Design for Cost, Manufacture, Assembly, and Other Measures

Chapter 11

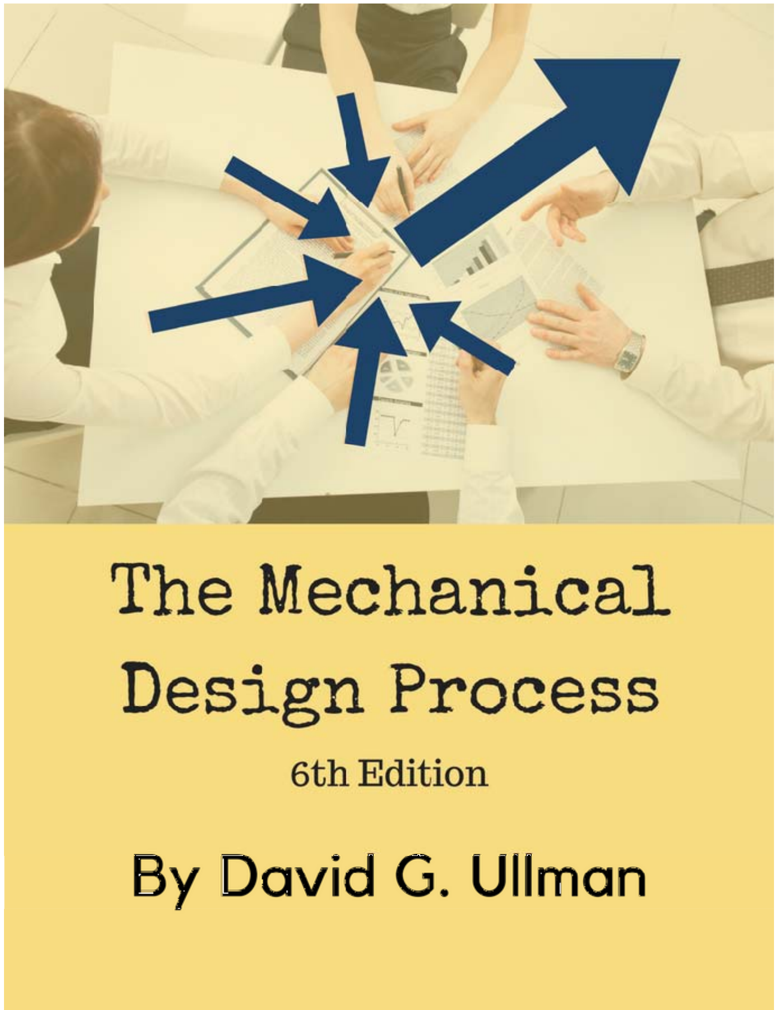


Table 11.1 DFX topics in this book

Best practice	Section	Other best practices included	Goal
Design For Cost (DFC)	11.2	Design for Value (DFV), value analysis	Minimize the cost to manufacture the product
Design For Manufacture (DFM)	11.3		Establish the shape of components to allow for efficient, high-quality manufacture
Design For Assembly (DFA)	11.4		Measure the ease with which a product can be assembled
Design For Reliability (DFR)	11.5	Failure Modes and Effects Analysis (FMEA), fault tree analysis, reliability engineering, design for safety, risk assessment and management	Measure how the quality of a product is maintained over time
Design For Test and Maintenance (DFT and DFM)	11.6		Measure critical performance so it is easy to diagnose problems and design the product so it is easy to repair
Design For Sustainability (DFS)	11.7	Design For Environment (DFE), green design	Measure the effect of the product on the environment throughout its entire life cycle

Figure 11.1

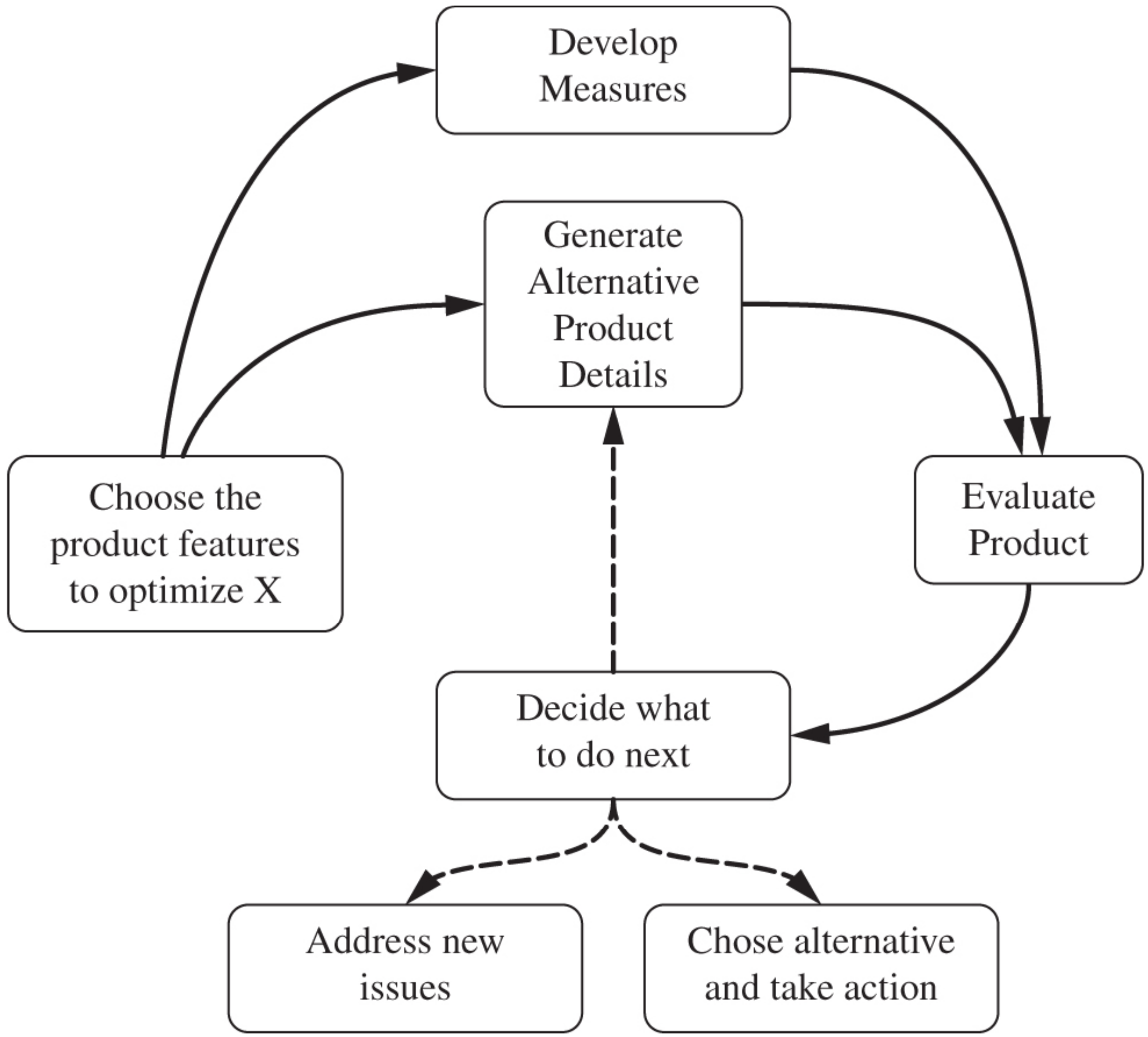

Develop
Measures
Generate
Alternative
Product
Details
Choose the
product features
to optimize X
Evaluate
Product
Decide what
to do next
Address new
issues
Chose alternative
and take action

Figure 11.2

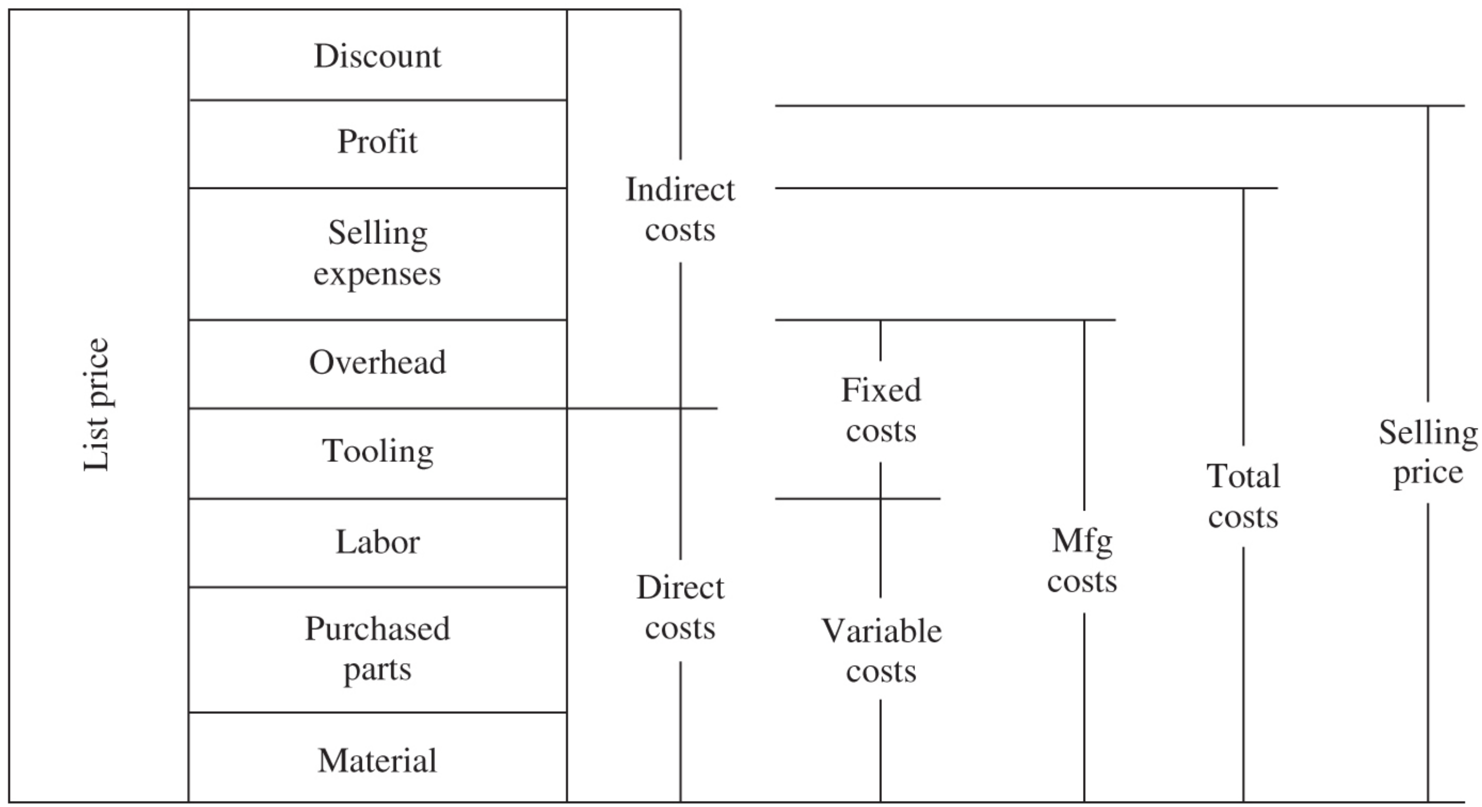

List price
Discount
Profit
Selling expenses
Overhead
Tooling
Labor
Purchased parts
Material
Indirect costs
Direct costs
Fixed costs
Variable costs
Mfg costs
Total costs
Selling price

Figure 11.3

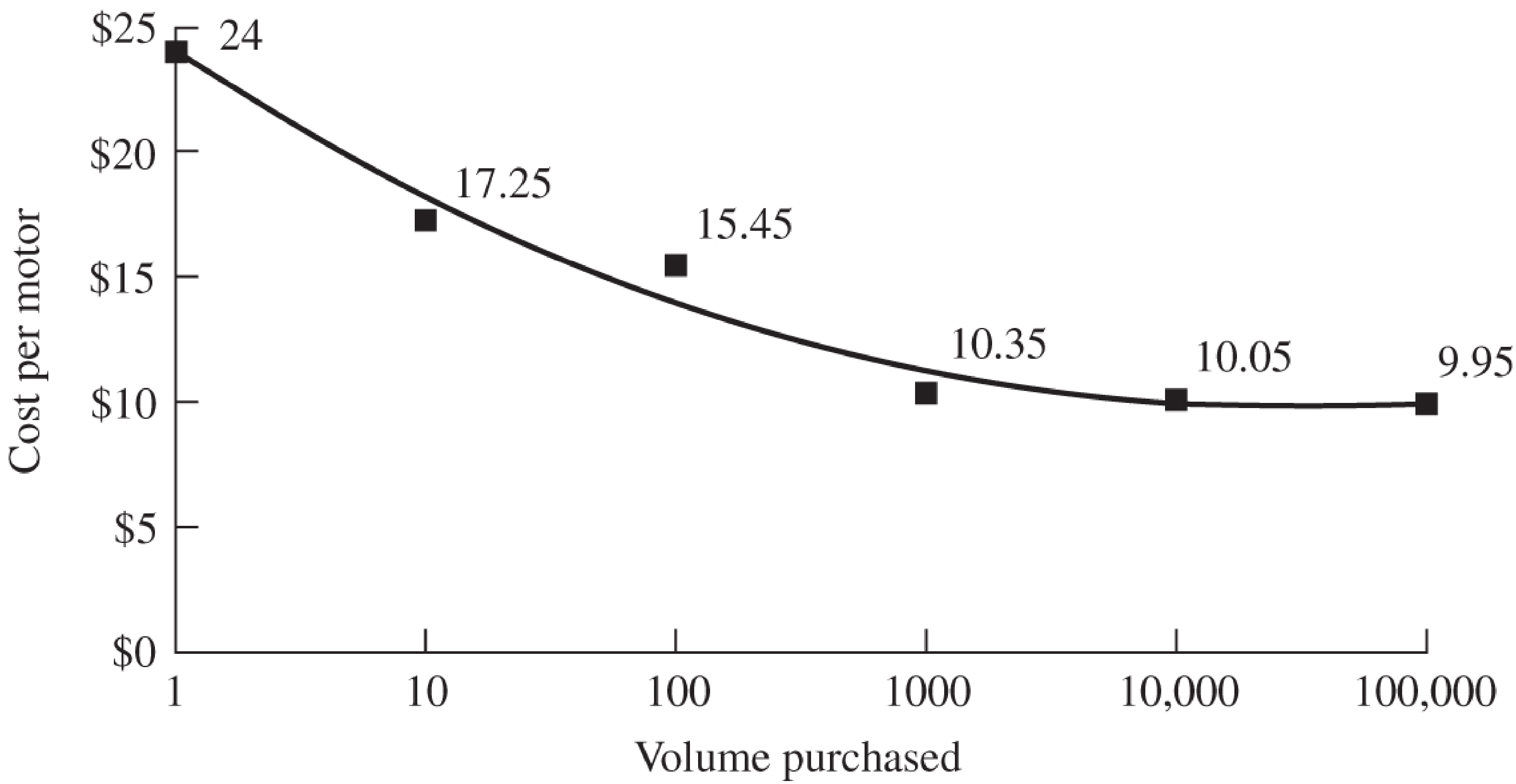

$25
$20
$15
$10
$5
$0
Cost per motor
24
17.25
15.45
10.35
10.05
9.95
1
10
100
1000
10,000
100,000
Volume purchased

Figure 11.4

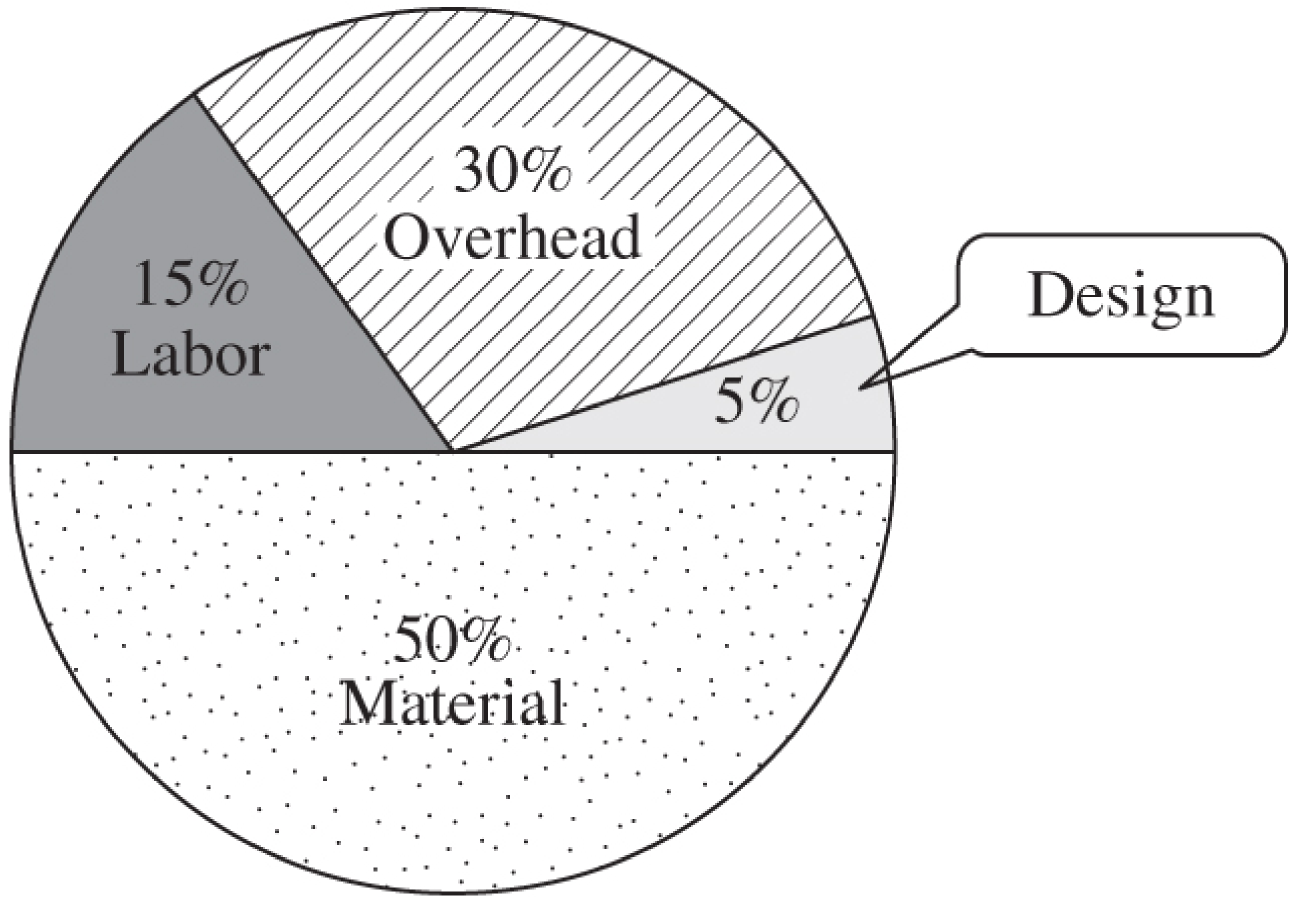


Figure 11.5

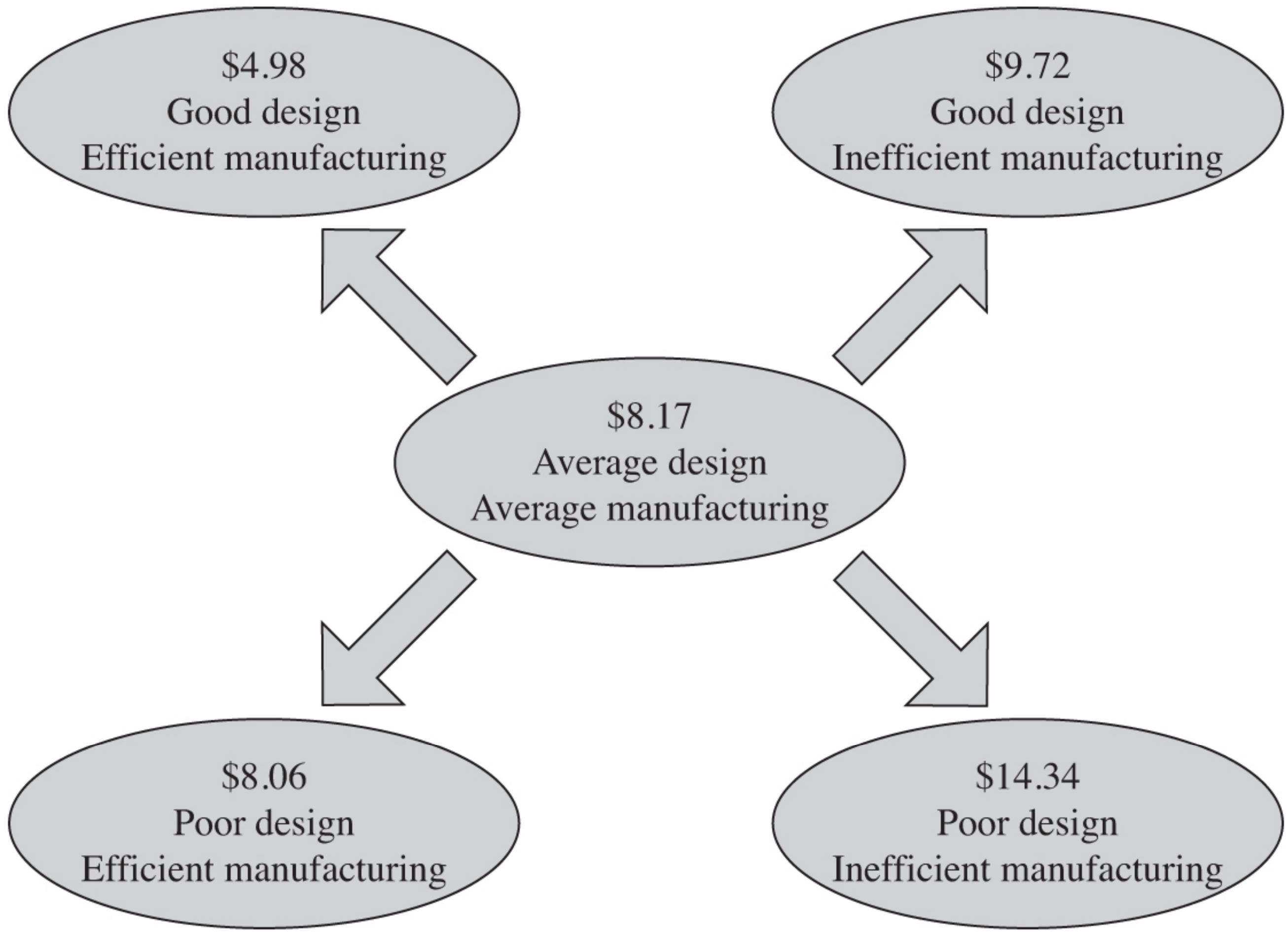

$4.98
Good design
Efficient manufacturing
$9.72
Good design
Inefficient manufacturing
$8.17
Average design
Average manufacturing
$8.06
Poor design
Efficient manufacturing
$14.34
Poor design
Inefficient manufacturing

Figure 11.6

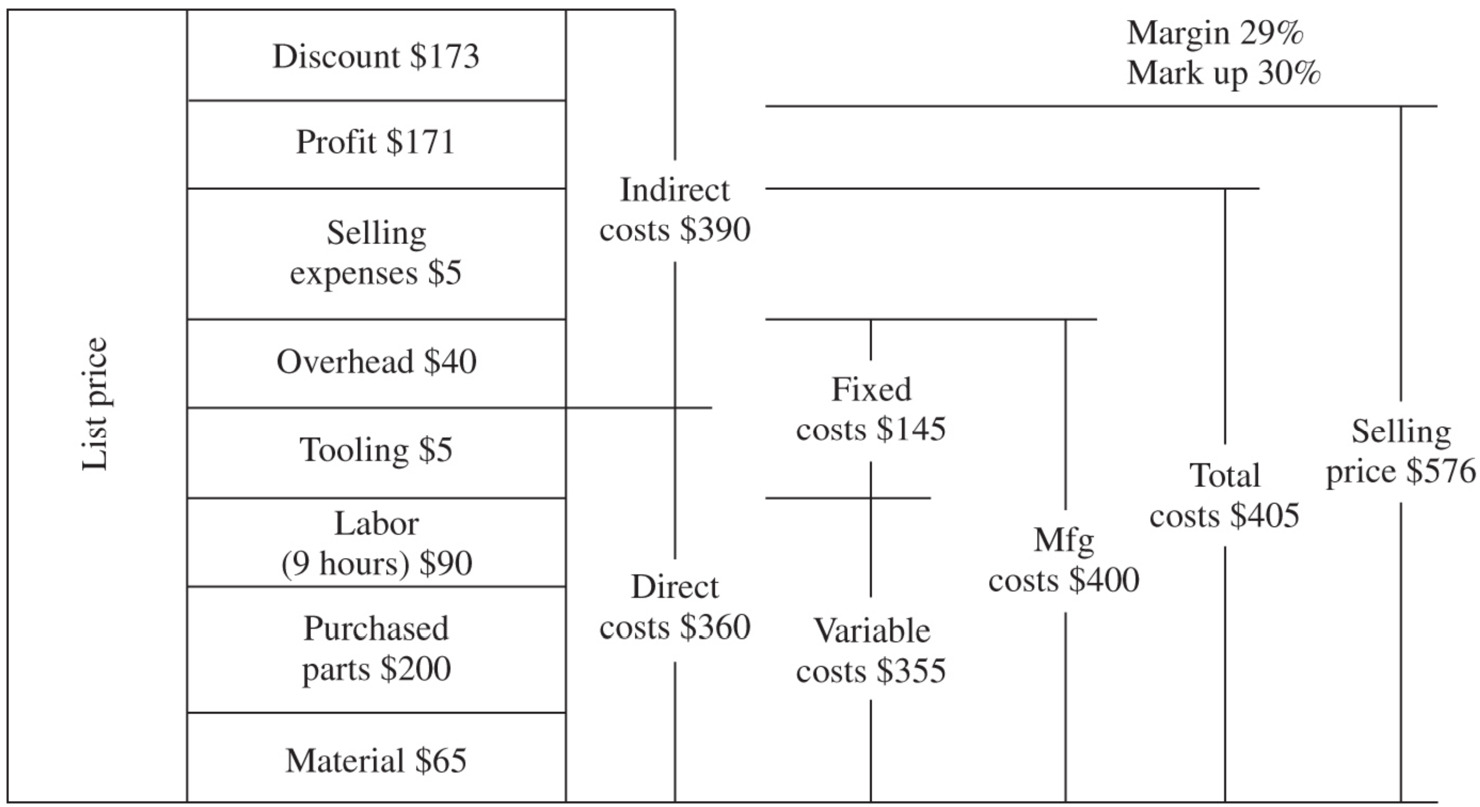
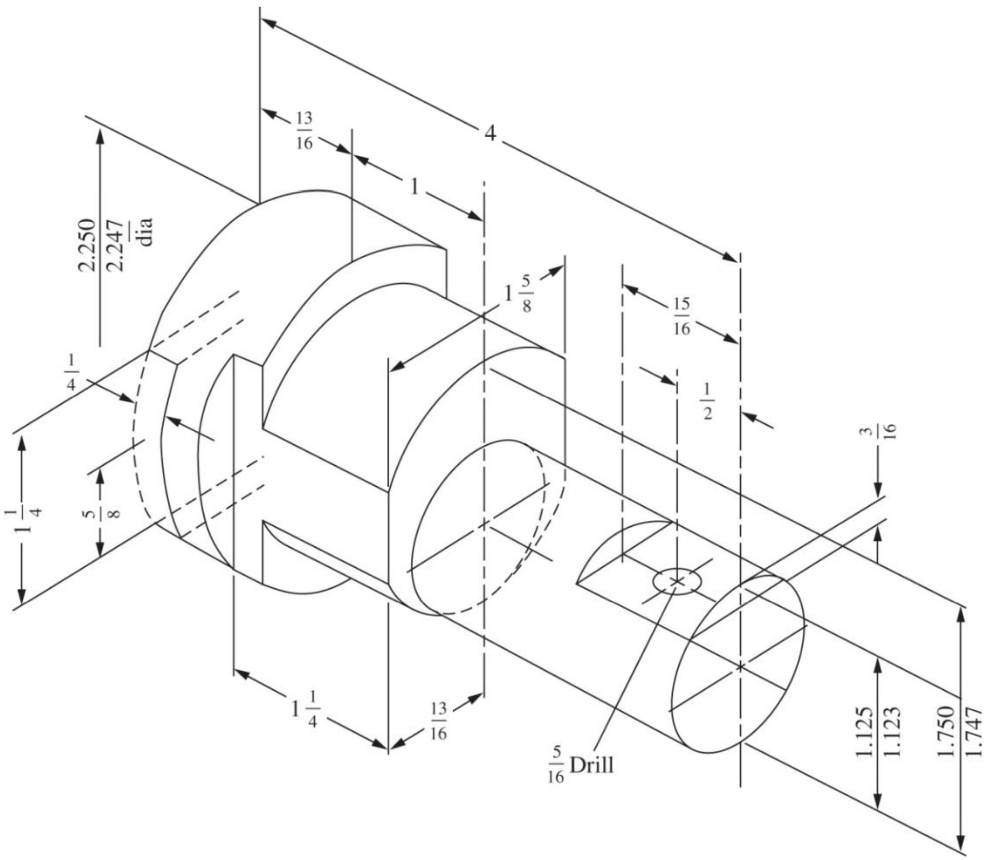

List price
Discount $173
Profit $171
Selling expenses $5
Overhead $40
Tooling $5
Labor (9 hours) $90
Purchased parts $200
Material $65
Indirect costs $390
Direct costs $360
Fixed costs $145
Variable costs $355
Mfg costs $400
Total costs $405
Selling price $576
Margin 29%
Mark up 30%

Figure 11.7

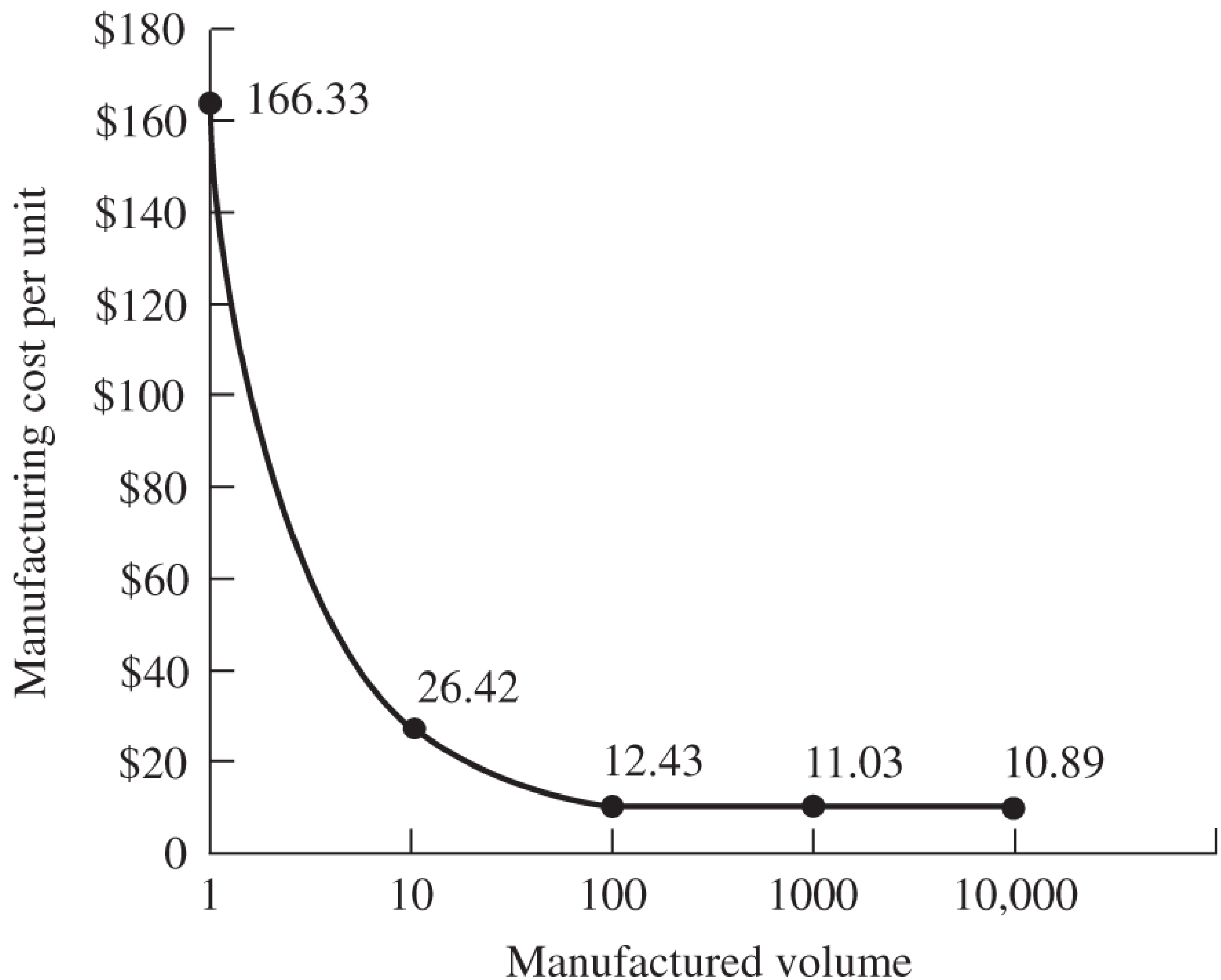


Tolerances 0.00 – 0.99 → ± 0.004
1.00 – 2.79 → ± 0.006
2.80 – 7.49 → ± 0.009
except as noted
All dimensions in inches

Material: steel 1020

Surface finish 32

Figure 11.8

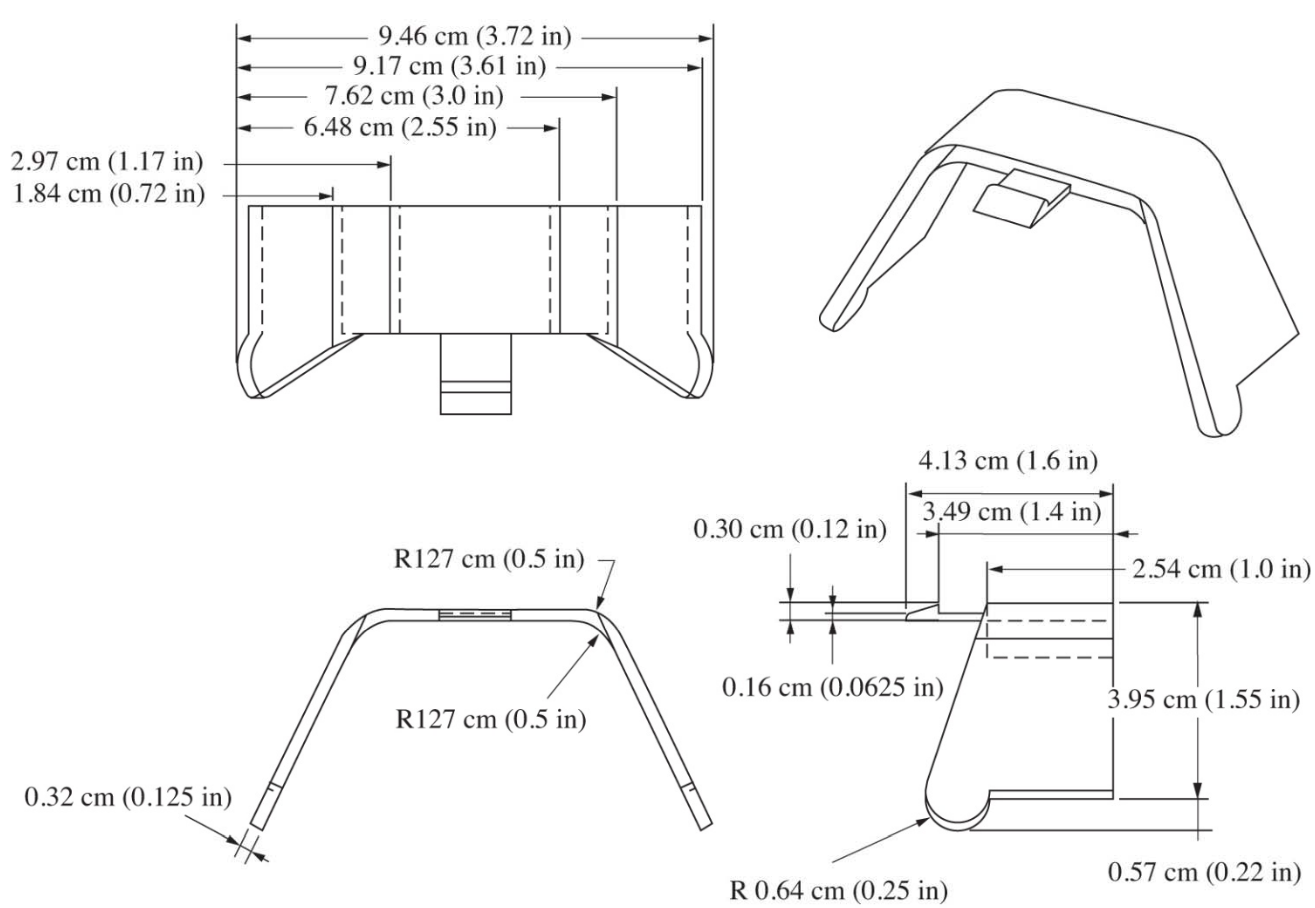


$180
$160
$140
$120
$100
$80
$60
$40
$20
0
166.33
26.42
12.43
11.03
10.89
1
10
100
1000
10,000
Manufacturing cost per unit
Manufactured volume

Table 11.2 Effect of tolerance, finish, and material on cost

Control parameters		
Tolerance	**Surface finish**	**Manufacturing cost**
1. Fine	Intermediate	$11.03
2. Nominal	Intermediate	$8.83
3. Rough	Intermediate	$7.36
4. Fine	Polished	$14.85
5. Fine	As turned	$8.17
6. High-carbon steel		$22.45

Note: For 1000 units.



Brad Tittle Oregon State Univ. December 28, 1990	CLIP	Tol: +– 0.01 cm Approved: [illegible]

Figure 11.10

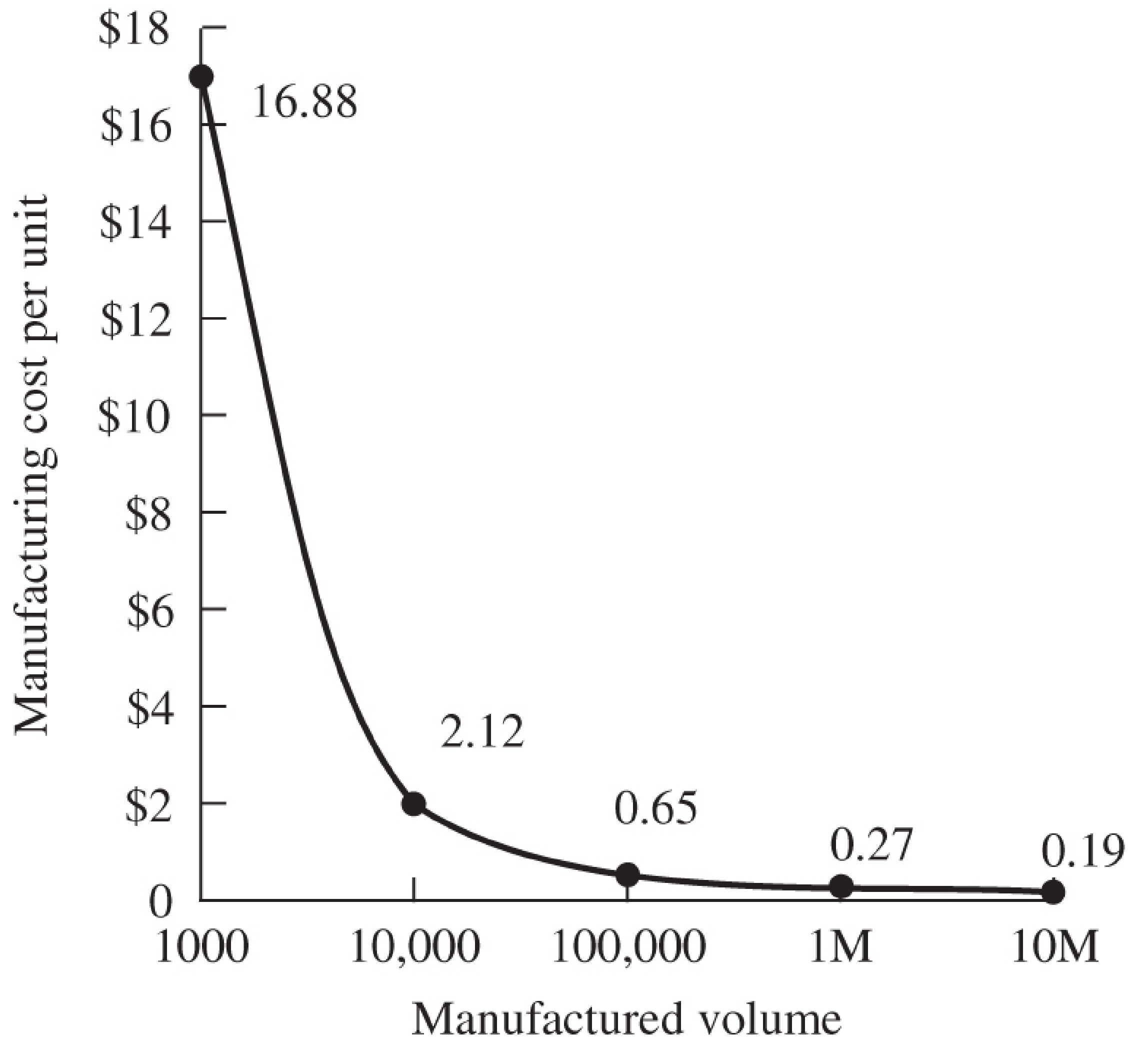

$18
$16
$14
$12
$10
$8
$6
$4
$2
0
16.88
2.12
0.65
0.27
0.19
1000
10,000
100,000
1M
10M
Manufacturing cost per unit
Manufactured volume

Figure 11.11

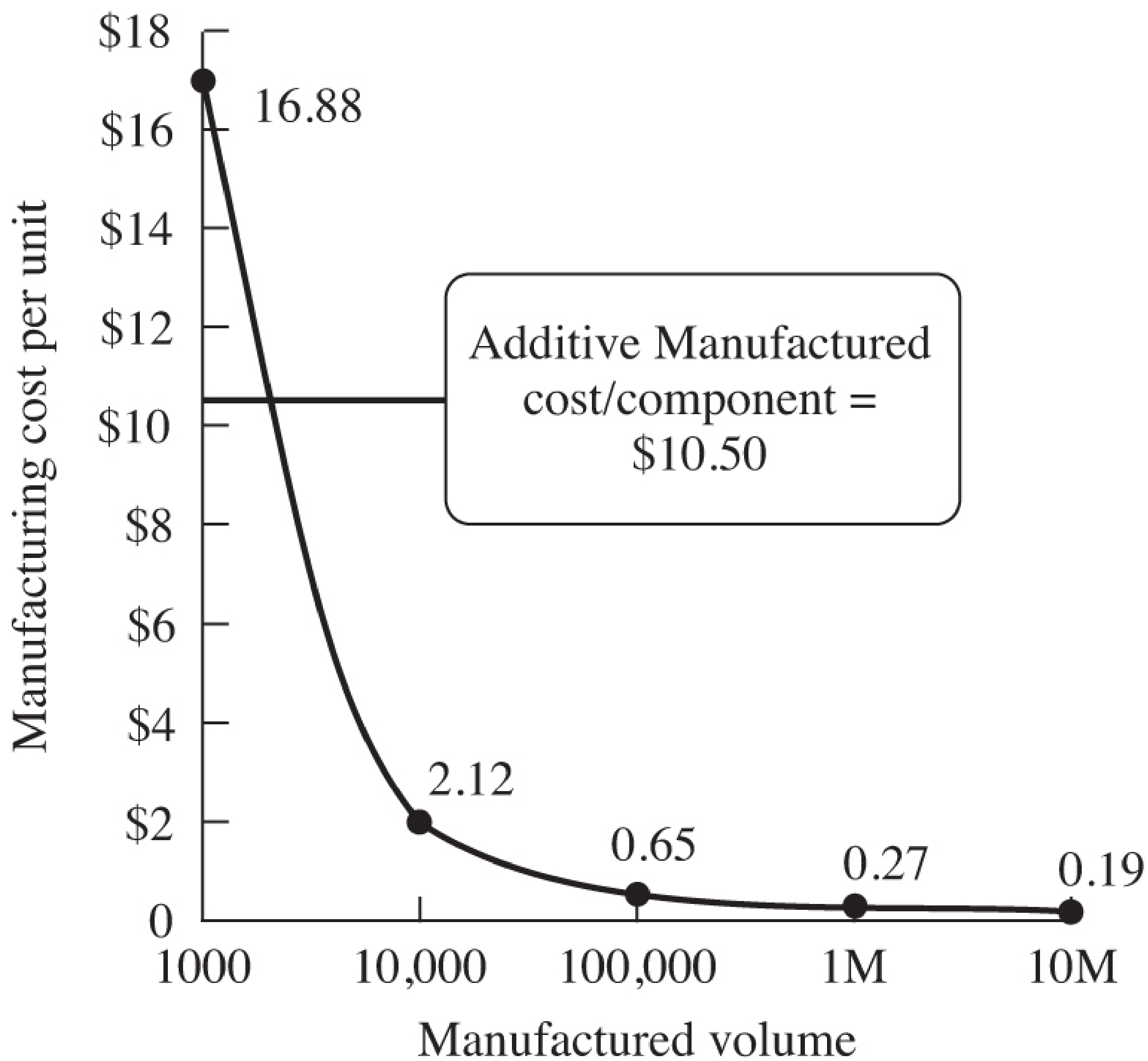

$18
$16
$14
$12
$10
$8
$6
$4
$2
0
16.88
2.12
0.65
0.27
0.19
Additive Manufactured
cost/component =
$10.50
Manufacturing cost per unit
1000
10,000
100,000
1M
10M
Manufactured volume

Figure 11.12

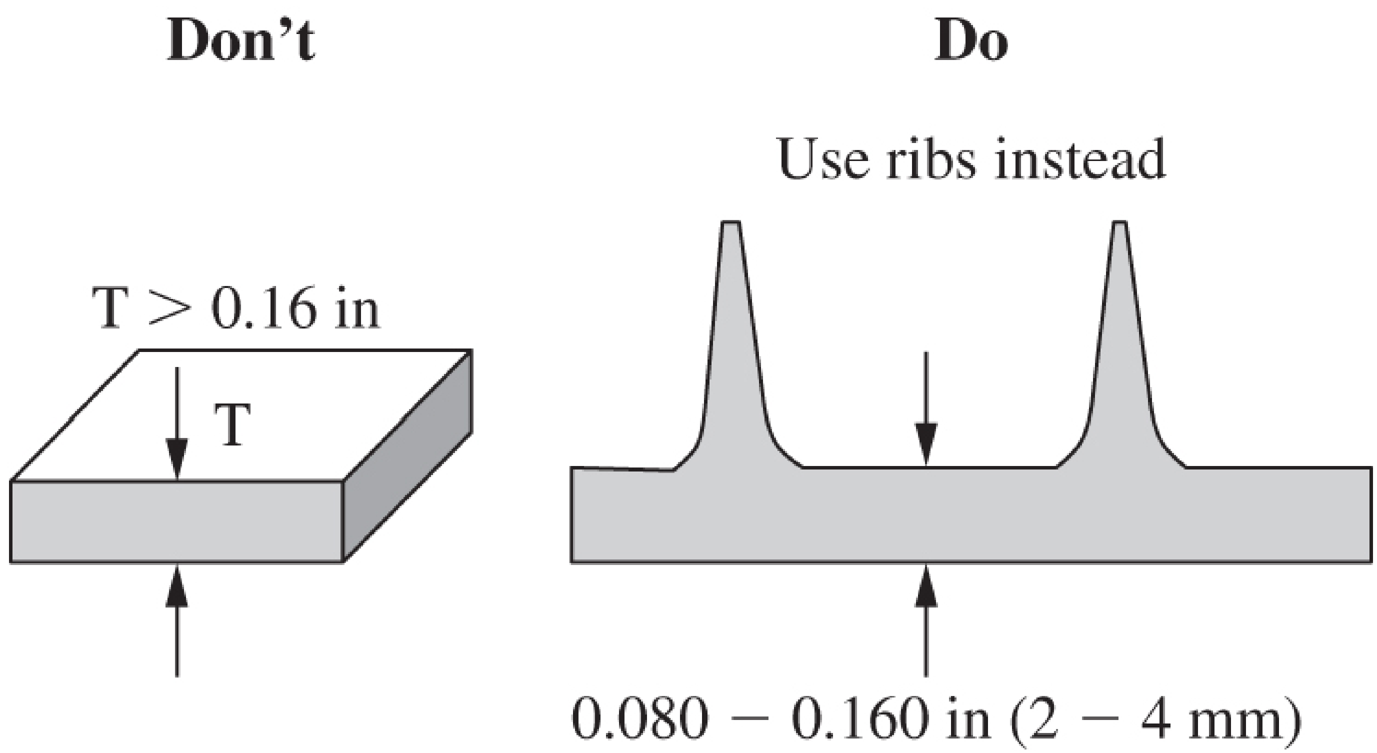


Figure 11.13

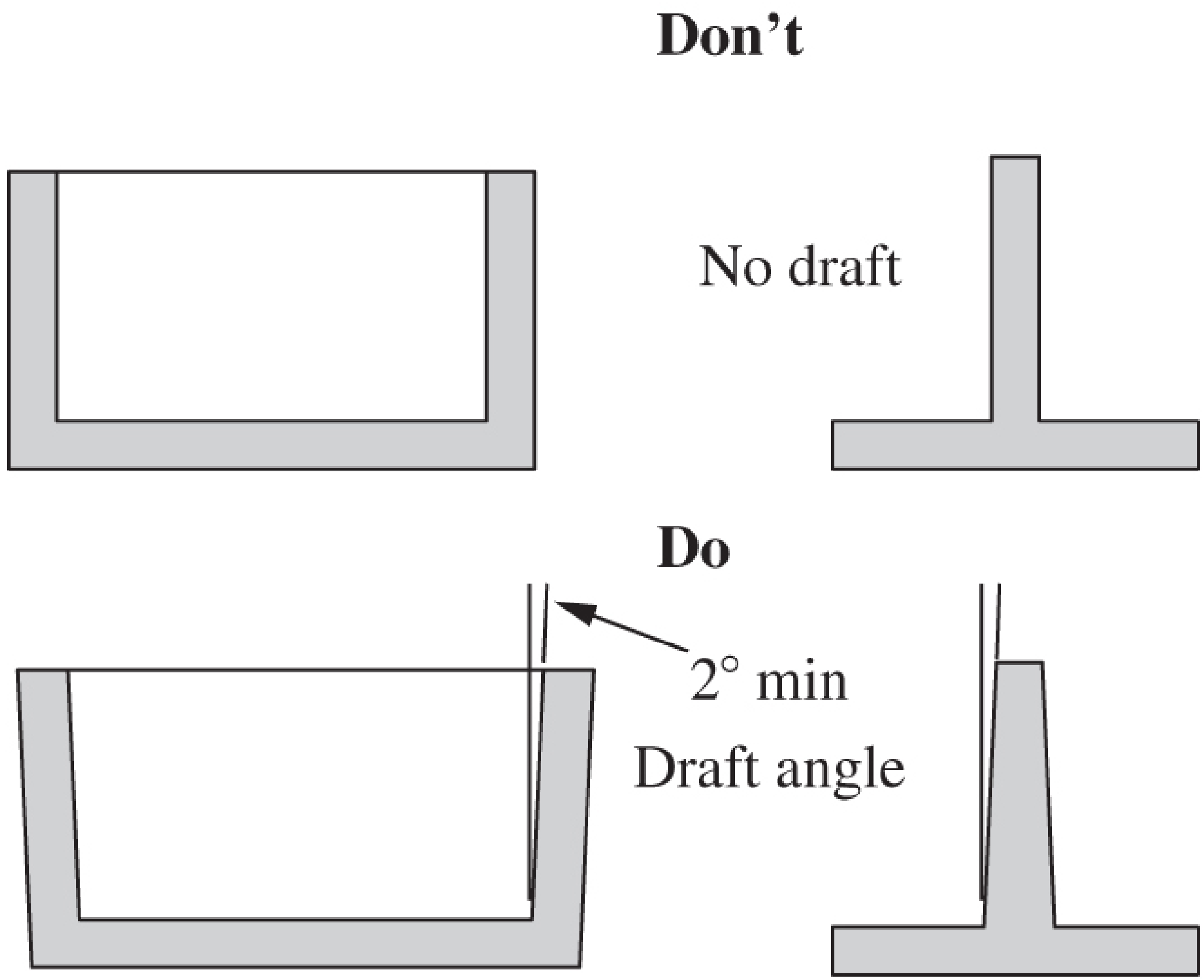
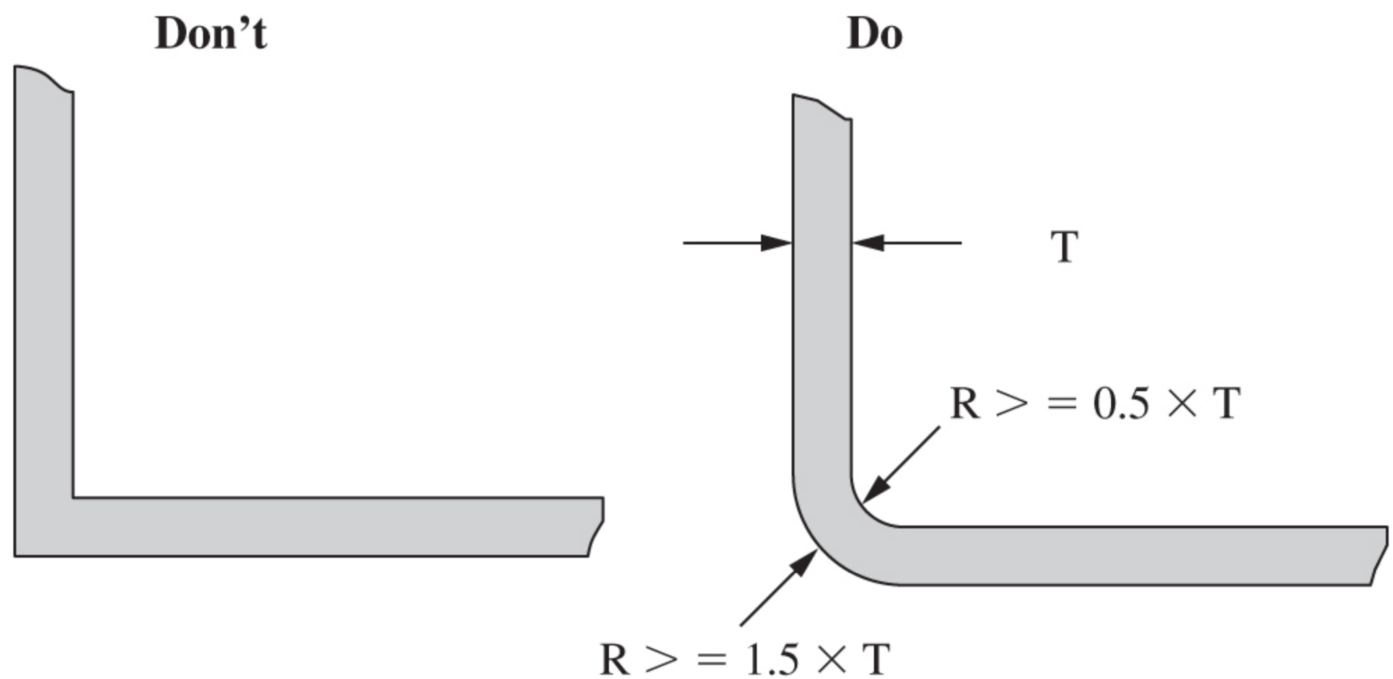


Figure 11.14



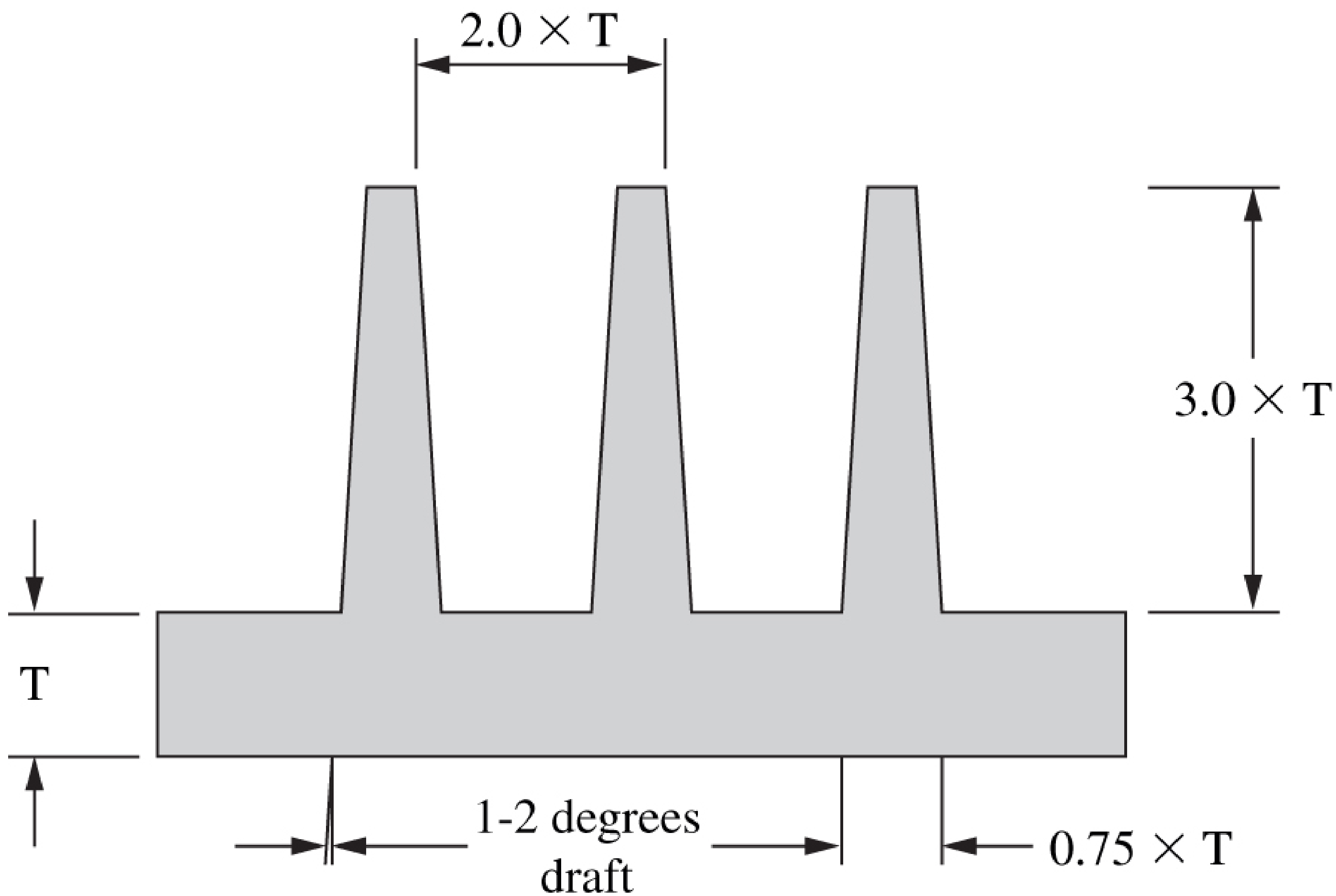

2.0 × T
3.0 × T
T
1-2 degrees
draft
0.75 × T

Figure 11.16

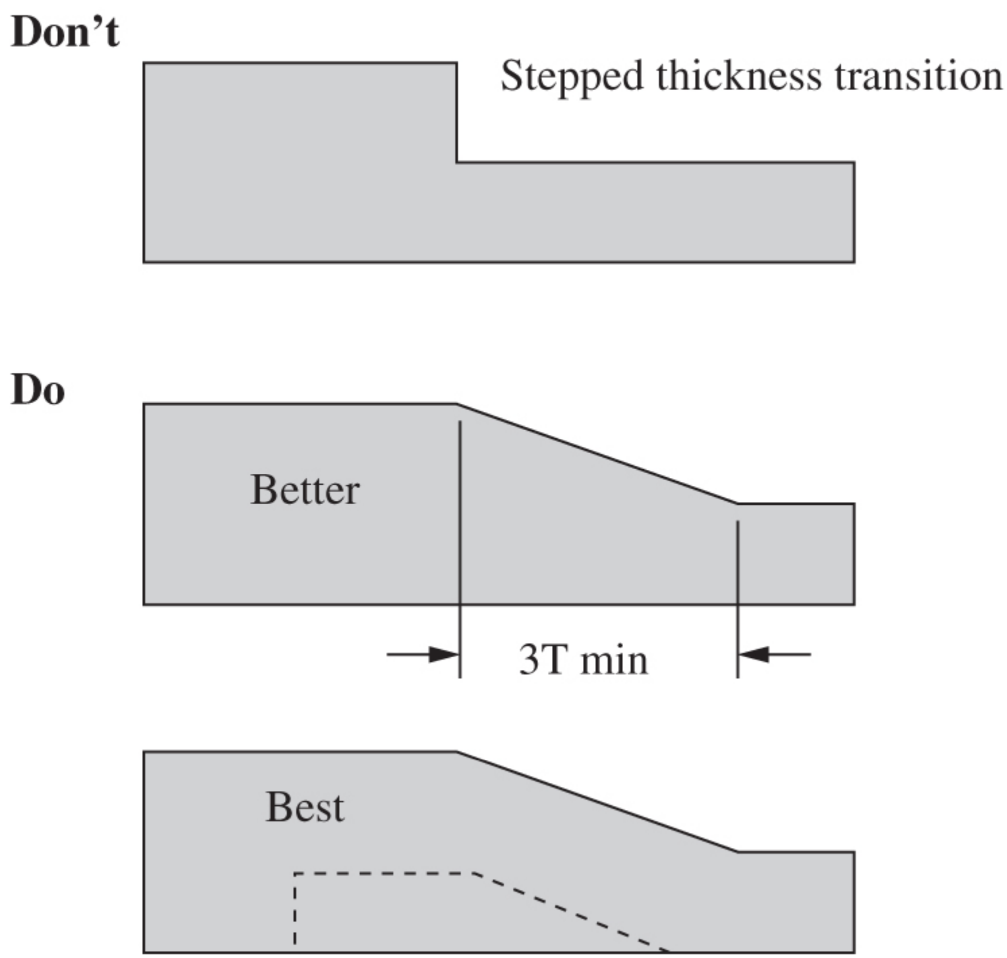


Figure 11.17

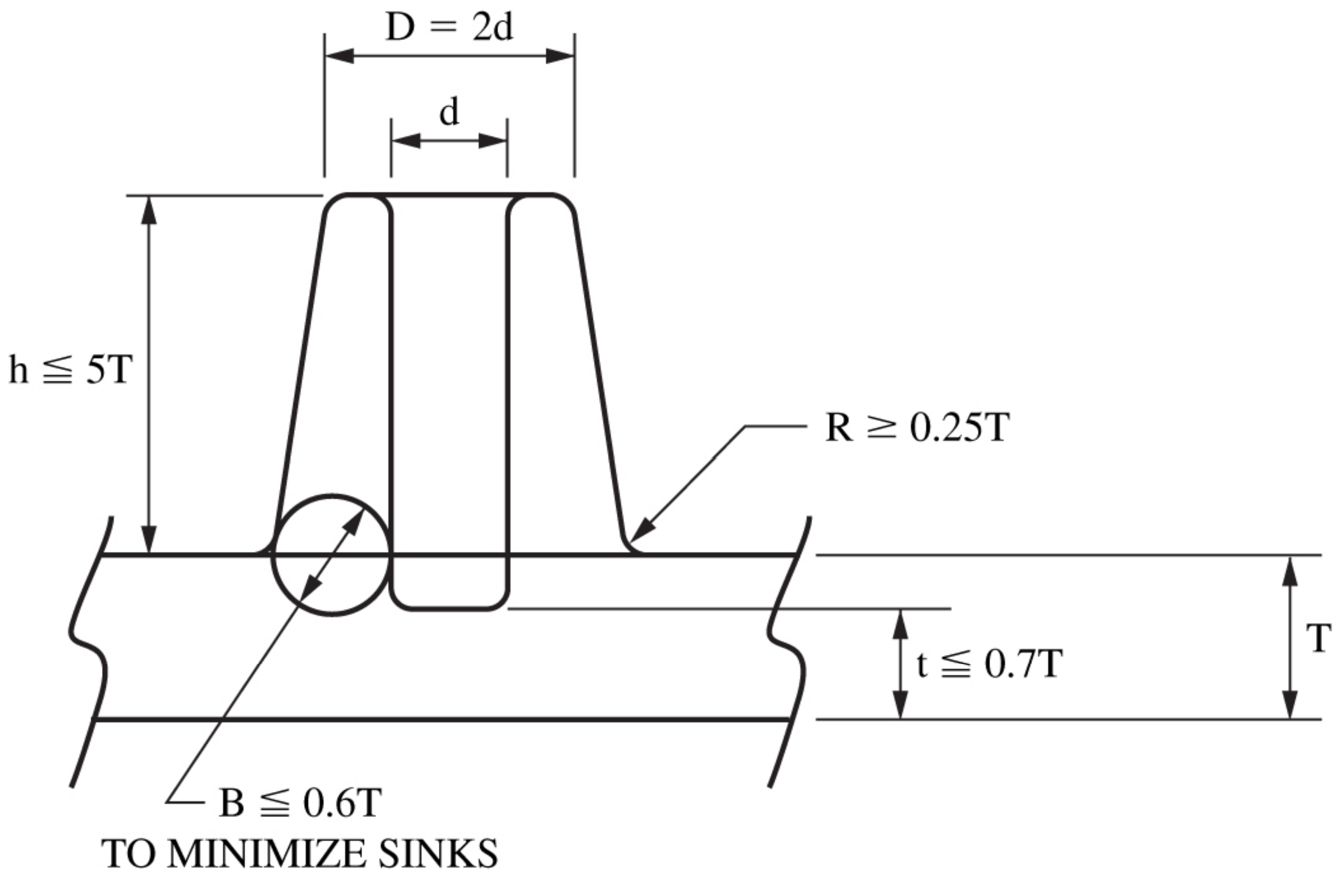


Figure 11.18

T

(DFA) Design For Assembly

Individual Assembly Evaluation for: Irwin pre 2014 Clamp | **Organization Name:** Example

	OVERALL ASSEMBLY		
1	Overall part count minimized	Very good	6
2	Minimum use of separate fasteners	Outstanding	8
3	Base part with fixturing features (locating surfaces and holes)	Outstanding	8
4	Repositioning required during assembly sequence	> = 2 Position	4
5	Assembly sequence efficiency	Very good	6
	PART RETRIEVAL		
6	Characteristics that complicate handling (tangling, nesting, flexibility) have been avoided	Most parts	6
7	Parts have been designed for a specific feed approach (bulk, strip, magazine)	Few part	2
	PART HANDLING		
8	Parts with end-to-end symmetry	Some parts	4
9	Parts with symmetry about the axis of insertion	Some parts	4
10	Where symmetry is not possible, parts are clearly asymmetric	Most parts	6
	PART MATING		
11	Straight-line motions of assembly	Some parts	4
12	Chamfers and features that facilitate insertion and self-alignment	Some parts	4
13	Maximum part accessibility	All parts	8
Note:	Only for comparison of alternate designs of same assembly	TOTAL SCORE	70

Team member: Fred Smith	Team member:Jason Peterson	Prepared by: Fred Smith	
Team member: Omhi Ubolu	Team member:	Checked by: Prof Chan	Approved by:

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 — Form # 21.0

Figure 11.19

David Ullman

Figure 11.20

David Ullman

Figure 11.21

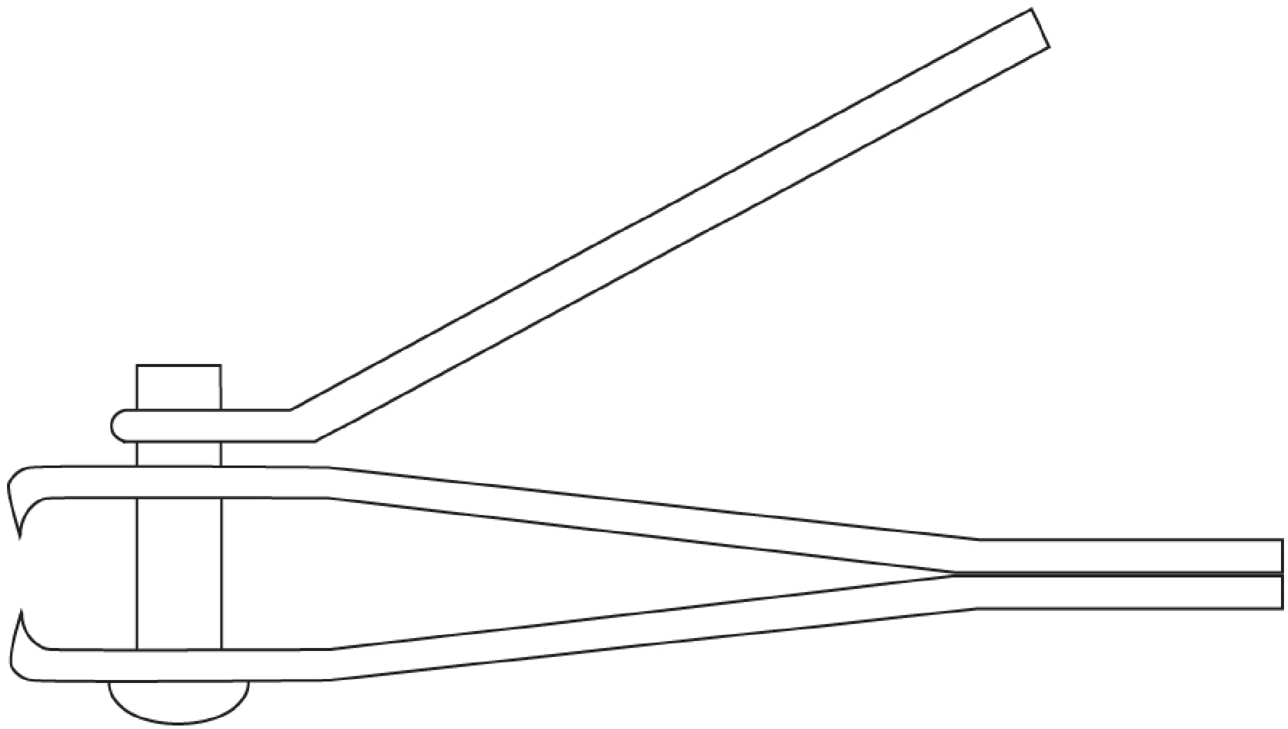


Figure 11.22

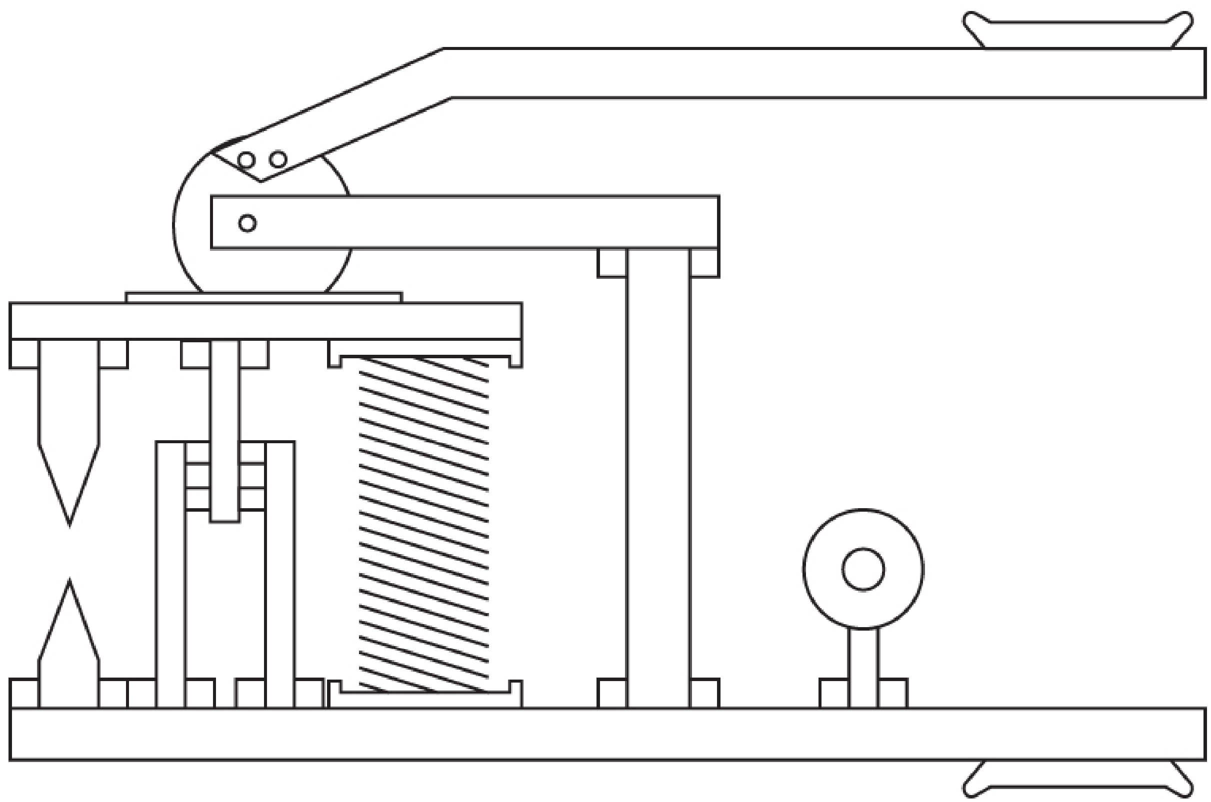


Figure 11.23

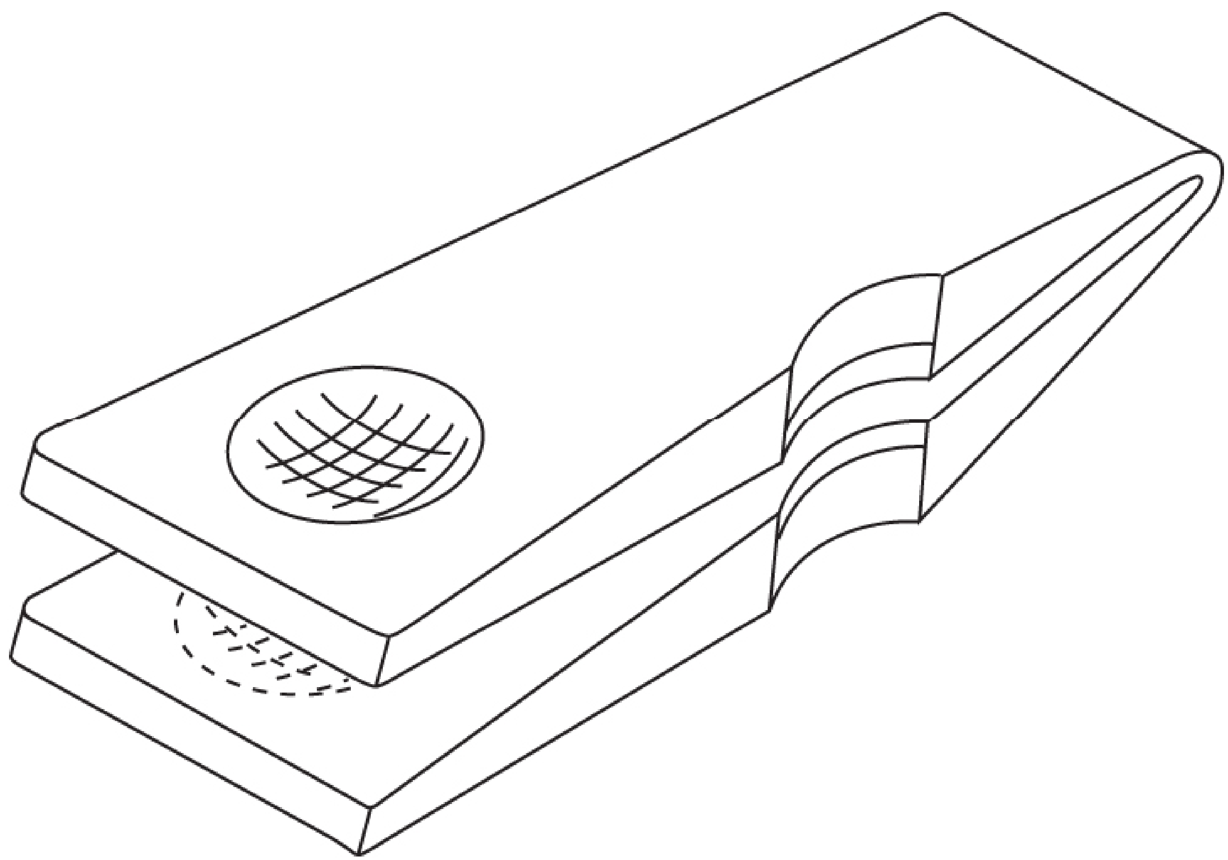


Figure 11.24

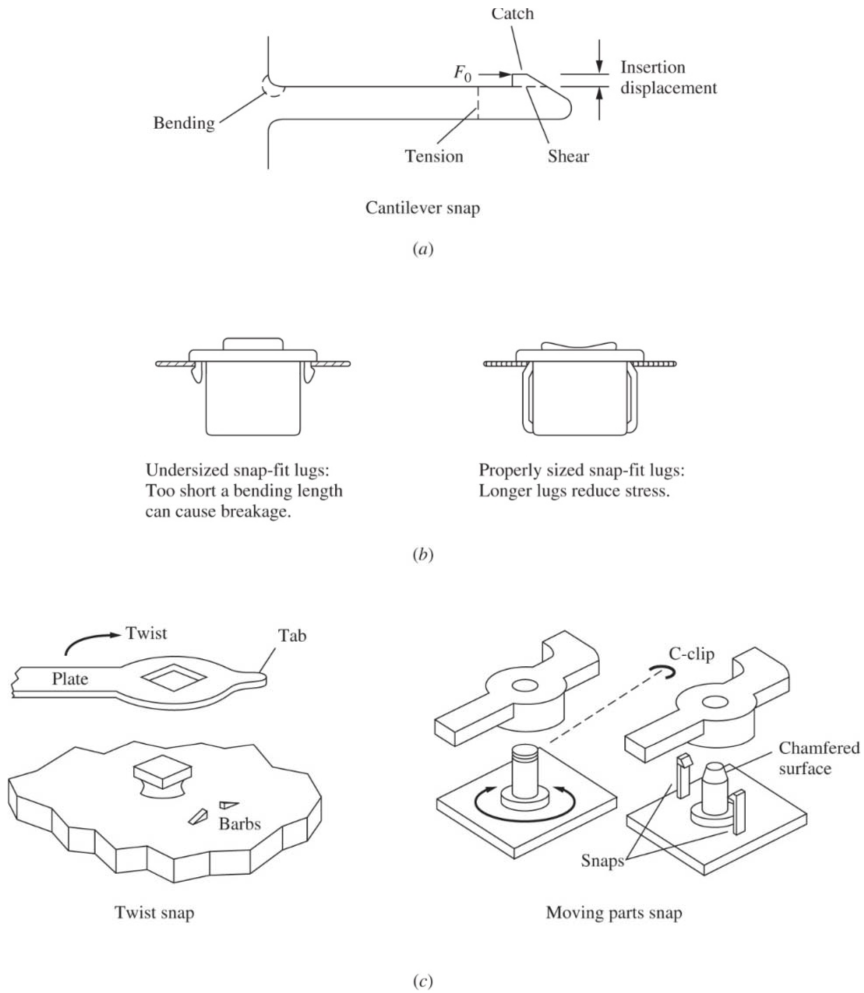
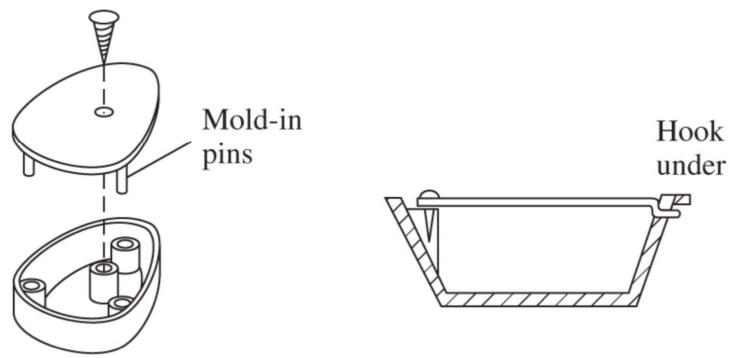
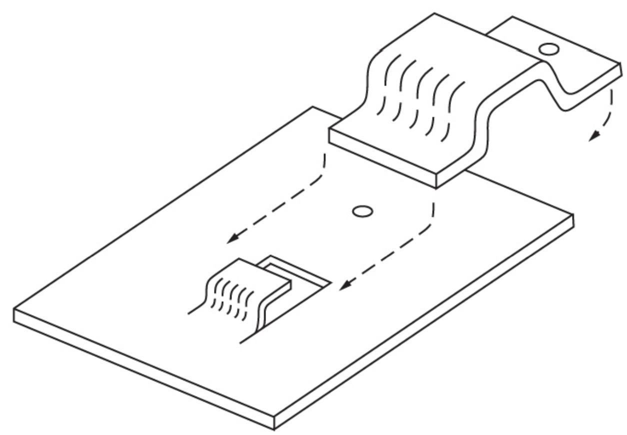

Catch
F_0
Insertion displacement
Bending
Tension
Shear
Cantilever snap
(a)
Undersized snap-fit lugs: Too short a bending length can cause breakage.
Properly sized snap-fit lugs: Longer lugs reduce stress.
(b)
Twist
Tab
Plate
Barbs
Twist snap
C-clip
Chamfered surface
Snaps
Moving parts snap
(c)

Figure 11.25



(*a*)



(*b*)

Figure 11.26

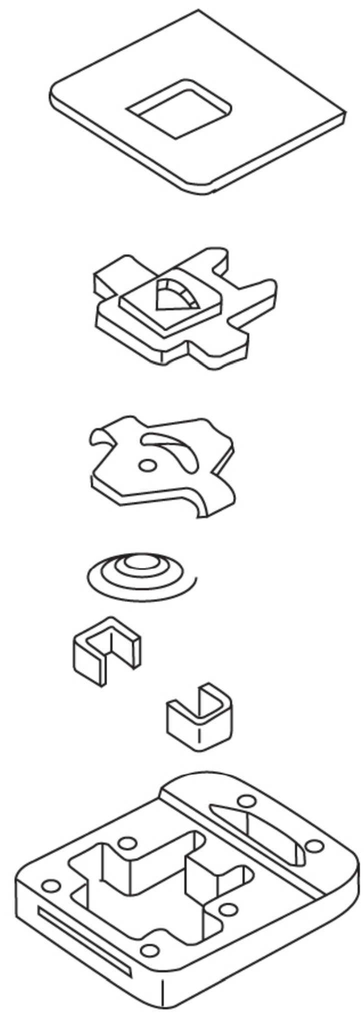


Figure 11.27

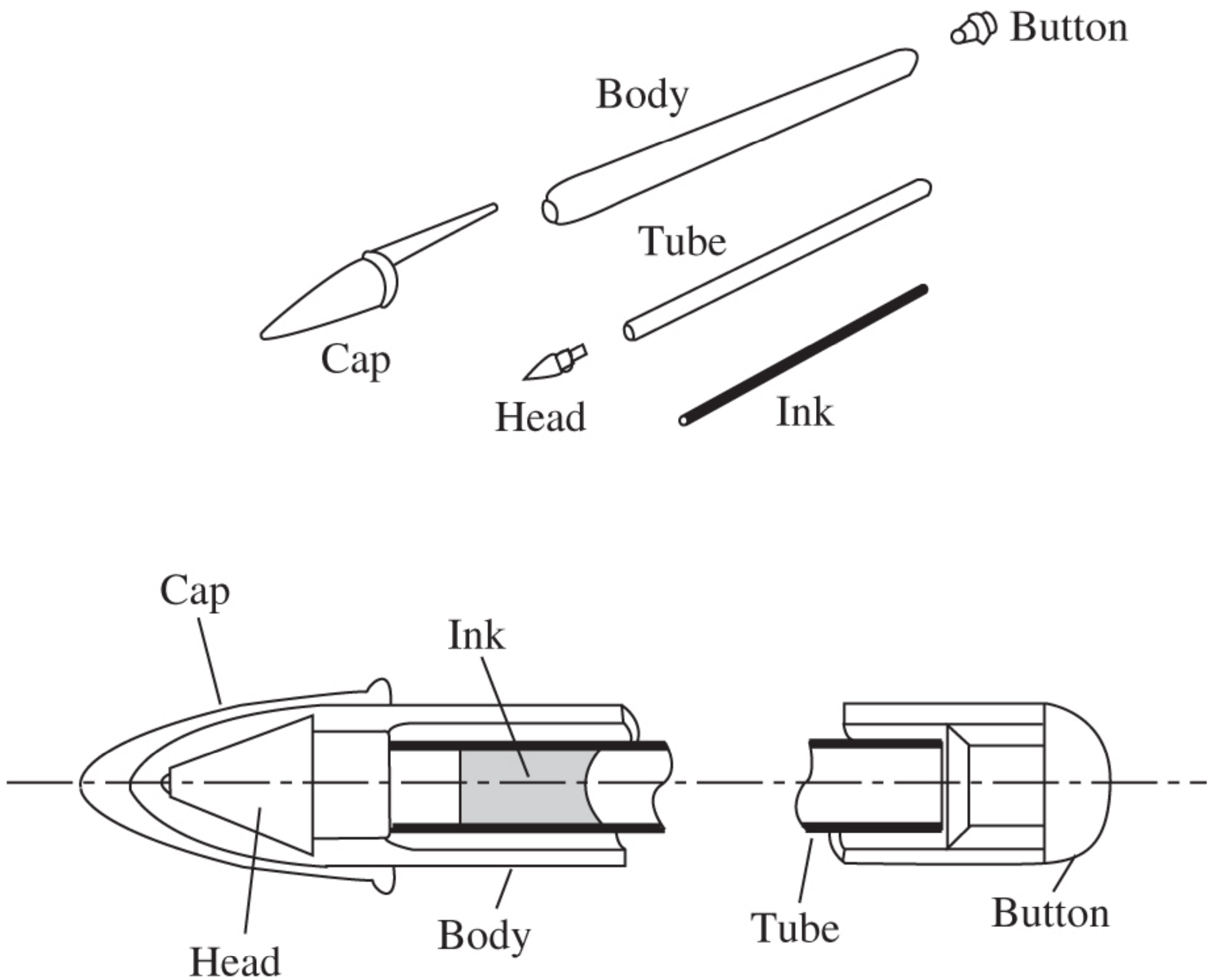


Figure 11.28

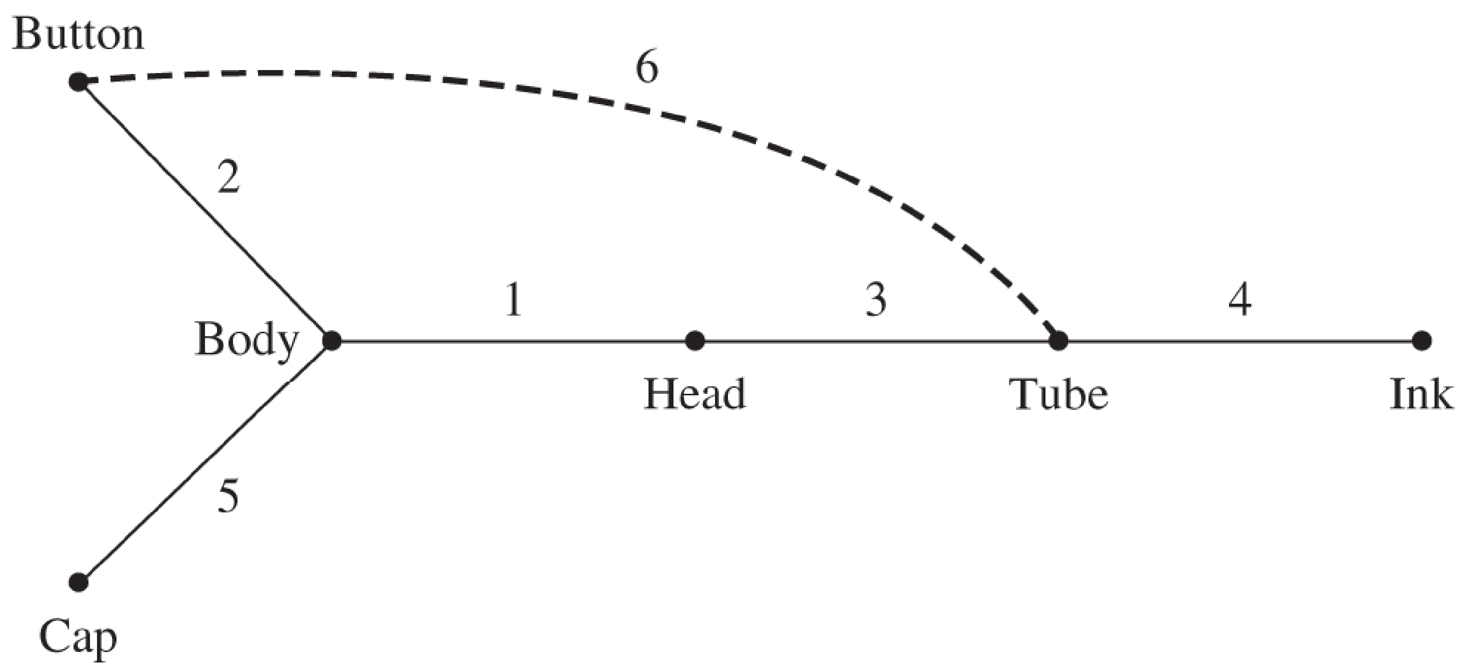


Figure 11.29

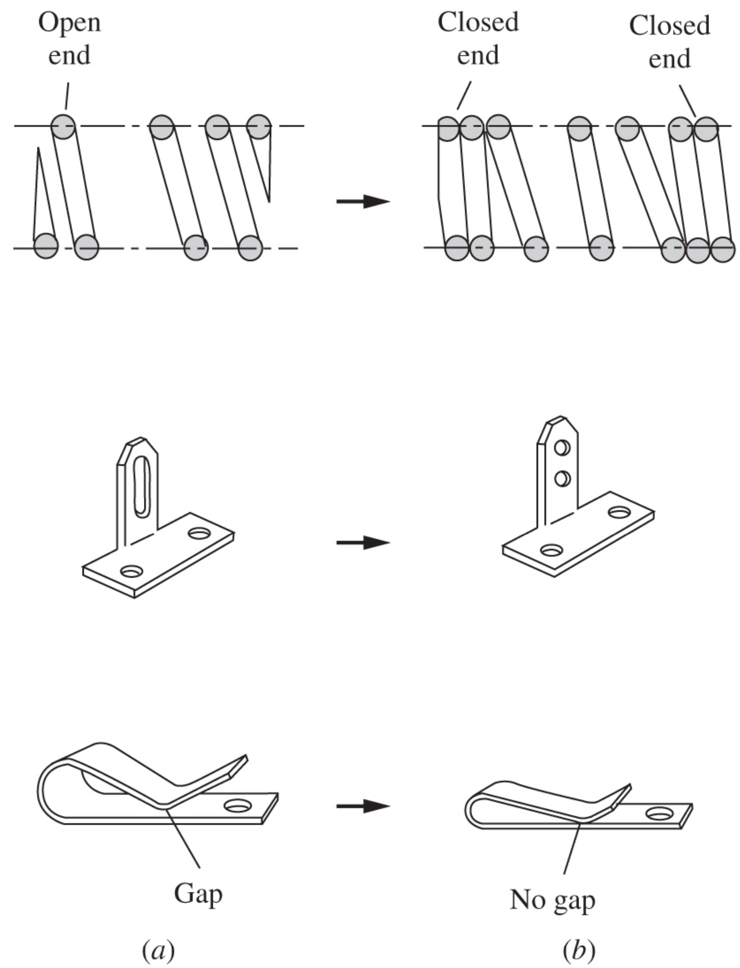


Figure 11.30

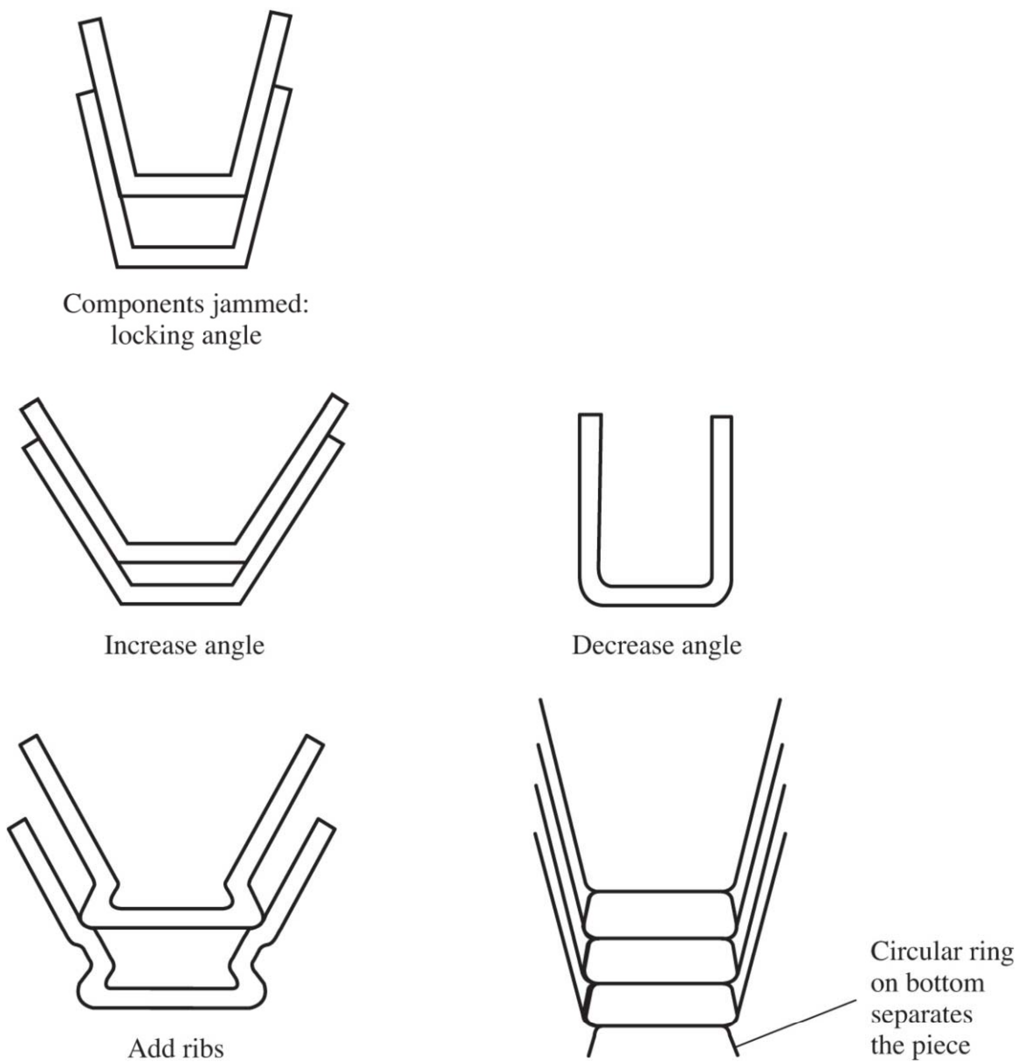

Components jammed:
locking angle
Increase angle
Decrease angle
Add ribs
Circular ring
on bottom
separates
the piece

Figure 11.31

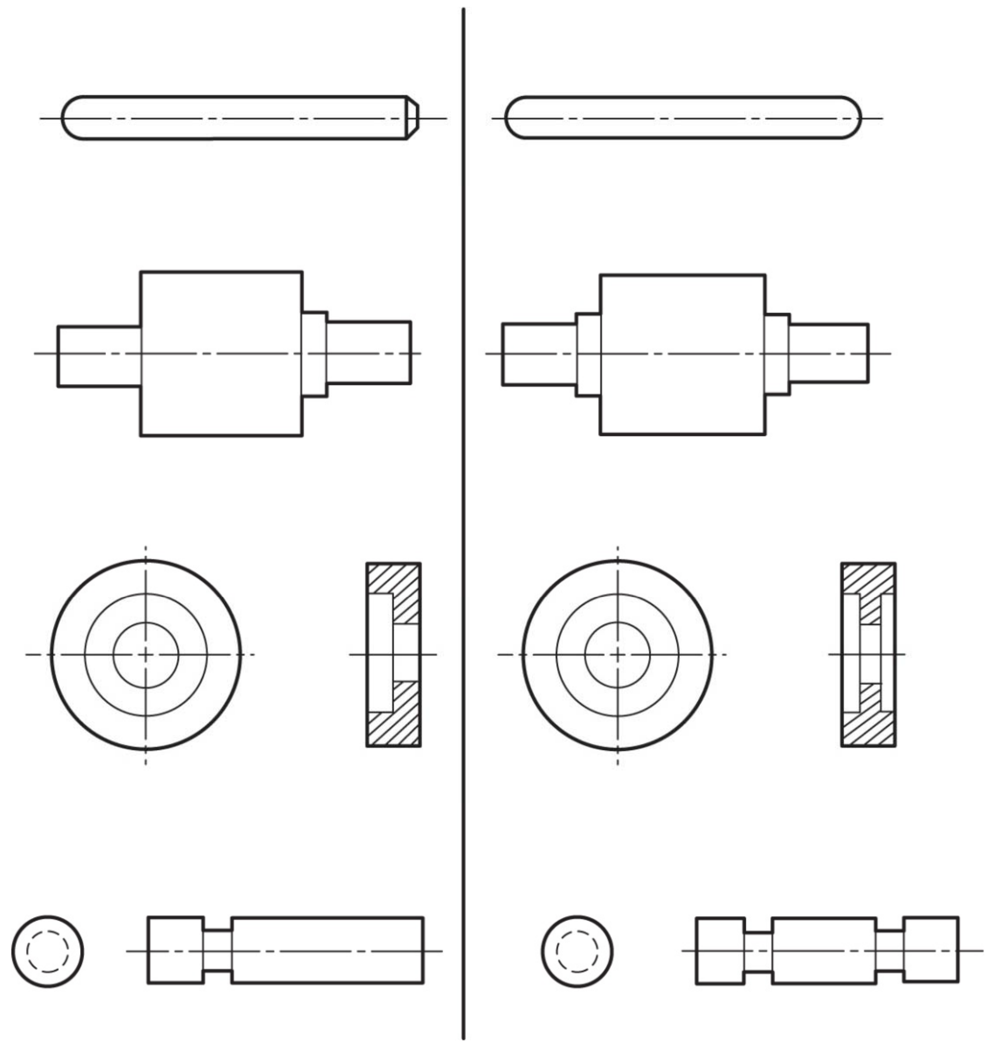
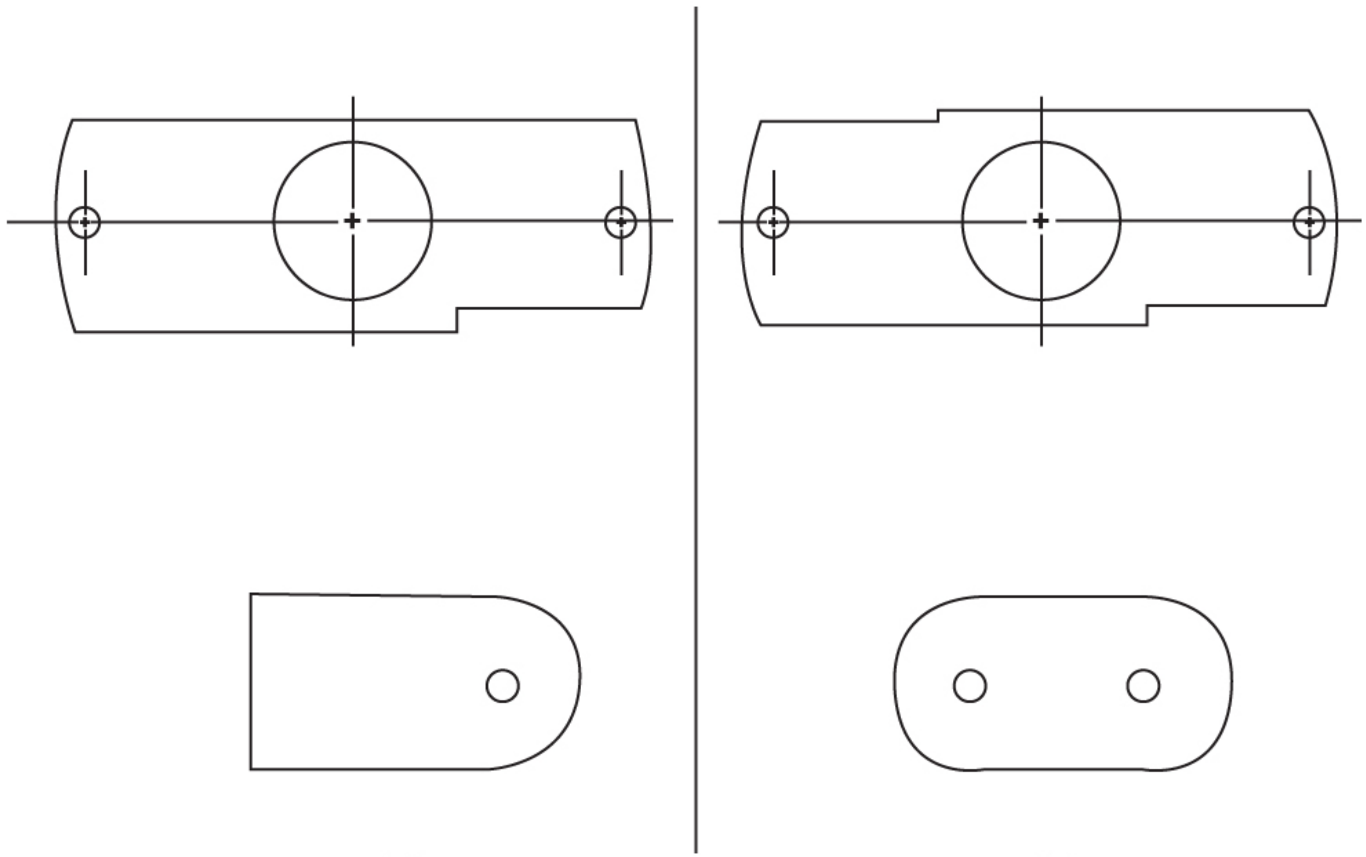
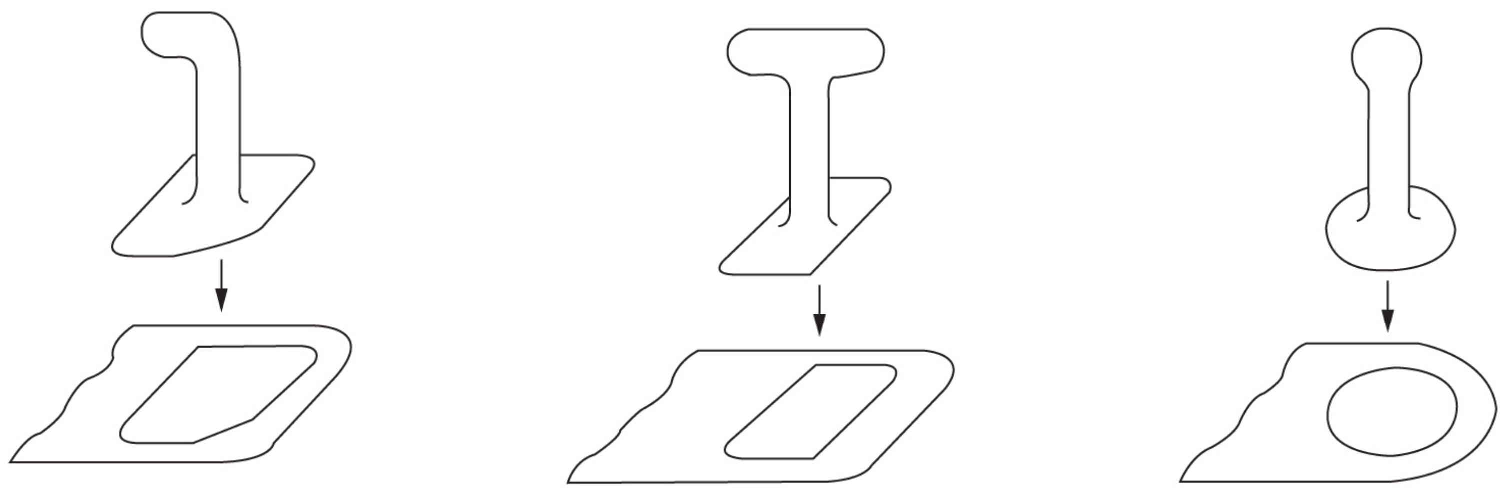


Figure 11.32



(*a*) (*b*)

Figure 11.33



(*a*) The assembly fits together only one way

(*b*) Two possible directions of insertion

(*c*) 360° rotational symmetry

Figure 11.34

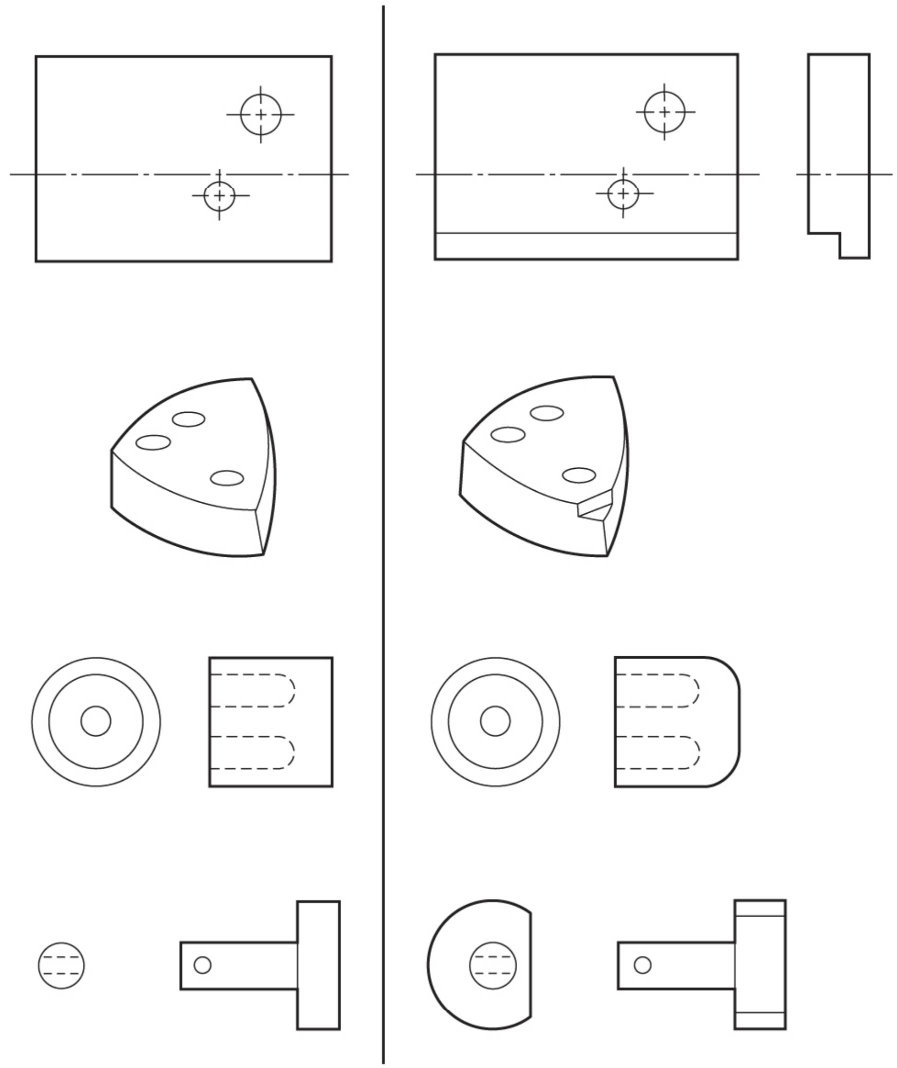


Figure 11.35

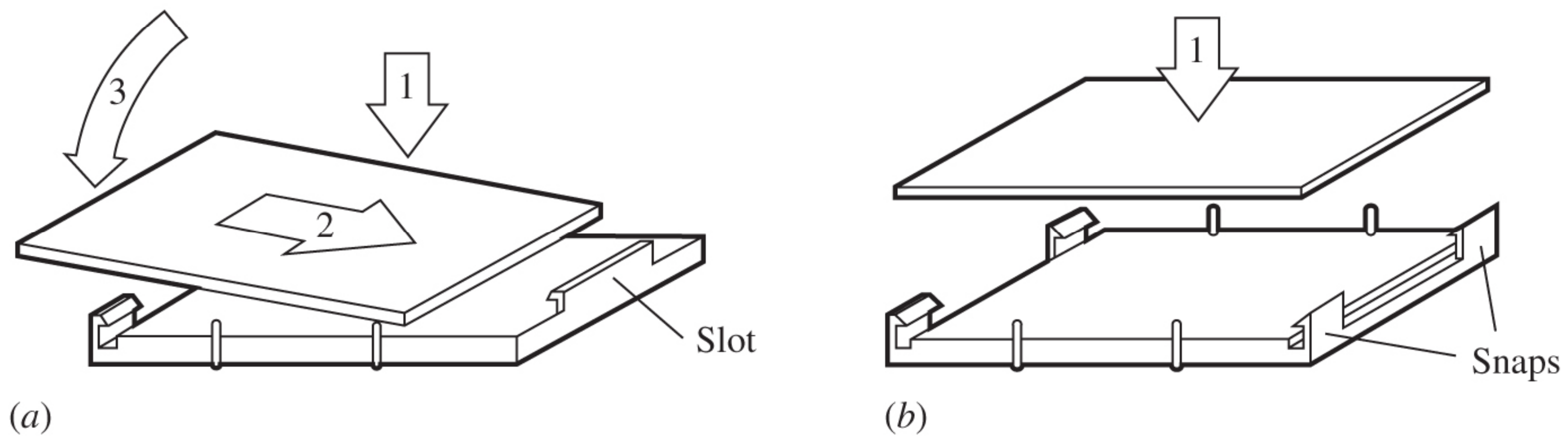


Figure 11.36

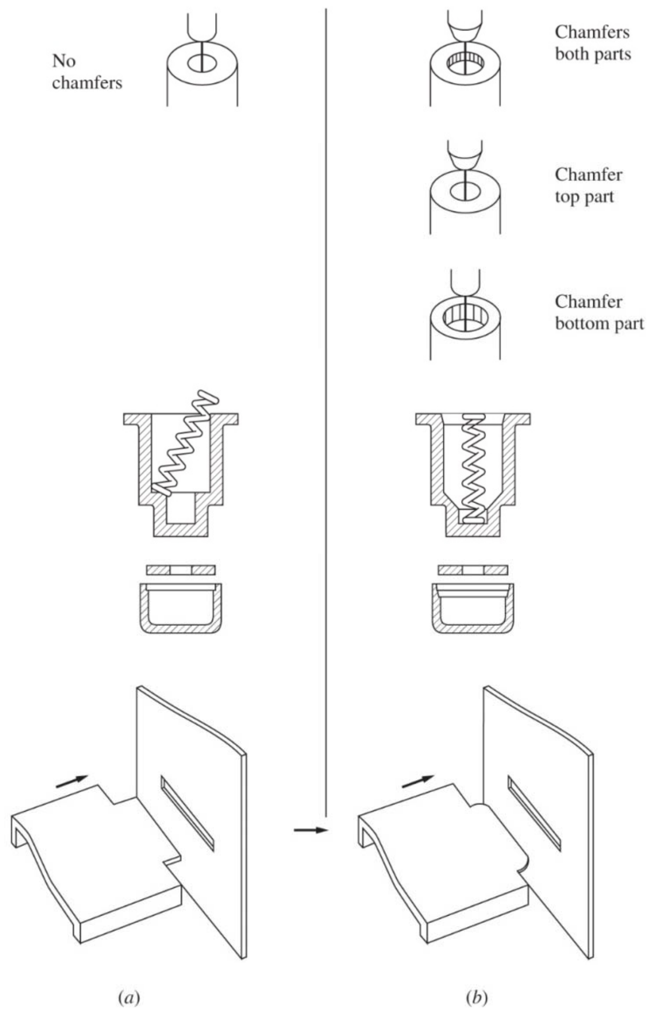

No
chamfers
Chamfers
both parts
Chamfer
top part
Chamfer
bottom part
(a)
(b)

Figure 11.37

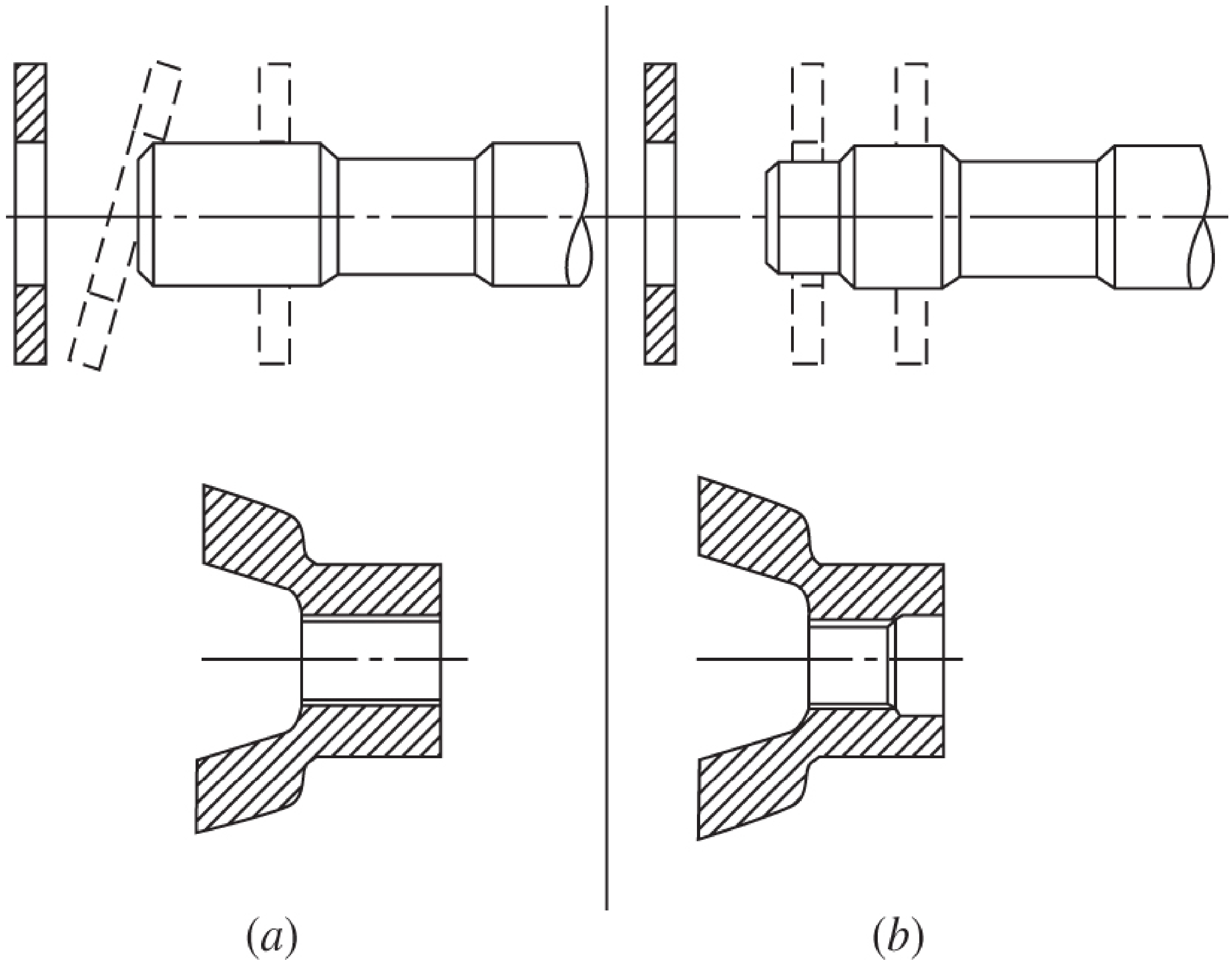


Figure 11.38

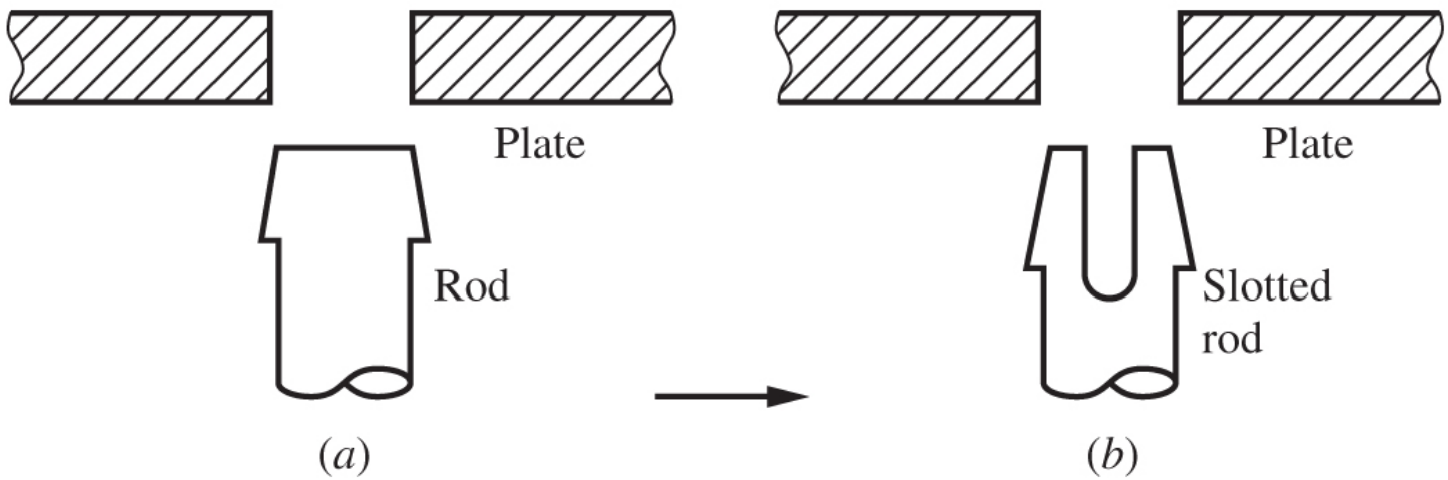


Figure 11.39

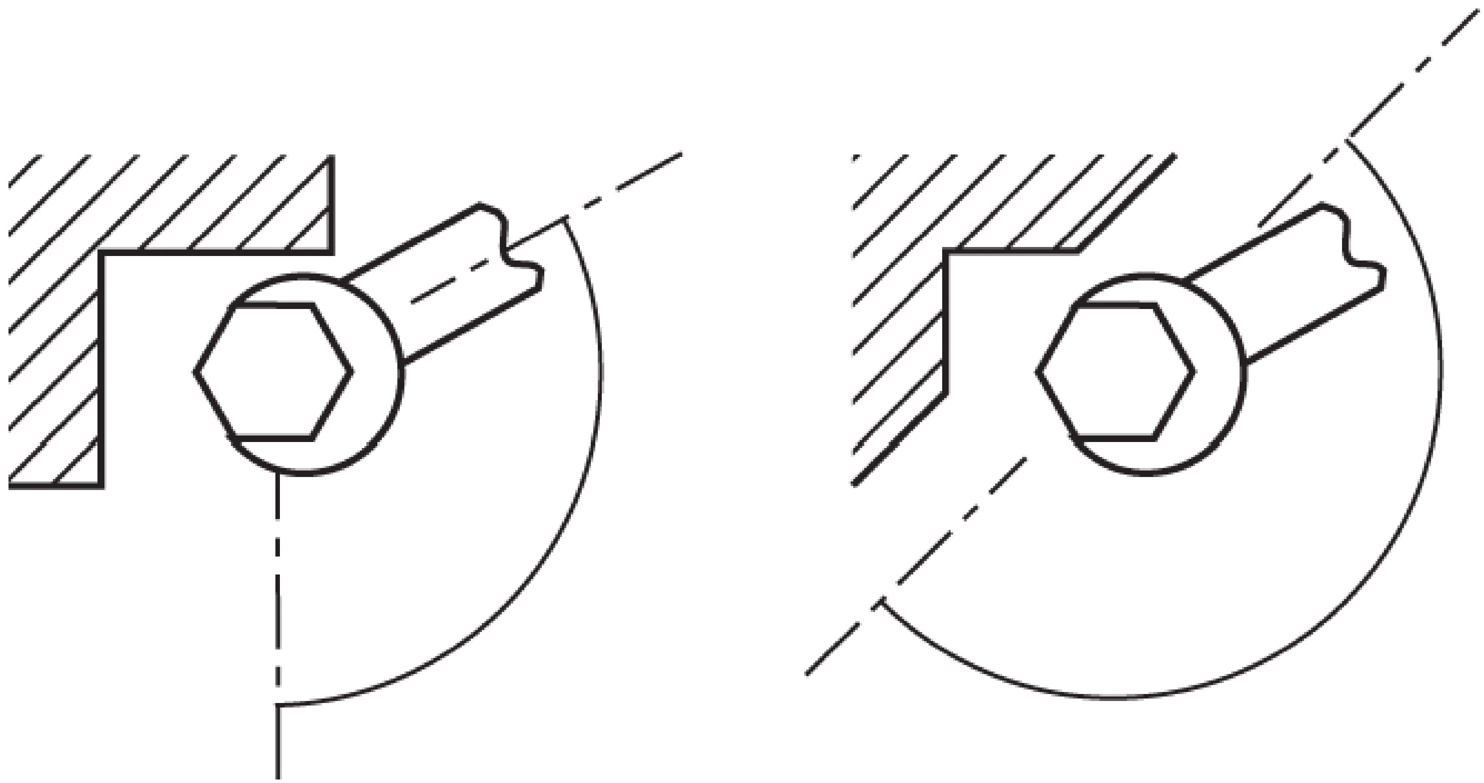


Figure 11.40

T

FMEA (Failure Modes and Effects Analysis)

Product: Mars Rover | **Organization Name:** Jet Propulsion Lab

#	Function Affected	Potential Failure Modes	Potential Failure Effects	Potential Causes of Failure	Recommend Actions	Responsible Person	Taken Actions
1	Propel Rovert	No torque o wheel	Wheel stops turning	Motor failure	Ensure motors have high reliability—at least >99% for a 90 sol mission	Tim Smithson, Electronics Div.	Vendor required to submit failure test results
2			Wheel stops turning	Motor failure	Test ability to propel Rover with 1 or 2 drive wheels inoperative	Barb Rojo	Prototype tested with 2 motors off line
3		Wheel jambs against rock	Wheel stops turning	Inability to sense rocks	Develop ability to sense and avoid rocks or feedback torque increase	B. J. Smith	Work in progress
4			Wheel damages surface	Wheel surface too soft	Specify surface that can with stand abrasion	N. Knovo	Hard test developed

Team member: B. Rojo	Team member:	Prepared by: N. Knovo	
Team member: B. J. Smith	Team member:	Checked by: A	pproved by:

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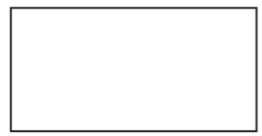
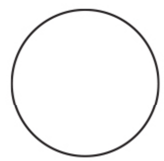
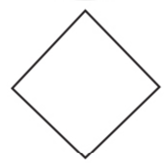
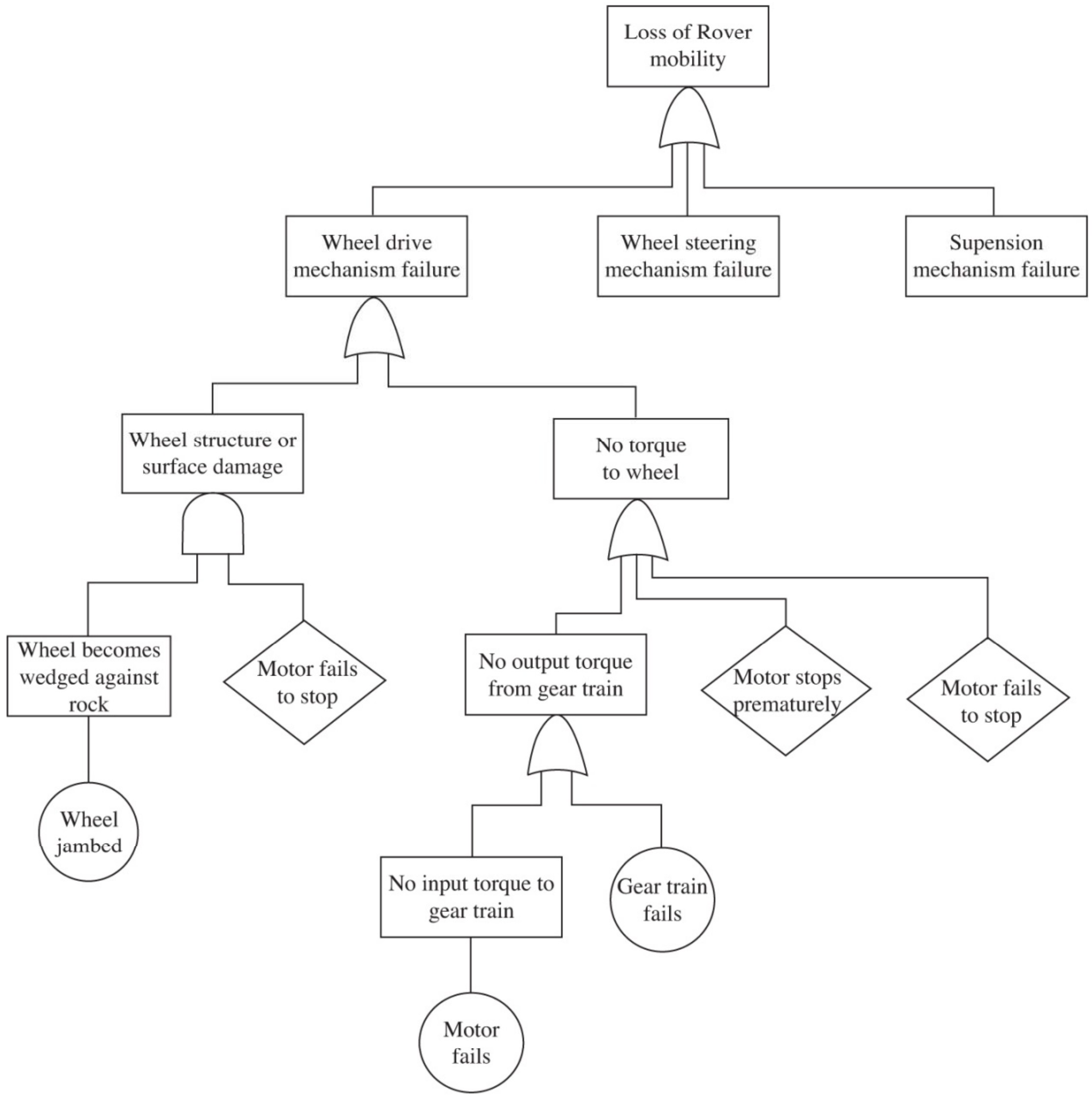
 — Form # 22.0

Table 11.3 Basic fault tree symbols

Event block	FTA symbol	Description
Event		An event, something that happens to something and causes a function to fail
Basic Event		A basic initiating fault or a failure event
Undeveloped Event		An event that is not further developed

Logical operation	FTA symbol	Description
AND		The output event occurs if all input events occur
OR		The output event occurs if at least one of the input events occurs

Figure 11.41

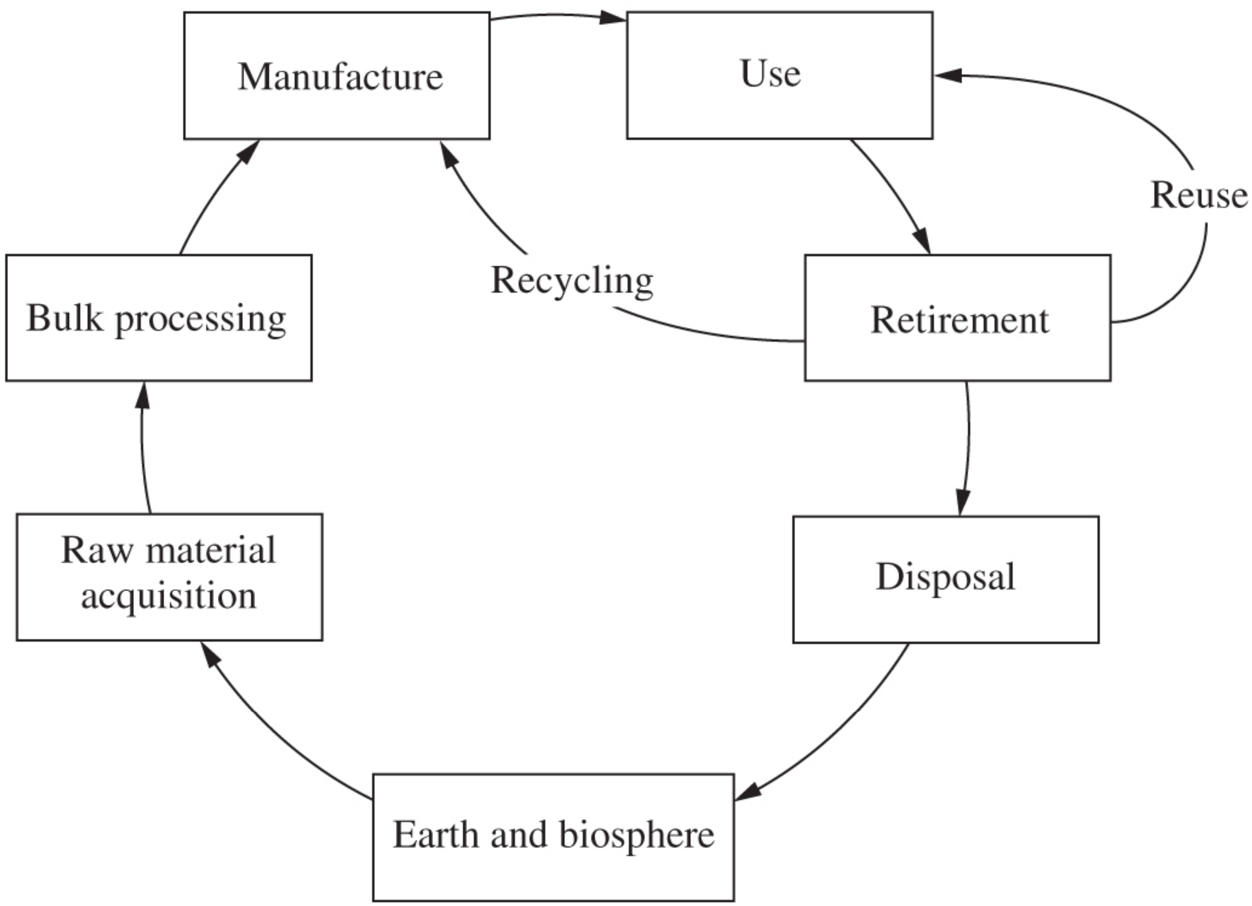


Loss of Rover mobility
Wheel drive mechanism failure
Wheel steering mechanism failure
Supension mechanism failure
Wheel structure or surface damage
No torque to wheel
Wheel becomes wedged against rock
Motor fails to stop
No output torque from gear train
Motor stops prematurely
Motor fails to stop
Wheel jambed
No input torque to gear train
Gear train fails
Motor fails

Table 11.4 Failure rates of common components

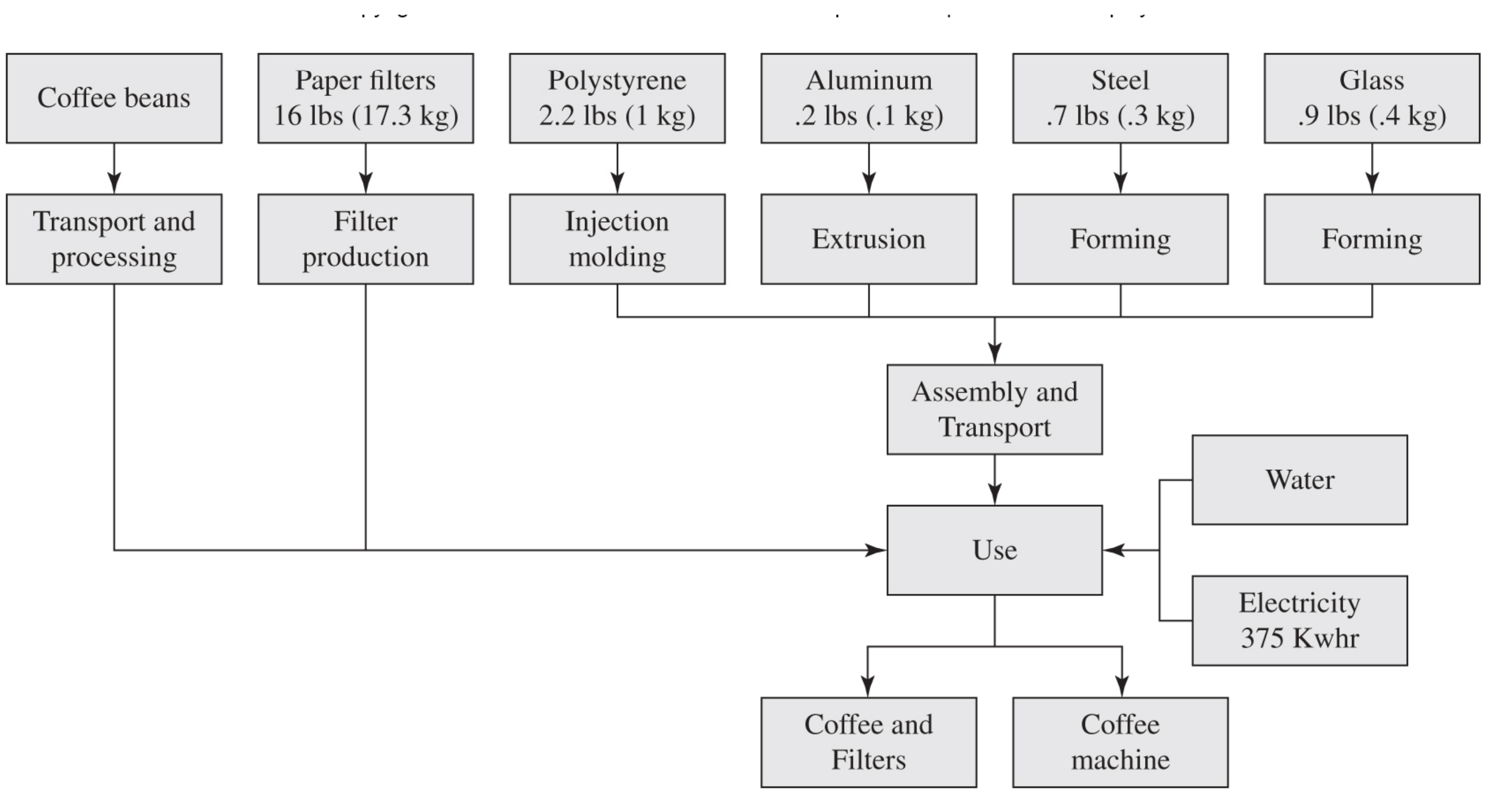
Mechanical failures, per 10^6 hour		Electrical failures, per 10^6 hour	
Bearing (life function of load)		Meter	26
Ball	13	Battery	
Roller	200	Lead acid	0.5
Sleeve	23	Mercury	0.7
Brake	13	Circuit board	0.3
Clutch	2	Connector	0.1
Compressor	65	Generator	
Differential	15	AC	2
Fan	6	DC	40
Heat exchanger	4	Heater	4
Gear	0.2	Lamp	
Pump	12	Incandescent	10
Shock absorber	3	Neon	0.5
Spring	5	Motor	
Valve	14	Fractional hp	8
		Large	4
		Solenoid	1
		Switch	6

Figure 11.42



Manufacture
Use
Reuse
Bulk processing
Recycling
Retirement
Raw material acquisition
Disposal
Earth and biosphere

Figure 11.43



Coffee beans
Paper filters 16 lbs (17.3 kg)
Polystyrene 2.2 lbs (1 kg)
Aluminum .2 lbs (.1 kg)
Steel .7 lbs (.3 kg)
Glass .9 lbs (.4 kg)
Transport and processing
Filter production
Injection molding
Extrusion
Forming
Forming
Assembly and Transport
Water
Use
Electricity 375 Kwhr
Coffee and Filters
Coffee machine

Figure 11.44

Product or component *Coffee Machine*	Project *Example*
Date *18-8-2014*	Author *Ullman*

Notes and conclusions
Analysis of a coffee machine. Assumption: 5 years use, 2 × day, half capacity, keep hot for 30 minutes

Production
Materials, treatments, transport and extra energy

Material or process class	Material or process detail	Units	Amount	Indicator	Result
Plastics	PS (HIPS)	kg	1.00	360.000	360.00
Plastics_processing	Injection moulding –1	mPts		21.000	21.00
Non_ferro_metals	Aluminium 0% Rec.	kg	0.10	780.000	78.00
Metals_processing	Extrusion–aluminium	kg	0.10	72.000	7.20
Ferro_metals	Steel	kg	0.30	86.000	25.80
Packaging	Glass (white)	kg	0.4	58.000	23.20
Heat	Heat gas (industrial furnace)	MJ	4	5.300	21.00
Total (mPt)					**536.40**

Use
Transport, energy and possible auxiliary materials

Use class	Use detail	Amount	Measure unit	Indicator	Result
Electricity	Electricity LV the Netherlands	kWh	375	37.000	13875.00
Packaging	Paper	kg	7.3	96.000	700.80
Total (mPt)					**14575.80**

Disposal
Disposal processes for each material type

Disposal class	Disposal detail	Amount	Measure unit	Indicator	Result
Municipal_waste	Municipal waste PS	kg	1	2.000	2.00
Municipal_waste	Municipal waste ECCS steel	kg	0.4	–5.900	–2.36
Household_waste	Glass	kg	0.4	–6.900	–2.76
Municipal_waste	Municipal waste Paper	kg	7.3	0.710	5.18
Total (mPt)					**2.06**
Total (mPt) (all phases)					**15114.26**