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FORMAL REPORT

Feasibility of Measuring Iron in vivo Using Fast 14 MeV Neutrons

To the
Cooley's Anemia Foundation, Inc.

Lucian Wielopolski

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Brookhaven National Laboratory
Upton, New York 11973-5000

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Executive Summary

In this short report, I reassess the feasibility of measuring iron *in vivo* in the liver and heart of thalassemia patients undergoing chelation therapy. Despite the multiplicity of analytical methods for analyzing iron, only two, magnetic resonance imaging, and magnetic susceptibility, are suitable for *in vivo* applications, and these are limited to the liver because of the heart's beat. Previously, a nuclear method, gamma-resonance scattering, offered a quantitative measure of iron in these organs; however, it was abandoned because it necessitated a nuclear reactor to produce the radioactive source. I reviewed and reassessed the status of two alternative nuclear methods, based on iron spectroscopy of gamma rays induced by fast neutron inelastic scattering and delayed activation in iron. Both are quantitative methods with high specificity for iron and adequate penetrating power to measure it in organs sited deep within the human body. My experiments demonstrated that both modalities met the stated qualitative objectives to measure iron. However, neutron dosimetry revealed that the intensity of the neutron radiation field was too weak to reliably assess the minimum detection limits, and to allow quantitative extrapolations to measurements in people. .

A review of the literature, included in this report, showed that these findings agree qualitatively with the published results, although the doses reported were about three orders-of-magnitude higher than those I used. Reviewing the limitations of the present work, steps were outlined for overcoming some of the shortcomings. Due to a dearth of valid quantitative alternatives for determining iron *in vivo,* I conclude that nuclear methods remain the only viable option. However, from the lessons learned, further systematic work is required before embarking on clinical studies.

1. BACKGROUND

Thalassemia patients cannot produce mature red blood cells, so that they must regularly receive blood transfusions. However, since there are no natural excretory pathways for iron in the human body, it rapidly builds up in critical organs. For example, dangerously high levels of iron regularly accumulate in the liver, pancreas, spleen, thyroid, bone marrow, zona glomerulosa, and heart of these patients resulting in siderosis, organs dysfunction, and heart [1]. These life-threatening conditions are mitigated by iron-chelation therapy, which slows down and possibly reverses the accumulation of iron. . However, the lack of noninvasive sensitive and quantitative methods to measure iron in various organs hampers testing of the efficacy of the therapy and of finding optimal prescriptive regimens for various chelating drugs. Furthermore, iron levels in specific organs cannot be determined precisely without having instrumentation that can target these organs with adequate selectivity and sensitivity to it. In addition to the standard method of taking liver biopsies, which cannot be repeated too often, nor applied to a critical organ such as the heart, several methods, both passive and active, were implemented previously to measure iron stores *in vivo*. They included magnetic susceptibility (MS), magnetic resonance imaging (MRI), x-ray fluorescence (XRF), computerized tomography (CT), and nuclear resonance scattering (NRS). However, passive, indirect methods, such as MS and MRI that measure bulk properties are non-specific; in addition, they face the yet-unresolved problem of measuring iron content in the heart because of its movement. XRF, an active method, specifically measures iron but its low energy limits its application to the skin; it is unsuitable for assessing iron in any deeply sited organ. CT, with higher energies, is non-specific with low sensitivity to changes in tissue density due to iron. The active NRS method was the only one with high specificity for iron that can quantitatively evaluate its content in the liver and heart. Nevertheless, its clinical applicability was seriously hindered because access to a nuclear reactor was needed to prepare the ^{56}Mn radioactive source used for generating gamma radiation for resonance scattering from iron. Only about fifty patients were measured and followed up by NRS.

In this report, I briefly review direct and indirect methods to measure iron *in vivo,* and outline the possible value of alternative nuclear methods that might be used. The inelastic neutron scattering (INS) and fast neutron activation methods appear to be the most attractive option among them. The methodology appears to be feasible and, if confirmed, it could be easily implemented in a clinical environment. I discuss my preliminary results from measuring iron using these approaches.

2. CURRENT AND PAST METHODOLOGIES

During the April 2001 NIDDK Workshop on "Non-invasive Measurement of Iron" it become apparent that the current indirect MS method and the emerging magnetic resonance imaging (MRI) method, suffer from serious calibration problems and are profoundly affected by the heart's movement. MS is a quantitative method that measures the magnetic properties of the liver, reflecting the presence of paramagnetic ferritin and homosiderite proteins. These proteins are the body's major forms of iron storage. An increase in the level of these proteins increases the magnetic susceptibility of an organ, which can be detected using the super-conducting SQUID detector [2-5]. Similarly, the concentrations of the iron-containing paramagnetic proteins affect the spin-lattice relaxation time (T_1) observed by MRI [6]. These non-specific methods

require calibration with data from liver biopsies, calculations that are error prone when dealing with high iron concentrations. Since MS and MRI are based on comparable principles that depend on the tissue's magnetic environment, they have similar restrictions and cannot be used for cross-validation. Furthermore, they are severely limited in accommodating the heart's movement so that it does not distort the iron reading. XRF measures 5.6 keV characteristic x-rays from iron that, being at very low energy, are limited to superficial parts of the body, like the skin. Although the assessments are quantitative ones, the method is completely unsuitable for measuring iron in deeply sited organs [7]. Therefore, alternative quantitative and, preferably, direct methods are needed to measure iron *in vivo* in human organs that are both specific with high penetration, and insensitive to cardiac movements.

The direct NRS method, developed at Brookhaven National Laboratory (BNL), satisfied the requirements for specificity, quantification, penetration, and insensitivity to the heart's movements. Its widespread clinical use was hindered by the requirement for a nuclear reactor to produce the ^{56}Mn, the radioactive source used for resonance scattering. The shutdown of the BNL reactor terminated our employment of the only system able to measure iron in the heart. The purpose of the following, more detailed, description of the NRS method is to emphasize the general characteristics of nuclear devices, and their unique suitability for determining iron in *vivo*.

The NRS method is based on nuclear resonance scattering (NRS) of gamma radiation from the iron nucleus [8-11]. Here, the nucleus of the iron isotope ^{56}Fe (92% abundance) is resonantly raised to its first excited state by gamma radiation whereafter, within 7 psec, it decays back to the ground state by emitting an 847 keV gamma ray. Thus, the number of resonantly scattered and detected gamma rays is proportional to the number of ^{56}Fe nuclei present in the organ's scattering volume. The source of gamma rays used to excite the ^{56}Fe nuclei consisted of 4 mg $^{56}MnCl_2$ powder sealed in an evacuated quartz ampoule and irradiated in the core of the Brookhaven High Flux Beam Reactor for 4 hours. After cooling for about one hour, the source was transferred to the patient counting facility and delivered an approximate dose of about 1 cGy to the patient's liver. Figure 1 shows the facility used for patient measurements. A collimated gamma source is placed under the patient's bed, while two detectors monitor the resonantly scattered radiation (in this case, from iron in the liver).

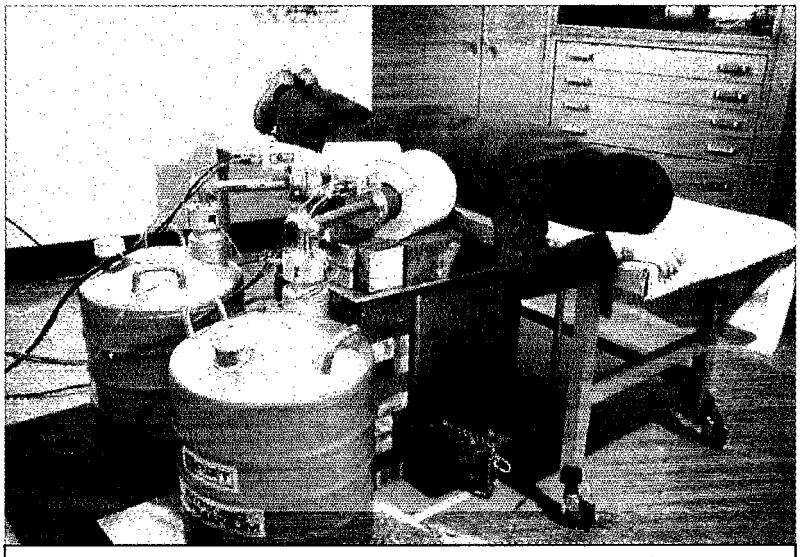

Figure 1. Setup to measure iron in a patient's liver by the NRS method.

Fig. 2 shows the linearity of the NRS signal versus iron concentration in the liver, assessed from liver biopsies. This linear calibration line is typical of all nuclear counting systems where the concentration of the element of interest is low. The results from NRS measurements of iron in the liver and heart in several patients suffering iron overload from different causes were published in [12-15]. These volunteers also were followed sequentially to observe the changes following chelation therapy. The limited correlation between the heart index versus the liver index of iron depicted in Fig. 3 clearly demonstrates the need to independently measure their content; thus, separate measurements might reveal a build up of iron in the heart at the same time as relatively low levels exist in the liver.

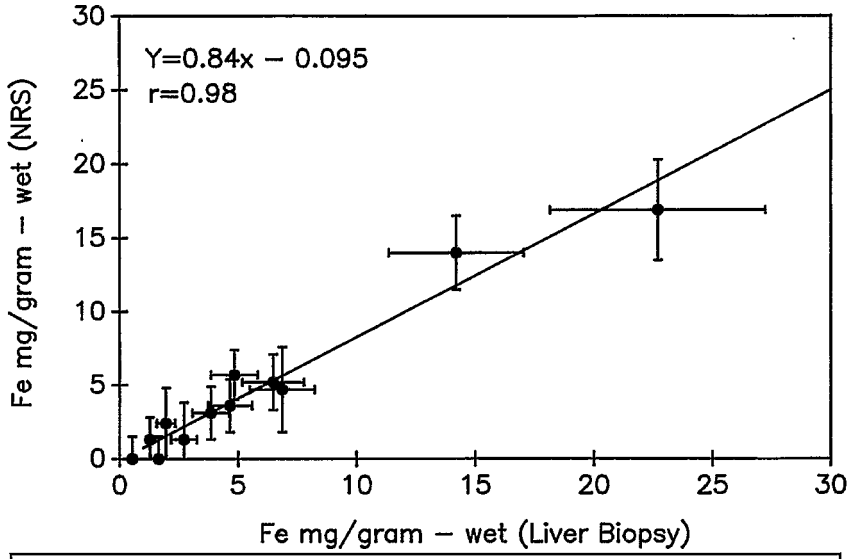

Figure 2. Iron calibration versus liver biopsies measured using the NRS system.

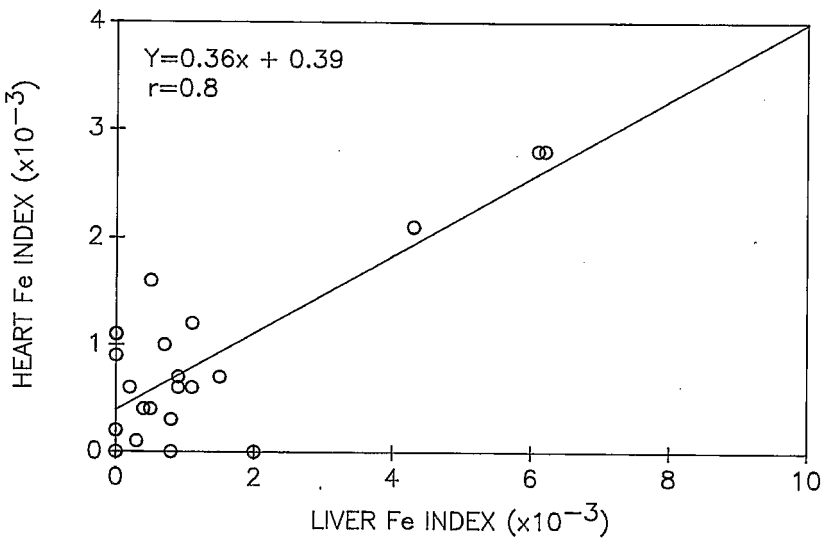

Figure 3. Heart index versus liver index measured using NRS.

3. New Approaches

Our implementation of the NRS method to measure directly iron in the liver and heart demonstrated the value of nuclear methods in attaining high specificity and accuracy. Although this particular method was abandoned due to the closure of BNL's High Flux Beam Reactor wherein the irradiation source was prepared, here I review the suitability of several alternative nuclear methods for determining iron in *vivo*.

Several nuclear reactions were used in the past for studying the structure of the iron nucleus. They included inelastic proton scattering (p,p',γ) reactions [16-22], proton-induced gamma rays (p,γ) reactions on ^{55}Mn [23-25], and exotic ones in which elements further away from iron may induce nuclear transmutations after irradiation with heavy nuclei. Fig.4 depicts

these different combinations; for example, irradiating ^{56}Fe with heavy nuclei and adding the number of proton and neutrons will point to the product nucleus and its decay characteristics. The axes indicate the increasing number of protons (p) and neutrons (n). Although these methods are used for nuclear spectroscopy, they are unsuitable for *in vivo* analysis because protons have a limited range in the human body. Conceivably, with high-intensity proton accelerators a two-step process might be devised whereby a proton induces gamma emission that subsequently interacts resonantly with the iron in the human body, identical to the way it was implemented in the NRS method. Then, the product nucleus should be ^{56}Fe (Fig. 4). Two examples are described below; first, of protons on manganese (^{56}Mn), and second of inelastic proton scattering from Fe.

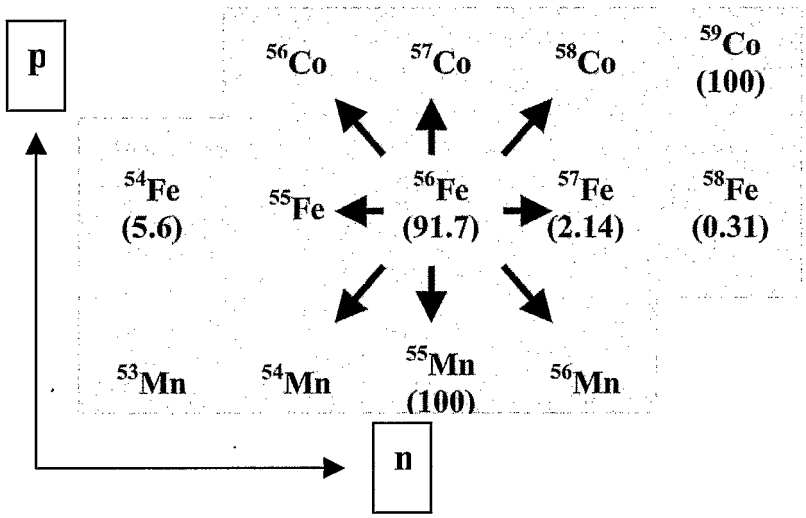

Figure 4. Table of the isotopes surrounding ^{56}Fe nucleus

$^{55}Mn(p,\gamma)$, $^{56}Fe(p,p'\gamma)$

A manganese target irradiated with protons could well serve in such a two-step process for detecting iron in *vivo*. Protons at energies, E_p, between 1.3 MeV and 1.85 MeV can interact resonantly with ^{55}Mn to excite high lying states in ^{56}Fe. These promptly decay to the ground state through the 847 keV level, thus producing the desired 847 keV gamma beam identical to that used in NRS method [23-25].

Alternatively, the 847 keV nuclear level in iron can be excited through a proton inelastic scattering, $^{56}Fe(p,p'\gamma)$, process. Several researchers successfully used protons with energies, E_p, between 3.5- and 11-MeV [16-21, 26]. But, as I pointed out, high-intensity accelerators are required in this approach.

$^{56}Fe(n,n'\gamma)$

Instead of irradiating patients with protons or gamma rays, they can be exposed to fast or thermal (slow) neutrons. A recent review of analytical methods for *in vivo* compartmental analysis was based on extensive work on using neutrons to explore body composition (27). Neutrons interact with iron in the body by three fundamental mechanisms: In the first, termed delayed activation, ^{58}Fe captures a thermal neutron and becomes ^{59}Fe from which delayed gamma rays at energies of 1.1 and 1.29 MeV are measured (Fig.4). This process is rather ineffective due to the scarcity of ^{58}Fe (0.31%), and the long half-life of ^{59}Fe (44.5 days). The second is the (n,p) reaction in which a fast neutron is captured by ^{56}Fe with the subsequent

prompt emission of a proton to produce ^{56}Mn, and a delayed gamma-ray emission at 847 keV (Fig. 4). Iron in the liver can be feasibly measured with a dose of about 10rem [28]. The cross-section for this reaction is about 0.1 barns. The third mechanism for detecting iron is by inelastic neutron scattering (INS), denoted (n,n',γ) with threshold energy of 850 keV [29]. Here, fast neutrons are inelastically scattered from the ^{56}Fe inducing gamma-ray emission from the 846 keV level. This reaction has a tenfold higher cross-section than the previous one, and was also demonstrated using fast neutrons from a nuclear reactor [30, 31]. Rather than obtaining neutrons from a nuclear reactor, they might be produced by neutron generators that work like an x-ray machine, generating fast 2.2 MeV neutrons by impinging deuterium on deuterium, a (d,d) reaction, or fast 14 MeV neutrons resulting from impinging deuterium on tritium (d,t) reaction. Iron measurements based on the latter were carried out using a Van de Graff Tandem accelerator. The measured cross-section for generating the 847 keV gamma rays for neutron energies, E_n, above 3 MeV is about 1 barn [26, 32]. Table 1 gives nuclear data for 14 MeV delayed reactions with neutrons and iron.

Table 1. Nuclear data for reactions with 14 MeV Neutrons-Iron

Nuclear Reactions	Target Isotope Abundance (%)	Cross Sections (mb)	Half-life (min)	Gamma Ray Energy (MeV)	Gamma Yield (%)	Detector Efficiency (%)	Peak/Total Ratio
$^{54}Fe(n,2n)^{53}Fe$	5.84	15	8.50	0.51	196	40	0.63
$^{56}Fe(n, p)^{56}Mn$	91.68	103	154.56	0.85	99	34	0.44
$^{56}Fe(n, p)^{56}Mn$	91.68	103	154.56	1.81	29	27	0.28
$^{56}Fe(n, p)^{56}Mn$	91.68	103	154.56	2.11	15	26	0.26
$^{57}Fe(n, p)^{57}Mn$	2.17	60	1.70	0.12	100	50	0.99
$^{57}Fe(n, p)^{57}Mn$	2.17	60	1.70	0.13	100	50	0.98
$^{56}Fe(n,n',\gamma)^{56}Fe$	91.68	~1 b	Prompt	0.85	99	34	-

Clearly, nuclear methods are amenable for *in vivo* quantitative elemental analysis of human body and afford at least two direct methods for iron analysis, both of which have high elemental specificity. The INS method, suggested for analyzing silicon in the lung, uses pulsed 4.7 MeV neutrons [33], and, compared with the (n,p) reaction using a californium source [34], is proposed as the method of choice to measure iron in the liver and heart. Its selection is further corroborated by the success of the feasibility studies that measured iron in a synovial membrane (35).

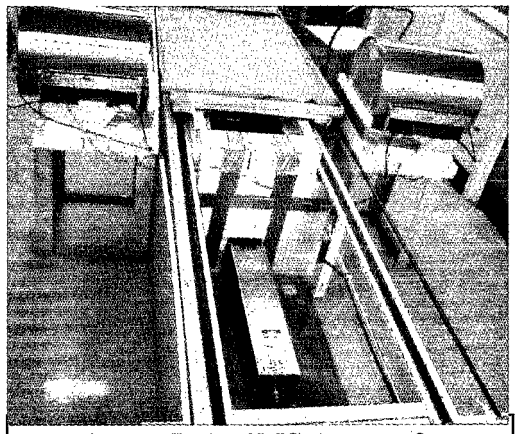

Figure 5. An INS system for measuring whole body carbon using a neutron generator.

4. Experimental Setup

Iron Facility.

The experimental setup for measuring iron *in vivo* was a modified counting facility that previously was used for determining total carbon in the human body based on fast 14 MeV neutrons inelastically scattering from carbon, Fig. 5. The neutron generator (NG) is the rectangular box on the floor removed from

its shielding and collimator tower (painted white in the figure). It is a commercial unit of the deuterium on tritium (d,t) type producing 14 MeV neutrons. Ciskai [36] extensively discusses various types of NGs and their operational characteristics.

The patient was scanned on a moving bed and the radiation emitted from the body was detected by two large NaI detectors placed in shielded containers on each side of the bed. This system was thoroughly modified by rebuilding the shielding tower to exclude any iron present in the previous structure that served as fast neutron shielding, and by replacing the large NaI detectors with a single high-energy resolution High Purity Germanium (HPGe) detector. These changes entailed our taking extensive spectroscopic measurements to ascertain that iron was removed, and optimizing the detector's positioning and shielding. The outside dimensions of the new shielding tower are 30.25" wide, 25" deep, and 30" high. The collimator opening on the top is 7" x 7" x 5". Figure 6 shows the new configuration of the tower with the pertinent material composition and dimensions. Cadmium sheets introduced between the borated polyethylene bricks reduced the neutron background. However, the cadmium sheets must not be placed too close to the detector since that may complicate the spectrum with many cadmium gamma lines.

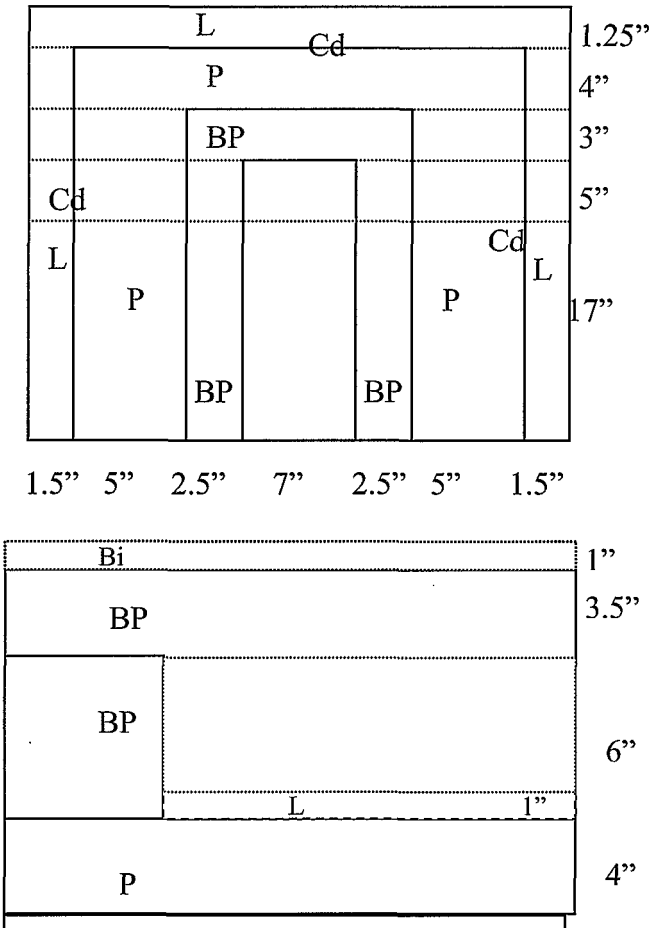

Figure 6. Configuration of the new collimator tower and the materials used; L – Lead, P – Polyethylene, BP – Borated Poly, Cd – Cadmium, and Bi – Bismuth.
Top View is shown in the upper figure and the side view in the lower one.

Figure 7 illustrates the positions of the partially shielded new HPGe detector, together with the flow ionization chamber for dosimetry in the monitoring position. Optimizing the position of the HPGe detector ensured obtaining the maximum yield of counts from a phantom bottle containing iron, while simultaneously preventing (minimizing) fast neutrons from entering the detector where their interactions interfere with iron measurements.

Electronics

The electronics consisted of a 14 MeV NG that included a delay & gate unit to control the gate of a PCA-III multichannel analyzer (MCA) data acquisition system installed in a PC

computer. In addition, it included a high-resolution N-Type, 30% efficient, 2" diameter HPGe detector. A preamplifier and spectroscopy amplifier for signal processing from the detector was connected into the MCA. Figure 8 is the block diagram of the electronics with all the connections. The acquired spectra were processed off-line for the iron signals after the measurements.

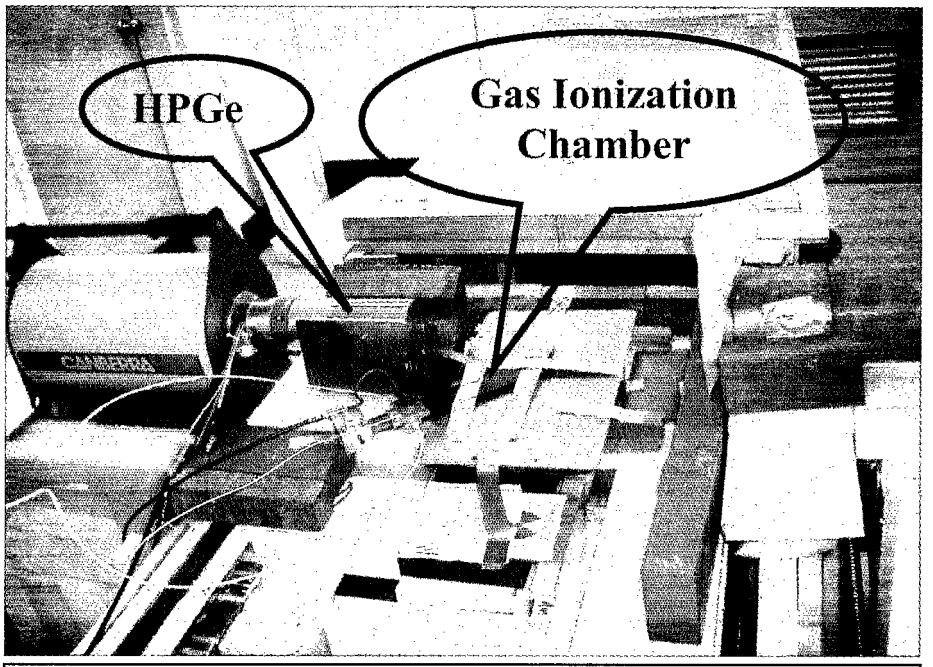

Figure 7. A new HPGe detector, on the left, and a dosimetry detector placed in the center.

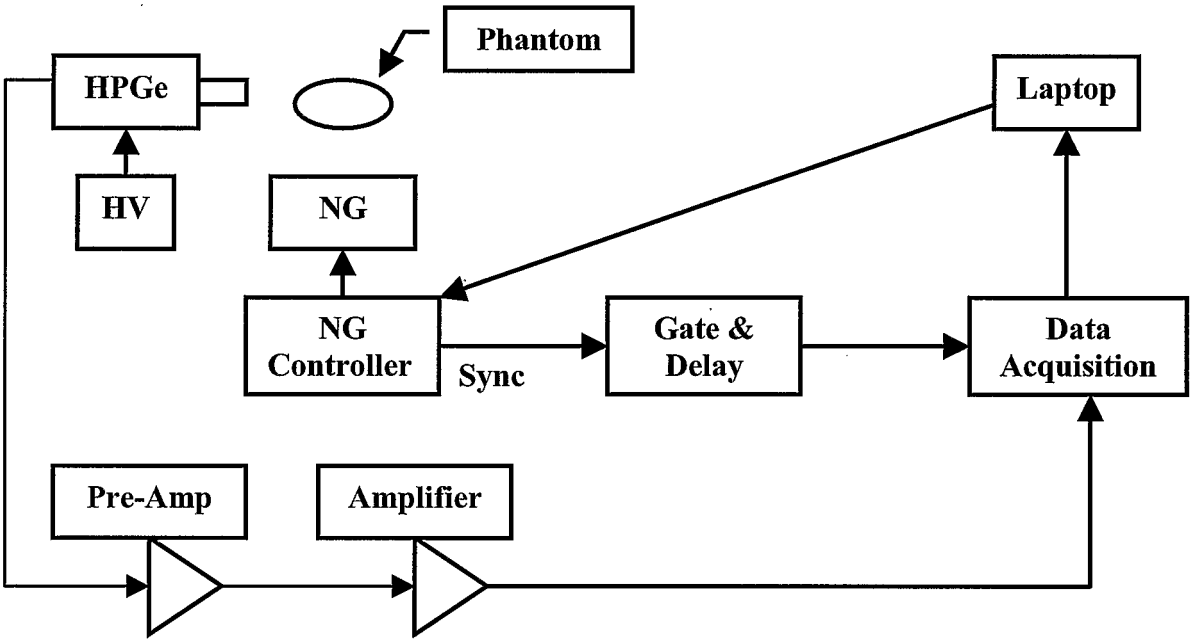

Figure 8. The electronics block diagram and the wiring.

5. RESULTS

Calibration of the Detector's Energy

The detector's energy was calibrated using sources Cs-137 and Co-60 emitting 662 keV and 1332 keV gamma rays, respectively. The amplifier's settings and the multichannel analyzer with 1024 channels was set for approximately 2.3 keV/ch to cover approximately the full range of the pulse height of 2400 keV. The fitted energy-calibration regression line is given as **E (keV) = 14.95 + 2.295xch#**. This calibration was maintained during the experiments.

Spectral Analyses

An extensive effort was devoted to considerably reducing both the direct background from neutrons interacting within the HPGe detector, and the contribution to the iron signal from the background; nevertheless, they could not be eliminated completely under the present setup. Fig.9a shows the background spectrum acquired from a bottle containing pure water, and Fig.9b is its expanded section with peaks of interest between 400 and 1000 keV. These spectra were acquired for 1 hour in coincidence with the neutron pulse that lasts for 10 microseconds and has a repetition rate of 10 kHz. I pointed out that this particular set-up constrains the observed gamma rays to those resulting from the inelastic events that occur only when fast neutrons are present. Hence, the multiplicity of gamma lines in the spectra in Fig. 9 represent neutron interactions with the structural materials and the HPGe detector. The unusual triangular-shaped peaks originate in the detector from the interactions of fast neutrons with germanium, resulting in the Doppler-broadening of the gamma rays due to recoil energy from the neutrons. These events are typical when fast neutrons interact inside the detector. Morgan [37] acquired identical spectra from a ^{238}Pu,Be and ^{252}Cf neutron source [37]. Unfortunately, the iron peak at 847 keV is located exactly above the germanium peak as is clear in the expanded spectrum in Fig. 9b. This is better demonstrated in Fig. 10 where a 15-min spectrum from an iron plate reveals the position of the iron peak on top of the germanium peak.

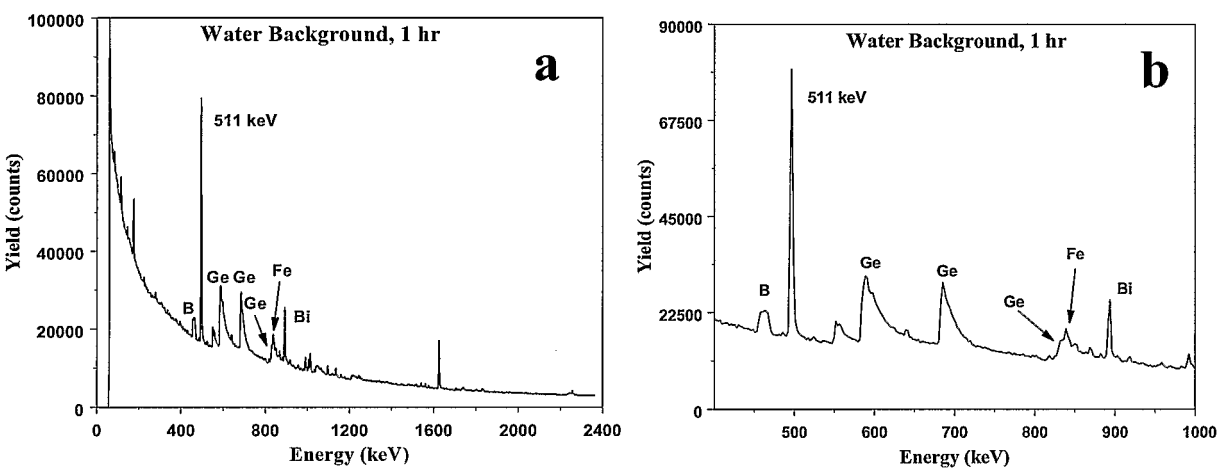

Figure 9. A one-hour gamma ray spectrum from one liter bottle with water counted during the neutron pulse; (a) The entire spectrum (b) expanded region

In addition to evaluating the prompt inelastic gamma ray spectra, I assessed delayed activation by counting and obtaining a spectrum, over one hour, from a 1 liter water bottle

containing 12 g iron immediately after the end of irradiation (Fig.11). Thus, according to the reactions summarized in Table 1 this enables counting of the same iron gamma ray at 847 keV; the other lines indicated in the table are much weaker although they still were visible in the spectrum. . Notice the entirely different shape of the spectrum from that of the prompt spectrum, i.e., a different background and adjacent peaks.

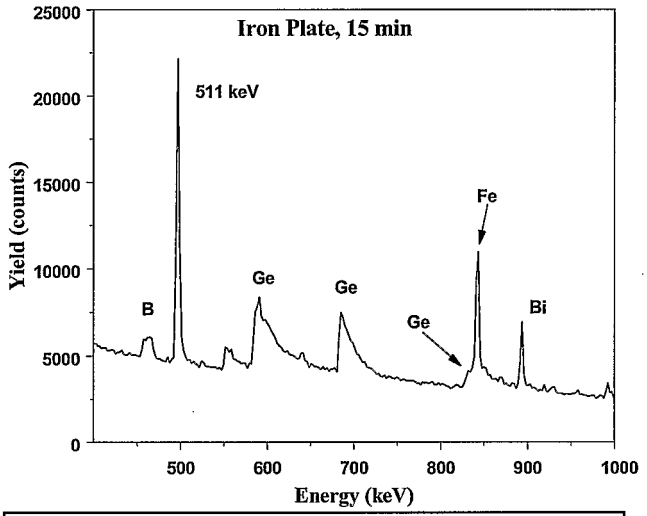

Figure 10. Gamma ray spectrum acquired from an iron plate showing the iron peak located above the germanium peak.

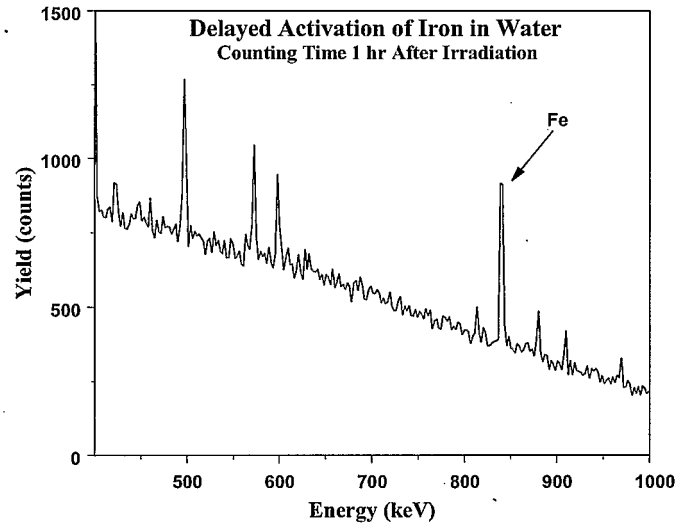

Figure 11. A delayed spectrum measured from 12 g iron in a 1L of water.

After establishing the best possible conditions for the system, the subsequent gamma ray spectra obtained, shown in Figs. 9, 10, and 11, demonstrated all the physical qualitative features involved with inelastic and delayed gamma ray spectroscopy of iron. Quantitative analysis was undertaken separately of the 847 keV peak from the inelastic reactions, and from the delayed activation; the half-life, $T_{1/2}$, of the delayed 847 keV line is 154.56 min. In addition, the line at 120 keV from ^{57}Fe with $T_{1/2}$ 1.7 min was analyzed.

Two integration windows were established to analyze the inelastic gamma ray spectra: For the first, with a 15-channel-wide window between 825.09 and 857.22 keV (which included the

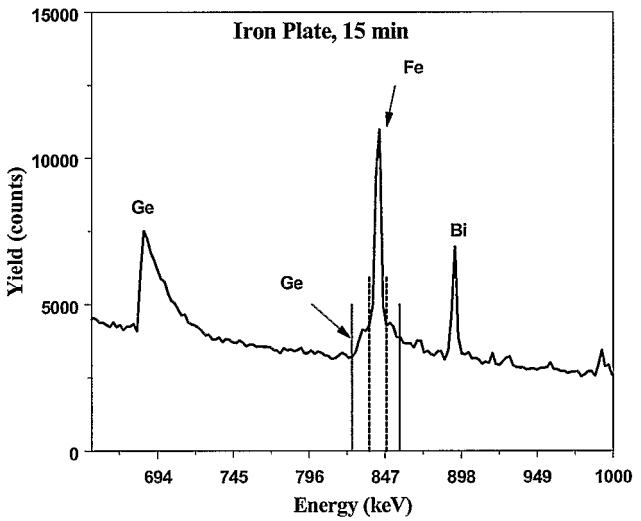

Figure 12. Solid lines show the wide window settings whereas the dashed lines show the narrow window settings.

germanium peak and was 15 channels wide), the net counts in the iron peak were evaluated by subtracting the net counts in the water spectrum from those with the water plus 12 g of iron. These calculations were repeated using a narrow window encompassing the iron peak only, at 834.26 and 845.74 keV (6 channels wide); Table 2 summarizes the results. This same narrow window was used for the delayed gamma ray spectra, and an additional narrow window was established for the 120 keV line at 109.05 and 120.5 (5 channels). The settings of the counting windows are shown in Fig. 12 using a spectrum from an iron plate for demonstration. The delayed gamma peaks were determined using the trapezoidal method. These results are also summarized in Table 2. Appendix A gives the raw data spectra

Table 2. Calculations of the net count in the iron peak.

Raw Data File	Half-Life (min)	Energy (keV)	Total Counts	Background Counts	Net Counts ±SEM[a]
Water[b]	Prompt wide window	847	225209	192535	32976[e] (2.0%)
12gFe1lW[b]	Prompt wide window	847	226117	192487	33629 (2.0%)
12gFe1lW[b]	Wide window net iron signal				653±810 (124%)
Water[b]	Prompt narrow window	847	97793	93588	4205 (10.5%)
12gFe1lW[b]	Prompt narrow window	847	98013	92613	5400 (10.5%)
12gFe1lW[b]	Narrow window net iron signal				1195 (52%)
12gFe1lWD[c]	Delayed	847	1516	774	742±48 (6.5%)
12gFe1lWDD[d]	Delayed	847	1899	1623	276±60 (22%)
Sum (c+d)	Delayed	847	3415	2397	1018±76 (7.5%)
12gFe1lWD[c]	Delayed	120	4040	3187	852±85 (10%)
12gFe1lWDD[d]	Delayed	120	6949	6700	246±116 (47%)

[a]SEM – Standard error of the mean.
[b]1 hr irradiation and counting time.
[c]1 hr irradiation and delayed 15 min counting time.
[d]1 hr irradiation and delayed 45 min counting time following "c".
[e]The net counts are due to germanium and residual iron in the background.

A few basic observations emerge from the results in Table 2. 1) The significance of the high cross-section of 1barn for the prompt inelastic reactions, about a factor ten higher than that of the delayed processes, in Table1, is reduced considerably due to a correspondingly increased background of about 100 times in the former. 2) There is a residual iron signal present in the

background. 3) The strongest iron 847 keV gamma line resides on top of the germanium peak, thus significantly raising the background and the error propagation. 4) Narrowing the window improves the signal and reduces the error. 5) For the present geometrical configuration and inadequate NG intensity, the net iron yields are too weak for using in any clinical system. The observed spectra were consistent with those reported in the literature and all reported peaks, used and unused in the analysis, in the prompt and delayed spectra were identified.

6. DOSIMETRY

Surface Dose

Measurements of the total dose rates were made using a parallel-plate ionization chamber fabricated from A150 tissue-equivalent (TE) plastic. The chamber's collection volume was approximately 2.5 cm in diameter and 0.5 cm thick, ~2.5 cm^3, with a 2.4 mm thick wall. Methane-based tissue-equivalent gas at atmospheric pressure flowed through the chamber. The ionization current was measured using a custom-made electrometer system that produces an output of 1 V per pA of input current. The electrometer's output was connected to a custom-made voltage-to-frequency converter producing 10^3 Hz/V, and these pulses were simultaneously counted in a scaler with those from a plastic scintillator (PS) used as a monitor for normalizing the number of neutrons produced. The ionization chamber and electrometer were previously calibrated with a ^{137}Cs source.

The gamma-ray dose rate was measured using a compensated Geiger-Mueller (GM) detector (Wagner and Hurst, 1961). It consists of miniature GM tube in a shield made of tin and lead mesh. The shield is configured to create an approximate uniform response to a gamma-ray dose over the energy range of 50 keV to 1.25 MeV. An advantage of this type of dosimeter in mixed field dosimetry is that it has very low response to neutrons, particularly to those at 14 MeV (3% dose wise). Pulses from the GM counter were also normalized with those from the PS monitor.

The response of the TE ion chamber was corrected for temperature and pressure, attenuation of the neutron dose, response relative to muscle tissue, the W value for neutrons relative to the gamma rays used for calibration, and the relative mass-stopping power of the wall to the gas. The GM was corrected for neutron response; the dead time correction was negligible because of the low count rate. The conversion factors used were 1.37E-06 rad/count for ion chamber and 1.98E-07 rad/count for the GM tube.

Dosimetry was carried out with the iron phantom placed about 32 cm above the NG. The NG was operated at 80 kV, 10.0 kHz, 25% duty cycle, and at three current intensities of 50, 60, and 70 μA. Four repetitive counts of the background were measured for 10 sec each, while the repetitive dose measurements with TE and GM were carried out for 100 sec each. Table 3 summarizes the results.

Table 3. In-beam neutron and gamma ray dosimetry measured in the patient's position.

Beam Current (μA)	Dose Rate (μGy/hr)			Gamma Dose (%)	Dose/Monitor Count (μGy/count)		
	Neutron	Gamma	Total		Neutron	Gamma	Total
50	340	25	365	6.9	1.05E-04	7.8E-06	1.13E-04
60	468	32	500	6.5	1.11E-04	7.6E-06	1.19E-04
70	642	43	685	6.3	1.14E-04	7.7E-06	1.22E-04

Dosimetry *in vivo*

The reported dosimetry measured with tissue equivalent dosimeters represents the different components of the patient's entrance dose. This dose is important for designing a facility and for preliminary measurements. However, internal dosimetry requires using proper phantoms in which electronic equilibrium can be established. About 90% of fast neutrons incident on biological tissue interact with light elements by elastic collisions, causing ionizations due to recoils. When they slow down to thermal energies, their energy is deposited via secondary electrons due to induced gamma radiation from the nuclear reaction $^{1}H(n,\gamma)^{2}H$, which emits 2.2 MeV gamma rays, and from protons from the reaction $^{14}N(n,p)^{14}C$. The overall dose calculations for thermal neutrons include the contribution from both these processes. More detailed calculations can be found in reference [38].

7. Discussion

Iron exists in nature in the four isotopic forms of mass 54, 56, 57, and 58. It is perhaps the most widely studied element from an analytical standpoint, and there exist many excellent methods of its analysis that compete very favorably with the neutron-activation method. Exceptions are when other elements in a given matrix must be analyzed, or when preparing a sample is unusually difficult and can be avoided by using a nondestructive method. This is the case with humans where samples simply cannot be taken or prepared, thus necessitating *in vivo* measurements. However, these impose the following very stringent constraints. 1) Geometrical – the human body represents a volumetrically large sample that precludes using a compact irradiation-detection system. 2) Dose - the intensity or time of the measurement is limited due to the radiation dose that a patient receives. Acceptable radiation doses to humans should not exceed 10rem, and should be lower when repetitive measurements are planned. 3) Time - for practical reasons, the counting times should not be more than 1 hr because it is troublesome for patients to remain still for so long. There are limited numbers of methods that facilitate direct quantitative elemental analysis in human body *in vivo* with high degree of specificity, penetration power, and adequate sensitivity. Those that do typically would include gamma radiation, high-energy protons, and neutrons, generally referred to as ionizing radiation.

The present results using 14 MeV neutrons demonstrated the ability to measure iron by prompt inelastic scattering and by delayed activation. However, the main drawback identified was the extremely low dose at the patient's position. Similar studies have utilized radiation doses, or calculated ones, of 10 rem [28] and 1 rem [39]. However, ours are a few orders-of-

magnitude lower than what would be practical for this type of procedure. Furthermore a high-energy resolution HPGe detector was chosen to separate from the background and to identify the proper gamma lines in the system for potential use. In addition these detectors also have a superior signal to noise ratio in comparison to NaI detectors. Once a useful line is identified it might be possible to use a NaI detector with a better detection efficiency. At this stage, it is difficult to assess which method is preferable, either prompt inelastic or delayed activation. Although the cross-section favors the former, background considerations definitely suggest delayed activation. In particular, when using germanium detectors the iron peak resides on top of a germanium peak; however, this problem might be overcome using NaI detectors that also offer higher detection efficiency. It is very important to emphasize that the need to increase the source intensity or design a more compact geometry will impose more stringent requirements on shielding the detector, and preventing neutrons intercepting in it, while, at the same time, increasing yield from the target.

In conclusion, the present results support the possibility of measuring iron quantitatively *in vivo* by either prompt or delayed activation. Unfortunately, the low source intensity in that geometry resulted in doses that insufficient to yield quantitative conclusions. Nevertheless, the results corroborate general observations reported in the literature. Future work should explore a stronger source, a better optimized and more compact geometry, and increase in the number of detectors, or, alternatively, the use of detectors with larger efficiency, such as the NaI scintillation detector. Modulating the fast neutron pulse to reduce the dose might further optimize the system [40]. This report could serve as a short review of the nuclear technologies for measuring iron *in vivo.*

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APPENDIX A

Raw data spectra used in this report.

Channel #	Channel number of the spectrum.
Energy(keV)	Using the calibration line in the text with the corresponding energy to each channel.
Water Spectrum	Prompt gamma-ray spectrum from a one-liter bottle with water counted for 1 hr.
12gFe1lw	Prompt gamma-ray spectrum from 12 g of iron dissolved in one-liter bottle with water and counted for 1 hr.
12gFe1lwD	Delayed gamma-ray spectrum from 12 g of iron dissolved in one-liter bottle with water irradiated for 1 hr and counted for 15 min.
12gFe1lwDD	Delayed gamma-ray spectrum from 12 g of iron dissolved in one-liter bottle with water irradiated for 1 hr and counted for 45 min following the previous 15 min.
Fe Plate	A prompt gamma-ray spectrum counted from iron plate for 15 min.

Channel #	Energy (keV)	Water Spectrum	12gFe1lw Spectrum	12gFe1lwD Spectrum	12gFe1lwDD Spectrum	Fe Plate Spectrum
1	17.245	0	0	0	0	0
2	19.54	0	0	0	0	0
3	21.835	0	0	0	0	0
4	24.13	0	0	0	0	0
5	26.425	0	0	0	0	0
6	28.72	0	0	0	0	0
7	31.015	0	0	0	0	0
8	33.31	0	0	0	0	0
9	35.605	0	0	0	0	0
10	37.9	0	0	0	0	0
11	40.195	0	0	0	0	0
12	42.49	0	0	0	0	0
13	44.785	0	0	0	0	0
14	47.08	0	0	0	0	0
15	49.375	0	0	0	0	0
16	51.67	0	0	0	0	0
17	53.965	0	0	0	0	0
18	56.26	0	0	0	0	0
19	58.555	8761	8594	53	133	9240
20	60.85	100777	98483	1186	2551	24596
21	63.145	85590	82798	1023	2013	20167
22	65.44	76998	74766	915	1884	18030
23	67.735	70063	68443	888	1816	16115
24	70.03	68168	66155	782	1722	16122
25	72.325	67454	64722	786	1715	15420
26	74.62	65196	63991	808	1606	15292

27	76.915	64183	62855	836	1593	15418
28	79.21	63483	62111	832	1668	15429
29	81.505	62823	61215	767	1642	15126
30	83.8	65668	63628	741	1623	15729
31	86.095	61832	60838	816	1580	15251
32	88.39	60165	58725	751	1557	14651
33	90.685	60161	58011	729	1554	15036
34	92.98	58815	57545	728	1475	14995
35	95.275	58261	57233	681	1486	15058
36	97.57	57296	55816	687	1477	15038
37	99.865	56139	55431	731	1493	15350
38	102.16	55365	54877	729	1439	14580
39	104.455	54771	53877	689	1498	14414
40	106.75	53919	52667	654	1330	14268
41	109.045	53177	52506	680	1364	14040
42	111.34	52532	51173	664	1443	14024
43	113.635	58218	58389	984	1472	15429
44	115.93	59148	58638	1102	1325	15430
45	118.225	50665	50161	610	1345	13745
46	120.52	49808	48305	610	1217	13558
47	122.815	48797	48219	651	1336	13218
48	125.11	47824	47361	582	1300	13563
49	127.405	47636	47002	614	1260	13246
50	129.7	46432	46294	584	1195	13072
51	131.995	46048	45425	615	1180	13205
52	134.29	45912	44849	550	1146	12730
53	136.585	45575	44644	568	1177	12589
54	138.88	44880	44479	550	1176	12347
55	141.175	44221	43765	547	1099	12400
56	143.47	44671	43915	553	1136	12221
57	145.765	46326	45875	554	1168	12412
58	148.06	43173	42888	504	1095	12173
59	150.355	43449	42851	534	1097	12117
60	152.65	43203	42648	540	1050	12141
61	154.945	43169	42539	494	1064	12332
62	157.24	42448	41832	527	1035	12081
63	159.535	42004	41652	521	1031	12065
64	161.83	41276	40873	494	1043	12039
65	164.125	40955	40249	543	998	11922
66	166.42	40430	39993	495	1006	11457
67	168.715	39324	39368	526	947	11548
68	171.01	39622	39037	455	1023	11192
69	173.305	48986	48684	464	933	13482
70	175.6	53450	52765	427	990	14544
71	177.895	39394	39354	428	977	11467
72	180.19	38083	37996	459	894	11186
73	182.485	37551	37315	488	895	10816
74	184.78	37035	36703	443	922	10755

75	187.075	36539	35974	456	916	10732
76	189.37	36324	35615	425	912	11105
77	191.665	35699	35666	404	839	10438
78	193.96	35716	34714	431	899	10232
79	196.255	35195	34497	393	846	10359
80	198.55	34883	34358	422	865	9890
81	200.845	34523	34294	428	831	9740
82	203.14	34090	33827	406	886	9987
83	205.435	34146	33461	406	813	9833
84	207.73	33332	33142	406	838	9838
85	210.025	33138	33250	419	841	9713
86	212.32	32781	32631	403	803	9244
87	214.615	32822	32785	441	862	9373
88	216.91	32385	32238	523	1094	9342
89	219.205	32426	32346	417	906	9365
90	221.5	32147	31983	372	849	9230
91	223.795	33229	32991	413	817	9448
92	226.09	31830	31410	404	806	9090
93	228.385	30976	31018	416	737	8992
94	230.68	31274	30763	390	770	9070
95	232.975	30864	30621	376	744	8895
96	235.27	30676	30499	368	763	8643
97	237.565	30179	30006	381	735	8503
98	239.86	30083	29909	386	685	8568
99	242.155	30119	29913	380	795	8585
100	244.45	29430	29189	383	858	8297
101	246.745	29500	29240	377	791	8316
102	249.04	29302	29410	401	791	8225
103	251.335	29360	29305	353	728	8418
104	253.63	29178	29180	378	750	8299
105	255.925	29238	29168	381	717	8155
106	258.22	28219	28531	375	730	8042
107	260.515	28173	28457	372	690	8052
108	262.81	28517	27912	366	720	8013
109	265.105	28707	28262	374	685	7863
110	267.4	28177	27905	379	719	7721
111	269.695	28130	28167	346	685	7859
112	271.99	27960	27928	343	737	7743
113	274.285	28066	27759	381	781	7737
114	276.58	29088	29306	324	750	7661
115	278.875	29414	29012	335	681	7720
116	281.17	27700	27546	334	746	7685
117	283.465	27655	27611	295	712	7487
118	285.76	27760	27114	336	676	7427
119	288.055	27055	27154	335	675	7567
120	290.35	26925	26847	311	677	7442
121	292.645	26935	26857	367	647	7394
122	294.94	26581	26424	337	695	7546

123	297.235	26462	26558	331	700	7355
124	299.53	26637	26428	332	675	7272
125	301.825	26417	26157	317	685	7367
126	304.12	26320	26514	310	690	7305
127	306.415	26813	26659	330	645	7221
128	308.71	26585	26227	332	683	7191
129	311.005	26293	25942	342	696	7166
130	313.3	25683	25830	322	680	7214
131	315.595	25701	25657	309	681	7266
132	317.89	25371	25430	294	694	7119
133	320.185	25566	25352	336	703	7004
134	322.48	25321	24992	318	624	6909
135	324.775	24992	24695	301	617	6613
136	327.07	24402	23856	307	630	6587
137	329.365	24121	24365	278	625	6557
138	331.66	24233	24175	304	693	6641
139	333.955	24109	23902	360	921	6679
140	336.25	24867	24359	292	605	6768
141	338.545	24030	24212	310	640	6628
142	340.84	23775	23970	294	617	6588
143	343.135	24130	23929	300	613	6535
144	345.43	23599	23667	283	620	6398
145	347.725	23904	23525	276	570	6570
146	350.02	23398	23216	276	601	6362
147	352.315	22909	23183	258	616	6286
148	354.61	22957	22895	287	647	6151
149	356.905	22771	23166	261	584	6324
150	359.2	22617	22402	298	597	6314
151	361.495	22916	22644	271	600	6227
152	363.79	22562	22531	254	552	6125
153	366.085	22621	22355	294	620	6114
154	368.38	22308	22064	288	587	6019
155	370.675	22227	22208	289	589	6037
156	372.97	22375	22064	258	612	5950
157	375.265	22549	22165	294	566	6050
158	377.56	22004	21678	261	622	5989
159	379.855	22319	22371	254	602	5884
160	382.15	21683	21773	265	558	5867
161	384.445	21563	21352	283	597	6150
162	386.74	21307	21127	278	581	5775
163	389.035	21385	21384	266	594	5856
164	391.33	20988	21368	265	549	5810
165	393.625	21182	21107	270	596	5927
166	395.92	21975	21924	276	536	6018
167	398.215	21228	21133	323	645	5719
168	400.51	21124	20740	493	1038	5714
169	402.805	20683	20484	265	605	5711
170	405.1	20519	20454	266	556	5591

171	407.395	20704	20678	270	556	5549
172	409.69	19918	20156	246	558	5435
173	411.985	20065	19797	262	540	5480
174	414.28	20146	20184	276	553	5471
175	416.575	20080	20088	247	590	5303
176	418.87	19554	20003	252	537	5338
177	421.165	19852	19850	265	653	5365
178	423.46	19557	20055	296	616	5345
179	425.755	19728	19507	261	555	5149
180	428.05	19064	19056	254	519	5220
181	430.345	19691	19587	234	583	5227
182	432.64	19335	19238	254	513	5329
183	434.935	19170	18990	223	539	5127
184	437.23	18789	18725	238	540	5070
185	439.525	18786	18987	238	574	5069
186	441.82	18796	18661	265	532	5197
187	444.115	18616	18346	237	562	5053
188	446.41	18417	18567	272	570	5058
189	448.705	18554	18236	267	586	5057
190	451	18015	18279	248	543	5015
191	453.295	18115	18269	288	514	4974
192	455.59	20308	20544	264	520	5346
193	457.885	22576	22333	254	518	5972
194	460.18	22656	22432	281	584	5898
195	462.475	22896	22555	237	523	6066
196	464.77	22907	22891	251	482	6089
197	467.065	22321	21935	261	530	6004
198	469.36	20040	19492	246	508	5354
199	471.655	17978	18018	250	499	4981
200	473.95	17394	17219	256	548	4856
201	476.245	17314	17127	236	532	4862
202	478.54	17144	17157	269	502	4747
203	480.835	17430	17467	271	498	4735
204	483.13	17152	17155	242	504	4687
205	485.425	17901	17756	234	526	4933
206	487.72	17453	17388	254	525	4630
207	490.015	16994	17148	224	498	4825
208	492.31	18124	17920	259	516	4920
209	494.605	40859	41195	310	568	10312
210	496.9	79395	79402	425	843	22148
211	499.195	34004	33739	322	654	10956
212	501.49	20844	20546	253	452	6029
213	503.785	18504	19218	254	520	5338
214	506.08	17725	17691	241	490	4983
215	508.375	17258	17100	247	507	4766
216	510.67	16968	16757	237	503	4793
217	512.965	16689	16529	249	496	4588
218	515.26	16200	16066	243	491	4698

219	517.555	16553	16262	223	497	4562
220	519.85	16072	16207	223	455	4498
221	522.145	16314	16289	211	509	4354
222	524.44	16868	17108	236	495	4713
223	526.735	16305	16271	232	453	4631
224	529.03	15853	15751	237	515	4416
225	531.325	15728	15637	246	462	4399
226	533.62	15535	15493	242	482	4384
227	535.915	16002	15677	254	434	4370
228	538.21	15898	15501	214	466	4356
229	540.505	15724	15481	233	491	4366
230	542.8	15567	15429	212	454	4275
231	545.095	15474	15446	212	455	4332
232	547.39	15382	15381	278	451	4217
233	549.685	16684	16184	229	483	4488
234	551.98	20513	20193	211	453	5497
235	554.275	19536	19411	225	447	5420
236	556.57	19817	19637	213	475	5226
237	558.865	19293	19291	203	444	5383
238	561.16	18067	17898	232	407	4851
239	563.455	17407	17415	261	483	4798
240	565.75	17140	17110	240	469	4723
241	568.045	16816	16857	243	452	4672
242	570.34	16625	16752	244	532	4572
243	572.635	16393	16474	296	750	4608
244	574.93	16278	16583	240	496	4567
245	577.225	16092	16019	213	448	4312
246	579.52	15756	15905	223	464	4583
247	581.815	16268	16106	242	429	4545
248	584.11	24280	24415	234	446	5944
249	586.405	28484	28371	225	423	7524
250	588.7	31038	30927	236	464	7860
251	590.995	30633	30661	225	427	8384
252	593.29	27707	28005	218	415	7299
253	595.585	27016	27151	251	426	7063
254	597.88	27005	26839	308	638	7086
255	600.175	25766	25356	257	520	6904
256	602.47	24360	24449	260	436	6709
257	604.765	23604	24146	204	422	6453
258	607.06	22753	23081	204	462	6262
259	609.355	22053	22051	230	469	6066
260	611.65	21258	20881	208	435	5729
261	613.945	20570	20195	217	428	5587
262	616.24	20152	20041	192	406	5501
263	618.535	19596	19660	207	418	5316
264	620.83	19144	18997	230	446	5240
265	623.125	19110	18747	205	414	5290
266	625.42	18802	18794	211	384	5105

267	627.715	18193	18213	220	473	5076
268	630.01	17759	17637	202	425	5034
269	632.305	17702	17756	227	451	4960
270	634.6	17612	17308	208	421	4841
271	636.895	17242	17174	207	413	4873
272	639.19	18481	18657	218	400	5155
273	641.485	18404	18432	197	429	5186
274	643.78	16797	16701	184	409	4737
275	646.075	16758	16481	216	393	4697
276	648.37	16256	16174	196	379	4375
277	650.665	16279	16308	214	394	4538
278	652.96	15974	16191	194	407	4496
279	655.255	16180	16057	190	386	4383
280	657.55	15558	15748	212	415	4383
281	659.845	15806	15586	166	400	4310
282	662.14	15657	15715	179	405	4234
283	664.435	15505	15431	194	417	4389
284	666.73	15509	15455	187	383	4238
285	669.025	15334	15553	200	376	4297
286	671.32	15354	15559	197	363	4139
287	673.615	15457	15183	203	378	4250
288	675.91	15255	15203	189	378	4256
289	678.205	15258	15210	165	354	4327
290	680.5	15745	15505	192	389	4086
291	682.795	24339	24383	187	401	6126
292	685.09	29427	29093	186	371	7505
293	687.385	27446	27418	201	399	7228
294	689.68	25718	25760	195	377	6754
295	691.975	24333	24179	175	354	6522
296	694.27	23414	23210	165	361	6169
297	696.565	22150	22096	176	380	5870
298	698.86	21144	21260	207	362	5774
299	701.155	20263	20457	189	358	5393
300	703.45	19035	19251	167	379	5134
301	705.745	18627	18519	193	365	5051
302	708.04	17667	17816	195	351	4832
303	710.335	17239	17229	160	355	4640
304	712.63	16729	16650	178	352	4656
305	714.925	16565	16176	170	342	4389
306	717.22	15727	16015	157	361	4317
307	719.515	15910	15509	186	364	4282
308	721.81	15153	15301	148	354	4209
309	724.105	14938	15062	169	319	4094
310	726.4	14593	14798	169	322	3947
311	728.695	14678	14540	174	348	3969
312	730.99	14626	14921	161	374	3821
313	733.285	14463	14348	155	321	3808
314	735.58	14252	14178	154	349	3876

315	737.875	14386	14406	149	340	3719
316	740.17	14169	14333	157	346	3816
317	742.465	14050	13855	160	313	3791
318	744.76	13853	13832	149	322	3709
319	747.055	13611	13796	170	322	3688
320	749.35	13623	13499	146	322	3774
321	751.645	13512	13406	165	320	3698
322	753.94	13433	13295	152	324	3580
323	756.235	13356	13147	153	309	3633
324	758.53	13375	13363	156	338	3633
325	760.825	13131	13172	154	318	3558
326	763.12	13091	13203	169	320	3560
327	765.415	13028	13125	153	276	3557
328	767.71	13239	13195	156	298	3554
329	770.005	12990	12828	162	297	3536
330	772.3	12732	12609	155	276	3441
331	774.595	13055	12944	130	298	3430
332	776.89	12711	12914	147	323	3332
333	779.185	12655	12459	148	317	3499
334	781.48	12563	12702	140	313	3436
335	783.775	12635	12464	135	333	3468
336	786.07	12767	12476	145	281	3393
337	788.365	12331	12551	145	291	3451
338	790.66	12406	12352	131	296	3509
339	792.955	12332	12215	147	302	3332
340	795.25	12098	12225	160	283	3335
341	797.545	12540	12186	141	268	3422
342	799.84	12200	12152	133	290	3314
343	802.135	12471	12278	145	280	3384
344	804.43	11974	11866	148	270	3347
345	806.725	11915	11729	119	260	3263
346	809.02	11550	11576	139	264	3232
347	811.315	11434	11752	129	284	3132
348	813.61	11455	11407	182	318	3160
349	815.905	11765	11660	134	279	3249
350	818.2	12442	12523	124	260	3339
351	820.495	11921	12150	146	285	3282
352	822.79	11572	11743	144	271	3170
353	825.085	12227	12096	128	243	3215
354	827.38	12554	12758	126	247	3385
355	829.675	13980	14542	110	269	3781
356	831.97	15912	15620	125	260	4135
357	834.265	16042	16112	136	250	4089
358	836.56	16336	16200	146	247	4273
359	838.855	18653	18639	473	442	4999
360	841.15	17172	17368	488	423	9342
361	843.445	16076	16284	145	292	10979
362	845.74	14696	14851	128	245	4975

363	848.035	14860	14671	129	272	4283
364	850.33	15181	15216	114	250	4370
365	852.625	14886	14879	134	224	4258
366	854.92	13490	13312	119	228	3894
367	857.215	13444	13569	113	265	3890
368	859.51	13081	13079	117	251	3686
369	861.805	13039	12808	123	228	3668
370	864.1	13279	13251	119	241	3675
371	866.395	12965	12792	121	258	3527
372	868.69	14292	14276	133	247	3766
373	870.985	13636	13463	103	250	3747
374	873.28	12531	12549	133	226	3351
375	875.575	12125	12287	97	241	3419
376	877.87	12148	12230	129	260	3302
377	880.165	12144	11982	147	339	3257
378	882.46	12884	12571	106	243	3403
379	884.755	12158	11983	123	195	3389
380	887.05	11911	11718	104	237	3110
381	889.345	12668	12793	100	238	3422
382	891.64	20384	20780	102	190	4653
383	893.935	25465	25341	96	225	6974
384	896.23	13582	13501	98	210	3886
385	898.525	12487	12504	85	204	3319
386	900.82	12153	12101	110	209	3287
387	903.115	12431	12078	107	204	3357
388	905.41	11873	11724	94	197	3150
389	907.705	11399	11522	118	225	3168
390	910	11008	11327	122	298	3113
391	912.295	11239	11309	91	184	2969
392	914.59	11171	10904	115	206	3043
393	916.885	11936	11558	92	182	3010
394	919.18	12128	12156	97	215	3318
395	921.475	11072	10850	95	193	2964
396	923.77	10958	10715	86	199	2930
397	926.065	10922	10634	100	180	3056
398	928.36	10677	10717	105	167	3178
399	930.655	10553	10450	98	181	3218
400	932.95	10691	10336	101	201	2922
401	935.245	10758	10699	91	170	2846
402	937.54	10406	10415	91	202	2836
403	939.835	10285	10121	112	175	2837
404	942.13	10052	10147	100	193	2771
405	944.425	10255	10057	88	194	2797
406	946.72	9896	9974	78	171	2805
407	949.015	10110	10044	88	181	2760
408	951.31	9982	9977	76	168	2815
409	953.605	10246	10118	76	179	2828
410	955.9	10295	10408	89	171	2851

411	958.195	10863	10783	96	147	3010
412	960.49	10293	10416	79	186	2783
413	962.785	9904	9841	76	172	2778
414	965.08	9625	9801	78	194	2726
415	967.375	9894	9747	89	175	2724
416	969.67	10035	9993	104	225	2655
417	971.965	9715	9650	71	160	2687
418	974.26	9739	9663	81	152	2699
419	976.555	9508	9346	82	171	2704
420	978.85	9429	9415	81	160	2545
421	981.145	9480	9509	79	126	2613
422	983.44	9935	10013	84	145	2703
423	985.735	9714	9573	71	141	2709
424	988.03	9543	9438	79	153	2568
425	990.325	11047	11197	78	127	2931
426	992.62	12734	12883	77	158	3435
427	994.915	10613	10627	73	154	2878
428	997.21	10258	10197	69	142	2921
429	999.505	9614	9432	76	142	2588
430	1001.8	9500	9364	78	159	2664
431	1004.095	9715	9637	73	139	2646
432	1006.39	12226	12433	70	137	3146
433	1008.685	12039	12096	64	127	3310
434	1010.98	9935	9867	68	148	2744
435	1013.275	12169	11985	120	151	3070
436	1015.57	13740	13599	224	213	3808
437	1017.865	10169	10141	113	149	2780
438	1020.16	9676	9260	49	147	2726
439	1022.455	9307	9077	86	143	2505
440	1024.75	9069	9119	65	129	2496
441	1027.045	8941	9071	69	109	2565
442	1029.34	8993	8826	73	126	2561
443	1031.635	9107	9179	70	134	2512
444	1033.93	9797	9981	59	123	2631
445	1036.225	9099	9063	67	132	2672
446	1038.52	9040	8757	58	130	2925
447	1040.815	9956	9847	59	131	2824
448	1043.11	10385	10479	74	131	2812
449	1045.405	10409	10556	56	122	2799
450	1047.7	10660	10616	55	115	2815
451	1049.995	10530	10581	61	129	2830
452	1052.29	10439	10398	78	123	2714
453	1054.585	10175	10237	68	140	2798
454	1056.88	10075	10063	74	109	2809
455	1059.175	9784	9930	69	133	2828
456	1061.47	9892	9832	48	119	2698
457	1063.765	9777	9771	57	121	2710
458	1066.06	9984	9965	63	104	2673

459	1068.355	9583	9504	55	129	2611
460	1070.65	9367	9106	64	102	2572
461	1072.945	9155	9175	43	115	2446
462	1075.24	9182	8891	58	130	2510
463	1077.535	9003	9080	47	112	2509
464	1079.83	9089	8858	53	118	2466
465	1082.125	8897	8804	54	103	2478
466	1084.42	8657	8622	63	108	2467
467	1086.715	8634	8615	59	110	2395
468	1089.01	8568	8605	60	103	2435
469	1091.305	8460	8321	55	93	2355
470	1093.6	8371	8415	66	106	2352
471	1095.895	9533	9598	64	86	2412
472	1098.19	10584	10711	81	120	2947
473	1100.485	8954	8793	185	392	2511
474	1102.78	8507	8541	114	231	2335
475	1105.075	8490	8372	44	100	2323
476	1107.37	8219	8192	48	91	2331
477	1109.665	8337	8219	59	93	2241
478	1111.96	8286	8199	66	125	2287
479	1114.255	8307	8362	56	101	2317
480	1116.55	8470	8528	58	94	2210
481	1118.845	8649	8473	58	109	2313
482	1121.14	8493	8256	119	282	2334
483	1123.435	8349	8325	91	238	2341
484	1125.73	8320	8165	58	147	2296
485	1128.025	8303	8219	52	104	2275
486	1130.32	8258	8195	55	84	2200
487	1132.615	8346	8196	37	77	2288
488	1134.91	9819	9889	50	90	2440
489	1137.205	9944	9824	53	100	2685
490	1139.5	8479	8389	49	88	2273
491	1141.795	8138	8308	51	81	2286
492	1144.09	8172	8008	37	92	2220
493	1146.385	8040	8024	37	80	2247
494	1148.68	7709	7986	46	94	2112
495	1150.975	7917	7749	47	91	2113
496	1153.27	7668	7817	40	84	2107
497	1155.565	7883	7769	42	82	2080
498	1157.86	7734	7841	36	68	2132
499	1160.155	8383	8615	46	79	2256
500	1162.45	7940	7835	58	70	2171
501	1164.745	7861	7644	47	71	2170
502	1167.04	7661	7519	34	82	2100
503	1169.335	7659	7738	39	61	2158
504	1171.63	7542	7563	41	79	2045
505	1173.925	7627	7524	35	84	2071
506	1176.22	7689	7599	48	91	2029

507	1178.515	7885	7921	36	80	2239
508	1180.81	7411	7678	47	95	2107
509	1183.105	7433	7576	32	59	2019
510	1185.4	7269	7267	40	75	2006
511	1187.695	7351	7353	40	52	2062
512	1189.99	7186	7174	39	61	1990
513	1192.285	7309	7225	34	77	1996
514	1194.58	7352	7428	35	74	1978
515	1196.875	7349	7333	32	82	2082
516	1199.17	7267	7390	42	85	1925
517	1201.465	7312	7222	29	69	1947
518	1203.76	7239	7353	31	79	1947
519	1206.055	7251	7307	40	60	1966
520	1208.35	7542	7499	39	74	2000
521	1210.645	7849	7789	30	74	2050
522	1212.94	7953	7887	34	72	2134
523	1215.235	8256	8155	42	66	2201
524	1217.53	7996	8049	39	69	2204
525	1219.825	8105	7986	35	60	2112
526	1222.12	8080	8051	37	69	2130
527	1224.415	8112	8281	35	50	2231
528	1226.71	8015	8081	42	57	2200
529	1229.005	7820	7909	35	53	2145
530	1231.3	7943	7916	37	54	2039
531	1233.595	7885	7846	39	62	2100
532	1235.89	7656	7591	41	68	2065
533	1238.185	7438	7631	39	64	2102
534	1240.48	7576	7497	40	79	2108
535	1242.775	7819	7887	44	77	2477
536	1245.07	8091	8313	44	97	3986
537	1247.365	7615	7666	43	91	2903
538	1249.66	7368	7444	33	72	2183
539	1251.955	7913	7903	35	50	2133
540	1254.25	7534	7378	32	62	2085
541	1256.545	7171	7253	25	51	2015
542	1258.84	7314	7319	23	56	1913
543	1261.135	7400	7143	23	66	1940
544	1263.43	7012	7245	36	66	2007
545	1265.725	7043	7176	36	51	1974
546	1268.02	7094	7223	24	48	1877
547	1270.315	6976	6915	28	41	1896
548	1272.61	7114	7042	40	59	1906
549	1274.905	7040	7048	31	68	1957
550	1277.2	7007	7022	30	47	1910
551	1279.495	6857	6975	29	47	1911
552	1281.79	6812	6969	33	42	1891
553	1284.085	7068	6801	31	52	1863
554	1286.38	6972	6874	36	50	1882

555	1288.675	6843	6839	31	56	1889
556	1290.97	6760	6941	22	55	1879
557	1293.265	6827	6620	29	70	1786
558	1295.56	6838	6727	31	58	1887
559	1297.855	6845	6905	23	44	1994
560	1300.15	6840	6773	51	85	1857
561	1302.445	6950	6797	187	371	1839
562	1304.74	6661	6780	105	254	1856
563	1307.035	6816	6741	26	54	1887
564	1309.33	6651	6629	27	46	1893
565	1311.625	6715	6894	19	54	2088
566	1313.92	6615	6730	30	44	2046
567	1316.215	6777	6556	26	49	1895
568	1318.51	6577	6745	36	53	1772
569	1320.805	6705	6625	21	49	1893
570	1323.1	6692	6672	30	34	1853
571	1325.395	6789	6853	23	51	1977
572	1327.69	6719	6627	24	58	1883
573	1329.985	6492	6561	22	46	1801
574	1332.28	6529	6389	20	60	1769
575	1334.575	6624	6688	30	47	1832
576	1336.87	6780	6673	27	42	1858
577	1339.165	6526	6607	31	47	1798
578	1341.46	6606	6752	18	64	1785
579	1343.755	6921	6817	34	56	1860
580	1346.05	6660	6572	26	36	1860
581	1348.345	6494	6507	24	46	1859
582	1350.64	6544	6451	18	39	1645
583	1352.935	6387	6520	24	42	1818
584	1355.23	6296	6367	18	46	1797
585	1357.525	6647	6564	32	62	1868
586	1359.82	6504	6599	26	67	1710
587	1362.115	6478	6534	23	42	1761
588	1364.41	6532	6515	19	29	1743
589	1366.705	6457	6482	28	38	1753
590	1369	6343	6304	23	43	1676
591	1371.295	6408	6387	21	46	1786
592	1373.59	6377	6392	26	44	1620
593	1375.885	6552	6430	24	41	1701
594	1378.18	6541	6388	46	139	1772
595	1380.475	6455	6287	151	377	1733
596	1382.77	6467	6477	58	142	1789
597	1385.065	6464	6376	27	53	1680
598	1387.36	6190	6160	18	42	1666
599	1389.655	6188	6274	13	48	1663
600	1391.95	6203	6056	12	47	1635
601	1394.245	6257	6340	28	43	1687
602	1396.54	6335	6131	20	45	1646

603	1398.835	6135	6015	22	44	1630
604	1401.13	6144	6040	25	27	1589
605	1403.425	6005	6200	23	30	1662
606	1405.72	6110	6021	18	39	1650
607	1408.015	6046	6071	23	35	1618
608	1410.31	5852	5846	14	34	1565
609	1412.605	5933	5907	20	26	1652
610	1414.9	5879	5892	25	43	1614
611	1417.195	5957	5938	13	42	1582
612	1419.49	5962	5994	23	36	1769
613	1421.785	6103	5884	14	41	1758
614	1424.08	5902	5947	20	43	1668
615	1426.375	5887	5881	19	33	1613
616	1428.67	5817	5956	17	29	1574
617	1430.965	5749	5822	22	31	1587
618	1433.26	5696	5853	19	36	1613
619	1435.555	5784	5552	15	35	1616
620	1437.85	5774	5756	17	32	1626
621	1440.145	5724	5785	15	33	1542
622	1442.44	5750	5672	22	33	1563
623	1444.735	5803	6087	27	33	1641
624	1447.03	6039	6059	12	33	1616
625	1449.325	5808	5807	23	27	1566
626	1451.62	5701	5755	14	31	1579
627	1453.915	5854	5769	22	33	1542
628	1456.21	5696	5750	21	29	1583
629	1458.505	5587	5660	16	19	1538
630	1460.8	5626	5579	12	26	1579
631	1463.095	5650	5669	17	29	1577
632	1465.39	5604	5618	12	29	1466
633	1467.685	5590	5723	11	23	1548
634	1469.98	5593	5574	17	30	1506
635	1472.275	5540	5536	34	58	1498
636	1474.57	5635	5658	75	215	1438
637	1476.865	5695	5670	72	188	1524
638	1479.16	5875	5931	16	51	1616
639	1481.455	5970	5899	21	23	1585
640	1483.75	5796	5936	14	24	1611
641	1486.045	5790	5949	14	23	1656
642	1488.34	5690	5747	17	27	1510
643	1490.635	5826	5805	14	29	1485
644	1492.93	5760	5757	15	30	1519
645	1495.225	5747	5762	10	21	1621
646	1497.52	5688	5600	15	32	1535
647	1499.815	5764	5721	16	30	1469
648	1502.11	5754	5656	8	19	1521
649	1504.405	5616	5681	18	22	1528
650	1506.7	5695	5527	10	30	1588

651	1508.995	5408	5441	21	38	1490
652	1511.29	5702	5516	22	33	1561
653	1513.585	5557	5600	11	33	1620
654	1515.88	5582	5556	18	21	1578
655	1518.175	5899	5796	17	26	1586
656	1520.47	5556	5733	19	27	1522
657	1522.765	5322	5452	32	65	1493
658	1525.06	5412	5397	31	51	1506
659	1527.355	5365	5335	19	29	1456
660	1529.65	5376	5276	12	26	1449
661	1531.945	5296	5292	11	17	1485
662	1534.24	5301	5339	16	30	1407
663	1536.535	5494	5466	19	29	1461
664	1538.83	5509	5484	11	22	1459
665	1541.125	6179	5984	13	23	1563
666	1543.42	5973	5878	11	31	1612
667	1545.715	5340	5380	18	23	1446
668	1548.01	5302	5445	12	35	1450
669	1550.305	5391	5417	12	23	1480
670	1552.6	5519	5341	19	18	1502
671	1554.895	5360	5094	19	29	1418
672	1557.19	5229	5308	9	27	1448
673	1559.485	5491	5366	17	26	1437
674	1561.78	6072	6038	18	28	1542
675	1564.075	5533	5610	16	26	1598
676	1566.37	5317	5112	13	33	1410
677	1568.665	5176	5104	14	22	1428
678	1570.96	5068	5031	14	23	1440
679	1573.255	5104	5115	8	11	1437
680	1575.55	5589	5401	11	21	1446
681	1577.845	5470	5470	11	17	1480
682	1580.14	5005	5018	11	22	1373
683	1582.435	4959	5229	18	19	1330
684	1584.73	4958	5077	11	17	1424
685	1587.025	5044	4981	8	25	1399
686	1589.32	4926	4928	10	22	1372
687	1591.615	5153	5054	13	25	1339
688	1593.91	5021	5002	14	16	1383
689	1596.205	5067	4941	13	22	1289
690	1598.5	4831	5018	10	23	1318
691	1600.795	4875	4857	9	18	1392
692	1603.09	4835	4931	9	30	1402
693	1605.385	4896	4967	14	21	1353
694	1607.68	4984	4917	8	31	1362
695	1609.975	5024	4956	8	29	1372
696	1612.27	5007	4895	11	30	1266
697	1614.565	4872	4824	14	17	1294
698	1616.86	4821	4941	14	14	1314

699	1619.155	4842	4795	11	24	1318
700	1621.45	5262	5175	17	32	1355
701	1623.745	8786	8830	10	19	1847
702	1626.04	17005	16958	10	17	3992
703	1628.335	9135	9036	8	23	3000
704	1630.63	5819	5763	14	21	1595
705	1632.925	5395	5313	9	17	1433
706	1635.22	5152	5227	4	14	1408
707	1637.515	5074	5121	13	17	1397
708	1639.81	4917	4995	10	20	1374
709	1642.105	4957	4931	15	25	1394
710	1644.4	4914	4909	9	15	1316
711	1646.695	4951	4917	9	19	1332
712	1648.99	4884	5064	12	23	1321
713	1651.285	4777	4834	12	27	1381
714	1653.58	4705	4755	7	19	1342
715	1655.875	4837	4866	7	16	1300
716	1658.17	4880	5014	8	26	1282
717	1660.465	4795	4816	9	22	1344
718	1662.76	4866	4708	9	19	1235
719	1665.055	4626	4783	10	25	1258
720	1667.35	4602	4617	10	10	1315
721	1669.645	4687	4626	10	18	1232
722	1671.94	4607	4696	7	14	1244
723	1674.235	4549	4646	8	20	1254
724	1676.53	4565	4606	13	18	1288
725	1678.825	4582	4613	10	21	1267
726	1681.12	4404	4623	5	20	1250
727	1683.415	4660	4638	12	19	1219
728	1685.71	4650	4554	8	25	1285
729	1688.005	4675	4666	15	21	1378
730	1690.3	4701	4511	4	17	1366
731	1692.595	4379	4574	8	19	1302
732	1694.89	4415	4553	5	21	1150
733	1697.185	4439	4543	9	18	1252
734	1699.48	4407	4469	11	12	1169
735	1701.775	4436	4453	6	18	1233
736	1704.07	4560	4666	4	21	1241
737	1706.365	4917	4899	10	19	1371
738	1708.66	4550	4614	9	14	1279
739	1710.955	4489	4476	10	16	1226
740	1713.25	4513	4329	12	27	1232
741	1715.545	4578	4568	3	13	1212
742	1717.84	4589	4636	6	12	1227
743	1720.135	4602	4715	12	20	1259
744	1722.43	4479	4683	9	16	1234
745	1724.725	4504	4473	4	24	1240
746	1727.02	4370	4403	10	14	1245

747	1729.315	4516	4412	8	19	1240
748	1731.61	4723	4591	15	26	1212
749	1733.905	4704	4675	10	17	1285
750	1736.2	4778	4816	7	21	1190
751	1738.495	4974	4882	9	22	1348
752	1740.79	5153	5084	5	20	1332
753	1743.085	4914	4860	15	19	1365
754	1745.38	4691	4746	10	27	1304
755	1747.675	4739	4639	9	13	1276
756	1749.97	4520	4712	8	14	1251
757	1752.265	4486	4466	9	37	1208
758	1754.56	4446	4481	21	50	1187
759	1756.855	4462	4450	13	27	1294
760	1759.15	4347	4447	12	18	1177
761	1761.445	4477	4543	3	17	1240
762	1763.74	4375	4476	11	20	1226
763	1766.035	4418	4367	11	15	1249
764	1768.33	4499	4454	8	23	1180
765	1770.625	4334	4327	9	17	1207
766	1772.92	4271	4417	10	18	1173
767	1775.215	4480	4365	18	29	1225
768	1777.51	4397	4360	12	29	1199
769	1779.805	4261	4346	5	18	1137
770	1782.1	4256	4325	7	16	1168
771	1784.395	4220	4363	6	22	1135
772	1786.69	4271	4228	18	46	1170
773	1788.985	4156	4257	26	57	1174
774	1791.28	4265	4294	5	21	1151
775	1793.575	4298	4296	8	25	1162
776	1795.87	4260	4351	6	16	1121
777	1798.165	4469	4278	10	13	1188
778	1800.46	4415	4440	15	22	1205
779	1802.755	4579	4462	23	18	1268
780	1805.05	4531	4377	18	14	1249
781	1807.345	4405	4420	13	11	1192
782	1809.64	4251	4203	11	20	1210
783	1811.935	4247	4142	8	16	1071
784	1814.23	4299	4096	14	15	1131
785	1816.525	4200	4180	3	24	1106
786	1818.82	4162	4259	9	18	1154
787	1821.115	4302	4308	4	19	1109
788	1823.41	4208	4248	5	13	1154
789	1825.705	4312	4226	7	12	1163
790	1828	4262	4172	5	11	1138
791	1830.295	4729	4645	8	25	1246
792	1832.59	4721	4792	8	21	1417
793	1834.885	4562	4431	13	44	1423
794	1837.18	4387	4239	15	33	1168

795	1839.475	4268	4279	8	15	1177
796	1841.77	4162	4152	7	11	1087
797	1844.065	4116	4045	11	11	1155
798	1846.36	3987	4089	3	13	1112
799	1848.655	4145	4102	5	20	1160
800	1850.95	4134	4038	4	22	1142
801	1853.245	4119	4053	8	13	1170
802	1855.54	4077	4133	9	13	1070
803	1857.835	4032	4058	3	19	1099
804	1860.13	4100	3955	4	6	1065
805	1862.425	4025	3990	4	19	1114
806	1864.72	3867	4057	4	19	1047
807	1867.015	3997	4023	7	21	1135
808	1869.31	3980	3975	7	17	1101
809	1871.605	4039	4051	13	16	1128
810	1873.9	3974	4012	9	15	1104
811	1876.195	4041	3980	7	26	1092
812	1878.49	3961	4025	6	14	1138
813	1880.785	3906	4032	5	20	1129
814	1883.08	3897	3962	7	7	1036
815	1885.375	3976	4101	8	9	1104
816	1887.67	4076	3935	8	16	1048
817	1889.965	3912	3880	13	25	1081
818	1892.26	3901	3982	9	16	1039
819	1894.555	3905	4004	7	9	1072
820	1896.85	3889	3965	9	15	1061
821	1899.145	3961	3956	3	20	1024
822	1901.44	3973	3938	7	19	1090
823	1903.735	3962	3969	5	13	1086
824	1906.03	3924	4003	11	13	1102
825	1908.325	4008	3947	8	12	1077
826	1910.62	3899	3841	6	15	1041
827	1912.915	3833	3899	8	22	1087
828	1915.21	3852	3835	8	14	1108
829	1917.505	3828	3865	6	15	1047
830	1919.8	3848	3892	8	17	1011
831	1922.095	3844	3745	8	19	1066
832	1924.39	3978	3859	7	17	1040
833	1926.685	3772	3954	7	12	1072
834	1928.98	3753	3811	3	15	1039
835	1931.275	3758	3884	4	15	1075
836	1933.57	3786	3693	8	22	1035
837	1935.865	3799	3864	8	13	1076
838	1938.16	3728	3761	7	15	1030
839	1940.455	3831	3812	5	13	986
840	1942.75	3818	3758	5	11	1042
841	1945.045	3901	3739	6	20	1018
842	1947.34	3809	3923	7	22	1069

843	1949.635	3933	3833	8	9	1009
844	1951.93	3728	3699	7	17	1066
845	1954.225	3863	3798	7	19	1017
846	1956.52	3766	3806	8	11	999
847	1958.815	3876	3918	4	23	1081
848	1961.11	3823	3639	8	21	988
849	1963.405	3852	3762	6	21	1019
850	1965.7	3834	3828	9	17	1031
851	1967.995	3836	3886	5	10	1055
852	1970.29	3698	3854	7	17	1026
853	1972.585	3683	3706	9	13	978
854	1974.88	3715	3663	9	15	1030
855	1977.175	3744	3849	6	14	1021
856	1979.47	3763	3880	11	20	984
857	1981.765	3742	3811	8	11	1023
858	1984.06	3759	3682	5	13	1039
859	1986.355	3791	3742	6	12	1044
860	1988.65	3729	3800	3	13	992
861	1990.945	3760	3839	7	18	1024
862	1993.24	3793	3658	2	7	1025
863	1995.535	3801	3733	9	19	950
864	1997.83	3695	3657	7	13	1038
865	2000.125	3704	3743	10	10	988
866	2002.42	3795	3719	5	20	993
867	2004.715	3784	3850	4	10	1003
868	2007.01	3795	3761	8	8	968
869	2009.305	3823	3821	1	11	1110
870	2011.6	3818	3651	5	14	1070
871	2013.895	3708	3779	9	12	1114
872	2016.19	3832	3764	8	9	970
873	2018.485	3641	3740	7	14	1017
874	2020.78	3767	3646	4	9	974
875	2023.075	3650	3656	6	13	971
876	2025.37	3712	3642	6	16	929
877	2027.665	3664	3641	2	19	971
878	2029.96	3584	3612	7	15	959
879	2032.255	3640	3545	7	14	1001
880	2034.55	3645	3660	4	14	960
881	2036.845	3761	3577	6	11	1015
882	2039.14	3852	3725	7	14	1026
883	2041.435	3568	3626	5	11	996
884	2043.73	3598	3528	4	6	968
885	2046.025	3546	3585	5	16	1010
886	2048.32	3540	3563	7	9	970
887	2050.615	3570	3568	6	14	922
888	2052.91	3530	3552	1	11	949
889	2055.205	3484	3511	6	14	979
890	2057.5	3580	3496	8	16	939

891	2059.795	3601	3511	2	11	941
892	2062.09	3374	3467	4	15	958
893	2064.385	3595	3506	4	14	970
894	2066.68	3493	3486	6	15	935
895	2068.975	3442	3517	2	10	925
896	2071.27	3390	3502	3	11	917
897	2073.565	3465	3471	5	19	951
898	2075.86	3494	3454	6	8	970
899	2078.155	3501	3465	7	14	914
900	2080.45	3512	3459	6	12	962
901	2082.745	3584	3560	5	12	929
902	2085.04	3586	3650	6	11	942
903	2087.335	3455	3479	7	15	889
904	2089.63	3455	3439	3	11	915
905	2091.925	3581	3447	5	9	897
906	2094.22	3525	3478	9	10	956
907	2096.515	3474	3408	5	8	975
908	2098.81	3454	3460	11	13	940
909	2101.105	3424	3560	13	8	901
910	2103.4	3495	3510	6	17	949
911	2105.695	3470	3434	8	10	888
912	2107.99	3459	3505	6	14	952
913	2110.285	3354	3364	7	9	993
914	2112.58	3375	3541	6	7	994
915	2114.875	3440	3320	3	12	954
916	2117.17	3541	3323	6	11	906
917	2119.465	3451	3473	8	18	975
918	2121.76	3446	3447	7	13	938
919	2124.055	3339	3494	7	16	915
920	2126.35	3522	3421	6	10	927
921	2128.645	3339	3407	8	12	959
922	2130.94	3228	3351	2	10	903
923	2133.235	3331	3385	4	14	836
924	2135.53	3512	3326	5	15	889
925	2137.825	3439	3366	9	31	938
926	2140.12	3503	3417	6	16	954
927	2142.415	3400	3278	7	17	951
928	2144.71	3415	3453	17	46	1008
929	2147.005	3372	3501	23	68	966
930	2149.3	3478	3520	10	34	933
931	2151.595	3425	3379	6	13	951
932	2153.89	3432	3257	6	18	905
933	2156.185	3438	3321	6	18	919
934	2158.48	3335	3326	7	16	946
935	2160.775	3453	3433	7	14	905
936	2163.07	3467	3553	8	8	944
937	2165.365	3514	3470	5	9	931
938	2167.66	3476	3339	4	13	927

939	2169.955	3254	3333	10	12	873
940	2172.25	3300	3250	6	9	830
941	2174.545	3410	3392	5	10	904
942	2176.84	3330	3269	3	12	939
943	2179.135	3372	3263	5	14	849
944	2181.43	3413	3216	6	15	874
945	2183.725	3274	3221	8	11	881
946	2186.02	3122	3210	5	10	895
947	2188.315	3247	3237	6	8	850
948	2190.61	3258	3246	3	13	844
949	2192.905	3217	3267	7	13	932
950	2195.2	3244	3200	4	8	887
951	2197.495	3157	3303	4	13	879
952	2199.79	3253	3174	3	21	860
953	2202.085	3158	3246	6	17	874
954	2204.38	3175	3259	4	18	889
955	2206.675	3167	3183	6	12	860
956	2208.97	3117	3217	6	14	875
957	2211.265	3262	3201	5	8	877
958	2213.56	3265	3170	2	12	842
959	2215.855	3279	3144	6	6	807
960	2218.15	3210	3114	4	12	848
961	2220.445	3184	3254	2	13	791
962	2222.74	3247	3127	1	14	859
963	2225.035	3296	3261	4	7	836
964	2227.33	3138	3196	5	16	873
965	2229.625	3207	3232	6	15	851
966	2231.92	3213	3312	8	10	892
967	2234.215	3362	3300	6	10	934
968	2236.51	3353	3427	2	6	906
969	2238.805	3397	3293	5	18	937
970	2241.1	3574	3558	12	32	924
971	2243.395	3535	3675	8	16	965
972	2245.69	3732	3914	5	14	958
973	2247.985	3736	3799	3	11	1081
974	2250.28	3601	3690	4	12	963
975	2252.575	3576	3560	3	13	964
976	2254.87	3674	3632	3	13	926
977	2257.165	4087	4005	5	12	964
978	2259.46	4349	4100	2	17	949
979	2261.755	3604	3628	7	9	906
980	2264.05	3502	3427	4	8	916
981	2266.345	3509	3447	5	7	899
982	2268.64	3295	3366	9	15	900
983	2270.935	3197	3263	6	5	910
984	2273.23	3112	3211	8	7	801
985	2275.525	3328	3250	5	12	916
986	2277.82	3281	3225	9	24	824

987	2280.115	3252	3068	7	26	848
988	2282.41	3136	3185	10	37	871
989	2284.705	3107	3063	7	17	835
990	2287	3124	3140	1	8	895
991	2289.295	3178	2968	7	7	839
992	2291.59	3067	3110	3	7	862
993	2293.885	3120	3074	3	10	827
994	2296.18	3094	3094	6	13	847
995	2298.475	2983	3122	6	7	834
996	2300.77	3055	3064	5	11	896
997	2303.065	3151	3032	5	6	847
998	2305.36	3162	3058	12	11	788
999	2307.655	3038	3042	2	19	881
1000	2309.95	3097	3026	7	14	850
1001	2312.245	3112	3038	6	11	796
1002	2314.54	3090	3135	4	10	860
1003	2316.835	3080	3082	10	5	787
1004	2319.13	3119	3172	9	15	902
1005	2321.425	3095	3133	4	5	833
1006	2323.72	3062	3015	2	8	781
1007	2326.015	3049	3007	5	11	871
1008	2328.31	3112	3085	4	11	809
1009	2330.605	2985	3028	6	9	846
1010	2332.9	3088	2995	4	9	799
1011	2335.195	3141	3189	10	5	849
1012	2337.49	3119	3156	3	11	878
1013	2339.785	3130	3167	9	13	828
1014	2342.08	3130	3062	8	9	798
1015	2344.375	3041	3131	4	9	841
1016	2346.67	3120	3096	2	10	835
1017	2348.965	3044	3086	4	12	830
1018	2351.26	3001	2991	6	8	795
1019	2353.555	3112	3024	1	7	794
1020	2355.85	2997	3046	2	10	780
1021	2358.145	3031	3005	2	13	796
1022	2360.44	3004	3063	6	11	828
1023	2362.735	3023	2921	5	10	826