Mixing and Purification of Master Solution for JUNO

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1 – Introduction

Producing 20,000 tons of ultra-pure liquid scintillator poses one of the most challenges for the Jiangmen Underground Neutrino Observatory (JUNO). The three components of the liquid scintillator—linear alkylbenzene (LAB), 2,5-diphenyloxazole (PPO), and 1,4-bis(2-methylstyryl) benzene (bis-MSB)—do not meet the strict radioactive content standards upon purchase from suppliers, necessitating the implementation of purification stages. To address this issue, a comprehensive on-site liquid scintillator production and purification system that incorporates several facilities was developed and constructed.

The crucial task of purifying PPO and bis-MSB is assigned to the mixing system. This process begins with dissolving PPO and bis-MSB in LAB to create a highly concentrated master solution, subsequently decontaminated of radioactivity through acid extraction and filtration processes. Following purification, the master solution undergoes online dilution to produce the liquid scintillator, subsequently transported to the underground laboratory.

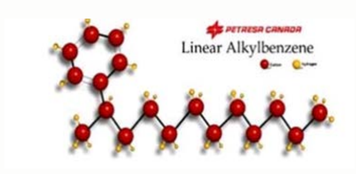
Results from joint commissioning have demonstrated that this methodology significantly reduces the radioactive content of the master solution, marking a considerable advancement for JUNO.

This poster aims to elucidate the composition of liquid scintillator and its radioactive content specifications. It details the mixing and purification processes of the master solution, as well as the design, parameters, and distinctive construction features of the mixing system, while highlighting the successes of joint commissioning efforts.

2 – The composition of liquid scintillator

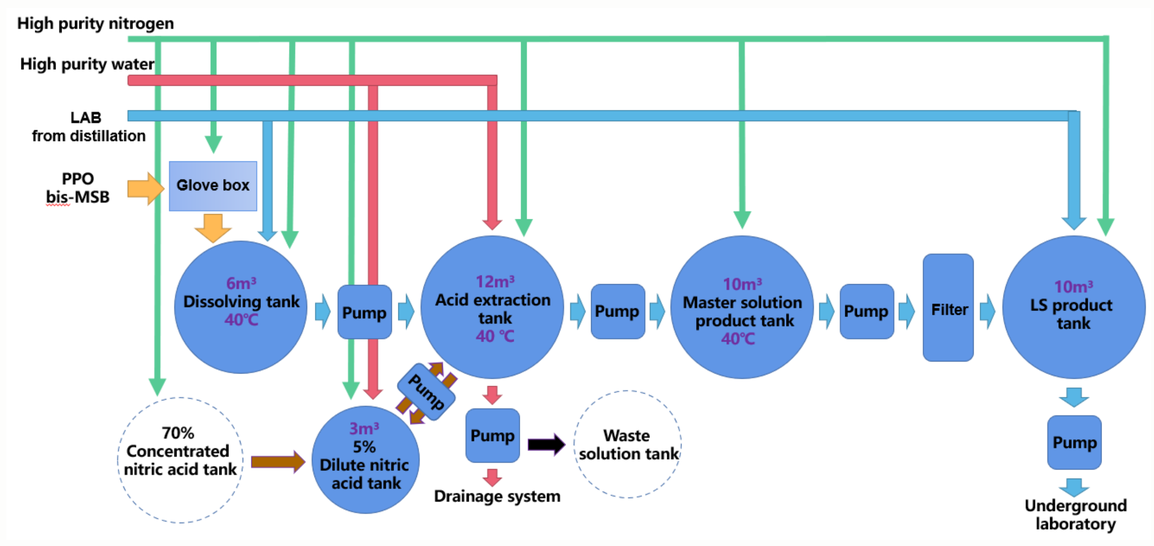
- LS Recipe: LAB + 2.5 g/L PPO + 3 mg/L bis-MSB
- Solvent: LAB – 20 ktons
- Fluor: PPO – 60 tons
- Wavelength shifter: bis-MSB – 72 kg
- Purity requirmetnts of ^{238}U, ^{232}Th: $<1.0\times10^{-17}$ g/g
- Master solution concentration:

  LAB + 105 g/L PPO + 126 mg/L bis-MSB

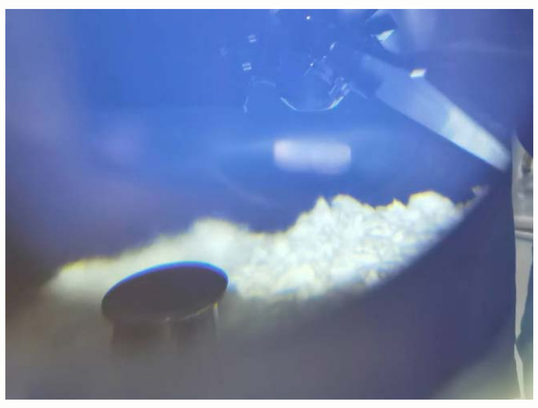


3 – The mixing and purification flow chat

The process includes six steps: feeding, dissolving, acid extraction, filtering, diluting and pumping.



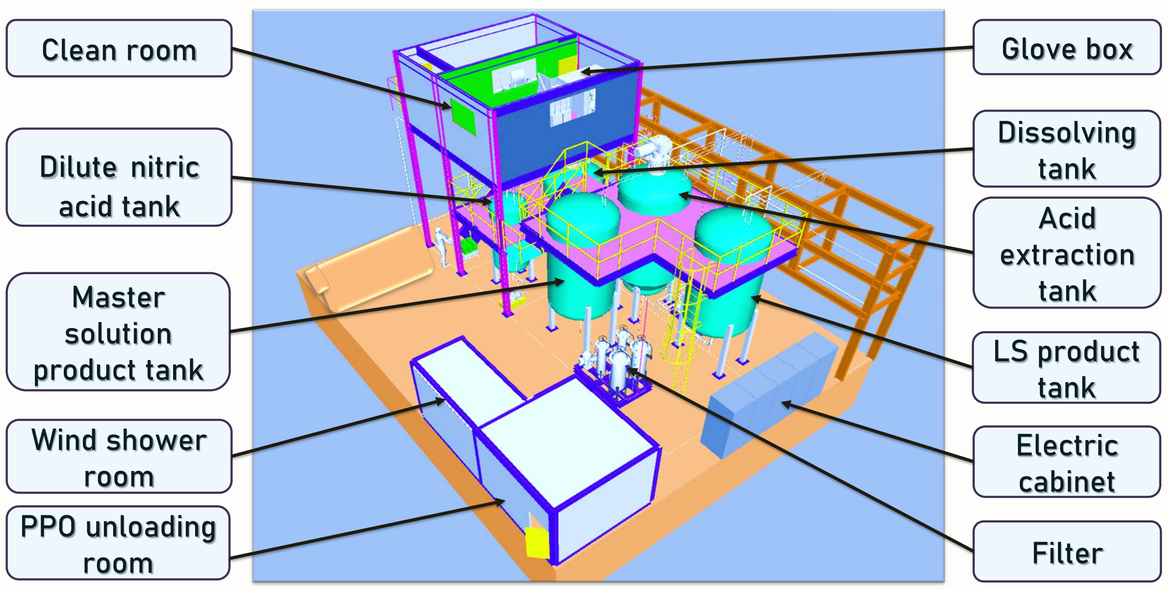
Feeding PPO through glove box



Dissolving PPO in LAB

4 – The mixing system composition and features

The system mainly consists of 11 parts.



- PPO, bis-MSB are fed into the dissolving tank through a glove box in the clean room, prevent radon and dust pollution
- Heated acid extraction (40 ℃), 2-stage filters (200 nm, 50 nm) to ensure effective purification of the master solution
- Magnetic fluid sealed shaft and Double O-ring, to ensure air tightness
- Clean manufacturing, installation and strict cleaning, to ensure system cleanliness

5 – Joint commissioning results

- Remarkable purification effect for master solution
- U/Th <0.30 ppq (reach ICPMS lower limit)
- Particle content reduced by 3 orders of magnitude (0.1-0.5 μm)