THE DISPOSAL OF INTERMEDIATE-LEVEL RADIOACTIVE LIQUID WASTE BY HYDRAULIC FRACTURING PROCESS

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1. Introduction

It is a preferable method that intermediate-level liquid waste (ILLW) is disposed of by the hydraulic fracturing process with low cost and large capacity of disposal, a continuous injection of 8 hours can dispose of ILLW about 300～350 m^3, more than 10,000 m^3 radioactive liquid waste can be disposed of in each well, therefore it is an attractive process for the disposal of ILLW.

Since Sichuan Nuclear Fuel Plant has better geological conditions, it is possible to dispose of its ILLW by using hydraulic fracturing process. Since 1980s, the research and development of the hydraulic fracturing process have been initiated for disposal of ILLW. It is demonstrated that the hydraulic fracturing process is considered suitable for disposal of ILLW in that region.

2. Description of Hydraulic Fracturing Process

The hydraulic fracturing process is characterized by combination of the treatment with the disposal of ILLW. It is similar to the cement-solidified process in respect of treatment technology, but is of cement solidification in deep geology stratum. In carrying out the hydraulic fracturing process, first of all, it is necessary to select a suitable disposal site with detailed information on geology and hydrogeology. The rock stratum between the lower limit of groundwater and above 1,000 m in depth of underground will be selected as the disposal layer. The ILLW which is mixed with cement and other additives to form grout is injected into the underground closed stratum with extremely low permeability to solidify with rock to become an integral body by using matured fracturing technology and equipment available to oil industry and the technology and facilities related to nuclear safety. As a result, the purpose that the radioactive waste is isolated from human environment can be reached.

2. 1 Advantages of hydraulic fracturing process

Compared with the near surface disposal of ILLW, the hydraulic fracturing process has such advantages as small in building area and simple, safe, and reliable in technology. Since the treatment and the disposal of ILLW are carried out simultaneously, the cost of final disposal is much less than the others. It is clear that this process benefits the environment and mankind.

2. 2 Basic requirements

2. 2. 1 Requirements for radioactive waste grout

a. Liquid waste must have good chemical compatibility with cement and additives;
b. The viscosity of the grout does not exceed 4×10^{-2} Pa • S;
c. After solidification, the product contains a great part of water, and the free water will not

be allowed to exceed 3 to 5 %;

d. The densifying time of the grout should be corresponding to the pumping time and a time of 10 to 12 hours should be guaranteed;
e. The setting time of the grout is not allowed to exceed 7 days;
f. The leaching rate of the solidified product should be very low; and
g. The compressive strength of the solidified product should not be less than 700 kPa.

2. 2. 2 Geological requirements for disposal site

Types of rock, stability of geological structure, history of earthquake, distribution of crustal stress, effective porosity of rock stratum, compressive strength of rock stratum, mineral composition in rock including their absorbability to ions and their exchange capacity, etc. must satisfy the requirements for disposing of ILLW when the hydraulic fracturing process is used.

2. 2. 3 Radiation protection

The rock stratum of the site to be selected should be thick enough to provide a shielding layer against radiation.

2. 2. 4 Maximum conceivable accident

The injecting process should be safe and reliable, and the emergency measures are provided for the maximum conceivable accident.

2. 3 Site selection

On the basis of the principles mentioned above, a stretch of steady mass of shale rock with complete geological construction has been discovered near the Sichuan Nuclear Fuel Plant. The shale is wide in distributive scope and large in thickness, the content of clay mineral is high, the lower limit of groundwater moving range is 100 m deep. The earthquake intensity of the area is low and the crustal stress in three-dimensional space is advantageous to the hydraulic fracturing injection.

3. Hydraulic Fracturing Tests with Water and Grout Injection

The water and grout injection tests started in May 1980, and about 270 m^3 of water and 291 m^3 of grout were injected. The clefts approximate to horizontal were produced in both injections.

Measured parameters are shown as follow:

Breakdown pressure: 26 MPa; Corresponding injection rate: 0. 13 m^3/min;
Prolongation pressure: 20 MPa; Corresponding injection rate: 1 to 1. 13 m^3/min.

The results of the grout injection test conformed to those of the water injection test, and the expected purpose of the test was achieved.

4. Concept Design for Disposal ILLW with the Hydraulic Fracturing Process

4. 1 Flow diagram

The flow diagram of the hydraulic fracturing process is shown in Fig. 1. Solid materials such as cement, fly ash, activated clay, and zeolite are weighed according to the prescription that is determined by the test, then they are blent and transferred into a high-level blended material tank. When the ILLW, added with retarder and deaeration agent, is pumped into a jet located at the bottom of the mixer under a certain pressure and a certain flowrate, thanks to the action of negative pressure, the solids fall into the bottom of mixer and is mixed with ILLW in a certain solid-liquid ratio to form the grout that meets the requirements. This grout is pressured by the injection pump and flows through the coiled tubing into the injection well.

The radioactive grout with high enough pressure cleaves the shale stratum, and is solidified under pressure, thus an integral body with the rock stratum formed.

4. 2 Safety measures

4. 2. 1 Monitoring for operation

During each injection operation, the change of injection pressure and the exposure dosage of the operational crew must be monitored. The injection pressure is steady in general in the whole injection process, if a large fluctuation or a pressure drop which is not explainable appears, which means that a vertical cleft is probably produced, the operation shall be stopped at once and causes must be analyzed.

4. 2. 2 Determination of orientation and distribution range of underground grout sheet

Orientation and distribution range of the radioactive grout in underground are determined by the micro-earthquake method, and the distribution range diagrams can be drawn out by a drafter.

4. 2. 3 Observation wells for covering rock stratum

Observation wells for covering rock stratum are built around the injection well. In general, after every four injections, it is needed to observe the leakage rate of water of the naked part at the bottom of wells under 0. 5 MPa pressure. If the leakage rate of water increases evidently after injecting, which means the airtightness of the rock stratum where the grout is injected is damaged, the injection shall be stopped.

4. 2. 4. Determination of rise value of earth surface

In order to protect the safety of buildings and structures on the earth surface, and to know the orientation of underground grout and the change of rock stratum indirectly, the rising value of earth surface must be determined after each injection.

4. 2. 5 Emergency waste pool

In order to prevent the grout which has been injected into the rock of underground from coming back to the earth surface in case that the injection pump or the high pressure manifold or the well-head device ruptures, in addition to the blowout preventer assembly, an emergency waste pool of 150 m^3 is established to store the radioactive grout coming back to the earth surface.

5. Workshop Arrangement

The layout of main equipment of the hydraulic fracturing workshop is shown in Fig. 2.

The workshop is arranged according to the principle of four zones. The equipment for storing and handling radioactive materials are arranged in Waste Liquid Storage Room, Mixing Room, Injection Pump Room, and Well-head Device Room respectively. In addition to the concrete shielding layer which is safety enough, all rooms are lined with stainless steel cladding. Viewing windows are installed in the walls of the rooms to monitor the whole injection process and the equipment's running conditions directly.

6. Maintenance and Decommissioning of Equipment

6. 1 Maintenance

According to the radioactive levels of the materials to be handled, the workshop's equipment are maintained with direct and indirect methods respectively. But the method of direct maintenance is adopted for mixing equipment, injection pump, and coiled tubing, and so on which are introduced from the oil industry. Before maintained, they must be cleaned with high pressure water.

6. 2 Decommissioning

When the task of hydraulic fracturing is completed, the well field shall be sealed with cement, covered by clay, cultivated with plants and marked with "Disposal Area". and it can be isolated safely, so the environment can be guaranteed not to be polluted.

Conclusions

There is a stretch of mass of shale rock near Sichuan Nuclear Fuel Plant which geological structure fits the disposal of ILLW by the hydraulic fracturing process. The geology of the site is steady. The rock stratum is thick and distributes extensively, and contains rich mineral clay, so it is an ideal site.

The concept design of the process, equipment, and workshop building has clearly explained that this project is feasible, and the operation can be accomplished in safety. And the purpose of economic disposing of ILLW is achieved.

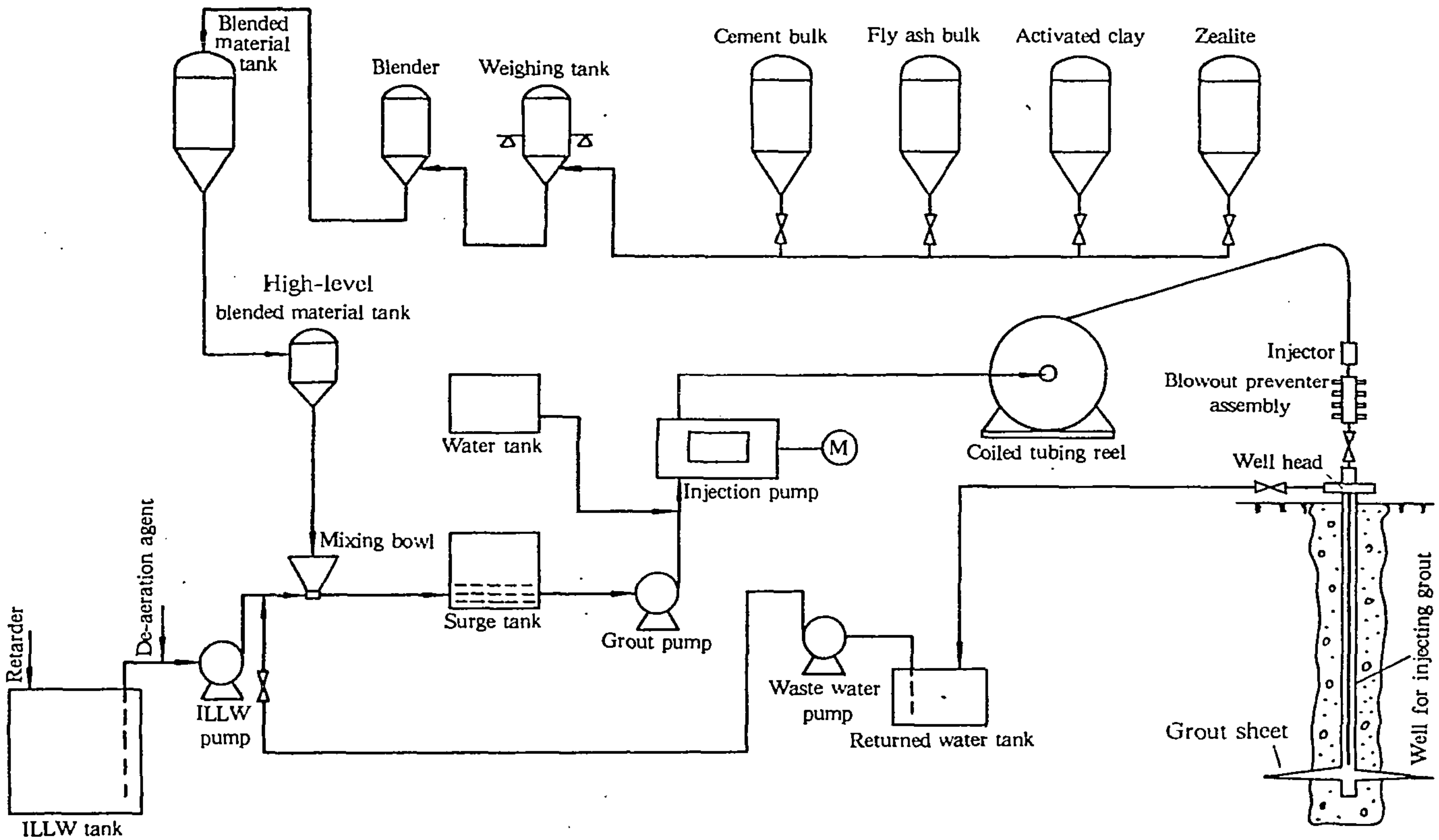

Fig. 1 Flow diagram of the hydraulic fracturing process for disposing of ILLW

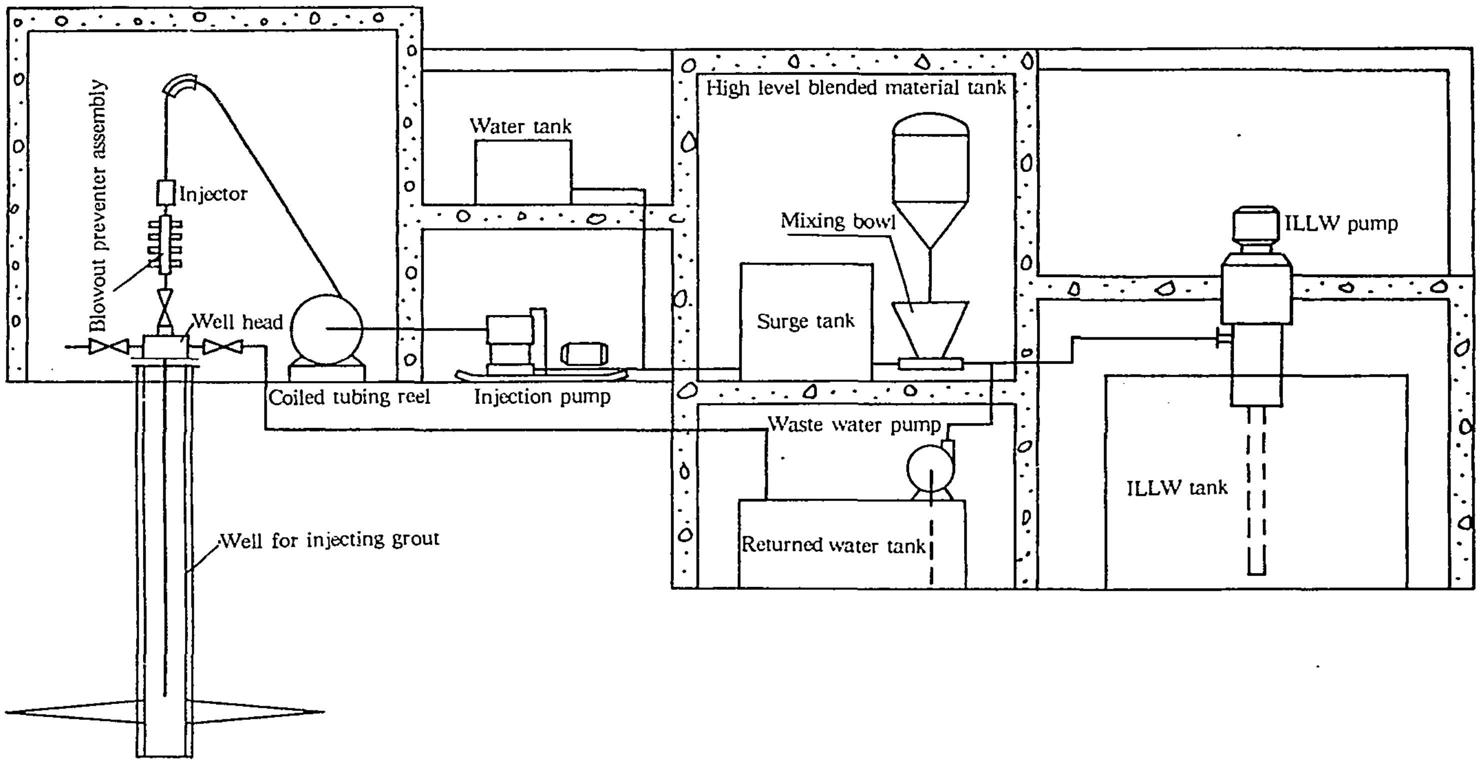

Fig. 2 Layout of workshop building for hydraulic fracturing process