# *Design for X*

# *ME – 2110*
# *Creative Decisions and Design*


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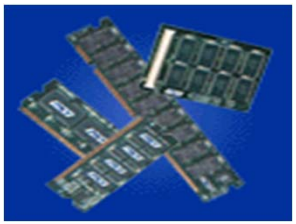
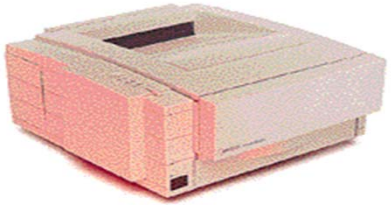
# *Design for X (DFX)*

- Design for Manufacture

# *Design for X (DFX)*

- Design for Assembly





# *Design for X (DFX)*

- Design for Environment
- Design for Maintenance

Top view yellow

Interior and instrument panel


Rear view in yellow with hatch and doors open

- Design for Disassembly

# *Design for Assembly*

- Methods consists of a design review by
  - Design and development personnel
  - Production personnel
- The technique imposes
  - Discipline
  - Objectiveness
- The technique imposes
  - Exciting rivalries
  - Defensive postures within an organization

# *Aspects of Design for Assembly*

- DFA is applicable to
  - Products consisting of 20 -200 parts
  - Mainly for mechanical parts (not electronics)
  - Dimensions lie between those of watches and cars
- No specialized knowledge of the means of production is needed
- Requires 1-2 days to perform for a product
- Average 30% improvement in the assembly cost
- Can be performed in the various stages in the design process and repeated

# *Design for Assembly (Criteria)*

- Execution of assembly operations
  - Storing
  - Handling
    - Identifying
    - Picking-Up
    - Moving
  - Positioning
    - Orientating
    - Aligning
  - Joining
  - Adjusting
  - Securing
  - Inspecting

# *Design for Assembly (Criteria)*

- Standardization of assembly operations
- Possible use of existing assembly equipment and tools
- Possible use of standard assembly tools

# *Design for Assembly (Criteria)*

- Number of operations in overall assembly
- Favorable sequence (preassembly, parallel assembly)

# *Design for Assembly (Criteria)*

- Possibility of automation
- Freedom from possible assembly errors
- Avoidance of damage to components
- Avoidance of special training of the assembly staff

## *Design for Assembly (Criteria)*

- Maintenance of safe working conditions
- Observance of ergonomic standards

## *Questions Raised during DFA*

- Is it possible, in principle, to eliminate the part of process?
  - Must the part move more than than elasticity of the material allows?
  - Are there inherently different material needs
  - Can the product be assembled if the part is integrated with another part?
- What does it cost to bring the part from the packaging to the place of assemble and give it the correct spatial orientation and position required for being assembled?
- What does it cost to carry out the actual assembly of the part?

# *Design for Assembly Guidelines*

- During the operation of the product, does the part move relative to all other parts already assembled?
  - Only gross motions should be considered
  - Small motions that can be accomplished by elastic hinges, for example, are not sufficient for a positive answer.
- Must the part be of a different material than, or be isolated from all other parts already assembled?
  - Only fundamental reasons concerned with material properties are acceptable.
- Must the part be separate from all other parts already assembled to ensure that necessary assembly or disassembly of other separate parts is possible?

# *Design for Assembly Worksheet*

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Name of Assembly |
|---|---|---|---|---|---|---|---|---|---|
| Part I.D. Number | Number of times the operation is carried out consecutively | Two-digit manual handling code | Manual handling time per part | Two-manual insertion code | Manual insertion time per part | Operation time (sec) (2)*[(4) + (6)] | Operation cost (¢) 0.4 * (7) | Figures for theoretical minimum parts Estimation | |
| | | | | | | | | | |
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| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | TM | CM | NM | $design\ efficiency = \frac{(3) * NM}{TM} =$ |

TM = Total manual assembly time
CM = Total cost of manual assembly
NM = Theoretical minimum number of parts

# *Pneumatic Piston Sub-Assembly*

1 - Screw (2) (steel)

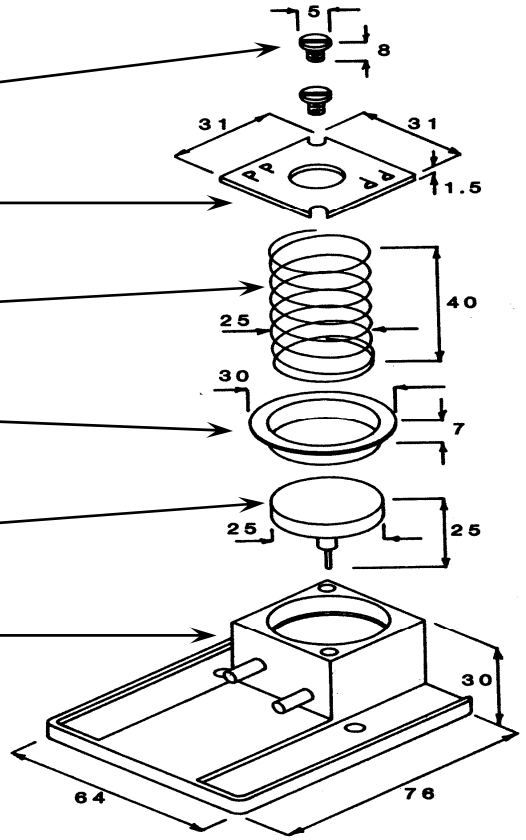
2 - Cover (steel)

3 - Spring (steel)

4 - Piston stop (nylon)

5 - Piston (aluminum)

6 - Main block (plastic)



# *Worksheet for Pneumatic Piston*

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Name of Assembly |
|---|---|---|---|---|---|---|---|---|---|
| Part I.D. Number | Number of times the operation is carried out consecutively | Two-digit manual handling code | Manual handling time per part | Two-digit manual insertion code | Manual insertion time per part | Operation time (sec) (2)*[(4) + (6)] | Operation cost ($\phi$) 0.4 * (7) | Figures for theoretical minimum parts Estimation | Pneumatic Piston |
| 6 | 1 | 30 | 1.95 | 00 | 1.5 | 3.45 | 1.38 | 1 | Main Block |
| 5 | 1 | 10 | 1.50 | 02 | 2.5 | 4.00 | 1.60 | 1 | Piston |
| 4 | 1 | 10 | 1.50 | 00 | 1.5 | 3.00 | 1.20 | 1 | Piston Stop |
| 3 | 1 | 05 | 1.84 | 00 | 1.5 | 3.34 | 1.34 | 1 | Spring |
| 2 | 1 | 23 | 2.36 | 08 | 6.5 | 8.86 | 3.54 | 0 | Cover |
| 1 | 2 | 11 | 1.80 | 39 | 8.0 | 19.60 | 7.84 | 0 | Screw |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | 42.25 | 16.90 | 4 | $design\ efficiency = \frac{(3) * NM}{TM} =$ 0.29 |
| | | | | | | TM | CM | NM | |

TM = Total manual assembly time
CM = Total cost of manual assembly
NM = Theoretical minimum number of parts

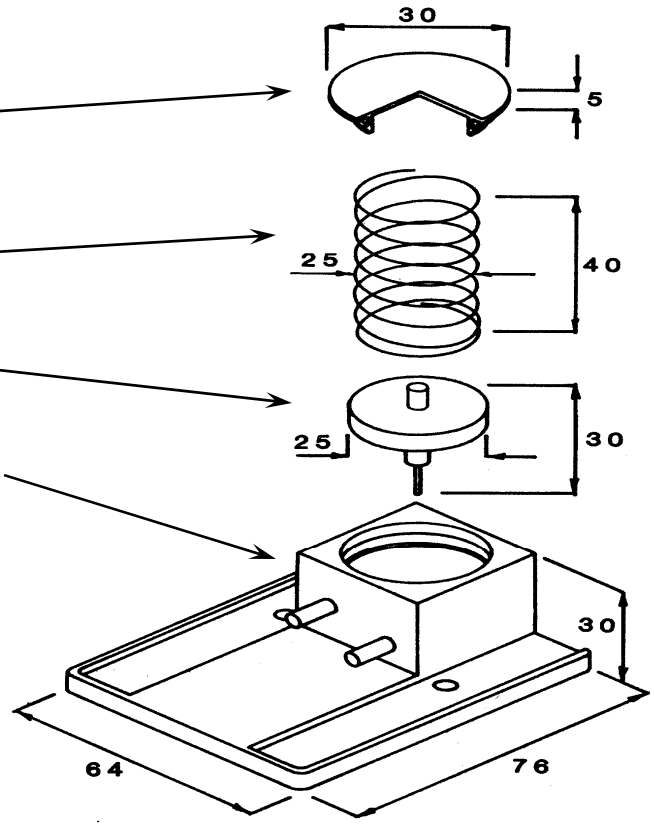
# *Redesigned Pneumatic Piston*

1 - Snap on cover and stop (plastic)

2 - Spring (steel)

3 - Piston (aluminum)

4 - Main block (plastic)



# *Worksheet for Redesigned Pn. Piston*

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Name of Assembly |
|---|---|---|---|---|---|---|---|---|---|
| Part I.D. Number | Number of times the operation is carried out consecutively | Two-digit manual handling code | Manual handling time per part | Two-digit manual insertion code | Manual insertion time per part | Operation time (sec) (2)*[(4) + (6)] | Operation cost (¢) 0.4 * (7) | Figures for theoretical minimum parts Estimation | Pneumatic Piston (re-design) |
| 4 | 1 | 30 | 1.95 | 00 | 1.5 | 3.45 | 1.38 | 1 | Main Block |
| 3 | 1 | 10 | 1.50 | 00 | 1.5 | 3.00 | 1.20 | 1 | Piston |
| 2 | 1 | 05 | 1.84 | 00 | 1.5 | 3.30 | 1.34 | 1 | Spring |
| 1 | 1 | 10 | 1.50 | 30 | 2.0 | 3.50 | 1.40 | 1 | Cover & Snap |
| | | | | | | | | | |
| | | | | | | | | | |
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| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | 13.29 | 5.32 | 4 | $design\ efficiency = \frac{(3) * NM}{TM} =$ 0.90 |
| | | | | | | TM | CM | NM | |

TM = Total manual assembly time
CM = Total cost of manual assembly
NM = Theoretical minimum number of parts

# *Diaphragm Assembly*

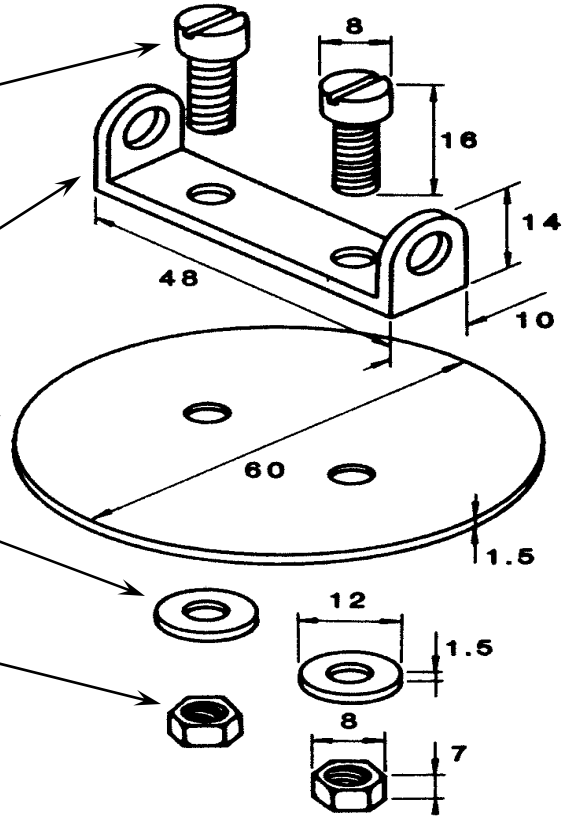
1 - Screw (2) (mild steel)

2 - Bearing housing (mild steel)

3 - Plate (spring steel)

4 - Washer (2) (mild steel)

5 - Nut (2) (mild steel)



# *Worksheet for Diaphragm Assembly*

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Required rate of assembly, FR (per minute) | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Part I.D. Number | Number of times the operation is carried out consecutively | Five-digit automatic handling code | Orienting Efficiency (OE) | Relative Feeder Cost (CR=FC+DC) | Maximum Basic Feed Rate (FM) | Difficulty Rating for Automatic Handling (DF) | Cost of automatic handling per part (CF = 0.03*DF) | Two-digit automatic insertion code | Relative work head cost, WC | Difficulty for automatic insertion, DI | Cost of automatic insertion per part (CI = 0.06*DI) | Operation cost (2)*[(8) + (12)](¢) | Figures for theoretical minimum parts Estimation | Name of Assembly | |
| 5 | 2 | 10000 | 0.70 | 1 | 131 | 2 | 0.06 | 00 | 1 | 2 | 0.12 | 0.36 | 1 | nut | |
| 4 | 2 | 00000 | 0.70 | 1 | 88 | 2 | 0.06 | 00 | 1 | 2 | 0.12 | 0.36 | 0 | washer | |
| 3 | 1 | 00800 | Manual assembly required | | | | | | | | | 3.42 | 1 | plate | |
| 2 | 1 | 72500 | 0.25 | 1 | 7.8 | 7.7 | 0.23 | 08 | 2 | 4 | 0.24 | 0.47 | 0 | bearing housing | |
| 1 | 2 | 21000 | 0.90 | 1 | 84 | 2 | 0.06 | 39 | 1.8 | 3.6 | 0.22 | 0.56 | 0 | screw | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | 5.17 | 2 | | |
| | | | | | | | | | | | | CA | NM | | |

Column 6

$$FM = 1500\left(\frac{OE}{Y}\right)$$

$$Y = Part\ Size$$

Column 7

$$DF = \left(\frac{60}{FR}\right)CR, FR < FM$$

$$DF = \left(\frac{60}{FR}\right)CR, FR \geq FM$$

Column 11

$$DI = \left(\frac{60}{FR}\right)WC, FR < 60$$

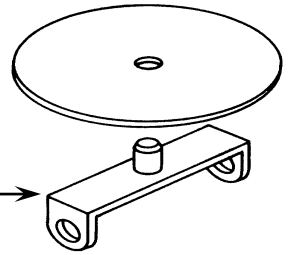
$$DI = WC, FR \geq 60$$

# *Redesign Diaphragm Assembly*

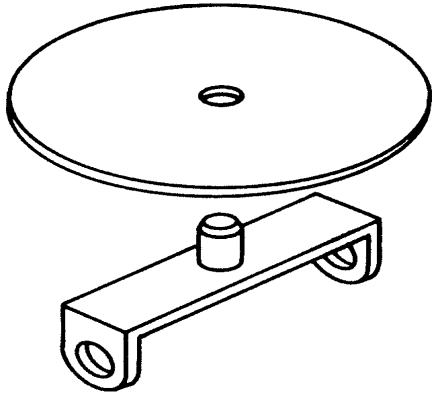
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Required rate of assembly, FR (per minute) | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Part I.D. Number | Number of times the operation is carried out consecutively | Five-digit automatic handling code | Orienting Efficiency (OE) | Relative Feeder Cost (CR=FC+DC) | Maximum Basic Feed Rate (FM) | Difficulty Rating for Automatic Handling (DF) | Cost of automatic handling per part (CF = 0.03*DF) | Two-digit automatic insertion code | Relative work head cost, WC | Difficulty for automatic insertion, DI | Cost of automatic insertion per part (CI = 0.06*DI) | Operation cost (2)*[(8) + (12)](¢) | Figures for theoretical minimum parts Estimation | Name of Assembly | |
| 2 | 1 | 82000 | 0.5 | 1 | 15.6 | 3.85 | 0.12 | 00 | 1 | 2 | 0.12 | 0.24 | 1 | bearing housing | |
| 1 | 1 | 00000 | 0.7 | 1 | 17.5 | 3.43 | 0.10 | 00 | 1 | 2 | 0.12 | 0.22 | 1 | plate | |
| | | | | | | | | 91 | 0.9 | 1.8 | 0.11 | 0.11 | 0 | Separation fastening operation | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | 0.57 | 2 | | |
| | | | | | | | | | | | | CA | NM | | |

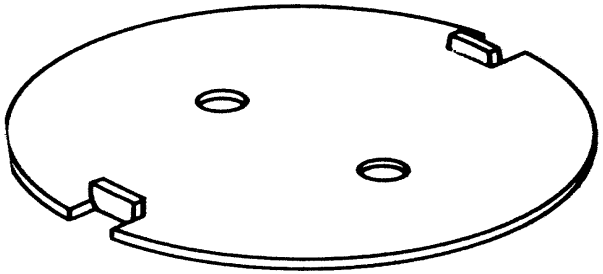
1 - Plate (spring steel)

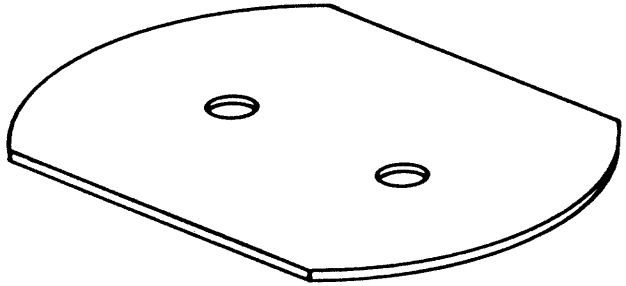
2 - Bearing housing (plastic)



# *Redesign of Plate*







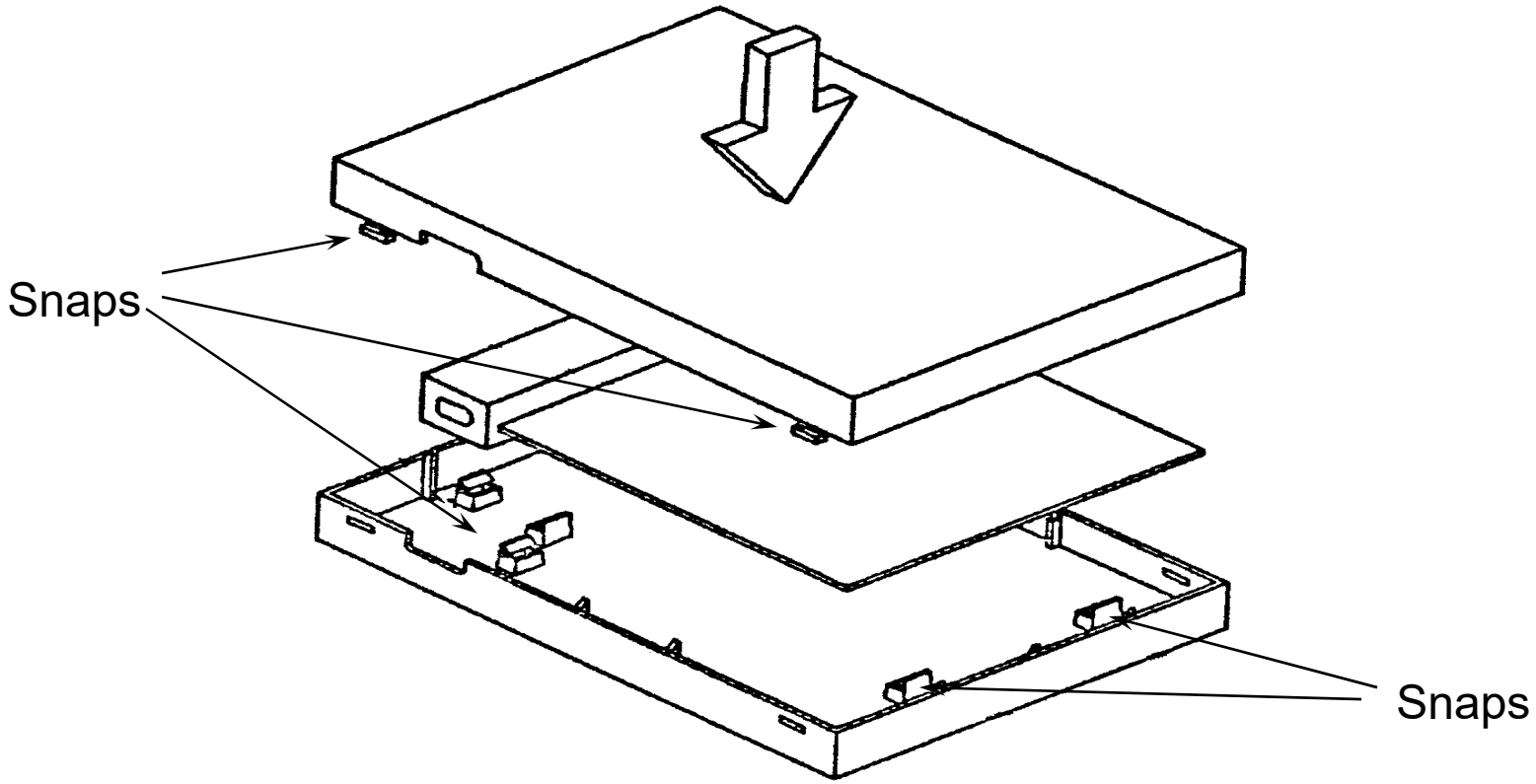
Redesign of plate with shear bent tabs to define orientation

Redesign of plate to be cropped from strip

# *Design for Automated Assembly (Concepts)*

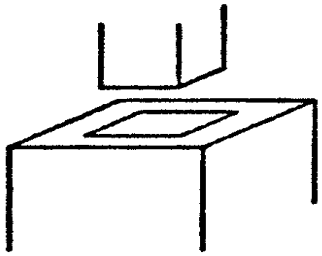
- Layered design
  - Clamshell base
  - Sequential assembly
  - Uni-directional
- Self-alignment
  - Chamfer/countersink
  - Posts/locating stops
- Combine detail parts
  - Screws & washers
  - Plastic moldings
  - Castings
- Symmetry
- Direct drive systems
  - Helical or gear vs. Belt/pulley
- Common fasteners
  - Minimize screws
  - Snap fasteners
- Minimize springs
  - Molded
  - Compression coil
  - Extensive coil
- Minimize cables
  - Integrated packaging
  - Solid connectors

# *Example of Layered Assembly*



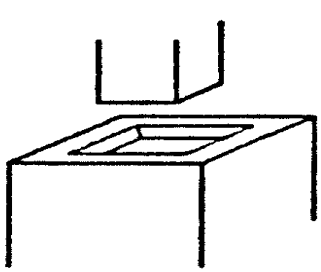
# *Compliance and Assembly*

Avoid

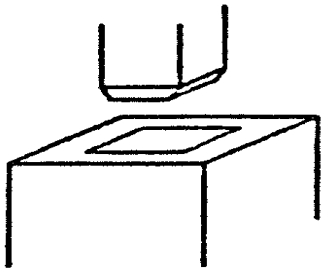


No Chamfers

Better

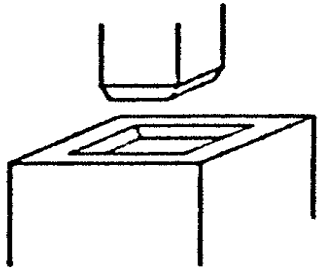


Bottom Part Chamfered



Bottom Part Chamfered

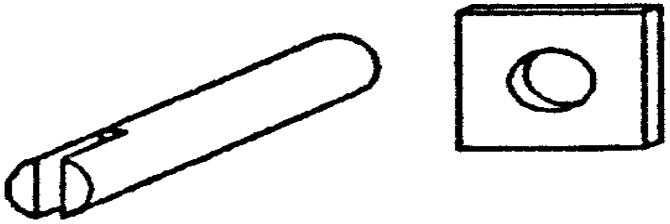
Best



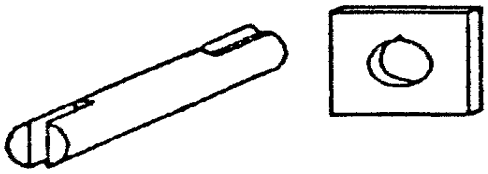
Both Parts Chamfered

# *Self Alignment of Parts*

This part could be oriented in any direction

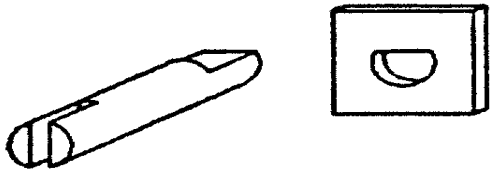


These parts can be oriented only one way



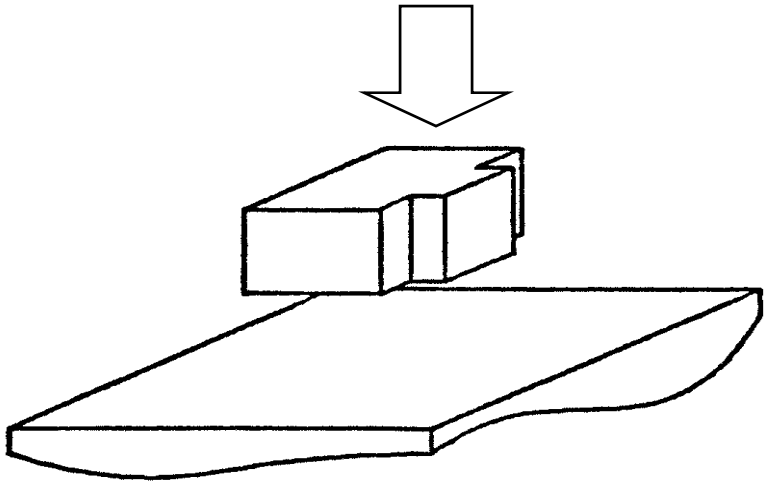
Hole to accept swaged part

Hole to accept notched part

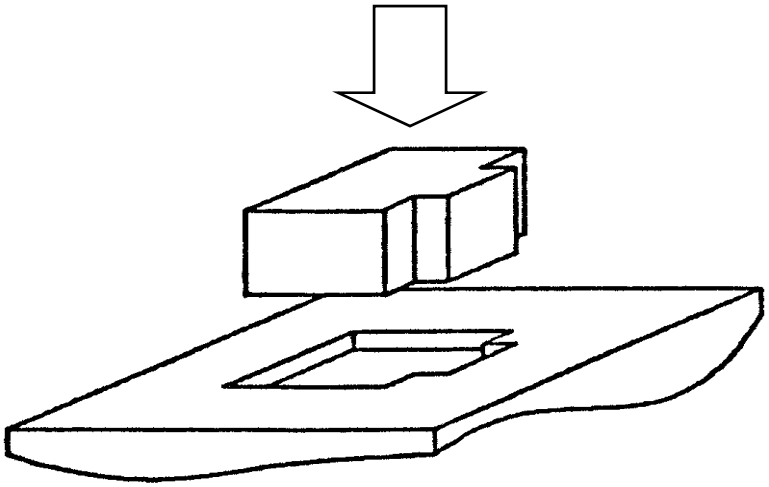


“D” shaped hole

# *Nesting of Parts*

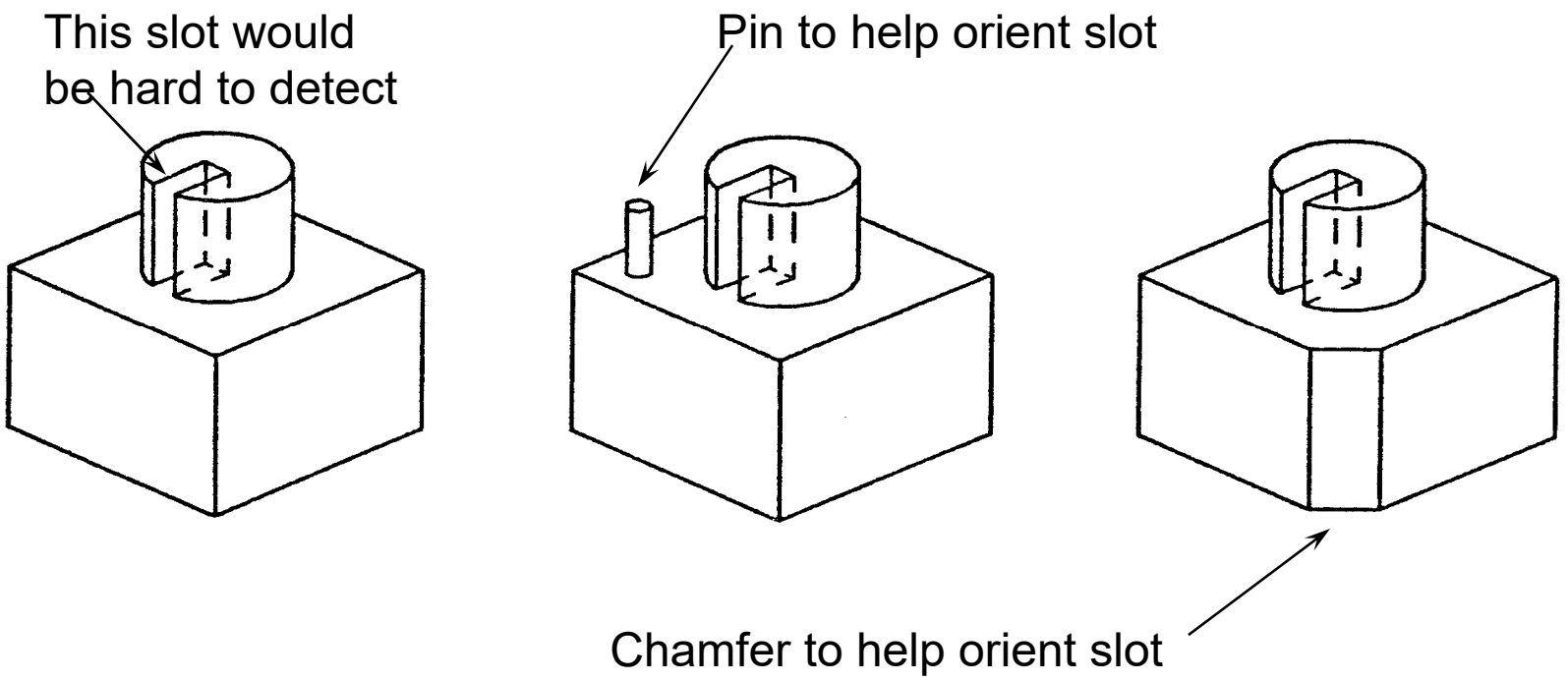


This part could be placed in any orientation and not be secured



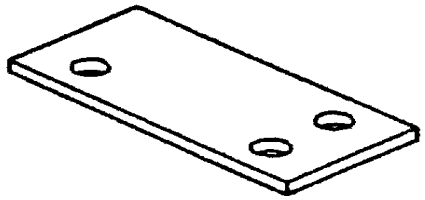
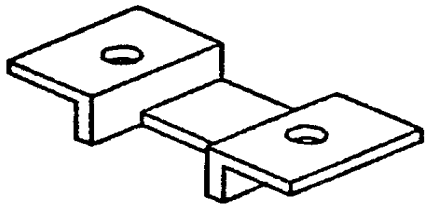
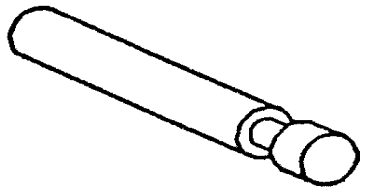
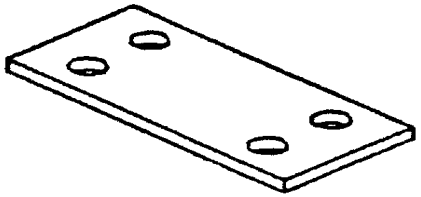
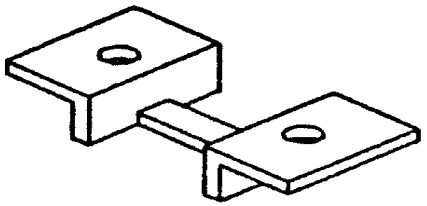
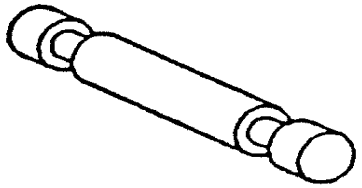
This part has a “nest” to orient and help it secure

# *Nonfunctional External Feature for Orientation*



## *Symmetry*

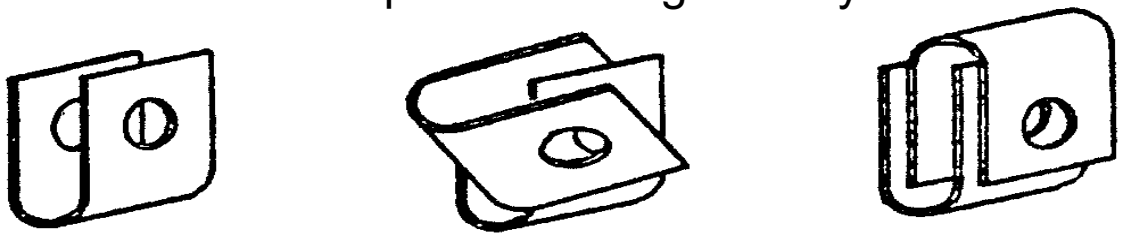
Orientation Required

Preferred

# *Tangling*

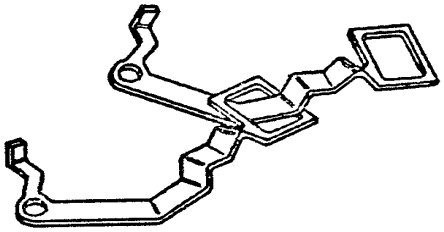
These parts can tangle easily



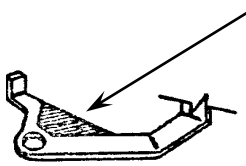
The same parts redesigned, will not tangle

# *Tangling (continued)*

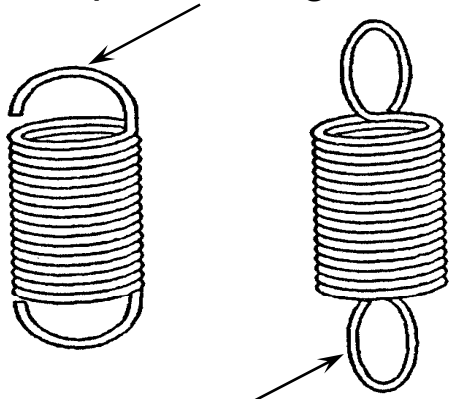
Parts that interconnect will not feed



A fillet will keep the parts from interconnecting

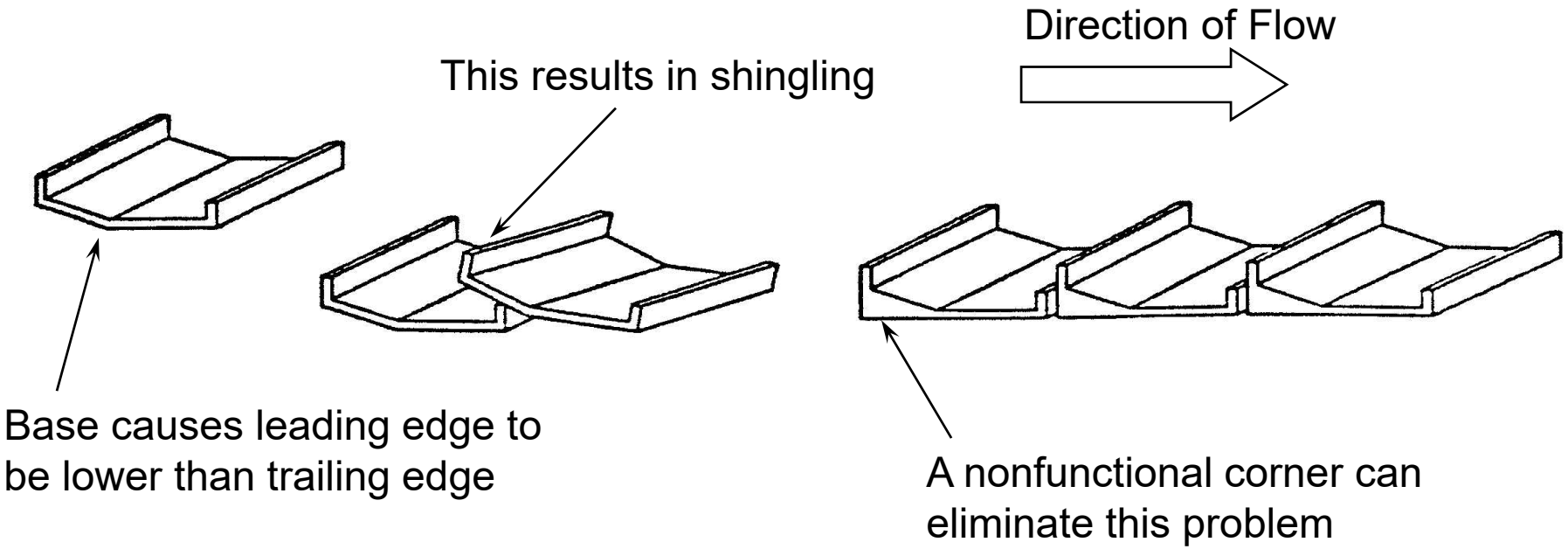


Springs with open loops will tangle

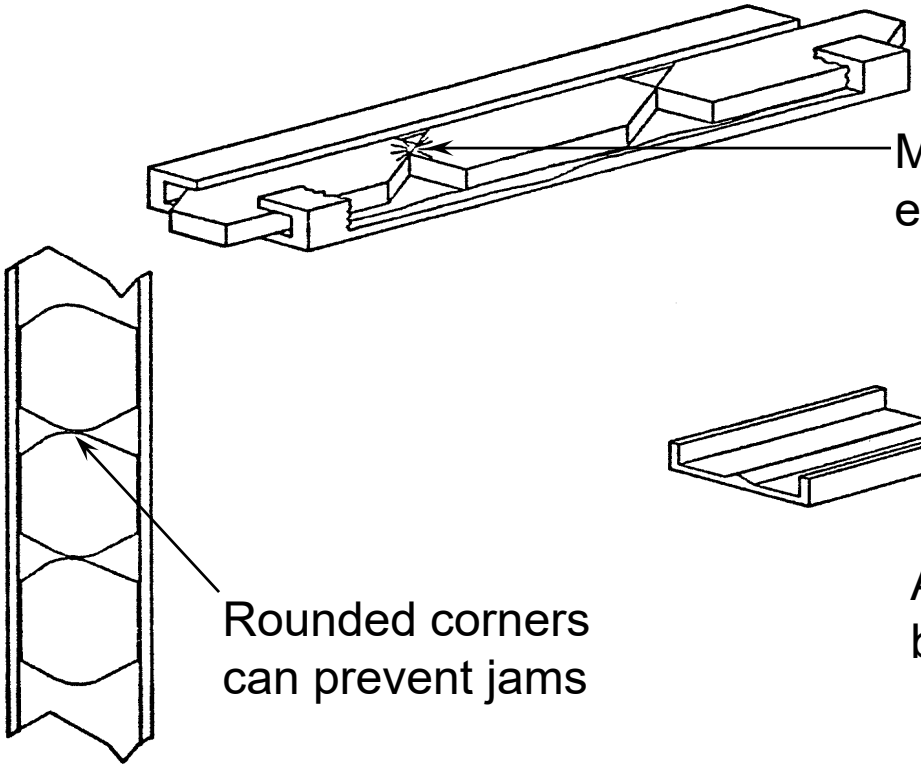


Springs with closed loops will not tangle

# *Methods to Avoid Jams (1 of 2)*



# *Methods to Avoid Jams (2 of 2)*



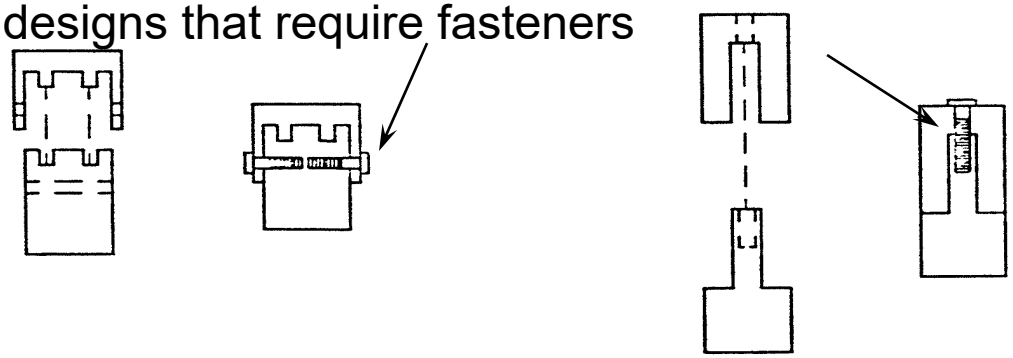
Mating surfaces with sharp edges can cause jams

Rounded corners can prevent jams

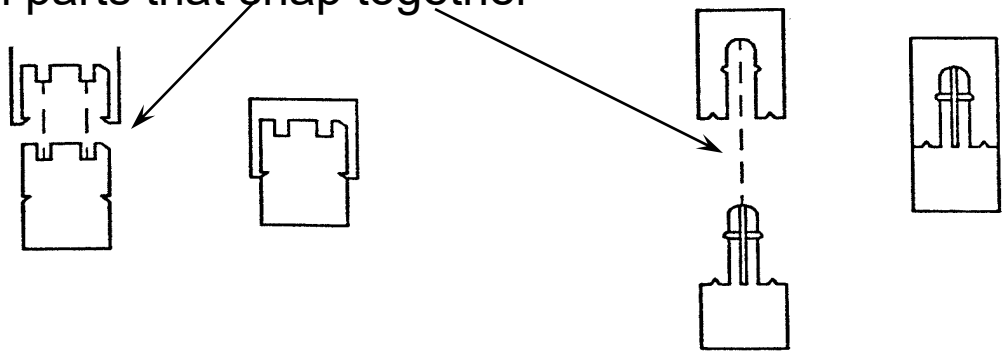
A groove can prevent jams by centering the part

# *Substitutes for Fasteners*

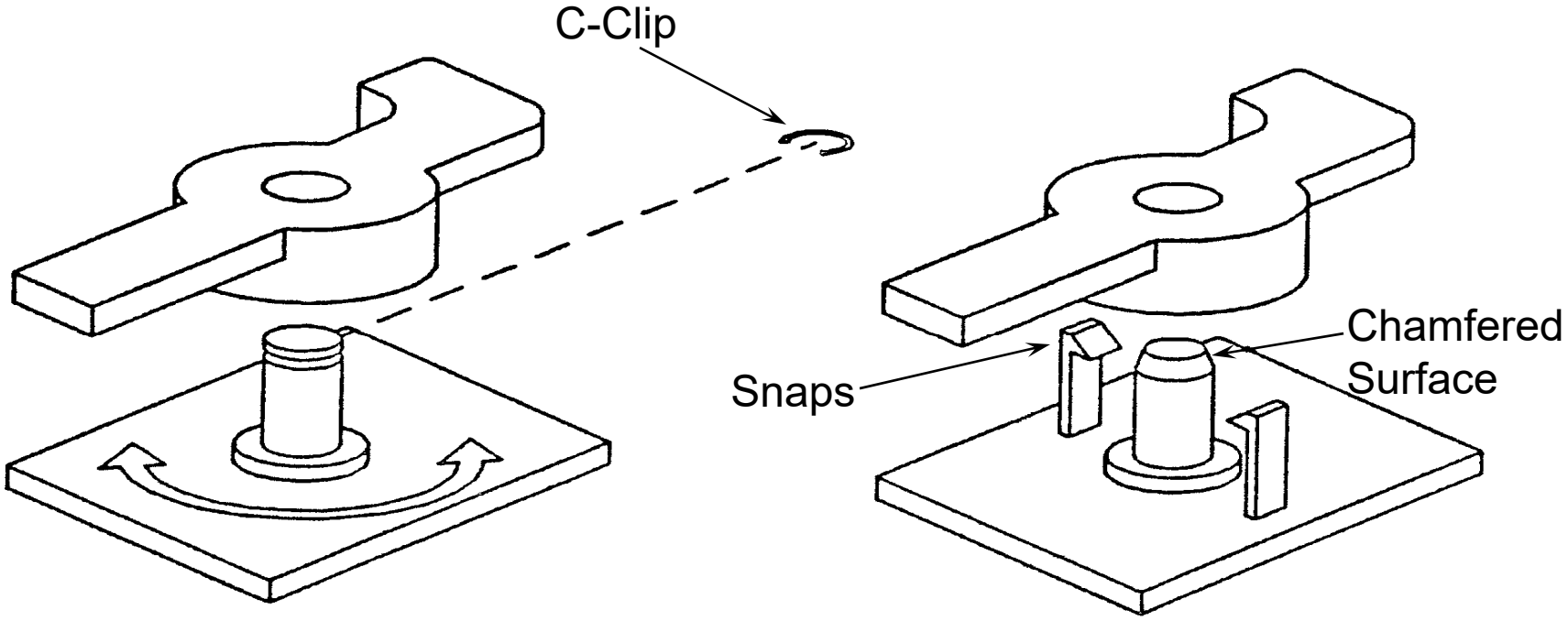
Avoid designs that require fasteners



Design parts that snap together

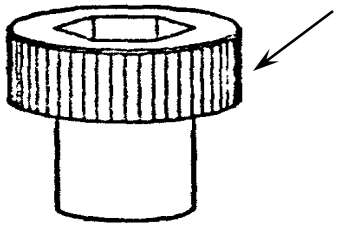


# *Joining Moving Parts without Fasteners*

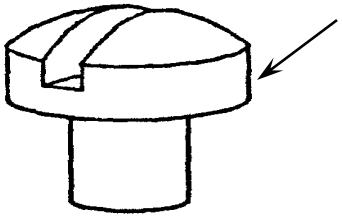


# *Fasteners*

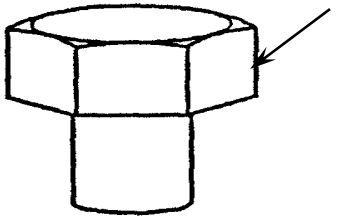
Preferred: Have flat vertical sides for vacuum pickup



Socket Head



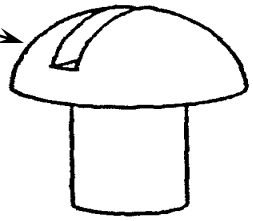
Fillister Head



Hex Head

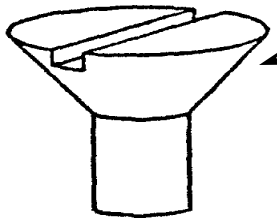
Avoid

Round Side



Round Head

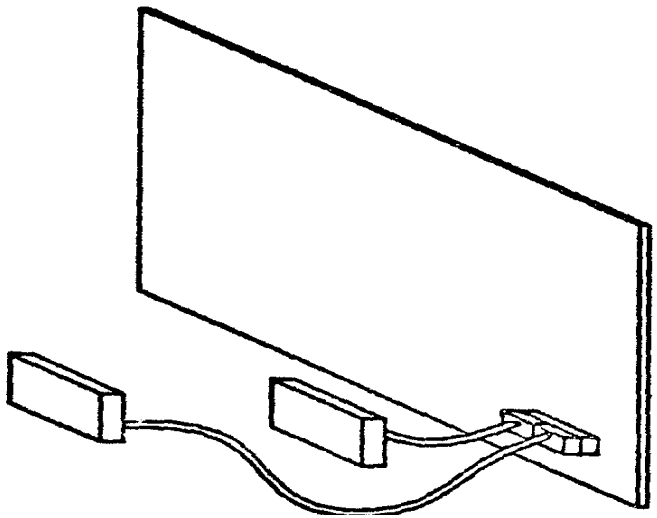
Slant Side



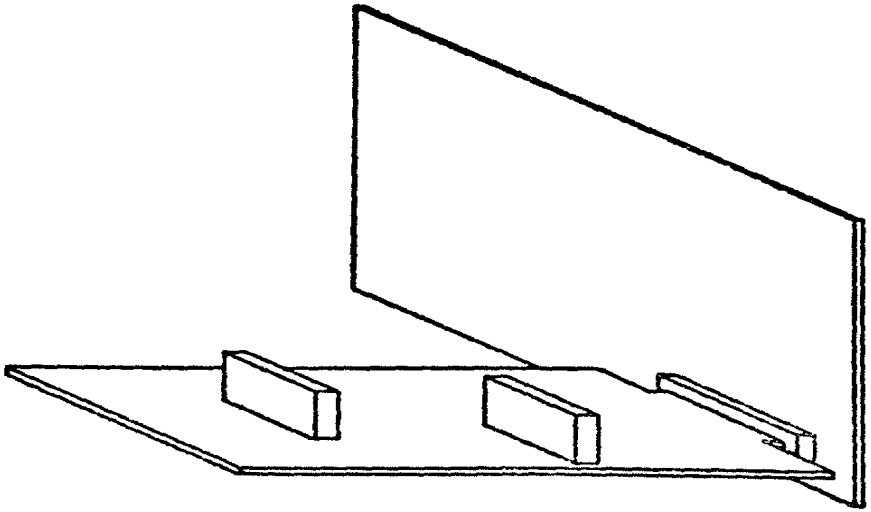
Flat Head

# *Cables and Connectors*

Example of a slave circuit board



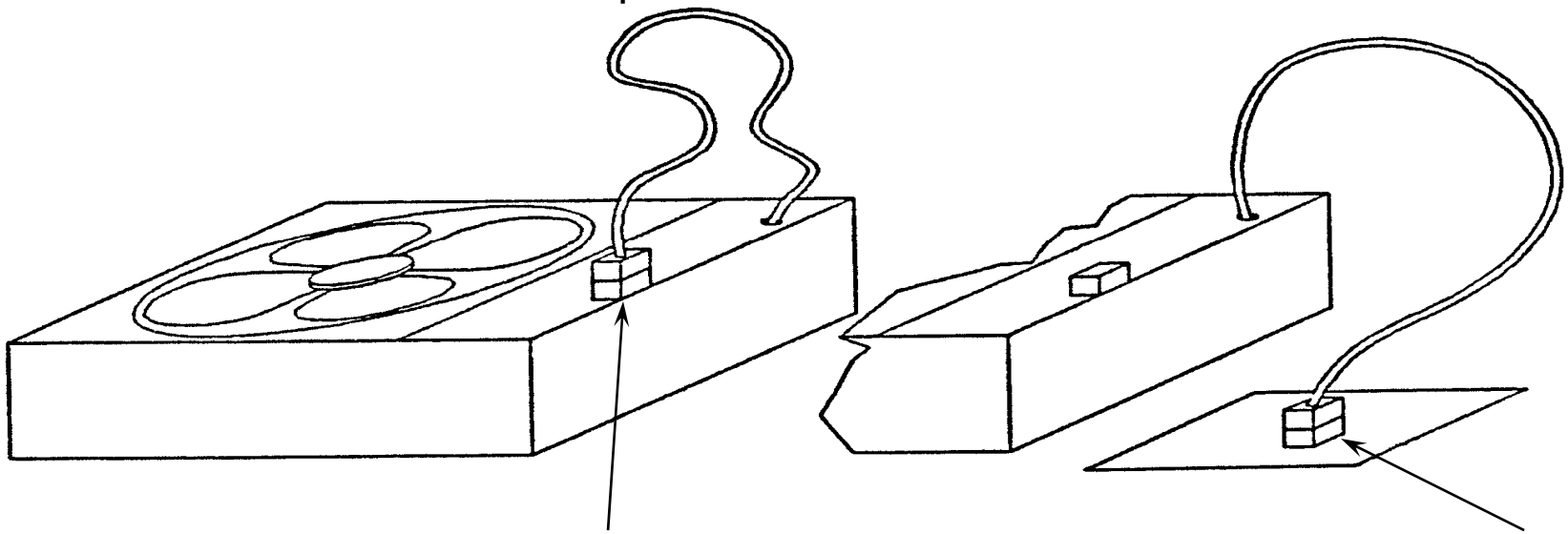
Avoid:
Components that are connected with cables to circuit board



Preferred:
Components that are plugged on a slave circuit board

# *Cables and Connectors*

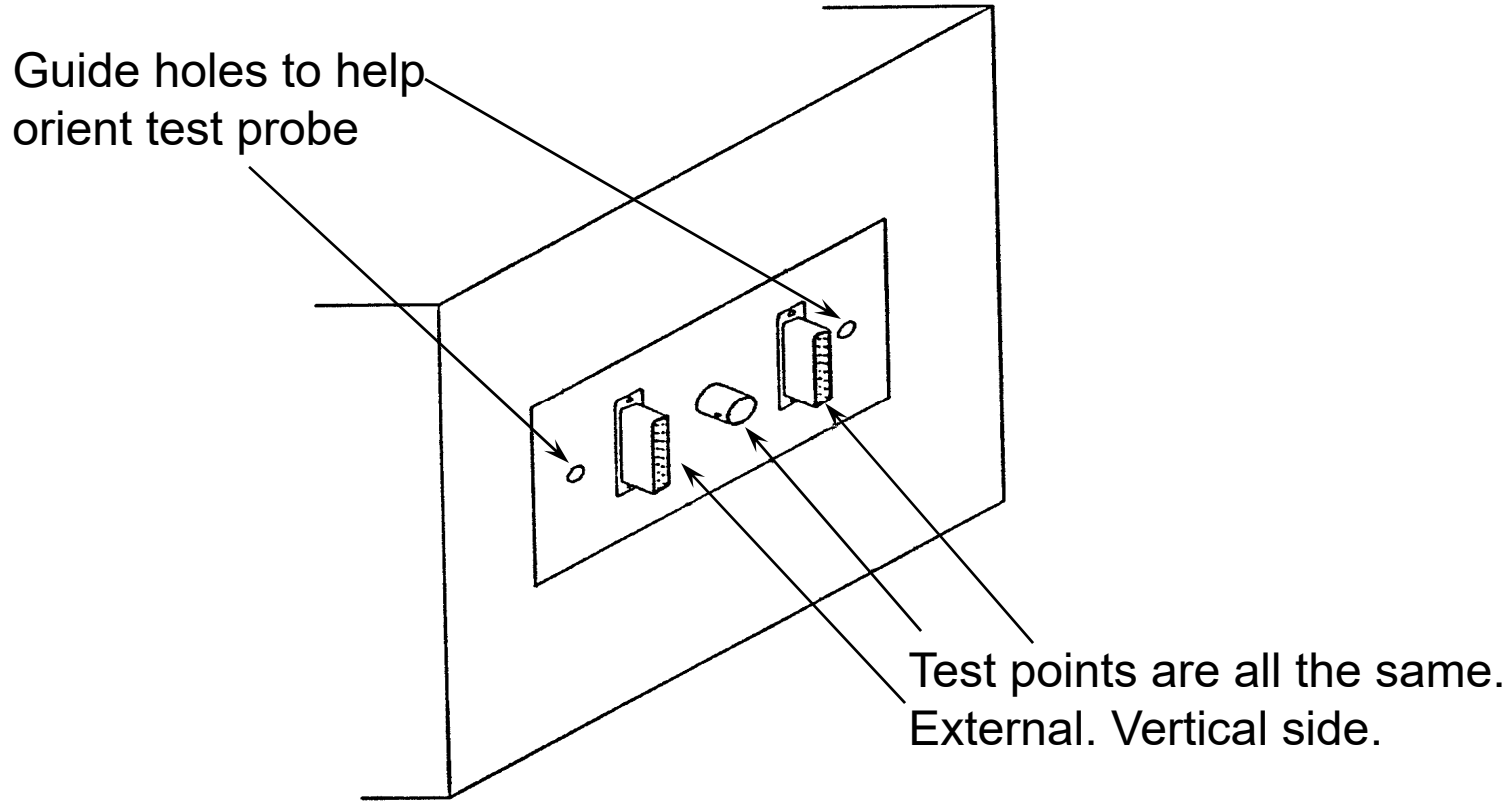
Example of a secured cable



If the use of a cable cannot be avoided. Have the cable plugged into a dummy connector to locate the cable end.

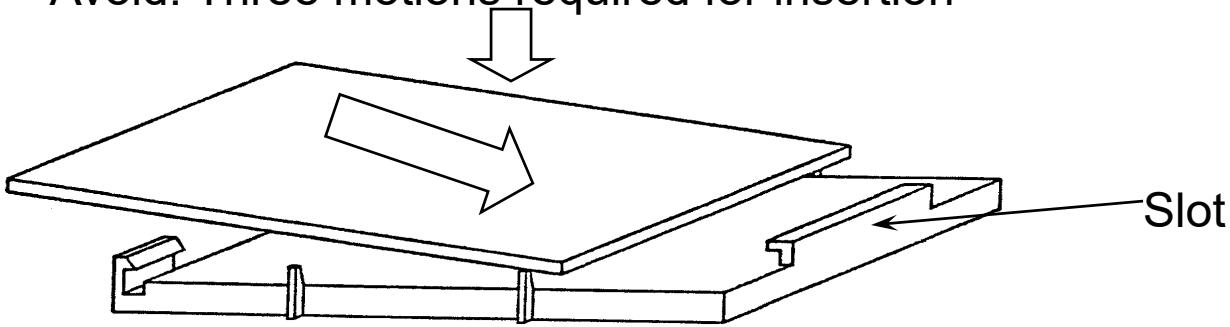
Then a robot can locate the connector and plug it in.

# External Test Points

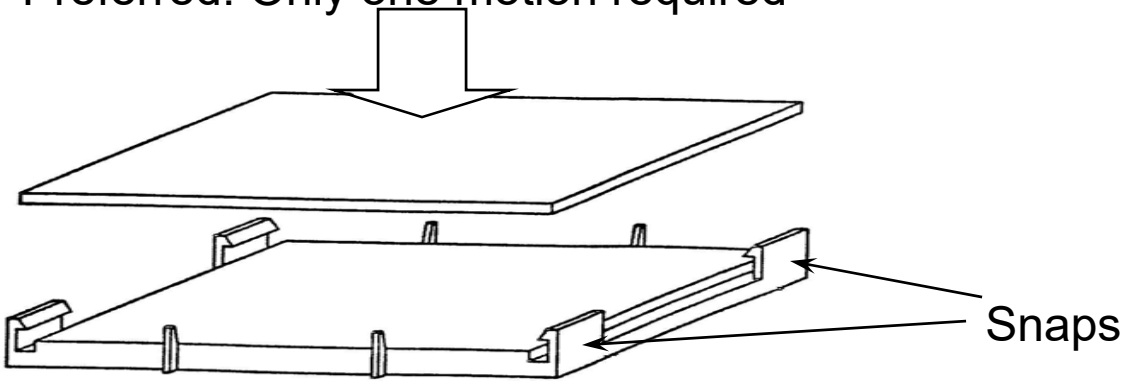


# *Motion and Design*

Avoid: Three motions required for insertion




Preferred: Only one motion required



# *Design for 3D Printing*

- Disperse the seams