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Environmental Protection Department
Waste Certification Program

A High-Sensitivity Neutron Counter
and
Waste-Drum Counting
with the
High-Sensitivity Neutron Instrument

April 1993

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A High-Sensitivity Neutron Counter

Abstract

At Lawrence Livermore National Laboratory (LLNL), a highly sensitive neutron counter was developed that can detect and accurately measure the neutrons from small quantities of plutonium or from other low-level neutron sources. This neutron counter was originally designed to survey waste containers leaving the Plutonium Facility. However, it has proven to be useful in other research applications requiring a high-sensitivity neutron instrument.

Instrument Construction

The instrument consists of two halves or units, each containing eight ^3He -filled proportional counter tubes 5.08 cm (2 in.) in diameter and 91.44 cm (3 ft) long. To maximize the sensitivity of the instrument to fission neutrons (^{252}Cf), polyethylene was placed on both sides of the tubes. Experiments determined that for fission neutrons the optimum thickness of polyethylene was 3.81 cm (1.5 in.) on the front and 11.43 cm (4.5 in.) on the back of the tubes. Strips of polyethylene 1.27 cm (0.5 in.) thick and 5.08 cm (2 in.) wide were also placed between the tubes. The polyethylene was bolted and braced onto the frame holding the tubes to strengthen the instrument so that it can be transported (see Figure 1-1).

Each of the units has its own electronics, consisting of a nuclear instrumentation module (NIM) bin, high-voltage power supply, pulse shaper, and timer/scaler. The units can be used together or separately by using only one of the timer/scalers. A rate meter was recently added that allows an operator to use a

strip chart recorder to record changes in the neutron counting rate. Special pulse size and shape circuitry and logic were designed to make the signals from the ^3He tubes compatible with the scalers.

The instrument is mounted on a wood cart. To limit sagging and bending, the cart required additional metal bracing. The cart has balloon tires that cushion the instrument to prevent possible damage to its electronics while it is being moved. There are lifting brackets on each unit, permitting the use of a hoist to remove the units from the cart if desired.

The units can be oriented to face outward for the counting of large waste containers, as shown in Figure 1-1, or they can be rotated to face each other with a minimum spacing of 42.5 cm (16.75 in.) between the polyethylene faces. When the units face each other, the solid angle for a source located between the halves is large and the counting efficiency is correspondingly high.

Figure 1-1. Photo of the high-sensitivity neutron instrument during assembly, showing the two units positioned on the cart. At the time the photograph was taken, only one unit had polyethylene surrounding the ^3He tubes. The aluminum bracing and the NIM-bin electronics for one of the units can also be seen.

Counting Rates

The instrument has been calibrated and subsequently used in a number of interesting studies. The instrument's background counting rate of cosmic neutrons varies, depending on where the instrument is being used. Table 1-1 shows the counting rates that were obtained inside various buildings at LLNL. The lowest counting rate was 108 counts per minute (cpm), observed inside the Calibration Facility cell with the door to the cell closed. When the cell door is open, the rate is 158 cpm. The increase is caused by neutrons leaking from the source storage cell located at the other end of the Calibration Facility.

Indoor Counting Rates

The counting rate inside buildings depends on the amount of shielding the building provides from cosmic neutrons. For example, Table 1-1 shows that in a building with poured concrete walls, the count rate was only 243 cpm compared with 309 cpm in a building with concrete block walls. A reading of 352 cpm was obtained in the Instrument Calibration Laboratory, which has a neutron source stored at the bottom of a calibration well. The count rate observed at the control console of the Calibration Facility was 3,810 cpm, caused by neutrons leaking through the cell door to the source storage room. Near this door the count rate was 23,800 cpm.

Table 1-1. Background counting rate with the instrument at selected locations inside buildings.

Location of measurement	cpm
Inside Calibration Facility with cell door closed	108
Inside Calibration Facility with cell door open	158
Inside a poured concrete building	243
Laboratory in concrete block building	309
Instrument Calibration Laboratory	352
Control console of Calibration Facility	3,810
Outside door of source storage room	23,800

Outdoor Counting Rates

Usually the background count rate outdoors at LLNL is about 400 cpm, although in Table 1-2 only 345 cpm was obtained near a building with poured concrete walls. The cosmic background is a function of elevation above sea level and is significantly greater at higher elevations. The high count rate observed at a distance of about 15.24 m (50 ft) from a Radiochemistry Building is due to neutrons leaking through the walls of the building. Table 1-3 shows that a PuBe source of $4.1 \text{ E}+06$ neutrons per second (n/s) was easily detected at a distance of about 64 m (210 ft) from the source. This indicates that the instrument would be useful as a survey meter to search for lost neutron sources.

Results Using Calibration Sources

Table 1-4 shows the results obtained from several neutron sources, depleted uranium metal, and plutonium. The sensitivity of this instrument is very high. It was therefore difficult to find a source with a National Institute of Standards and Technology calibration that had a small enough neutron fluence to calibrate the instrument without significant count rate losses. We used a ^{252}Cf source with a source yield of $9.73 \text{ E}+04$ n/s to obtain calibrations with the source at 2 m and also located between the units. The counting efficiency of the instrument for ^{252}Cf is 0.036% at a distance of 2 m (6.6 ft) and 7.8% with the source located between the units separated by 42 cm (16.75 in.)

The relative counting rates per source neutron given in Table 1-4 for PuLi, ^{252}Cf , and

Table 1-2. Background counting rate with the instrument at selected locations outside.

Location of measurement	cpm
Near a poured concrete building	345
Near a concrete block building	395
Driveway, away from buildings	396
Near east end of Radiochemistry Building	1,700
North of Radiochemistry Building	1,820

PuBe neutron sources indicate that the instrument is energy dependent. Because the thickness of the polyethylene on the front of each unit was selected to be optimal for ^{252}Cf , it is too thin for the higher-energy PuBe neutrons and too thick for low-energy neutrons.

The counting rate from 3 g of plutonium metal is 400 cpm/g compared to 1,030 cpm/g of plutonium oxide. We can detect quantities as small as 0.1 g of either plutonium metal or plutonium oxide in a large waste container by making a series of 4 or 6 counts of 10 minutes each on both sides of the container. This kind of measurement requires a room with a low neutron background.

Measuring Waste Containers

The original purpose for this instrument was to determine the amount of plutonium located inside a 1.22m x 1.22m x 2.13 m (4 ft x 4 ft x 7 ft) waste shipping container. Since the location of the plutonium in the box is an unknown, a realistic estimate of the error caused by variations in location was required. This was done experimentally by using a matrix of points at the center of about each 15.24 cm^3 (6.6 in.³) inside the box. The source was placed at these points and the counting rate was determined at six positions around the box. The results of this study show that when compared to the count rate obtained with plutonium uniformly distributed throughout the box, a source near the edge of the box would give high readings of up to 25% greater than correct values. A source near the

Table 1-3. Count rate of the instrument from a PuBe neutron source (4.1 E+6 n/s).

Distance to source (ft)	cpm
212	765
6	191,400

note: At a distance of 212 ft, a PuBe source of $2.1\text{ E}+6\text{ n/s}$ would have a count rate equal to the background—396 cpm.

center of the box would give readings as low as 16% below correct values.

An interesting observation (see Table 1-4) is that a 309-g piece of depleted uranium gives a counting rate of 210 cpm when placed between the two units. Normally one does not consider depleted uranium to be a neutron source, but with this instrument, neutrons from depleted uranium can be detected easily.

Conclusions

We conclude that the high-sensitivity neutron instrument has fulfilled our design goals and is well suited for the screening of low-level contamination in drums of waste.

Table 1-4. Counting rate of the instrument to several types of neutron sources (neutron background subtracted).

Neutron source	Location A ^a (cpm)	Location B ^b (cpm)
PuLi (1.63 E 6 n/s)	402,000	—
^{252}Cf (9.73 E 4 n/s)	20,800	455,000
PuBe (4.1 E 6 n/s)	606,000	—
PuBe (small wand source)	3,240	63,000
Pu metal (3 g)	—	1,200
Pu oxide (1 g)	—	1,030
Depleted U (350 g)	—	210

^a Two meters between source and units facing outward.

^b Source located between units.

Waste-Drum Counting with the High-Sensitivity Neutron Instrument

Abstract

The high-sensitivity neutron instrument described in Volume 1 of this report has been modified in order to use it as a waste-drum counter for plutonium-contaminated laboratory wastes. The sensitivity of the modified instrument is about ten times higher than the sensitivity of the x- and gamma-ray instruments previously used. This higher sensitivity enables us to count drums that contain light or bulky wastes and confirms that the drums contain less than 100 nCi/g. We can then classify such drums as low-level waste and dispose of them in a much more cost effective way.

Introduction

A drum containing plutonium waste is classified as low-level waste if the plutonium content in the drum is less than 100 nCi/g of waste. A drum filled with bulky waste, such as shoe covers or paper, has little weight, and a radiation measuring instrument must be extremely sensitive in order to detect the small amount of plutonium allowed in the drum. If it cannot be confirmed that a drum contains less than 100 nCi of plutonium, the drum must be classified as containing more than the allowable limit of plutonium. The drum must then be handled and buried using more stringent and much more expensive burial methods. Unfortunately, some of the plutonium waste drums have too little weight to be counted adequately using the existing x- and gamma-ray

detectors. The new high-sensitivity neutron counter was used to address this problem.

Calculations based on the observed efficiency of the high-sensitivity neutron instrument indicated that it could be successfully used to measure these drums. The confirmed detection limit would permit an operator to ascertain that the drums contain the allowable limit of 100 nCi/g or below. This procedure would require that the background be low and counting times fairly long. These requirements were acceptable considering the great usefulness of such measurements. Therefore, since it appeared that the neutron counter could solve a difficult counting problem, the instrument was modified for use as a drum counter.

Instrument Modifications

To keep the background counting rate low, the instrument had to be moved to a building or area with a low neutron background. The background counting rates were determined at a number of possible locations. The Laboratory's Building 334 was selected, in part because background readings in the facility were suitably low. The instrument was removed from the cart and placed onto a unistrut frame with the two halves of the instrument facing each other. The distance between the two halves is only slightly larger than the diameter of a 55-gal waste drum. A device to rotate the drum was positioned on the floor between the halves of the instrument. Measurements were made of the background counting rate. The counting rate was also measured with a ^{252}Cf source located at various positions inside a rotating drum.

To determine its effectiveness in reducing the background counting rate, polyethylene 5.08 cm (2 in.) thick was placed on the sides and over the top of the instrument. This polyethylene caused a significant decrease in the background counting rate. Because the polyethylene was effective in reducing the background, the instrument was shielded by adding 10.16 cm (4 in.) of polyethylene to the sides, over the top, and between the bottom of the

instrument and the floor. This shielding reduced the background counting rate to 1.88 cps. The scattering of neutrons inside the added shielding increased the overall sensitivity of the instrument by about 37% and made the response of the instrument more uniform when the ^{252}Cf source was placed at various positions in the test drum.

A photo of the instrument is shown in Figure 2-1. The instrument and polyethylene shielding were seismically braced. The additional polyethylene and the seismic bracing can be removed and the instrument remounted on the cart if the instrument is needed for counting large items or for use at other facilities. The electronics for the nuclear instrumentation module (NIM) bin was left in place so it can be used if needed, making the instrument more portable for field applications.

The polyethylene shielding over the top of the instrument must be removed by using the building's bridge crane. This crane and a barrel clamp are also used to load the drums as shown in Figure 2-2. The time required to remove the top shielding, change drums, and replace the shielding is about 10 minutes.

Computer and Program

The NIM-bin electronics was replaced by a personal computer that included four plug-in boards to provide the necessary counters and power supplies. Two of the plug-in additions are multiple-scaler boards that allow a person to view and record individually the counting rate of each of the sixteen ^3He tubes. The high voltage for the ^3He tubes is provided by two power supply boards designed and built at LLNL by John Thorngate.

Dr. Thorngate also wrote the computer program. A complete description of the program is included in the report, *Computer Operation of the Sensitive Neutron Counter* by John H. Thorngate and Dale E. Hankins, UCRL-ID-111749, 1992. The main menu for the program is shown in Figure 2-3. The first three menu items are used to count a drum, calibrate the instrument, and determine the background.

Figure 2-1. Photo of the instrument with the polyethylene shielding and seismic bracing installed.

Figure 2-2. Drums being loaded into the instrument using the bridge crane and a drum-lifting device. The 10.16-cm (4-in.) polyethylene top shielding has been removed and is on the cart.

The computer program provides a live display of the counting (see Figure 2-4). This display shows the count (C) and the counting rate (R) for each of the 16 ^3He tubes. The tubes are divided into two banks, A and B, and the sum of the counts and the average counting rate are shown for each bank. The total count and the average counting rate for all the tubes are shown at the right of the figure. The bar at the left displays the elapsed counting time. This display makes it possible to determine if the ^3He tubes, amplifiers, and scalers are functioning properly.

Calibration and Counting

Prior to counting a waste drum, a background count and a calibration of the instrument are required. The computer program provides the option of an immediate or delayed start for background counting. The delayed start allows background counting (usually 900 minutes) to be completed just prior to the counting of the drums. This is especially useful on week-

ends and holiday periods, when the delayed start allows the background data to be taken the night before the drum counting is to occur.

The instrument is calibrated by using a certified plutonium source (STDISO 6L). The source consists of 9.773 g of plutonium. The isotopic content is shown in Table 2-1. The neutron emission rate from the source was calculated using the values given in Table 2-2 for the neutrons/decay, the spontaneous fission neutron half-lives, and the neutron reaction rates of oxides. The calculated neutron yield of the source from spontaneous fissioning and oxide neutrons is ~105 neutrons per second per gram (n/s/g). The counting rate of the instrument with this source rotating between the halves of the instrument is about 114 cps, and the efficiency of the instrument is 11%.

To determine the quantity of plutonium in a waste drum, it is necessary to know the isotopic composition of the plutonium. Table 2-3 shows the isotopic composition being used for five types of plutonium that may be encountered in the plutonium facility:

MS ON
13:34:01 03-28-1993 (005)

S E L E C T P R O G R A M F U N C T I O N

U = measure an Unknown

K = measure a Known source

B = measure a Background

P = Print an existing data file

D = Display a control chart

Q = Quit and exit program

Entering a for most queries will cause the program to return to this menu

■ Enter letter corresponding to desired program function

Figure 2-3. The main menu of the computer program as displayed by the monitor.

weapons-grade, fuel-grade, reactor-grade, americium-enriched, and mixed plutonium. If the type of plutonium is not known, it is assumed that it is weapons grade because this is the type of plutonium used most extensively in the facility. If the plutonium is known to be one of the other types, it will be indicated on the label that is attached to the drum when it is sealed. Because the neutron yield from weapons-grade plutonium is the lowest of the five types, assuming the waste to be weapons-grade plutonium would result in a conservative (high) value for the plutonium content assigned to the drum.

The computer must know the weight of the waste in the drum to calculate the nCi content

of the waste. The total weight is entered in the computer, which subtracts the weight of the drum.

The calibration data and background data are used by the computer program in calculating the plutonium content of a drum in grams of plutonium and in nCi/g of waste. The program also calculates the mathematical uncertainty of these values. The counting time for a waste drum is normally 20 minutes. If the results from the counting of a drum indicate that the drum contains no plutonium, the results are reported as being below the lower limit of detection or the minimum detectable amount (MDA). For a drum that is counted for 20 minutes and has a background count of 900 minutes, the MDA is

Figure 2-4. The display during counting showing the counts and the count rate of each of the sixteen ^3He tubes individually, the total for banks A and B, and the total for all the tubes. Also shown at the left is a bar graph of the elapsed time.

Table 2-1. Calculations of the neutron yields from the calibration sources.

Calibration Source STDISO 6L (9.773176 g)				
Isotope	Weight percent	Specific Activity (Ci/g)	Spontaneous Fissioning (n/s)	Pu Oxide (n/s)
²³⁸ Pu	0.01409	17.300	0.375	1.888
²³⁹ Pu	93.50055	0.063	0.022	35.624
²⁴⁰ Pu	6.12852	0.230	56.382	8.641
²⁴¹ Pu	0.29995	104.000	0	0
²⁴² Pu	0.0569	0.004	1.021	0.001
²⁴¹ Am	0.022383	3.470	0	0.602
		sum	57.800	46.756
		total	104.556 n/s/g	

Table 2-2. Documentation of the method used to calculate the neutron yields from the various types of plutonium.

Spontaneous Fission Neutrons			
The values used to calculate the spontaneous fission neutrons are listed below:			
Isotope	Neutrons/decay ^a	half life years ^b	n/s/g
²³⁸ Pu	4.20 E-09	4.77 × E10	2,663
²³⁹ Pu	—c	5.5 × E15	0.0226
²⁴⁰ Pu	1.09 E-07	1.34 × E11	920
²⁴² Pu	1.23 E-05	6.75 × E10	1,795
²⁴¹ Am	—c	1.147 × E14	1.07
Neutrons from Plutonium Oxides			
The neutron yield of plutonium oxides from the alpha-neutron reaction for each of the different types of plutonium was determined by using the following values taken from "Passive Nondestructive Assay of Nuclear Materials" NUREG/CR-5550, Edited by: Doug Reilly, Norver Ensslin, and Hastings Smith, Jr., LA-UR-90-732, March 1991			
²³⁸ Pu	13,400 n/s/g		
²³⁹ Pu	38.1 n/s/g		
²⁴⁰ Pu	141 n/s/g		
²⁴² Pu	2.0 n/s/g		
²⁴¹ Am	2,690 n/s/g		
^a Spontaneous fission neutrons/decay values taken from ICRP Publication #38, Vol. 11-13, Radionuclides Transformations, 1983. ^b Spontaneous fission half lives were taken from Table of Isotopes 7th edition, C. Michael Lederer and Virginia S. Shirley, 1978. ^c The spontaneous fission neutrons/decay values were not given for ²³⁹ Pu and ²⁴¹ Am. The half lives listed above were used to calculate the specific activity of these isotopes and we used a value of 2.2455 neutrons/fission (the average neutrons/fission for the other three isotopes).			

Table 2-3. Calculations of the neutron yields from the various types of plutonium.

Type of Pu	Isotope	Weight percent	Specific Activity (Ci/g)	Spontaneous Fissioning (n/s)	Pu Oxide (n/s)
Weapons Grade	²³⁸ Pu	0.016	17.300	0.43	2.14
	²³⁹ Pu	93.464	0.063	0.02	35.61
	²⁴⁰ Pu	5.900	0.230	54.28	8.32
	²⁴¹ Pu	0.381	104.000	0	0
	²⁴² Pu	0.040	0.004	0.72	0
	²⁴¹ Am	0.202	3.470	0.00	5.43
	sum total			55.46	51.50
Fuel Grade	²³⁸ Pu	0.066	17.300	1.76	8.84
	²³⁹ Pu	78.964	0.063	0.02	30.09
	²⁴⁰ Pu	17.427	0.230	160.32	24.57
	²⁴¹ Pu	1.180	104.000	0	0
	²⁴² Pu	0.432	0.004	7.72	0.01
	²⁴¹ Am	1.942	3.470	0.02	52.24
	sum total			169.84	115.75
Reactor Grade	²³⁸ Pu	0.011	17.300	0.29	1.47
	²³⁹ Pu	73.657	0.063	0.02	28.06
	²⁴⁰ Pu	24.896	0.230	229.04	35.10
	²⁴¹ Pu	0.424	104.000	0	0
	²⁴² Pu	0.018	0.004	0.32	0
	²⁴¹ Am	0.994	3.470	0.01	26.74
	sum total			229.68	91.37
Americium Enriched	²³⁸ Pu	0.055	17.300	1.46	7.37
	²³⁹ Pu	63.557	0.063	0.01	24.22
	²⁴⁰ Pu	14.027	0.230	129.05	19.78
	²⁴¹ Pu	0.950	104.000	0	0
	²⁴² Pu	0.347	0.004	6.20	0.01
	²⁴¹ Am	21.073	3.470	0.23	566.86
	sum total			136.95	618.24
Mixed Pu	²³⁸ Pu	0.042	17.300	1.12	5.63
	²³⁹ Pu	86.149	0.063	0.03	32.82
	²⁴⁰ Pu	11.714	0.230	107.77	16.52
	²⁴¹ Pu	0.784	104.000	0	0
	²⁴² Pu	0.237	0.004	4.24	0.01
	²⁴¹ Am	1.079	3.478	0.01	29.03
	sum total			113.17	84.01
				197.18 n/s/g	

Note: The neutron rates for each of the different types of plutonium given in this table are determined by multiplying the weight percents of each isotope by the neutron rate in n/s/g values given in Table 2-2 for spontaneous fission and plutonium oxide neutrons.

around 0.007 g for weapons-grade plutonium. (See Figure 2-5.) The nCi/g of waste is a function of the weight of the waste in the drum and will be different for each drum. Error limits of one sigma are given by the computer for the waste weight in grams and the activity in nCi/g. The program allows these values to be observed before the counting is started, as shown in Figure 2-5. If the indicated values are unacceptably high, a longer counting time can be programmed into the computer, and the new values are calculated and displayed.

Control Chart

The control chart has proven to be a very useful tool to determine if the background and calibration counts are consistent with earlier counts. The control chart displays the results from the most recent 50 counts (see Figure 2-6). The chart shows the average gross count rate. Each data point is shown as a vertical line, the

length of which is plus and minus one standard deviation, based on the count rate. The short lines in Figure 2-6 are from 900-minute counts and the longer ones are from 20-minute counts. The vertical scale of the display is from -4 to +4 standard deviations of a weighted average of all the data sets. The results in this figure indicate that the background counts are usually within one standard deviation of the weighted average, with only two counts being three sigma from the weighted average. This display chart immediately reveals any problems in the functioning of the instrument or the computer.

Effect of Source Location in a Drum

The plutonium may not be uniformly distributed in a waste drum. To determine the effect of nonuniform plutonium distribution on the resulting neutron count, a series of measurements using a small ^{252}Cf source was made. The source was positioned in a drum at

MS ON
13:42:25 09-28-1993 <085>

YOU HAVE ENTERED: 20 minutes (1200 sec)

If this is the correct choice enter 7. If not enter 0.

This time will give an MDA of 0.007 ± 0.001 g < 20.9 ± 2.1 nCi/g>

Enter 7 or 0

Figure 2-5. The monitor indicating the MDA that will be obtained using the selected counting time. If this is not low enough, the counting time can be increased, and a new value will be calculated and displayed.

sixteen locations. Fifteen of these locations were selected by first dividing the height of the drum into five equal sections. These were then subdivided into three sections of equal volume. A drawing of these sections is given in Figures 2-7 and 2-8, which show a side and top view of a drum. The source was vertically positioned midway in each section. Horizontally, it was located so that when rotated, the source equally divided the volume of the section. The source locations are also shown in Figures 2-7 and 2-8. Although they do not at first appear to be correctly positioned, closer

examination will show that they are in the correct locations.

The ^{252}Cf source was positioned in a drum at each of the locations shown in Figures 2-7 and 2-8 by using styrofoam. The drum was rotated and the counting rates were determined. When data was obtained at the center of the drum, the source was at the same location as the calibration source during calibration of the instrument. The data obtained at each of the fifteen locations were normalized to the counting rate at the center of the drum, and these results are shown in

Figure 2-6. A display chart of the background counts showing the standard deviation of each count, the average gross count, and a plot of the deviation of the count from the average. This display chart will include up to 50 of the most recent counts.

Figure 2-7. Side view of the source locations inside a 55-gallon drum. The source was positioned midway in each section. Each of the sections have the same volume when rotated.

Table 2-4. They show that the average count rate is 4% lower than the count rate at the center of the drum, with the lowest counting rate being at the top-center (-23%) and the highest being at the side-center of the drum (+8%). We included a geometry correction in the computer program for this positioning error, which changes the extremes to -19% at the top-center and +12% at the side-center.

Conclusions

We conclude that the high-sensitivity neutron instrument can be very useful in verifying the plutonium waste content in bulky, low-level waste packed in 55-gallon drums. Using the instrument for this purpose will make the disposal of low-level radioactive waste much more efficient and cost effective.

Figure 2-8. Top view of the source locations inside a 55-gallon drum. Each of the sections have the same volume, and the source was positioned to equally divide each of the volumes when rotated.

Table 2-4. Results obtained to determine the positioning error that exists, caused by having a source at various locations inside a 55-gallon drum when compared to the results from a calibration source located at the center of the drum.

Location number	Average cps	Relative cps
1	225,944	0.766 low 23%
2	239,671	0.813
3	247,337	0.839
4	274,690	0.931
5	286,075	0.970
6	296,047	1.004
7	299,468	1.015
8	309,344	1.049
9	317,649	1.077 high 8%
10	298,004	1.010
11	307,378	1.042
12	316,009	1.071
13	274,529	0.931
14	280,270	0.950
15	284,524	0.965
		avg 0.962 low 4% compared to center
16 center	294,928	1.000