

Computer Aided Pulsator Control in Milking Systems

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Abstract: In this study, a computer based system was developed for controlling the electronic pulsators used in milking. By changing parameters of the pulsation rate and pulsator ratio, pulsation characteristics were measured at different vacuum pressures using a written software. The pulsation rate between 40 - 70 min⁻¹, pulsator ratio between 50 - 75 % and vacuum pressure between 40-60 kPa were altered in experiments. The limping was remained in the level of 0.1 % in nominal operating conditions (50 kPa, 60 min⁻¹ and 70 %). The greatest limping value was measured as 2.9 % in determined trial intervals. As a result, the pulsation characteristics of the control system were obtained as mentioned in international standard.

Key Words: Pulsator, computer aided control, pulsation ratio, pulsation rate, limping

Süt Sağım Sistemlerinde Bilgisayar Tabanlı Pulsatör Kontrolü

Özet: Bu çalışmada, süt sağımında kullanılan elektronik pulsatörlerin kontrolü için bilgisayar tabanlı bir sistem geliştirilmiştir. Geliştirilen yazılımla nabız frekansı ve nabız oranı parametreleri değiştirilerek, farklı vakum basınç değerlerindeki pulsatör karakteristikleri ölçülmüştür. Denemelerde nabız frekansı 40-70 min⁻¹, nabız oranları % 50-75 ve vakum basıncı 40-60 kPa aralıklarında değiştirilmiştir. Nominal işletme koşullarında (50 kPa, 60 min⁻¹ ve %70) aksama % 0.1 düzeyinde kalmıştır. Belirlenen deneme aralıklarında aksamanın en büyük değeri % 2.9 olarak ölçülmüştür. Sonuç olarak geliştirilen kontrol sisteminin uluslararası standartlarda bildirilen pulsasyon karakteristiklerini sağladığı belirlenmiştir.

Anahtar Kelimeler: Pulsatör, bilgisayar tabanlı kontrol, nabız oranı, nabız frekansı, aksama

Introduction

The basic requirements for the construction and performance of milking machines for animals are determined by physiology of the animal and the need for a high standart of hygiene and milk quality. In addition, the equipment must be effective and easy to use and test (ISO 5707, 1996).

Pulsator is one of the most important element of milking vacuum systems. There are four types: mechanic, hydrolic, pneumatic and electronic. Some electronic milking systems include a centrally pulsator control unit (Cant ve Reitsma, 1979).

The pulsation is cyclic opening and closing of a teatcup liner. Pulsation rate is the number of pulsation cycles defined as one complete liner movement sequence per minute. Pulsator ratio is one of the most important parameters in pulsation system. The pulsator ratio is duration of the increasing vacuum phase and maximum vacuum phase as a percentage of the complete pulsation cycle in the pulsation chamber vacuum record. Each cycle of the record of pulsation chamber vacuum consists of four phases (ISO 3918, 1996):

- Increasing vacuum phase (a),
- Maximum vacuum phase (b),
- Decreasing vacuum phase (c),
- Minimum vacuum phase (d).

The duration of each phase as a percentage of the total cycle time is measured between the points at which the record intersects abscissae drawn at 4 kPa below nominal working vacuum and above atmospheric pressure (Figure 1).

The pulsator ratio (PR) is expressed by the following formula (ISO 3918, 1996) :

$$PR = \frac{a+b}{a+b+c+d} \times 100 \quad (1)$$

where, "a+b" : expansion time (milking phase),
 "c+d" : compression time (massage phase),
 "a+b+c+d" : total cycle time.

The pulsator ratio should be within ± 5 units of percentage of the value stated by the manufacturer. Phase "d" of the pulsation chamber vacuum record should be not values either less than 15 % or less than 150 ms. Phase "b" of the pulsation chamber vacuum record should be not less than 30 % (ISO 5707, 1996).

On the other hand, "a+b", "b" and "d" phases and pulsation rate have to be changed according to race, age, health and lactation time of the cow.

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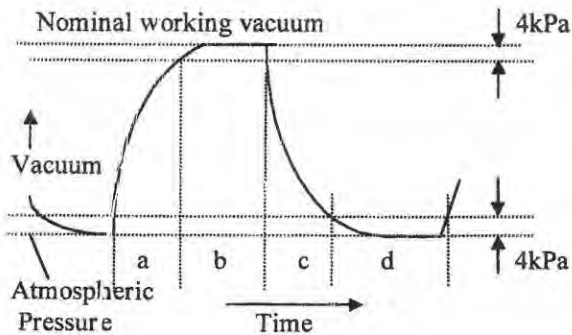


Figure 1. Pulsation chamber vacuum record (ISO 3918, 1996)

In pulsating, alternatively, the limping is a number, expressed in percentage, indicating the unintentional difference between the pulsation ratios of an alternating pulsator (ISO 3918, 1996).

In this study, a computer controlled system was developed. The solenoid valves were used in electronic pulsators operated by a microcomputer. The set and measured values of pulsation rate and pulsator ratio were investigated under different vacuum pressures. From these values, limping parameters were observed. Furthermore, characterizations of maximum and minimum vacuum phases were inspected. The milking was also aimed by means of computer control in the feeding system controlled by computer with this way.

Material and Method

To control the pulsator in the milking system, programmable parallel interface card was connected to the expansion slot of the computer. The control hardware consisted of 8255 programmable parallel peripheral interface (PPI), 74LS85 magnitude comparator, 74LS138 decoder, two transistors and solenoid valves (Figure 2).

In Figure 2, 74LS85 compares the data coming from the expansion bus of the computer against a reference level and sends to decoder (74LS138) to convert the signal. The converted data is sent from output bits (PA1 and PB1) of PPI (8255) to the solenoids for setting desired value through the transistors.

Alfatronic tester Mk IV used for experimental measurements was shown in Figure 3 and its technical parameters are given in Table 1. This tester has two channels (Ch1 and Ch2) to record data coming from pulsation chambers.

Pulsation rate and pulsator ratio were entered as input to the computer. Vacuum pressure was adjusted at different values by vacuum gauge. Data were recorded by using tester.

The automation system was tested for some pulsation characteristics. Vacuum pressures were considered to be 40, 45, 50, 55 and 60 kPa. Set values of pulsation rates were 40, 50, 60 and 70 min^{-1} , and pulsator ratios were 50, 55, 60, 65, 70 and 75 %.

Results and discussion

Both the set values and the records of tester on pulsation rate, pulsator ratio and limping values are given in Table 2. The set values were compared to the recorded values from the tester.

For example, in Table 2, the limping value was 0.1 % under vacuum pressure of 50 kPa, pulsation rate of 60 min^{-1} and pulsator ratio of 70 %. In the experiment, even though the limping mentioned as at most 5 % by ISO 5707, the limping was not higher than 2.9 %, majority close to zero.

When the set pulsation rate and pulsator ratio were compared to the measured values, under the same conditions, they were determined as 59.6 min^{-1} and 69.1 %, respectively.

Table 1. Technical parameters of Alfatronic Tester Mk IV

Pulsation rate (P)	30<P<80	$\Delta P \pm 0.3 \text{ min}^{-1}$
	80<P<120	$\Delta P \pm 0.5 \text{ min}^{-1}$
	120<P<199	$\Delta P \pm 0.8 \text{ min}^{-1}$
Vacuum level	$\pm 1 \text{ kPa}$	
Measurement range	25<P<300 min^{-1}	
Maximum vacuum	100 kPa	
Measuring condition	-5 °C...+40 °C	
Recorded channel number	2 (Ch1, Ch2)	

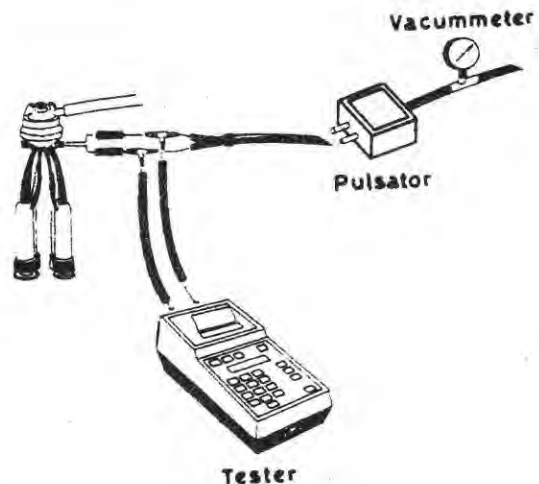


Figure 3. Pulsator tester and its connections to teatcup

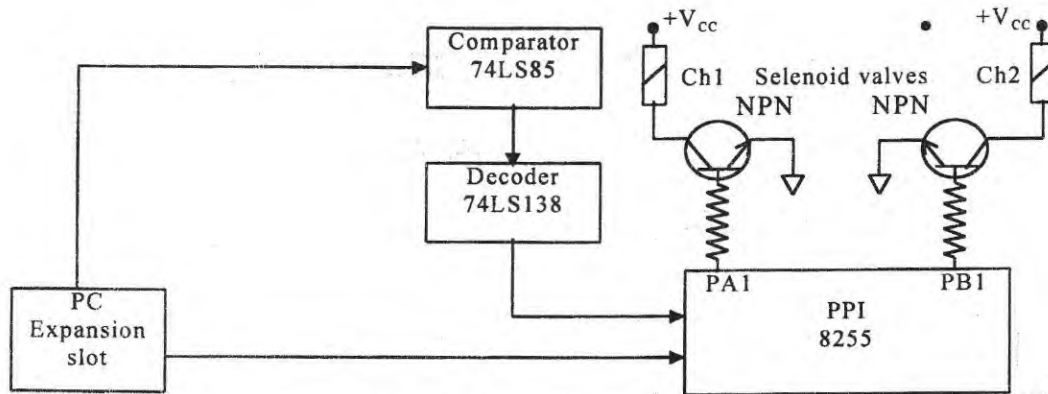


Figure 2. Simplified scheme of control hardware

In Table 3, the rates of maximum vacuum phase (b) of channels (1 and 2) were given according to different pulsation rate and pulsator ratio and vacuum pressure. For the set values taken into consideration in the previous example for Table 2, the percentages of maximum vacuum phase of channel 1 and 2 are 50.9 % and 51.0 %, respectively. From experimental records, the maximum vacuum phase (b) was generally higher than 30 %, but there were some extreme values as marked in Table 3.

It can be concluded that the higher values of pulsation rate, pulsator ratio and vacuum pressure would provide maximum vacuum phase (b) less than 30 %. However, this working conditions are not generally used in reality.

Pulsator characteristics in various vacuum pressures (40, 50 and 60 kPa), pulsator ratio (70 %) and pulsator rates (40, 50, 60 and 70 min^{-1}) were given in Figure 4.

Figure 4 illustrates the changes in period of the expansion time and cycle time with respect to vacuum level for channel 1 and channel 2. As the vacuum level of two of teatcups falls down, another channel rises up, which indicates the expansion and compression phases of teatcups.

The rates of minimum vacuum phase (d) of channel 1 and 2 are given in Table 4. For example, the percentages of minimum vacuum phase of channel 1 and 2 are 20.3 % and 19.7 %, respectively. The experimental

results indicated that the majority of minimum vacuum phase was higher than 15 %.

Conclusions

1. From the experimental results, it is evident that the developed pulsation system is more effective than the conventional system.
2. The suitable pulsation characteristics could be adjusted depending on features of cows.
3. If there are a number of pulsators, they could be simultaneously and independently controlled from a central unit by changing set pulsation rate and set pulsator ratio
4. In all conditions, limping was found within values the given in standard
5. Pulsation characteristics were not dependent on the system pressure.
6. In all conditions, pulsation rate had a high stability.

Table 2. Set and measured values of pulsation rate and limping parameters in different vacuum pressures
 P pulsation rate (min^{-1}), PR set values of pulsator ratio (%), PR_1 measured pulsator ratio of channel 1 (%),
 L Limping (%)

Set Values		Vacuum Pressures (kPa)														
P	PR	40			45			50			55			60		
		P	PR_1	L	P	PR_1	L	P	PR_1	L	P	PR_1	L	P	PR_1	L
40	50	39.8	49.5	0.1	39.7	49.3	0.3	39.8	49.3	0.1	39.8	49.4	0.0	39.7	49.3	0.3
	55	39.8	54.4	0.1	39.8	54.3	0.0	39.7	54.1	0.3	39.7	54.2	0.1	39.8	52.4	1.6
	60	39.8	59.4	0.0	39.8	59.2	0.3	39.7	59.3	0.3	39.7	59.2	0.1	39.7	59.2	0.2
	65	39.8	64.4	0.1	39.8	64.4	0.2	39.7	64.2	0.3	39.8	64.6	0.0	39.8	64.3	0.1
	70	39.7	69.4	0.1	39.8	69.5	0.1	39.8	69.4	0.1	39.8	69.3	0.1	39.8	69.3	0.1
	75	39.8	74.5	0.1	39.7	74.4	0.1	39.8	74.3	0.2	39.8	74.5	0.2	39.8	74.5	0.1
50	50	49.7	49.3	0.1	49.7	49.1	0.2	49.8	49.3	0.0	49.7	49.5	0.3	49.7	49.1	0.2
	55	49.7	54.1	0.0	49.7	54.1	0.1	49.8	54.1	0.0	49.7	53.1	0.9	49.7	54.1	0.2
	60	49.7	59.1	0.3	49.8	59.0	0.2	49.7	59.2	0.1	49.7	59.2	0.1	49.8	59.0	0.2
	65	49.7	64.3	0.0	49.8	64.0	0.3	49.7	64.2	0.2	49.7	64.3	0.0	49.7	63.9	0.2
	70	49.7	69.3	0.0	49.8	69.2	0.0	49.7	69.0	0.4	49.7	69.2	0.0	49.7	69.0	0.2
	75	49.7	74.3	0.1	49.7	74.3	0.1	49.7	74.3	0.2	49.7	74.1	0.3	49.7	74.2	0.0
60	50	59.6	49.1	0.0	59.6	48.9	0.0	59.6	49.1	0.1	59.6	49.0	0.2	59.6	49.0	0.0
	55	59.6	54.1	0.1	59.6	53.9	0.1	59.6	53.8	0.2	59.6	53.2	0.8	59.7	53.8	2.2
	60	59.6	59.0	0.0	59.6	58.9	0.1	59.6	58.7	0.3	59.7	58.8	0.2	59.6	58.9	0.3
	65	59.6	64.1	0.2	59.6	64.0	0.3	59.6	63.9	0.1	59.6	63.8	0.0	59.6	63.7	0.2
	70	59.6	69.1	0.1	59.6	69.0	0.2	59.6	69.1	0.1	59.6	68.8	0.4	59.6	68.8	0.1
	75	59.6	74.3	0.1	59.6	74.3	0.3	59.6	74.0	0.3	59.6	74.0	0.3	59.6	74.0	0.3
70	50	69.5	48.8	0.0	69.5	48.9	0.0	69.6	48.8	0.1	69.5	48.7	0.3	69.5	48.9	0.2
	55	69.7	53.4	0.0	69.8	53.6	0.2	69.6	53.5	0.2	69.6	53.5	0.0	69.6	53.7	2.9
	60	69.7	58.8	0.1	69.6	58.5	0.3	69.6	58.5	0.2	69.7	58.7	0.0	69.6	57.4	1.2
	65	69.7	63.8	0.0	69.6	63.8	0.2	69.7	63.8	0.2	69.7	63.6	0.0	69.8	63.7	0.0
	70	69.7	68.9	0.2	69.7	68.6	0.2	69.7	68.8	0.1	69.6	68.6	0.2	69.7	68.6	0.1
	75	69.7	73.6	0.2	69.6	73.5	0.5	69.6	73.5	0.3	69.8	73.6	0.2	69.6	73.5	0.0

Table 3. Maximum vacuum phase of Ch.1 and maximum vacuum phase of Ch.2 values b_1 , maximum vacuum phase of channel 1 (%), b_2 maximum vacuum phase of channel 2 (%), and * values < 30 %

Set Value		Vacuum (kPa)									
P	PR	40		45		50		55		60	
		b_1	b_2	b_1	b_2	b_1	b_2	b_1	b_2	b_1	b_2
40	50	38.9	39.1	37.8	38.3	36.4	36.6	35.2	35.3	34.6	34.4
	55	44.5	44.6	43.0	43.1	42.2	42.1	40.4	40.3	35.4	36.9
	60	48.2	48.1	48.0	48.0	47.7	47.6	45.0	45.9	44.1	44.4
	65	54.6	54.7	52.9	53.1	51.8	52.1	50.9	50.9	48.3	48.2
	70	59.3	59.7	57.6	58.1	56.8	57.0	55.5	55.5	54.4	54.2
	75	65.4	65.0	62.7	62.8	61.8	62.0	61.0	60.6	59.4	59.5
50	50	37.0	36.8	35.1	35.3	33.9	34.3	32.6	32.6	30.0	30.2
	55	41.5	41.5	39.5	39.5	38.1	38.7	35.6	37.4	33.2	35.8
	60	47.1	47.5	46.5	46.8	43.7	43.6	41.9	43.0	40.2	40.3
	65	51.5	52.4	47.8	51.0	47.8	47.9	47.7	47.5	46.6	44.7
	70	56.9	57.3	55.1	55.5	54.4	54.8	52.2	52.6	49.7	50.0
	75	62.2	62.3	60.2	60.7	59.9	59.7	56.8	57.4	55.2	55.3
60	50	33.7	34.4	31.4	32.1	30.3	31.2	28.7*	29.3*	28.6*	26.9*
	55	41.1	40.4	37.5	37.4	35.7	36.4	32.8	33.6	31.0	33.1
	60	46.2	45.5	41.9	42.1	41.7	41.5	39.1	38.4	30.0	36.9
	65	47.9	48.6	46.9	46.9	46.5	46.4	44.6	42.9	42.3	42.4
	70	54.7	54.3	52.8	53.0	50.9	51.0	47.4	48.5	46.8	47.0
	75	59.1	59.3	57.3	57.5	55.4	57.1	53.8	54.2	52.4	52.8
70	50	30.9	31.4	29.5*	29.7*	28.2*	28.4*	25.3*	26.1*	25.6*	25.0*
	55	35.5	35.5	34.5	34.3	33.3	33.1	31.1	30.4	26.7*	29.2*
	60	40.8	40.8	39.4	39.7	38.5	37.8	35.8	35.5	31.0	29.5*
	65	46.1	46.6	45.8	46.4	43.1	41.8	40.7	40.7	36.7	36.3
	70	51.0	51.3	48.2	49.6	46.7	47.0	45.9	46.4	43.9	43.2
	75	56.3	56.7	54.2	55.3	52.3	54.2	50.5	50.8	47.1	49.2

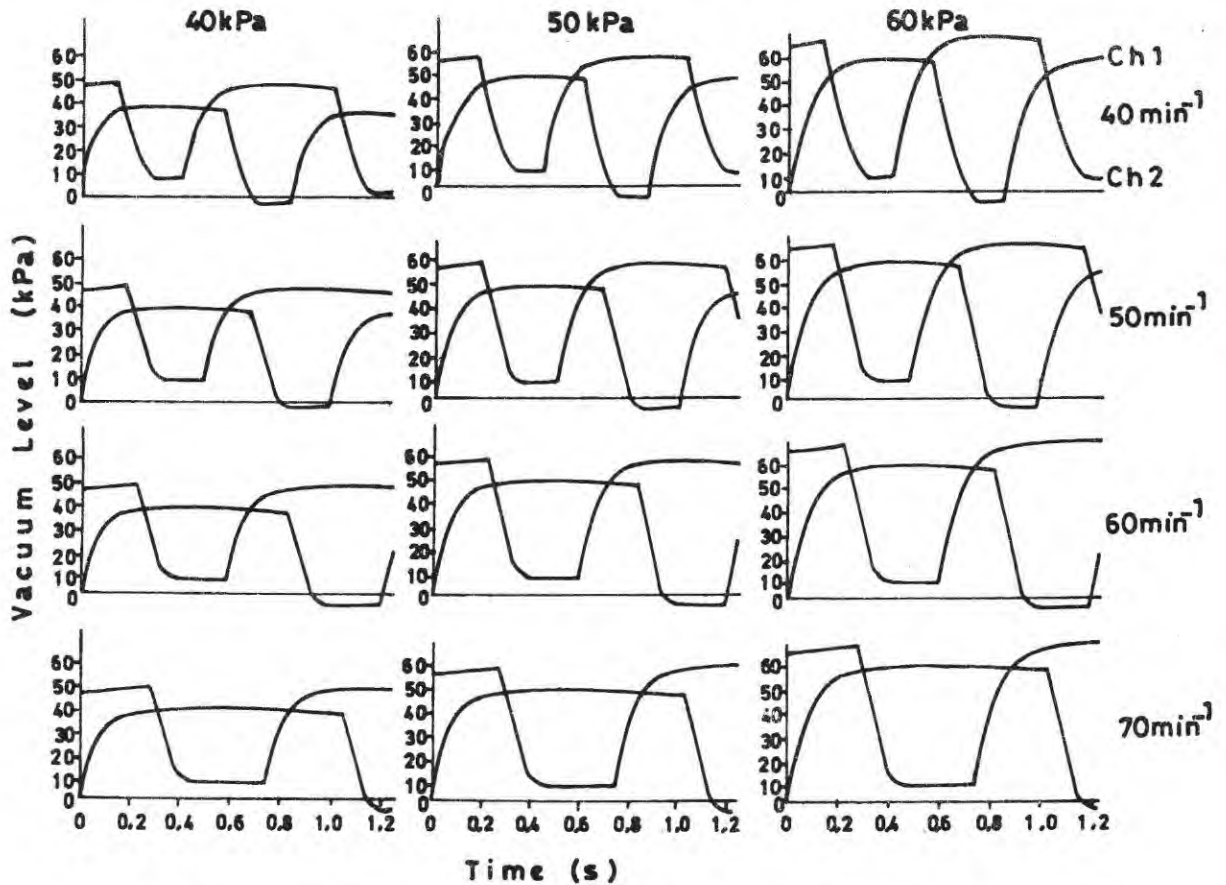


Figure 4. Pulsator characteristics at various vacuum pressures and pulsation rates

Table 4. Minimum vacuum phase of Ch.1 and minimum vacuum phase of Ch2. values, d₁ minimum vacuum phase of channel 1 (%), d₂ minimum vacuum phase of channel 2 (%), and * values either less than 15 % or less than 150 ms

Set Values		Vacuum (kPa)									
P	PR	40		45		50		55		60	
		d ₁	d ₂	d ₁	d ₂	d ₁	d ₂	d ₁	d ₂	d ₁	d ₂
40	50	44.0	43.6	43.6	43.2	43.5	43.0	42.8	42.4	42.6	42.1
	55	39.1	38.9	38.8	38.5	38.7	38.3	38.1	37.8	38.1	37.7
	60	34.0	33.8	33.8	33.5	33.5	33.0	33.0	32.6	32.9	32.2
	65	29.0	28.7	28.7	28.3	28.3	28.0	27.9	27.4	27.6	27.2
	70	24.0	23.8	23.5	23.1	23.3	23.0	22.9	22.5	22.6	22.3
75	19.0	18.7	18.5	18.1	18.4	18.0	17.8	17.5	17.4	17.1	
50	50	42.5	42.2	42.3	41.4	41.7	41.2	40.8	40.6	41.0	40.1
	55	37.9	37.6	37.4	37.3	37.2	36.7	36.6	36.1	36.4	35.6
	60	32.7	32.3	32.3	31.8	31.7	31.6	31.3	30.9	31.3	30.7
	65	27.6	27.3	27.2	26.7	26.9	26.3	26.3	25.7	26.3	25.5
	70	22.5	22.4	22.1	21.6	21.8	21.4	21.3	20.6	20.9	20.4
75	17.5	17.2	17.1	16.7	16.7	16.3	16.1	15.7	15.9	15.1	
60	50	41.2	40.9	40.7	40.3	40.2	39.5	39.5	39.1	39.3	38.4
	55	36.5	36.2	36.2	35.5	35.7	35.0	35.2	34.5	34.7	34.0
	60	31.3	31.0	30.9	30.5	30.4	29.9	30.0	29.3	29.9	29.0
	65	26.2	25.8	25.5	25.2	25.3	24.8	24.8	24.3	24.5	23.9
	70	21.3	20.8	20.6	20.3	20.3	19.7	19.7	19.0	19.4	18.7
75	16.2	15.7	15.5	15.0	15.3	14.5*	14.5*	13.7*	14.2*	13.1*	
70	50	39.5	39.6	39.2	38.4	38.6	37.8	37.9	36.8	37.5	36.8
	55	35.1	35.2	34.7	34.0	34.1	33.6	33.4	32.8	33.4	32.0
	60	30.1	30.0	29.6	28.9	29.1	28.7	28.6	27.8	27.0	27.3
	65	24.9	24.5	24.4	23.9	23.8	23.1	23.3	22.6	21.9	21.9
	70	19.7	19.4	19.0	18.8	18.8	18.1	18.2	17.4	16.5	17.4
75	14.9*	14.5*	14.2*	13.3*	13.7*	13.2*	12.9*	12.1*	11.5*	12.9*	

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