# **Tutorial for Response Spectrum Analysis using CAEPIPE**

# General

• The <u>Response Spectrum</u> is a plot of the maximum response (maximum displacement, velocity, acceleration or any other quantity of interest) to a specified dynamic loading applied on all possible single degree-of-freedom systems. The abscissa of the spectrum is the natural frequency (or period) of the system, and the ordinate is the maximum response.

In general, response spectra for a seismic event are prepared by calculating the maximum response to a specified ground motion excitation of single degree-of-freedom systems with various amounts of damping. Numerical integration with short time steps is used to calculate the response of each single degree-of-freedom system. The step-by-step process is continued until the total earthquake record is completed, the results of which becomes the response of that system to that excitation. Change the parameters of the system to change its natural frequency, repeat the process for the same excitation and record the new maximum response. This process is repeated until all frequencies of interest have been covered and the results plotted. Typically the El Centro, California earthquake of 1940 is used for this purpose. Attached ("ElCentro.txt") is an ASCII file that contains spectrum from El Centro, California earthquake of 1940. [*First line in this file is the name of the spectrum. Second line defines the "Units" for Abscissa (X-axis) and Ordinate (Y-axis) axes, separated by a space. Starting from the 3<sup>rd</sup> line, the first column is Abscissa and the second column is Ordinate. For further details on this ASCII file, refer to the "Spectrums" subsection under "Misc." section of Menus in the CAEPIPE User's Manual.]* 

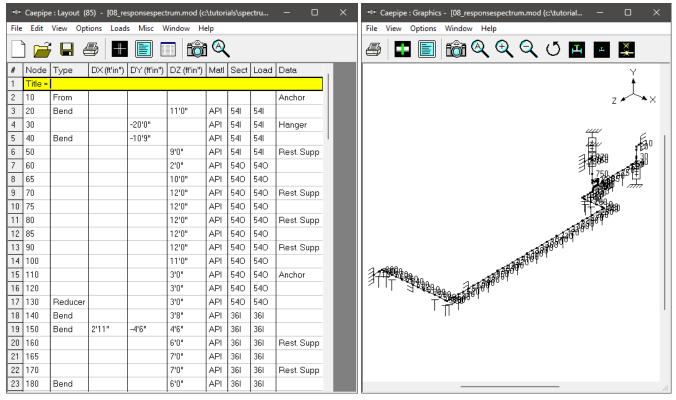
- Response Spectrum thus prepared as explained above is then input/imported into CAEPIPE Stress model for analysis through CAEPIPE Layout window > Misc > Spectrums.
- Once the inputting of different spectrums are done, input the Spectrum levels applicable for the current analysis through Layout window > Spectrum. Define a single level for uniform response spectrum analysis. For piping supported at different elevations with each elevation experiencing different seismic loads, define multiple levels with the corresponding spectrum loads. In the latter case, the levels should be assigned to each support.
- Save the model and perform analysis using CAEPIPE.
- Spectrum load specified will be applied at all supports, following which CAEPIPE will compute the modal and directional responses, which are further combined as per the combination method selected.
- Since the response spectra give only maximum response, only the maximum values for each mode are
  calculated and then superimposed (modal combination) to give a total response. A conservative upper
  bound for the total response may be obtained by adding the absolute values of the maximum modal
  components (absolute sum). However, this is excessively conservative and a more probable value of the
  maximum response is the square root of the sum of squares (SRSS) of the modal maxima.
- Ensure the CAEPIPE results meet project specific analysis requirements. If not, make changes to the piping layout and/or changes to support types and their locations and then reanalyze the model until the analysis requirements are met.

# **Uniform Response Spectrum Analysis**

## The following are the Steps for performing the Uniform Response Spectrum Analysis using CAEPIPE.

## Step 1:

Attached is a sample CAEPIPE model with Response Spectrum. The piping layout shown below (extracted from the attached model) is for a water supply line that has the following layout and properties. The Analysis Code is selected as ASME B31.9 for this sample model.



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1	361	36"	STD	36	0.375	0.075		13	2						
2	360	36"	STD	36	0.375	0.075		13	2.5				1		
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3									3	-100	30.2E+6	5.65E-6	20000		
									4	70	29.5E+6	6.07E-6	20000		
									5	200	28.8E+6	6.38E-6	20000		
									6	300	28.3E+6	6.60E-6	20000		
									7	400	27.7E+6	6.82E-6	19900		
									8	500	27.3E+6	7.02E-6	19000		
									9	600	26.7E+6	7.23E-6	17900		

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2	361	100	125	100	125	1.0						
3	30O	100	125	100	125	1.0	65.9	Y				
4	301	100	125	100	125	1.0						
5	240	100	125	100	125	1.0	54.6					
6	241	100	125	100	125	1.0						
7	200	100	125	100	125	1.0	48.9	Y				
8	201	100	125	100	125	1.0						
9	180	100	125	100	125	1.0	45.2	Y				
10	181	100	125	100	125	1.0						
4.4	100	100	100	100	100	10	44 4	0				

## Step 2:

Input Spectrums into CAEPIPE. This can be done in three ways:

- 1. Input spectrums directly into the model.
- 2. Create a spectrum library and load spectrums from it.
- 3. Input spectrums from a text file.

When the first two methods are used, the units for the X-axis and Y-axis as well as the interpolation method are set through the menu Options > Spectrum.

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		15						

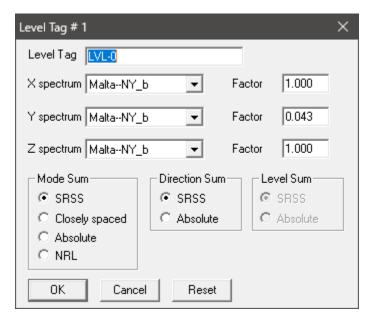
For the sample layout described above, spectrum was input directly into CAEPIPE model manually. If you wish to read the spectrum file "ElCentro.txt" supplied into the CAEPIPE model, select "Read Spectrum" through Spectrum List Window > File.

# Step 3:

Once the inputting of different spectrums are done, input the Spectrum load itself for analysis through Layout window > Spectrum.

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# X, Y and Z spectrums

Select a spectrum from the drop-down combo box, which should have been input in the spectrum table for each direction.

## Factor

The multiplying (scale) factor for the spectrum is input here. The same spectrum may be multiplied by different (Scale) factors to apply spectrum loads for different dynamic events. For example, vertical spectrum can be input as the same as that of the horizontal spectrum with a factor as shown above.

## Mode Sum

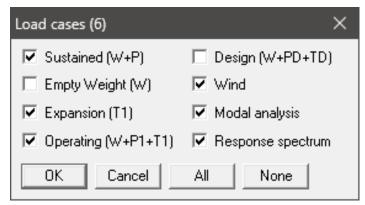
Pick one of three choices, "SRSS" (square root of sum of squares), "Closely spaced" or "Absolute".

## **Direction Sum**

Pick one of two choices, "SRSS" (square root of sum of squares) or "Absolute".

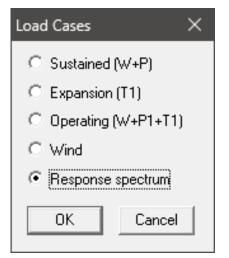
## Step 4:

Turn ON the load case "Response spectrum" through Layout window > Loads > Load cases. Save the model and perform the analysis through Layout window > File > Analyze. CAEPIPE will apply these loads to compute the response of the piping system by performing a Response Spectrum analysis along with other load cases defined in the piping system.



#### Step 5:

Upon analysis, CAEPIPE will show a "Load case" with name "Response spectrum" under "Support Loads", "Displacements", "Element forces" and "Support load summary" results.



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4	30	0.877	0.015	0.01	7	0.0017	0.11	46 0.	2332				
5	40A	1.073	0.015	0.01	6	0.0020	0.11	13 0.	2324				
6	40B	1.375	0.001	0.00	)6	0.0024	0.05	32 0.	1013				
7	50	1.351	0.000	0.00	)6	0.0020	0.05	58 0.	0987				
8	60	1.328	0.001	0.00	)6	0.0015	0.05	33 0.	0964				
9	65	1.195	0.002	0.00	)6	0.0001	0.07	18 0.	0850				
10	70	0.996	0.000	0.00	)5	0.0005	0.08	75 0.	0712				
11	75	0.762	0.000	0.00	)4	0.0000	0.09	77 0.	0574				
12	80	0.512	0.000	0.00	)3	0.0001	0.09	79 0.	0437				

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6	40B 50	3814 3814	2647 2647	4372 4372	71282 71282		13836 19257		91806 100776					6012 6253	26600 26600	0.23 0.24	
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8	60 65	5395 5395	861 861	2478 2478	71282 71282		17702 9446		107539 123741					6237 6590	26600 26600	0.23 0.25	
9	65 70	7590 7590	1171 1171	2484 2484	71282 71282		9446 4642		123741 107572					6624 6565	26600 26600	0.25 0.25	

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Sustained+Wind	0	-9858	-150	36176	0	0								
Operating1+Wind	0	39163	-13410	-301387	2	4								
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Sustained-Response	-10164	-12568	-2286	8811	-59452	-191368								
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Maximum	10164	41844	1999	63740	59454	191372								
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# **Multi-level Response Spectrum Analysis**

The model shown below is a 3 inch nominal diameter water line extending between two elevations, namely Level L1 and Level L2, with each Level experiencing different seismic loads. The layout has two anchors with a number of intermediate supports. The seimsic excitation consists of two separate spectra, with each spectrum corresponding to the two different Levels. All supports connected from node 1 through mode 11 (inclusive of the two end nodes) experience the upper level (Level L1) spectra excitation, while the remaining supports experience the lower level (Level L2) spectra excitation.

For this Multi-Level Response Spectrum Analysis, only the first 15 modes are used to approximate the response of the system. For each Level, the same spectrum load is applied along X, Y and Z directions with weighting factors of 1.0, 0.667 and 0.0 in the three global directions respectively.

# The following are the Steps to perform the Multi-level Response Spectrum Analysis using CAEPIPE.

## Step 1:

Attached is a sample CAEPIPE model with Response Spectrum. The piping layout shown below (extracted from the attached model "08\_ResponseSpectrum\_MLRSA.mod") has the following layout and properties.

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# Step 2:

Input Spectrum load data from layout window: Misc Menu > Spectrums. This can be done in three ways:

- 1. Input spectrums directly into the model.
- 2. Create a spectrum library and load spectrums from it.
- 3. Input spectrums from a text file.

For further details, refer to the section titled "Spectrum Loads" in CAEPIPE User's Manual.

When the first two methods are used, the units for the X-axis & Y-axis and the interpolation method are set through the Options > Spectrum.

101	Caepipe : Spectrums (	(2) -	[08_res	- 0	×	101	Caepipe : Spectrums (	(2) -	[08_res	- 0 X			
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-#	$\blacksquare \blacksquare \blacksquare \textcircled{\otimes} \bigcirc \bigcirc \frown \bigcirc $												
#	Name	#	Period (Sec)	Acceleration (in/sec2)		#	Name	#	Period (Sec)	Acceleration (in/sec2)			
1	<mark>51</mark>	1	0.029	338.1		1	S1	1	0.029	231.84			
2	S2	2	0.034	386.4		2	S <mark>2</mark>	2	0.032	270.48			
3		3	0.043	386.4		3		3	0.037	289.8			
		4	0.048	309.12				4	0.043	289.8			
		5	0.059	357.42				5	0.046	231.84			
		6	0.074	357.42				6	0.063	270.48			
		7	0.081	309.12				7	0.071	270.48			
		8	0.125	386.4				8	0.08	260.82			
		9	0.2	879.06				9	0.143	289.8			
		10	0.4	879.06				10	0.25	540.96			
		11						11	0.333	540.96			

# Step 3:

Define Spectrum Levels through Layout window > Loads > Spectrum. From the list window shown, double click on an empty row and input Level Tag, select Spectrums; input factors and select Mode Sum, Direction Sum and Level Sum. Levels L1 and L2 defined for this analysis are shown below.

Level Tag # 1	×	
Level Tag 📘		
X spectrum S1	Factor 1.000	
Y spectrum S1	▼ Factor 0.667	
Z spectrum	▼ Factor	
Mode Sum SRSS C Closely spaced C Absolute C NRL OK Cancel	Direction Sum SRSS Absolute Reset	
•II• Caepipe : Spectrum L	Levels (2) - [08_responsespectrum_mlrs	sa.mod (c:\tutorials\spectrumtutorial)]
File Edit View Optic	ons Misc Window Help	

	Caepipe : Sp	ectrum Levels	(2) - [08_respo	onsespectrum_	mirsa.mod	(c:\tutorials)	spectrumti	itorial)]	—		۲.		
File	Edit View	Options N	Aisc Window	Help									
-#													
#	Level Tag	XSpectrum	YSpectrum	Z Spectrum	×Factor	YFactor	Z Factor	Mode Sum	Direction Sum	Level Su	r _		
1	L1	S1	S1		1.000	0.667		SRSS	SRSS	SRSS			
2	L2	S2	S2		1.000	0.667		SRSS	SRSS	SRSS			
-													

## Step 4:

Assign Spectrum Level to each support in the analysis model by selecting the appropriate Level Tag from the list. Snapshots shown below are for a Restraint and an Anchor.

Skewed restraint at node 4 $\qquad \qquad \times$	
Tag Type Translational C Rotational	
Stiffness 2.000E+7 (lb/inch)	Anchor at node 1 ? X
X comp Y comp Z comp	Tag Level Tag L1 💌
Connected to	Translational stiffness (lb/inch)       Rotational stiffness (in-lb/deg)         KX       KY       KZ         [2.000E+7]       2.000E+7       2.000E+7
Axial Sheary Shearz	Releases for hanger selection       X       Y       Z       XX       YY       ZZ         OK       Cancel       Displacements       Rigid       Anchor in Pipe LCS

Alternatively, one can use the command "Change" through "Layout Window > Edit" to assign Level Tag for all supports in the Layout for a range specified as shown below.

Change Rows $ imes$	Change Rows X
From # 2 To # 15	From # 16 To # 47
Change Material to 📃 🚽	Change Material to
Change Section to	Change Section to
🗌 Change Load to 📃 🖃	Change Load to
🗹 Change Level Tag to 📘 👻	🗹 Change Level Tag to 📃 🗨
Change Friction coefficient to	Change Friction coefficient to
Change DX (inch)	Change DX (inch)
Change DY (inch)	Change DY (inch)
Change DZ (inch)	Change DZ (inch)
OK Cancel	OK Cancel

## Note:

The Level Tag selection list will be enabled and available for selection only when two or more Spectrum Levels are input in the analysis model. On the other hand, the Level Tag selection list will be disabled and the same Level Tag will be assigned automatically to all supports when only one Spectrum Level is defined in the analysis model.

## Step 5:

The users can review the Levels assigned to different supports using the List command. Snapshots shown below are from List command for Anchors and Skewed Restraints.

	*** Caepipe : Anchors (2) - [08_responsespectrum_mlrsa.mod (c:\tutorials\spectrumtutorial)]													
File	Edit Vie		tions Misc Wind	ow Help										
+			<b>i al 🖉</b> 🗲	• 🔿										
#	Node Ta	ag KXVI	kx KY/ky	KZ/kz KX	γk∞ Kγ	Y/kyy	KZZ/k		Releases		Level Tag			
						·lb/deg)	(in-lb/		z 🗙 🗠					
<u> </u>	1			2.000E+7 Rig		gid	Rigid			GCS	L1			
2	36	2.00	0E+7 2.000E+7	2.000E+7 1.0	DE+11 1.0	0E+11	1.00E	+11		GCS	L2			
	■ Caepipe : Skewed restraints (11) - [08_responsespectrum_mIrsa.mod (c:\tutorials\ — □ ×													
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-#			1 👘 🙆											
					-									
#	Node	Tag	Туре	Stiffness	Units	Xco	mp	Y comp	Z comp	CNode	Level Tag			
1	4		Translationa	I 2.000E+7	(lb/inch	)		1.000			L1			
2	7		Translationa	2.000E+7	(lb/inch	)   1.00	0				L1			
3	7		Translationa	I 2.000E+7	(lb/inch	)			1.000		L1			
4	14		Translationa	1 20000	(lb/inch	) 1.00	0				L2			
5	14		Translationa	1 20000	(lb/inch	)			1.000		L2			
6	20		Translationa	1 20000	(lb/inch	) 1.00	0				L2			
7	20		Translationa	1 20000	(lb/inch	)			1.000		L2			
8	26		Translationa	I 2.000E+7	(lb/inch	) 1.00	0				L2			
9	26		Translationa	I 2.000E+7	(lb/inch	)			1.000		L2			
10	28		Translationa	I 2.000E+7	(lb/inch	)		1.000			L2			
11	28		Translationa	I 2.000E+7	(lb/inch	)			1.000		L2			
						·								

**Note:** CAEPIPE will terminate the analysis, if a level tag is not assigned to a support. For further details, refer to the flowchart under the section titled "Spectrum Loads" in CAEPIPE User's Manual.

## Step 6:

Turn ON the load case "Response spectrum" through Layout window > Loads > Load cases. Save the model and perform the analysis through Layout window > File > Analyze. CAEPIPE will apply these loads to compute the response of the piping system by performing a Response Spectrum analysis along with other load cases defined in the piping system.

Load cases (5)	×
☑ Sustained (W+P)	🔲 Design (W+PD+TD)
🔲 Empty Weight (W)	🔽 Modal analysis
💌 Expansion (T1)	🔽 Response spectrum
🔽 Operating (W+P1+T1)	
OK Cancel	All None

Upon analysis, CAEPIPE will show a "Load case" with name "Response spectrum" under "Support Loads", "Displacements", "Element forces" and "Support load summary" results.

Load Cases	×								
C Sustained (W+P)									
C Expansion (T1)									
O Operating (	W+P1+T1)								
Response :	spectrum								
ОК	Cancel								

When selected, each results window (such as Support Loads, Displacements, etc.) will display the title as "Response Spectrum (Multi-level)" as shown in the snapshots below.

-0-	📲 Caepipe : Loads on Anchors: Response spectrum (Multi-level) - [08_responsespectrum_mlrs — 🛛 🛛 🛛																
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4																	
#	Node	Tag	g FX (lb)	FY (lb)	FZ	(lb)	MX (ft-lb)	MY (ft-lk	o) MZ (f	t-lb)							
1	1		87	93	82		238	110	231								
2	36		84	67	74		36	394	374								
-0-																	
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	Node	Tag	туре	Load	Units			Z comp	CNode		↓ <	, ,	~				
#	Node 4	Tag	Type Translational	Load	Units (lb)	× comp		Z comp 1.000	CNode		<b>↓</b> <	, , ,	~				
# 1 2	Node 4 7	Tag	Type Translational Translational	Load 202 84	Units (Ib) (Ib)	× comp			CNode		<b>↓</b> <	, ,	~				
# 1 2 3	Node 4 7 7	Tag	Type Translational Translational Translational	Load 202 84 74	Units (lb) (lb) (lb)	× comp			CNode		↓ <	, <u> </u>					
# 1 2 3 4	Node 4 7 7 14	Tag	Type Translational Translational Translational Translational	Load 202 84 74 55	Units (lb) (lb) (lb) (lb)	× comp		1.000	CNode		↓ < _	(	_/				
# 1 2 3 4 5	Node 4 7 7 14 14	Tag	Type Translational Translational Translational Translational Translational	Load 202 84 74 55 34	Units (lb) (lb) (lb) (lb) (lb)	× comp 1.000 1.000		1.000	CNode		↓ < _		_/				
# 1 2 3 4 5 6	Node 4 7 7 14 14 20	Tag	Type Translational Translational Translational Translational Translational	Load 202 84 74 55 34 57	Units (lb) (lb) (lb) (lb) (lb)	× comp 1.000 1.000		1.000	CNode		↓ <	, (	~				
# 1 2 3 4 5 6 7	Node 4 7 7 14 14 20 20	Tag	Type Translational Translational Translational Translational Translational Translational	Load 202 84 74 55 34 57 26	Units (lb) (lb) (lb) (lb) (lb) (lb)	× comp 1.000 1.000 1.000		1.000	CNode		↓ <		~				
# 1 2 3 4 5 6 7 8	Node 4 7 7 14 14 20 20 26	Tag	Type Translational Translational Translational Translational Translational Translational Translational	Load 202 84 74 55 34 57 26 136	Units (lb) (lb) (lb) (lb) (lb) (lb) (lb)	× comp 1.000 1.000 1.000		1.000	CNode		↓ <						

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2	2	0.0024	0.00		0.002		0.021		0.0151		0.0205	-1						
3	201A	0.0024	0.00		0.002		0.021		0.0151		0.0205	-1						
4	201B	0.0622	0.00		0.068		0.064	8	0.0480		0.0586	-1						
5	3	0.0622	0.00		0.068		0.064		0.0480		0.0586	-1						
6	4	0.0738	0.00		0.081		0.073		0.0283		0.0679							
7	5	0.0783	0.02		0.086		0.086		0.0098		0.0830	_						
8	501A	0.0783	0.02		0.086		0.086		0.0098		0.0830							
9	501B	0.0125	0.05		0.013		0.069		0.0296		0.0629							
10	6	0.0125	0.05		0.013		0.069		0.0296		0.0629							
11	7	0.0000	0.05		0.000		0.061		0.0291		0.0557	_						
12	8	0.0197	0.05		0.021		0.041		0.0281		0.0387	_						
13	9	0.0320	0.05		0.034		0.022		0.0272		0.0221	_						
14	10	0.0368	0.05		0.039	0364 0.01			0.0264		0.0082	_						
15	11	0.0343	0.05						0.0256		0.0154	_						
16	12	0.0256	0.05		0.0272		0.027		0.0249		0.0263	_						
17	13	0.0135	0.05				0.032		0.0243		0.0304	_						
18	14	0.0028	0.05		0.001		0.028		0.0238		0.0272	_						
19	15	0.0135	0.05		0.011	9 0.01			0.0232		0.0218	_						
20	16	0.0220	0.05		0.018		0.007		0.0229		0.0098	_						
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QΟ	erating	1		104		82		94		174		0		-192				
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		(lb)	(lb)	(lb)	Moment	SIF	Moment	SIF	Moment	SIF	FFi	FFo	FFt	(psi)	(psi)	
1	1 2	93 93	87 87	82 82	110 110		231 159		238 170					4116 2454	1 1	solololok solololok
2	201A 201B	93 108	108 93	45 45	110 28		111 97	1.00 1.00	205 71	1.00 1.00				2454 1556	1 1	Xaladalak Xaladalak
3	3 4	92 92	97 97	19 19	28 28		97 264		71 110					1556 5300	1 1	Xolololok Xolololok
4	4 5	88 88	114 114	5 5	28 28		264 65		110 116					5300 1172	1 1	Yolololok Yolololok
5	501A 501B	93 105	105 93	30 30	28 6		65 71	1.00 1.00	116 96	1.00 1.00				1172 1343	1 1	solololok solololok
6	6 7	92 92	75 75	69 69	6 6		84 111		84 111					1343 1553	1 1	solololok solololok
7	7 8	87 87	22 22	17 17	6 6		111 95		111 102					1553 1349	1 1	Yolololok Yolololok
8	8 9	81 81	20 20	16 16	6 6		95 92		102 98					1349 1222	1 1	skololole skololole
9	9 10	75 75	15 15	13 13	6 6		92 89		98 91					1222 1094	1 1	solololok solololok
10	10 11	69 69	12 12	12 12	6 6		89 76		91 76					1094 869	1 1	kolololok kolololok
11	11 12	65 65	18 18	16 16	6 6		76 48		76 48					869 513	1 1	solololok solololok
12	12 13	61 61	26 26	22 22	6 6		48 36		48 19					513 336	1 1	skolalak skolalak
10	4.5	r0	20	<u>ac</u>	c i		20		10					226	-	solololok