

# Machining and its Importance in Engineering

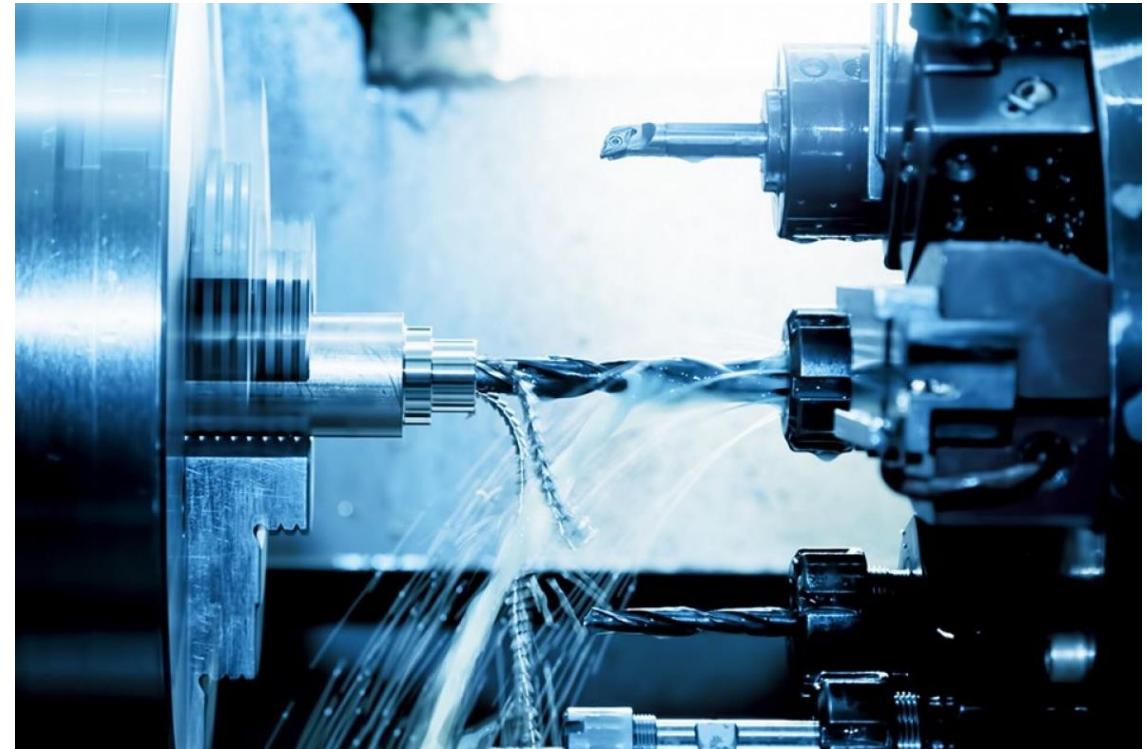


# Engineering and its Importance in Machining



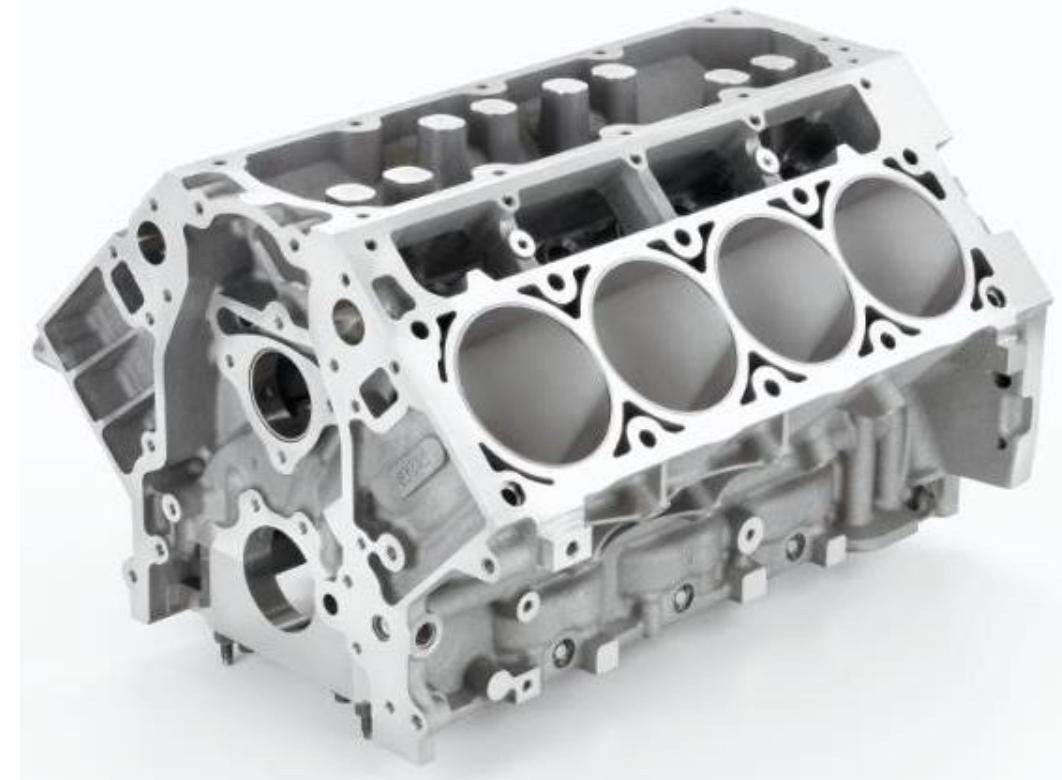
# The Importance of Machining

- I'd say by now we are well aware of how machining is important.
- If we want to take our designs from the virtual to the real world, this can only be achieved through manufacturing.
- Machining is incredibly important for the manufacture of metal products, but can also be applied to plastics, woods, ceramics and composites.



# The Rules of Engagement

- If we want to manufacture products, we must face reality.
- Tolerancing systems are the only way we can reconcile the perfect (nominal) dimensions in CAD/CAM and what the machine is capable of achieving.
- Let's take a closer look at one of the most important tolerancing systems in engineering.
- This is a great video that covers off all the fundamentals
  - <https://www.youtube.com/watch?v=wvVMs2BZdeU>



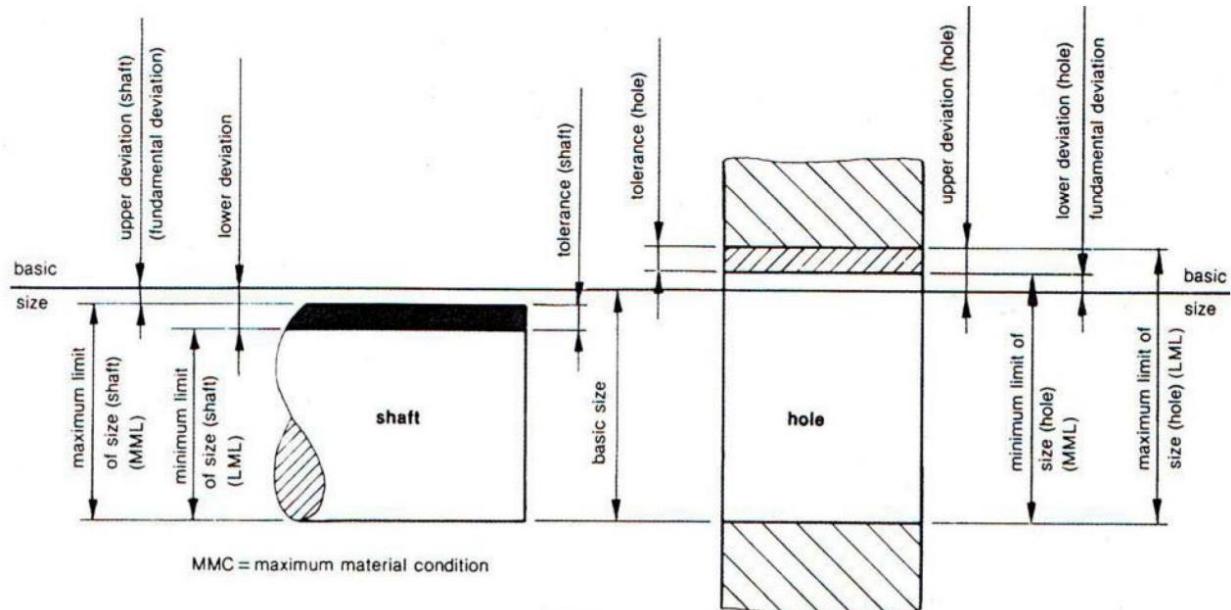
# Hole-Basis and Shaft-Basis Systems

- A shaft is a component that fits into a hole.
  - Can be stationary or rotating
- A hole is a feature in a component that (often) houses or fits a shaft
  - Can also be stationary or rotating



# Hole-Basis and Shaft-Basis Systems

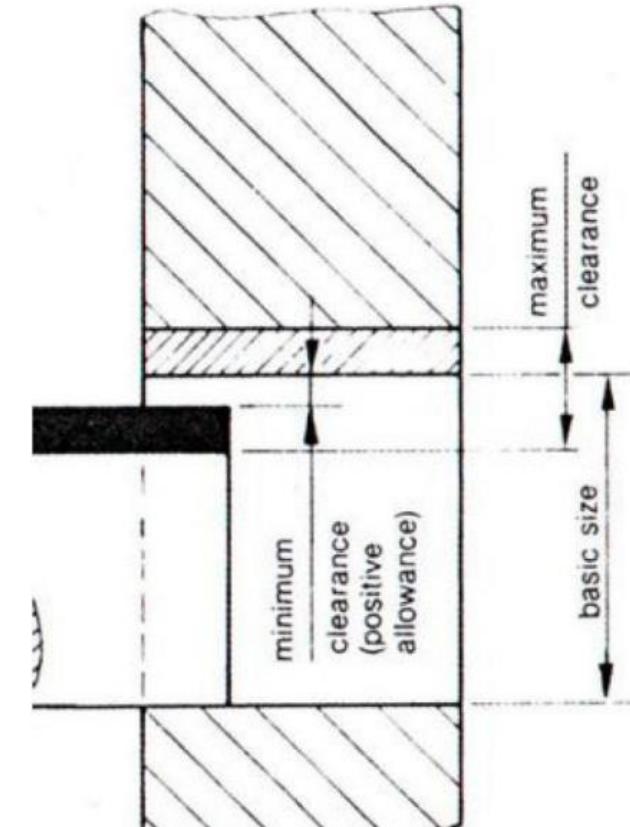
- Any time we talk about tolerances, we need to appreciate the physical limits for the holes and shafts.
- Maximum Material Limit (MML)
  - The maximum (upper) limit for an external feature (shaft)
  - The minimum (lower) limit for an internal feature (hole)
- Least Material Limit (LML)
  - The minimum (lower) limit for an external feature (shaft)
  - The maximum (upper) limit for an internal feature (hole)



# Hole-Basis and Shaft-Basis Systems

There are three main types of fits:

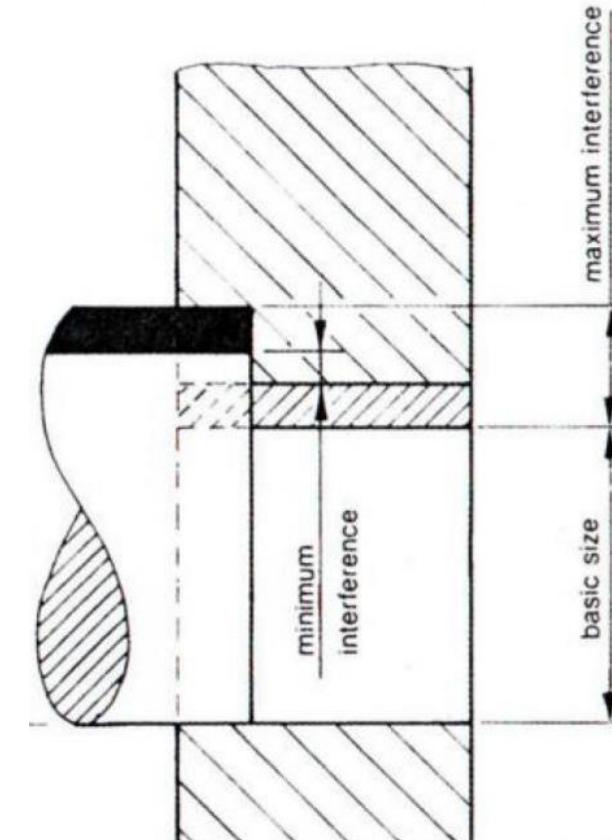
1. Clearance fit
  - Relative motion between the shaft and the hole is always possible.
  - Shaft is always smaller than the hole.
  - Minimum clearance occurs at maximum shaft and minimum hole size.
  - Maximum clearance occurs at minimum shaft size and maximum hole size.



# Hole-Basis and Shaft-Basis Systems

There are three main types of fits:

2. Interference fit
  - Relative motion between the shaft and the hole is not possible.
  - Shaft is always larger than the hole.
  - Minimum interference occurs at minimum shaft and maximum hole size.
  - Maximum interference occurs at maximum shaft size and minimum hole size.

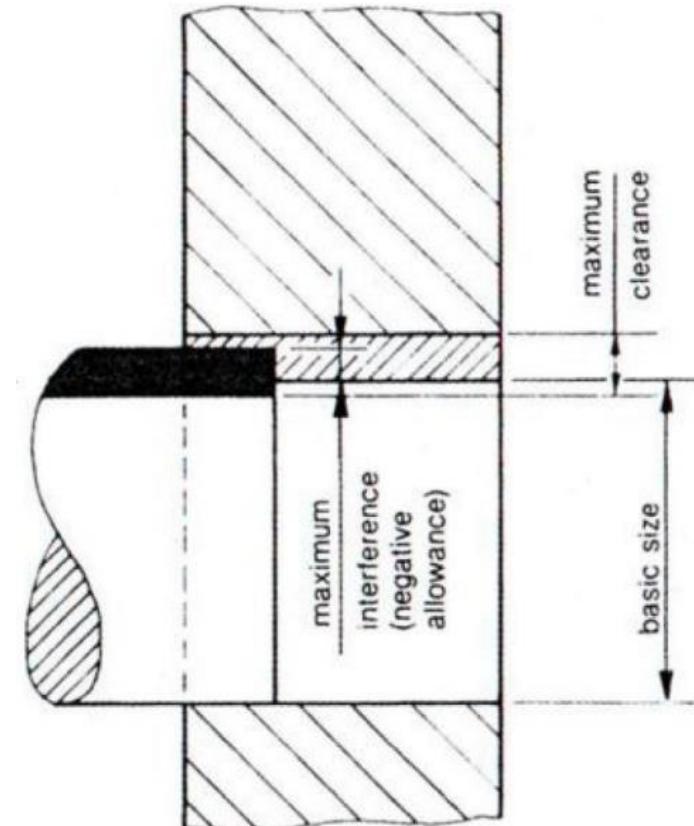


# Hole-Basis and Shaft-Basis Systems

There are three main types of fits:

## 3. Transition fit

- Relative motion between the shaft and the hole is sometimes possible.
- The tolerance zones overlap and allows for either clearance or interference fits.
- Maximum interference occurs at maximum shaft and minimum hole size.
- Maximum clearance occurs at minimum shaft size and maximum hole size.
- Two common transition fits are light push fit and heavy push fit



# Hole-Basis and Shaft-Basis Systems

- When designing systems that utilise shafts and holes, we have two options.
- Hole-basis (Tables 4.1a in Boundy)
  - Hole is treated as standard with zero fundamental deviation
  - More commonly used.
  - Easier to produce standard holes
  - Easier to turn the shaft to accommodate the hole

# Hole-Basis and Shaft-Basis Systems

- When designing systems that utilise shafts and holes, we have two options.
- Shaft-basis (Tables 4.1b in Boundy)
  - Shaft is treated as standard with zero fundamental deviation
  - Is desirable in some cases when the shaft needs to have a large number of parts fitted to it.
    - » Such as?

# Hole-Basis System

Clearance fit (Normal Running) H8/f7

TABLE 4.1(a) A selection of fits—hole-basis system (deviations)

		CLEARANCE FITS				TRANSITION FITS				INTERFERENCE FITS											
		H11	H 9	H 9	H 8	H 7	H 7	n6	p6	s6	H 7										
TOLERANCE unit = 0.001mm		COARSE TOLERANCE	LOOSE	EASY	NORMAL RUNNING	PRECISION RUNNING, SLIDING	AVERAGE LOCATION	LIGHT	HEAVY	PRESS FIT (FERROUS)	HEAVY PRESS FIT (NON-FERROUS)										
BASIC SIZES (mm)		H11/c11	H9/d10	H9/e9	H8/f7	H7/g6	H7/h6	H7/k6	H7/n6	H7/p6	H7/s6										
OVER TO																					
0	3	+60 0	-60 -120	+25 0	-20 -60	+25 0	-14 -39	+14 0	-6 -16	+10 0	-2 -8	+10 0	0	+10 0	+6 0	+10 0	+10 4	+10 0	+12 +6	+10 0	+20 +14
3	6	+75 0	-70 -145	+30 0	-30 -78	+30 0	-20 -50	+18 0	-10 -28	+12 0	-4 -12	+12 0	0	+12 0	+9 +1	+12 0	+16 +8	+12 0	+20 +12	+12 +27	+27 +19
6	10	+90 0	-80 -170	+36 0	-40 -98	+36 0	-25 -61	+22 0	-13 -28	+15 0	-5 -14	+15 0	-9	+15 0	+10 +1	+15 0	+19 +12	+15 0	+24 +15	+15 +32	+32 +23
10	18	+110 0	-95 -205	+43 0	-50 -120	+43 0	-32 -75	+27 0	-16 -34	+18 0	-6 -17	+18 0	0	+18 0	+12 +1	+18 0	+23 +12	+18 0	+29 +18	+18 0	+39 +28
18	30	+130 0	-110 -240	+52 0	-65 -149	+52 0	-40 -92	+33 0	-20 -41	+21 0	-7 -20	+21 0	-13 -20	+21 0	+15 +2	+21 0	+28 +15	+21 0	+35 +22	+21 0	+48 +35

This chart is on scale only for 31mm basic size

Legend: □ = holes ■ = shafts

Assume Basic size  
31mm diameter

Hole tolerance: +0.039 max and +0.000 min  
Shaft tolerance -0.025 max and -0.050 min

30	40	+160 0	-120 -280	+62 0	-80 -180	+62 0	-50 -112	+39 0	-25 -50	+25 0	-9 -25	+25 0	0 -16	+25 0	+18 +2	+25 0	+33 +17	+25 0	+42 +26	+25 0	+59 +43	
40	50	0	-130 -290	0	-180	0	-112	0	-50	0	-25	0	-16	0	+2	0	+17	0	+26	0	+43	
50	65	+190 0	-140 -330	+74 0	-100 -220	+74 0	-134	+46 0	-30 -60	+30 0	-10 -29	+30 0	-19	0	+21 +2	+30 0	+39 +20	+30 0	+51 +32	+30 0	+53 +59	
65	80	0	-150 -340	0	-220	0	-134	0	-60	0	-29	0	-19	0	+2	0	+20 +32	0	+32	0	+78 +59	
80	100	+220 0	-170 -390	+87 0	-120 -260	+87 0	-134	+54 0	-36 -71	+35 0	-12 -34	+35 0	-22	0	+25 3	+35 0	+45 +23	+35 0	+59 +37	+35 0	+93 +71	
100	120	0	-180 -400	0	-260	0	-159	0	-71	0	-34	0	-22	0	3	0	+23 0	0	+37	0	+101 +79	
120	140	+250 0	-200 -450	+100 0	-155 -305	+100 0	-84	+63 0	-43 -83	+40 0	-14 -39	+40 0	-25	0	+28 +3	+40 0	+52 +27	+40 0	+68 +43	+40 0	+92 +50	
140	160	0	-210 -460	0	-305	0	-185	0	-83	0	-39	0	-25	0							+125 +100	
160	180	-230 -480																			+133 +108	
180	200	+290 -240	-300 -530	+115 0	-170 -355	+115 0	-115	+100 -81	+72 +63	-50 -83	+46 0	-15 -44	+46 0	-29	+46 0	+33 +4	+46 0	+60 +31	+46 0	+79 +50	+46 0	+151 +122
200	225	0	-260 -550	0	-355	0	-215	+72 0	-52 -96	+46 0	-15 -44	+46 0	-29	+46 0								+159 +130
225	250	-280 -570																				+169 +140
250	280	+320 -300	-320 -620	+130 0	-190 -400	+130 0	-240	+81 0	-56 -108	+52 0	-17 -49	+52 0	-32	0	+52 0	+36 +4	+52 0	+66 +34	+52 0	+88 +56	+52 0	+190 +158
280	315	0	-330 -650	0	-400	0	-240	+81 0	-56 -108	+52 0	-17 -49	+52 0	-32	0	+52 0	+36 +4	+52 0	+66 +34	+52 0	+88 +56	+52 0	+202 +170
315	355	-360 -720		+140 0	-210 -440	+140 0	-125	+89 0	-62 -119	+57 0	-18 -54	+57 0	-36	0	+57 0	+40 +4	+57 0	+73 +37	+57 0	+98 +62	+57 0	+226 +190
355	400	0	-400 -760	0	-440	0	-265	+89 0	-62 -119	+57 0	-18 -54	+57 0	-36	0	+57 0	+40 +4	+57 0	+73 +37	+57 0	+98 +62	+57 0	+244 +208
400	450	+400 -440	-400 -840	+155 0	-230 -480	+155 0	-195	+97 0	-68 -131	+63 0	-20 -40	+63 0	-20	0	+63 0	+45 +4	+63 0	+80 +20	+63 0	+108 +68	+63 0	+272 +232



# Shaft-Basis System Example

### **Clearance fit (Normal Running) F8/h7**

CLEARANCE FITS										TRANSITION FITS		INTERFERENCE FITS	
TOLERANCE unit = 0.001mm	COARSE TOLERANCE	NO RUNNING				PRECISION RUNNING, SLIDING	AVERAGE LOCATION	LIGHT	HEAVY	PRESS. FIT (FERROUS)	PRESS. FIT (NON FERROU)		
		LOOSE	EASY	RUNNING FIT	PUSH FIT								
BASIC SIZES (mm)	C11/h11	D10/h9	E9/h9	F8/b7	G7/b6	H7/b6	K7/b6	N7/b6	P7/b6	S7/b6	T7/b6	U7/b6	V7/b6
0	3 +120 +60 -60	0 +60 +20 -25	0 +39 +14 -25	0 +20 +6 -10	-0 +12 +2 -6	0 +10 +0 -6	0 -10 -0 -6	0 -6 -0 -4	0 -14 -6 -6	0 -16 -6 -6	0 -14 -6 -6	0 -24 -8 -8	0 -24 -8 -8
3	6 +145 +70 -75	0 +78 +30 -30	0 +50 +20 -30	0 +28 +10 -12	0 +16 +4 -8	0 +12 +0 -8	0 +3 -9 -6	0 -4 -8 -6	0 -8 -20 -8	0 -8 -27 -7	0 -15 -8 -8	0 -15 -8 -8	0 -27 -32 -1
6	10 +170 +80 -90	0 +98 +40 -36	0 +61 +25 -36	0 +35 +13 -15	0 +20 +5 -9	0 +15 +0 -9	0 +5 -10 -9	0 -4 -9 -19	0 -9 -24 -9	0 -9 -32 -7	0 -17 -8 -8	0 -17 -8 -8	0 -32 -37 -1
10	16 +205 +95 -110	0 +120 +50 -43	0 +75 +32 -43	0 +43 +16 -18	0 +24 +6 -11	0 +18 +0 -11	0 +6 -12 -11	0 -5 -23 -11	0 -11 -29 -11	0 -11 -39 -7	0 -21 -8 -7	0 -21 -8 -7	0 -37 -47 -1
18	30 +240 +110 -130	0 +149 +65 -52	0 +92 +40 -52	0 +53 +20 -21	0 +28 +7 -13	+21 0 0 -13	0 +6 -15 -13	0 -7 -28 -13	-14 0 -35 -15	0 -27 -48 -1	0 -27 -48 -1	0 -27 -48 -1	0 -48 -85 -1

Assume Basic size  
31mm  
diameter

Hole tolerance: +0.064 max and +0.025 min  
Shaft tolerance: -0.000 max and -0.025 min

30	40	+280 +120	0 -160	+180	0	+112	0	+64	0	+34	0	+25	0	+7	0	-8	0	-17	0	-34
40	50	+290 +130	0 -160	+80	-62	+50	-62	+25	-25	+9	-16	0	-16	-18	-16	-33	-16	-42	-16	-59
50	65	+340 +140	0 -190	+220	0	+134	0	+76	0	+40	0	+30	0	+9	0	-9	0	-21	0	-42
65	80	+340 +150	0 -190	+100	-74	+60	-74	+30	-30	+10	-19	0	-19	-21	-19	-39	-19	-51	-19	-78
80	100	+390 +170	0 -220	+260	0	+159	0	+90	0	+47	0	+35	0	+10	0	-10	0	-24	0	-58
100	120	+400 +180	0 -220	+120	-87	+72	-87	+36	-35	+12	-22	0	-22	-25	-22	-45	-22	-59	-22	-101
120	140	+450 +200	0 -250	+305	0	+185	0	+106	0	+54	0	+40	0	+12	0	-12	0	-28	0	-77
140	160	+460 +210	0 -250	+145	-100	+85	-100	+43	-40	+14	-25	0	-25	-28	-25	-52	-25	-68	-25	-117
160	180	+480 +230	0 -250																	-85
180	200	+530 +240	0 -290	+355	0	+215	0	+122	0	+61	0	+46	0	+13	0	-14	0	-33	0	-105
200	225	+550 +260	0 -290	+170	-115	+100	-115	+50	-46	+15	-29	0	-29	-33	-29	-60	-29	-79	-29	-113
225	250	+570 +280	0 -290																	-123
250	280	+620 +300	0 -320	+400	0	+240	0	+137	0	+62	0	+52	0	+16	0	-14	0	-36	0	-138
280	315	+650 +330	0 -320	+190	-130	+110	-130	+56	-52	+17	-32	0	-32	-36	-32	-66	-32	-88	-32	-150
315	355	+720 +360	0 -360	+440	0	+265	0	+151	0	+75	0	+57	0	+17	0	-16	0	-41	0	-169
355	400	+760 +400	0 -360	+210	-140	+125	-140	+62	-57	+18	-36	0	-36	-40	-36	-73	-36	-98	-36	-187
400	450	+840 +440	0 -400	+480	0	+290	0	+165	0	+83	0	+63	0	+18	0	-17	0	-48	0	-209

# What fit and system is best here?



# What fit and system is best here?



# What fit and system is best here?

