APPLICATION NOTES

MODEL 122
ETCHANT CONTROL

MODEL 123
ACID ETCHANT CONTROL

OPTROL

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1. Introduction

1.1 Description — Model 122/123

The Model 122/123 Etchant Control contains a hydrometer to measure etchant specific gravity. Electronics in the control read hydrometer position, encode the information, and transmit it to the PLC as digital TTL signals.

1.2 Principle of Operation — Model 122/123

The Control consists of two compartments, one wet and one dry. The wet compartment contains a hydrometer which responds to etchant density. Hydrometer motion is transmitted by a pivoted beam through a isolating elastomeric diaphram into the dry compartment. A moveable balance weight on the beam mechanically sets the operating solution density (set point) at which the beam is horizontal. Optical sensors in the dry side frictionlessly detect pivot beam position and thus hydrometer position. The position sensor is an optical encoder which passes between light emitting diode-phototransistor pairs to cut the infrared beams passing between them.

During operation the etchant continuously flows into the bottom of the wet inner chamber, over the dam and out the wet chamber drain. Changes in etchant density cause the float to move up or down. A drain fitting on the bottom allows the inner chamber to drain when the etchant supply turns off. The gas bubbles in the solution leave the wet chamber through a vent pipe on the bottom of the Control unit. The encoder can measure deviations as much as ±1.9 degrees Baumé from the set point. The encoded hydrometer deviation information is produced as binary coded decimal data at TTL outputs.

The design and materials of the Model 122 Etchant Control have been specifically tailored to withstand the attack of ammoniacal etchant and give accurate data in spite of the effervescent gas bubbles it normally contains. Similarly, the Model 123 has been specifically designed to withstand the attack of 30% nitric acid.

1.3 Performance Capability — Model 122/123

The Model 122/123 Etchant Control can hold the density of the etchant in its measuring chamber within ±0.1 degree Baumé of the set point if the etcher replenishment feed pump and sump mixing pumps are large enough to keep up with the work load. With the unit correctly standardized and a digital display provided, the set point Baumé value will read correctly ±0.1 degree. Other displayed values above and below the set point will be accurate within ±2% of reading.

2. Signal Levels and What They Mean

2.1 SIGNALS Model 122/123

The power supply and digital TTL signals are transmitted to and from the Model 122/123 via an 11-conductor cable attached to the 120-11 circuit board. Each power and signal line is discussed in the sections that follow. Table 2.1 summarizes the signals and corresponding wire color.

POWER	SIGNALS									
16-40Vdc	Gnd	A	B	C	D	E	F	Pump	Limit	High-Level
red	green	blue	orange	yellow	violet	gray	pink	black	brown	white

Table 2.1 Summary of signals and wire colors on the 11-conductor cable.

2.1.1 Data Lines Model 122/123

The data lines, A - F, represent the float position in a binary coded decimal (BCD) number with A being the least significant bit (LSB). A TTL low voltage level on any of these lines indicates that the bit is true. The bits are arranged such that D, C, B, and A represent the tenths digit and F and E represent the units digit of the Baumé density number. A one unit change of float position signifies a one degree Baumé change in density or a 0.01 change in specific gravity.

Example:

F	E	D	C	B	A	BCD Equivalent
1	1	0	1	1	0	===> 0.9
0	0	1	1	0	1	===> 3.2

2.1.2 Pump Model 122/123

When the data lines read 2.0 and higher, a TTL high voltage level (2-5Vdc) on the PUMP line is produced, indicating that the pump should be on. When the data lines read 1.9 and lower, a low voltage level (0.2-0.8Vdc) is produced, indicating that the pump should be off.

2.1.3 Limit Model 122/123

A high voltage level on the LIMIT line indicates that the encoder card is within its valid data region. A low voltage level indicates that the card and hydrometer float are out of range.

2.1.4 Gnd Model 122/123

This is the common ground connection for the 120-11 circuit.

2.1.5 High-Level Model 122/123

As shipped, the high-level line is configured to provide +5Vdc to the pull-up resistors in the output circuitry. This voltage also appears on the white lead of the 11 conductor cable. It is used to supply +5Vdc, up to 350mA, to a PLC TTL input module. If the PLC in use requires a different level for the pull-up resistors, first cut the jumper J1 on the 120-11 circuit board, and then connect the white lead to a source of the required level.

2.2 POWER SUPPLY

2.2.1 +24Vdc Model 122/123

This is the nominal input voltage to the 120-11 circuit. The circuit will function satisfactorily with stable input voltages of 16 to 40 Vdc.

3. Installation

3.1 Location Model 122/123

The Etchant Control must be securely mounted to a vertical surface with the drain high enough above the etcher sump to allow proper drainage. The top of the Control must be level. Figure 3.1 shows the overall dimensions for the Model 122/123 Etchant controller.

Model 123

WARNING -- The acid etchant solution in the wet side of the Model 123 Control and in the inlet and drain tubes is very hazardous. It can cause blindness and severe skin burns. Eye and skin protection MUST be used. Tubes and their fittings may drip or even split. The wet chamber vent will overflow acid solution if the drain tube is blocked. Control of any possible acid spill must be considered when locating the Control unit. Do not in any circumstances mount the Control where a solution leak could cause damage or injury.

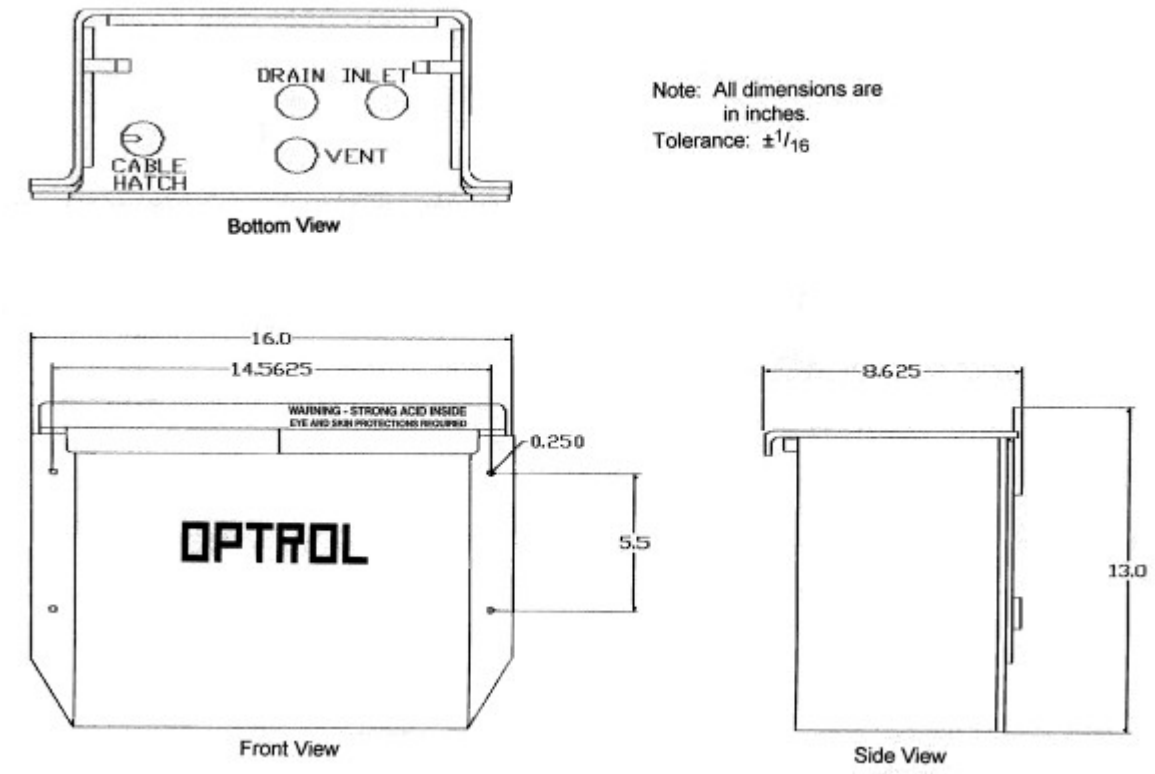

Figure 3.1 Dimensions of the Model 122/123 Etchant Control (Model 123 shown)

3.2 Mounting Model 122/123

Mount the Etchant Control securely to a vertical surface using corrosion resistant bolts through the mounting flanges on the sides of the unit. Four ¼ inch flange holes are provided (see figure 3.1). Shim between the mounting flanges and "vertical" surface as required to give a secure mount and make the top of the Etchant Control level. Remove the covers and carefully take the packaging material out from around the dry chamber pivots and from the float in the inner wet chamber. Replace the left cover to prevent etchant droplets from settling on the circuit board in the dry chamber.

3.3 Plumbing Connections Model 122/123

Use ¼ inch high pressure plastic tubing to connect between the etch machine spray manifold and the Etchant Control inlet at the bottom of the inner chamber. Make sure connections are secure and tube routing will not be subject to damage or cause a hazard. Use ¾ inch plastic drain hose or pipe to connect the drain on the bottom of the Etchant Control to the etcher sump. Make sure the drain routing always slopes away from the Control and does not cause a hazard. If the drain is allowed to sag so that the etchant must flow uphill in some section, then a trap is formed

which can become plugged. Turn on the etcher spray pump and observe the time required to fill the inner chamber to overflowing. If it is less than 20 seconds, reduce the flow by increasing the length of ¼ inch tubing used. If the fill time is over two minutes, then increase the flow by shortening the tubing used, changing the tap location on the etcher, or by using appropriate adapters and a larger diameter high pressure tubing. Carefully observe all plumbing connections and correct any leaks found. Turn the etcher off. The vent pipe on the bottom of the Etchant Control releases the gas from the bubbles in the solution entering the Control. The vent can ordinarily simply vent to the room air, but if desired it can be indirectly connected to the etcher venting system. Do not simply run a closed tube from the Control vent to the etcher vent vacuum. The vacuum created in the Control could distort the elastomeric diaphram and cause problems. Indirect venting in which a tube connected to the vent vacuum draws room air past the open end of the Control vent pipe can be used.

3.3.1 Clean Air Flush Model 123

The acid fumes from solder stripper have been found to sometimes attack the circuit board on the dry side even though the board is conformally coated and the sealed lid is in place. The dry side breathes thru the small hole in the cable clamp to be able to adjust for changes in ambient air pressure in the room. If there is any acid vapor in the region of the dry side vent hole it will be drawn in when the control cools or barometric pressure rises. If fitting drips are falling into the drip tray this provides a nearby acid vapor source. Also if the control is ever operated with both lids off during service or adjustment small acid droplets will enter the dry side to slowly evaporate releasing acid vapor. Acid on operator gloves when adjusting the set point will also contaminate the dry side. Since it is virtually impossible to guarantee that acid droplets or vapor will never enter the dry side, it has been found necessary to flush the dry side continuously with clean air to dilute and drive out the acid vapor. To provide this air flush a clean source of low pressure air is to be connected to the 1/4 inch fitting on the bottom of the dry side of the controller. Be very careful to connect only air and **not** **solution** to this fitting. The procedure is as follows:

1) Connect a pressure regulated clean air supply at any pressure between 1 psi and 5 psi guage to the air flush adapter 1/4 inch fitting using 1/4 inch polyethylene tubing. The air flush unit has a 1/16 inch diameter flow restrictor orifice at the bottom just above the 1/4 inch fitting which gives proper flow for any pressure between 1 and 5 psi and any length of tubing between 10 and 100 feet. The resulting flow rates will be between 4 and 16 liters per minute. The air supply must be on at all times, even when the plant is shut down for vacation.
2) Place a small scrap of circuit board in the bottom of the dry side to warn if the flow is interrupted by a failure of the air supply or trash plugging the 1/16 inch orifice.

3) Replace the dry side lid.

4) Instruct plant maintenance to periodically examine the test scrap for corrosion to detect air flow interruptions before the conformally coated operating circuit board can be damaged by fumes.

Replace the right cover, remove the left cover and turn on the etcher spray pump. With etchant in the solution chamber press down on the beam to make the encoder pass through the slot in the circuit board. Check to make sure the encoder is vertical, approximately centered in the slot, and swings freely without rubbing on anything. If the encoder is not vertical, loosen the encoder set screw which fastens the encoder bracket to the beam, twist the encoder to vertical, and tighten the set screw. Do NOT loosen the bottom screw which clamps the encoder to the encoder bracket. If the bottom screw is loosened the encoder alignment procedure in section 5.3 must be performed. The position of the encoder in the circuit board slot can be adjusted if necessary by loosening the screws which hold the circuit board. Position the board, re-tighten the screws, and replace covers. Turn the etcher spray pump off.

4. Suggested Programming for PLC

4.1 AUTO/MANUAL SWITCH Model 122/123

It is beneficial to provide the operator with a means to switch modes of operation of the etcher replenisher pump(s). The easiest way to accomplish this is to provide a 3-position switch. In the OFF position, power to the Model 122/123 and replenisher pump(s) is off. This mode of operation is useful for changing supply drums, when the pump(s) has to be off so as to not draw air. In The MANUAL position the replenisher pump(s) run continuously without any control from the Model 122/123. In the AUTO position the automatic control of the Model 122/123 is activated and replenisher pump(s) will be cycled on and off as needed to maintain the density as determined by the set point of the Model 122/123. This would be the normal mode of operation. It follows that an indicator should be provided to inform the operator of the present control mode and to call special attention to MANUAL operation.

4.2 PUMP DELAY TIMES Model 122/123

In order to avoid damage to and minimize wear on pump motors and relays caused by excessive rapid cycling on and off, it is beneficial to have a short delay programmed into the system. A 2 to 3 second delay between the time the pump line on the 120-11 goes high and the time the pump motor starts will help avoid these problems. Additionally, once the pump(s) is indeed powered it should run for at least 10 to 15 seconds before disengaging.

4.3 POSSIBLE PLC DISPLAY MODES

4.3.1 Minimal Display Model 122/123

Pump on/off indicator: Informs the operator that the Model 122/123 or MANUAL switch has turned on the pump.
High Density Indicator: Informs the operator that the density has risen more than about 0.2 degrees Bé above the set point. Use logic in PLC program to detect this condition.

Low Density Indicator: Informs the operator that the density has fallen more than about 0.2 degrees Bé below the set point. Use logic in PLC program to detect this condition.
Auto/Manual Mode Indicator: Informs operator of present control mode. See section 4.1.
Alarm: Alerts operator to problems. Alarm condition should exist when: 1) Low density is detected, 2) Pump(s) has run continuously for longer than 5 minutes, 3) High density has been detected and the replenisher pump(s) is not powered.
Alarm Cancel: Provides operator with a means to cancel alarm for 5 minutes only while problem is corrected.

4.3.2 Standard Display — Model 122/123

All the features of Minimal Display, plus:
Digital density display: Informs operator of actual etchant density in degrees Baumé or specific gravity. As shipped from the factory, the Model 122/123 encoder BCD TTL outputs report the density as 0.0 when the float is all the way down, to 3.9 when the float is all the way up. Since this scale does not match the density values for the solution, you must add an offset to the values read by the Model 122/123 to compute the displayed Baumé or specific gravity number. The BCD set point is 1.9. To determine the offset for your system, see section 5.1.
Over-range/Under-range Indicator: Provides a means to alert the operator that the controller is no longer in the valid range. Use the Pump and Limit lines as follows to detect over/under range condition.

Over-range (high limit): Pump=high AND Limit=low
Under-range (low limit): Pump=low AND Limit=low

An alternate method to display the over/under range condition is to blank the digital density display when the over or under range condition occurs.

4.3.3 Advanced Display — Model 122/123

All the features of Standard Display, plus:
Deviation from set point: Allows operator to see how far from the set point the density balance is, in degrees Baumé or specific gravity. Use PLC program logic to subtract 1.9 from the encoder BCD output of the Model 122/123 and display the difference obtained.
Diagnostic statements: The system would display any trouble situations when detected and also provide possible corrective actions to take. Use PLC programming to create a database of problems and possible solutions to be displayed when the corresponding conditions exist. Use Table 4.3.3 as a guide.

Table 4.3.3 Process monitor functions Model 122/123

AUTO	PUMP	HIGH	LOW	ALARM	SITUATION DETECTED AND possible corrective actions
on					NORMAL OPERATION, ETCHANT DENSITY IN BALANCE no action required
on	on				NORMAL REPLENISHER FEED no action required
on	on			on	INSUFFICIENT REPLENISHER REACHING SUMP AND PUMP HAS RUN MORE THAN 5 MIN. CONTINUOUSLY check replenisher supply, plumbing, pump, pump size
on	on	on	on		INSUFFICIENT REPLENISHER REACHING SUMP, PUMP HAS RUN 5 MIN. AND DENSITY IS 0.3 DEGREES BAUMÉ ABOVE SET POINT check replenisher supply, plumbing, pump, pump size
on		on		on	DENSITY ABOVE SET POINT BUT PUMP NOT POWERED check pump relay
on			on	on	LOW DENSITY 0.3 DEGREES BAUMÉ BELOW SET POINT DUE TO: NO OR LOW SOLUTION IN CONTROL cancel alarm and wait for control tank to fill, or if that doesn't work check etchant connection to control
					ETCHER SUMP HAS BEEN OVER REPLENISHED check for excessive manual operation check for possible replenisher syphoning and if found install a check valve or a syphon vacuum break
					WATER INTRUSION INTO ETCHER check for leaks, rinse spray being drawn into etchant, or excessive water on parts being fed in
					* LARGE AMOUNT OF AMMONIUM HYDROXIDE ADDED TO SUMP correct excessive ammonia loss or use anhydrous
					* ETCHANT CONTROLLER TURNED ON DURING HEAT-UP PROCESS instruct operator
	on				MANUAL MODE OF OPERATION no action required
	on			on	MANUAL OPERATION FOR OVER 5 MIN. instruct operator

* Does not apply to Model 123

Process Data Collection: An easy and useful method to monitor the etching process over time is to implement a program for process data collection. The program would monitor and store key information from the Model 122/123 as it controls the etchant density. As more and more data is accumulated, a process history file is developed. By analyzing records, the user would be able to detect flaws in the process. Once this data is stored it can be manipulated in many ways. One could calculate various statistical values for the process, produce a graphical representation of daily operation, or simply generate a table of status information. One possible report configuration might look like the following:

Raw Data Report 07/31/97 11:25 Page 1

Date	Time	Display	Error	Standard	Alarm	Mode	Pump-on
07/09/97	14:00	25.5	0.0	25.5		A	
07/09/97	14:01	25.6	0.1			A	*
07/09/97	14:02	25.7	0.2			A	*
07/09/97	14:03	25.7	0.2			A	*
07/09/97	14:04	25.5	0.0			A	
07/09/97	14:05	25.2	-0.3		!	A	
07/09/97	14:06	25.1	-0.4		!	A	

Note the process data that is available in just these few numbers. At 0.1 error the replenisher pump turned on as it should but the Baume continued to rise and the error went to 0.2 degrees indicating that the replenisher flow rate may be a little low or that the sump mixing could be impaired a little. After the error drops back to 0.0 and the replenisher pump shuts off as it should the Baume continued to drop and the error goes to -0.4 degrees indicating that the replenisher just added is finally being mixed in the sump. From these numbers it is likely that the etcher's mixing pump needs attention.

5. Service Procedures

5.1 Installation Checkout Model 122

Power up the etcher system. If the starting etchant density is above the set point, the replenisher pump(s) will run until the controller is satisfied. When the controller turns off the pump(s), the etchant density in the sump can be measured with an accurate, expanded scale hydrometer. The hydrometer should read between 20 and 30 degrees Baumé with 0.1 degree resolution. The density thus measured is the controller's set point. Determine this difference (offset) between the measured value and the encoder set point of 1.9. The PLC program setup must add the difference value to the Model 122 encoder output to generate a correct digital Baumé display. If the starting density is below the set point, then some work will have to be fed through the etcher until the replenisher pump(s) begin to cycle on and off. The set point of a virgin controller, as shipped, is about 24.7 degrees Baumé and will drift up about 1 degree during the first few hours of use as the plastic surface of the float cures in the etchant and fewer bubbles cling to it. After curing, the set point stabilizes and the performance outlined in section 1.3 will be obtained. For an actual set point display of 25.7 degrees Baumé, the PLC must add 23.8 to the 1.9 BCD number from the Model 122 encoder. To change the set point, refer to section 5.2.

Follow the same procedure as described above for measuring the solution density in the sump. The hydrometer should read between 25 and 35 degrees Baumé with 0.1 degree resolution. The set point of a virgin controller,as shipped, is about 31.7 degrees Baumé. For an actual set point display of 35.7 degrees Baumé, the PLC must add 33.8 to the 1.9 BCD number from the Model 123 encoder.

5.2 Set Point Adjustment — Model 122/123

Remove the left (dry) compartment cover of the Etchant Control. The PVC weight between the optical encoder and the pivot assembly is used to adjust the set point. Moving the weight one inch toward the optical encoder lowers the set point about 3 degrees Baumé. To move the weight loosen its set screw, slide the weight to the desired place, and tighten the screw. An auxiliary PVC weight has been provided which can be added to either the dry or wet side of the beam to increase the adjustment range. Replace any covers that have been removed. If a Baumé or specific gravity display is being used, its offset must also be set correctly. With the new set value measured using an accurate hydrometer, calculate the difference between the new measured value and the BCD 1.9 set point produced by the Model 122/123. Adjust the offset variable in the PLC program to make the display read correctly.

5.3 Encoder Alignment Procedure — Model 122/123

There are two set screws which determine the position of the encoder. The top screw controls position and twist upon the beam. The bottom screw controls tilt for proper counting. Loosen the top set screw and adjust the encoder mounting bracket to make the encoder card vertical as it swings through the slot in the 120-11 circuit board. Make sure the encoder does not rub against the edges of the slot. Move the bracket until the outside stripe runs between the outside sensor pair (left end). Tighten the set screw but don't overtighten. With the unit powered, swing the beam and monitor the encoder data output. If it counts properly in sequence up and down, no further adjustment is needed. If there are missing or out of sequence numbers while passing the encoder through the slot, then the encoder optical card tilt needs adjusting with the following procedure:

1) With the float on the bottom, look directly down along the optical card's edge checking to see that the card is centered through the slot in the 120-11 board. The set screw on the top of the card mounting bracket allows the card to be moved along the beam or twisted about it. Center the card in the slot making sure it is vertical and that the outside edge of the left most dark stripe is aligned with the silver arrow on the 120-11 circuit board (see figure 2.1.5). The card should not wander front to back in the slot as the beam is moved up and down.

2) The front to back position of the slot can be adjusted by loosening the two 120-11 circuit board mounting screws along the back edge of the board. The board can be repositioned to center the optical card in the slot front to back and side to side. With the float in its lowest position, adjust the circuit board position such that the optical card is centered in the slot and the outside edge of the left most dark stripe is aligned with the silver arrow on the 120-11 circuit board (see figure 2.1.5). When the circuit board is aligned properly, tighten the two board

mounting screws.

3) Gently raise and lower the float to make sure the optical card swings vertically and does not drag against the circuit board.

4) To adjust the tilt on the optical card toward or away from the pivots, loosen the clamping screw at the bottom of the card. Raise the float and tilt the card until the edge of the left most dark stripe aligns with the silver arrow on the circuit board (see figure 2.1.5). For proper alignment this arrow should continuously point to the stripe's edge as it passes by when the float is lowered.

5) Power up the unit. While raising and lowering the float, the BCD value should increase smoothly with no missing numbers. Look for excessive blanking, missing numbers, and reverse counting in which the BCD value goes down as the float comes up. If the encoder does not count properly, the card tilt needs to be adjusted slightly. If there are missing counts try tilting the card slightly to the right. If the count seems sluggish and fails to count as far as it should before the limit is reached, try moving the card slightly to the left.

5.4 Test Points — Model 122/123

Each signal and power supply line described above can be measured directly on the 120-11 circuit board. The best point to do so is where the cables are soldered to the circuit board. See figure 2.1.5.

5.5 Routine Maintenance — Model 122/123

The unit requires no routine maintenance. However, if the etchant is allowed to sludge in the etch machine sump then excessive sludge may also accumulate in the Etchant Control wet chamber. In that event the Etchant Control wet chamber should be cleaned. If excessive sludge has accumulated in the wet chamber then be sure the drain hole, fittings, and tube on the bottom are clear.

6.0 Baume to Specific Gravity Conversion

Specific gravity can be calculated from Baume using: (Specific Gravity) = 145 / (145 - (Baume)) or from the table below:

Degrees Baume	Specific Gravity	Degrees Baume	Specific Gravity
20.0	1.160	33.0	1.295
21.0	1.169	34.0	1.306
22.0	1.179	35.0	1.318
23.0	1.189	36.0	1.330
24.0	1.198	37.0	1.343
25.0	1.208	38.0	1.355
26.0	1.218	39.0	1.368
27.0	1.229	40.0	1.381
28.0	1.239	41.0	1.394
29.0	1.250	42.0	1.408
30.0	1.261	43.0	1.422
31.0	1.272	44.0	1.436
32.0	1.283		