INCORPORATION OF RADIOACTIVE WASTE IN BITUMEN
10 YEARS OF R&D AND COOPERATION BETWEEN CDTN AND ELETRONUCLEAR

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ABSTRACT

This paper presents a description of the contribution of the research center, Centro de Desenvolvimento da Tecnologia Nuclear, to the different stages of the implementation of the waste treatment process in Nuclear Power Plant, Angra 2, using national bitumen as a matrix. This work was comprised of the following phases: evaluation in the experimental tests in the pilot scale of the national bitumen to be used as a matrix in an industrial plant; the comparison with the specified imported bitumen; the implementation of the characterization tests of the wasteforms in accordance with national and international standards; the tests during the commissioning and during the operation of the bituminization system and the treatment of the radioactive evaporator concentrate waste generated in Angra 2. Also the laboratory technicians were trained by CDTN, according to ABNT and ISO standards, for the wasteform characterization thereby concluding the knowledge transfer. This cooperation between CDTN technicians and Eletronuclear specialists aimed at improving the implementation of conditioning the radioactive waste from nuclear power plant in national bitumen.

1. INTRODUCTION

The Brazilian nuclear power plant 1300 MW- PWR Angra 2 is in operation since 2000 and its radioactive wastes generated are immobilized in bitumen as required. Since 1997 the institute CDTN, through a joint research program, has provided technical support to ELETRONUCLEAR Nuclear Power Plant for the development process of conditioning the radioactive liquid waste.

Studies and experimental works have been carried out in order to improve wasteform characteristics such as homogeneity, long term stability, and low leachability rates according to established wasteforms acceptance criteria by the Licensing Authority [1,2,3,4].

The program was comprised of the following phases: evaluation in the experimental tests in the pilot scale of the national bitumen to be used as a matrix in an industrial plant; the comparison with the imported bitumen and the implementation of the characterization tests of the wasteforms in accordance with national and international standards developed at CDTN [5,6]. At ELETRONUCLEAR, the type tests during the commissioning to validate the Process Control Program (PCP), the control tests during the operation of the bituminization system
according to the PCP [7] and the treatment of the radioactive evaporator concentrate waste generated in the plant were developed.

In order to evaluate the wasteforms, the characterization methods were established and the Angra 2 laboratory technicians were trained by CDTN, according to ABNT and ISO standards for radioactive waste immobilized in bitumen.

2. COOPERATION PROGRAM

The cooperation program began in 1997 and ten year later the wasteform characterizations were done in Angra 2. Until now 36 m$^3$ of concentrate of evaporator were immobilized in national bitumen and 74 drums were produced.

2.1. Research and development works

The imported bitumen, specified in the design of the extruder-evaporator system, was compared with a similar national one, previously tested in the CDTN/CNEN facilities. The characterizations of both bitumen and the specification for the bituminization system are presented on Table 1.

The specification of the simulated solution composition of the evaporator concentrates was supplied by ELETRONUCLEAR, based on the experience data of PWR nuclear power stations in operation. The solution contained mainly boric acid and other chemicals such as sodium chloride, sodium phosphate, and sodium sulphate.

The experimental work had been carried out in a pilot plant of continuous flow, consisting of a screw-extruder with production capacity of 1 kg/h. The percentages of waste incorporated in bitumen varied from 43 to 55 wt%. The obtained products were evaluated according to national and international standards by means of thermodiferencial analysis and specific tests to assess the softening point, flash point, penetration, water content, and homogeneity of simulated waste distribution throughout the matrix.

The results confirmed the suitability of the national bitumen for the incorporation of the evaporator concentrates containing mainly boron. It presented lower leaching rates than those of the imported one [5].

2.2. Industrial scale processing

The concentrate processing system of Angra 2 processes evaporator concentrate mainly with boron contents. The radioactive liquid waste is collected in the restricted area into five of 70 m$^3$ tanks before the processing in one of two 4 ton/h evaporators plants installed. After several liquid waste tanks processing, achieving the limit criteria for evaporation, the concentrate is blowed down in one of three 35 m$^3$ storage tanks.

Although the system is designed to process 20,000 m$^3$/y of radioactive liquid waste resulting of 150 m$^3$/y of concentrates, the operation experience shows that about 10,000 m$^3$/y of liquid is processed resulting an amount of 12 to 18 m$^3$/y of concentrates.
About each two years, the concentrate processing system processes the stored concentrate. The process consists of the incorporation in bitumen of the concentrate in an extruder-evaporator equipment, where the solid part of the concentrate is mixed in bitumen, the distillate is collected for further processing and the mixture is poured into a 200 liters iron drum. About 500 liters of concentrate is conditioned in a 200 liters drum.

One of the phases of the development program was the performed works to validate of the PCP, when the incorporations in bitumen of radioactive waste concentrates were verified. The tests of PCP during the commissioning of the treatment system were a joint project between CDTN and ELETRONUCLEAR. It consisted of a series of campaigns of incorporation of simulated concentrates into the national bitumen. The percentages of incorporated waste varied from 20 to 60wt%. Samples were then collected and characterized at CDTN concerning the rheological and thermodifferential properties. The leaching tests were performed at the NPP laboratories, as previously foreseen in the PCP [7].

After the commissioning phase, two campaigns for incorporation of evaporator concentrates containing mainly boron, were carried out. The percentage of evaporator concentrate waste incorporated into the national bitumen was about 45wt%. The third campaign was performed at the beginning of last May.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Bitumen I&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Bitumen B&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Specification&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetrability (1/10 mm)</td>
<td>12-16</td>
<td>15</td>
<td>10-20</td>
</tr>
<tr>
<td>Flash Point (°C)</td>
<td>285</td>
<td>&gt;300</td>
<td>&gt;290</td>
</tr>
<tr>
<td>Softening Point (°C)</td>
<td>73-74</td>
<td>68</td>
<td>67-72</td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>1,03</td>
<td>1,04</td>
<td>1,03-1,06</td>
</tr>
<tr>
<td>Sol. in trichloroethylene</td>
<td>99,91</td>
<td>99,85</td>
<td>-</td>
</tr>
<tr>
<td>Ductibility – 25°C (cm)</td>
<td>6,9</td>
<td>6,0</td>
<td>min. 5</td>
</tr>
<tr>
<td>Ash content (%)</td>
<td>0,02</td>
<td>0,10</td>
<td>max. 0,5</td>
</tr>
<tr>
<td>Weight loss on heating-163°C (%)</td>
<td>0,01</td>
<td>0,02</td>
<td>max. 1</td>
</tr>
</tbody>
</table>

<sup>a</sup>: imported bitumen  
<sup>b</sup>: national bitumen  
<sup>c</sup>: DIN 1995 and Eletronuclear

The characterization of the radioactive wasteforms, according to the PCP, as well as the compilation of the results of the leaching tests, performed by ELETRONUCLEAR, was done by CDTN. The results were compared with those of the PCP.

The softening point and the flash point were higher for the wasteforms than those for the pure bitumen and also the penetration of the wasteforms was lower. This evaluation of the wasteforms showed the hardness of them when the solution were incorporated in bitumen. The free water content was less than 1%, below the limit according to literature data [8]. These data, comply with the safe management requirements of radioactive waste, prior its
They were in accordance to the results presented by the International Authorities [9] and under evaluation by the National Authorities [1].

2.3 Training on wasteforms characterization

Finally, the Angra 2 laboratory technicians were trained by CDTN specialists on wasteforms characterization, according to ABNT and of ISO standards, concluding the stage of knowledge transfer. The trained personnel will conduct the next campaigns of liquid radioactive waste incorporation in bitumen.

3. CONCLUSIONS

It is important to highlight the gained experience by both the CDTN and ELETRONUCLEAR teams as a result of this joint project in all of its phases: the selection of the national bitumen, the comparison with the imported bitumen, the commissioning of the bituminization plant, the treatment of the liquid radioactive waste generated in Angra 2 and the implementation of the methods in order to characterize the wasteforms.

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REFERENCES