2009 International Nuclear Atlantic Conference - INAC 2009
Rio de Janeiro, RJ, Brazil, September27 to October 2, 2009
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: **978-85-99141-03-8**

DEVELOPMENT OF AN AUTOMATION SYSTEM FOR IODINE-125 BRACHYTERAPY SEED PRODUCTION BY ND:YAG LASER WELDING

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ABSTRACT

The aim of this work is to develop an automation system for iodine-125 radioactive seed production by Nd:YAG laser welding, which has been used successfully in low dose rate (LDR) brachytherapy treatment. This small seed consists of a welded titanium capsule, with 0.8 mm in diameter and 4.5 mm in length, containing iodine-125 adsorbed onto a silver rod. The iodine-125 seeds are implanted into the human prostate to irradiate the tumor for cancer treatment. Nowadays, the Radiation Technology Center, at IPEN-CNEN/SP imports and distributes 36,000 iodine-125 seeds per year, for the clinics and hospitals in the country. However, the Brazilian market potential is now over 8,000 iodine-125 seeds per month. The local production of these iodine-125 radioactive sources became a priority for the Institute, in order to reduce the price and the problems of prostate cancer management. It will permit to spread their use to a larger number of patients in Brazil. On the other hand, the industrial automation plays an important role for iodine-125 seeds in order to increase the productivity, with high quality and assurance, avoiding human factors, implementing and operating with good manufacturing practices (GMP). The technology consists of appliance electronic and electro-mechanical parts and components to control machines and processes. The automation system technology for iodine-125 seed production developed in this work was mainly assembled employing a Programmable Logic Controller (PLC), a stepper motor, an Nd:YAG laser welding machine and a supervisory.

1. INTRODUCTION

Prostate cancer occurs when cells within the prostate grow uncontrollably, creating small tumors. The term “cancer” refers to a condition in which the regulation of cell growth is lost and cells grow uncontrollably. Most cells in the body are constantly dividing, maturing and then dying in a tightly controlled process. Unlike normal cells, the growth of cancer cells is no longer well-regulated. Instead of dying as they should, cancer cells outlive normal cells and continue to form new, abnormal cells [1].

Abnormal cell growths are called tumors. The term “primary tumor” refers to the original tumor; secondary tumors are caused when the original cancer spreads to other locations in the body. Prostate cancer typically is comprised of multiple very small, primary tumors within the prostate. At this stage, the disease is often curable (rates of 90% or better) with standard interventions such as surgery or radiation that aim to remove or kill all cancerous cells in the prostate. Unfortunately, at this stage the cancer produces few or no symptoms and can be difficult to detect [1].

With low dose rate (LDR) brachtherapy treatment, tiny little metal pellets containing radioactive iodine-125 or palladium-103 are inserted into the prostate via needles that enter through the skin behind the testicles. As with 3D conformal radiation therapy, careful and precise maps are used to ensure that the seeds are placed in the proper locations. Over the course of several months, the seeds give off radiation to the immediate surrounding area, killing the prostate cancer cells. By the end of the year, the radioactive material degrades, and the seeds that remain are harmless. Compared with external radiation therapy, brachytherapy is less commonly used, but it is rapidly gaining ground, primarily because it doesn't require daily visits to the treatment center.

Cancer was responsible for 7.6 millions of deaths in 2005. It represents 13% of all the deaths in the world. The main cancer kinds with bigger mortality were lung (1.3 million), stomach (1 million), liver (662 - 1,000), colon (655 - 1,000) and mamma (502 - 1,000). Above 70% happened in countries of medium or lower income. About 60% of new cases will occur in countries in development in 2020. It also is known that one third of the new cases of cancer that annually occurred in the world could be forewarned. Parkin and collaborators (2001) had esteemed that the number of new cases of cancer would be greater than 10 millions over would in 2000. The tumors of lung (902 - 1,000 new cases) and prostate (543 - 1,000) would be more frequent in the male, whereas in the female the bigger occurrences would be the tumors of mamma (1 million of new cases) and colon (471 - 1,000). In Brazil, the estimative in 2008 and valid also in 2009, point that will occur 466,730 new cases of cancer. The more incidents kinds, excepted of skin cancer type no melanoma, will be the cancers of prostate and lung in the male and the cancers of mamma and colon in the female, accompanying oneself profile of the bulk observed in the world. In 2008 are expected 231,860 new cases for male and 234,870 for female. Esteem that the of skin cancer type no melanoma (115 - 1,000 new cases) will be most incident in the Brazilian population, followed by the tumors of prostate (49 - 1,000), breast feminine (49 - 1,000), lung (27 - 1,000), stomach (22 – 1,000) and colon (19 – 1,000) [2].

The iodine-125 seeds are implanted into the human prostate to irradiate the tumor for cancer treatment. Nowadays, the Radiation Technology Center, at IPEN-CNEN/SP imports and distributes 36,000 iodine-125 seeds per year, for the clinics and hospitals in the country. However, the Brazilian market potential is now over 8,000 iodine-125 seeds per month. The local production of these iodine-125 radioactive sources became a priority for the Institute, in order to reduce the price and the problems of prostate cancer management. It will permit to spread their use to a larger number of patients in Brazil. On the other hand, the industrial automation plays an important role for iodine-125 seeds in order to increase the productivity, with high quality and assurance, avoiding human factors, implementing and operating with good manufacturing practices (GMP).

2. AUTOMATION

Automation is the use of control systems (numerical control, programmable logic control and other industrial control systems), in concert with other applications of information technology, such as, computer-aided technologies (CAD, CAM, CAx), to control industrial machinery and processes, reducing the need of human intervention. In the scope of industrialization, automation is a step beyond mechanization. Whereas mechanization provided human operators with machinery to assist them with the physical requirements of work, automation greatly reduces the need for human sensory and mental requirements as well. Processes and systems can also be automated. Automation plays an increasingly important role in the global economy and in daily experience. Engineers strive to combine automated devices with mathematical and organizational tools to create complex systems for a rapidly expanding range of applications and human activities. Many roles for humans in industrial processes presently lie beyond the scope of automation. Human-level pattern recognition, language recognition, and language production ability are well beyond the capabilities of modern mechanical and computer systems. Tasks requiring subjective assessment or synthesis of complex sensory data, such as scents and sounds, as well as high-level tasks such as strategic planning, currently require human expertise. In many cases, the use of humans is more cost-effective than mechanical approaches even where automation of industrial tasks is possible. Specialized hardened computers, referred to as Programmable Logic Controllers (PLCs), are frequently used to synchronize the flow of inputs from (physical) sensors and events with the flow of outputs to actuators and events. This leads to precisely controlled actions that permit a tight control of almost any industrial process. Human-machine interfaces (HMI) or computer human interfaces (CHI), formerly known as man-machine interfaces, are usually employed to communicate with PLCs and other computers, such as entering and monitoring temperatures or pressures for further automated control or emergency response. Service personnel who monitor and control these interfaces are often referred to as stationary engineers [3].

An automation system is a precisely planned change in a physical or administrative task utilizing a new process, method, or machine that increases productivity, quality, and profit while providing methodological control and analysis. The value of system automation is in its ability to improve efficiency; reduce wasted resources associated with rejects or errors; increase consistency, quality and customer satisfaction; and maximize profit [3].

2.1. Programmable Logic Controllers

Control engineering has evolved over time. In the past humans were the main methods for controlling a system. More recently electricity has been used for control and early electrical control was based on relays. These relays allow power to be switched on and off without a mechanical switch. It is common to use relays to make simple logical control decisions. The development of low cost computer has brought the most recent revolution, the Programmable Logic Controller (PLC). The advent of the PLC began in the 1970s, and has become the most common choice for manufacturing controls. Programmable Logic Controllers (PLCs) have been gaining popularity on the factory floor and will probably remain predominant for some time. Most of this is because of the advantages they offer, as well as:

- Cost effective for controlling complex systems;
- Flexible and can be reapplied to control other systems quickly and easily;
- Computational abilities allow more sophisticated control; and
- Trouble shooting aids make programming easier and reduce downtime.

2.2. Ladder Logic

Ladder logic is the main programming method used for Programmable Logic Controllers (PLCs). As mentioned before, ladder logic has been developed to mimic relay logic. The decision to use the relay logic diagrams was a strategic one. By selecting ladder logic as the main programming method, the amount of retraining needed for engineers and trades people were greatly reduced.

2.3. Stepper Motor and Driver

A stepper motor is a brushless, synchronous electric motor that can divide a full rotation into a large number of steps. The motor's position can be controlled precisely, without any feedback mechanism. Stepper motors are similar to switched reluctance motors, which are very large stepping motors with a reduced pole count, and generally are closed-loop commutated [4].

Driver is an electrical circuit or other electronic component used to control another circuit or other component, such as a high-power transistor. The term is used for a specialized computer chip that controls the high-power transistors in DC-to-DC voltage converters. An amplifier can also be considered the driver for loudspeakers or a constant voltage circuit that keeps an attached component operating within a broad range of input voltages [5].

2.4. Supervisory and Data Controls

SCADA stands for Supervisory Control and Data Acquisition. It generally refers to an industrial control system (computer system monitoring and controlling a process). The process can be industrial, infrastructure or facility. Industrial processes include those of manufacturing, production, power generation, fabrication and refining, and may run in continuous, batch, repetitive or discrete modes. Infrastructure processes may be public or private, and include water treatment and distribution, wastewater collection and treatment, oil and gas pipelines, electrical power transmission and distribution, civil defense siren systems, and large communication systems. Facility processes occur both in public facilities and private ones, including buildings, airports, ships, and space stations. They monitor and control HVAC, access, and energy consumption [6].

3. AUTOMATION PROCESS

The automation system technology for iodine-125 seed production developed in this work was mainly assembled employing:

- Electro-electronic and mechanical components;
- Programmable Logic Controller (PLC);
- Stepper motors and drives;
- Nd:YAG laser welding machine;
- Microcomputer, supervisory and interfaces;
- Photoelectric and optical sensors; and
- Distribution systems for titanium tubes and silver rod with iodine-125 adsorbed.

3.1. Integrate Hardware and Software

On the automation system for iodine-125 seed production developed in this work was necessary to integrate:

- Electro-electronic and mechanical parts and components;
- InduSoft Web Studio 6.1 supervisory (Fig. 1);
- Siemens Programmable Logic Controller (PLC) and Step S7 200 MicroWin 4.0 software (Fig. 2);
- Miyachi Unitek Nd:YAG laser welding machine 15 W; and
- Applied Motion drives of the stepper motors (Fig. 3).

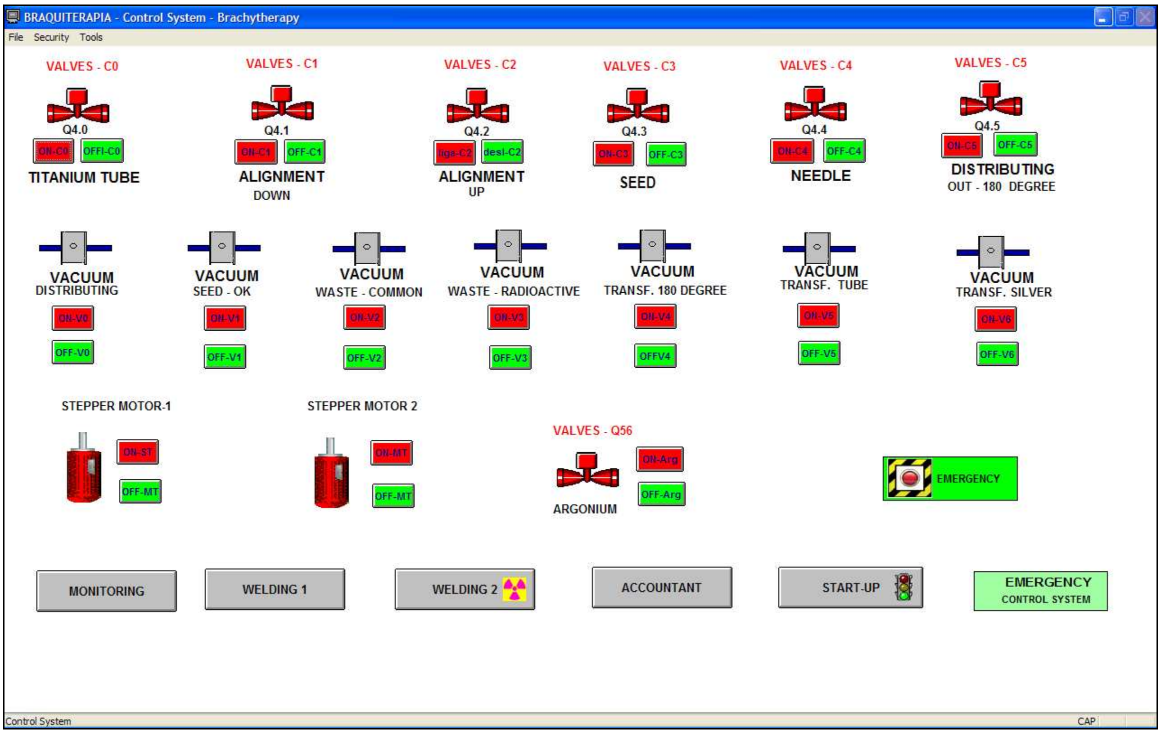

Figure 1. InduSoft Web Studio 6.1 supervisory [7].

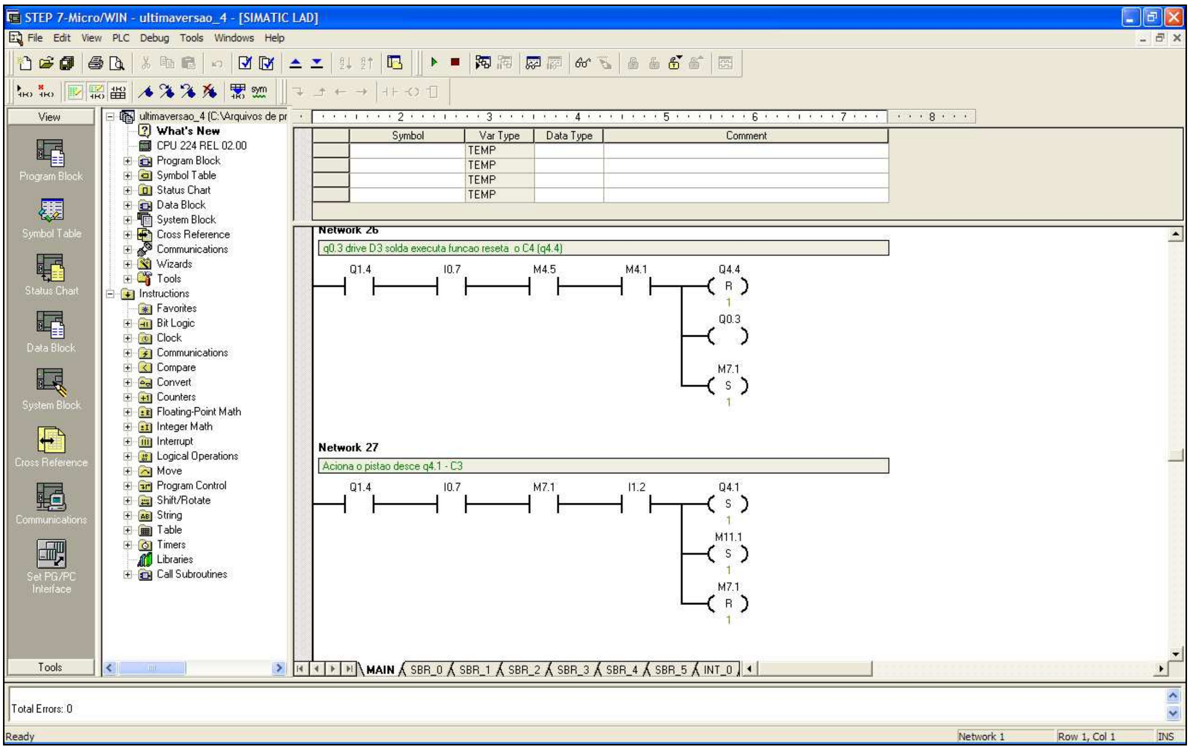

Figure 2. Siemens Step S7 200 MicroWin 4.0 software [8].

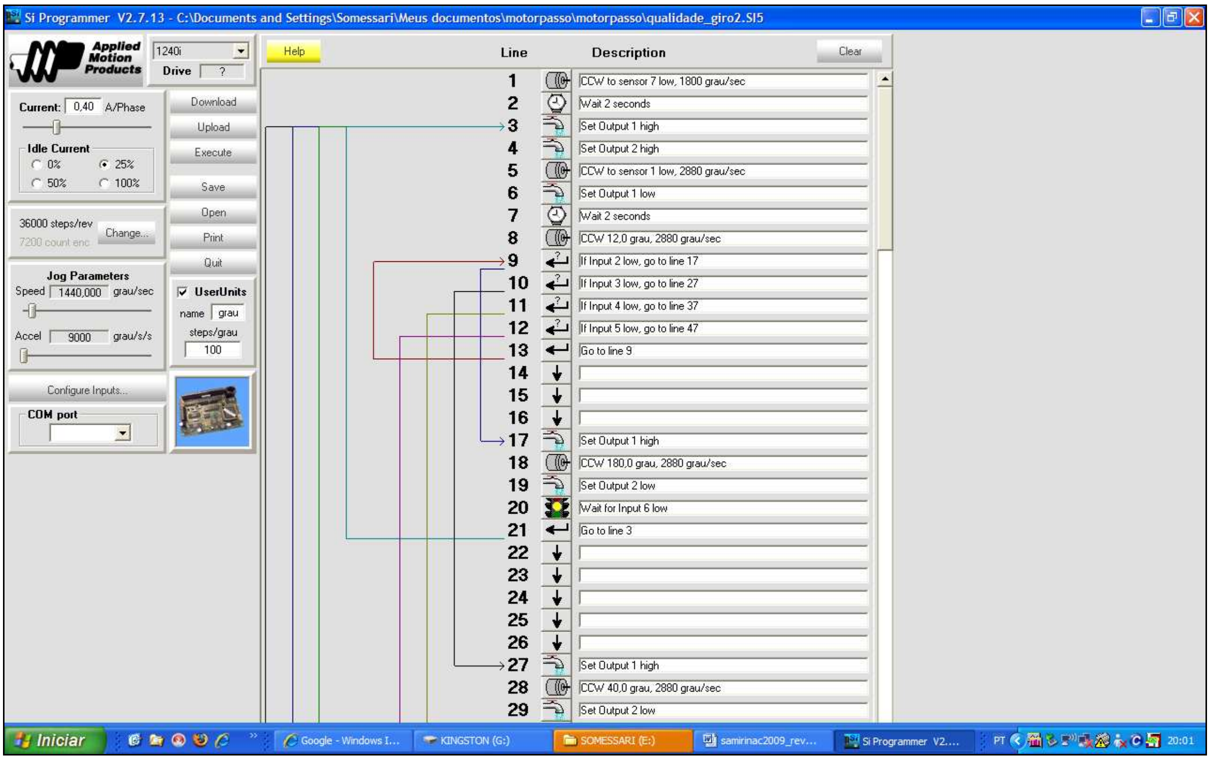

Figure 3. Applied Motion stepper motor controller software [9].

3.2. Iodine-125 Seed Production Process

The Fig. 4 shows the iodine-125 seed produced at IPEN – CNEN/SP. The iodine-125 seed consists of a titanium capsule with external diameter of 0.8 mm, 4.5 mm in length and 0.05 mm of thickness [10-13]. It is a radioactive sealed source, in which the silver rod with iodine-125 adsorbed is positioned inside the titanium capsule, welded in both extremities by Nd:YAG laser welding machine.

The automation system technology for iodine-125 seed production developed in this work was controlled by Applied Motion stepper motor controller supervisory and Siemens Step S7 200 MicroWin 4.0 software.

The production process of the iodine-125 seeds consists:

a) The distribution device takes the titanium tube. It is positioned accurately on the welding device, in which one titanium tube extremity is welded by laser;
b) After welding this first extremity the mechanism inverts the titanium tube, which goes back for the welding device;
c) When the titanium tube is in the right position, another distribution device transports the silver rod with iodine-125 adsorbed. Than, the silver rod is positioned into the titanium tube; and
d) Than, the welding device is positioned with accuracy to weld the second extremity of the titanium tube. The iodine-125 seed becomes a radioactive sealed source.

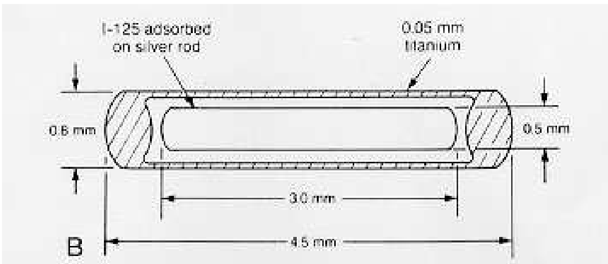

Figure 4. Iodine-125 radioactive seed produced at IPEN – CNEN/SP.

The Fig. 5 shows the automation system with electro-mechanical and pneumatic components for iodine-125 seed production. The Fig. 6 shows the automation system employing a Programmable Logic Controller (PLC) to control machines and processes for iodine-125 seed production.

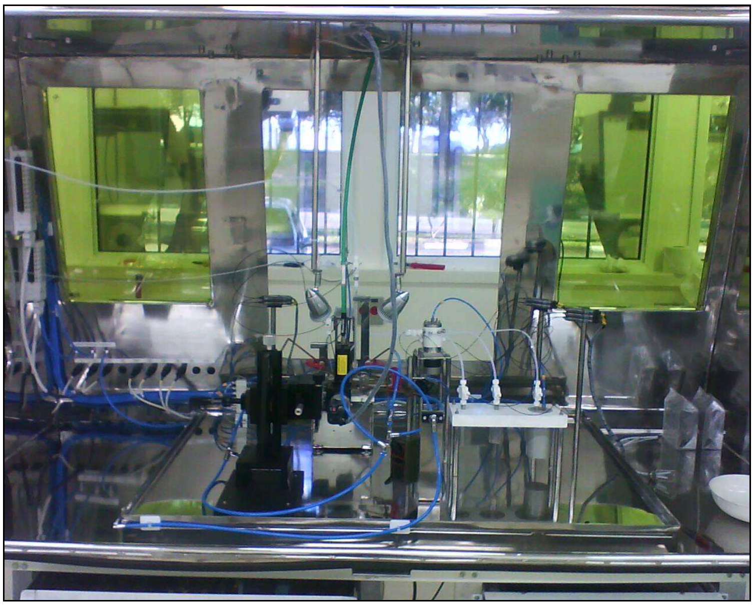

Figure 5. Automation system with electro-mechanical and pneumatic components for iodine-125 seed production.

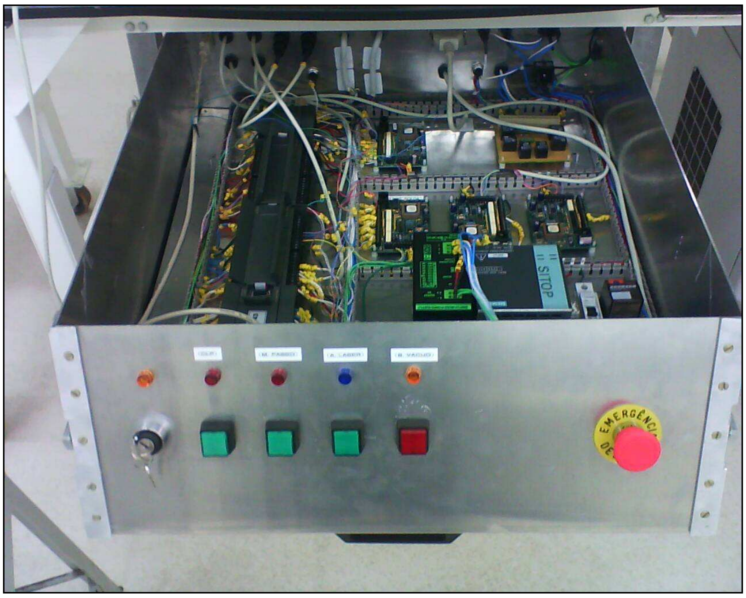

Figure 6. Automation system employing a Programmable Logic Controller (PLC) to control machines and processes for iodine-125 seed production.

4. CONCLUSIONS

The industrial automation plays an important role for iodine-125 seeds in order to increase the productivity and flexibility, with high quality and assurance, decreasing costs, avoiding human factors, implementing and operating with good manufacturing practices (GMP).

Complex automation systems integrate computer hardware and software, robotic equipment, line equipment, shipping processes, inventory control and employee training to increase manufacturing efficiency and productivity.

Computer software and hardware play an important role in automation systems. Computers control and manage the automation of physical and analytical tasks.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the State of Sao Paulo Research Foundation (FAPESP) for its financial support.

REFERENCES

1. Prostate Cancer Foundation. 1250 Fourth Street, Santa Monica, CA 90401, http://www.prostatecancerfoundation.org/site/c.itIWK2OSG/b.4983495/k.5C76/About_Prostate_Cancer.htm. Accessed in June 29th, 2009.
2. Ministério da Saúde. Instituto Nacional do Câncer. Estimativa da incidência e mortabilidade por câncer no Brasil 2008, Rio de Janeiro/RJ, 2008. http://www.inca.gov.br/estimativa/2008/index.asp?link=tabelaestados.asp&UF=br. Accessed in June 29th, 2009.
3. Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook, 2008-09 Edition*, Stationary Engineers and Boiler Operators, on the Internet at http://www.bls.gov/oco/ocos228.htm and http://en.wikipedia.org/wiki/Automation. Accessed in July 4th, 2009.
4. Stepper motor. http://en.wikipedia.org/wiki/Stepper_motor. Accessed in July 4th, 2009.
5. Stepper motor driver. http://en.wikipedia.org/wiki/Driver_circuit. Accessed in July 4th, 2009.
6. SCADA supervisory software.
7. InduSoft Web Studio 6.1 software manual.
8. Siemens Step 7 MicroWin 4.0 software manual.
9. Applied Motion stepper motor controller software manual.
10. Estudo e desenvolvimento de uma nova metodologia para confecção de sementes de iodo-125 para aplicação em braquiterapia - Tese de Doutorado (Dra. Maria Elisa M. C. Rostelato). IPEN/USP, São Paulo/SP, 2005.
11. ASTM - American Society for Testing and Materials, F 67-77: Unalloyed Titanium for Surgical Implant Applications, 1977.
12. ASM Committee on Titanium and Titanium A1loys, Metals Handbook Ninth Edition, Properties and Selection: Stainless Steels, Tool Materials and Special Purpose Metals, vol. 3, p.374 - 375, 1980.
13. ABNT - Associação Brasileira de Normas Técnicas, NBR ISO 5832-2: Implantes para Cirurgia - Materiais Metálicos. Parte 2: Titânio Puro, Maio 2001.