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Optimization design of incineration processing of radioactive solid waste

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Abstract. With the continuous development of nuclear power projects, solid radioactive waste are increasing year by year. The inventory of solid waste is overloaded and can't be handled in time, thus bringing great pressure on radioactive waste management. In order to solve the above problems, the design and research of radioactive solid waste incineration were carried out in this paper. Field investigation of solid waste management in a nuclear power station in China was carried out. Then the optimized scheme of incineration intensification was put forward. And combined with the feasibility evaluation results, the reliability of the treatment scheme was verified. There is theoretical significance for the incineration of radioactive solid waste.

Key words. Radioactive solid waste, incineration treatment, optimization design.

1. Introduction

Domestic research investment on nuclear power has increased year by year, and the number of nuclear power plants has been increasing steadily, as a result, the amount of radioactive material has increased. The annual output of nuclear waste of a basic nuclear power unit will be in the range of 500 square meters, and the output of solid waste will be higher [1]. If the generating capacity of nuclear power generation units in China reaches 10000 kilowatts, the accumulation of radioactive solid materials will be considerable. Therefore, under such circumstances, it is very important to explore the comprehensive treatment plan, introduce advanced management program and reduce the treatment cost for the storage and optimal management of solid waste for nuclear power plants [2]. China's relevant laws show that the processing of radioactive waste must be synchronized with the construction process, and it is subject to rigorous review and approval prior to commissioning. Some nuclear power stations have set up many relatively independent waste disposal systems to simplify approval procedures. Such an approach is likely to lead to the repeated use of equipment and human resources management [3]. In addition, the

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investment and use of nuclear power plants are different, therefore, the independent management of radioactive solid waste in nuclear power plants lacks unified operation and management, when the resources can't be shared, the operation of the nuclear power plant will suffer serious security threats [4]. In this paper, an optimized scheme for incineration of radioactive solid material was put forward, so as to improve the comprehensive utilization ratio of equipment and personnel and the management system of waste treatment, and minimize waste disposal. The research conclusions can provide management experience for the treatment of new radioactive solid wastes.

2. State of the art

Under the current situation, China advocates an intensive economic growth situation, and controls the extensive economic development situation as the intensive transformation of the development situation, and the main focus of the work is to control the growth mode of the national economy as a benign trend of development. The development of the enterprise is the key point of the control, and the regular theory control of the operation can achieve certain fruitful results [5]. The implementation of intensive economic development mode is mainly to increase production efficiency for enterprises, integrate a certain amount of manpower and material resources, and then carry out the unified deployment, so as to realize the concrete and practical management of specific affairs in the actual enterprise management, reduce the cost, and improve efficiency and achieve the sustainable development [6]. The main research direction of this paper is the process analysis of the pollution source of the radioactive waste from the resource enterprises, in particular, the optimization and design of the management is carried out for the incineration of solid radioactive waste, at the same time, the research combines the development of the enterprise and the reengineering theory of the new method of sustainable development to get the management innovation in technology, so as to achieve intensive management of radioactive waste and enhance the efficiency of waste incineration treatment. For the process intensive management of enterprise development, the main business process is to meet the core competitiveness of enterprises [7]. The key process is to eliminate the process of delivering value chains of environmental pollution, rather than change the core value chain [8]. Managers need to carry on the transformation from the angle of process and evaluation of incineration of radioactive solid waste, so as to achieve the intensive management of business results. In this study, a standardized model of intensive management of radioactive solid waste incineration was put forward in light of actual conditions, the theory of reengineering for enterprise management was innovated, and the intensive management of the scheme was evaluated with the combination of economic budget growth theory, so as to open up an optimized treatment approach with sustainable economic operation, safety management and scientific development.

3. Methodology

3.1. Treatment status analysis

The arranging mechanism of radioactive waste selected in this study is a nuclear power station in the Yangtze River delta, the nuclear power station in the region has many staging projects, and the average capacity of the power station unit is 700 thousand kilowatts. Since its establishment, nuclear power plant has established independent departments for the treatment of radioactive pollutants. The classification and management of radioactive waste are carried out with different technical standards. The management of solid emission waste is achieved in a division of responsibility system, senior engineer or deputy general manager of the management carries on the global control, and supervises the responsibilities of each department as head of the department, specific site management departments are responsible for daily solid material handling, equipment maintenance, etc. The overall storage method of radioactive solid waste is realized through the preliminary handling and transportation and the post shipment package, the main core problem is to convert the previously used waste into solid form, and some process waste also should be compressed and packaged. In addition to the compression and packing of solid wastes, the filter waste conditioning concrete way is also a commonly used process mode for a lot of radioactive solid waste factories. Table 1 shows the changes of the radioactive solid material before and after the overall treatment.

Table 1. Changes of radioactive solid waste before and after treatment

Scrap type	Technology	Before processing /m^3	After treatment /m^3	Volume reduction ratio
Technology	Pre compression	2397	799	3
Concentrate	Cement solidification	95	213	0.45
Silt	Cement solidification	0.9	3.1	0.33
Resin	Cement solidification	61.4	252	0.25
Filter	Cement solidification	14.9	97.7	0.15

In the study, three phases of management model are used for radioactive nuclear power companies. However, although the regions are slightly different, the waste treatment processes are basically the same, and the waste treatment problems faced are basically similar, the only difference is that the operators belonging to the enterprises are slightly different, the management's technical reserves are slightly different, but the technical and human resources can't be integrated completely. Because most of the solid wastes in reactors which have been used are not stored as a whole, the temporary storage has many security risks. If the overall optimization of managers can be carried out according to hierarchical classification, there is still a possibility of benefit improvement.

Figure 1 shows the annual waste production of a unit in a radioactive solid waste generating plant. As can be seen from Fig. 1, the annual solid waste reserves of the plant are roughly $70\,m^3$, although reserves of solid waste are decreasing year by year, which can remain at least $60\,m^3$, such solid waste reserve capacity should be taken seriously, as time goes on, these solid wastes will be the major source of radioactive solid waste disposal in the future. Radioactive pollution sources will continue to decrease as the equipment improves and the level of operation increases. However, there are still some gaps in the technology level between our country and foreign countries, and the utilization rate of foreign waste is still much higher than the domestic utilization rate. Our country can draw lessons from the management hierarchy of foreign countries and reduce the overall allocation of human resources.

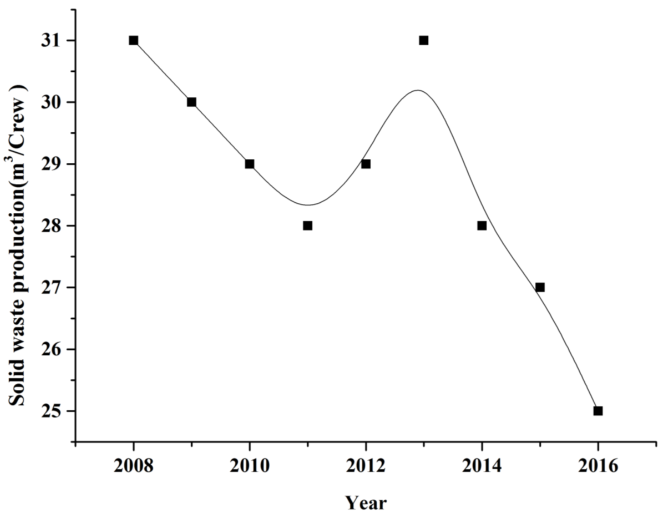

Fig. 1. Annual emissions of solid waste

3.2. Optimization design scheme

The solid waste in the plant was packed and disposed, the solid waste of the unit was setup, and the pre-compression and the post pyrolysis incineration were carried out, then, the conditioning treatment was made again after the cement was solidified, so as to achieve the post processing stability of solid wastes [9]. Because the total production of radioactive solid waste is gradually decreasing, the location of solid waste in that area can't always be in the same place, and it remains to be handled throughout the area. Although incineration is currently a more suitable method of handling solid radioactive pollutants, the metal scrap has a certain use value and can also be smelted after incineration [10]. In this study, the preliminary plan for the incineration of radioactive solid wastes and the treatment scheme for the later stage are shown in Fig. 2. The compressed solid waste was processed by compression, and the metals were cleaved, broken down, and finally sorted and packed. The reduction volume processing was made in the factory, the compression barrel management for the burning ashes produced after the waste material incineration was carried out. The smelting decontamination was done in the region away from the plant, and the fixed transportation processing for unqualified waste was carried out, while the qualified materials were re-used when the conditions and the technology were mature.

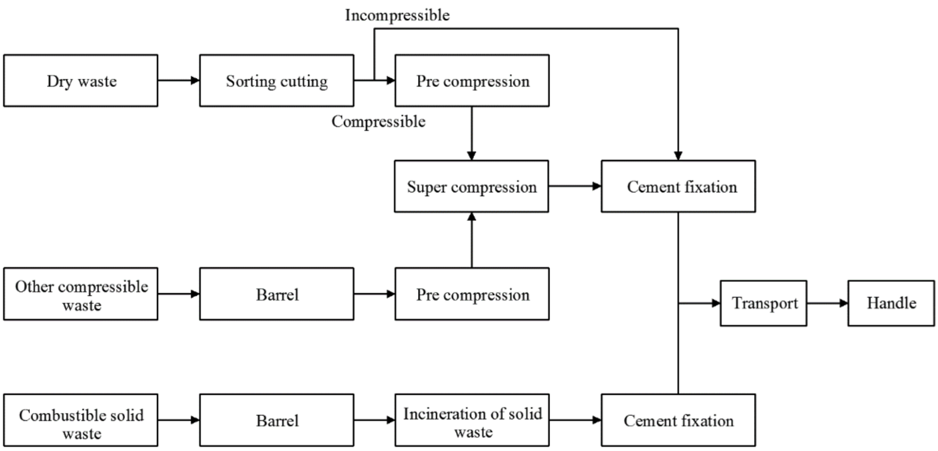

Fig. 2. Flow chart of solid radioactive waste treatment

After optimizing the disposal plan of radioactive solid waste, the mechanical and electrical groups in the factory were sorted, and the existing solid waste was fixed with concrete, and treated in a centrally fixed area [11]. The pyrolytic incineration of compression and waste materials was used to carry on the after-treatment and solidifying for the waste that had been treated once. The existing overall reserves were reduced, and the concentration of solid waste was setup furthest. The high pressure digestion for waste ashes after the incinerator was carried out, so as to reduce operators and improve technology and personnel reserves, thus, the waste was closer to the minimum requirement. Table 2 shows the technical standards and results of the overall disposal of solid waste in the plant area.

Table 2. Technical standards and results of solid waste treatment

Processing system	Pack	Pre-compression	Cement solidification	Concrete curing	Pyrolysis incineration
Before processing	4	4	4	4	0
After treatment	3	3	1	1	1

3.3. Evaluation method

The technology of high reducing capacity ratio was added in the intensive treatment scheme of radioactive solid waste incineration, including solid waste incineration technology, and the compression remelting technology for waste incineration [12]. The compression incineration technology was optimized and upgraded, and the level of radioactive solid waste treatment technology was enhanced as a whole. The promotion of technical level drove the promotion of production efficiency, and also drove the saving and control of production cost. By optimizing the selection and equipment, the entire incineration system can be optimized as an operation level with unified technical indicators [13]. Through the intensive management of the system, the irrational equipment is eliminated and the solid waste incineration and later cement solidification treatment can be carried out, which is the core point of the process plan, so that the enterprise's operation funds can be invigorated, and the running time and the daily maintenance cost can be reduced.

After a super burning compression device is installed in the treatment plan, and the pyrolysis and incineration of radioactive waste materials can be carried out after the equipment is debugged. The following is the evaluation for the pyrolysis of radioactive solid wastes with synergistic mechanisms and the return on the investment using incineration equipment. The capacity of pyrolysis incineration treatment of the installed treatment equipment is 30 kg per hour, and an annual handling capacity is about 145 t, which can meet the requirement of radioactive solid waste treatment in the plant area. The construction costs are about 41 million, and the purchase of equipment was about 22 million.

The return on investment for projects and equipment requires a certain amount of time to accumulate, and the main economic characteristics need a certain evaluation method for reference. Without considering the allocation of funds, the recycling standard configuration can be carried out through the time management of income and the construction of cycle return characteristics, the calculation method is:

$$\sum_{T=1}^{T_{\mathrm{J}}}(C_0 - C_i)_{\mathrm{T}} = 0\,. \tag{1}$$

Here, the term $(C_0 - C_i)_{\mathrm{T}}$ indicates that the cash outflow during the year T is the difference between the cash inflow and the cash inflow C_i. Symbol T_{J} represents the static payback period of construction investment.

The future dynamic payback period requires the budget of the recovery value of the time spent, the investment scheme is discounted at the base income of each year's capital flow, so as to predict the recovery investment and the dynamic payback period, and calculate the payback period of investment returns. The capital for incineration and compression processing equipment is obtained from bank loans, the expression of the net present value of the dynamic recovery fund is:

$$NPV = \sum_{T=1}^{T_{\mathrm{d}}}(C_i - C_0)_T(1+i)^{-T}\,. \tag{2}$$

Here, T_d represents the value of the cumulative payback period of the investment process. Quantity NPV describes the net cash value of the dynamic return on investment, and the interest rate for bank loans is expressed as i.

The process of technological innovation needs to consider the feasibility of the economy. Emphasizing the independent development of technology is not consistent with the law of sustainable development, emphasizing the catalytic role of innovation and using the treatment technology of the pre-compressed solid radioactive waste and the late sorting compression under the circumstances of economic permission can reduce the cost effectively [14]. In the process of the introduction of equipment, combustible solid radioactive waste should be strongly supported by remote sensing technology because of the influence of remote control. After entering the new century, the maintenance technology and remote sensing technology have made great progress, and the innovation technology has stridden forward while saving the economy, which has effectively improved the management level and economic operation state.

4. Result analysis and discussion

The combination of technological innovation and economic growth theory holds that the combination of knowledge accumulation and human resources will be the driving force for the cumulative economic growth of solid waste incineration in the future, the progress in technology and knowledge is also the driving force behind economic growth in the future, which can be put into the economic growth model budget for technological growth conditions. Nuclear power is a major trend in the development of clean energy in the future, which can promote national economic growth. The management of remaining radioactive solid waste during the use of nuclear power will be the stress and challenge in the future. In order to effectively manage the radioactive waste from nuclear power and achieve the optimization and allocation of resources, the extensive management mode and the intensive management method are used to optimize the management mode, and the innovation is carried out in technology, so as to further promote the optimization of radioactive solid incineration treatment program. Therefore, this study considers that the intensive treatment scheme of radioactive solid waste incineration not only can meet the needs of specialized management concepts and the optimization requirements of radioactive waste management mode, but also can save resources and improve the utilization ratio of equipment. It is considered that the scheme is feasible in theory.

In the disposal plan of radioactive solid waste incineration, the adjustment and optimization of management organization structure are defined. The human resource allocation scheme is also an important link of optimizing the solution, so that the lean operation goal can be realized. The basic composition of management personnel setting method is shown in Table 3. Through the remuneration of human resources, it can be seen that the salary level of managers is relatively high, the technicians are in the middle reaches, and the operators' income is in the middle and lower levels.

The treatment of radioactive solid waste can be divided into low and medium positions, and the methods for calculating the costs are different [15]. Outward delivery charges include the cost of the recovery of waste after combustion and the delivery within the plant; transportation expenses refer to the expenses of unloading, radiation monitoring and so on. The service life of disposal sites needs to be greater than 280 years to degrade radioactive solid incineration materials. Waste generated by the solid radioactive waste which is treated by intensive incineration is treated by compression, the volume is greatly reduced, and the cost of transportation is reduced. Table 4 shows the waste retention situation after the use of the scheme proposed in this study.

Table 3. Basic composition of management personnel

Personnel classification	All hands	Management	Artisan	Operator
Original number	265	28	22	214
New arrivals	123	23	20	80
Difference in number	141	5	2	134

Table 4. Retained waste after disposal

Waste type	Technology	Before processing /m^3	After treatment /m^3	Volume reduction ratio
Incinerating	Pre compression	96	32	3
liquid	Cement solidification	5.6	13.7	0.41
compress	Pre compression	33	13	2.5
Other	Concrete fixation	3.1	6	0.5

The intensive reform plan of the incineration of radioactive solid waste materials is based on the radioactive waste management template in the factory area for intensive engineering transformation, and the employees should be greatly reduced. The salary of employees will be increased, and 20 million of the salary can be saved every year on the basis of guaranteeing the salary level of the basic staff. In the study, the degradable pyrolysis incineration method is used for the waste which is compressed into solid, so the effect of volume reduction will be more obvious in the later stage, the volume of solid radioactive waste and the funds for disposal waste site can be reduced, the disposal area reduced is $200\,m^3$, and the disposal costs reduced is about 8 million.

The combination of flammable solid added and compression equipment for the incineration in the scheme can greatly reduce the freight. But the total consideration is that incineration covers a larger area, requiring the overall shutdown of equipment in the plant and the running production line, and thus spare plant resources will also be wasted. Therefore, the centralized processing plant is located outside the factory area, and the cost will not exceed more than 1 million 400 thousand per annum, the static recovery period is set to 8 years, and the dynamic recovery period of the development is 12 years. Therefore, in economic analysis, the optimized design scheme for incineration of radioactive solid waste studied in this paper is feasible as a whole.

5. Conclusion

Nuclear materials bring clean new energy to human beings, however, the radioactive waste after using brings great difficulties to later processing, which requires a great deal of manpower and material resources to manage and optimize treatment. In this study, the optimal management model of radioactive waste materials, the solutions and staffing and other problems at the present stage in China were analyzed and summarized, and a centralized and intensive optimization scheme was put forward. Taking a nuclear power station in an area of our country as an example, the remanufacturing of the enterprise was studied from the aspects of the theory of treatment, the method of disposal, the technology used, the economic return of the treatment and the corresponding expectation. It can be seen from the treatment plan that starting from the theory of economic growth, the incineration of radioactive solid wastes requires the pre-curing treatment and a unified management of the compressed equipment after incineration, the intensive disposal of radioactive solid waste requires rational human resource allocation and advanced technology, at the same time, the whole process and equipment need to maintain a reasonable design concept, reduce human resource costs, reduce return cycle and reduce processing budget. The optimized disposal plan of radioactive solid waste incineration proposed in this study is feasible in theory, and the economic budget evaluation meets the theoretical requirements. However, many problems may be encountered in the process of implementation, and so the program should be improved and perfected in practice.

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