Status of the design of the distillation and stripping plants

on behalf of the Liquid Scintillator group
OUTLINE

- Starting Point
- Distillation Plant
  - P&Id
  - Layout
- Stripping
  - P&Id
  - Layout
- DCS
- Hardware
- Software
- OPC
- Schedule
Starting Point: Pilot Plants

Since November 2017 we have started the design of the Distillation and Stripping plants for JUNO with the same company that realised the pilot plants:

**Polaris s.r.l.** - > trustable, reliable and already trained company

The final design is based on the best present knowledge and the experiences done so far at Daya Bay. The design adopt also most of the Borexino and SNO+ technical developments for their own purification plants.
Concerning the Stripping plant we have done a dedicated test at Daya Bay to prove the stripping efficiency. Results gave a Rn purification factor between 94 – 98 %. Final column will be 50% higher so we expect even better results. For Distillation we plan to have a dedicated test at Daya Bay and a feedback from SNO+ at the beginning of next year 2019.
Starting Point: Distillation

Absorption Length

<table>
<thead>
<tr>
<th>Sample</th>
<th>Raw Sample</th>
<th>LAB after Distillation</th>
<th>LAB After Stripping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attenuation Length [m]</td>
<td>16.08</td>
<td>25.31</td>
<td>24.35</td>
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</table>
For what concern radio-purity there is only a global indication of the level reached during the first filling: $2 \times 10^{-15}$ g/g_U

Some considerations:

- Daya Bay AD was not designed for $10^{-16}$ level
- Small contamination left in AD from LS + Gadolinium
- AD cover gas showed a significant Rn leakage
- Water plant was not at the required level during the first filling but improved later
- We expect that the real purification capability of the distillation plant itself should be at least in the range of $10^{-16}$ as required by the Juno experiment.
Distillation Plant

- Flow rate 7000 l/h with temperature around 200 °C
- Distillation under vacuum with sieve trays without downcomers
- 6 physical trays
- 1-2% bottom column discharge (sent back to Alumina column?)
- High adjustable reflux rate (up to 40%)
- Filtration up to 0.05 microns
- Parallelisation and spare parts on shelf to minimise filling dead time
- Heat exchanger energy recovery
- Nominal Electrical Power ~ 1000 kW (plants + heating) [1250 Kw available]

- Cooling water ~ 1000 kW (thermal power) ~ 350 kW electrical power or less if evaporative cooling tower
- Hot Oil system (electrical)
- All the plant is kept under continues nitrogen blanket either to avoid oxidation/contamination but also for safety reason (LAB temperature > flash point only inside the distillation column)
- Vapour condenser before nitrogen exhaust for safety (avoid LAB vapour exhausting)
- Rupture disks for pressure safety (plant certified up to 3.5 bar PED an SELO Norm.)
- Single leak rate < 10^{-8} mbar L / s
- Integral leak rate < 10^{-6} mbar L / s

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<td></td>
<td>4.0</td>
<td>2000</td>
<td>6</td>
<td>10</td>
<td>200</td>
<td>7000</td>
<td>2000</td>
<td>50</td>
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Distillation - Layout
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3D Plants drawing courtesy of POLARIS ENGINEERING

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Stripping plant will be based on the “steam stripping” technique to remove the impurities that are more volatile than LAB: Ar, Kr and Rn. Water steam to avoid to use huge quantity of nitrogen in underground (safety). Stripping is carried out with counter-current flow of the liquid LAB and water super heated steam and/or nitrogen with unstructured packing.

- Flow rate 7000 l/h
- Temperature around 90 °C for higher column efficiency
- Partial vacuum (around 300 mbar)
- Both steam and nitrogen stripping could be used
- Filtration up to 0.05 microns
- Parallelisation and spare parts on shelf to minimise filling dead time
- Nominal Electrical Power ~ 200 kW (plants + Hot Oil)
- Cooling Power ~ 200 kW (thermal power ~ 100 kW electrical power)
- Pure water from water plant (approx. 25 l/h)
- Hot Oil system (electrical)
- All the plant is kept under continues nitrogen blanket either to avoid oxidation/contamination
- Vapor condenser before water vapor/nitrogen exhaust for safety
- Rupture disks for pressure safety (plant certified up to 3.5 bar PED an SELO Norm.)
- Single leak rate < 10^-8 mbar L / s
- Integral leak rate < 10^-6 mbar L / s

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<tbody>
<tr>
<td></td>
<td>6</td>
<td>450</td>
<td>Unstructured packing</td>
<td>300</td>
<td>90</td>
<td>7000</td>
<td>25</td>
<td>60</td>
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Stripping - Sketch

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Stripping - Layout
DCS General Structure

- **PLC**
  - Designed for industrial processes.
  - Works under severe conditions.
  - Real time system.
  - Handles sensors and actuators (I/O).

- **Local Control PC**
- **Global Control PC**

**PLC**
- Collect all the measurement from instrument
- Control directly the plant equipment
- Run automatic process control

**OPC Server**
- Modbus/Profinet Communication

**Local Control PC**
- Human Machine Interface
- Permit actions on the plant
- Display plant parameter

**Global Control PC**
- OPC Client
- Display plant parameter
- Generate alarm

**Ethernet Communication**
**DCS - Hardware**

**ET200SP**
- Bit-modular design
- Exchange of modules during operation (Hot Swapping)
- Wide range of modules
- Integrated safety oriented design
- Integrated channel-specific diagnostics
- Easy to configure by joining modules
- Automatic diagnosis for each channel
- Use in hazardous areas (Zone 2)

**CPU (IM 1512SP-1PN) Bit-modular design**
- AMD Dual Core 1.0 Ghz (fanless)
- 2 GB RAM / 4 GB ROM
- Many communication options: PG/OP communication, PROFINET IO, TCP, web server
- SD/MMC memory slot
1. **Interface Modules**
   - Head Module of the IO station and connection to the PLC
2. **Modules**
   - Determination of terminal function
   - Digital and analog inputs and outputs
   - Simple integration of fail-safe modules based on the Safety integrated principle
3. **Base Unit**
   - Self-assembling backplane bus for electrical and mechanical connection of the modules
   - Conductors connected to the terminal box with push-in terminals
   - Modules can be replaced without rewiring
4. **Server module**
   - Terminates the station configuration
5. **Mounting Rail**
   - Mounting on a standard DIN rail
DCS - Software

- Stable Environment
- Reliable
- Scalable (easy way to add new instruments, alarms, etc.)
- Capable of taking Automatic action in response of some critical alarms (e.g. Emergency ShutDown)
- Capable of performing sequence in response of operators requirements (e.g. normal startup)
- Capable of sending notification (SMS, mail, etc)
- Record trends and Log alarms in a common DataBase
Requirements

- We need to implement a very user friendly UI to allow:
  - A quick learning of the Plant's operations
  - Easy way to understand the cause of any alarms generated by the control system and fast way to respond to them
- It will be important for the Operator if the Control System could record alarms and instrument value trends

**Alarm Pages**
- Display all the active and past alarms
- Color indication if the were acknowledged or not

**Instrument Panel**
- Display the process value of the instrument
- Display and set alarm thresholds

**PID controller**
- Permit a fine tuning of the variable part of the plant

**Trend**
- Permit to see and record the variation of the values measured by the instrument

**Totaliser**
- Automatically integrate the flows over the time, indicating the total liquid processed
SIMATIC OPC UA S7-1500

- Manufacturer independent communication for Industry 4.0
- The vendor- and platform-independent OPC Unified Architecture (UA) is the communication standard for Industry 4.0 and is the standard mechanism for accessing S7-1500 data from non-Siemens devices.
- OPC UA can be used in all Ethernet networks and is in particular fully compatible with PROFINET permitting parallel operation.

**Benefits**

- Simple, standardised and secure connectivity
- Platform and manufacturer independent
- No additional hardware
- Use only one network (parallel operation with PROFINET and TCP/IP)
- Maximum scalability
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Nov 2017
- Start of the final design with Polaris company

August 2018
- Design frozen and beginning of plants construction

Jan – Apr 2020
- Plants shipping to Jiangmen & installation of plants at site (distillation first)

Sep 2020
- Long term plants commissioning (8 month)

May 2021
- Plants ready for operations

Start of the final design with Polaris company
Design frozen and beginning of plants construction
Plants shipping to Jiangmen & installation of plants at site (distillation first)
Long term plants commissioning (8 month)
Plants ready for operations

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