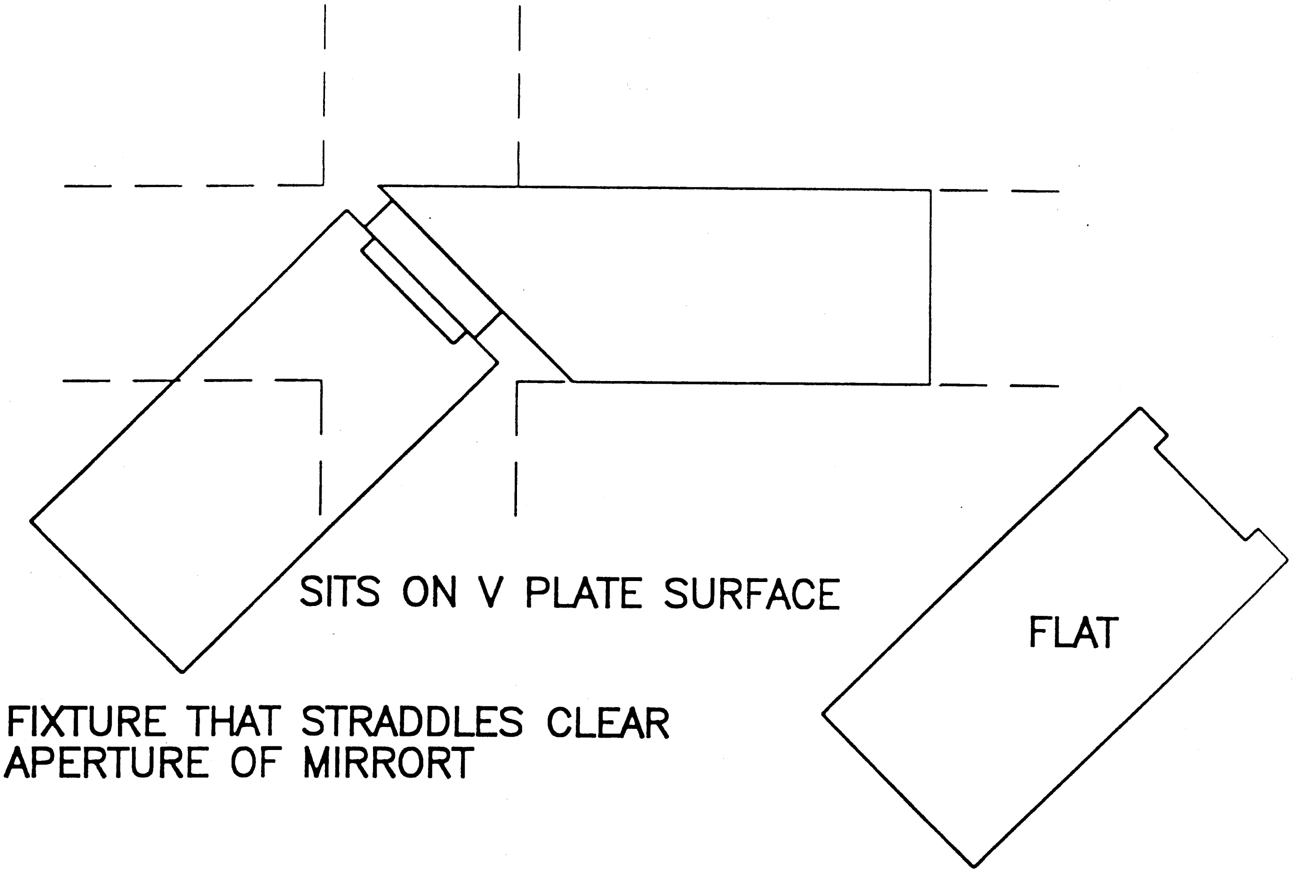
ALL DIAMETERS = 1



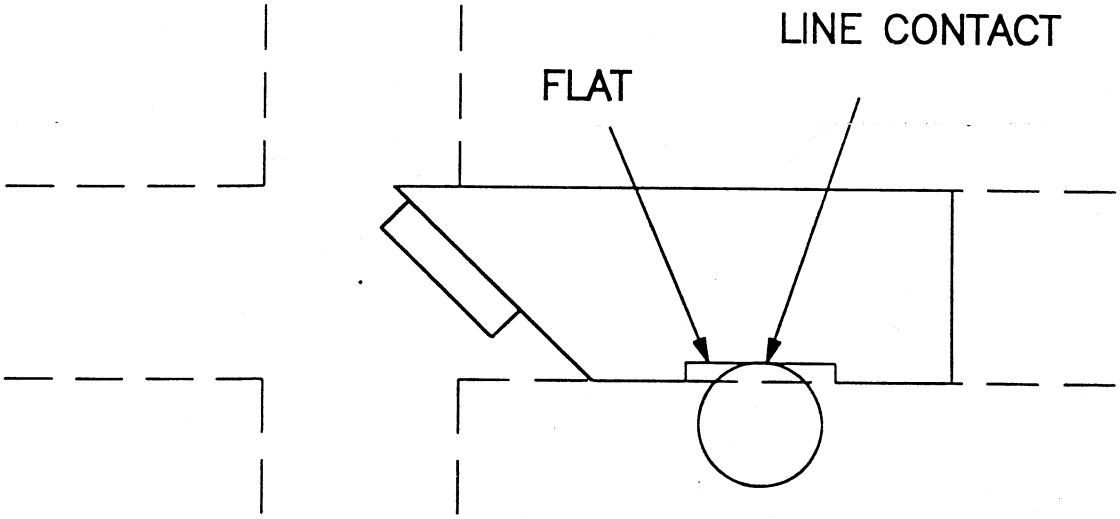


DOES NOT CONTROL AZIMUTH.

AZIMUTHAL ALIGNMENT



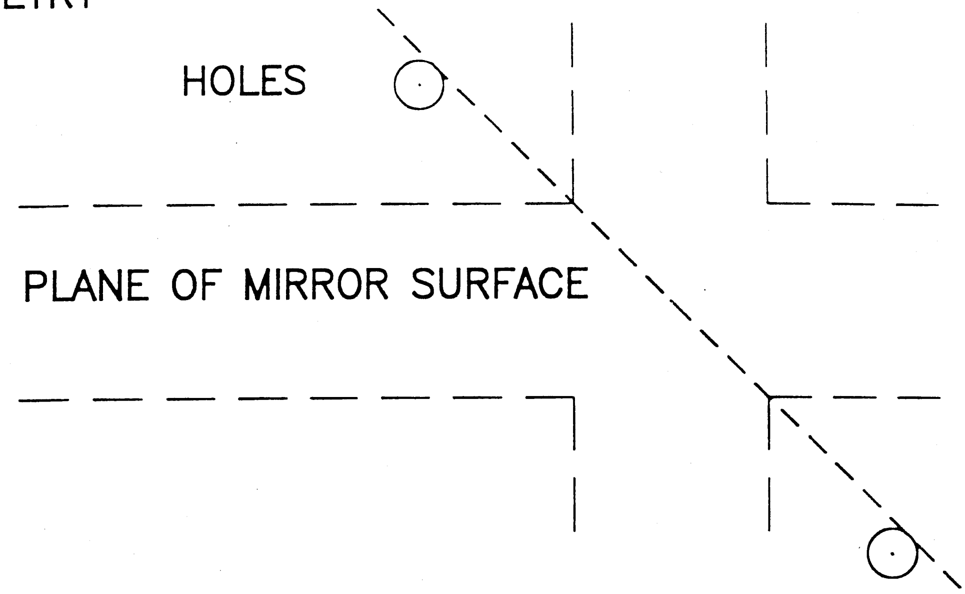
FIXTURE THAT STRADDLES CLEAR APERTURE OF MIRRORT



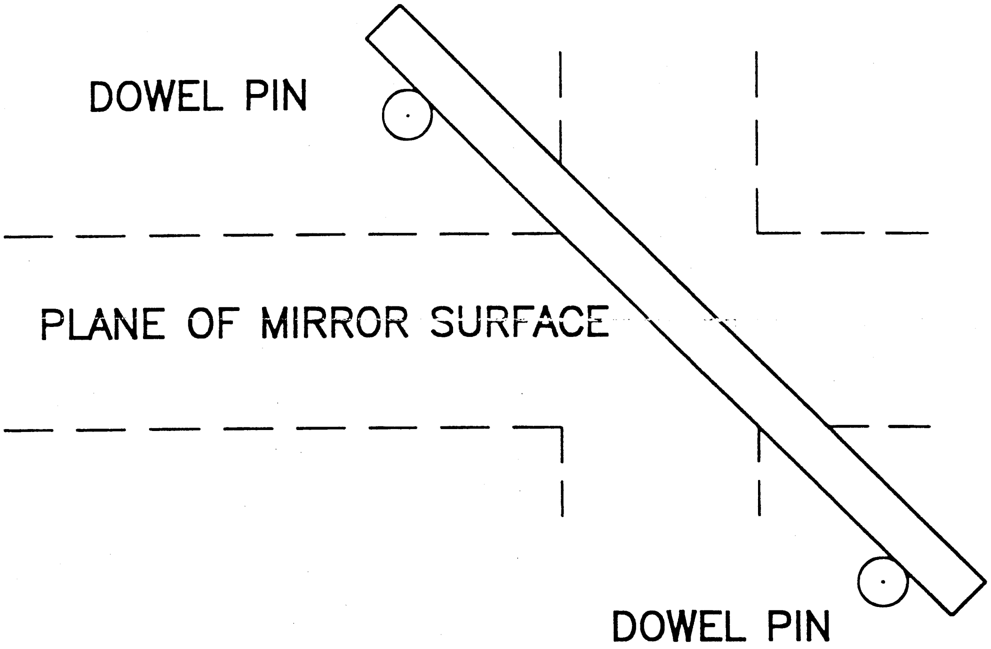
CYLINDRICAL PIECE WITH SQUARE END ON THE V PLATE SURFACE

ALIGNMENT HOLES IN V PLATE WITH BAR

GEOMETRY



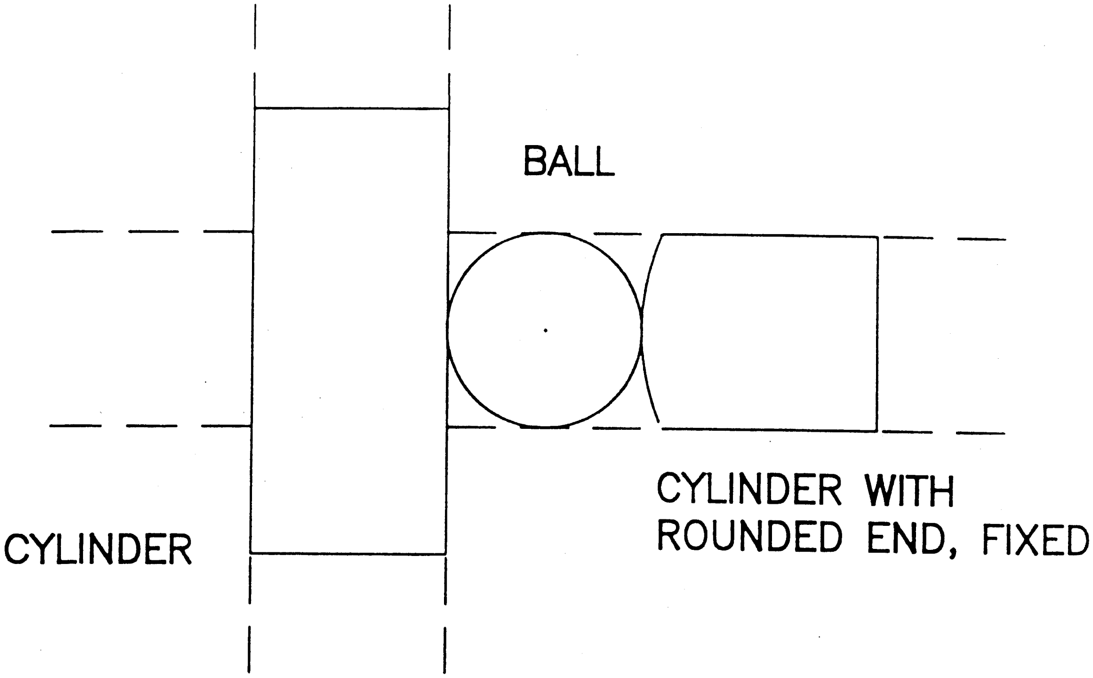
ALIGNMENT BAR

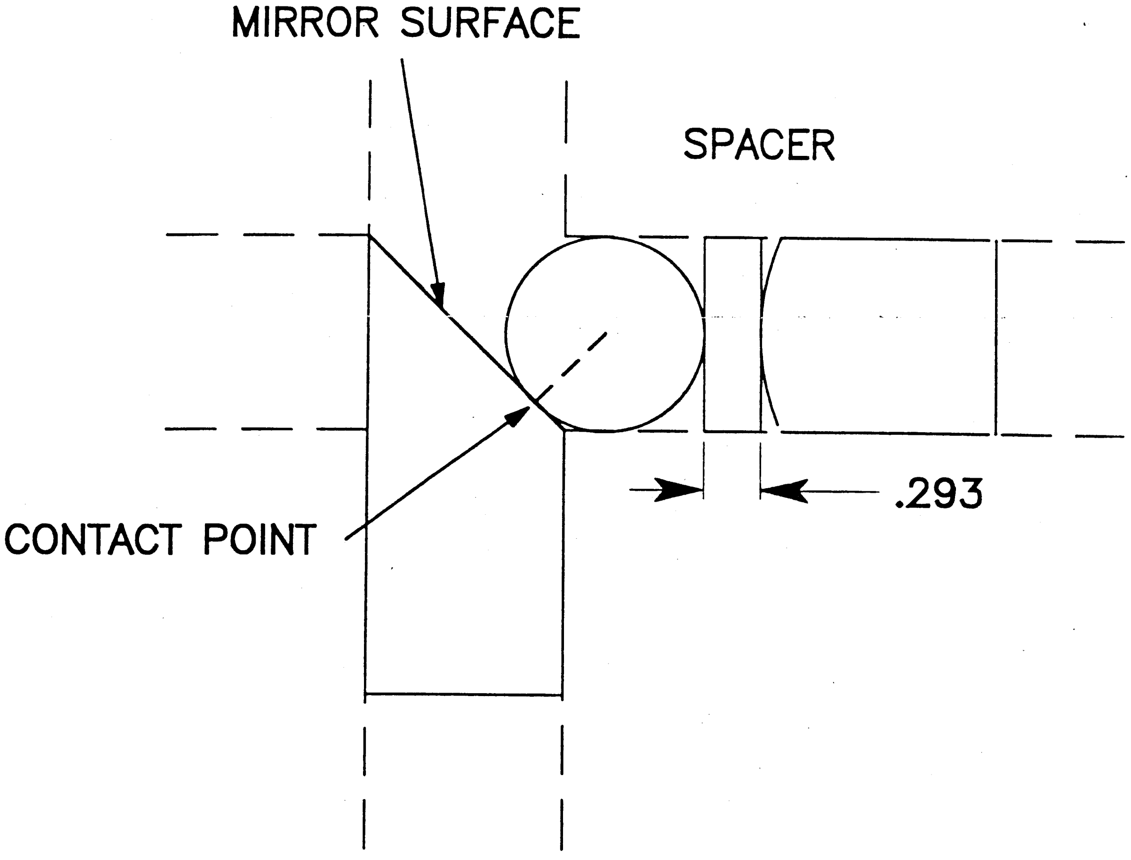


THIS ARRANGEMENT CAN BE USED IN SEVERAL WAYS .

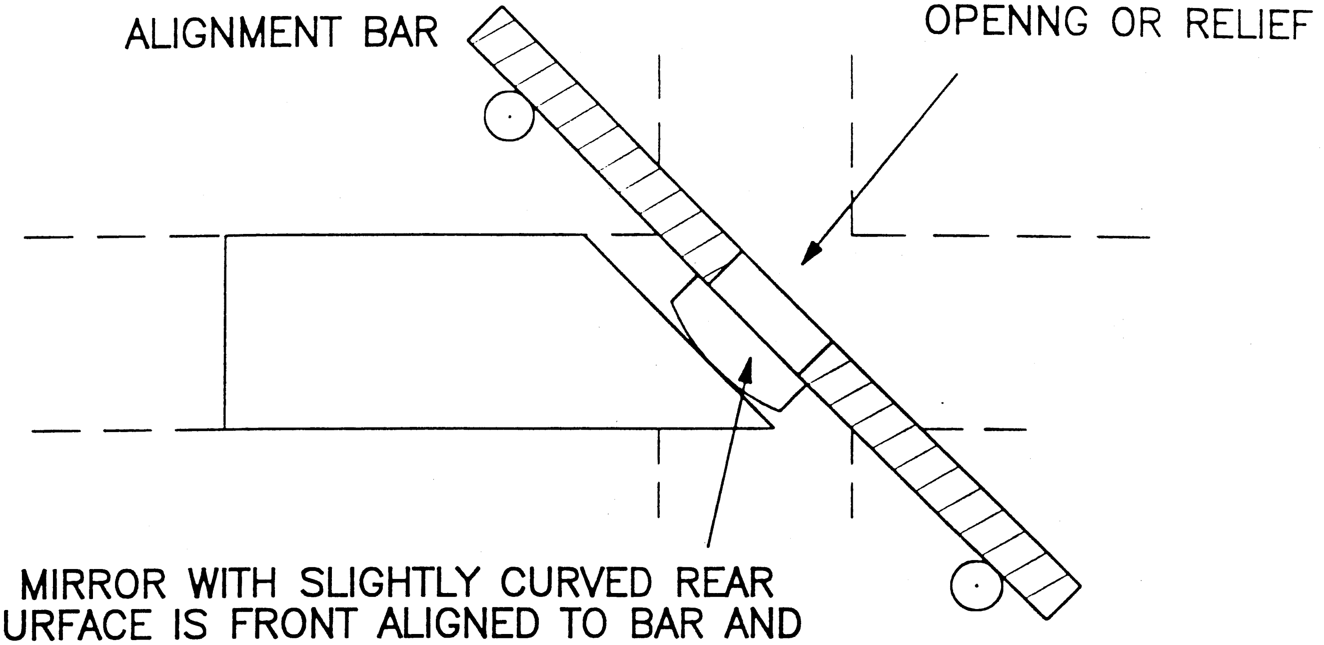
AXIAL SETTING METHOD FOR MIRROR

ALL DIAMETERS = 1

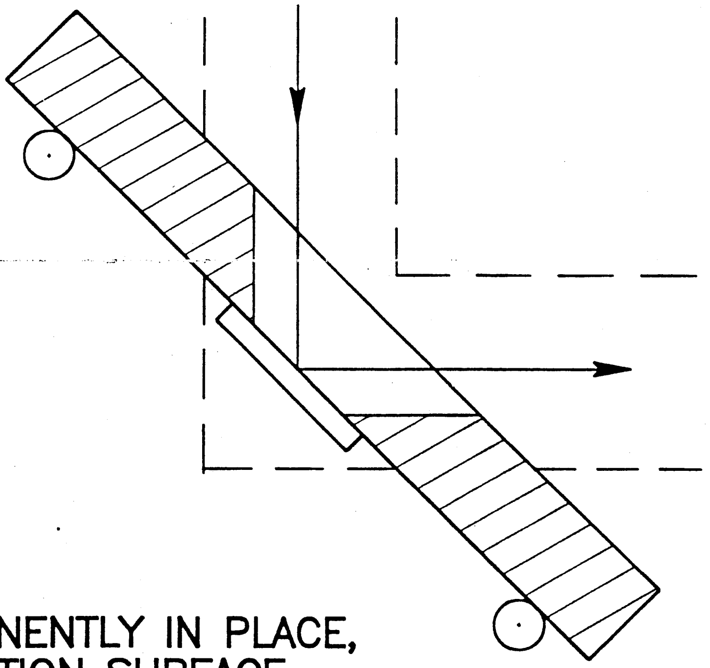




BAR ALIGNMENT

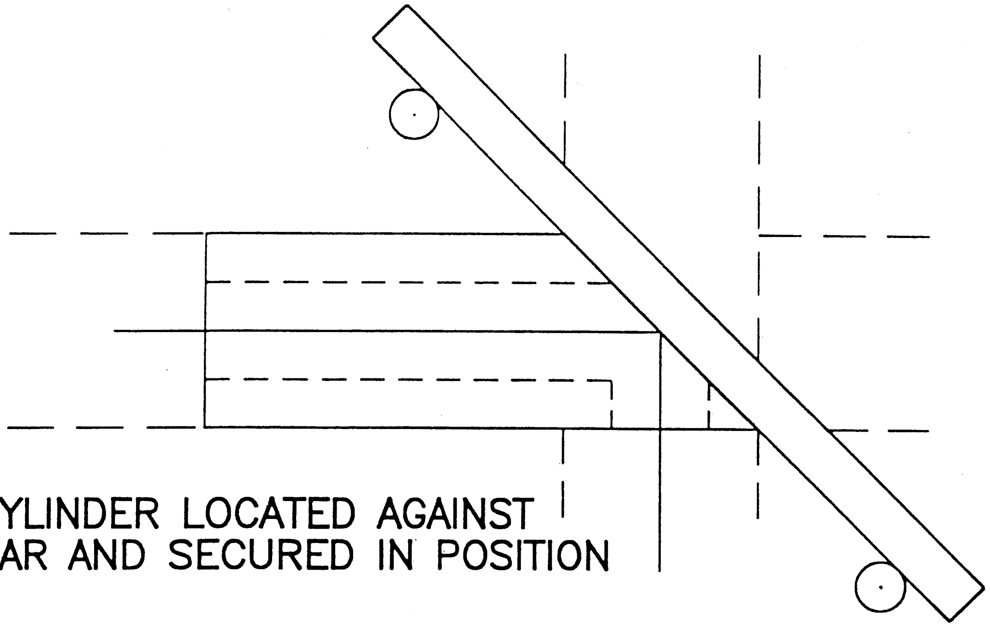


A MIRROR WITH SLIGHTLY CURVED REAR SURFACE IS FRONT ALIGNED TO BAR AND THEN CEMENTED TO A CYLINDER

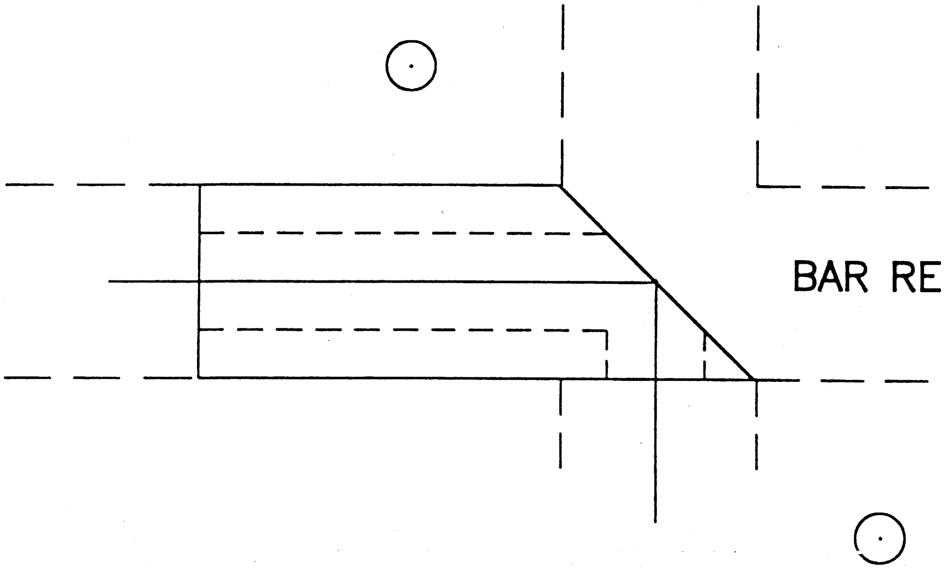


THE BAR, PERMANENTLY IN PLACE, LOCATES REFLECTION SURFACE.

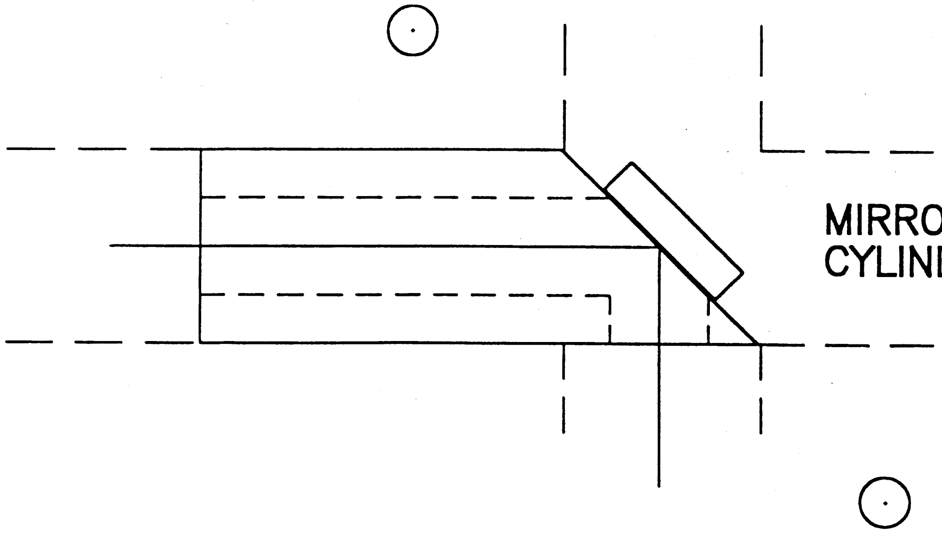
BAR ALIGNING MIRROR CYLINDER



CYLINDER LOCATED AGAINST BAR AND SECURED IN POSITION

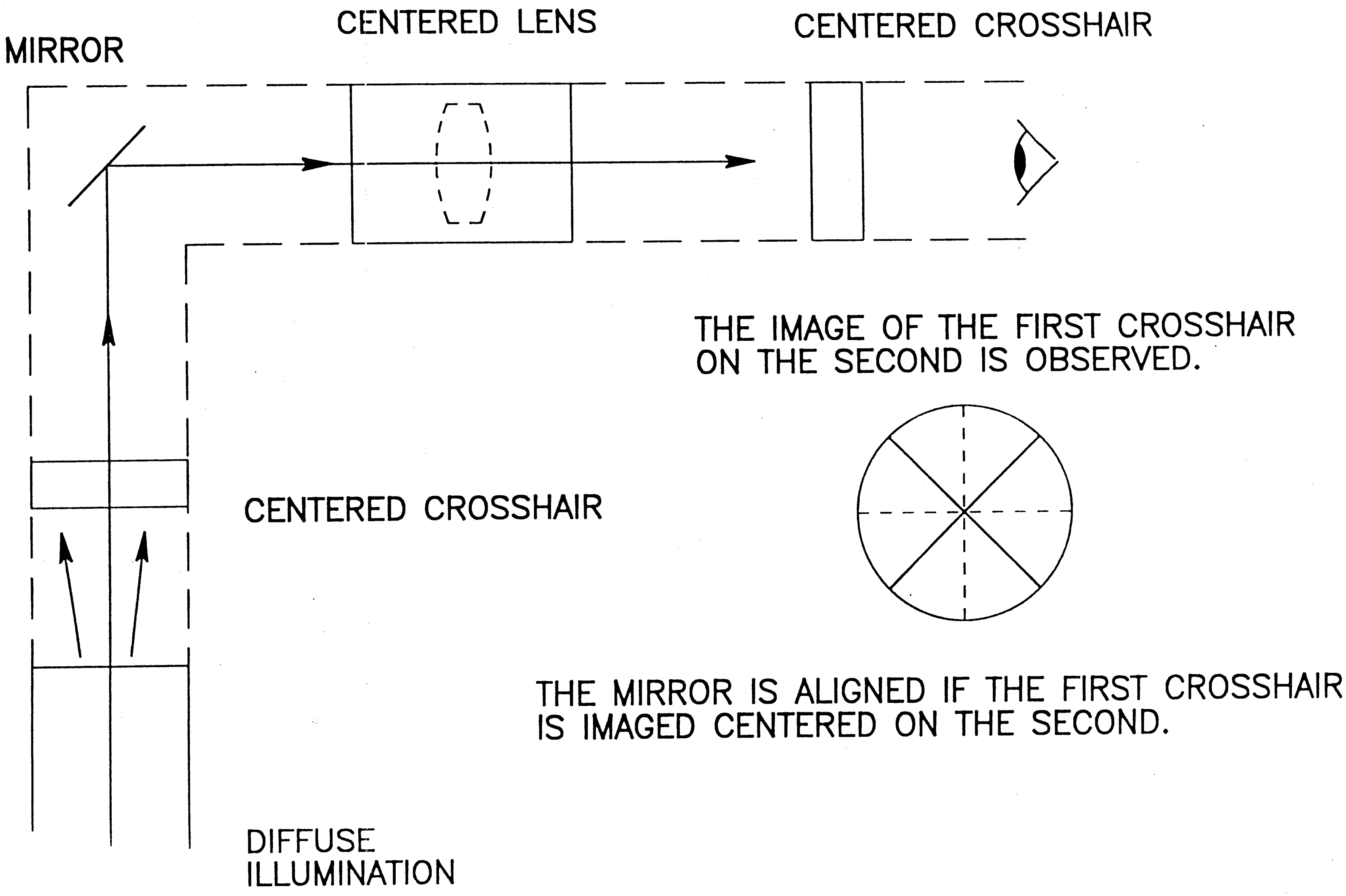


BAR REMOVED



MIRROR AFFIXED TO CYLINDER

OPTICAL TEST OF MIRROR ALIGNMENT

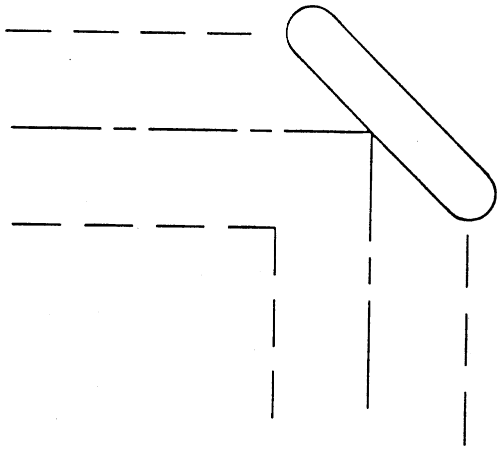


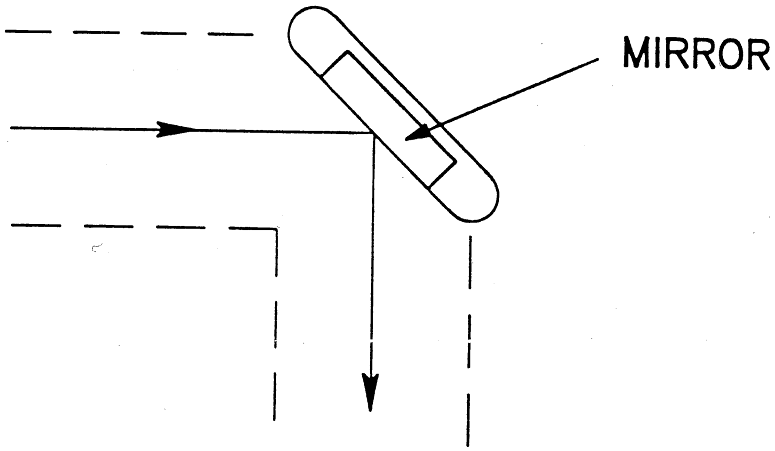
THE IMAGE OF THE FIRST CROSSHAIR ON THE SECOND IS OBSERVED.

THE MIRROR IS ALIGNED IF THE FIRST CROSSHAIR IS IMAGED CENTERED ON THE SECOND.

MIRROR IN A SLOT

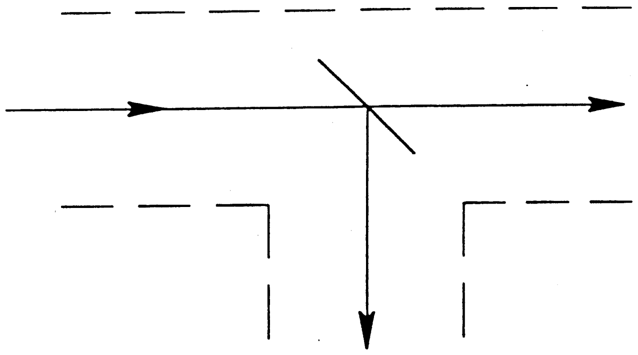
MILLED SLOT IN V PLATE



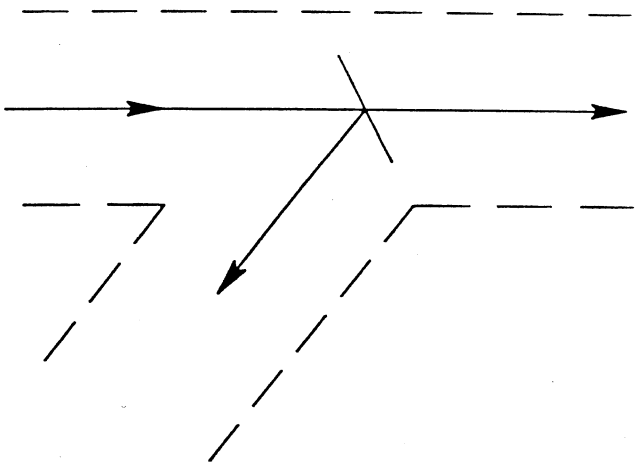


VARIATIONS

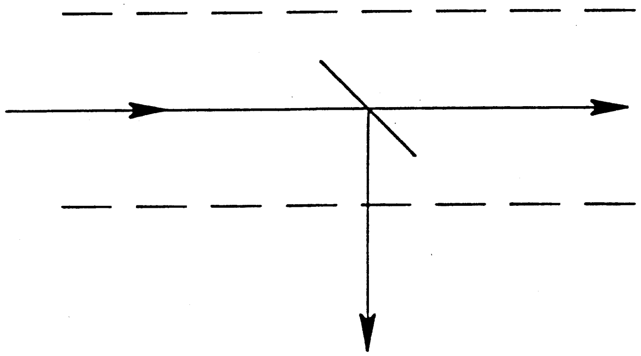
SPLIT AT 90°



SPLIT NOT AT 90°

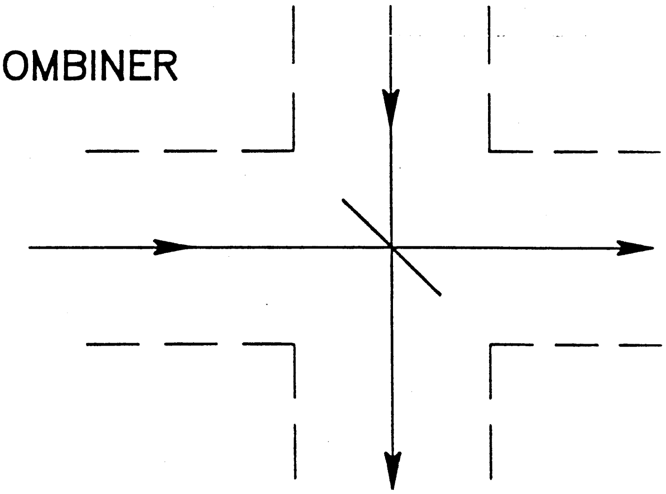


OUT OF THE V



COMBINER

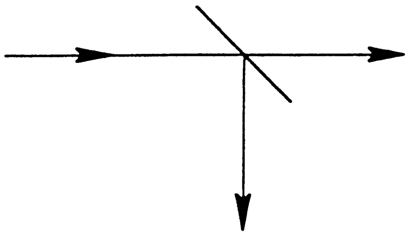
INTO/OUT OF V



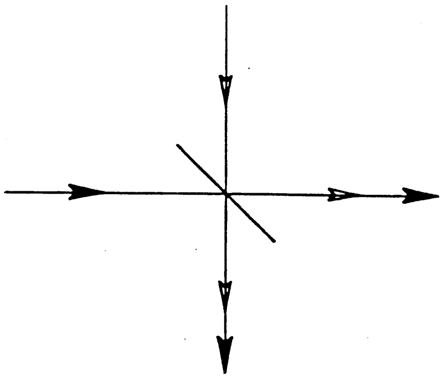
BEAMSPLITTERS AND COMBINERS

USES

BEAMSPLITTER SCHEMATIC



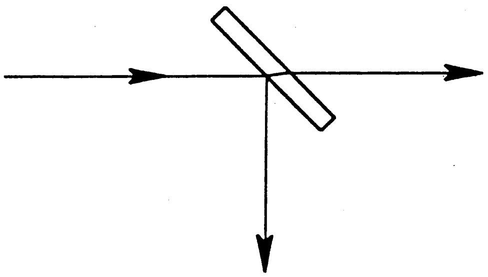
COMBINER SCHEMATIC



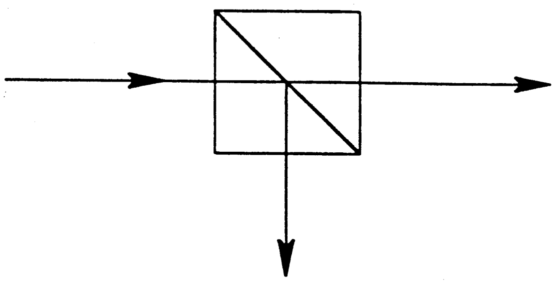
THE DIVISION OR COMBINATION CAN BE BY POLARIZATION, WAVELENGTH, OR MAGNITUDE.

TYPES

PLATE BEAMSPLITTER



CUBE BEAMSPLITTER



PELLICLE IS VERY THIN PLATE

BEAMSPLITTER ALIGNMENT

PLATE BEAMSPLITTER ALIGNMENT LIKE MIRROR ALIGNMENT.

PLATE

TREAT THE SAME AS A MIRROR

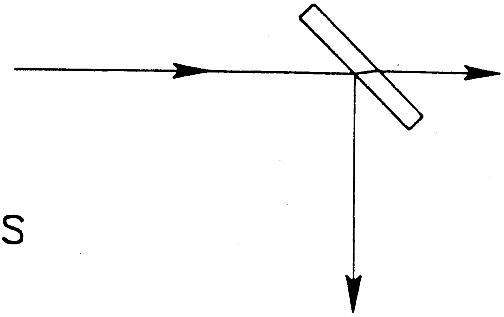
CUBE

CAN BE OPTICALLY ALIGNED AS A MIRROR

CAN BE MECHANICALLY ALIGNED IN OTHER WAYS

DEGREES OF FREEDOM

PLATE BEAMSPLITTER



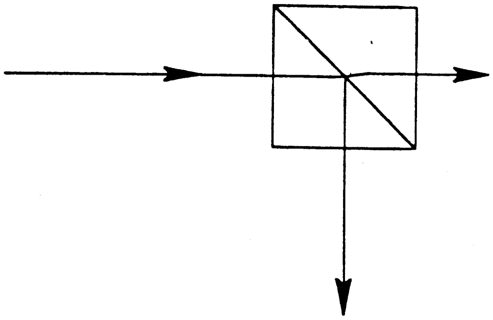
RELEVANT:
DIRECTION OF NORMAL, TWO ANGLES
AXIAL POSITION ALONG INPUT BEAM

REFLECTED AND TRANSMITTED BEAMS ARE AFFECTED
DIFFERENTLY AFFECTED BY TILT.
THE TRANSMITTED BEAM IS UNAFFECTED BY AXIAL POSITION

NON-CRITICAL OR IRRELEVANT:
ROTATION ABOUT SURFACE NORMAL,
UNLESS POLARIZATION DEPENDENT
TRANSLATION IN SURFACE PLANE, TWO DOF

CAN BE ALIGNED LIKE A MIRROR.

CUBE BEAMSPLITTER



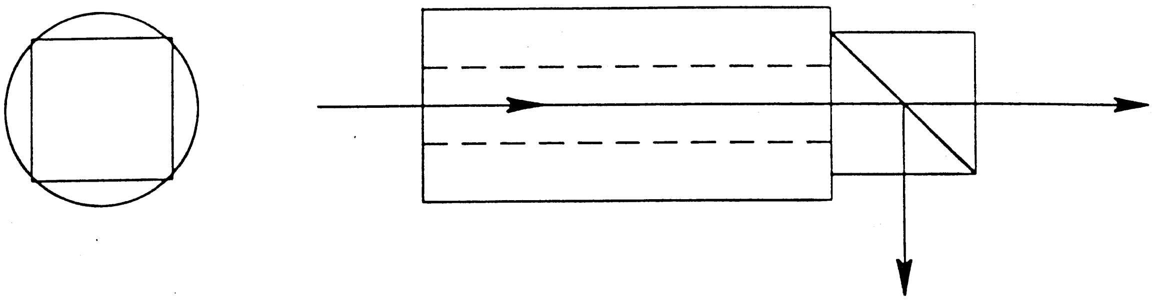
RELEVANT:
THREE ANGLES
TWO POSITIONS

REFLECTED AND TRANSMITTED BEAMS ARE DIFFERENTLY AFFECTED BY MISALIGNMENT.
THE TRANSMITTED BEAM IS UNAFFECTED BY AXIAL POSITION AND BY ROTATION ABOUT THE INPUT AXIS

NON-CRITICAL OR IRRELEVANT:
TRANSLATION PERPENDICULAR TO THE BEAM PLANE
I.E. "OUT OF THE PAPER"

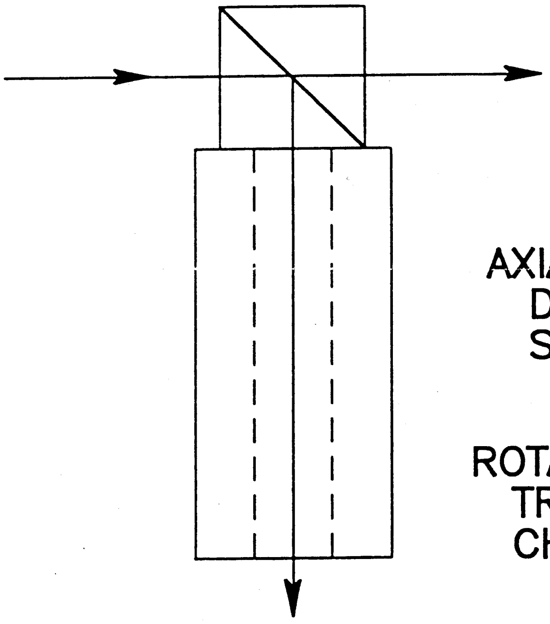
CUBE BEAMSPLITTER

- TRANSMITTED DIRECTION ALONG CYLINDER AXIS



TRANSMITTED LIGHT UNAFFECTED BY AXIAL POSITION OR ROTATION

- REFLECTED DIRECTION ALONG CYLINDER AXIS

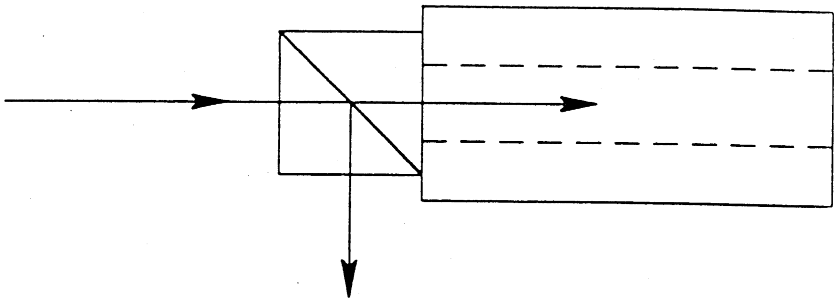


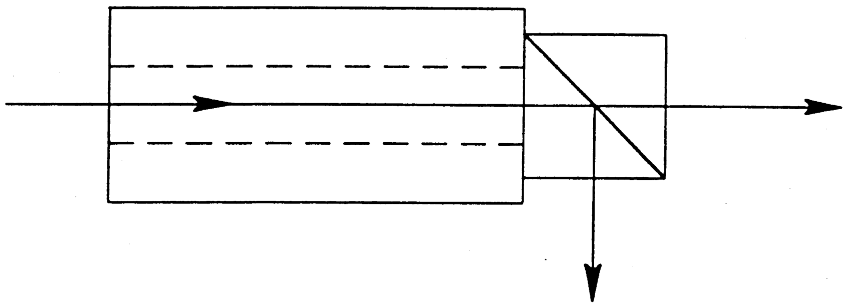
AXIAL SHIFT OF CYLINDER
  DOES NOT AFFECT TRANSMITTED LIGHT
  SHIFTS REFLECTED LIGHT

ROTATION OF CYLINDER
  TRANSLATES TRANSMITTED LIGHT
  CHANGES ANGLE OF REFLECTED LIGHT

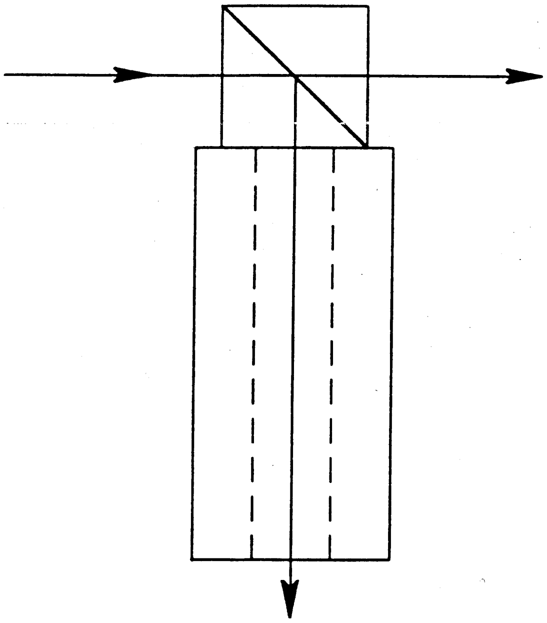
CUBE BEAMSPLITTER ON A CYLINDER

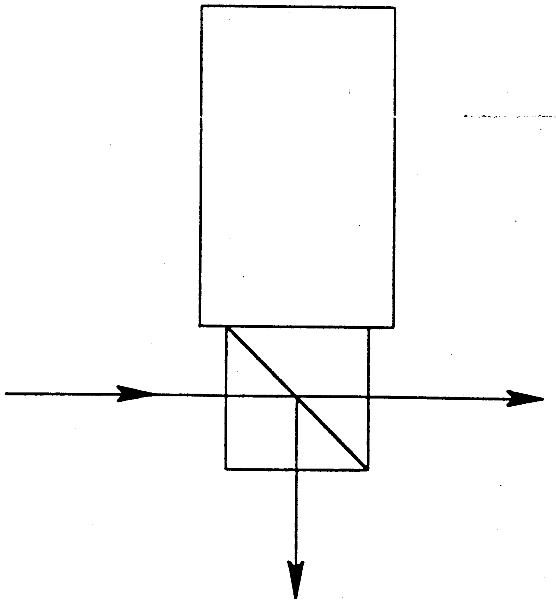
MECHANICALLY EQUIVALENT





MECHANICALLY EQUIVALENT

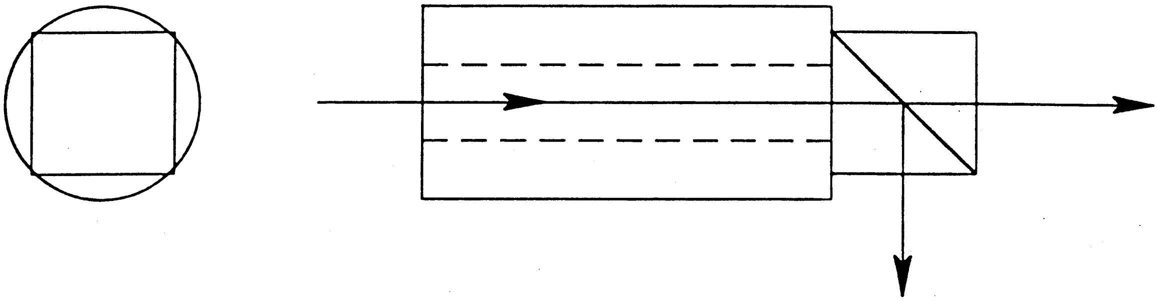




CUBE BEAMSPLITTER ON A CYLINDER ALONG THE INCIDENT AXIS

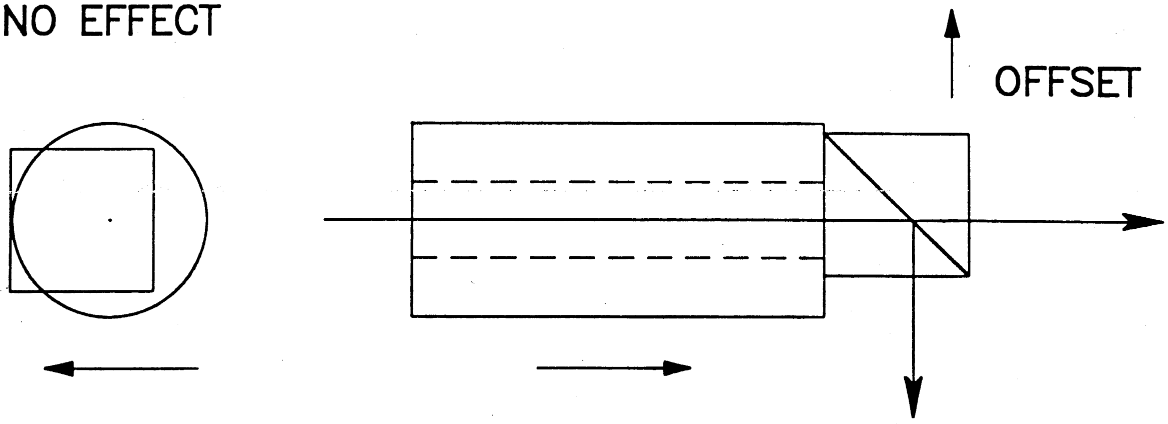
CYLINDER

TRANSMITTED LIGHT IS UNAFFECTED BY
AXIAL POSITION AND ROTATION.



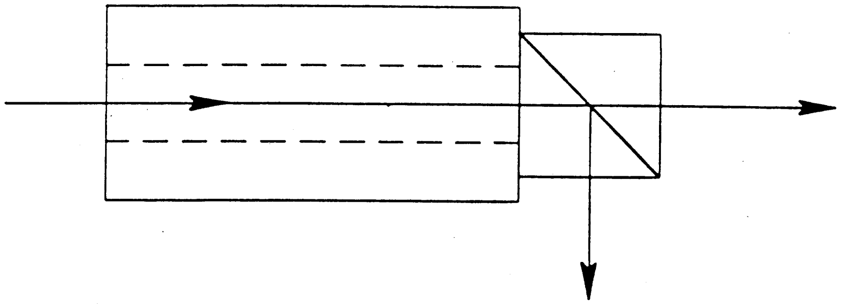
BEAMSPLITTER LATERAL POSITION

NO EFFECT



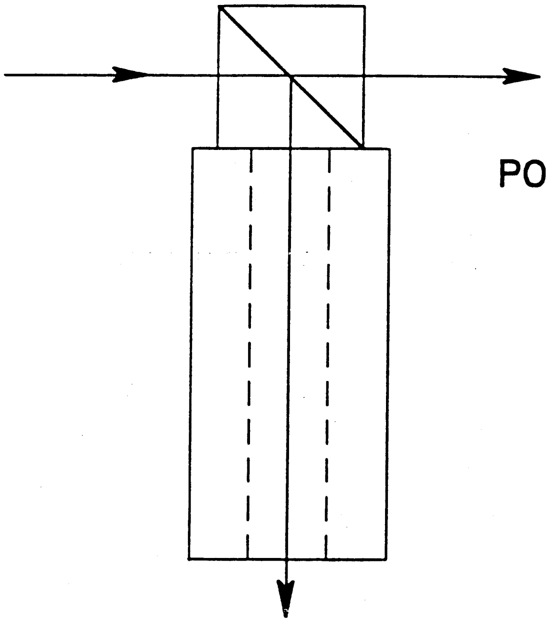
COMPENSATION

CUBE OPTICAL ALIGNMENT



NO INFORMATION.

TREAT AS A MIRROR, ALTHOUGH BEHAVIOR DIFFERS SOMEWHAT.



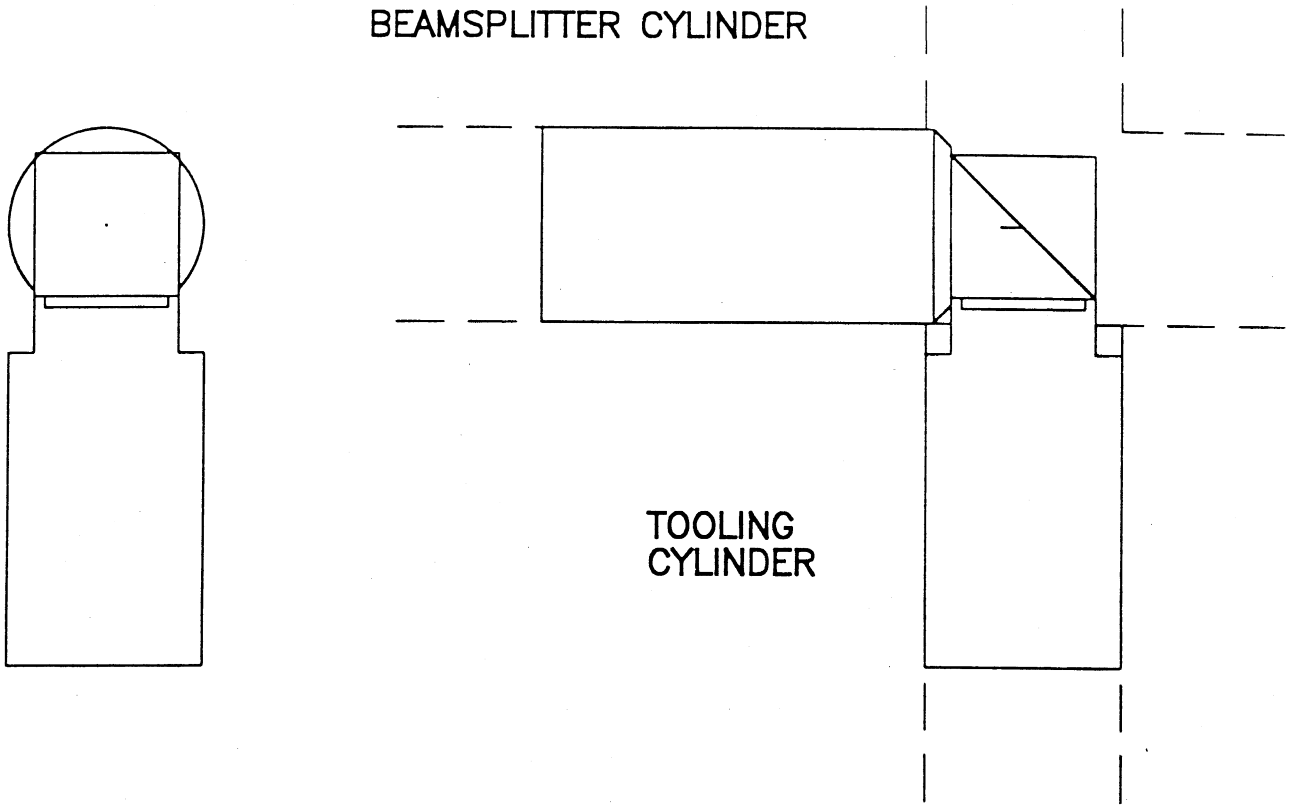
POSITION DEPENDS ON CYLINDER AZIMUTH.

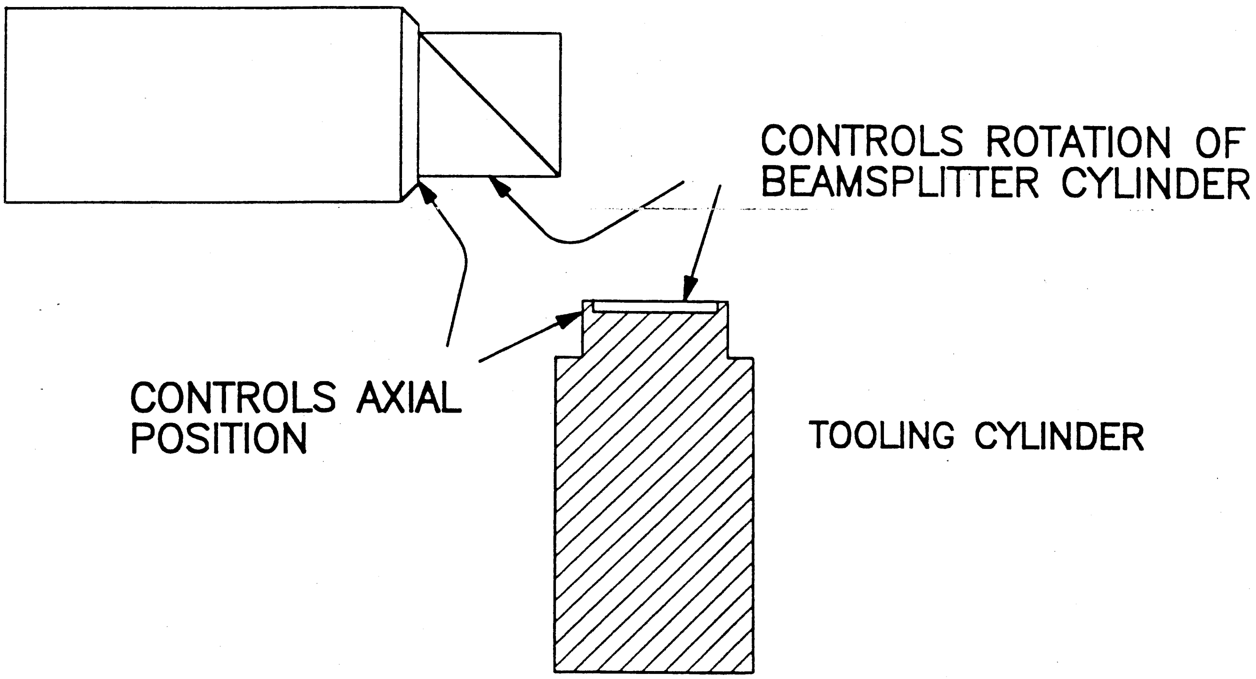
THREE EFFECTS FROM TWO DEGREES OF FREEDOM.

OUTPUT DEPENDS ON BOTH DEGREES OF FREEDOM.

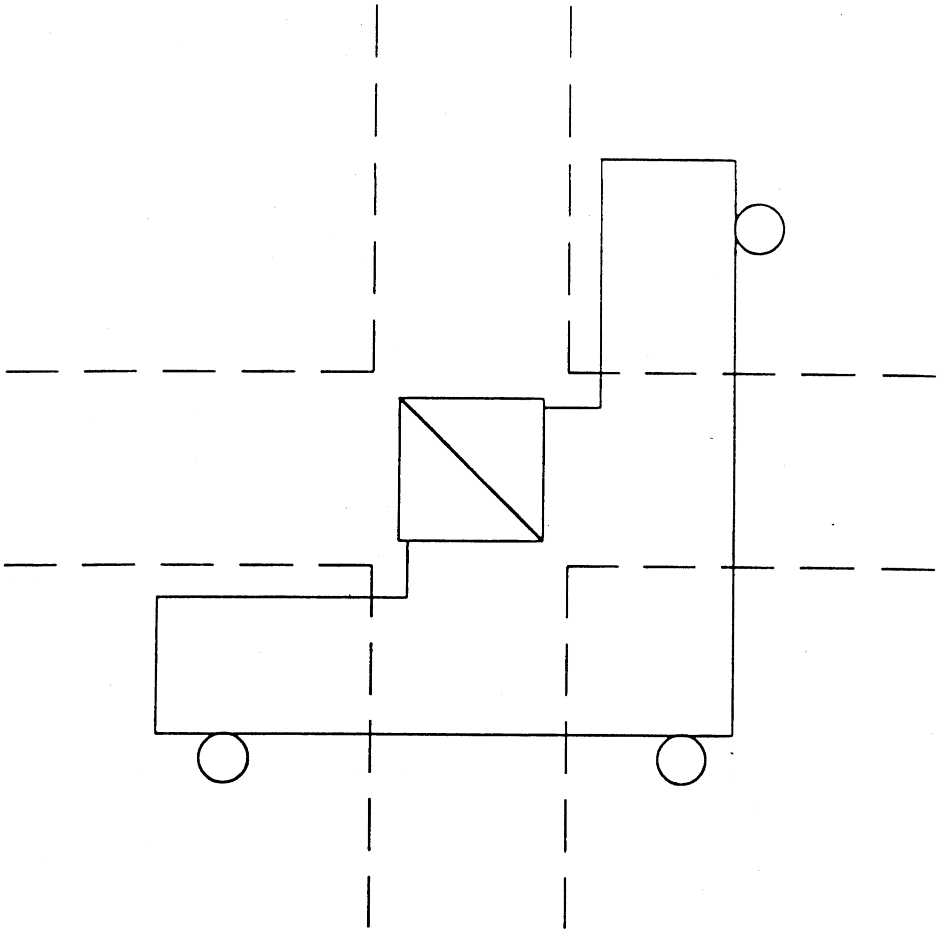
OUTPUT ANGLE DEPENDS ONLY ON CYLINDER ANGLE.

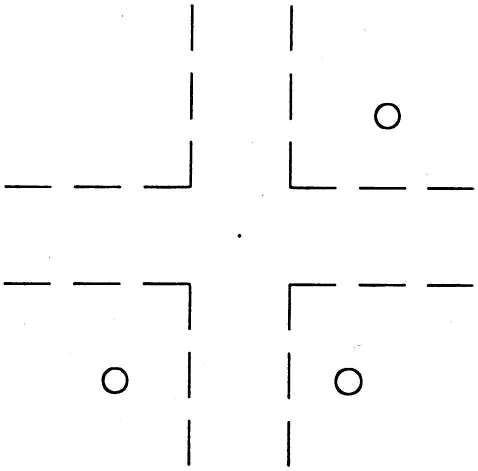
CUBE BEAMSPLITTER ALIGNMENT

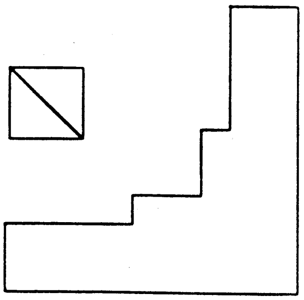




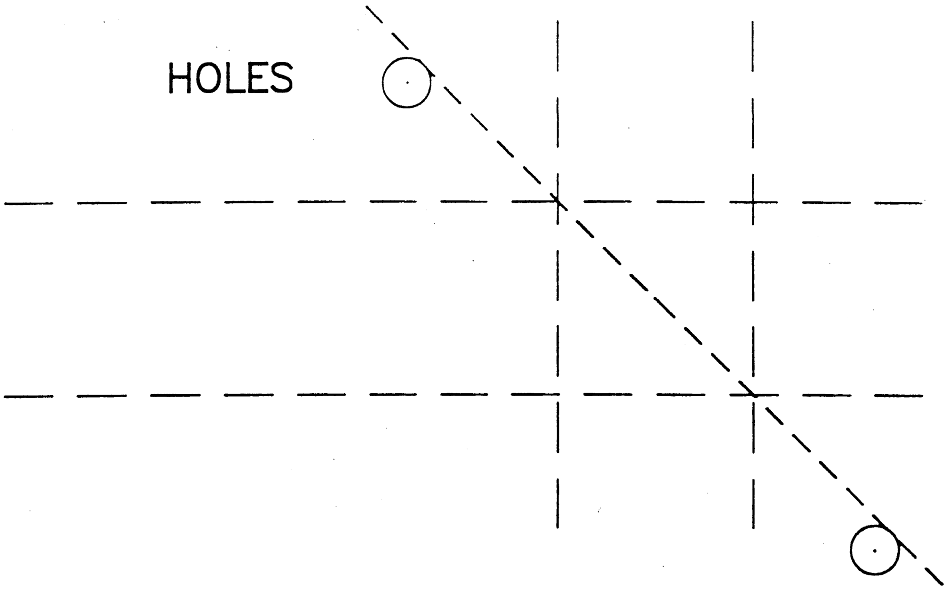
CUBE BEAMSPLITTER ALIGNMENT

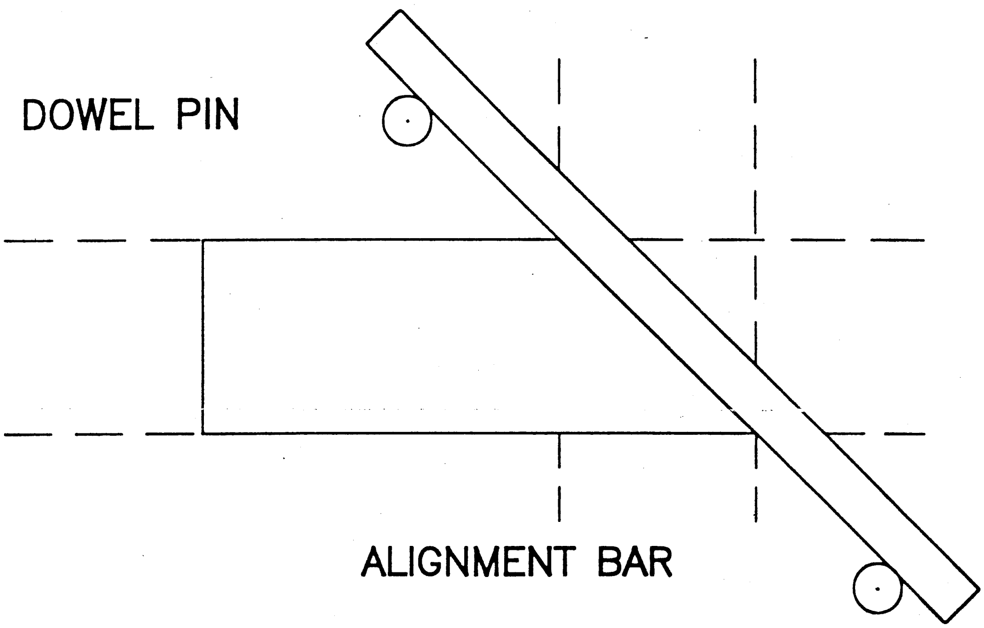






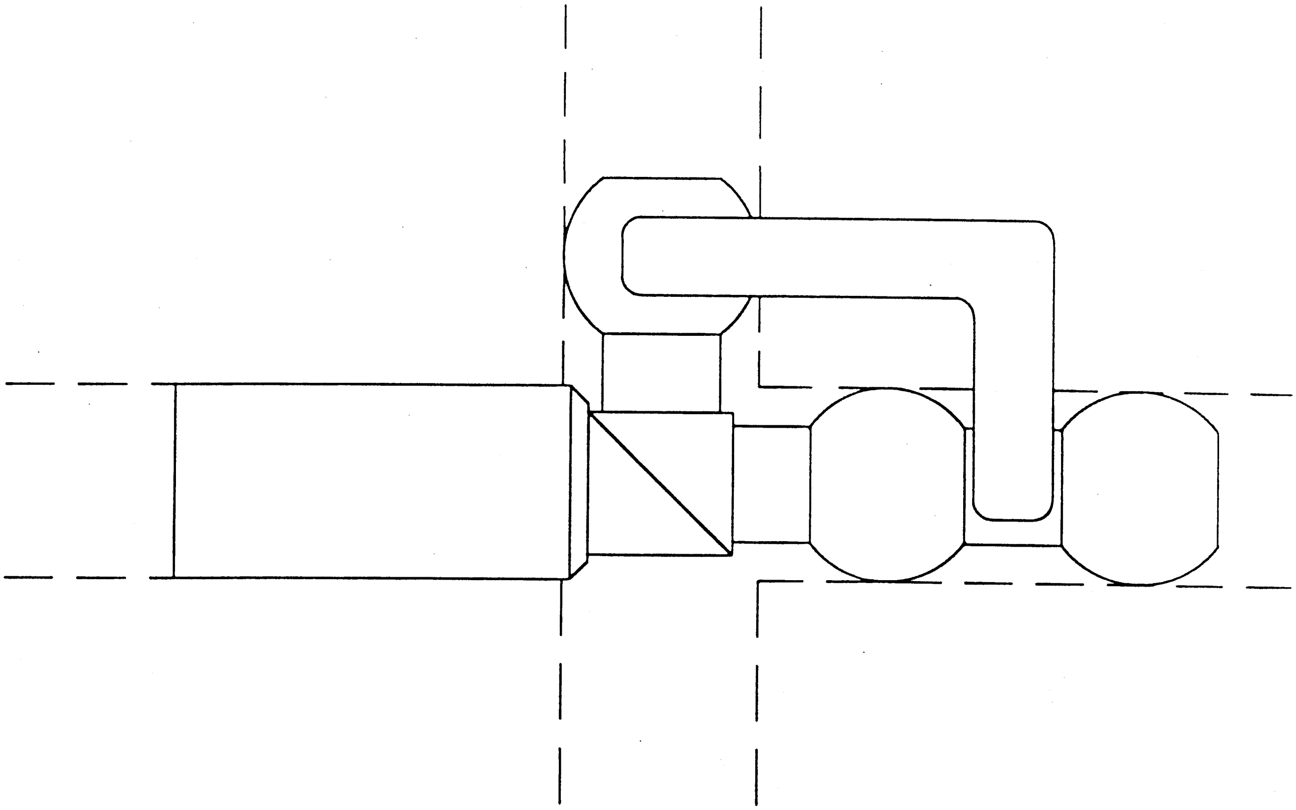
BEAMSPLITTER BAR

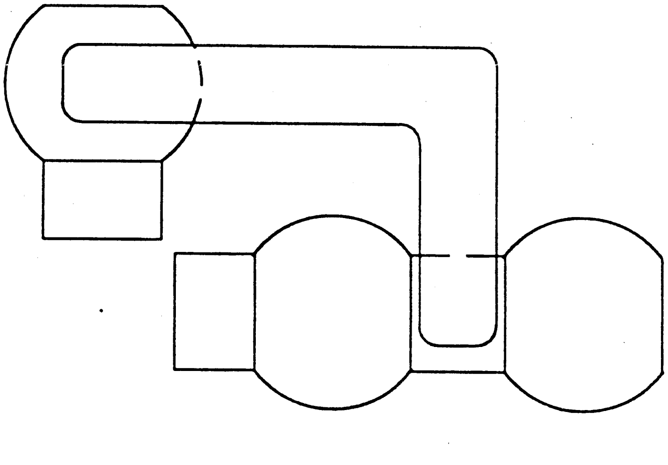




SAME METHODS AS MIRROR

KINEMATIC CUBE LOCATION FIXTURE

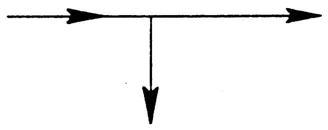




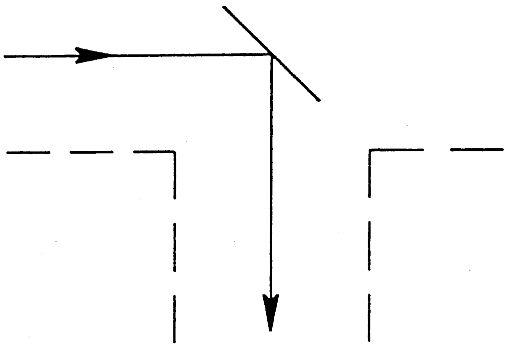
SWITCHING

DISCRETE CHANGES OF BEAM PATH BY MOVEMENT OF A MIRROR OR BEAMSPLITTER

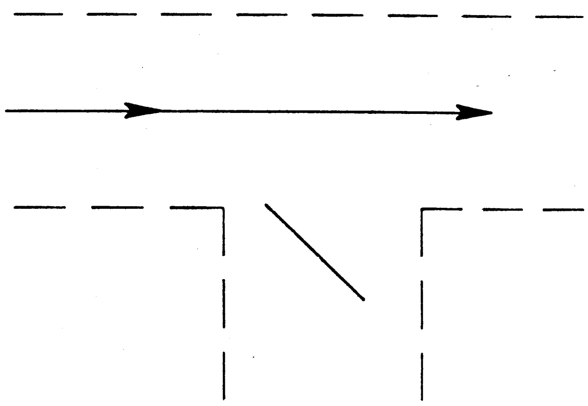
EXAMPLE



MIRROR IN BEAM



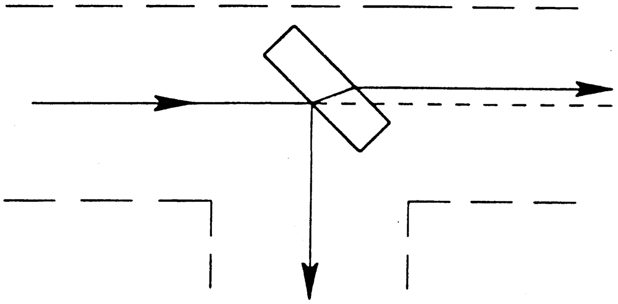
MIRROR OUT OF BEAM



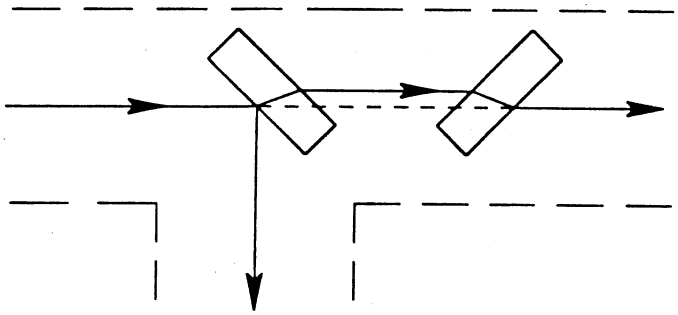
A FEW TYPES FOLLOW.

THESE METHODS CAN ALSO BE APPLIED TO FILTERS.

PLATE BEAMSPLITTER OFFSET

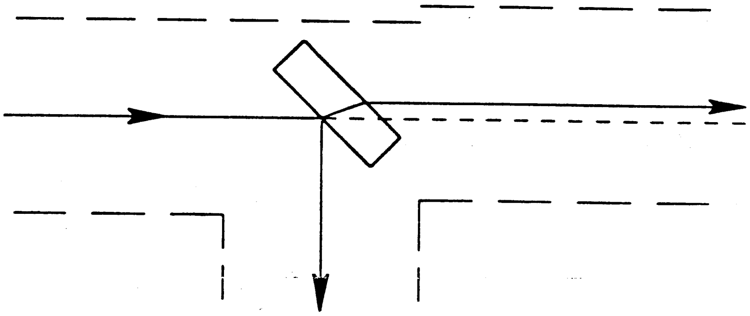


SOME WAYS TO DEAL WITH THIS FOLLOW

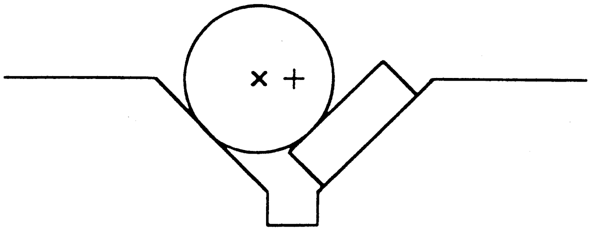


NOMINALLY COMPENSATORY PLANE PARALLEL PLATE

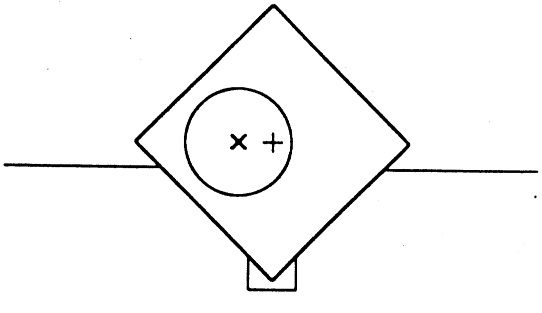
OFFSET V



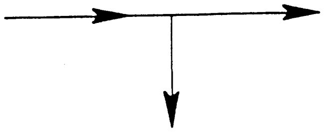
SMALLER CYLINDER AND SHIM

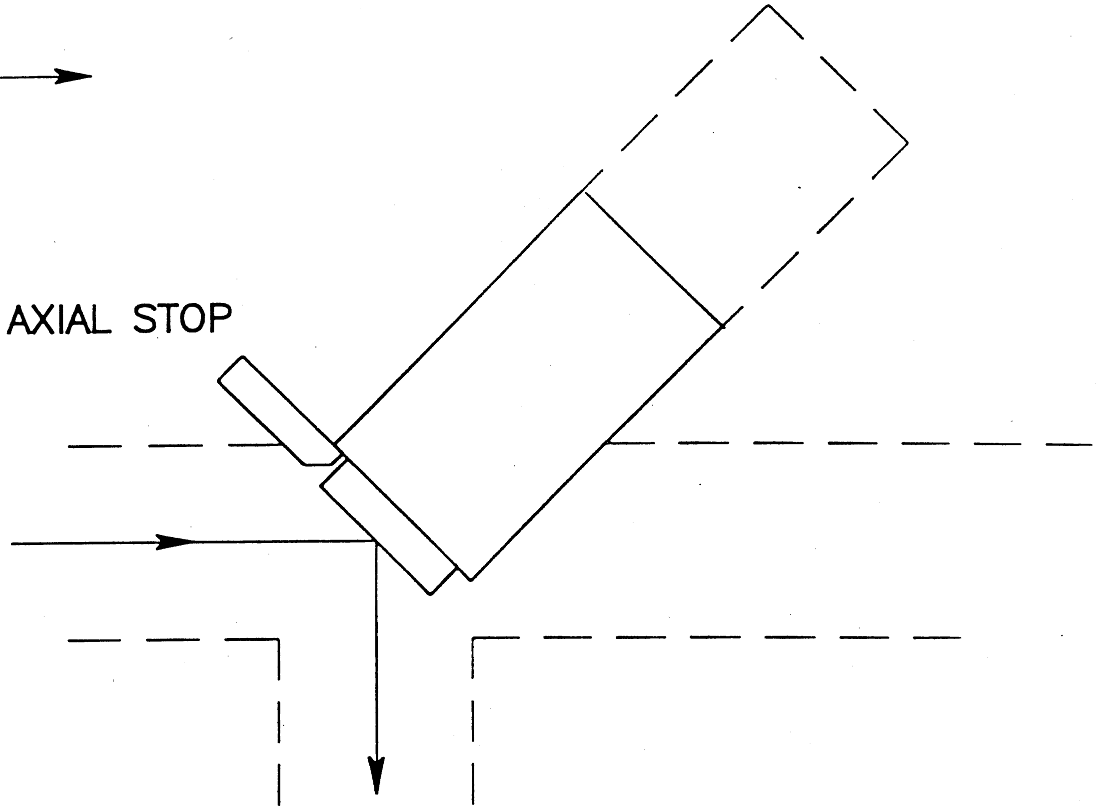


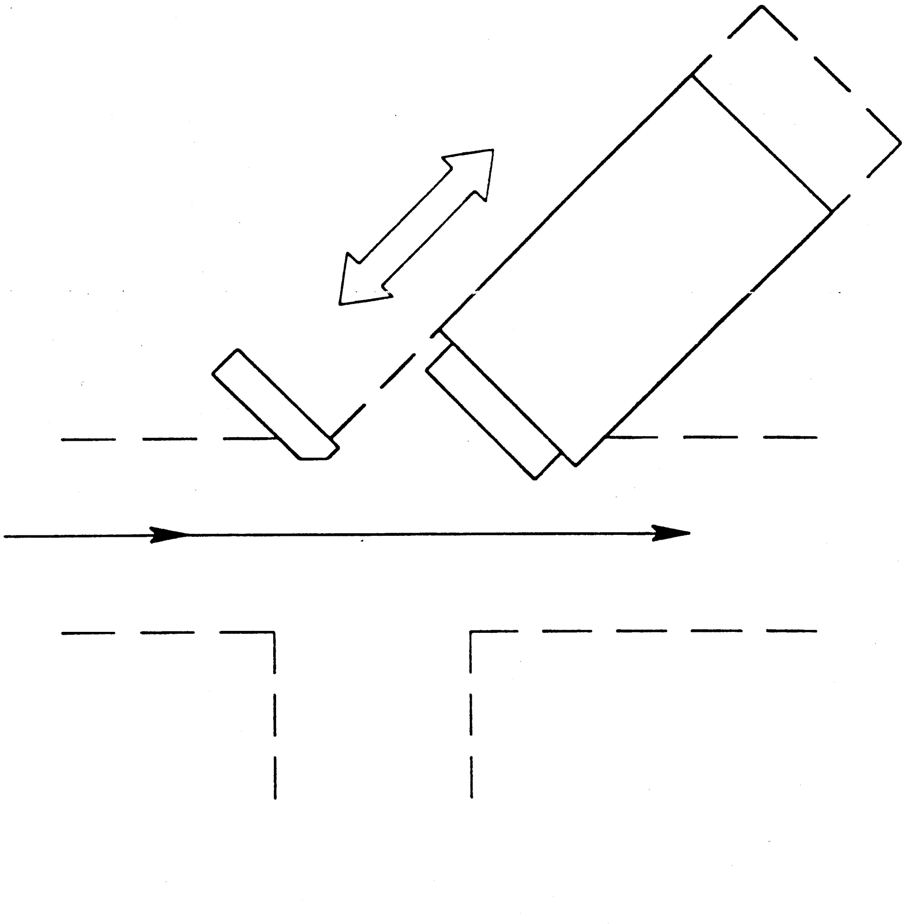
NON–ROUND CYLINDER WITH OFFSET ELEMENT



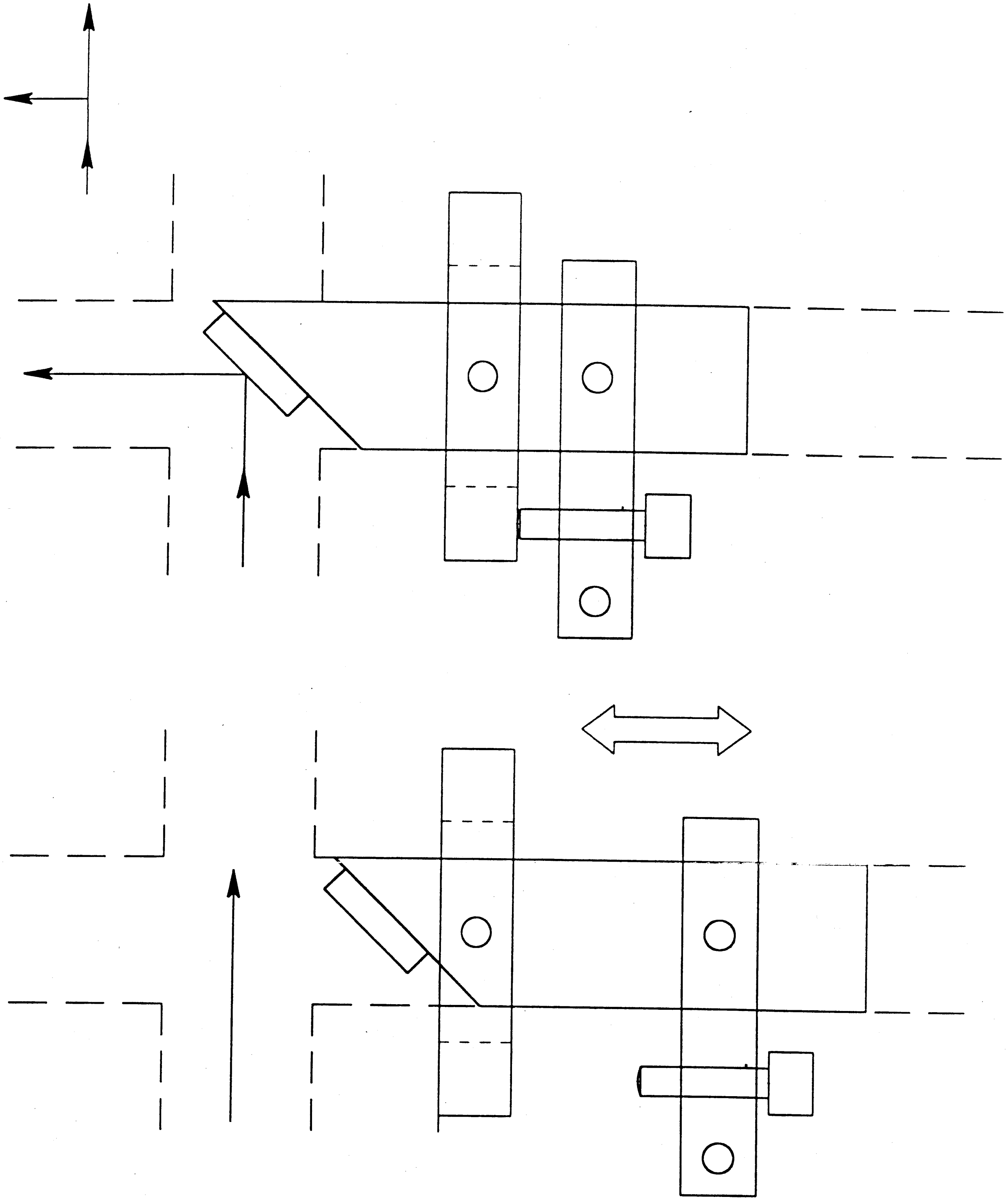
MIRROR HOLDER AT 45°



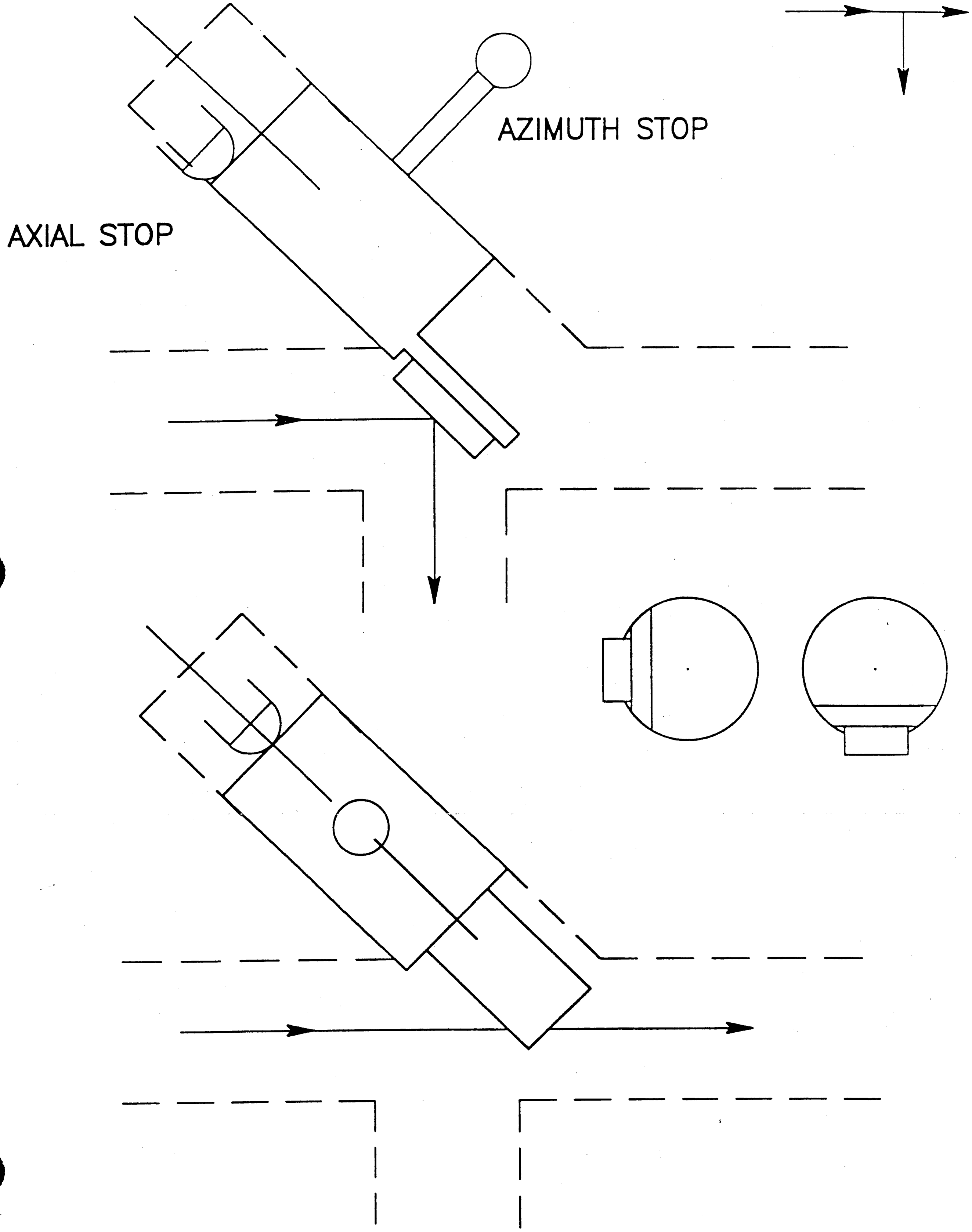




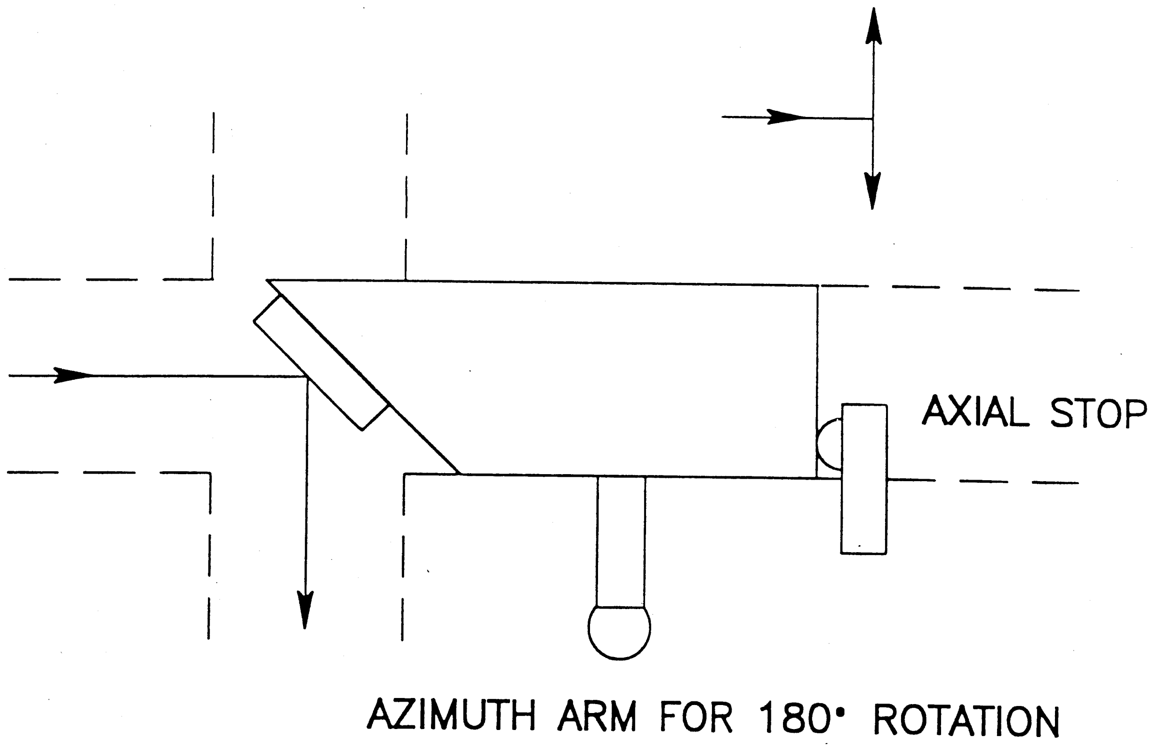
SEMI–KINEMATIC ARRANGEMENT FOR MOVING IN AND OUT



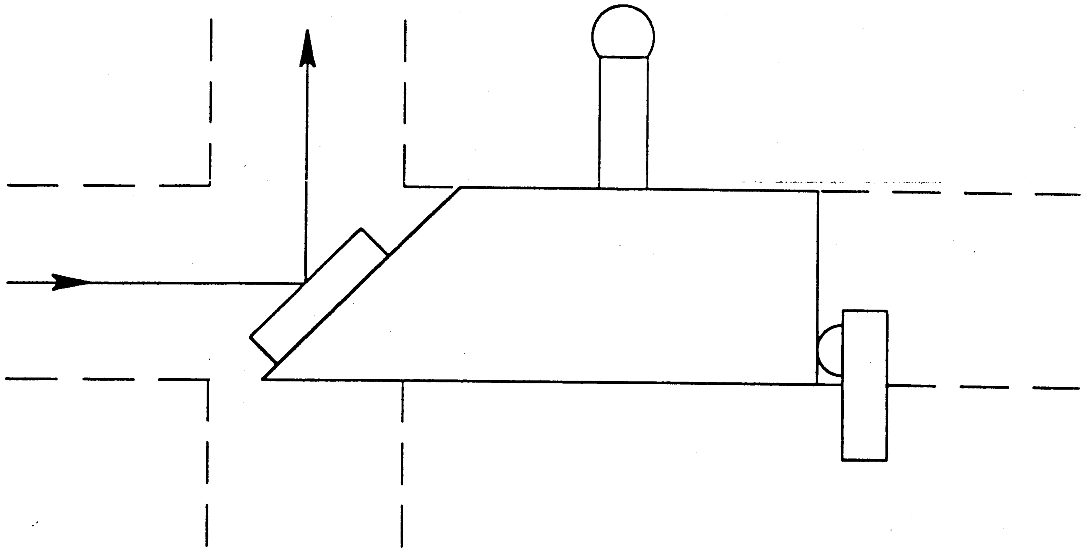
ROTATING CYLINDER SWITCH



CHANGING DIRECTION BY ROTATION



CYLINDER ROTATED 180°

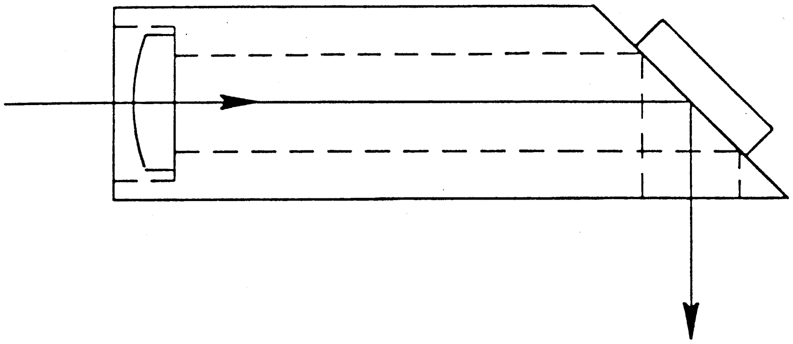


THIS ALSO WORKS WITH BEAMSPLITTERS.

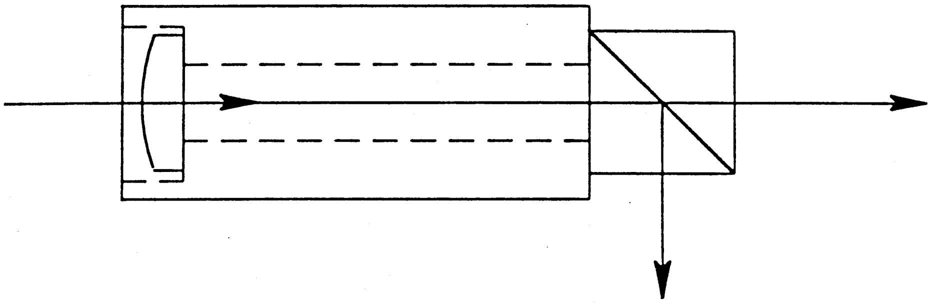
CYLINDER DUAL USE

- EXAMPLES

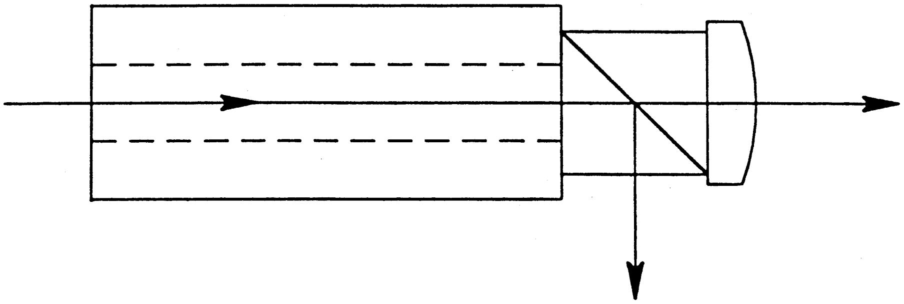
CYLINDER WITH A LENS AND A MIRROR



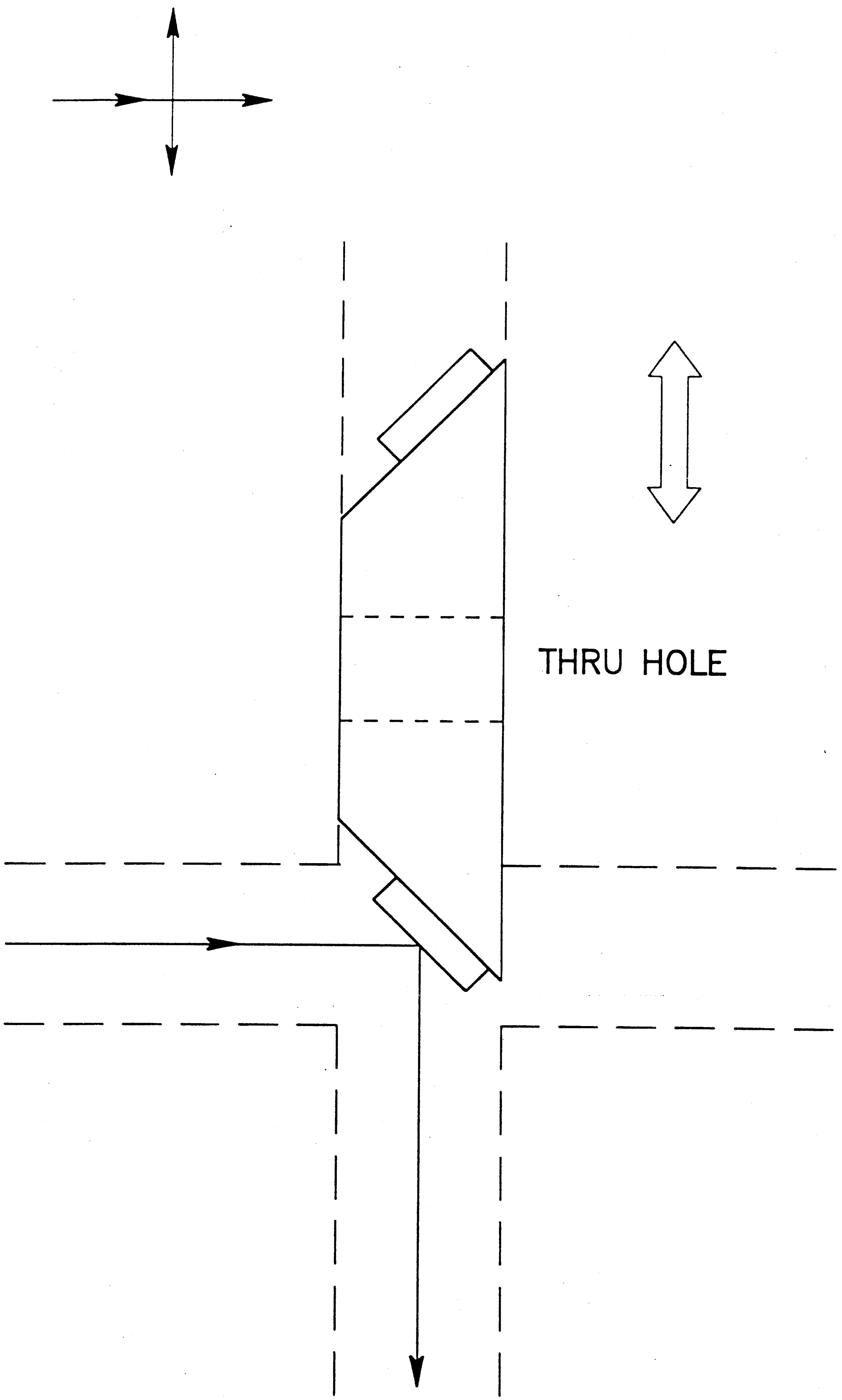
LENS AND CUBE BEAMSPLITTER



LENS CEMENTED TO CUBE BEAMSPLITTER

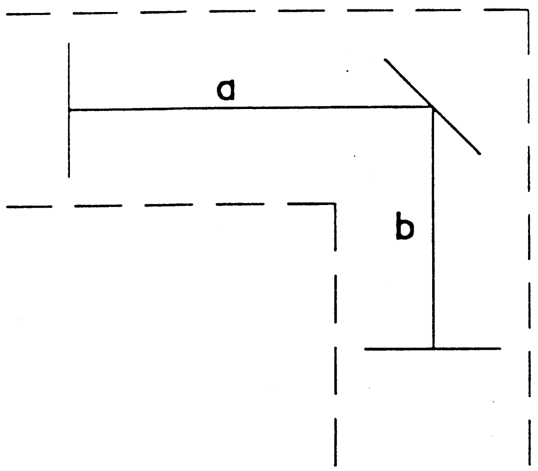


THREE OUTPUT PATHS

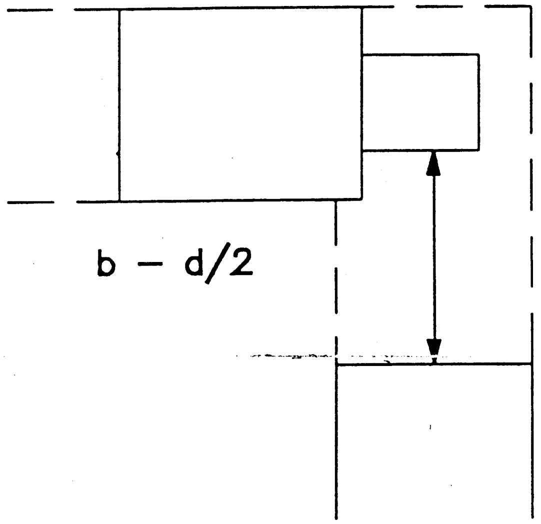


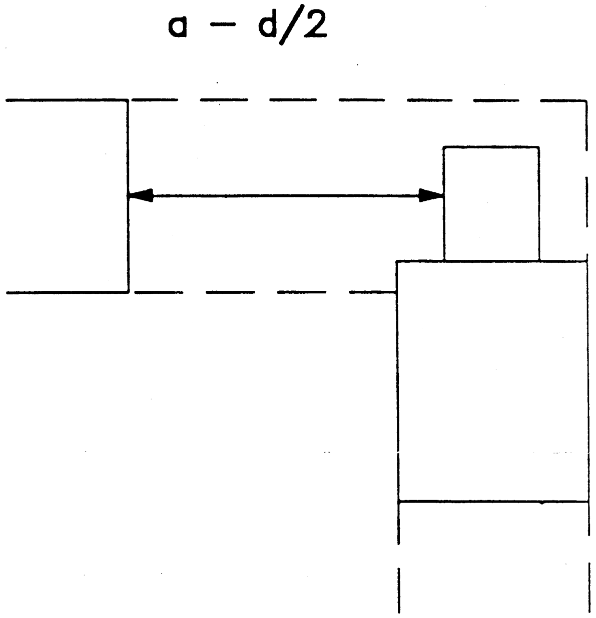
MEASURING AROUND A TIGHT CORNER

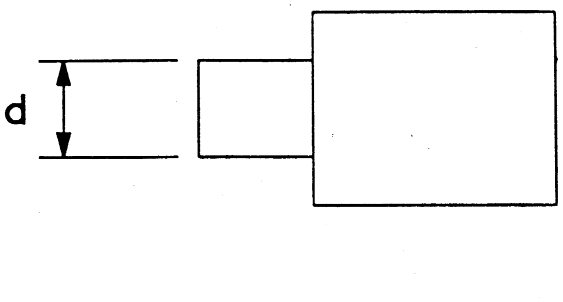
FIND a + b



CORNER TOO SMALL FOR
A FULL SIZE CYLINDER

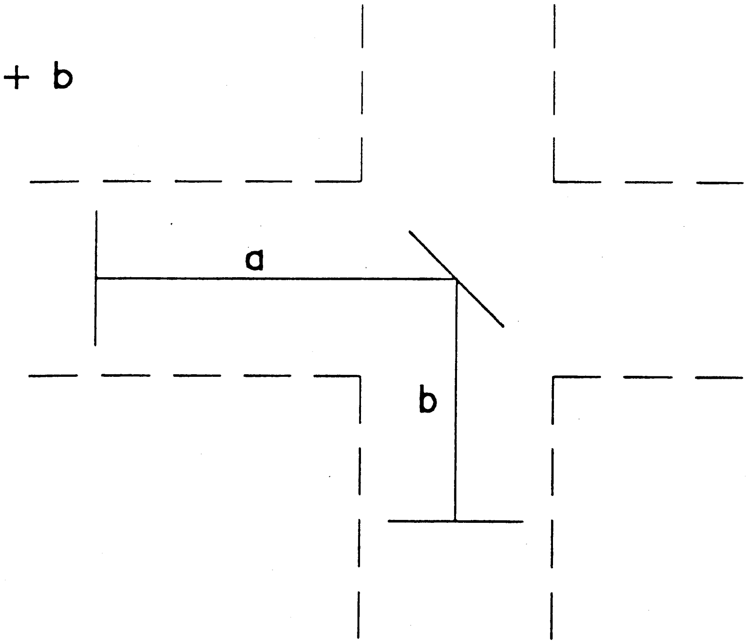




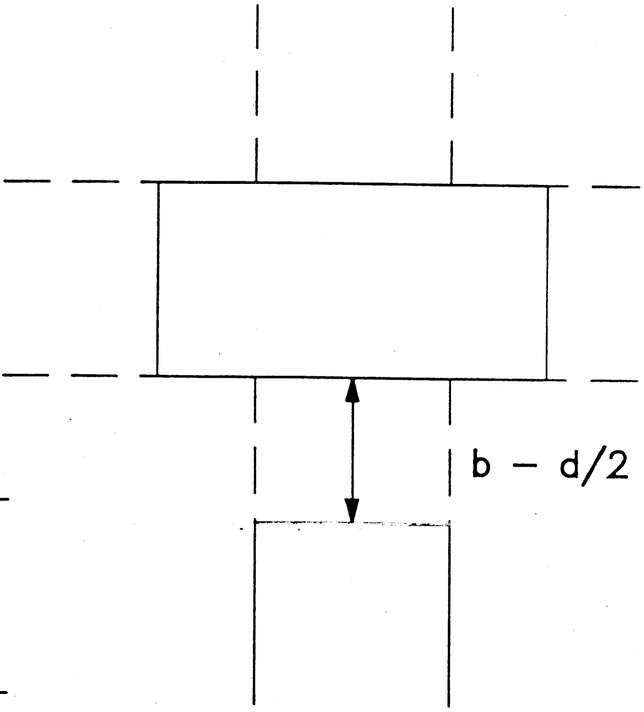


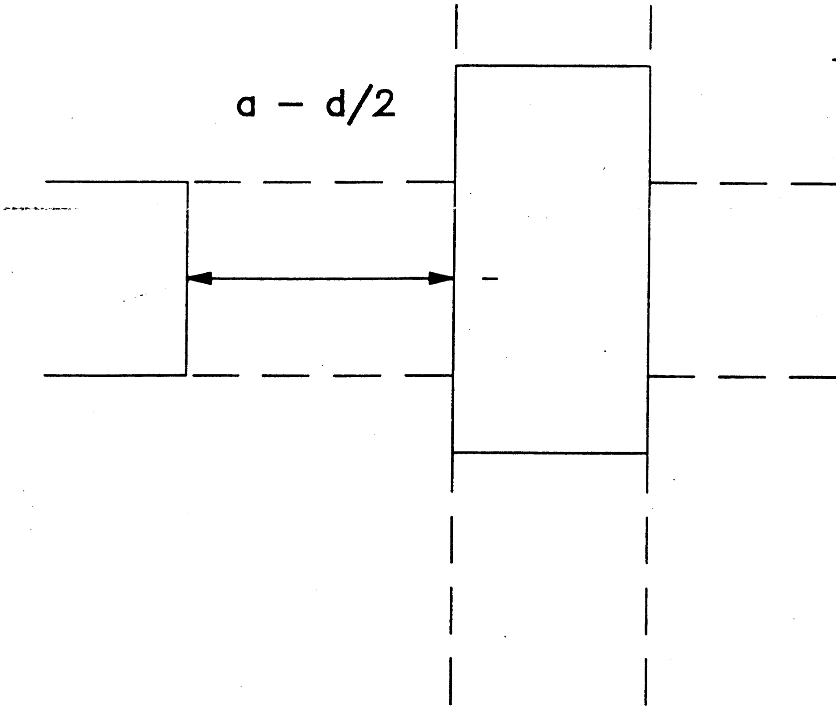
MEASURING AROUND A CORNER

FIND a + b



CYLINDER DIAMETER = d

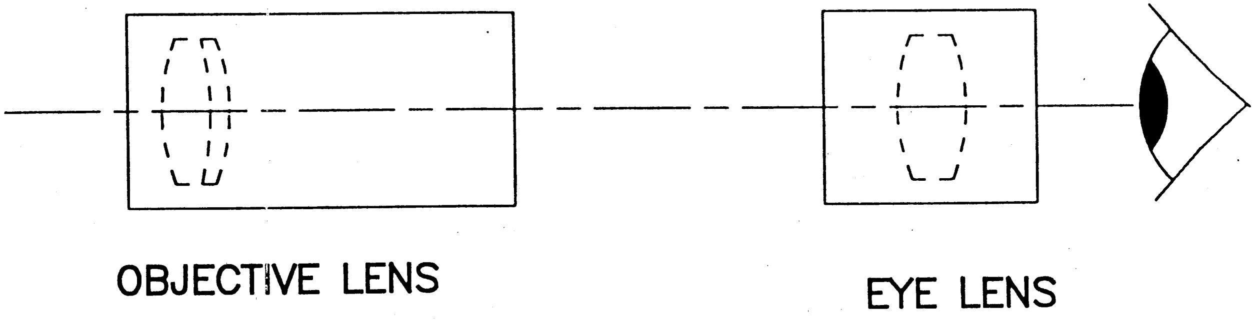




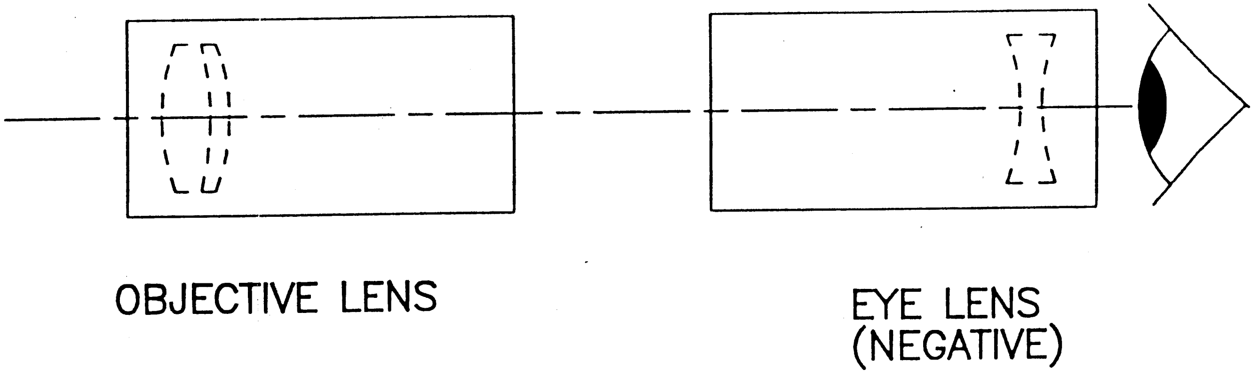
INSTRUMENT EXAMPL

BASIC VISUAL TELESCOPES

KEPLERIAN

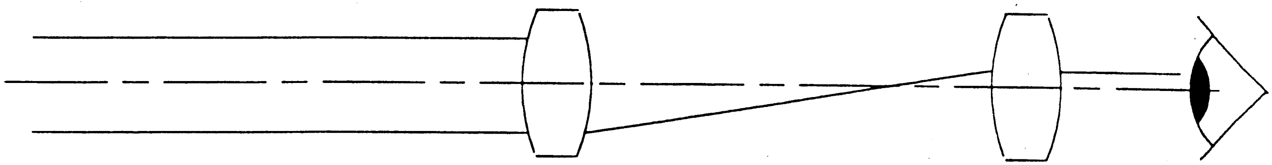


GALILEAN

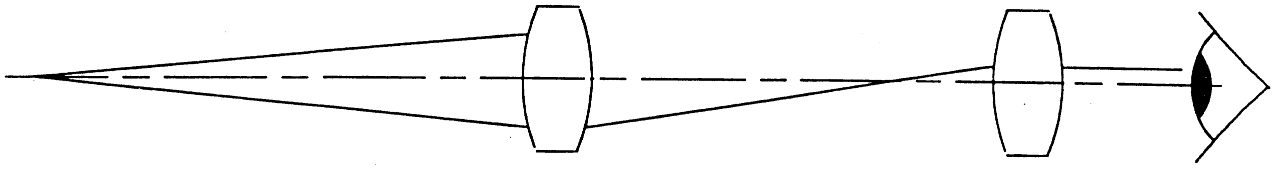


"SCOPES"

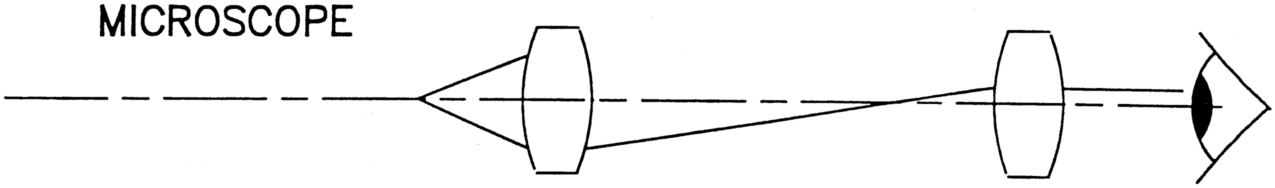
TELESCOPE



"MIDDLE SCOPE"

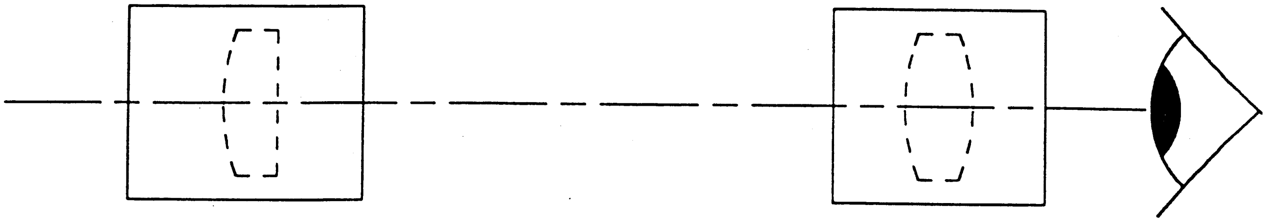


MICROSCOPE

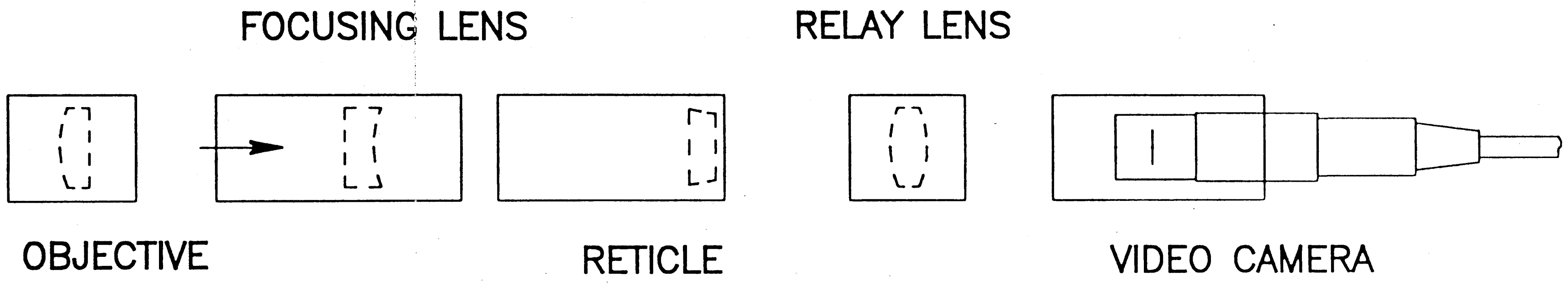


GENERAL FORM OBJECTIVE LENS EYE LENS

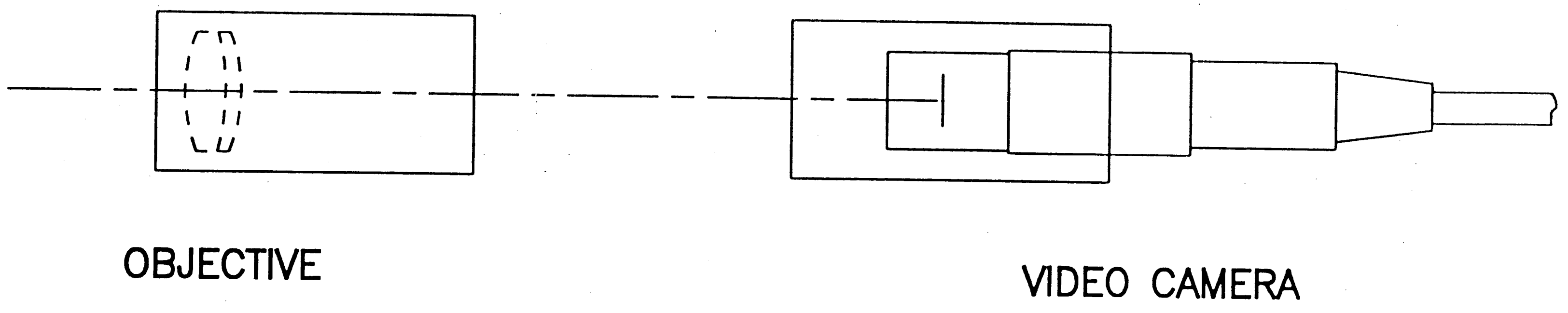
GENERAL CYLINDER IN V FORM

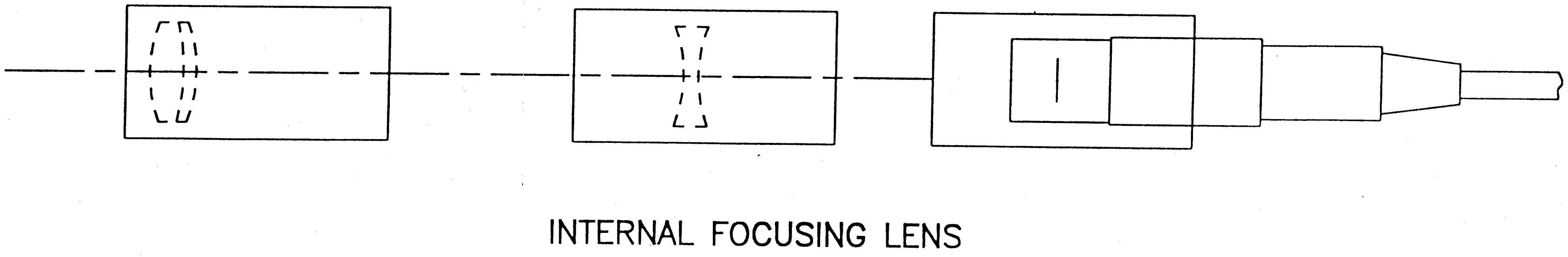


VIDEO ALIGNMENT TELESCOPE

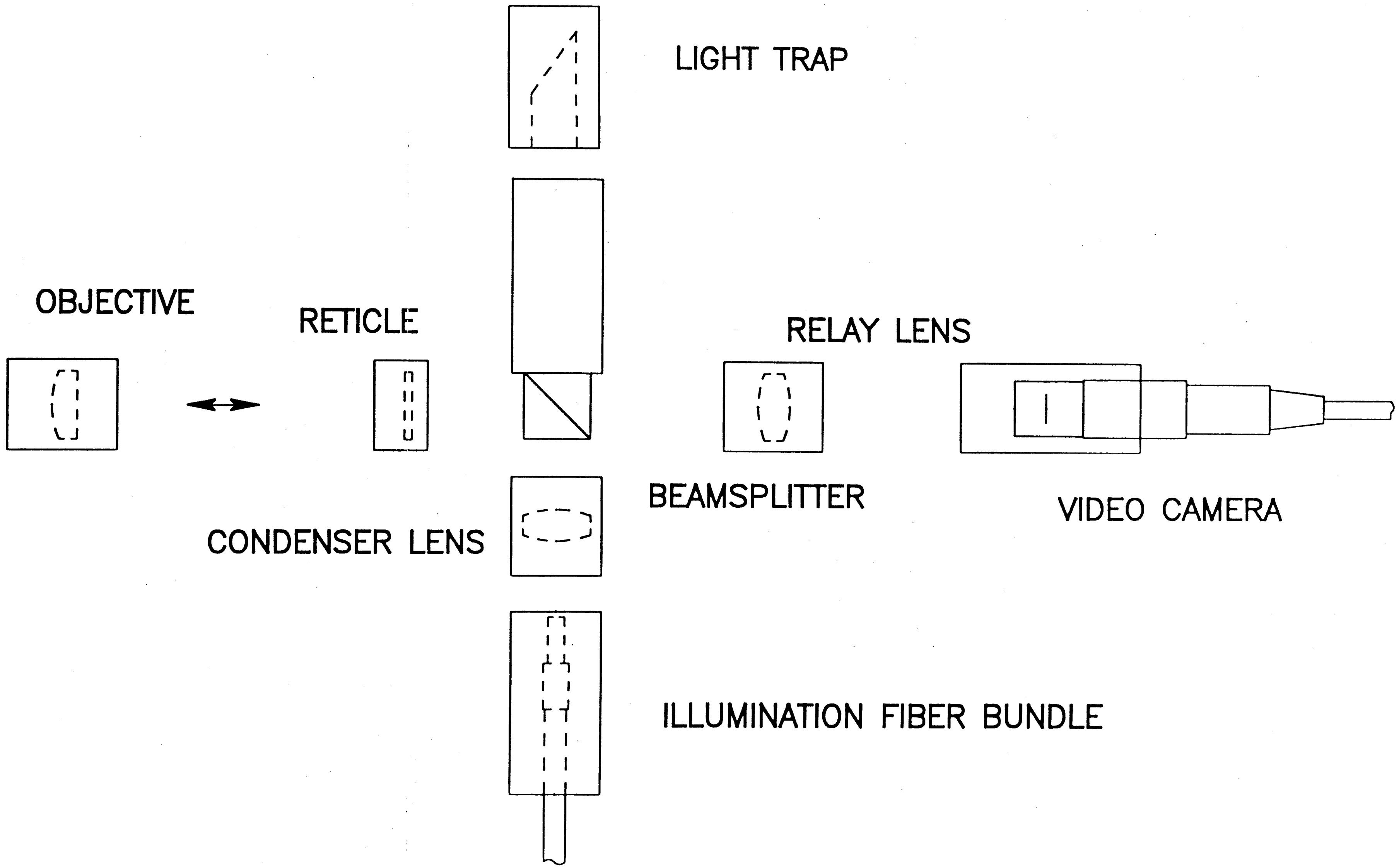


BASIC VIDEO TELESCOPES





VIDEO AUTOCOLLIMATOR



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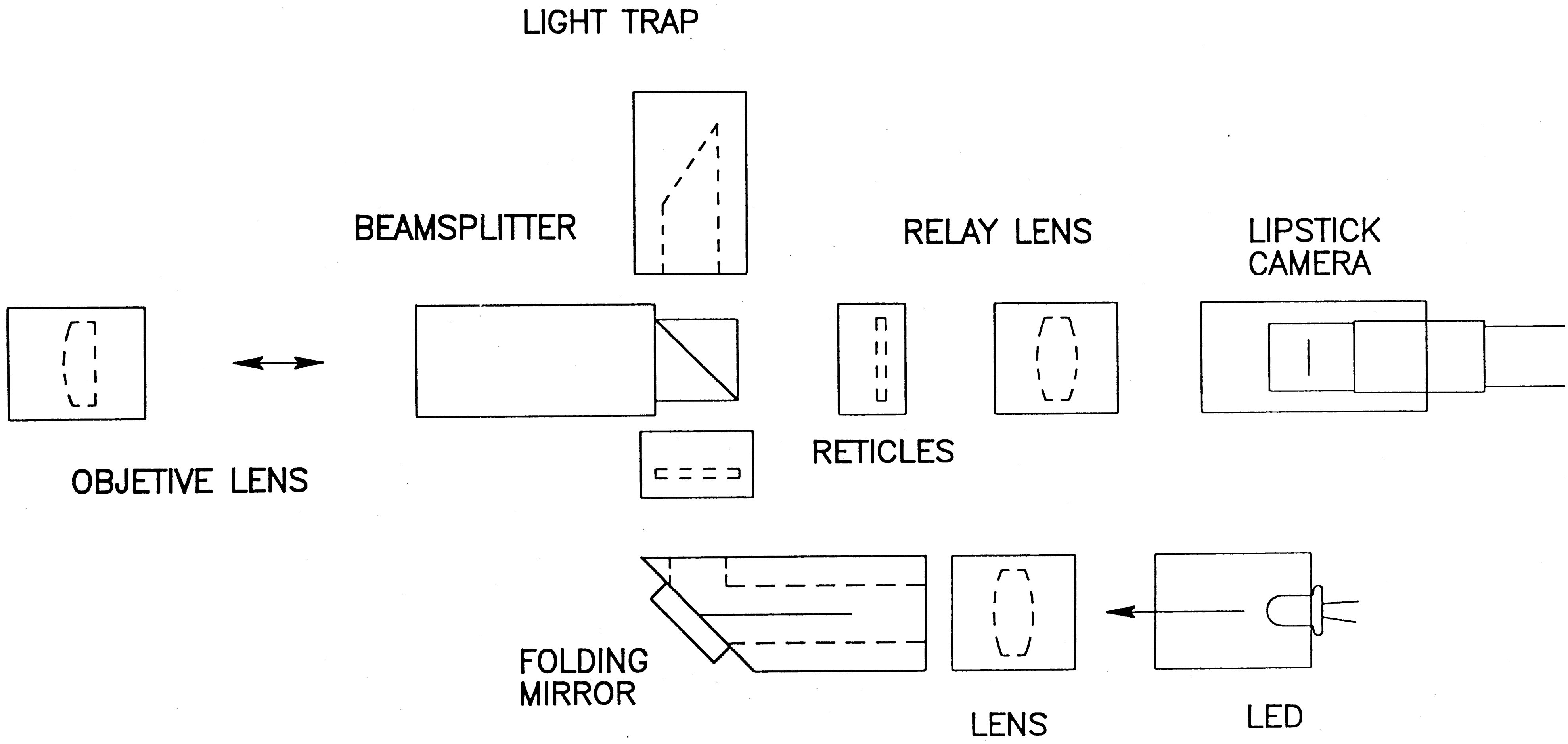

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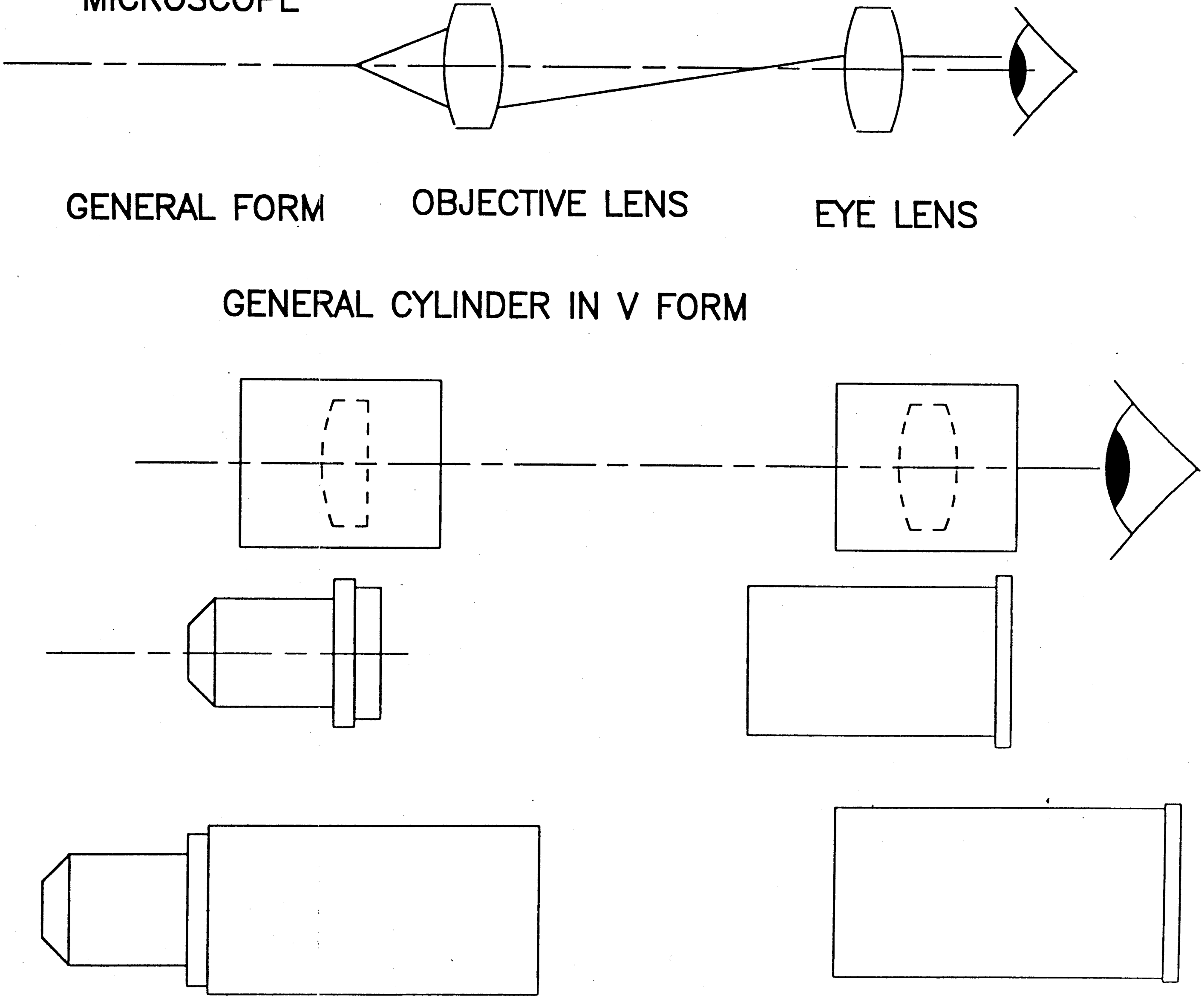
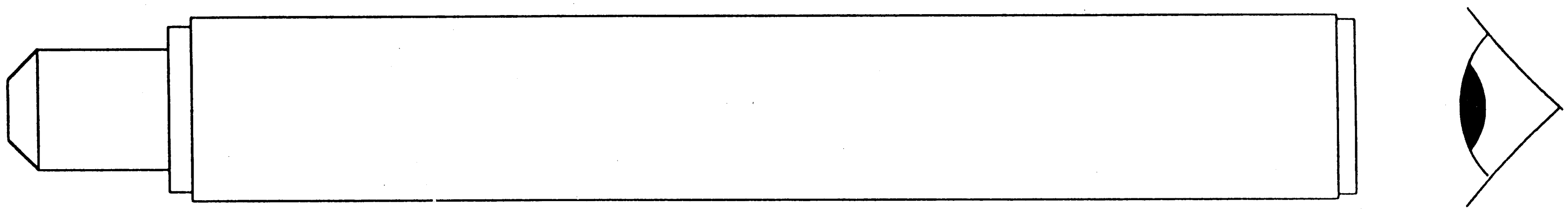
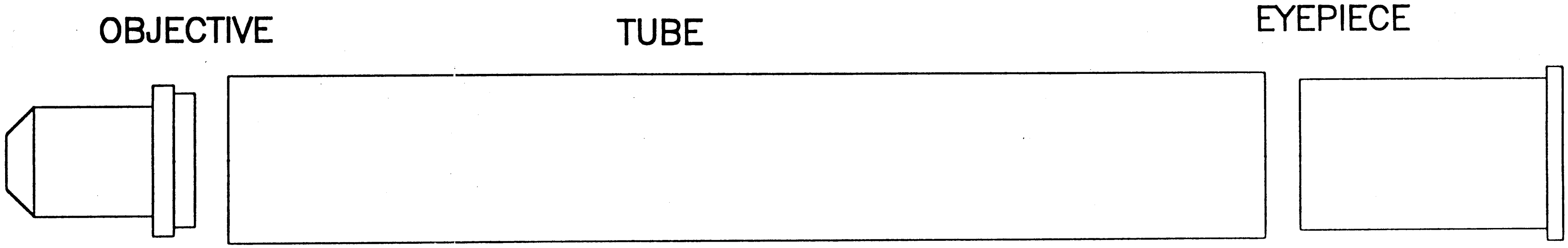
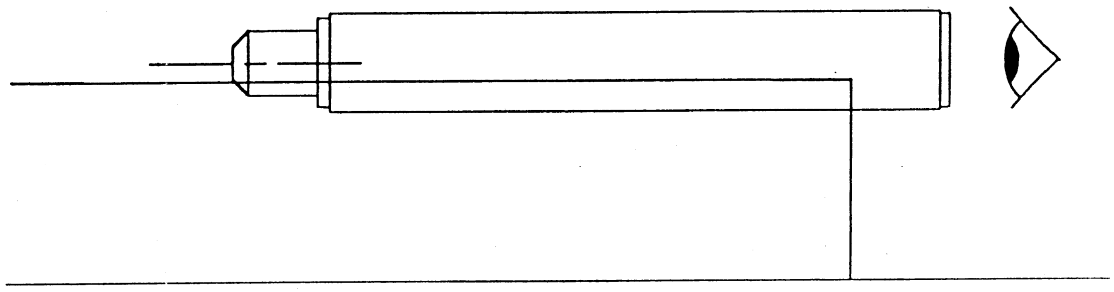

GENERAL FORM
OBJECTIVE LENS
EYE LENS
GENERAL CYLINDER IN V FORM

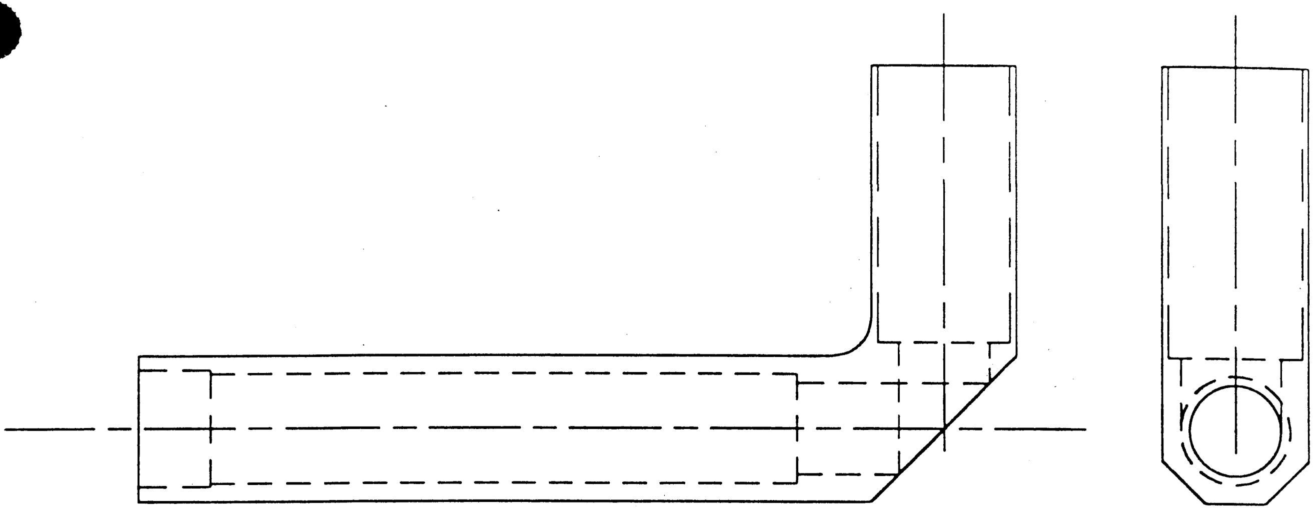
BASIC VISUAL MICROSCOPE

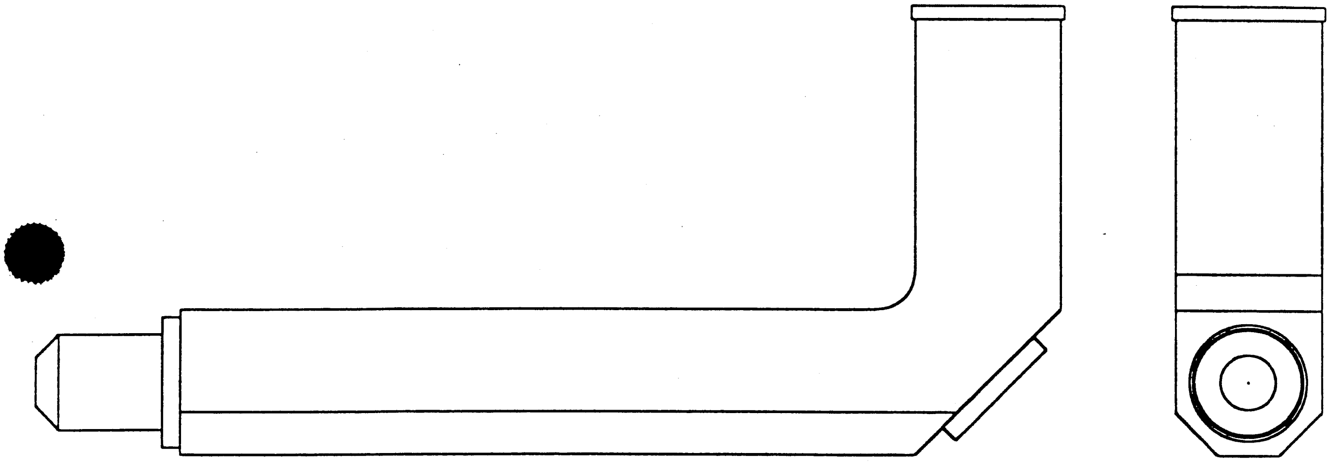




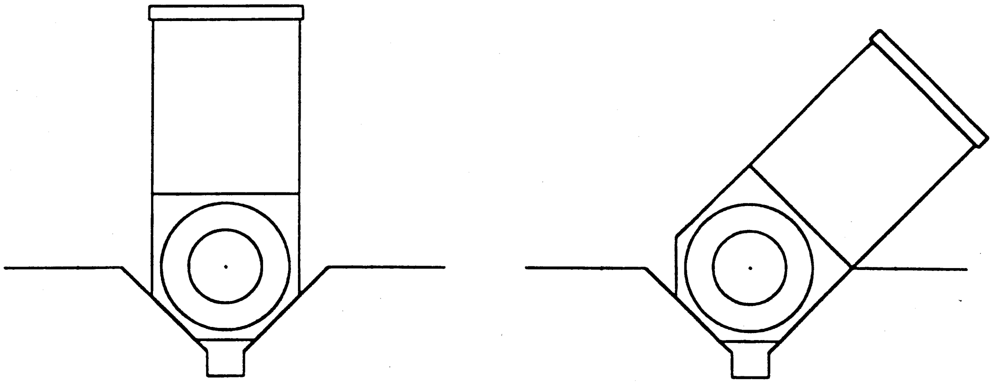


ERGONOMIC VISUAL MICROSCOPE

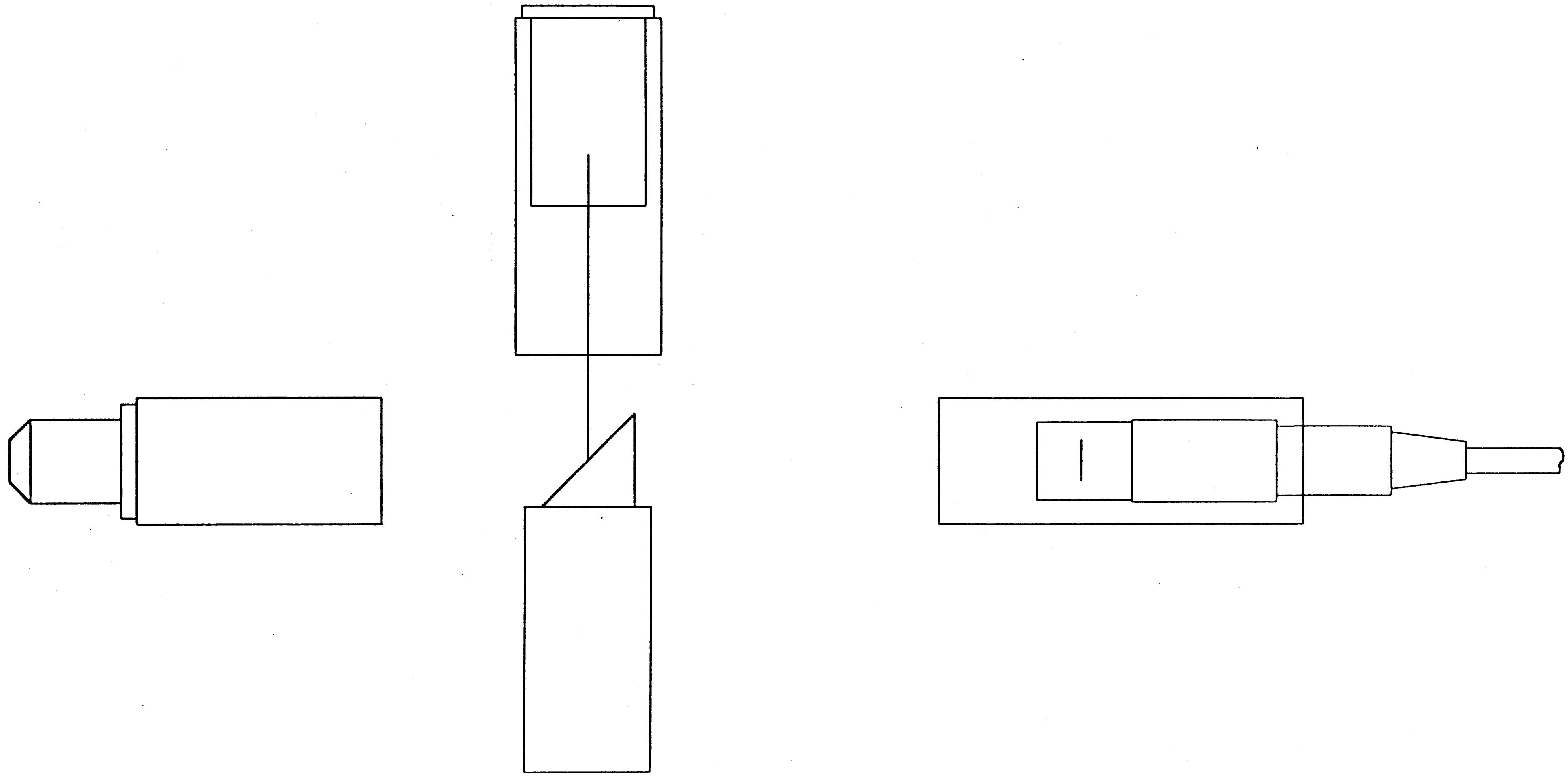




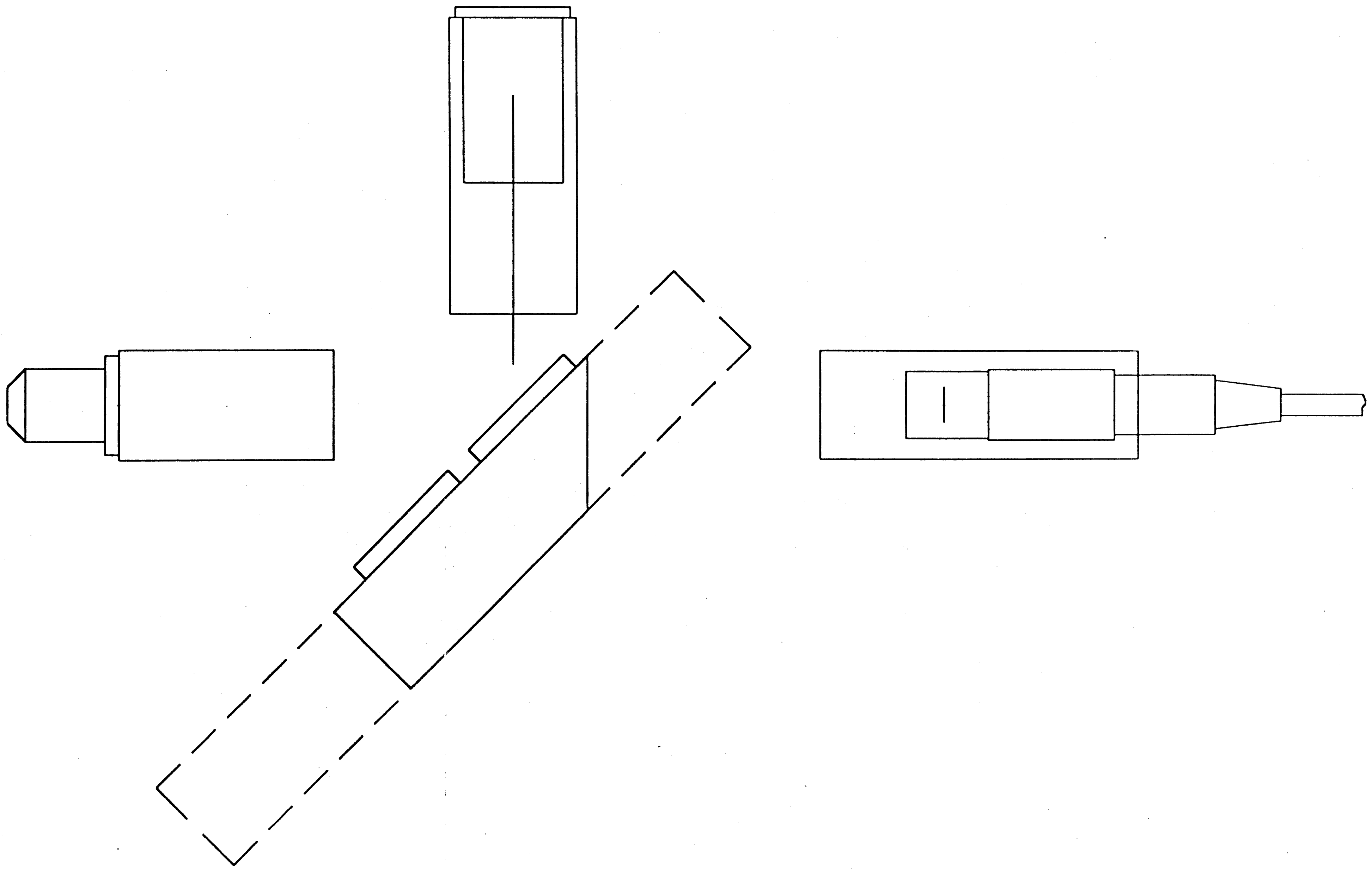
FRONT SURFACE MIRROR CEMENTED ON



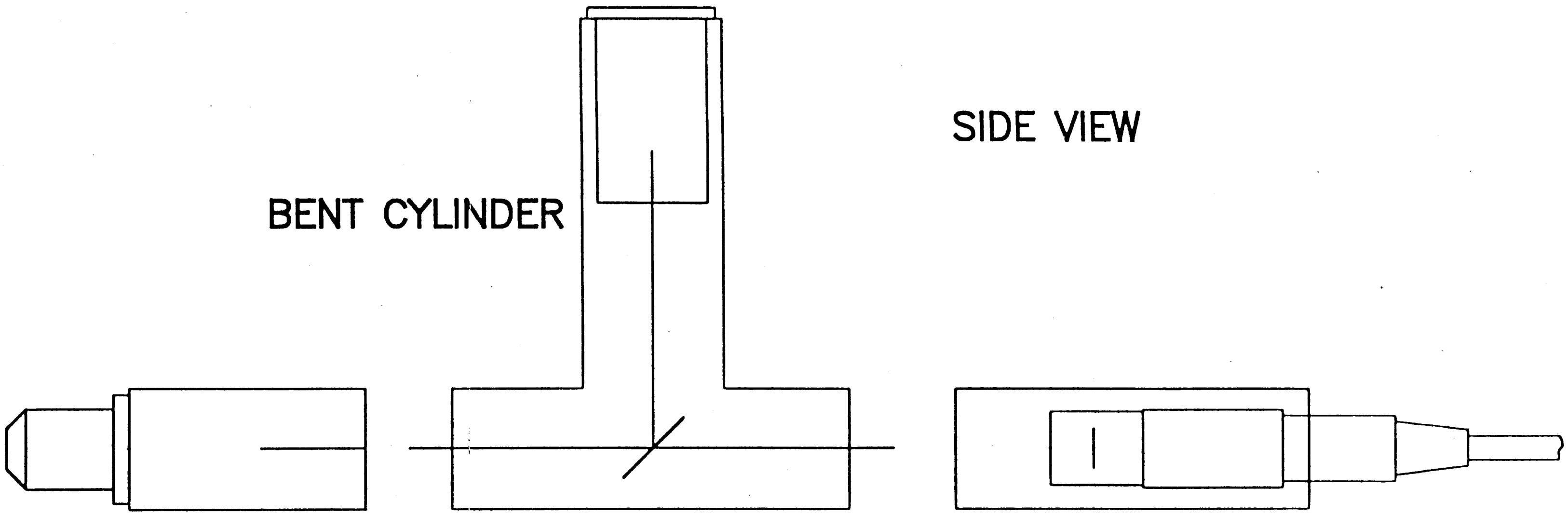
SWITCHABLE VISUAL/VIDEO

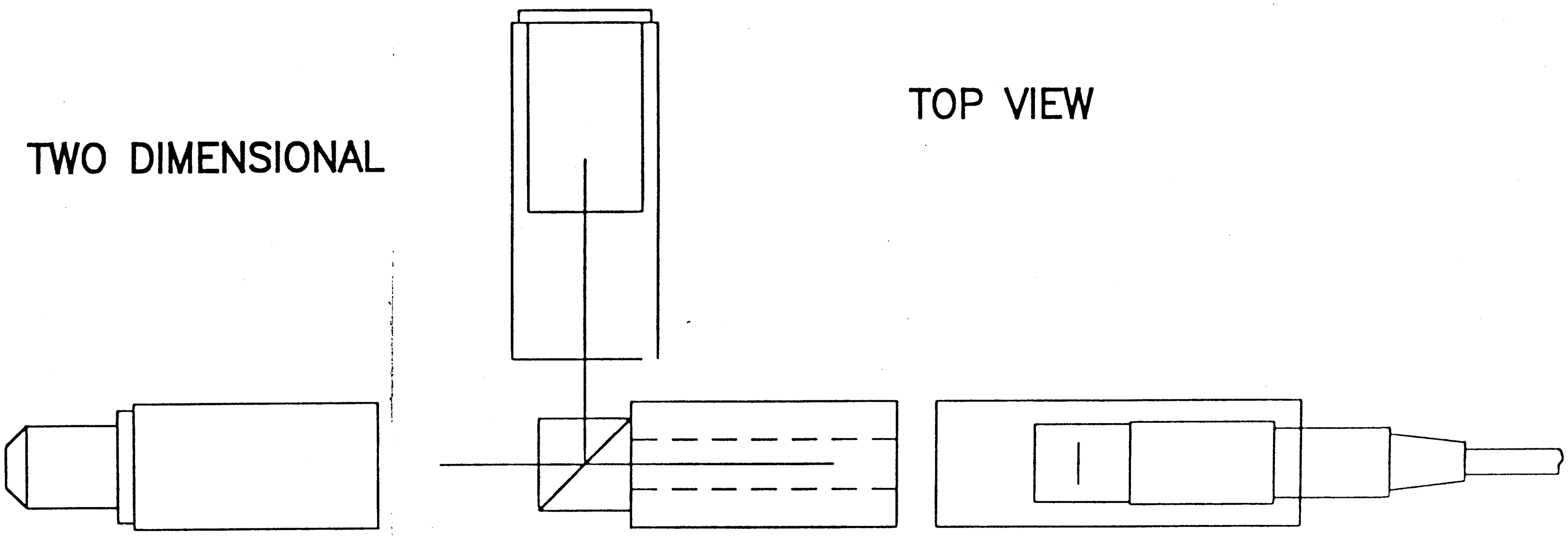


SWITCHABLE WITH THREE RATIOS

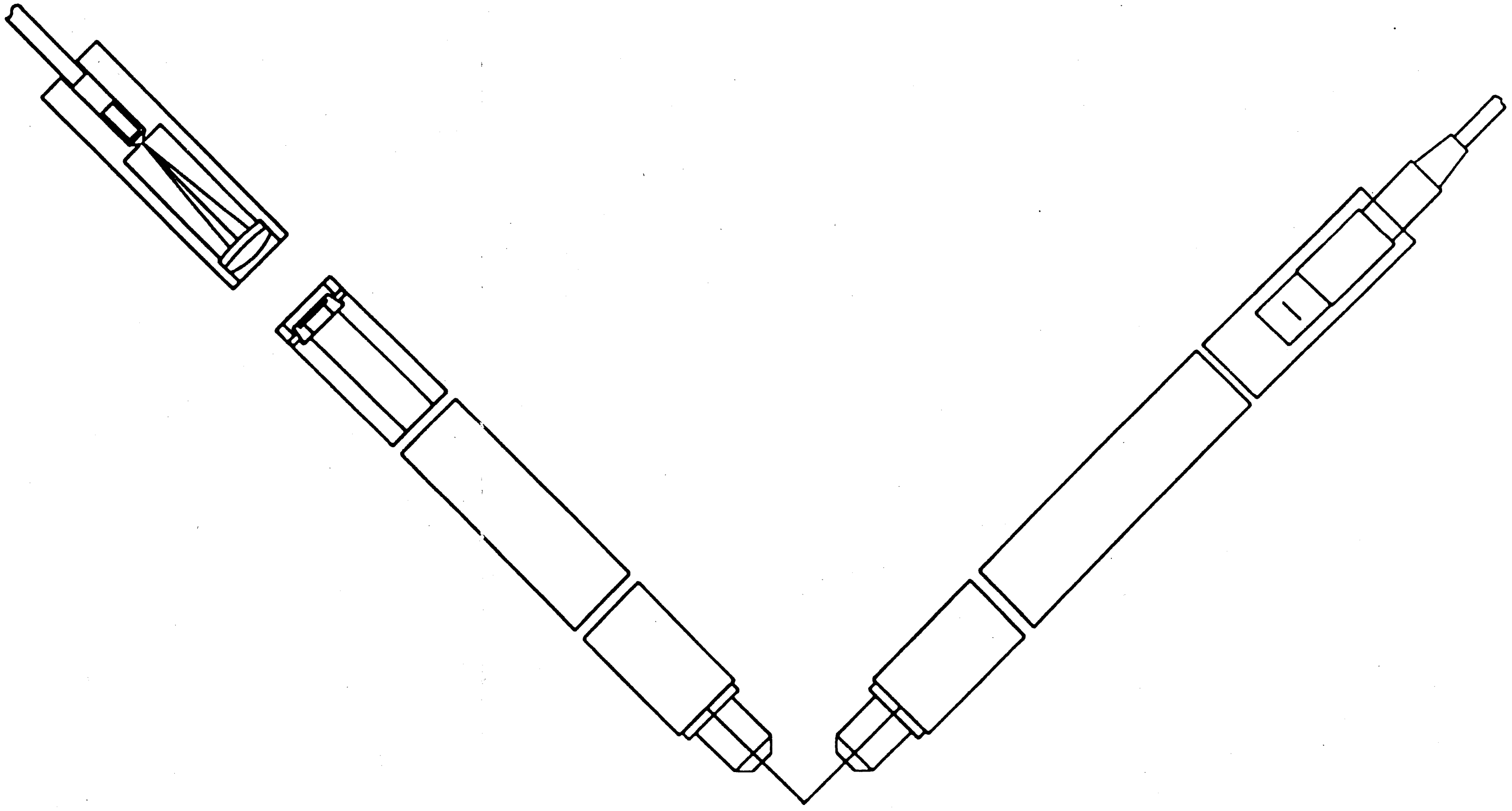


COMBINATION VISUAL/VIDEO

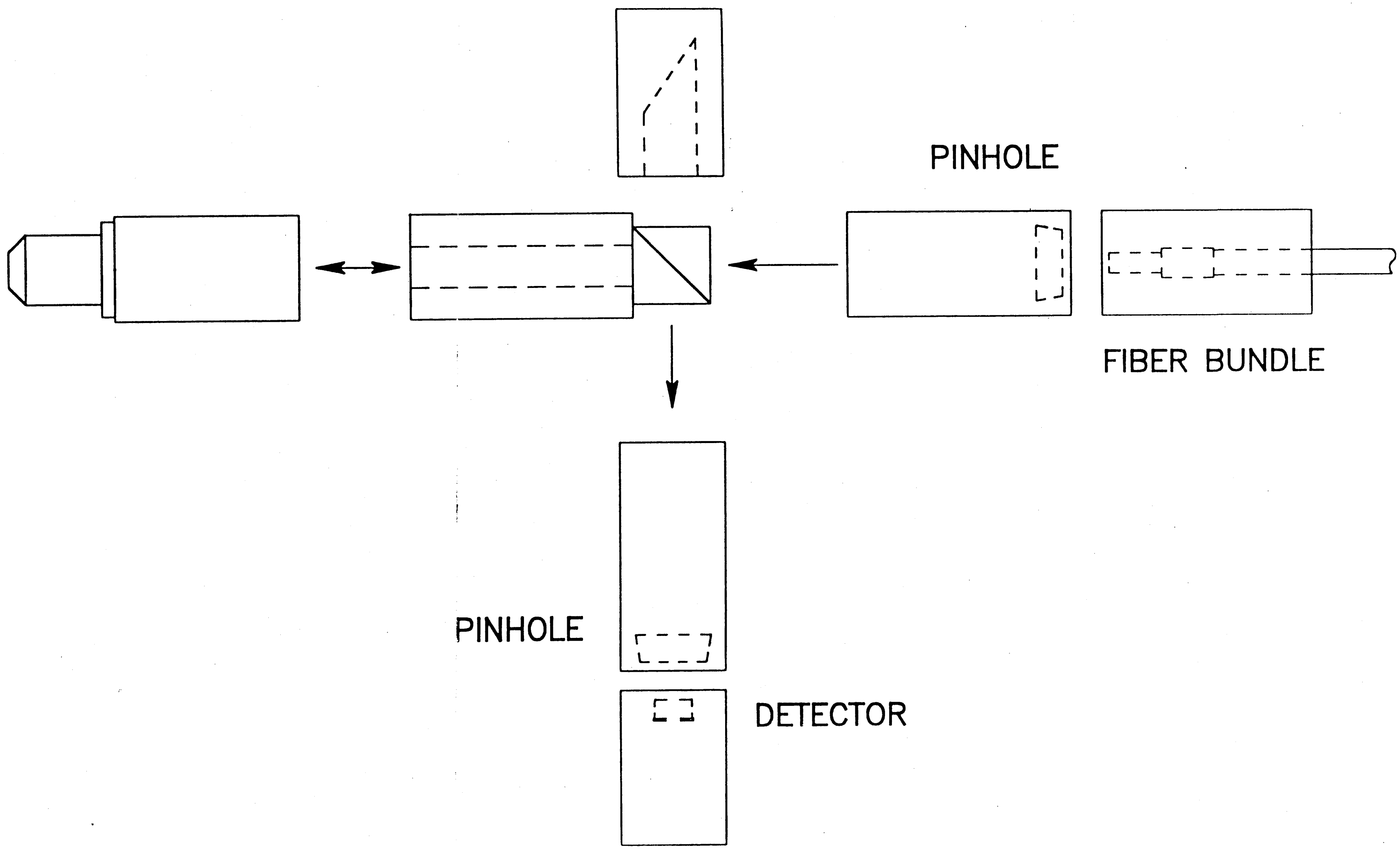




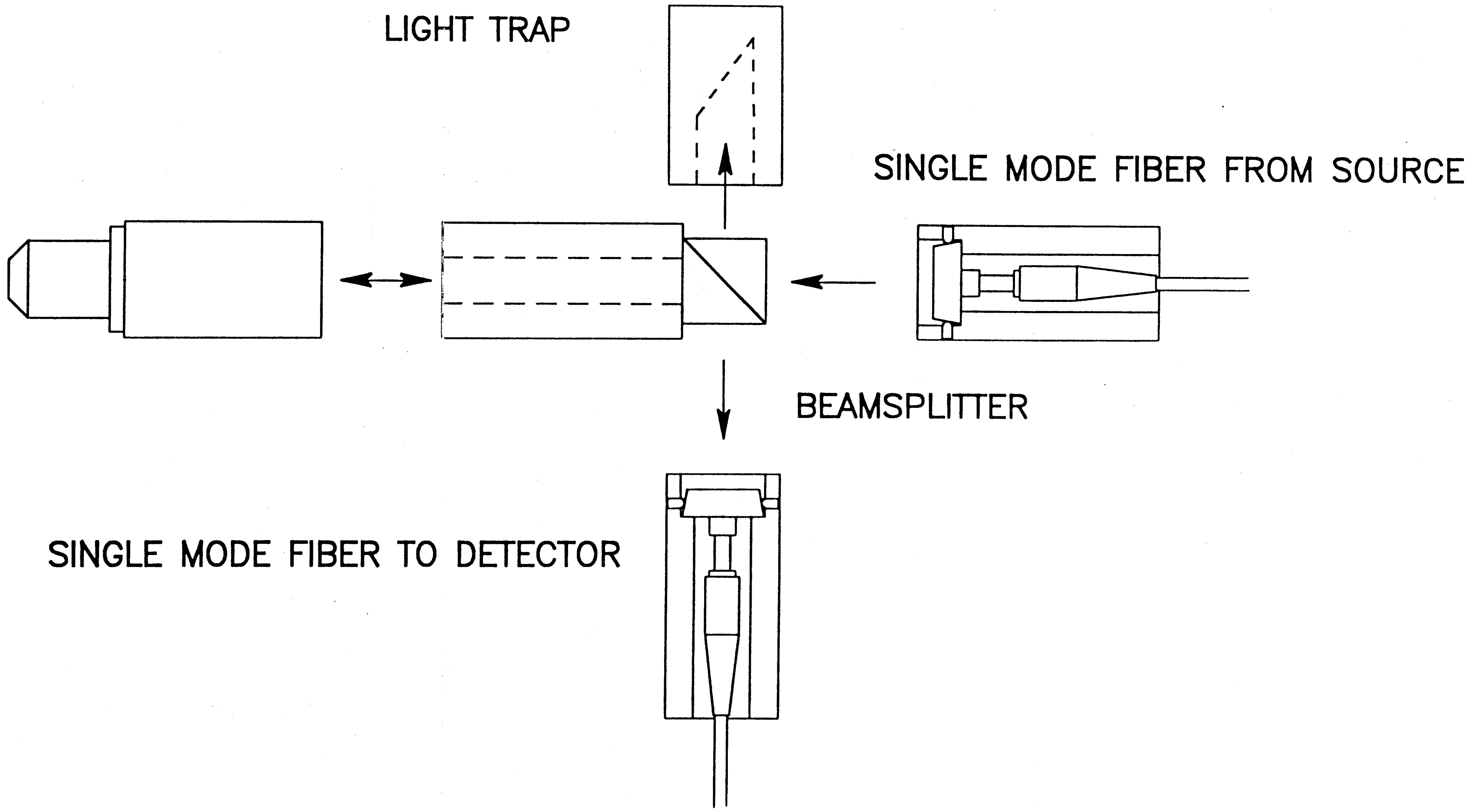
VIDEO LIGHT SECTION MICROSCOPE



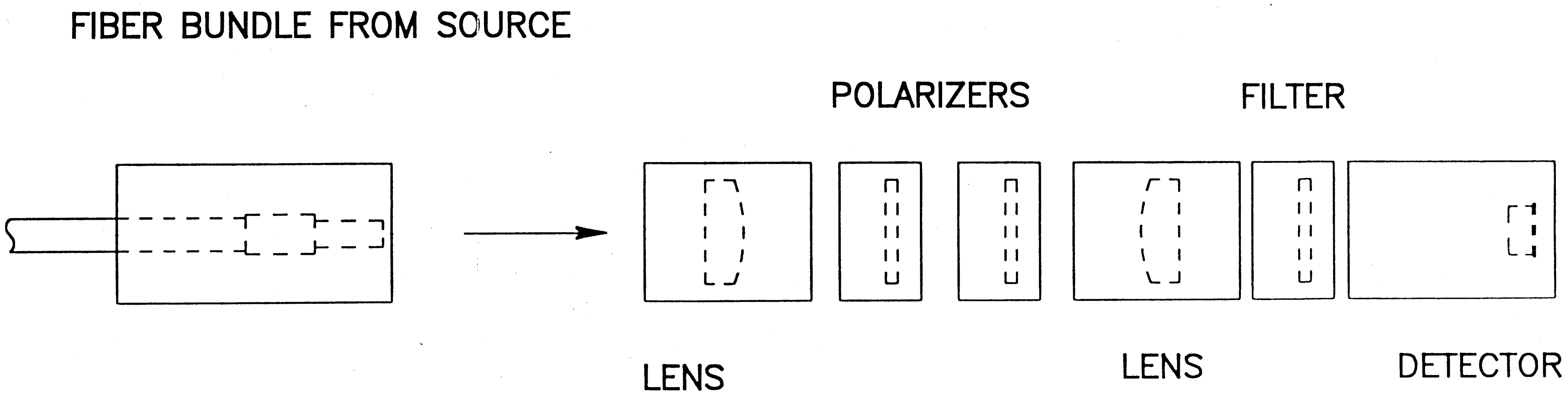
A CONFOCAL MICROSCOPE EMBODIMENT



A CONFOCAL MICROSCOPE EMBODIMENT

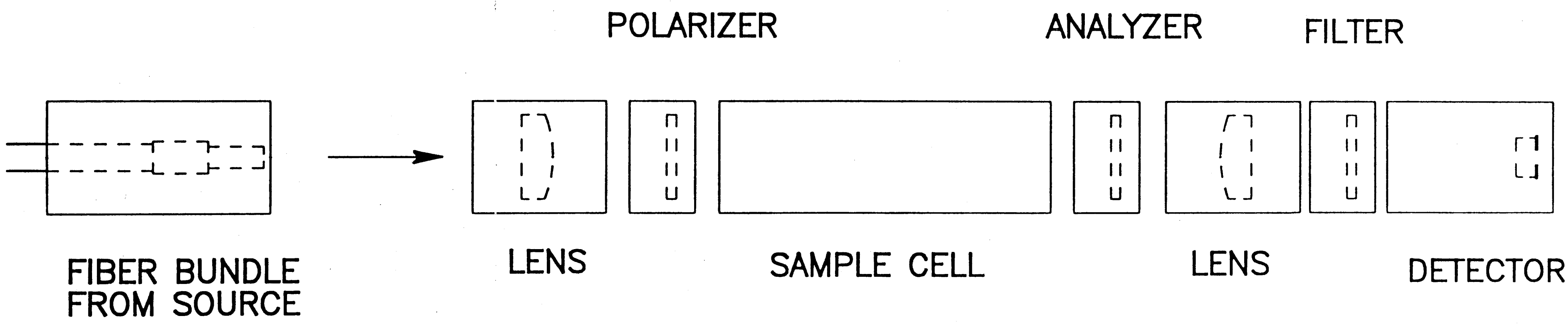


POLARIZER EXTINCTION MEASUREMENT



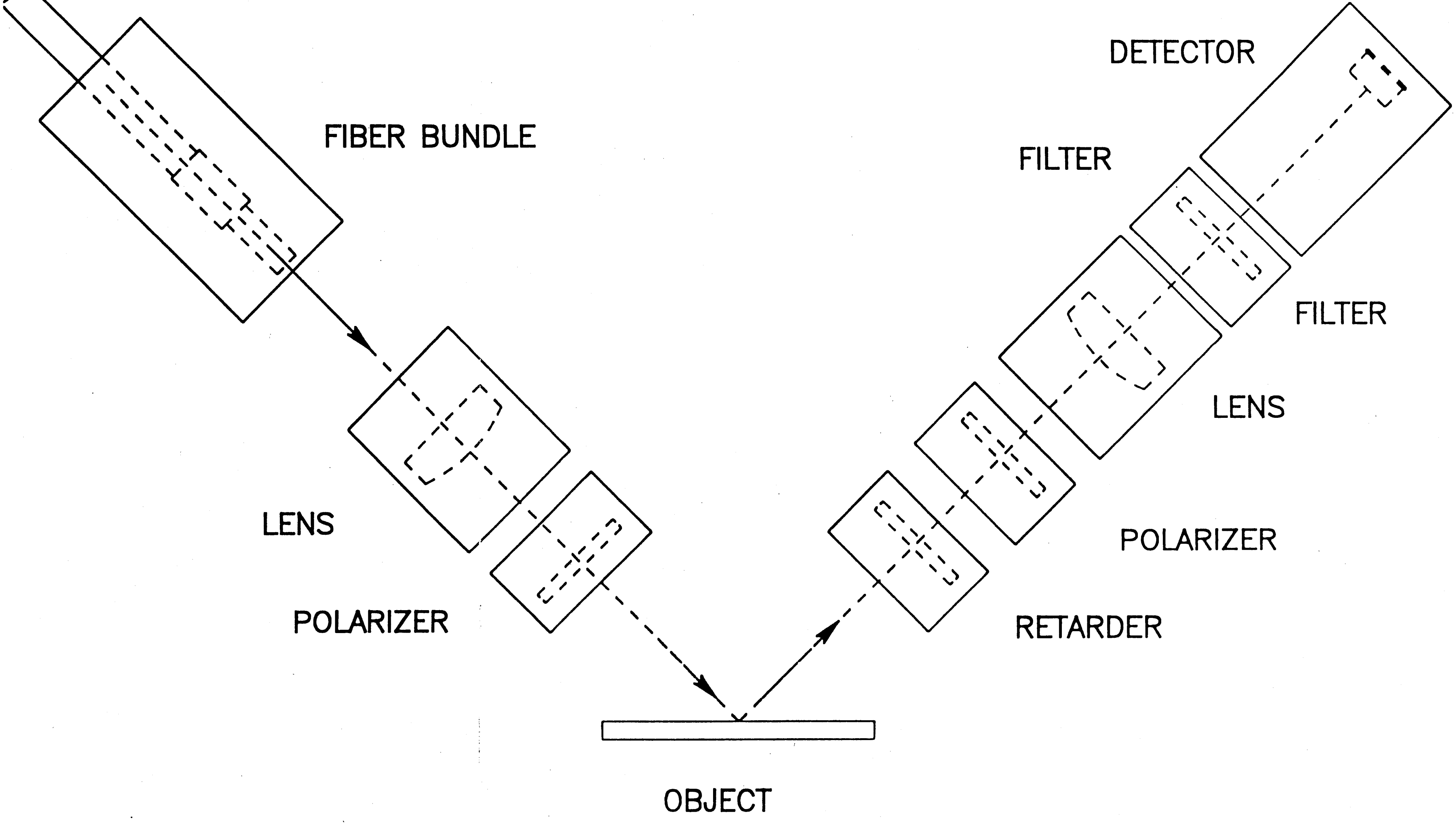
SACCHARIMETER

MEASURES ROTATION OF DIRECTION OF LINEARLY POLARIZED LIGHT

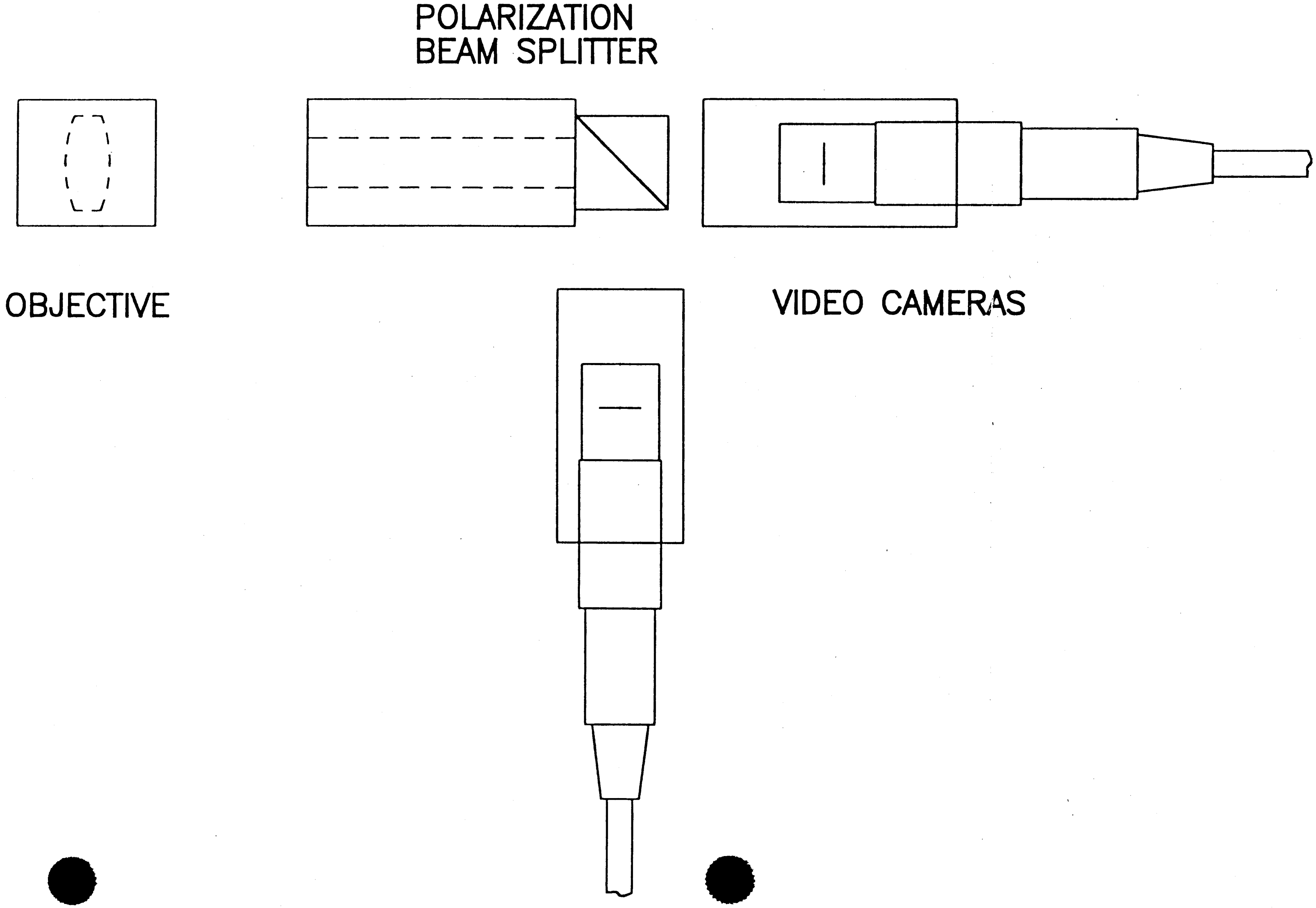


ELLIPSOMETER

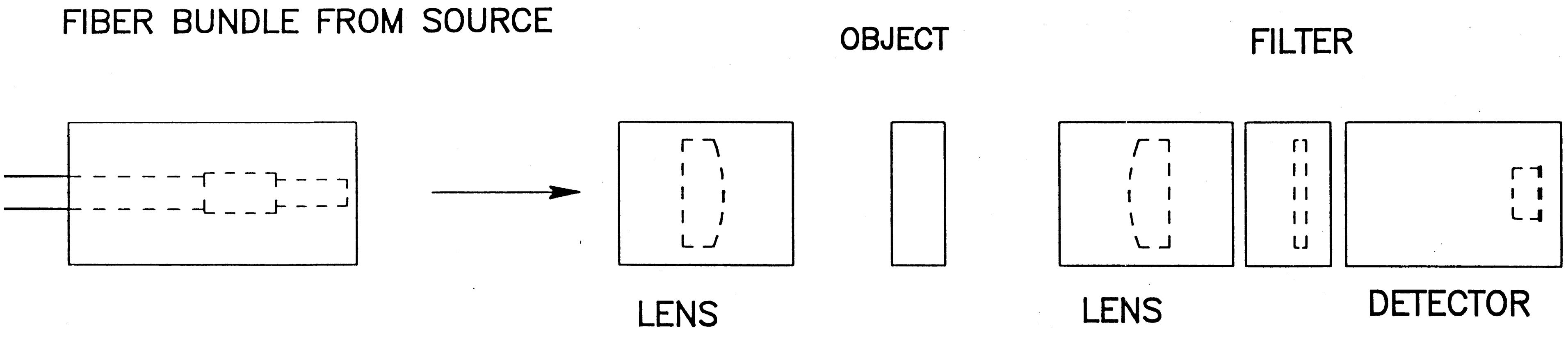
MEASURES CHANGE IN POLARIZATION OF REFLECTED LIGHT



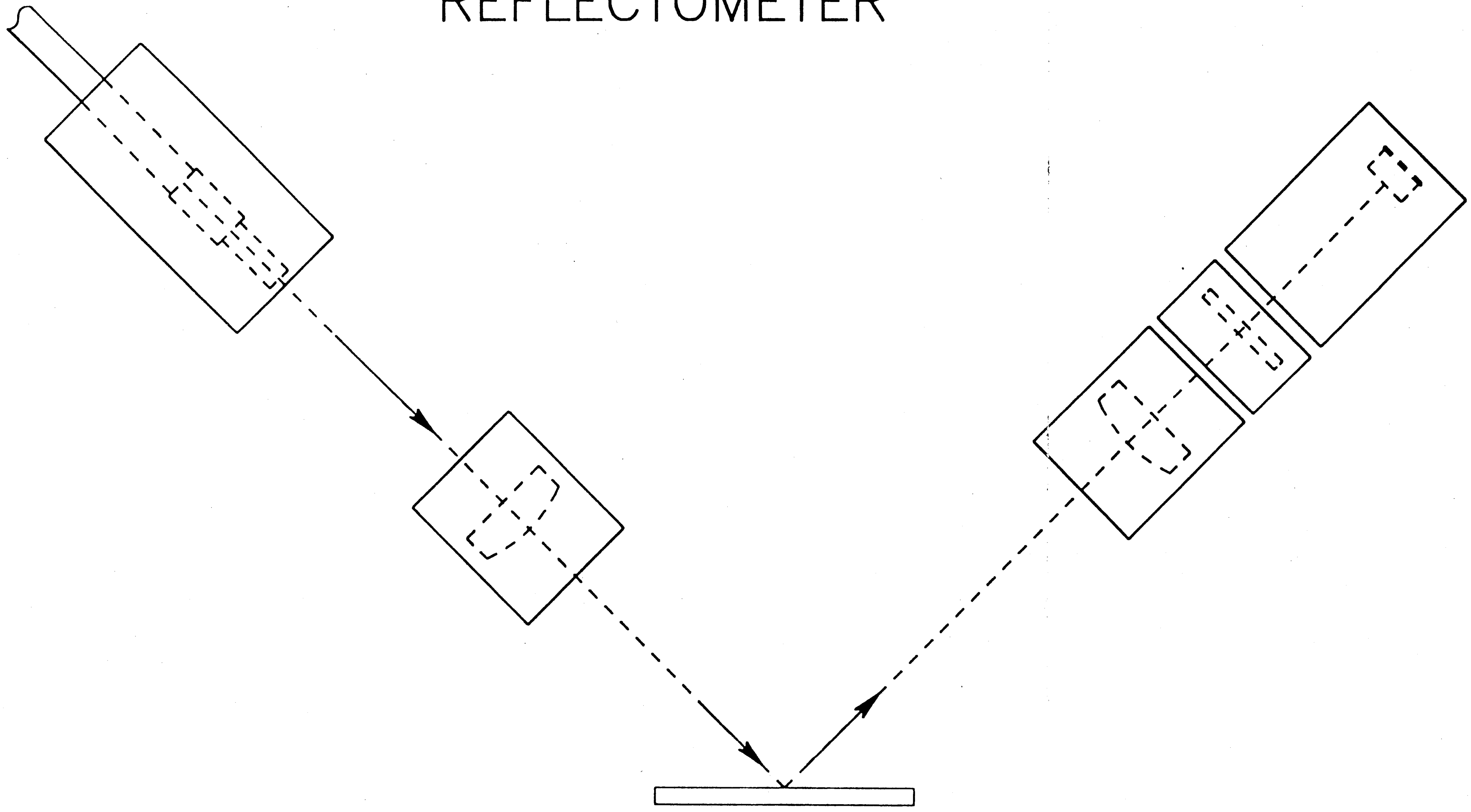
DUAL POLARIZATION TELESCOPE

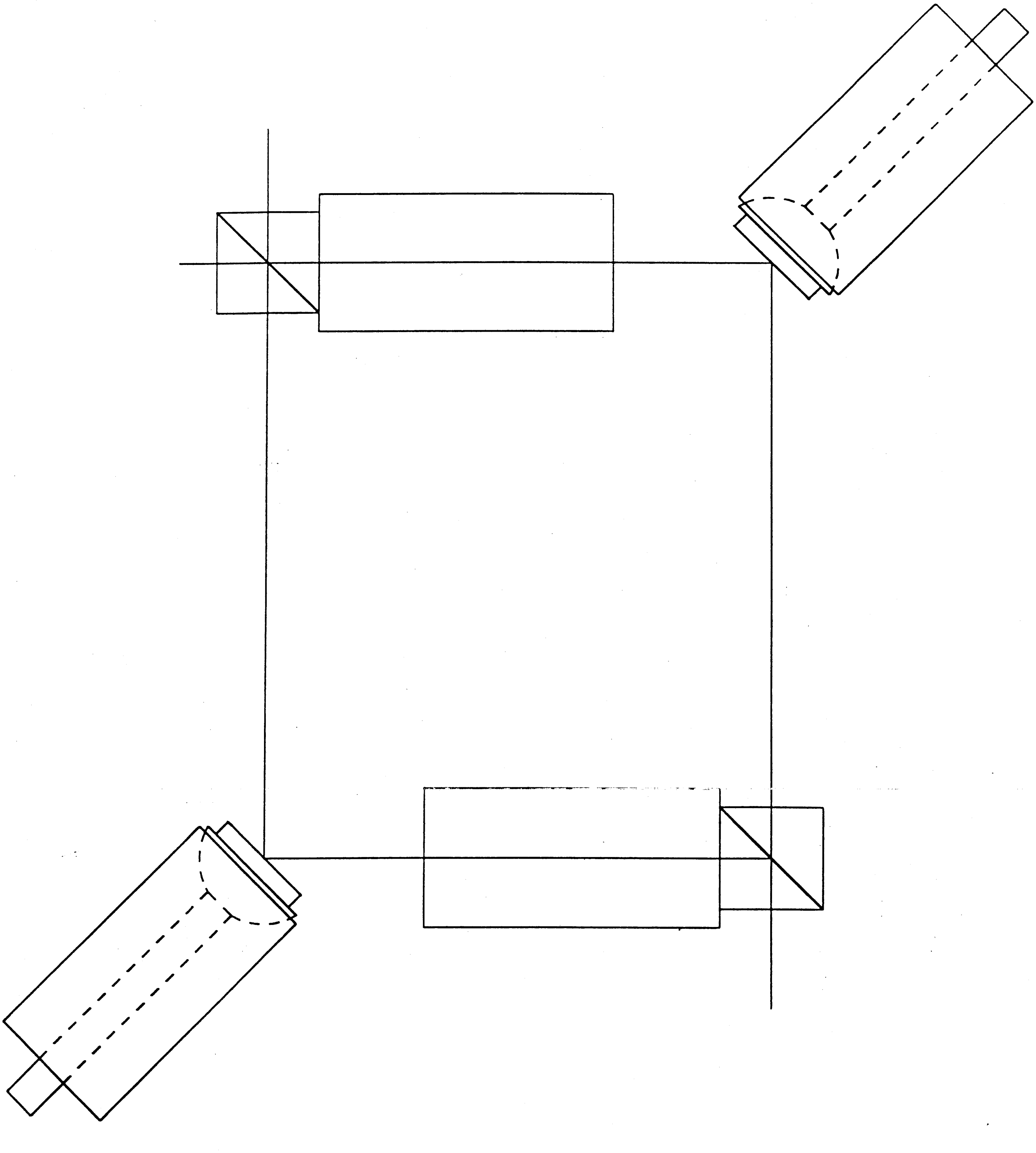


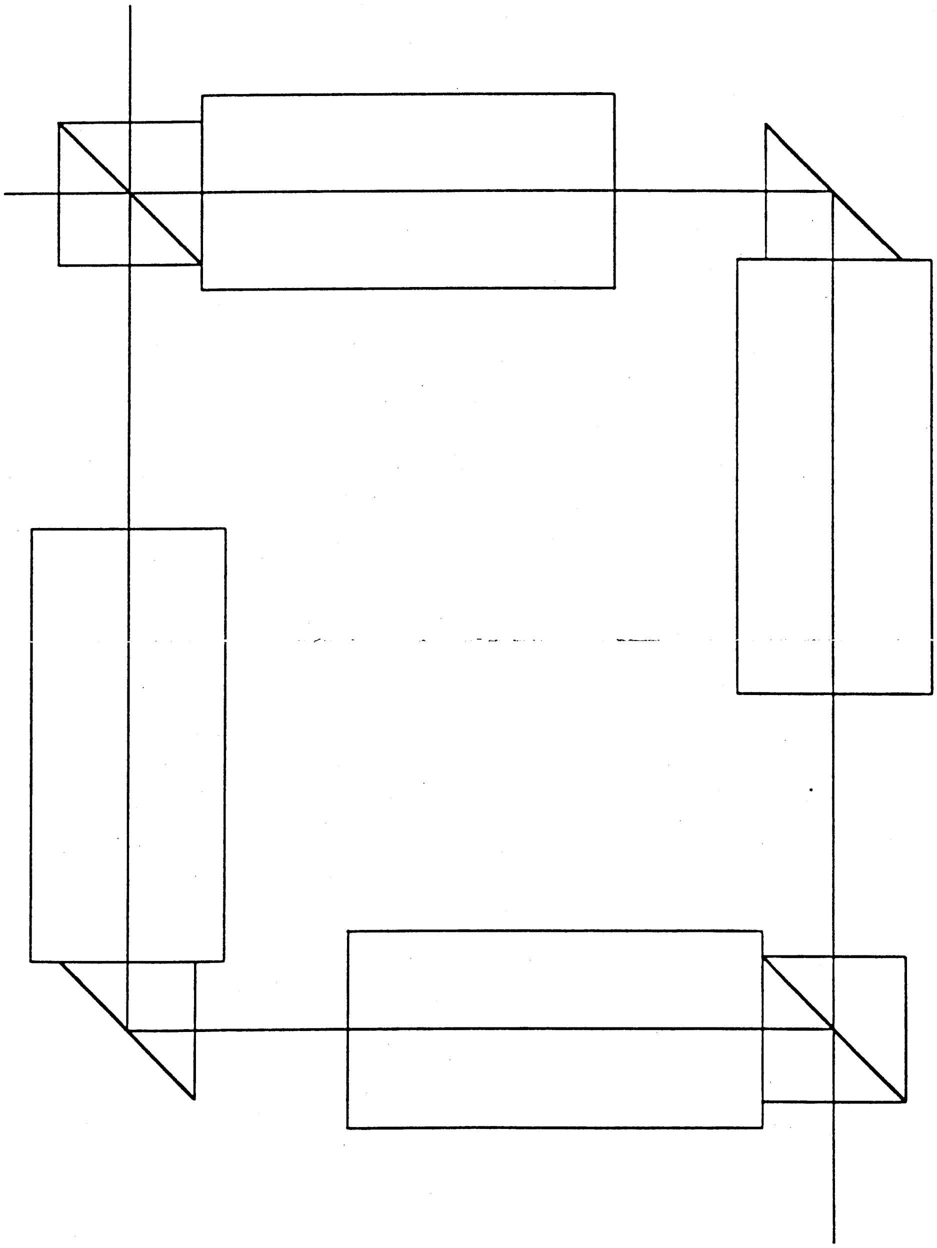
TRANSMISSION MEASUREMENT

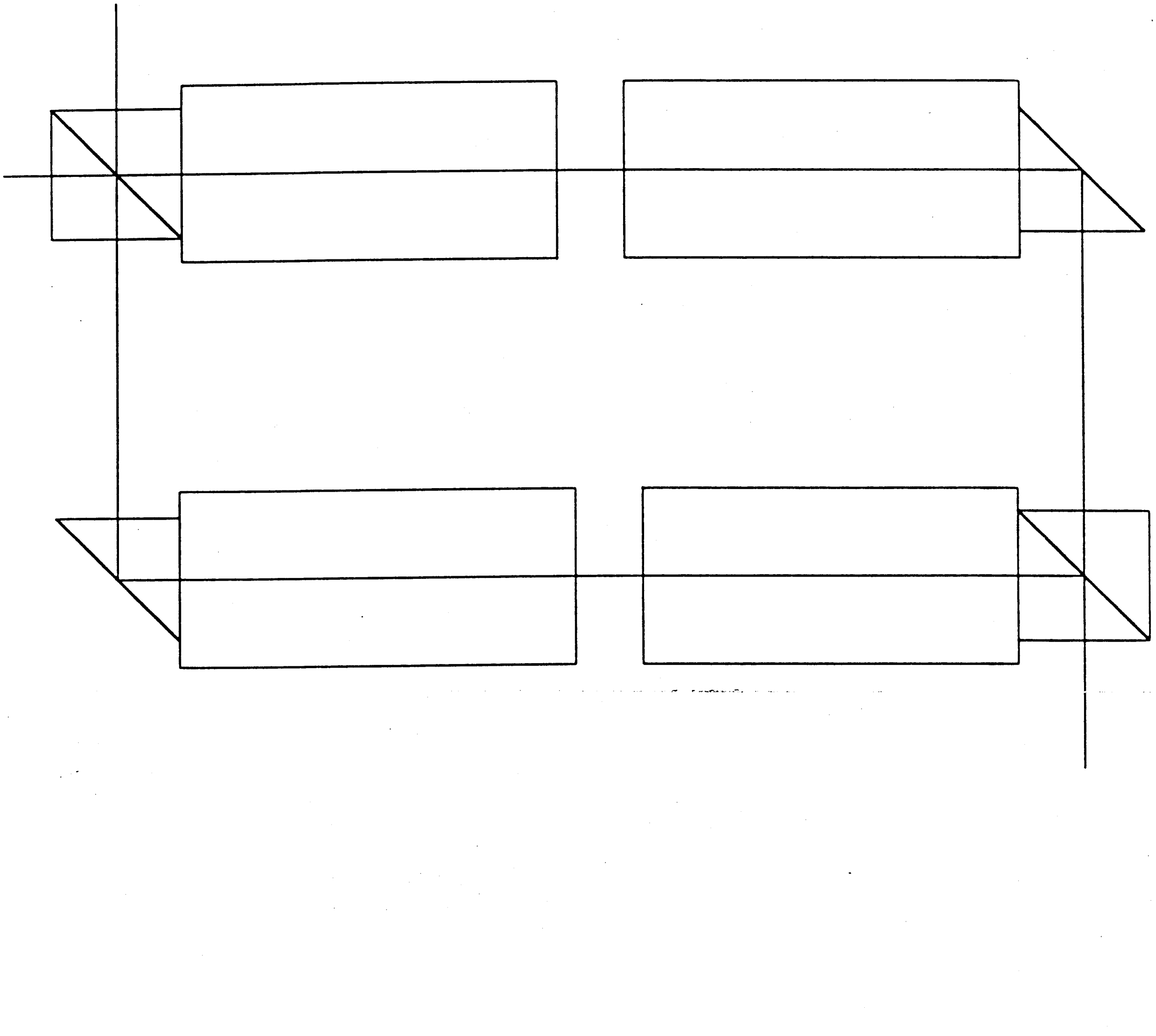


REFLECTOMETER









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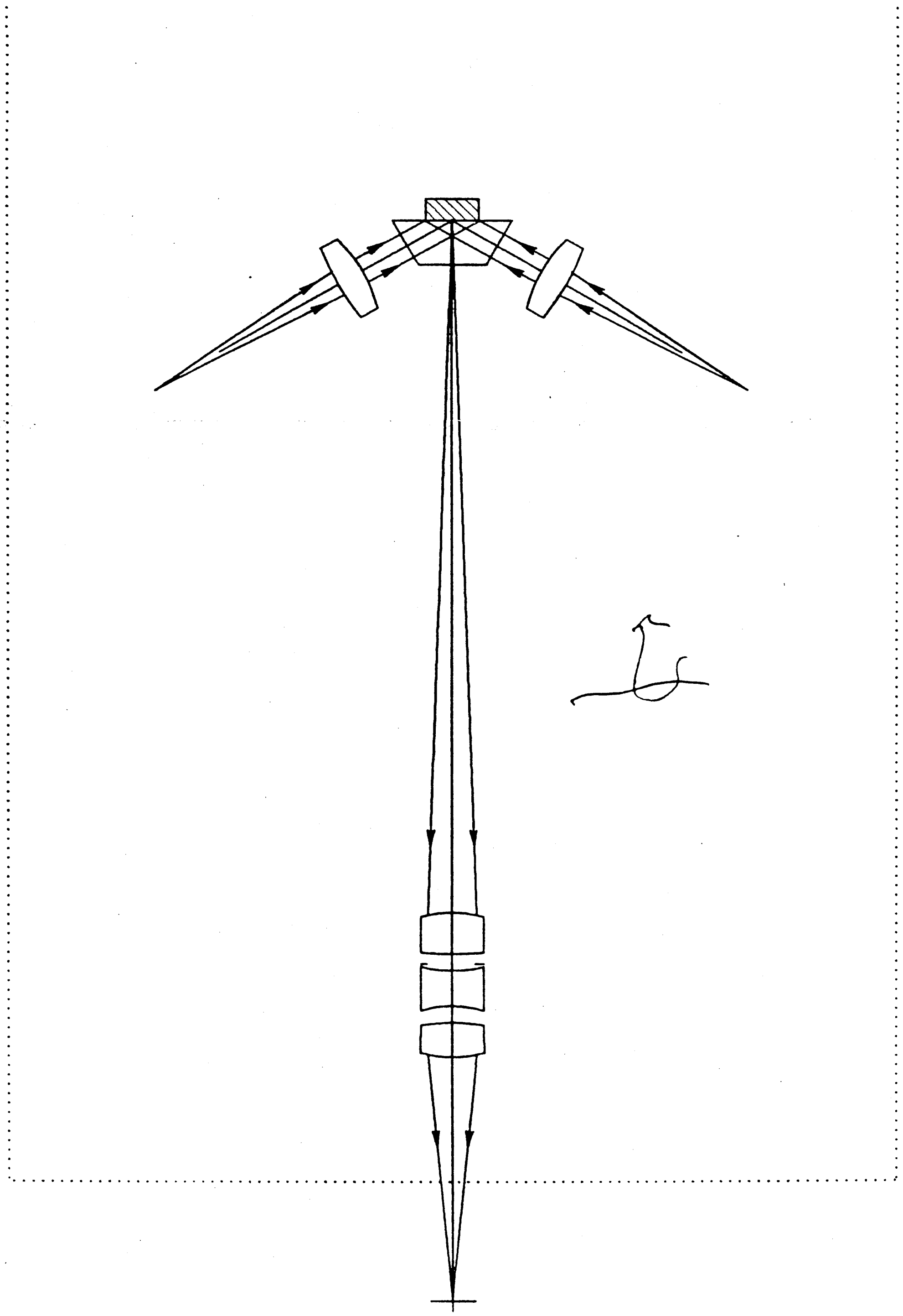
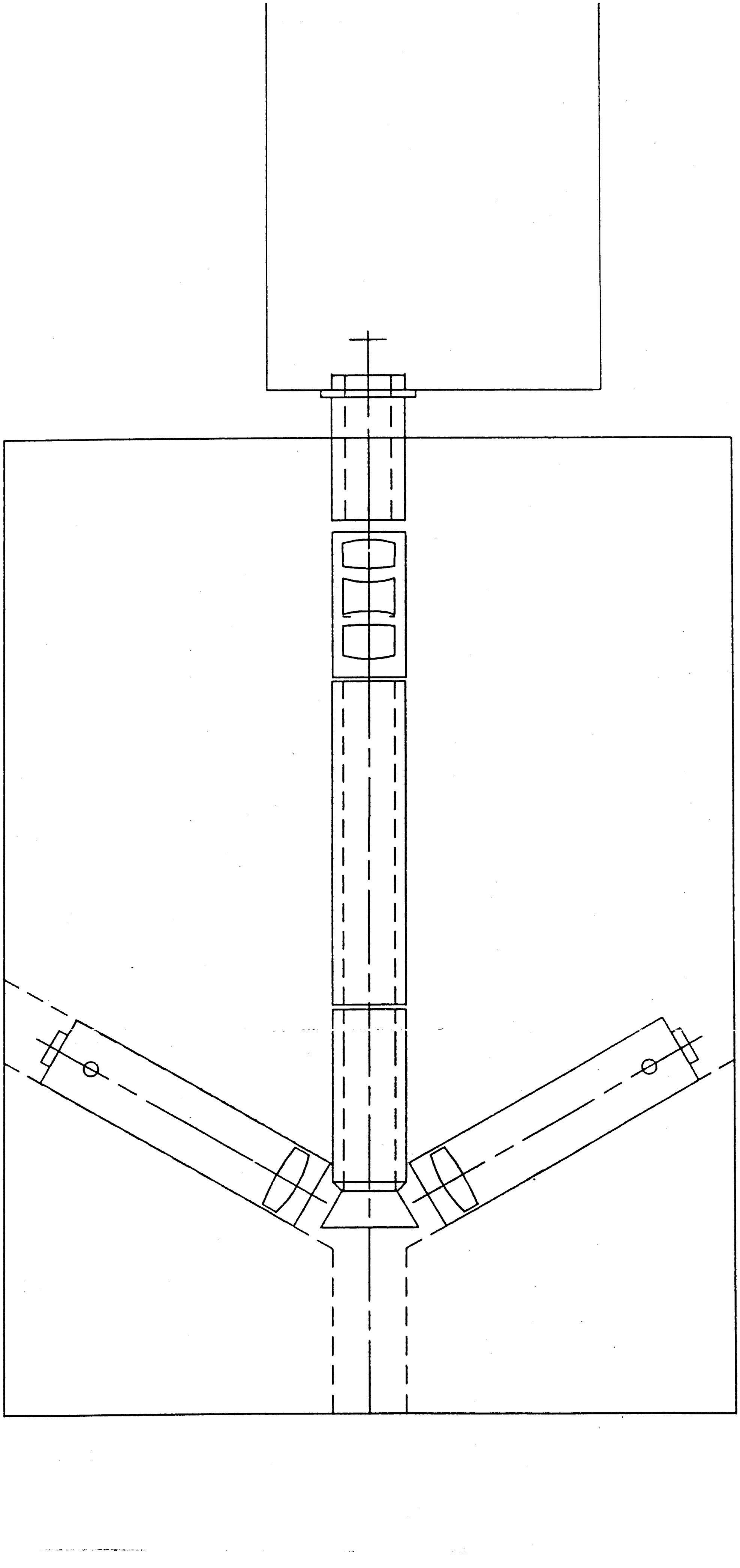
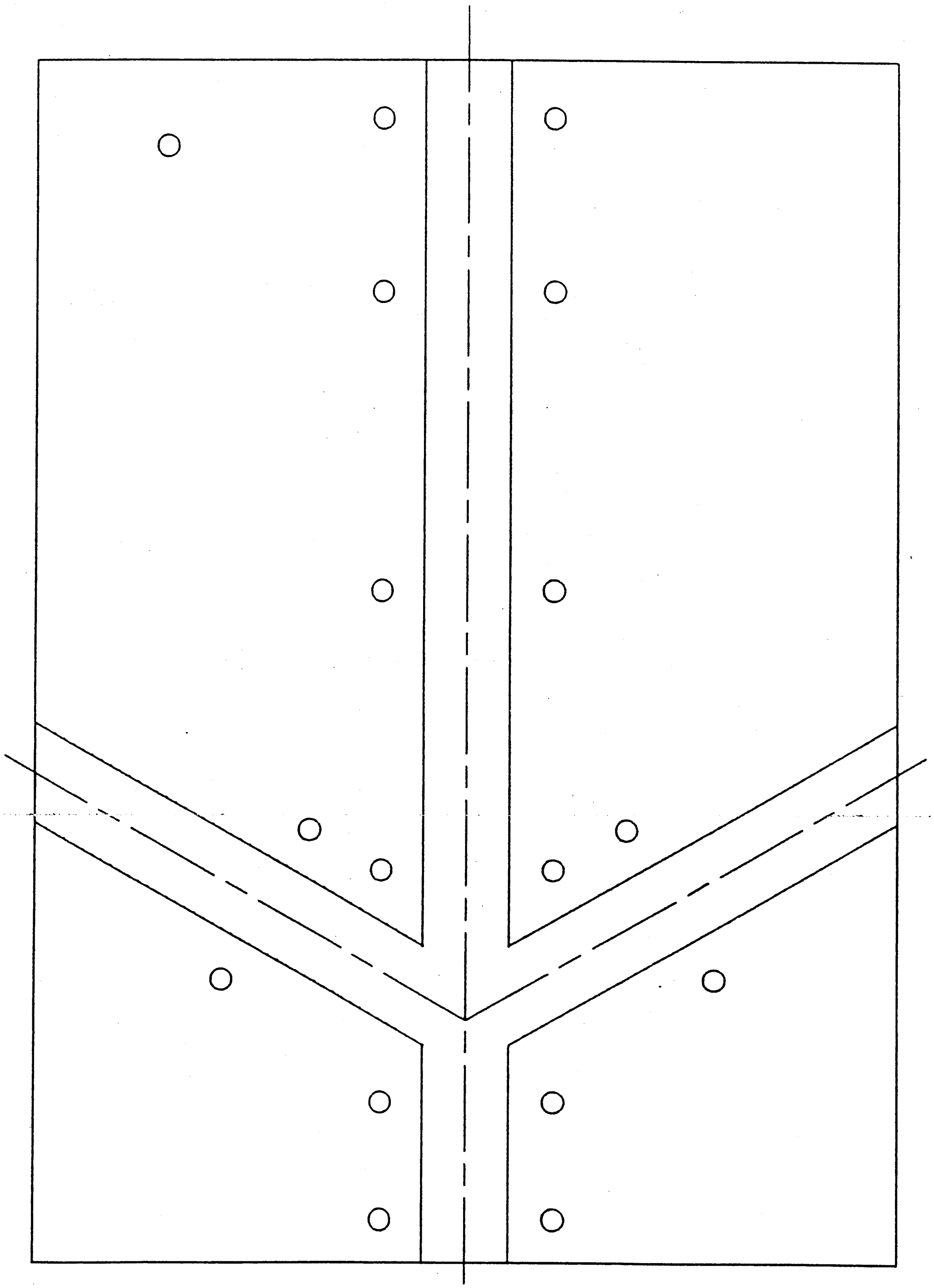
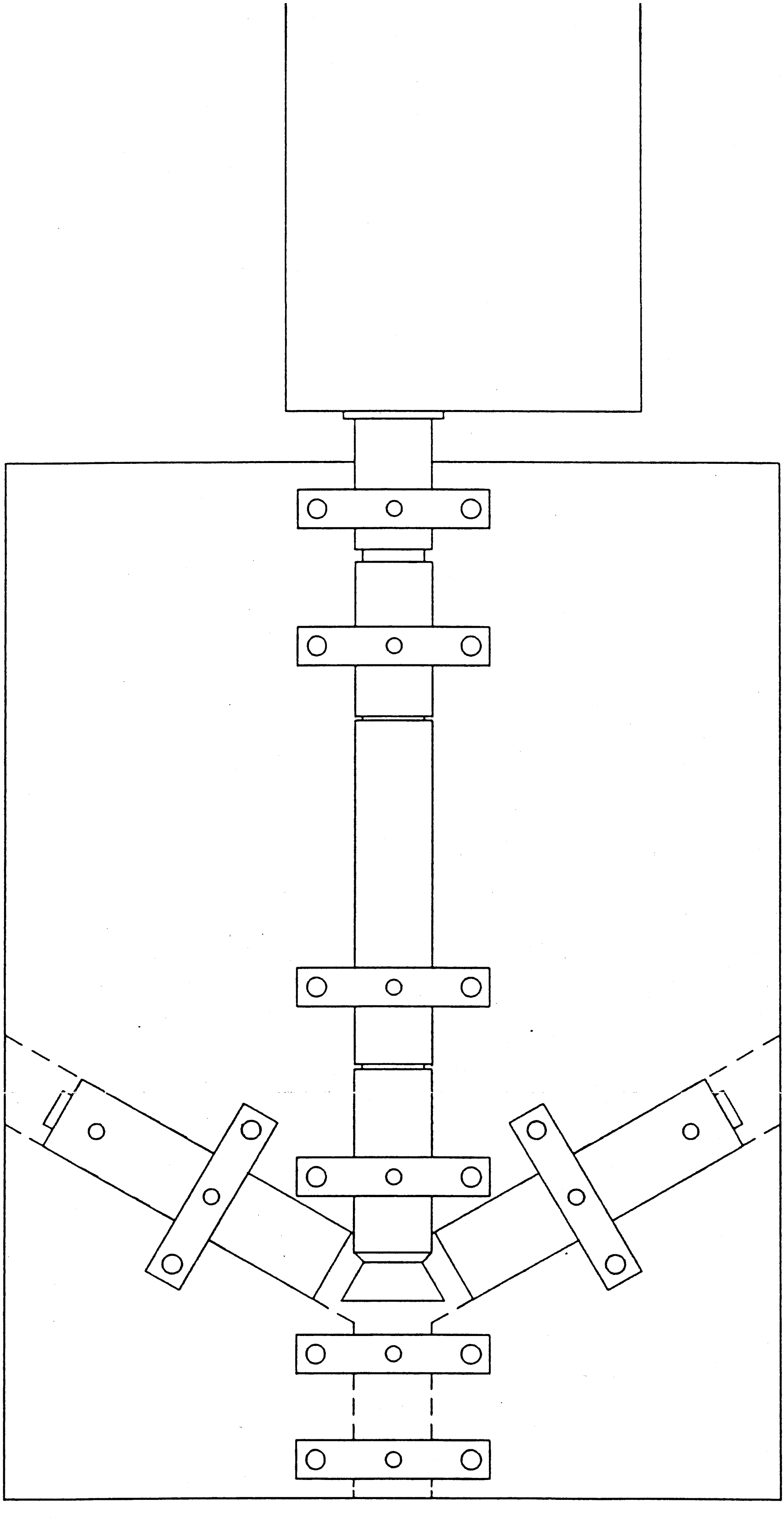
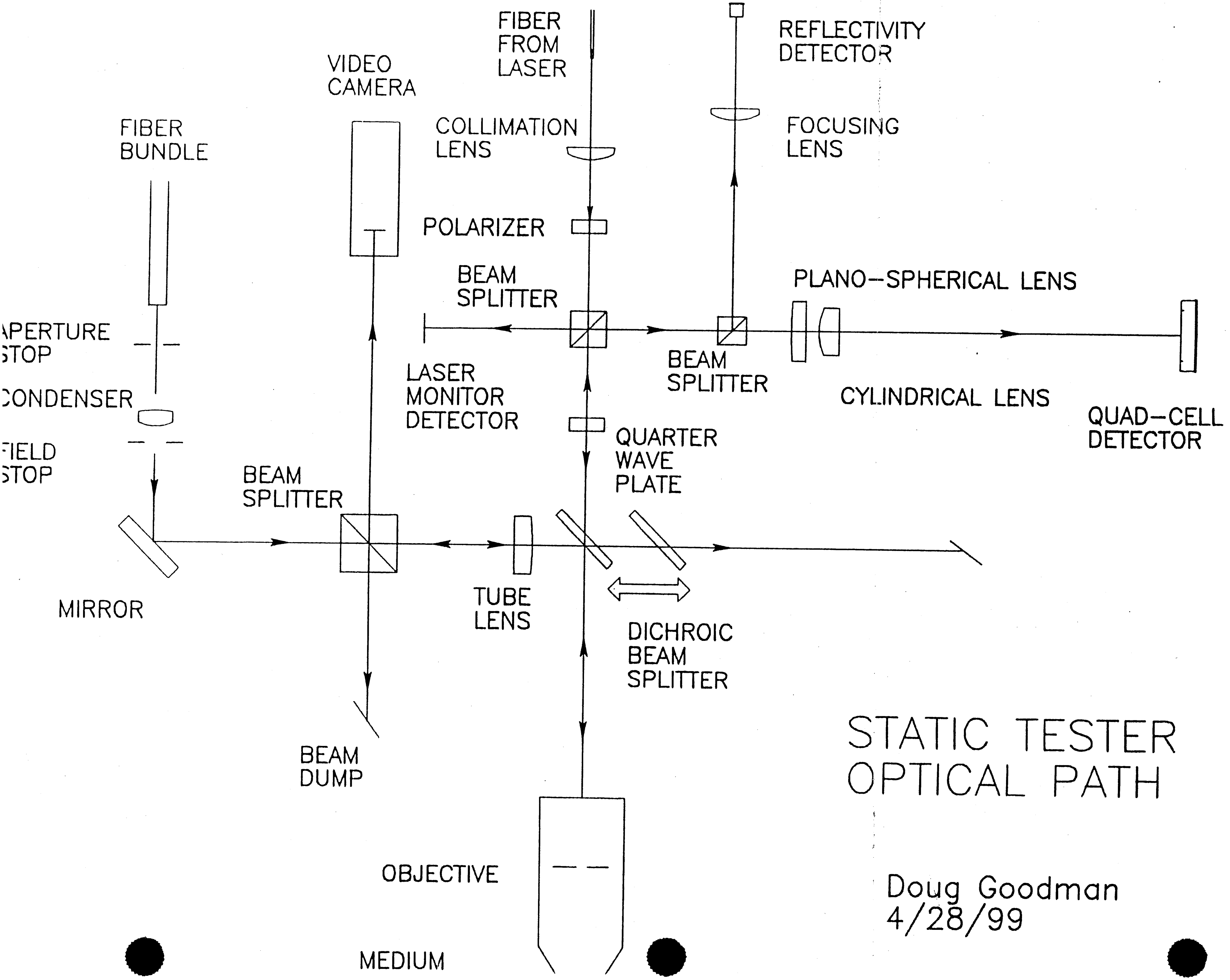
make image object







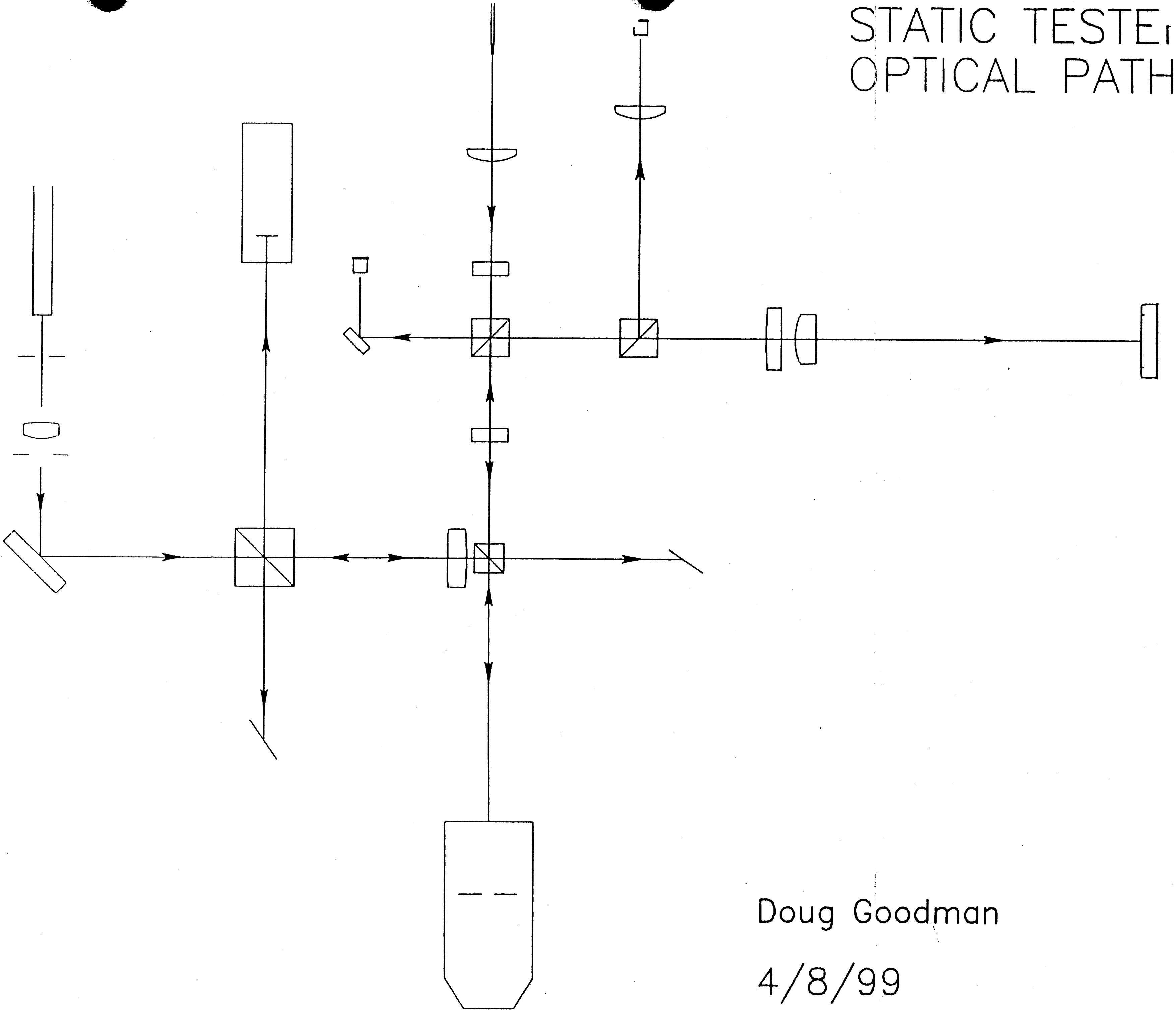




STATIC TESTER OPTICAL PATH

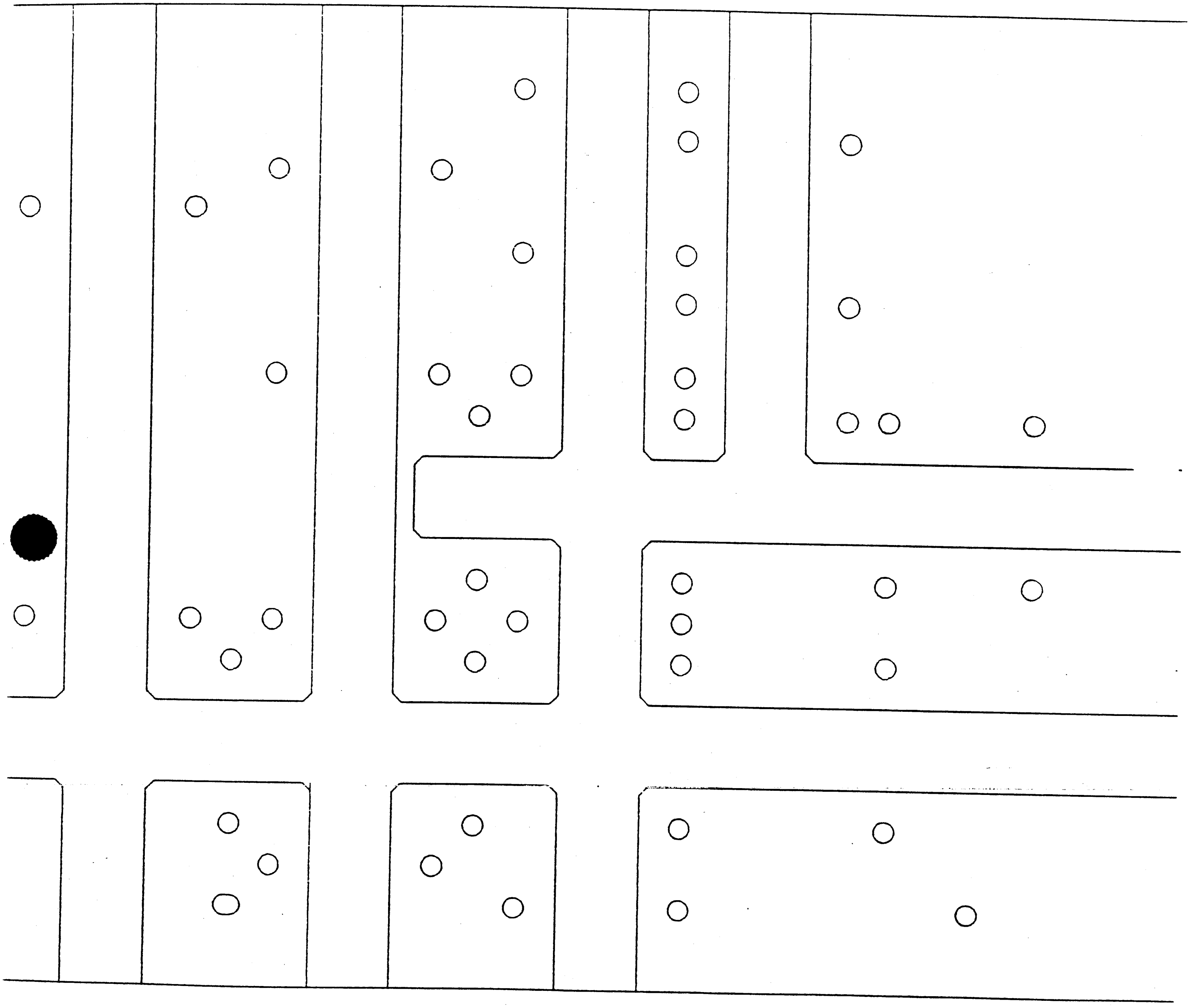
Doug Goodman
4/28/99

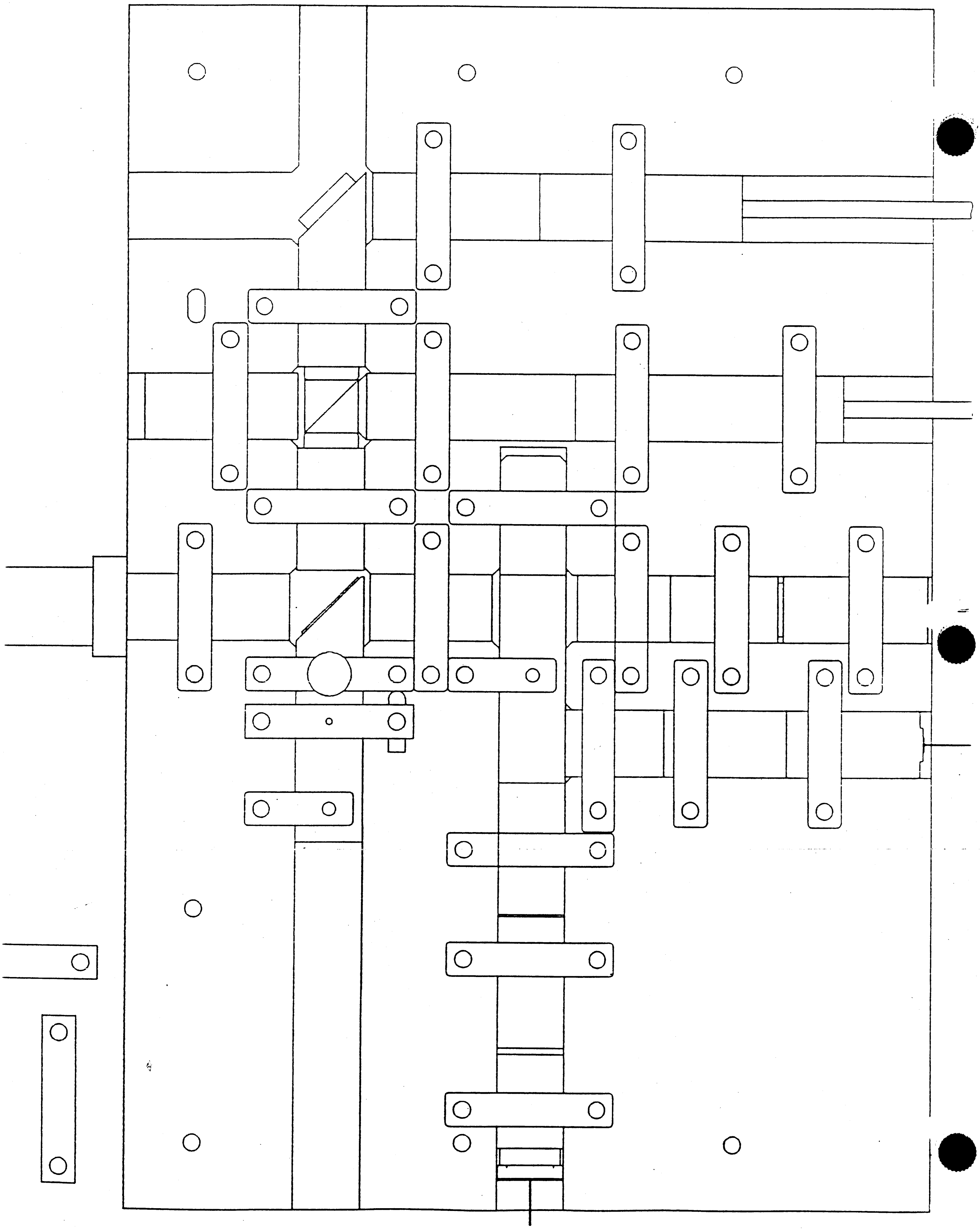
STATIC TESTER
OPTICAL PATH



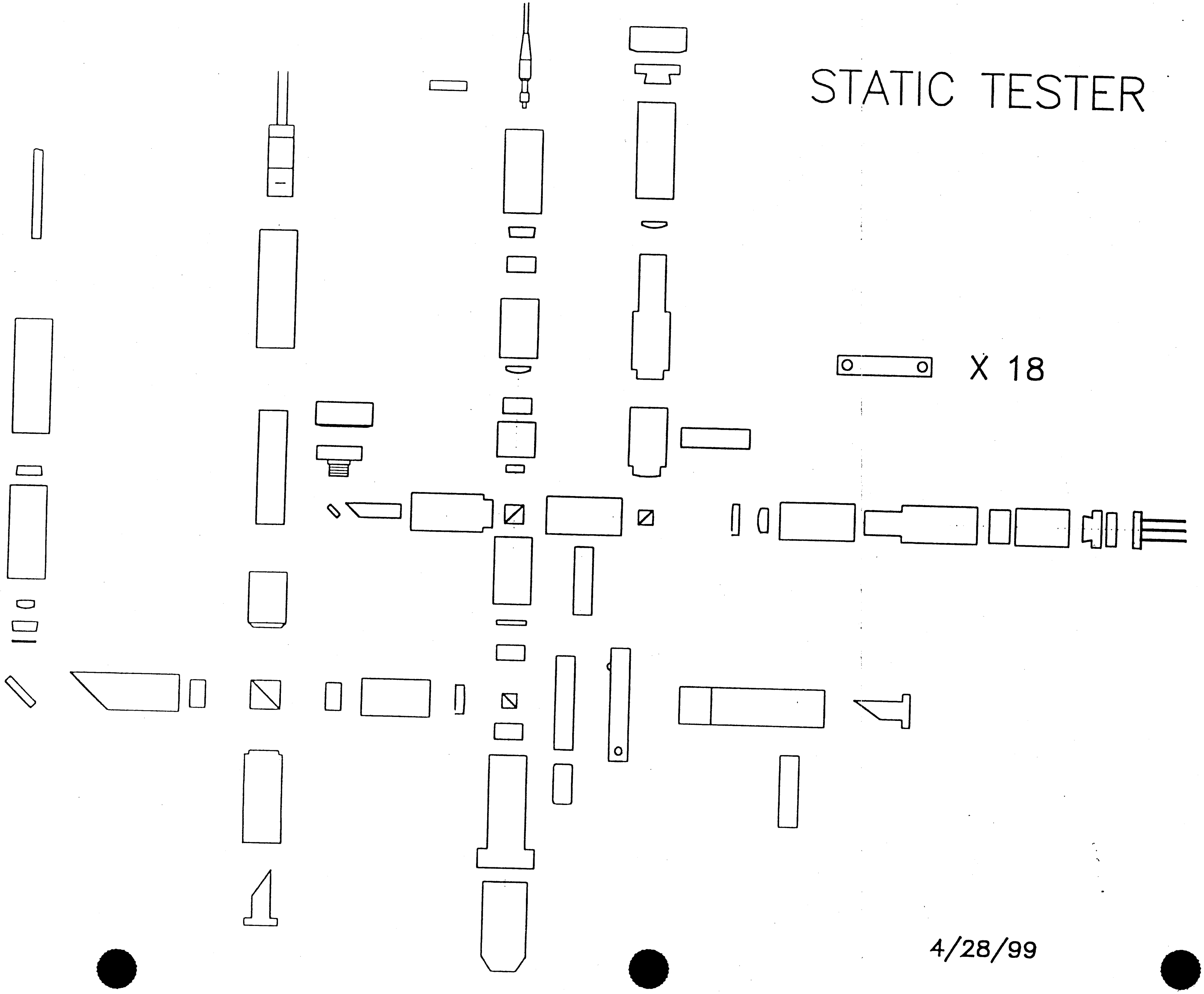
Doug Goodman

4/8/99





STATIC TESTER



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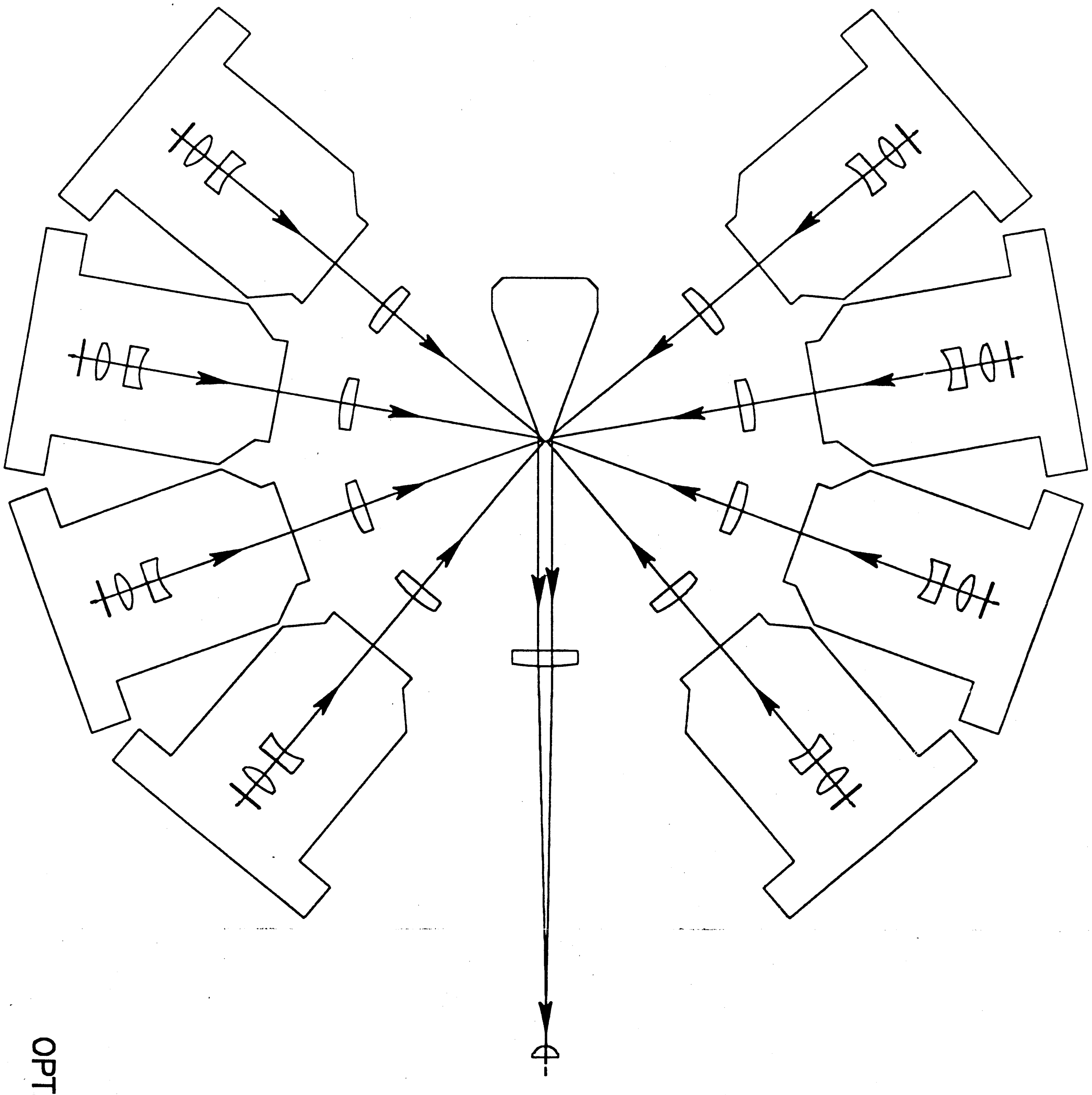

OPTICSI.VLM

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