Tolerancing

Objective

- To learn how to effectively tolerance parts such that parts function correctly and cost is kept to a minimum

Definition

- Tolerancing - Allowance for specific variation in the size and geometry of a part

Tolerancing

- Why is tolerancing necessary?
  - It is impossible to manufacture a part to an exact size or geometry
  - Since variation from the drawing is inevitable the acceptable degree of variation must be specified
  - Large variation may affect the functionality of the part
  - Small variation will effect the cost of the part
    - requires precise manufacturing
    - requires inspection and the rejection of parts

Functionality

- Assemblies:
  - Parts will often not fit together if their dimensions do not fall with in a certain range of values
- Interchangeability:
  - If a replacement part is used it must be a duplicate of of the original part within certain limits of deviation
- The relationship between functionality and size or shape of an object varies from part to part
  - the usefulness of eyeglasses is extremely sensitive to size and shape
  - the usefulness of glass marbles are not very sensitive to size and shape

Cost

- Cost generally increases with smaller tolerance
  - There is generally a lower limit to this relationship where larger tolerances do not affect cost (0.020 Vs 0.010)
  - Small tolerances cause an exponential increase in cost

Small Tolerances

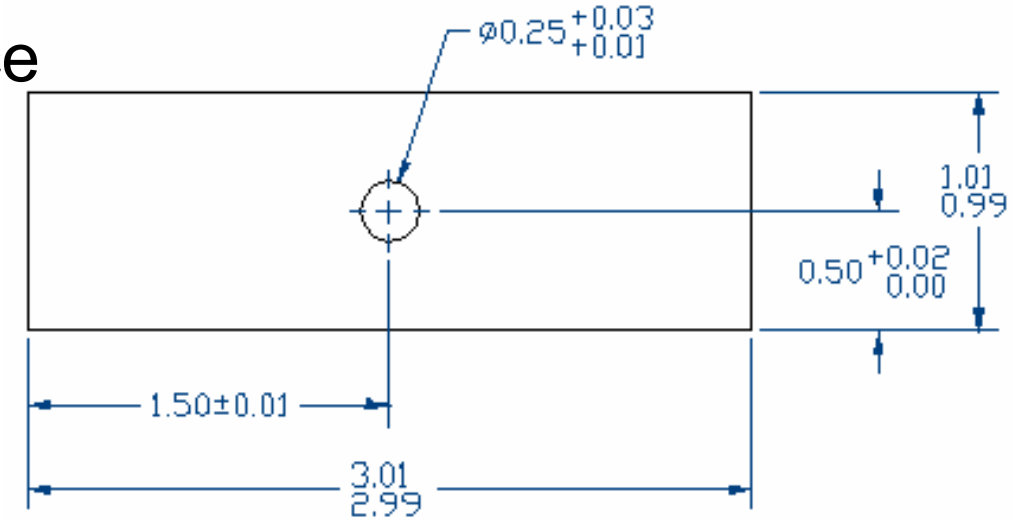
- Other effects of small tolerances
  - Parts with small tolerances often require special methods of manufacturing
  - Parts with small tolerances often require greater inspection and call for the rejection of parts
  - Do not specify a smaller tolerance than is necessary!

How Is Tolerance Specified?

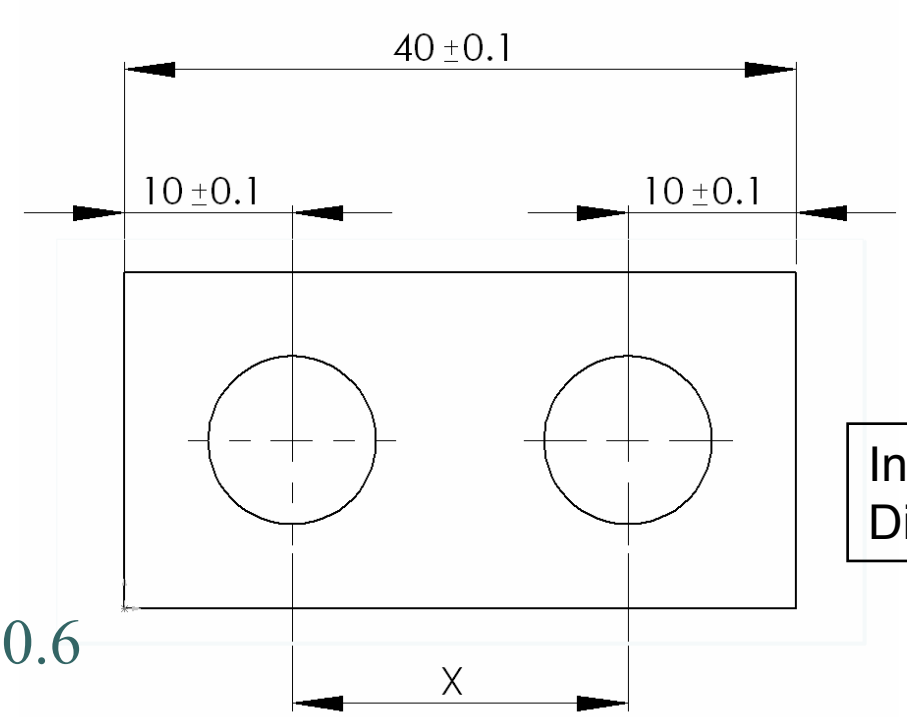
- Size
  - Limits specifying the allowed variation in each dimension (length, width, height, diameter, etc.) are given on the drawing
- Geometry
  - Geometric Tolerancing
    - Allows for specification of tolerance for the geometry of a part separate from its size
    - GDT (Geometric Dimensioning and Tolerancing) uses special symbols to control different geometric features of a part

Specific Tolerances

- The tolerance for a single dimension may be specified with the dimension
  - The tolerance is total variation between the upper and lower limits (tolerance = .020)
- Limits
- Unilateral tolerance
- Bilateral tolerance



Tolerance Stacking



Incomplete Dimensions

Tol X = 0.6

- **General Rule: Tol of X = Σtol of constituent dimensions**
- **Choice of Dimensions to define part is not arbitrary.**

Tolerancing Holes and Shafts

- Tolerancing Terms
  - Basic size
    - The size to which tolerances are applied
  - Nominal size
    - The general size (0.261 referred to as 1/4)
  - Allowance
    - The minimum space between two mating parts
    - Based on the largest shaft and the smallest hole
    - A negative number indicates that the parts must be forced together
  - Maximum Clearance
    - The maximum space between mating parts
    - Based on the smallest shaft and the largest hole

Fit Example

Tolerancing Holes and Shafts

- Types of Fit
  - Clearance fit
    - The parts are toleranced such that the largest shaft is smaller than the smallest hole
    - The allowance is positive and greater than zero
  - Transition fit
    - The parts are toleranced such that the allowance is negative and the max. clearance is positive
    - The parts may be loose or forced together
  - Interference fit
    - The max. clearance is always negative
    - The parts must always be forced together

Tolerancing Holes and Shafts

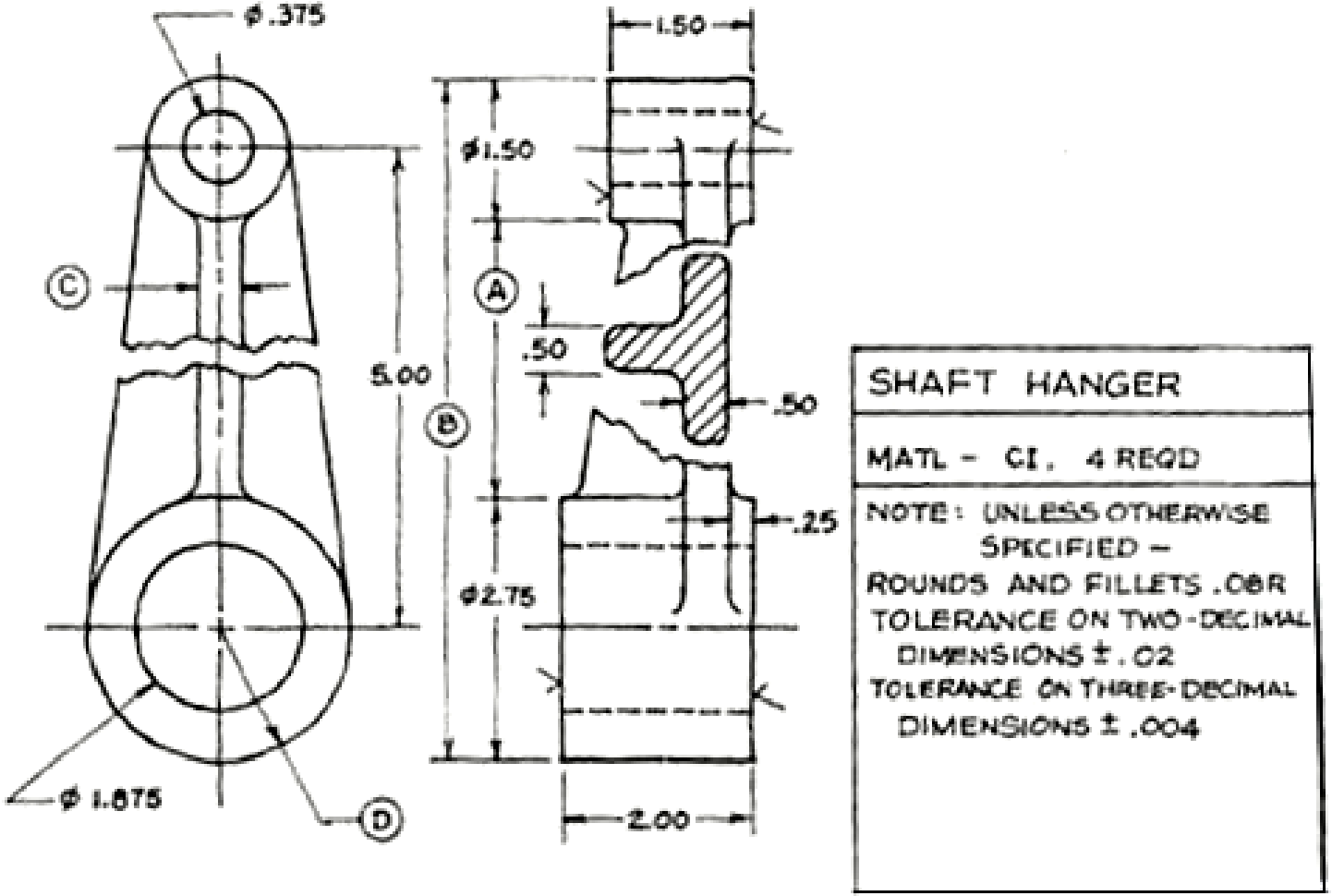
- Preferred fits:
  - A specified system of fits for holes and shafts for SI units
  - Hole basis
    - The minimum hole size equals the basic hole size
    - Uses the symbol “H” in the tolerance specification
- Preferred precision fits:
  - A specified system of fits for holes and shafts for English units
  - Based on hole basis

Preferred Precision Fits

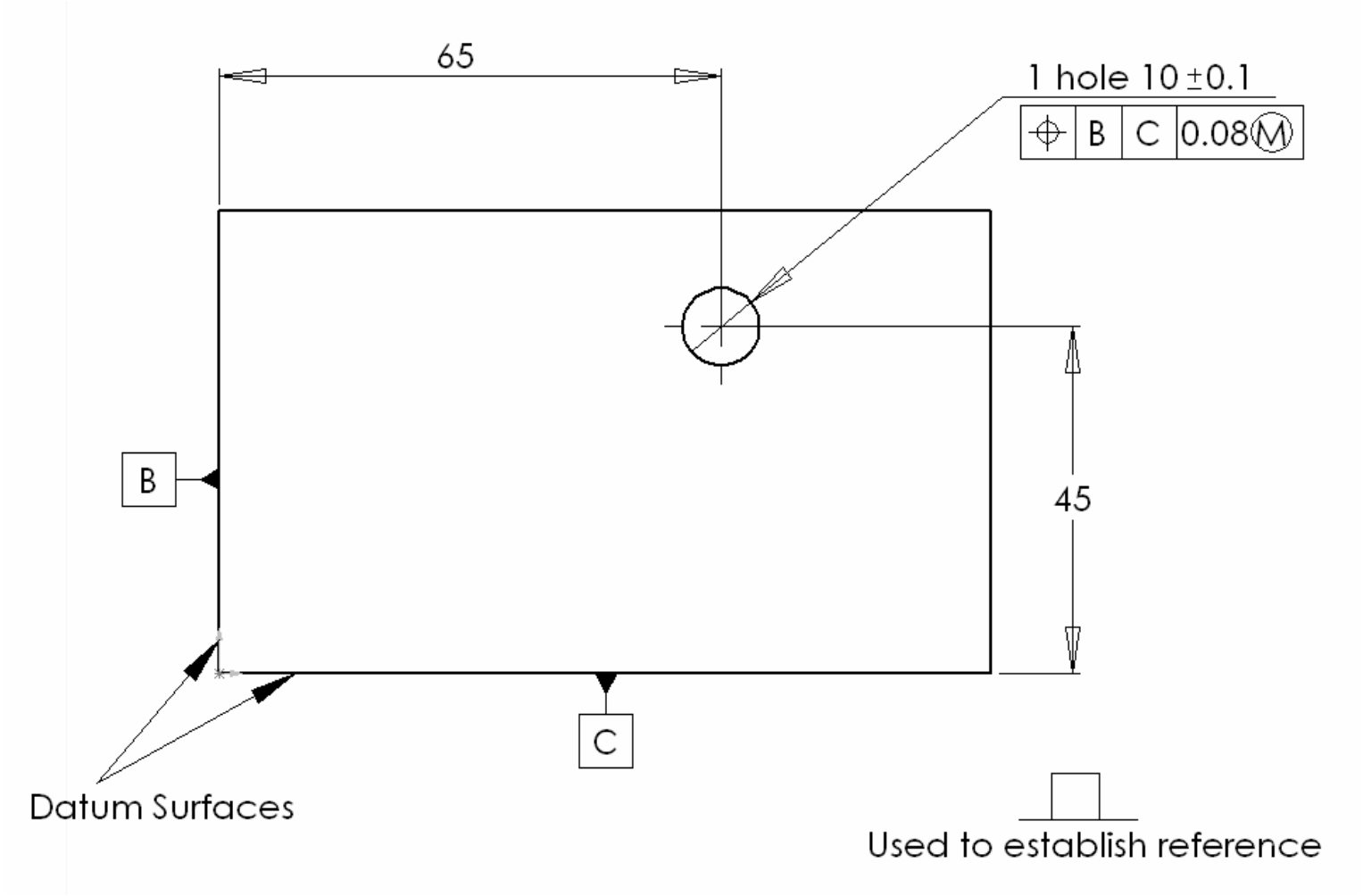
- Classes of fit specified
  - RC: Running and sliding
    - (Allowance >0, Max Clearance >0)
  - LC: Clearance and Locational
    - (Allowance =0, Max Clearance >0)
  - LT: Transition Locational
    - (Allowance <0, Max Clearance >0)
  - LN: Interference Locational
    - (Allowance <0, Max Clearance =0)
  - FN: Force and Shrink
    - (Allowance <0, Max Clearance <0)

Preferred Fit Example

Size Tolerance

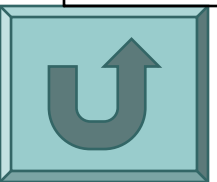


Example of GD & T

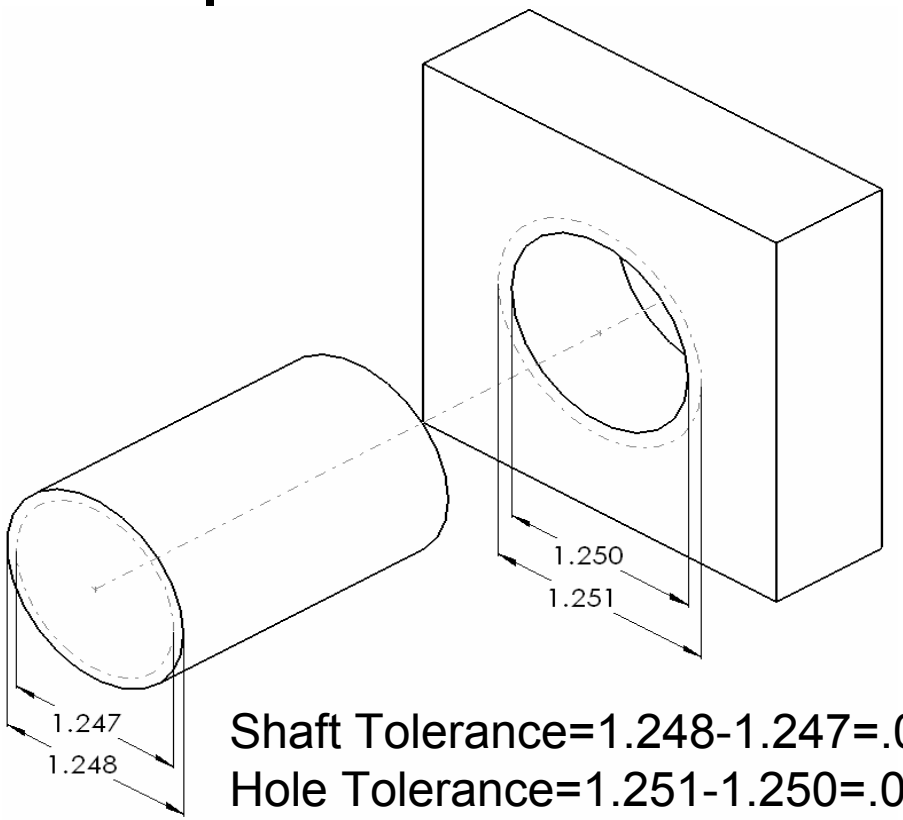


Manufacturing Tolerances

Size (in.)	Total Tolerance (in.)								
0.000-0.599	0.00015	0.0002	0.0003	0.0005	0.0008	0.0012	0.002	0.003	0.005
0.600-0.999	0.00015	0.00025	0.0004	0.0006	0.001	0.0015	0.0025	0.001	0.006
1.000-1.499	0.0002	0.0003	0.0005	0.0008	0.0012	0.002	0.003	0.005	0.008
1.500-2.799	0.00025	0.0004	0.0006	0.001	0.0015	0.0025	0.004	0.006	0.010
2.800-4.499	0.0003	0.0005	0.0008	0.0012	0.002	0.003	0.005	0.008	0.012
4.500-7.799	0.0004	0.0006	0.001	0.0015	0.0025	0.004	0.006	0.010	0.015
7.800-13.599	0.0005	0.0008	0.0012	0.002	0.003	0.005	0.008	0.012	0.025
Operation									
Lapping/Honing									
Grinding/Burnishing									
Broaching									
Reaming									
Turning/Boring									
Milling									
Stamping/Punching									

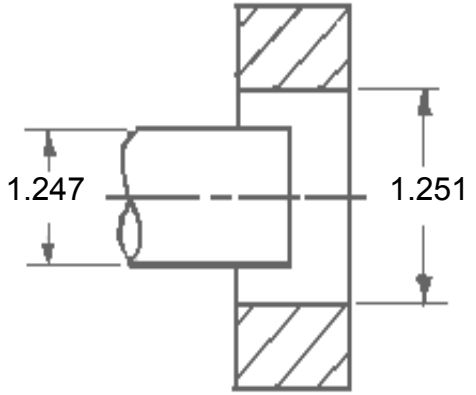


Fit Example

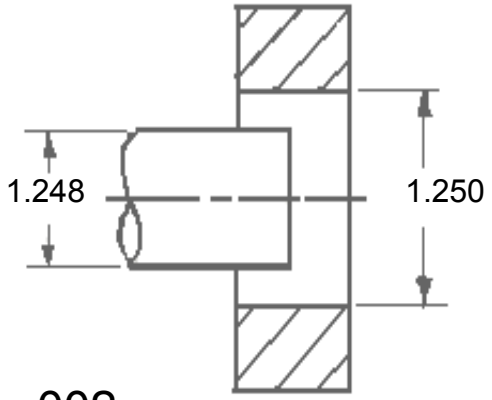


Shaft Tolerance=1.248-1.247=.001
Hole Tolerance=1.251-1.250=.001

Loosest Fit:
Smallest Shaft in Largest Hole



Tightest Fit:
Largest Shaft in Smallest Hole



Allowance=1.250-1.248=.002
Max.Clearance=1.251-1.247=.004

Preferred Fit Example

Running and Sliding Fits - American National Standards

RC 5, RC 6 — ***Medium runnings fits*** are intended for higher running speeds, or heavy journal pressures or both

RC 7 — ***Free running fits*** are intended for use where accuracy is not essential, or where large temperature variations are likely to be encountered, or under both these conditions

RC 8, RC 9 — ***Loose running fits*** are intended for use where wide commercial tolerances may be necessary, together with an allowance on the external member

Nominal Size Range, Inches	Class RC5			Class RC6			Class RC7			Class RC8			Class RC9		
	Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits		Limits of Clearance	Standard Limits	
		Hole	Shaft		Hole	Shaft		Hole	Shaft		Hole	Shaft		Hole	Shaft
Over To		H8	e7		H9	e8		H9	d8		H10	e9		H11	
0-0.12	0.6 1.6	+0.6 -0	- 0.6 - 1.0	0.6 2.2	+ 1.0 -0	- 0.6 - 1.2	1.0 2.6	+ 1.0 -0	- 1.0 - 1.6	2.5 5.1	+1.6 -0	- 2.5 - 3.5	4.0 8.1	+2.5 -0	- 4.0 - 5.6
0.12-0.24	0.8 2.0	+0.7 -0	- 0.8 - 1.3	0.8 2.7	+ 1.2 -0	- 0.8 - 1.5	1.2 3.1	+1.2 -0	- 1.2 - 1.9	2.8 5.8	+1.8 -0	- 2.8 - 4.0	4.5 9.0	+3.0 -0	- 4.5 - 6.0
0.24-0.40	1.0 2.5	+0.9 -0	- 1.0 - 1.6	1.0 3.3	+ 1.4 -0	- 1.0 - 1.9	1.6 3.9	+1.4 -0	- 1.6 - 2.5	3.0 6.6	+2.2 -0	- 3.0 - 4.4	5.0 10.7	+3.5 -0	- 5.0 - 7.2
0.40-0.71	1.2 2.9	+1.0 -0	- 1.2 - 1.9	1.2 3.8	+ 1.6 -0	- 1.2 - 2.2	2.0 4.6	+1.6 -0	- 2.0 - 3.0	3.5 7.9	+2.8 -0	- 3.5 - 5.1	6.0 12.8	+4.0 -0	- 6.0 - 8.5
0.71-1.19	1.6 3.6	+1.2 -0	- 1.6 - 2.4	1.6 4.8	+ 2.0 -0	- 1.6 - 2.8	2.5 5.7	+2.0 -0	- 2.5 - 3.7	4.5 10.0	+3.5 -0	- 4.5 - 6.5	7.0 15.5	+50 -0	- 7.0 - 10.5
1.19-1.97	2.0 4.6	+1.6 -0	- 2.0 - 3.0	2.0 6.1	+ 2.5 -0	- 2.0 - 3.6	3.0 7.1	+2.5 -0	- 3.0 - 4.6	5.0 11.5	+4.0 -0	- 5.0 - 7.5	8.0 18.0	+6.0 -0	- 8.0 - 12.0
1.97-3.15	2.5 5.5	+1.8 -0	- 2.5 - 3.7	2.5 7.3	+3.0 -0	- 2.5 - 4.5	4.0 8.8	+3.0 -0	- 4.0 - 5.8	6.0 13.5	+4.5 -0	- 6.0 - 9.0	9.0 20.5	+7.0 -0	- 9.0 - 13.5