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DEVELOPMENT OF A MOBILE UNIT WITH AN ELECTRON BEAM ACCELERATOR (20 kW AND 700 keV)

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ABSTRACT

The purpose of the present study is therefore to install an electron beam accelerator (20 kW and 700 keV) in a mobile unit to treat effluent from petroleum production, for petroleum desulfurization and, in addition, for degradation of toxic organic compounds in wastewater for reusein, in partnerships with private and public institutions. Several technical aspects were considered in this installation, such as following the national transport legislation and the safety requirements (BSS, IAEA and CNEN Safety Standards). Technical characteristics of the electron beam accelerator (EBA) are energy of 700 keV and 28.5 mA of beam current, with 60 cm scan length. The installation of the EBA includes the developing and manufacturing a radiological shield. In several points of the mobile unit, GM type radiation sensors will be installed for radiological monitoring during irradiation processing, interlocked with the accelerator's safe operating system. For the design of a vacuum system with mechanical pumps, ion pump and sensors, the following procedures will be carried out: a) design of an optimized system of the mobile unit power supply; b) development of a cooling system with deionized water and pressurized air for the cooling of the EBA systems in the scan horn, high voltage generator, control panel, vacuum system, among other peripherals; c) installation of the fan to cool the thin titanium window; d) installation of an ozone filter in the exhaust system to remove gas generated during irradiation; e) project of a mechanical structural reinforcement of the trailer was studied, improved and executed. In the mobile unit, a space was created for an analysis laboratory to monitor the wastewater before and after irradiation, establishing parameters in the quality control of the irradiated material.

Keywords: Mobile unit, electron beam accelerator, wastewater treatment, degradation of organic compounds, safety standards

1. INTRODUCTION

The mobile unit is made with a Chassis Frame structured to support the internal components, electron accelerator and its radiological shielding. [1, 2, 3] It has a table and king pin suitable for movement by 4x2 or 6x2 mechanical horse. The chassis frame is manufactured in compliance with CONTRAN, ABNT and automotive industry standards. The unit has a

double walled chest, structured by duralumin profiles. The outer surface is painted white with logo details of the design companies and illustration of the application for preserving the environment [4].
Electron beam processing is a manufacturing technique which uses a focused beam of high energy electrons, produced by an electron accelerator to promote chemical changes within a product. Ionizing radiation has many industrial applications, including the treatment of liquid and gas tailings, wire, cable and blanket irradiation, film polymerization and many other activities involving low energy electron accelerators. These applications are interesting for the industry, but their use is relatively restricted in Brazil and South America, due to the lack of knowledge, costs to maintain the investment in equipment for seasonal use and even rejection in the use of techniques involving ionizing radiation. The construction of the mobile accelerator aims to offer on-site irradiation services at a relatively low cost, solving problems with the use of ionizing radiation for evaluation, indicating the permanent installation of fixed units at customers' premises and proving the effectiveness of the irradiation. The mobile unit installed with a 20 kW electron accelerator will be used for irradiation of industrial and domestic effluents [5, 6, 7, 8]. The design presented will attempt to build off current technologies to take advantage of the benefits of a mobile effluents irradiator. Electron accelerators lack this ability and are only able to penetrate a few millimeters of dense effluent at a time. But the accelerators benefit in reduced shielding (although still significant) and the ability to safely turn on/off. This safety function could also prove to be more desirable in a regulation setting that would be very cautious with mobile irradiation technologies.

2. MATERIALS AND METHODS

The Radiation Technology Center (CETER) of IPEN-CNEN/SP is pioneer in activities focused on the application of radiation technology in the country and it has a history of important achievements in the most diverse industries, health and environment.
The Mobile Irradiation System consists of a 700 keV electron accelerator with scan-down (face down) and product exposure systems that will be mounted for each type of the irradiated product, radiological shielding to contain the X- rays generated, with geometry optimized to enclose the radiation and meet the dose limits established in CNEN NN 3.01, in areas adjacent to the accelerator.
The proposed Mobile Unit encompasses, not only the electron accelerator itself, but all the loads required for the industrial effluent treatment. Thus, all electrical loads need to be analyzed and sized, so that the input equipment may be rated for full load. Table 1 presents all the electric charges provided by the Mobile Unit and their basic data, such as operating voltage, power factor and demand. The data were obtained directly by the equipment manufacturers or by the team responsible for the project at IPEN, from previous calculations.

2.1 Power Supply (Electric Scheme)

It is the electrical scheme of the electron accelerator mobile unit with the peripherals showed in table 1 that is represented, this Mobile unit single-line electrical scheme showed Fig 1 with the components, all the conductors and connections between them. And the scheme that describes how any appliance is turned on, so as to facilitate practical implementation [9].

Table 1 - Estimated loads belonging to the Mobile Unit under development at IPEN.

Equipment	Voltage (V)	Energy Consumption (kW)	Power Factor	Total Consumption (kVA)
Electron Accelerator	3Ø – 380	30	0.90	33.33
cooling system (chiller)	3Ø – 380	20,3	0.90	22.55
Control Panel	1Ø – 220	2	0.92	2.17
Vacuum Pump (Ionic)	1Ø – 220	2	0.96	2.09
Titanium Window Cooling Fan	3Ø – 380	5	0.85	5.89
Air circulation fan	3Ø – 380	5	0.85	5.89
Air conditioning, lighting and sockets	2Ø – 220	5	0.94	5.31
Wastewater Circulation Pump	3Ø – 380	15	0.89	16.85
Microcomputer, projector and analytical instruments	1Ø – 220	5	0.92	5.43

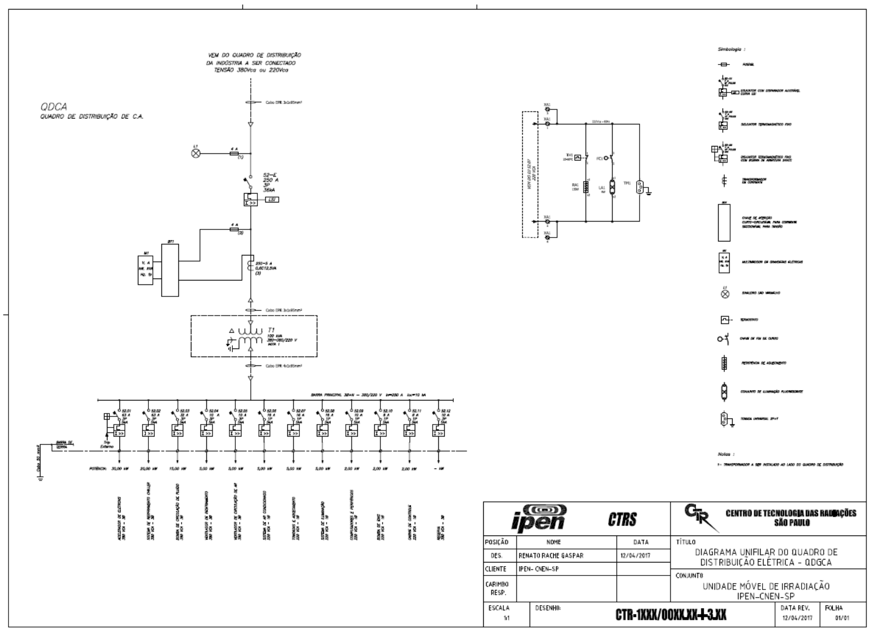

Figure 1 -Mobile unit single-line electrical scheme. Source: IPEN

2.2 Electron Beam Accelerator

Following a description of the facility, the major components in the electron beam accelerator installed in the truck [10]:

- Type: Vertical Standard Vessel in Fig 2 shows the electron accelerator
- Assembly pressure vessel with Scan System: Installed inside pressure vessel: Electron gun, beam tube; H.V power supply (rectifier stack); scan, X, Y Coils; Scan Chamber and magnets; Vacuum system (Turbo pump, valves, manifold, sensors and others accessories) and others accessories / components needed to be installed the accelerator.

- Control System Panel: Electron beam accelerator control panel with I/O digital data and analog signals and safety system, cables and others accessories. (Programmable logical controller - PLC) with supervisory PC.
- Oscillator System Panel: RF Oscillator; Oscillator tube; Power supply; and others accessories.
- Peripherals: Water pumps, exhaust gas (ozone), vacuum pump, water reservoir, chiller, external gas storage system SF6, electric transformer and others accessories.

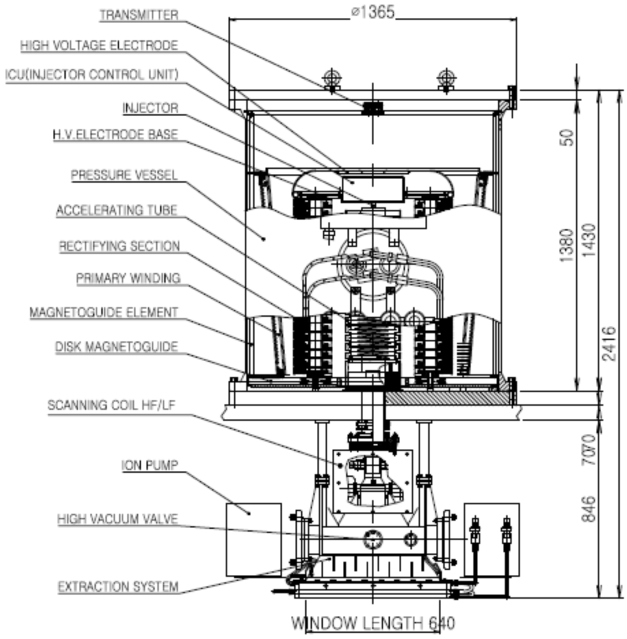

Figure 2- Electron Accelerator - Source EB-TECH

2.3 Radiological Shielding

According to CNEN-NN-3.01, radiological protection or radioprotection is the set of measures that aim to protect human beings and their descendants against possible unwanted effects caused by ionizing radiation. The shield consists of a physical protection made with some material that makes a coating.

The radiological shielding of the irradiation chamber shown in Fig. 3, is a safety measure against the risks of radiation exposure in which the insulation is essential for the protection of the personnel and the persons who worked near the mobile unit. The fabrication of the radiological shielding was made of lead, stainless steel, polypropylene and the thickness of the coating was calculated in order to radiological protection obeying the CNEN 3.01 standard.

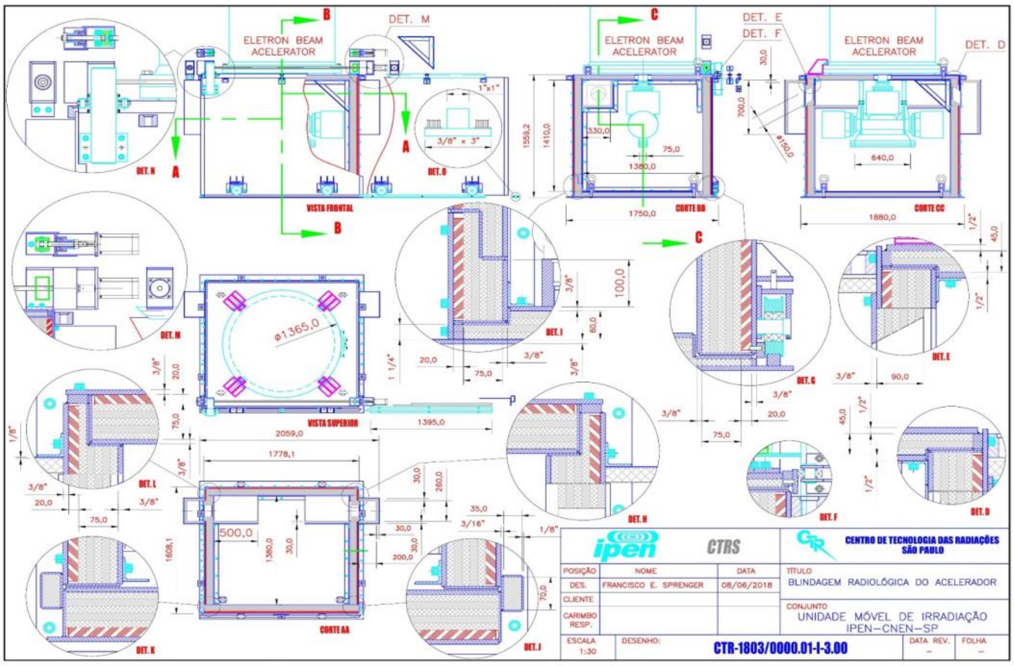

Figure 3- Radiological shielding - Source IPEN

3. RESULTS

In this paper, the result of the development of the accelerator mobile unit demonstrated in the distribution of loads in the mobile unit shown in Fig 4, according to the Brazilian road legislation.

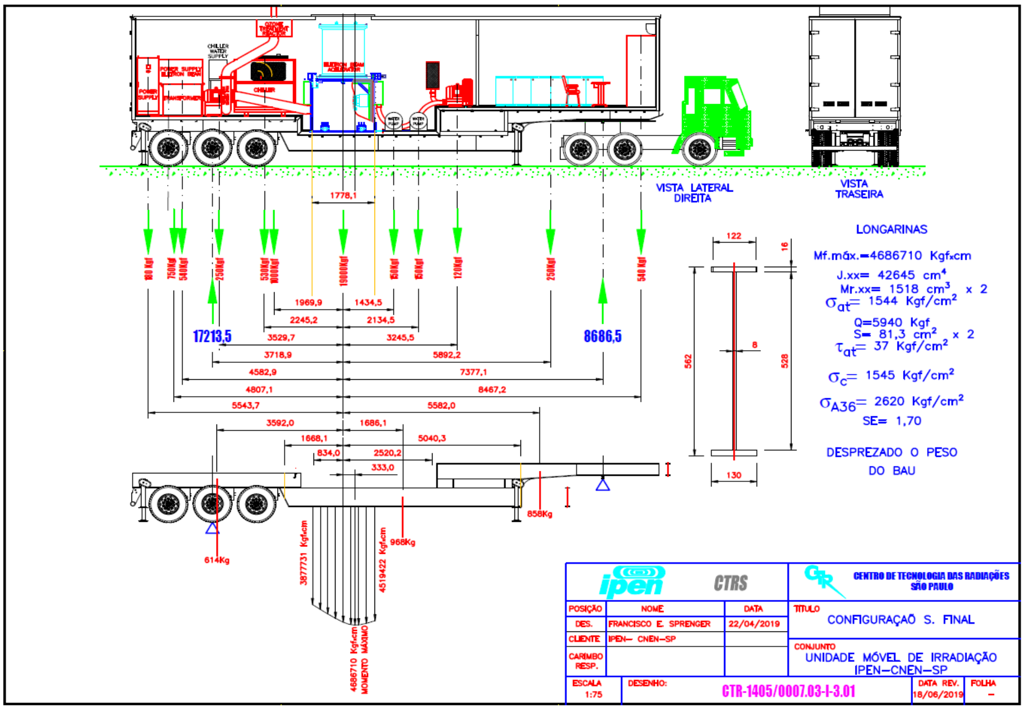

Figure 4 distribution of loads in the mobile unit - Source IPEN

The result of the electrical system panel was the mounting of the panel as shown in FIG. 5, presents the function test of the power input transformer shown Fig 6 in the mobile unit. In the transformer, the three-phase voltage input of 220, 380 and 440 volts (114kVA power) with output three-phase voltage of 380 volts (85kVA power) and output three-phase voltage 220 volts (25kVA power).

Figure 5 Electrical system panel. - Source: IPEN

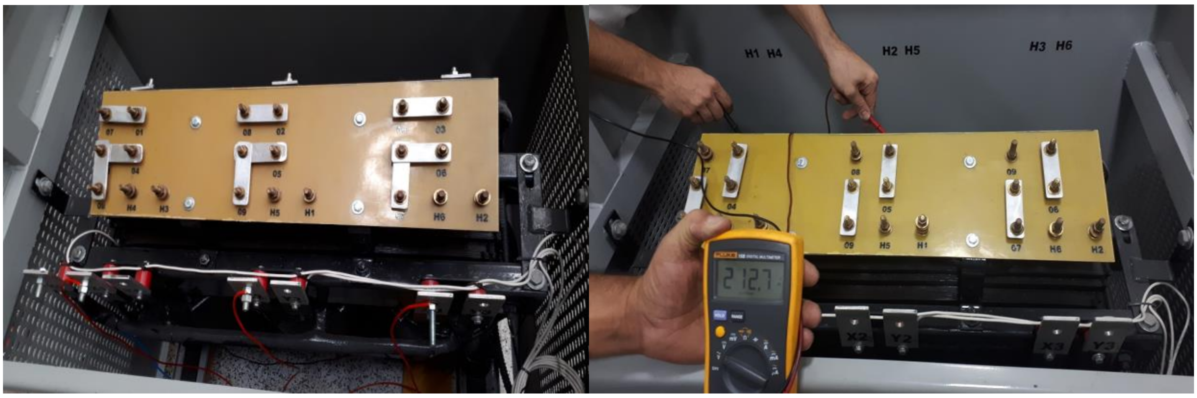

Figure 6 - Transformer - Source: IPEN

The general specifications of the electron accelerator and its peripherals installed in the mobile unit [10]:

Pressure vessel:
1) Material and Size ....steel, Φ1365×1550
2) Volume inside and Weight ....1.63 m3, 2100 kg
High voltage rectifier:

1) Type ....coreless transformer
2) Primary winding and Magnetic guide
3) Sectional secondary windings
4) Measuring dividers

Accelerating tube and Cathode
1) Accelerating tube
- Insulator
Material and Size .... ceramic, Dia Φ205×Φ180, Length around 700mm
- Electrode
Material and Size ....stainless steel, Dia Φ220×Φ100
- Neck with Focusing lens
2) Cathode
- Electron source LaB6, Φ10

Extraction system
1) Scanning chamber
- Material ....stainless steel
- Ti window length ....640 mm
- Scanning length ....about 510 mm

Vacuum system
1) Ion pump & pump power supply unit
- Type ....diode type
- Capacity ....200 liters/s
- Quantity ....2 set
2) Fore vacuum pump
- Type ....Turbo pump set
- Capacity ....250 liters/s
3) Thermocouple gauge ....Varian 0536 type
4) Unit vacuum automatic ....remote controller (in P/S cabinet)

Foil cooling system:
1) Cooling fan
- Capacity ....16 Nm^3/min, 5 kW (at 60Hz)
- Static pressure .... 7845.104 Pa at 20˚C
2) Air nozzle
- Material and Size ....stainless steel, Φ89.1 (3")

Power supply system:
1) Frequency converter (Inverter)
- Power module ....Semikron Skiip-942 type
2) Reactor ....water cooled iron core transformer
3) Capacitor bank ....water cooled, variable capacitance
4) Power control board ....4 ea

Control system:
1) Number of cabinet ....2 set (19" standard rack)
2) Circuit board ....12 ea

3) Interface ....LCS (modified CAMAC)
4) Communication module RS232
5) Control PC ....1 set
6) Line printer ....1 set
7) Oscilloscope ....1 set
- Type ....Analog
- Channel 2
- Band width ....60 MHz

Ventilation system:
1) Fan
- Capacity ....20 Nm^3/min, 3 kW (at 60Hz)
- Static pressure .... 2941.914 Pa - at 20˚C
2) Ozone treatment reactor
- Activated carbon filter ....800~1000 kg

In Fig. 7 shows the final configuration of the installation of the mobile unit with electron accelerator (20kW) and its peripherals.

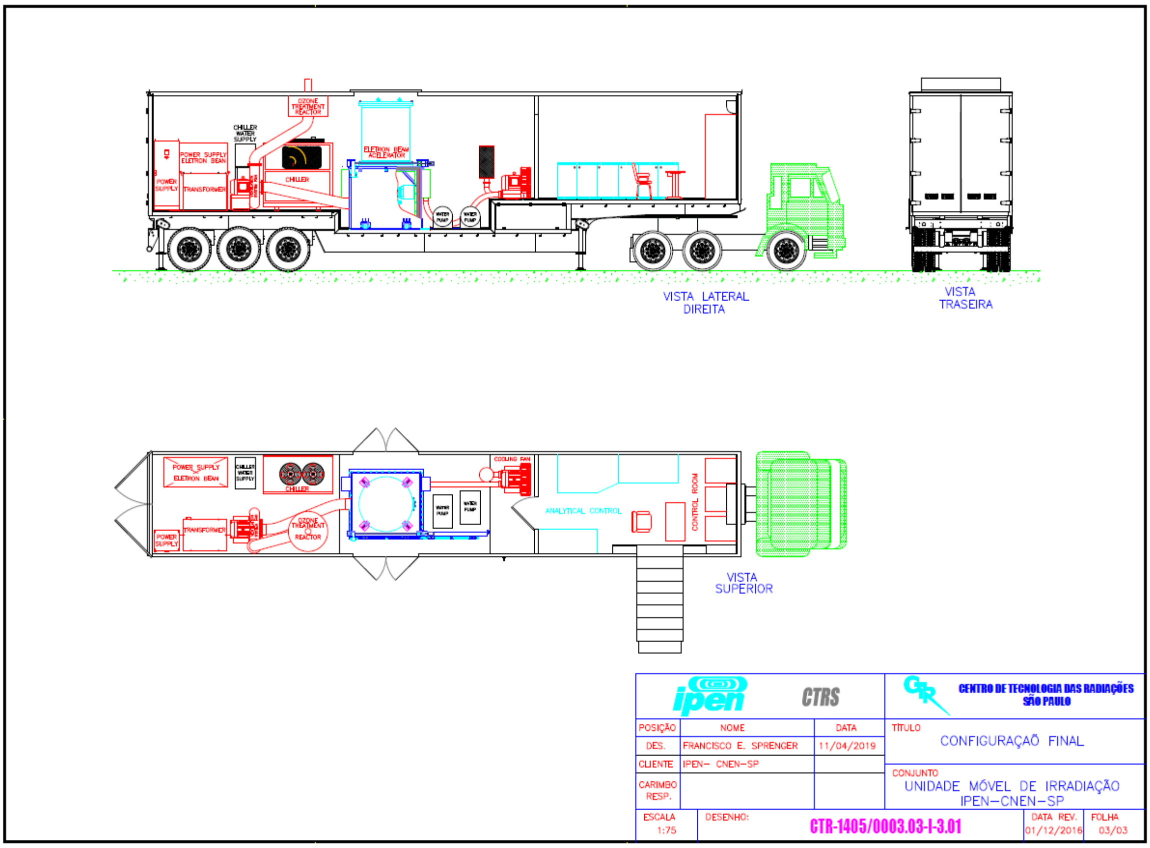

Figure- 7 Final Configuration (mobile Unit) - Source: IPEN

In Fig. 8 shows the manufactured mobile unit, where the electron accelerator and the peripherals are installed.

Figure 8 - manufactured mobile unit - Source: IPEN

3. CONCLUSIONS

The development of the mobile unit as a radioactive installation with a 20kW electron accelerator for effluent irradiation consists of state of the art technological innovation, in placing the researchers of IPEN-CNEN / SP, with great knowledge in developing, designing and executing the implementation of a mobile radioactive installation.

The construction of the mobile accelerator aims to offer on-site irradiation services and at a relatively low cost to solve problems with the use of ionizing radiation, both for evaluation and indicative for the permanent installation of fixed units at customers' premises, by proving the effectiveness of irradiation.

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