DFA Example

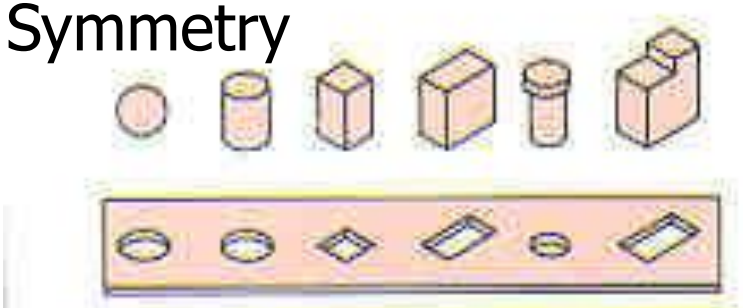
- Time estimation
- Design Rules
- Redesign

Time Estimation for Assembly

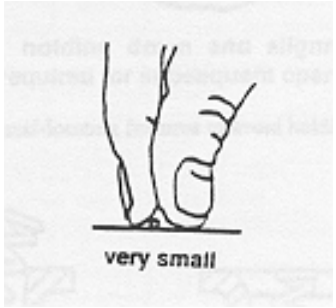
- Handling
  - pick up
  - orient
- Insertion
  - location (obstructed view? Self locating?)
  - hold down and resistance
  - securing method

Handling Issues

Symmetry

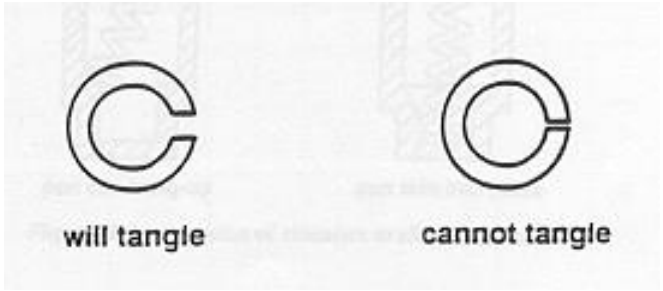


α	0	180	180	90	360	360
β	0	0	90	180	0	360

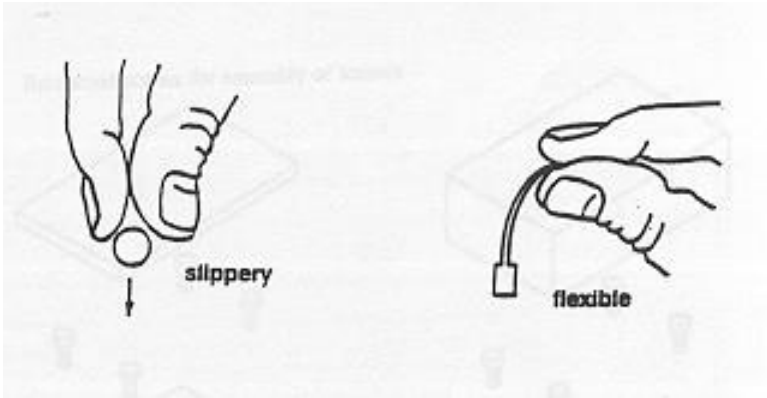


Size

Fragile/Sharp

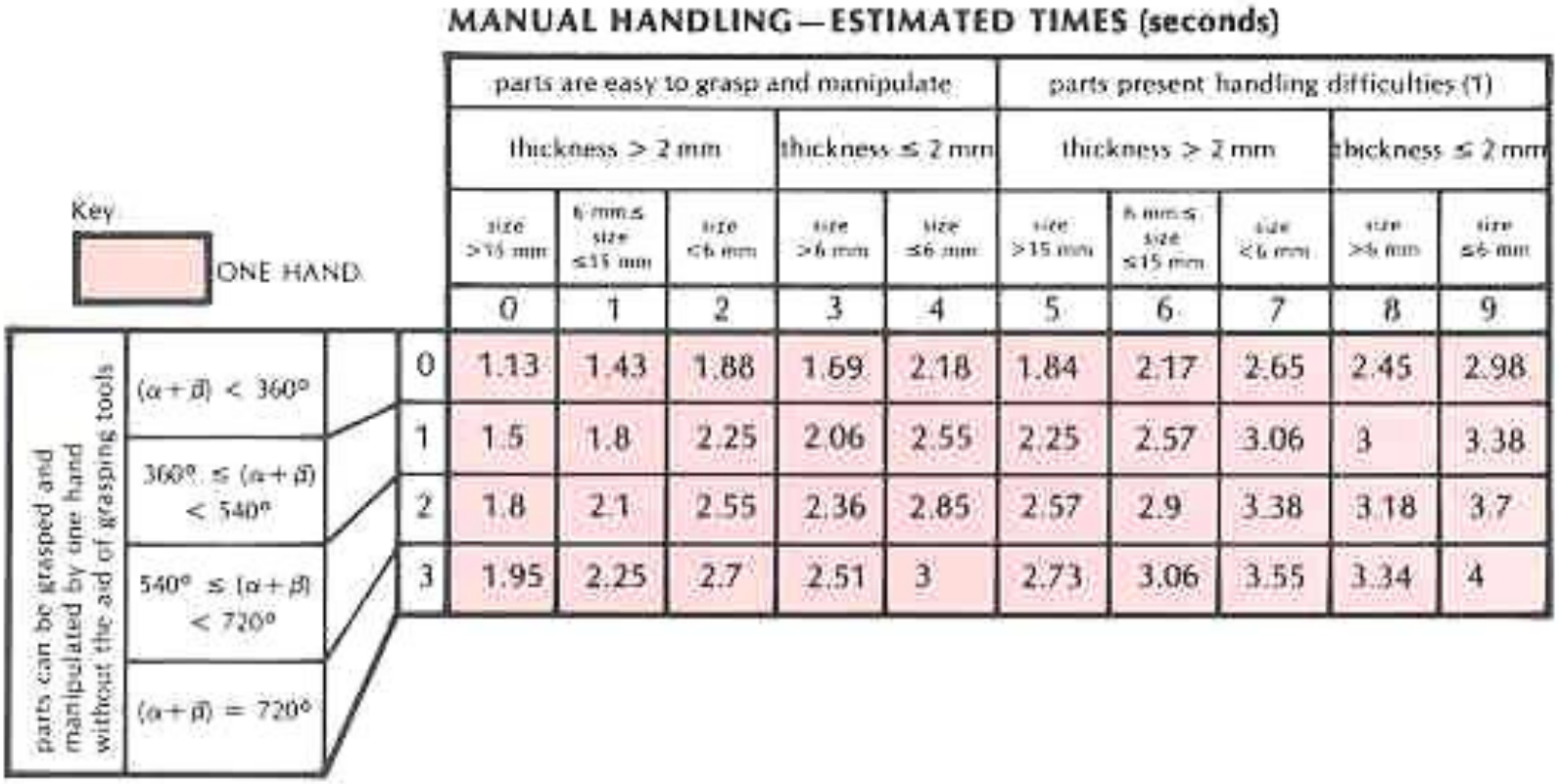


Nest/Tangle



Slippery/Flexible

B-D Manual handling chart



Key

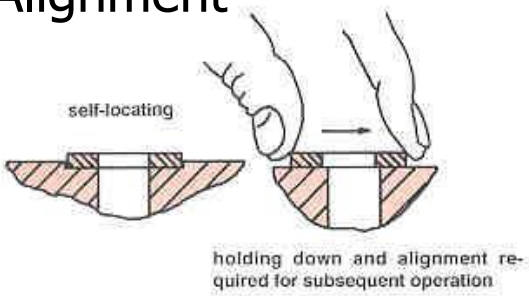
ONE HAND

MANUAL HANDLING—ESTIMATED TIMES (seconds)

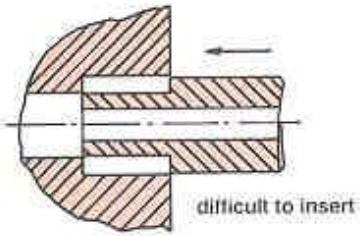
parts can be grasped and manipulated by one hand without the aid of grasping tools			parts are easy to grasp and manipulate					parts present handling difficulties (†)				
			thickness > 2 mm			thickness ≤ 2 mm		thickness > 2 mm			thickness ≤ 2 mm	
			size >15 mm	6 mm ≤ size ≤15 mm	size <6 mm	size >6 mm	size ≤6 mm	size >15 mm	6 mm ≤ size ≤15 mm	size <6 mm	size >6 mm	size ≤6 mm
			0	1	2	3	4	5	6	7	8	9
	$(\alpha+\beta) < 360°$	0	1.13	1.43	1.88	1.69	2.18	1.84	2.17	2.65	2.45	2.98
	$360° \leq (\alpha+\beta) < 540°$	1	1.5	1.8	2.25	2.06	2.55	2.25	2.57	3.06	3	3.38
	$540° \leq (\alpha+\beta) < 720°$	2	1.8	2.1	2.55	2.36	2.85	2.57	2.9	3.38	3.18	3.7
	$(\alpha+\beta) = 720°$	3	1.95	2.25	2.7	2.51	3	2.73	3.06	3.55	3.34	4

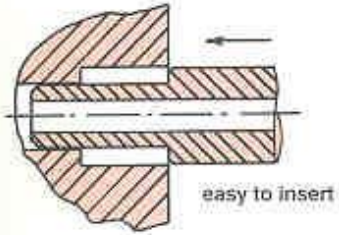
Insertion Issues

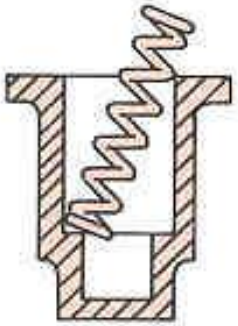
Alignment

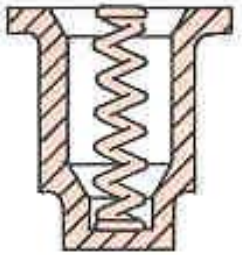


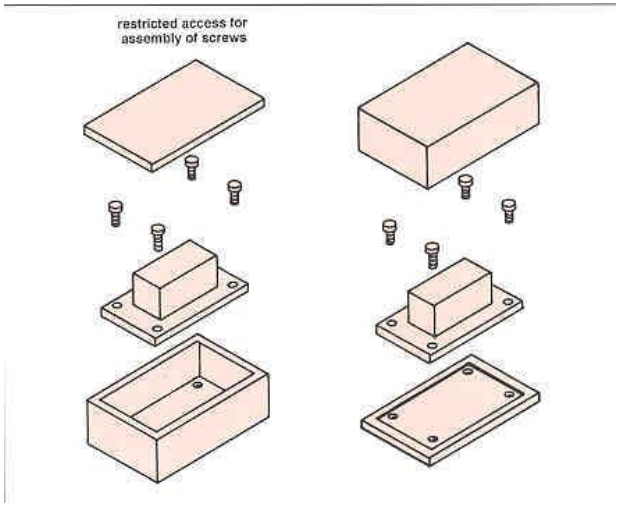
Insertion Force

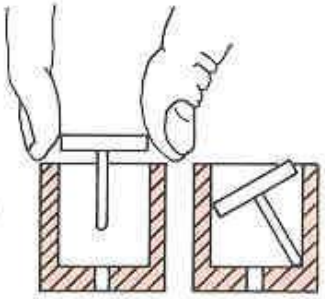


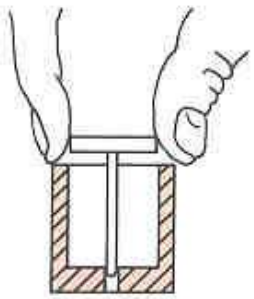




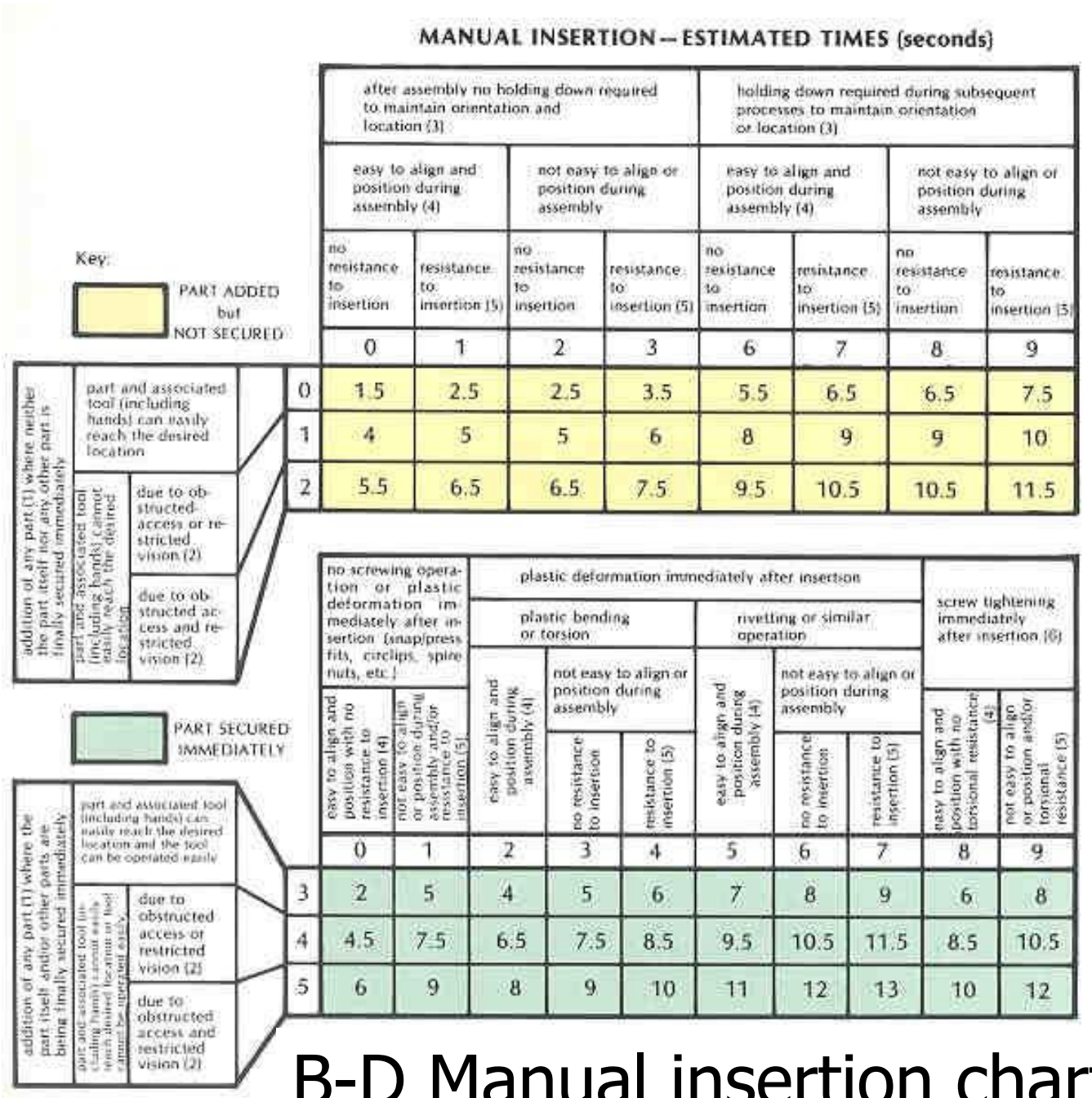








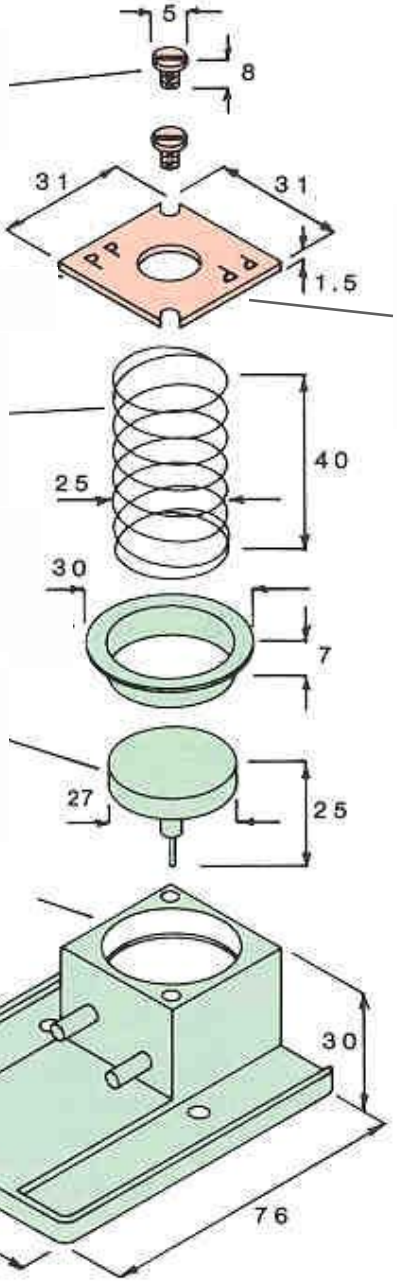
Obstructed Access/View



B-D Manual insertion chart

Pneumatic Piston Sub-Assembly

1 – screw(2) (steel) not easy to align



2 – cover(steel) not easy to align – assembly worker's fingers must be used to align edges

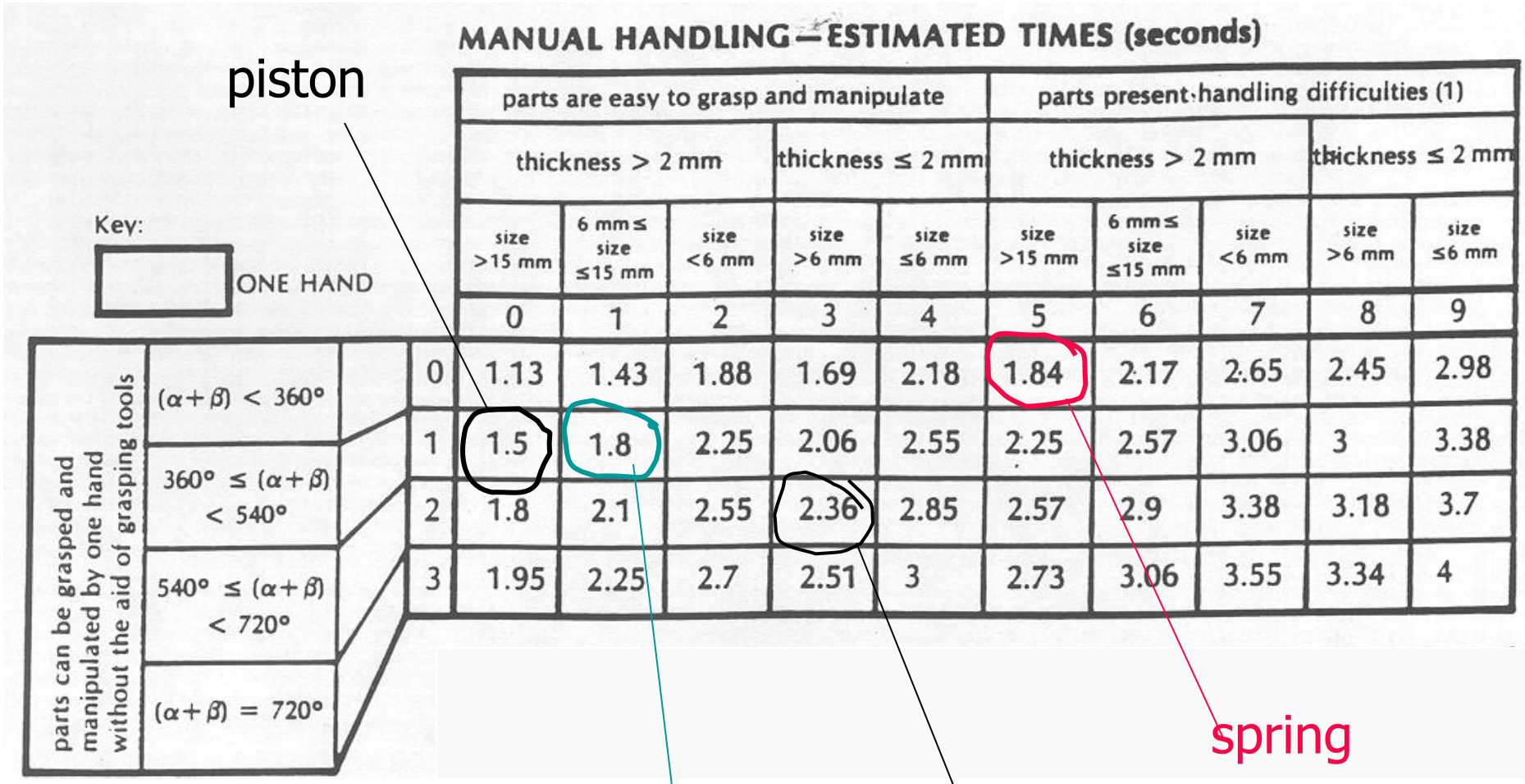
3 – spring(steel) (closed ends) subject to continuous cycling and must be spring steel

4 – piston stop(plastic) edge is chamfered for ease of alignment

5 – piston(aluminum) obstructed access for insertion of spindle into bottom of bore

6 – main block(plastic) depth of bore is 28mm with small through hole for piston spindle

B-D Manual handling chart



MANUAL HANDLING—ESTIMATED TIMES (seconds)

			parts are easy to grasp and manipulate					parts present handling difficulties (1)				
			thickness > 2 mm			thickness ≤ 2 mm		thickness > 2 mm			thickness ≤ 2 mm	
			size >15 mm	6 mm ≤ size ≤15 mm	size <6 mm	size >6 mm	size ≤6 mm	size >15 mm	6 mm ≤ size ≤15 mm	size <6 mm	size >6 mm	size ≤6 mm
			0	1	2	3	4	5	6	7	8	9
parts can be grasped and manipulated by one hand without the aid of grasping tools	(α+β) < 360°	0	1.13	1.43	1.88	1.69	2.18	1.84	2.17	2.65	2.45	2.98
	360° ≤ (α+β) < 540°	1	1.5	1.8	2.25	2.06	2.55	2.25	2.57	3.06	3	3.38
	540° ≤ (α+β) < 720°	2	1.8	2.1	2.55	2.36	2.85	2.57	2.9	3.38	3.18	3.7
	(α+β) = 720°	3	1.95	2.25	2.7	2.51	3	2.73	3.06	3.55	3.34	4

Key: ONE HAND

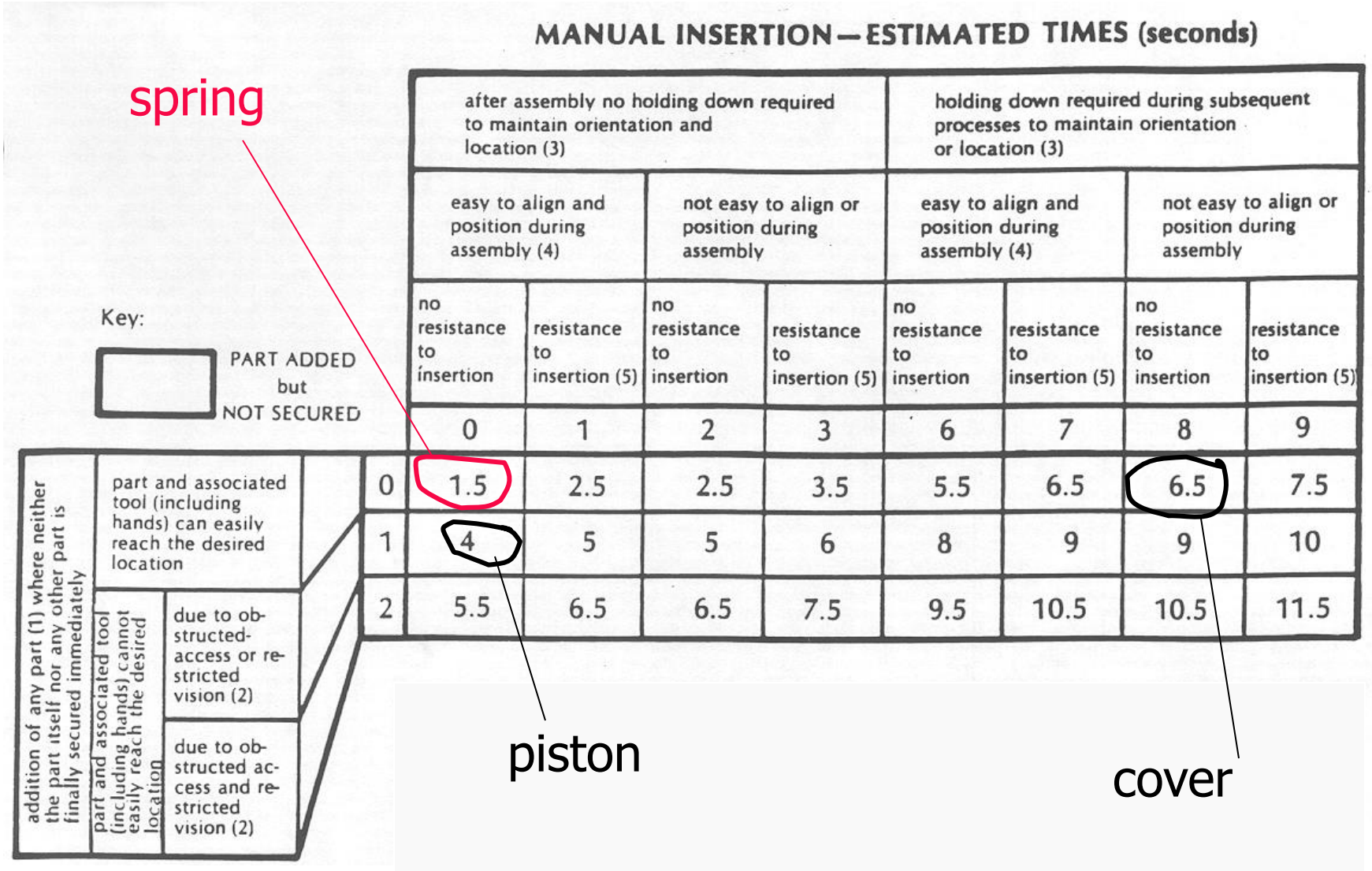
piston

screws

cover

spring

B-D Manual insertion chart A



MANUAL INSERTION—ESTIMATED TIMES (seconds)

spring

Key:

PART ADDED but NOT SECURED

addition of any part (1) where neither the part itself nor any other part is finally secured immediately				after assembly no holding down required to maintain orientation and location (3)				holding down required during subsequent processes to maintain orientation or location (3)			
				easy to align and position during assembly (4)		not easy to align or position during assembly		easy to align and position during assembly (4)		not easy to align or position during assembly	
				no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)	no resistance to insertion	resistance to insertion (5)
				0	1	2	3	6	7	8	9
	part and associated tool (including hands) can easily reach the desired location		0	1.5	2.5	2.5	3.5	5.5	6.5	6.5	7.5
			1	4	5	5	6	8	9	9	10
	part and associated tool (including hands) cannot easily reach the desired location	due to obstructed-access or restricted vision (2)	2	5.5	6.5	6.5	7.5	9.5	10.5	10.5	11.5
		due to obstructed access and restricted vision (2)									

piston

cover

B-D Manual insertion chart B

PART SECURED IMMEDIATELY

addition of any part (1) where the part itself and/or other parts are being finally secured immediately

- part and associated tool (including hands) can easily reach the desired location and the tool can be operated easily
- part and associated tool (including hands) cannot easily reach desired location or tool cannot be operated easily
  - due to obstructed access or restricted vision (2)
  - due to obstructed access and restricted vision (2)

	no screwing operation or plastic deformation immediately after insertion (snap/press fits, circlips, spire nuts, etc.)		plastic deformation immediately after insertion						screw tightening immediately after insertion (6)	
			plastic bending or torsion			rivetting or similar operation				
	easy to align and position with no resistance to insertion (4)	not easy to align or position during assembly and/or resistance to insertion (5)	easy to align and position during assembly (4)	not easy to align or position during assembly		easy to align and position during assembly (4)	not easy to align or position during assembly		easy to align and position with no torsional resistance (4)	not easy to align or position and/or torsional resistance (5)
				no resistance to insertion	resistance to insertion (5)		no resistance to insertion	resistance to insertion (5)		
	0	1	2	3	4	5	6	7	8	9
3	2	5	4	5	6	7	8	9	6	8
4	4.5	7.5	6.5	7.5	8.5	9.5	10.5	11.5	8.5	10.5
5	6	9	8	9	10	11	12	13	10	12

screws

Pneumatic Piston Sub-Assembly

1	2	3	4	5	6	7	8	9	Name of Assembly
Part I.D. No.	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, seconds (2)*[(4)+(6)]	operation cost, cents 0.4*(7)	figures for estimation of theoretical minimum parts	PNEUMATIC PISTON
6	1	30	1.95	00	1.50	3.45	1.38	1	MAIN BLOCK
5	1	10	1.50	10	4.00	5.50	2.20	1	PISTON
4	1	10	1.50	00	1.50	3.00	1.20	1	PISTON STOP
3	1	05	1.84	00	1.50	3.34	1.34	1	SPRING
2	1	23	2.36	08	6.50	8.86	3.54	0	COVER
1	2	11	1.80	39	8.00	19.60	7.84	0	SCREW
						43.75	17.50	4	design efficiency = (3*NM)/TM 0.27
						TM	CM	NM	

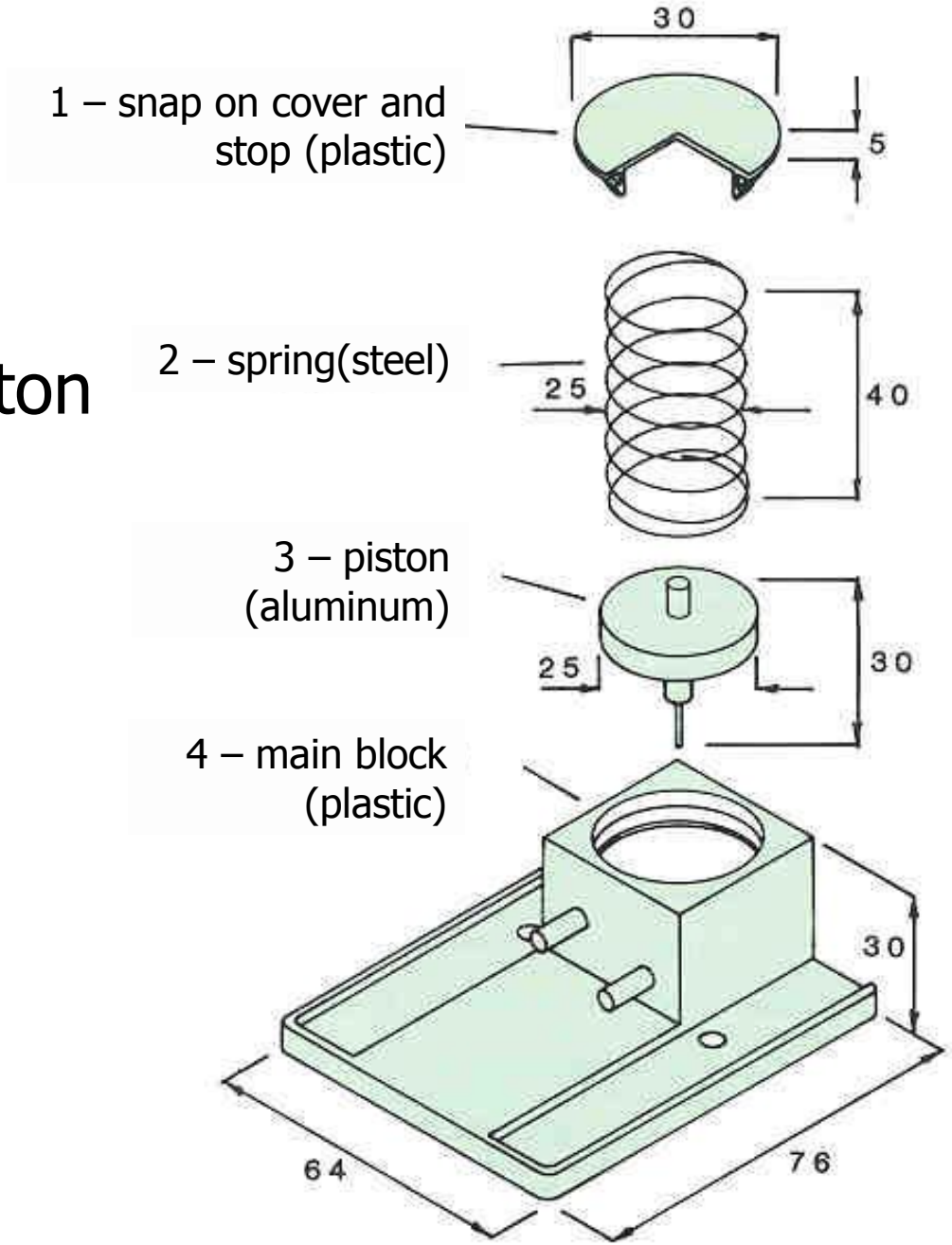
Boothroyd/Dewhurst Design Rules

- Reduce part count and part types
- Strive to eliminate adjustments
- Design parts to be self-aligning and self-locating
- Ensure adequate access and unrestricted vision
- Ensure the ease of handling of parts from bulk
- Minimize the need for reorientations during assembly
- Design parts that cannot be installed incorrectly
- Maximize part symmetry if possible or make parts obviously asymmetrical

Rules to reduce part count

- During operation of the product, does the part move relative to all other parts already assembled?
  - Only gross motion should be considered – small motions that can be accommodated 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 because otherwise necessary assembly or disassembly of other separate parts would be impossible?

Redesign: Pneumatic Piston Sub-Assembly



Re-design

1	2	3	4	5	6	7	8	9	Name of Assembly	
Part I.D. No.	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, seconds (2)*[(4)+(6)]	operation cost, cents 0.4*(7)	figures for estimation of theoretical minimum parts	PNEUMATIC PISTON (re-design)	
4	1	30	1.95	00	1.50	3.45	1.38	1	MAIN BLOCK	
3	1	10	1.50	00	1.50	3.00	1.20	1	PISTON	
1	1	05	1.84	00	1.50	3.34	1.34	1	SPRING	
2	1	10	1.50	30	2.00	3.50	1.40	1	COVER & STOP	
						13.29	5.32	4	design efficiency = (3*NM)/TM	0.90
						TM	CM	NM		