Canister Conditioning & Stabilization (Dry Packaging) Technologies For Spent Fuels (CANDU SC108 & PWR SC-21 CASKS) Possibility For TRISO Spent Fuels (HTGR)

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Pakistan Atomic Energy Commission

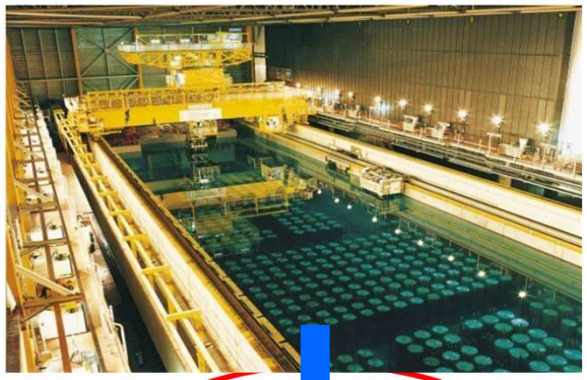
IAEA Technical Meeting Management of Spent Fuels (Pebbles, Compacts) From High Temperature Reactors

7 ~ 11 July 2025, Vienna, Austria.

OUTLINES

1. Spent Nuclear Fuel Cycle All Types (Generalize Flow)
2. Spent Fuels All Types & Worldwide Dry Storage Systems
3. Regulatory Requirements & Objectives (Dry Packaging)
4. Spent Fuel & Interim Dry Storage Facilities (Pakistan)
5. CANDU, PWR Canister Dry Packaging (Worldwide, Pak)
7. HTGR (Pebbles) Canister Internal Conditioning
8. Comparative Aspects Canister Conditioning Technologies (CANDU CASK SC108 & PWR CASK SC21) & Option for Canister of TRISO Spherical Pebbles of HTGR
9. Summary, Conclusion

NUCLEAR POWER PLANT



1- WET STORAGE

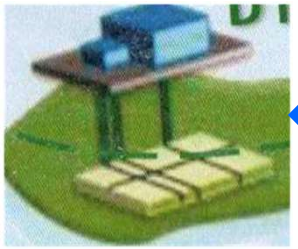
2- DRY PACKAGING

Canister Conditioning
Stabilization
ASTM-1553, 2021
NUREG-1536

SPENT NUCLEAR FUEL CYCLE

MOF FUELS

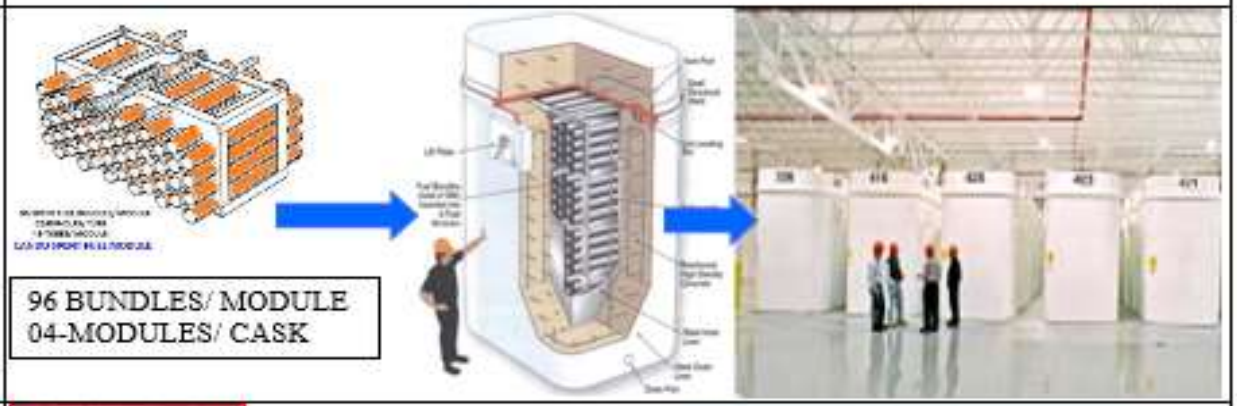
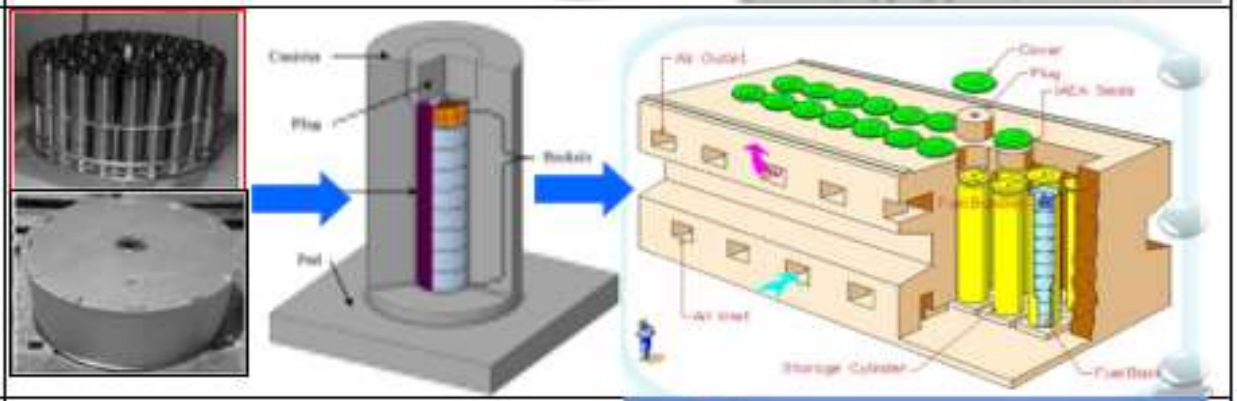
3- DRY STORAGE



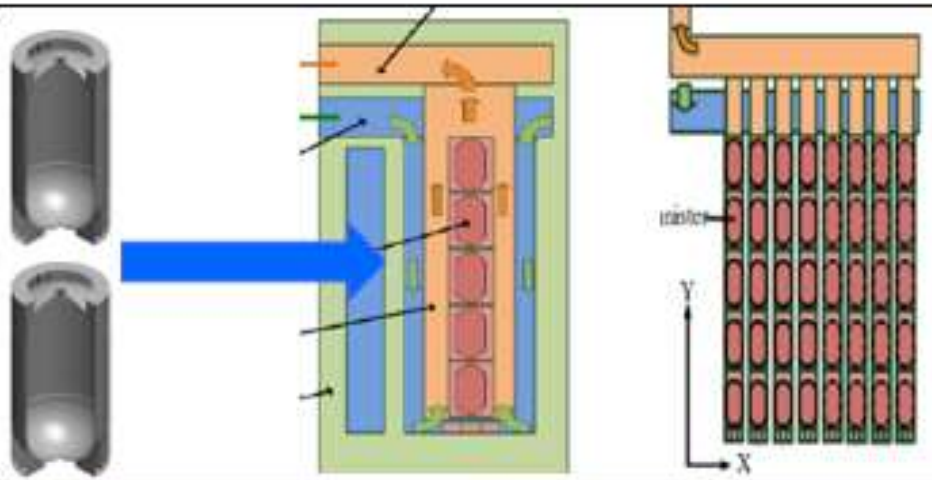
4A-Final Disposal

4B-Reprocessing

Spent Fuels & Worldwide Dry Storage Systems

FUEL TYPE	STORAGE SYSTEM	DRY STORAES (PACKAGING)
CANDU	**DSC CASK** SPENT FUEL **in** BUNDLES **in** MODULES **in** **CASK**	
	MACSTOR SPENT FUEL **in** BASKETS **in** **CYLINDERS** **SILOS**	
PWR	**CASK** SPENT FUEL **in** CANISTERS **in** **CASK**	

Spent Fuel & Dry Storage Systems (Worldwide)

FUEL TYPE	STORAGE SYSTEM	DRY STORAE SEQUENCES
TRISO FUEL **SPEHRICAL PEBBLES**	**CANISTERS** SPENT FUEL **in** CANISTERS **in** **STORAGE WELL**	
	CANISTERS SPENT FUEL **in** CANISTERS **in** **WET POOL/ CASK**	

Regulatory Requirements
Spent Fuel Conditioning & Stabilization

Dry Packaging Acceptance Criteria

ASTM-C1553-16, NUREG-1536

1> SVP ≤4.0×10-4Mpa **≤3Torr (4mBar)** ≥30min

2> **PDP (Dew Point) ≤-05.05ºC**, EMC ≤3.2gm/m3≥30min

Dry Packaging Cover Gas Backfill Criteria

PNL-6365, USNRC DOCKET# 72-1014-06

1> Gas Purity (Grade)≥ 99.9995% (N5)

2> Backfill Operation= Sub-atmospheric

*3> Dry Packaged Cover Gas Pressure = 80Kpa ~ 800KPa

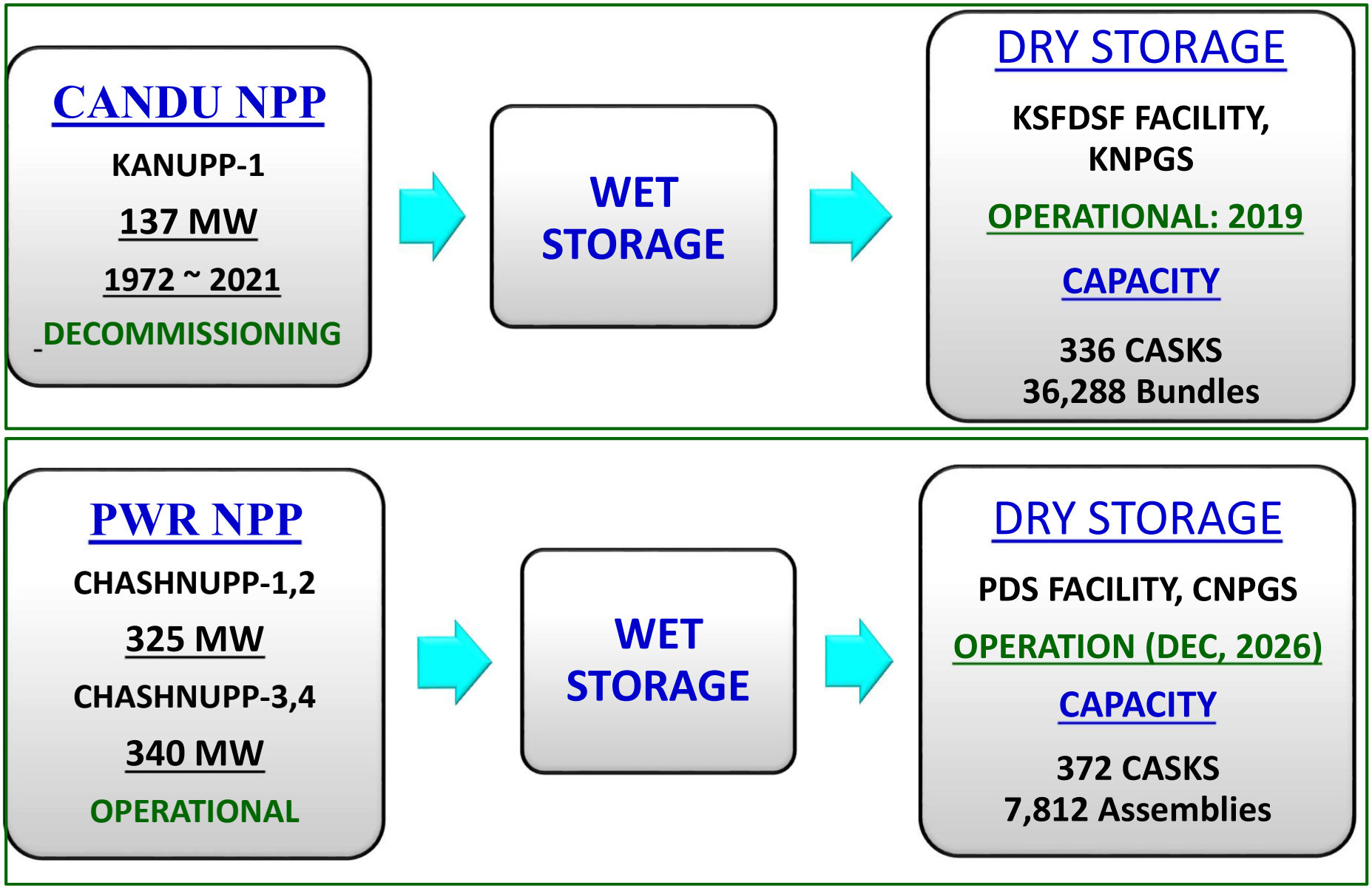
***BASIS**: Spent Nuclear Fuel (Type, Burnup, Decay Heat, Cooling Time)

OBJECTIVES

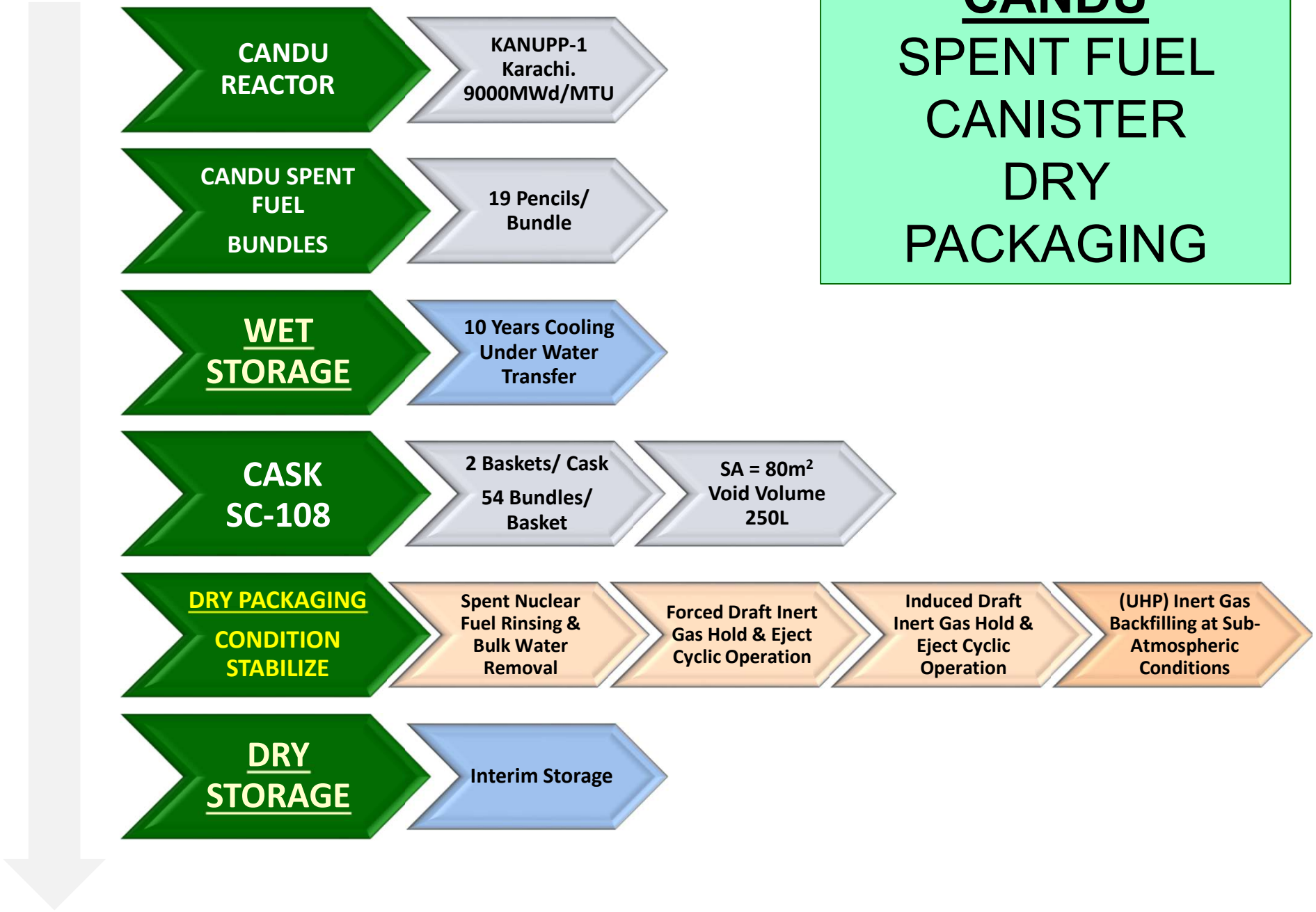
Canister Cond., Stabilization (Dry Packaging)

- Ensure Integrity Spent Nuclear Fuel (Reliable Stored)
- Fulfill Regulatory Requirement, Acceptance Criteria/ Rebound Test (ASTM-1553, 2021, NUREG-1356)
- Eliminate Free Trapped Moisture, Gases (Oxy, H2)
- Prevent Degradation Mechanisms (Embrittlement, Blistering, Swelling, Rupture etc)
- Provide Non-Corrosive Surrounding Environment
- Make Spent Fuel Retrievable (Transport, Disposal)

Spent Nuclear Fuels & Interim Dry Storage Facilities In Pakistan

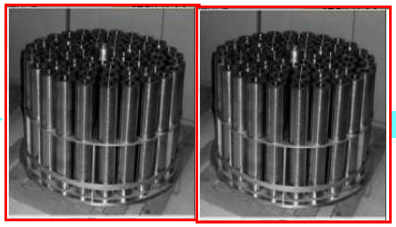


CANDU SPENT FUEL CANISTER DRY PACKAGING

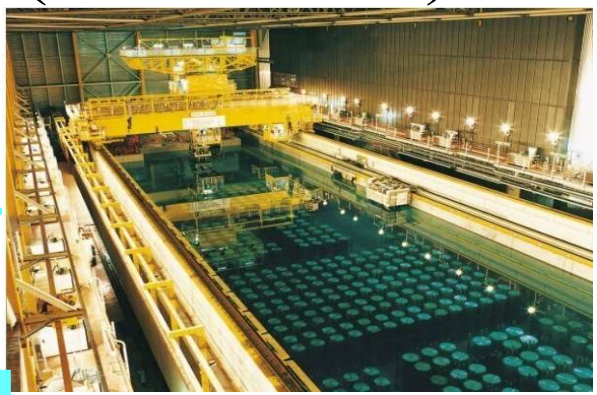


CANDU Spent Fuel Management (Worldwide)

CANDU PHWR REACTOR

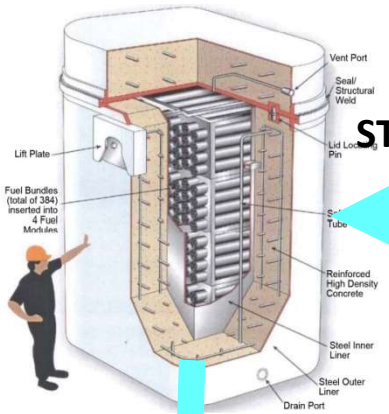


CANDU SNF BUNDLES



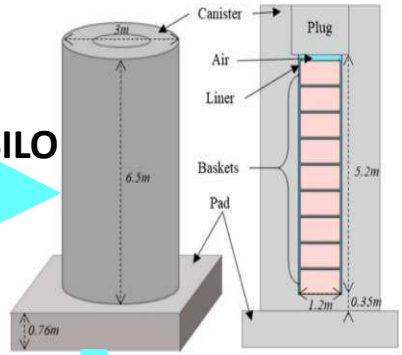
WET STORAGE POOL

DRY PACKAGING
CONDIONING
STABILIZATION
ASTM-1553
NUREG-1536-Rev1

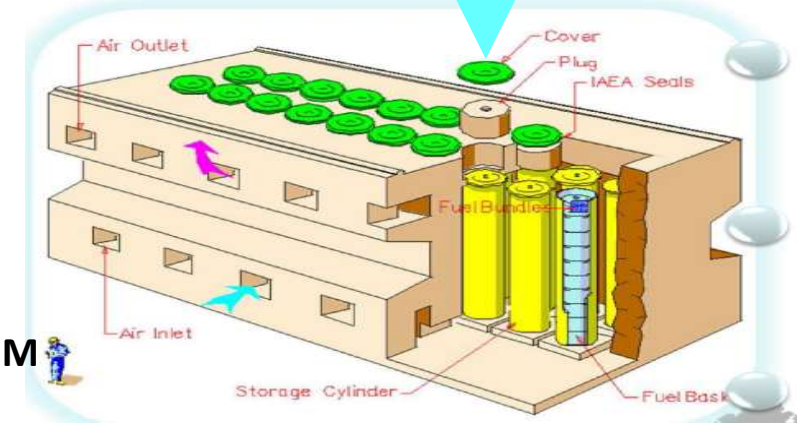


STORAGE CASK

BASKET CYLINDER, SILO

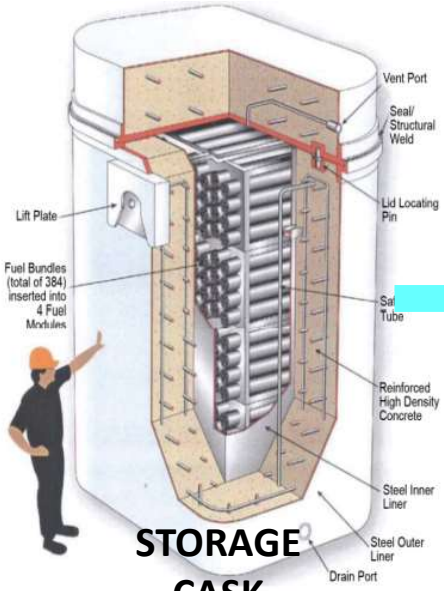


CASKS INTERIM DRY TORAGE



MACSTOR INTERIM DRY STORAGE

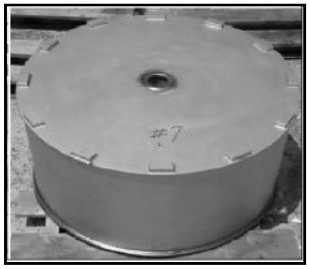
CANDU Spent Fuel Dry Packaging Pakistan



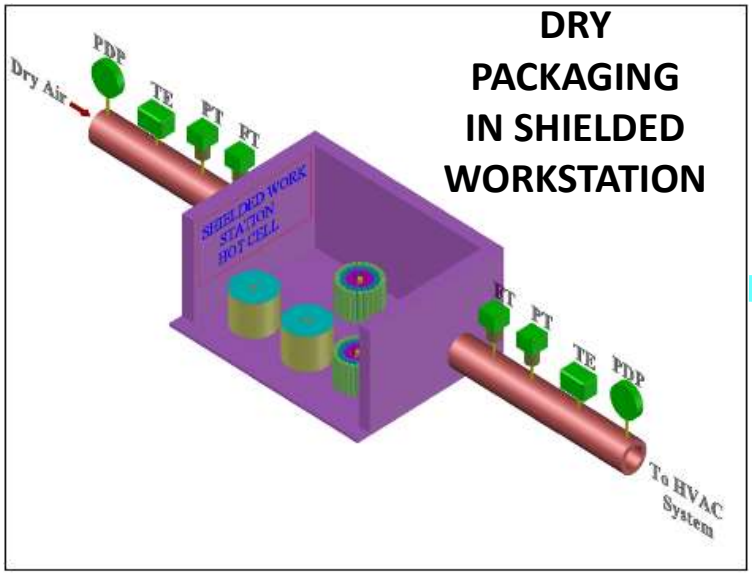
STORAGE CASK

INTERIM DRY STORAGE FACILITY

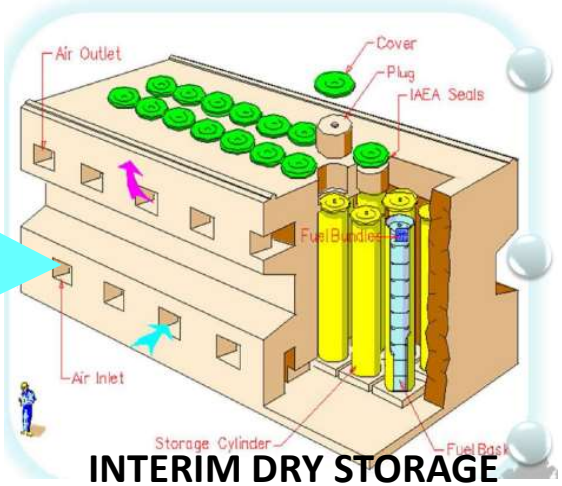
CANDU BUNDLE



BSKET

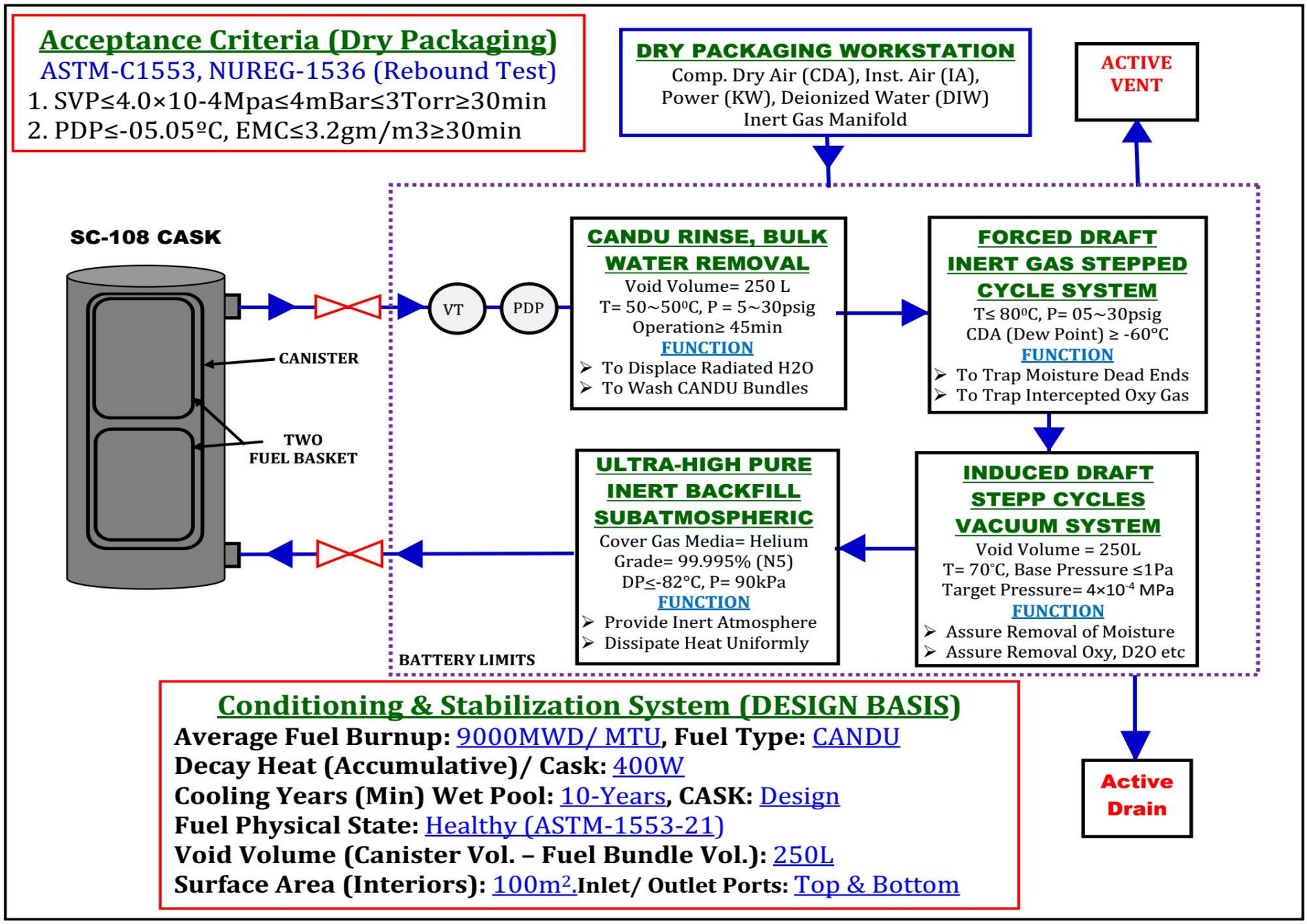


DRY PACKAGING IN SHIELDED WORKSTATION

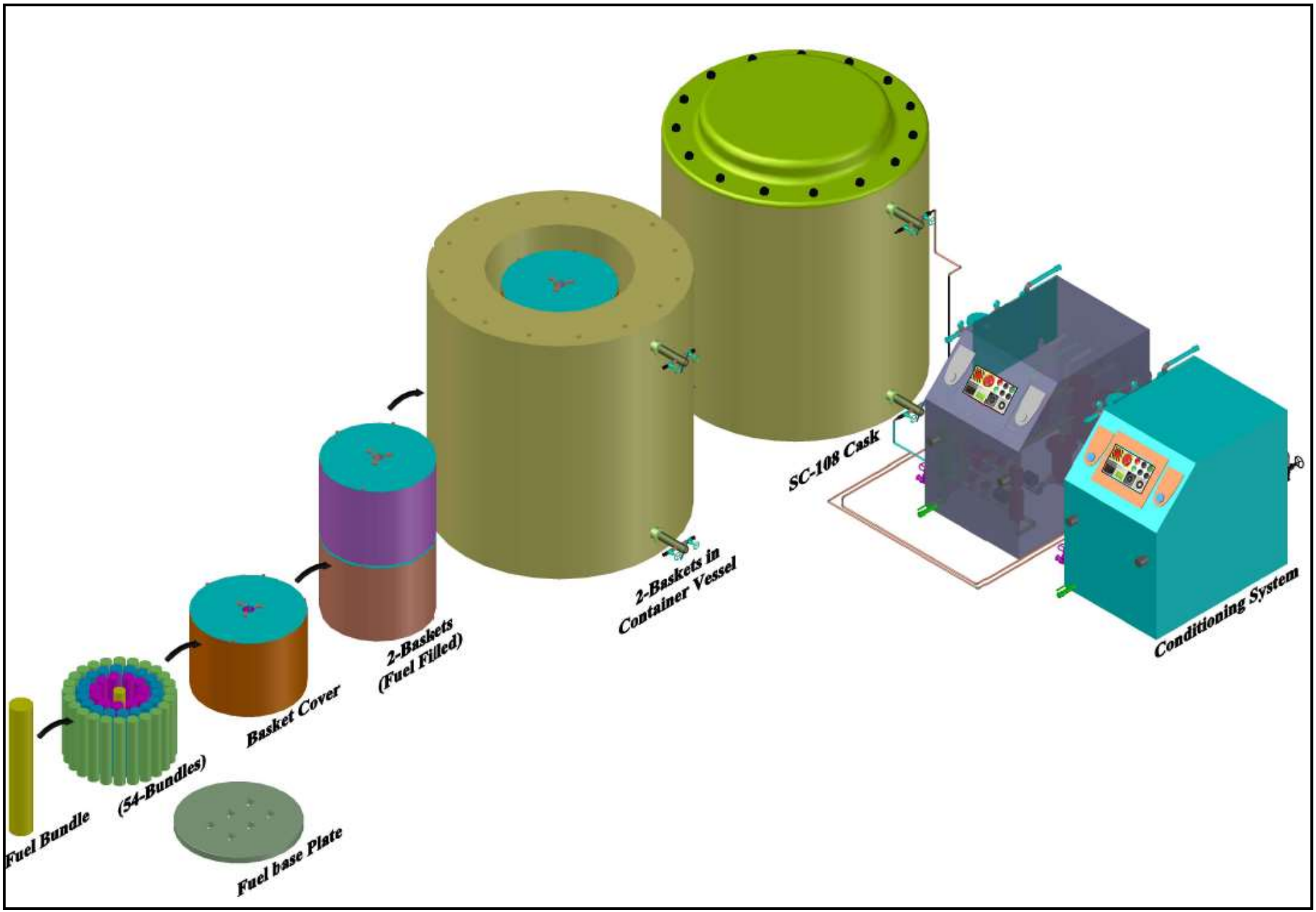


INTERIM DRY STORAGE FACILITY

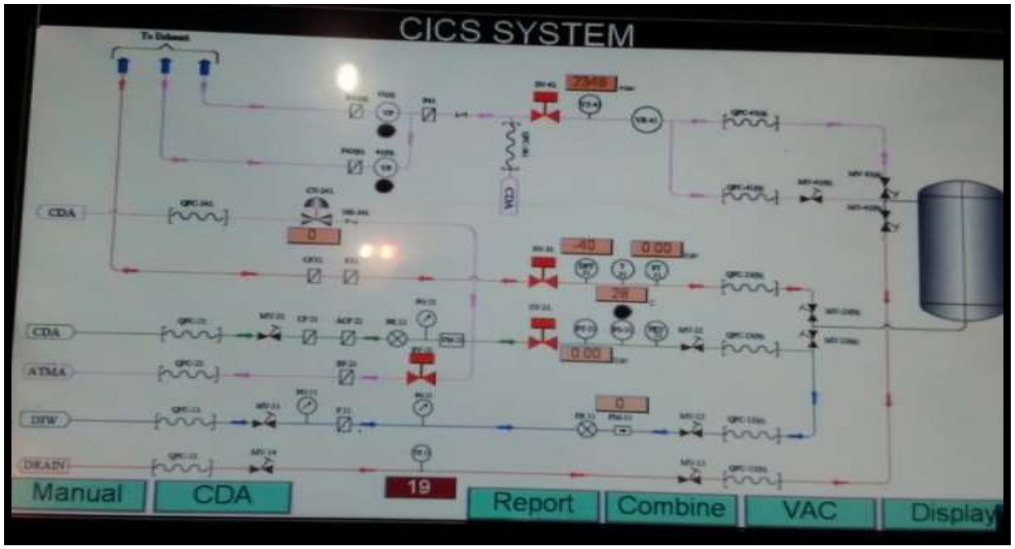
CANDU Spent Fuel Dry Packaging System (Pakistan)

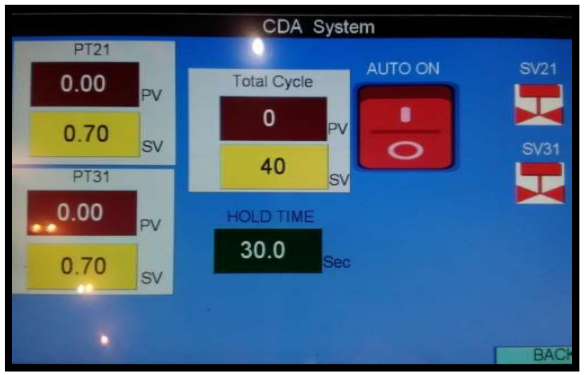


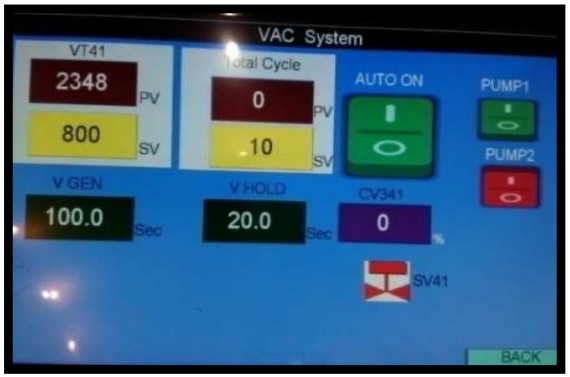
SC108 Cask Dry Storage System

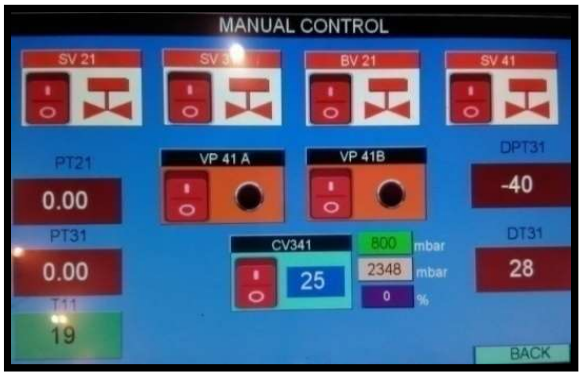


Conditioning System (Sequential Operations)





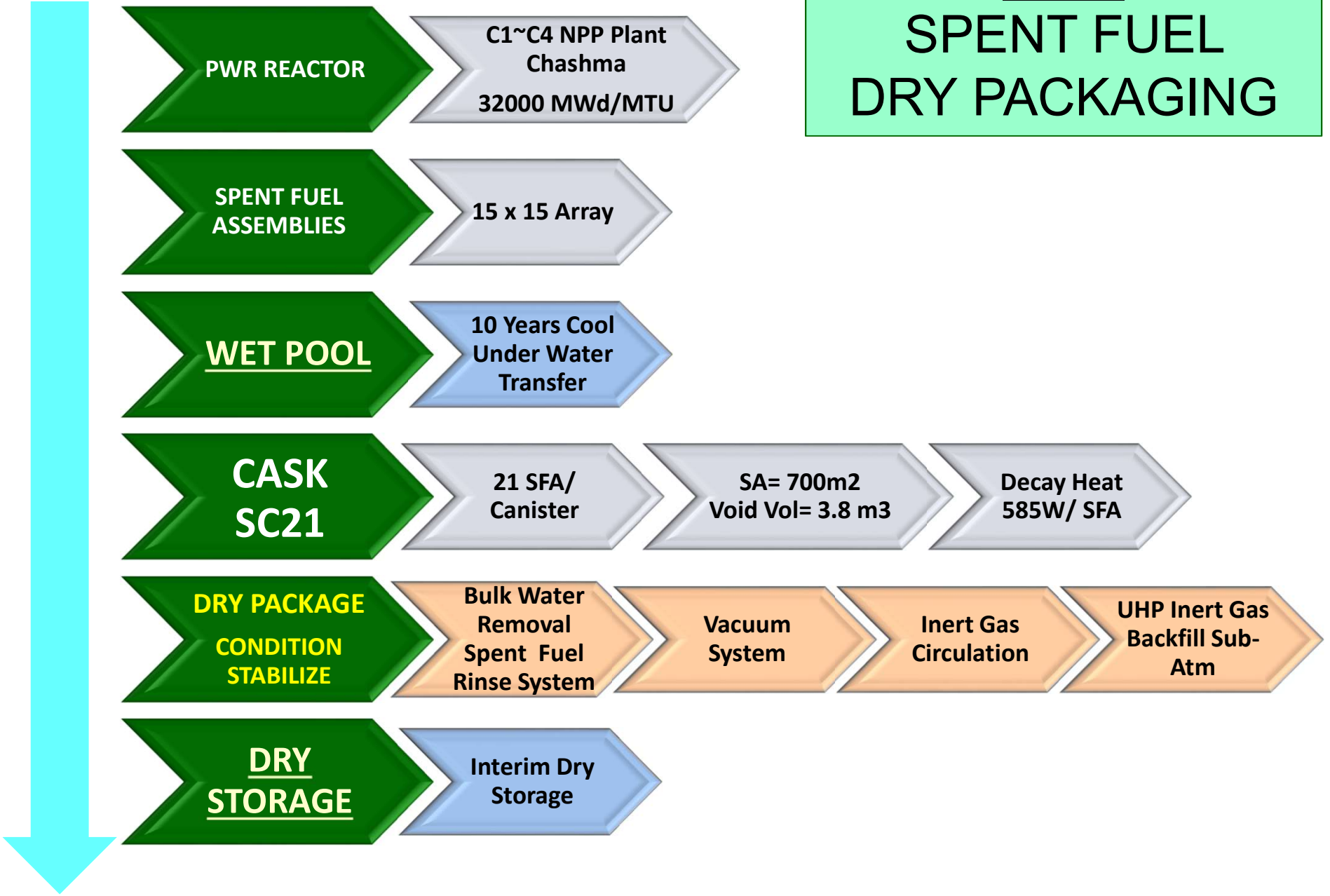




Conditioning System (Results Achieved)

Parameter	Acceptance Criteria	Results Achieved
PDP (Dew Point)	≤-05.05°C≥30min	≤-60.0°C≥60min
SVP (Sat. Vap. Pressure)	≤4.0×10−4Mpa≥30min	≥6.0×10-4Mpa≥30min
EMC (Moisture Cont.)	≤03.02gm/m3	≃0.031gm/m3

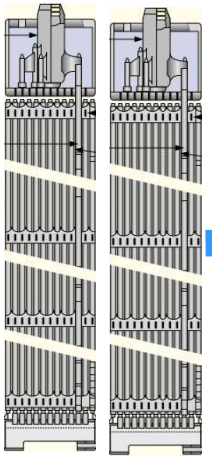
PWR
SPENT FUEL DRY PACKAGING

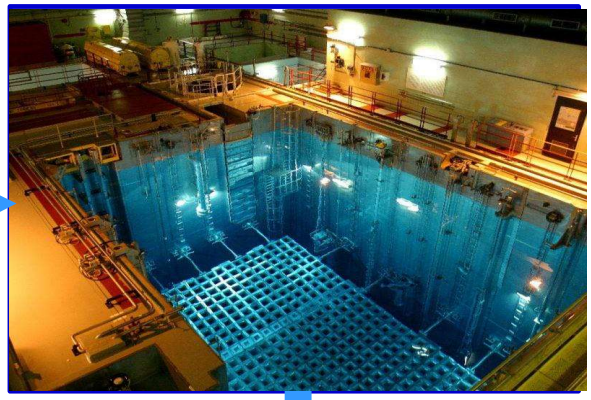


PWR Spent Fuel Management (Worldwide)

PWR REACTOR

PWR ASSEMBLY





WET STORAGE

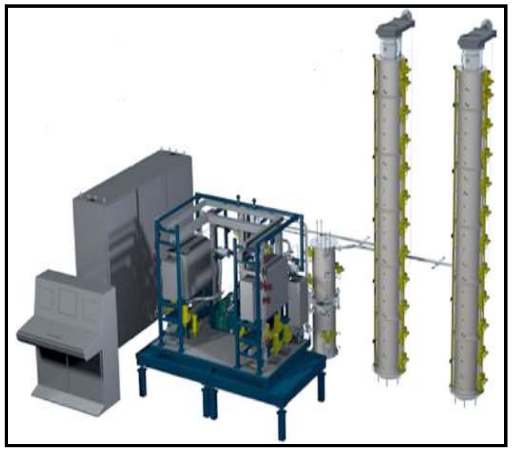
DRY PACKAGING
CONDIONING
STABILIZATION
ASTM-1553
NUREG-1536-Rev1

INTERIM DRY STORAGE FACILITY

DRY STORAGE CASK

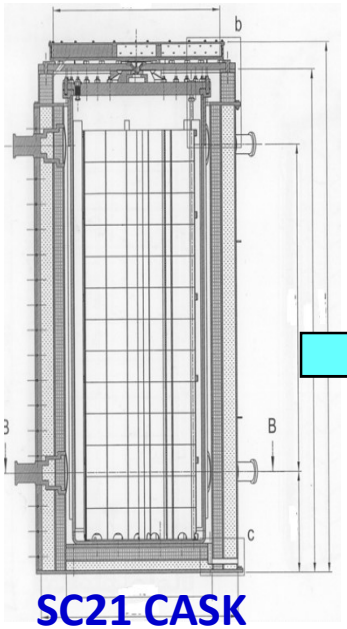
PWR Spent Fuel DRY PACKAGING Pakistan

DRY STORAGE CASK

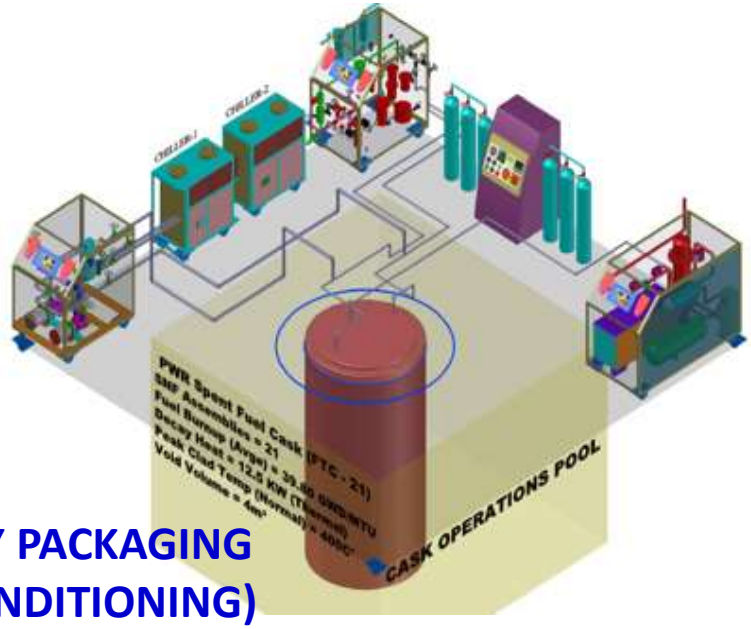


DRY PACKAGING
(CONDITIONING)

INTERIM DRY STORAGE



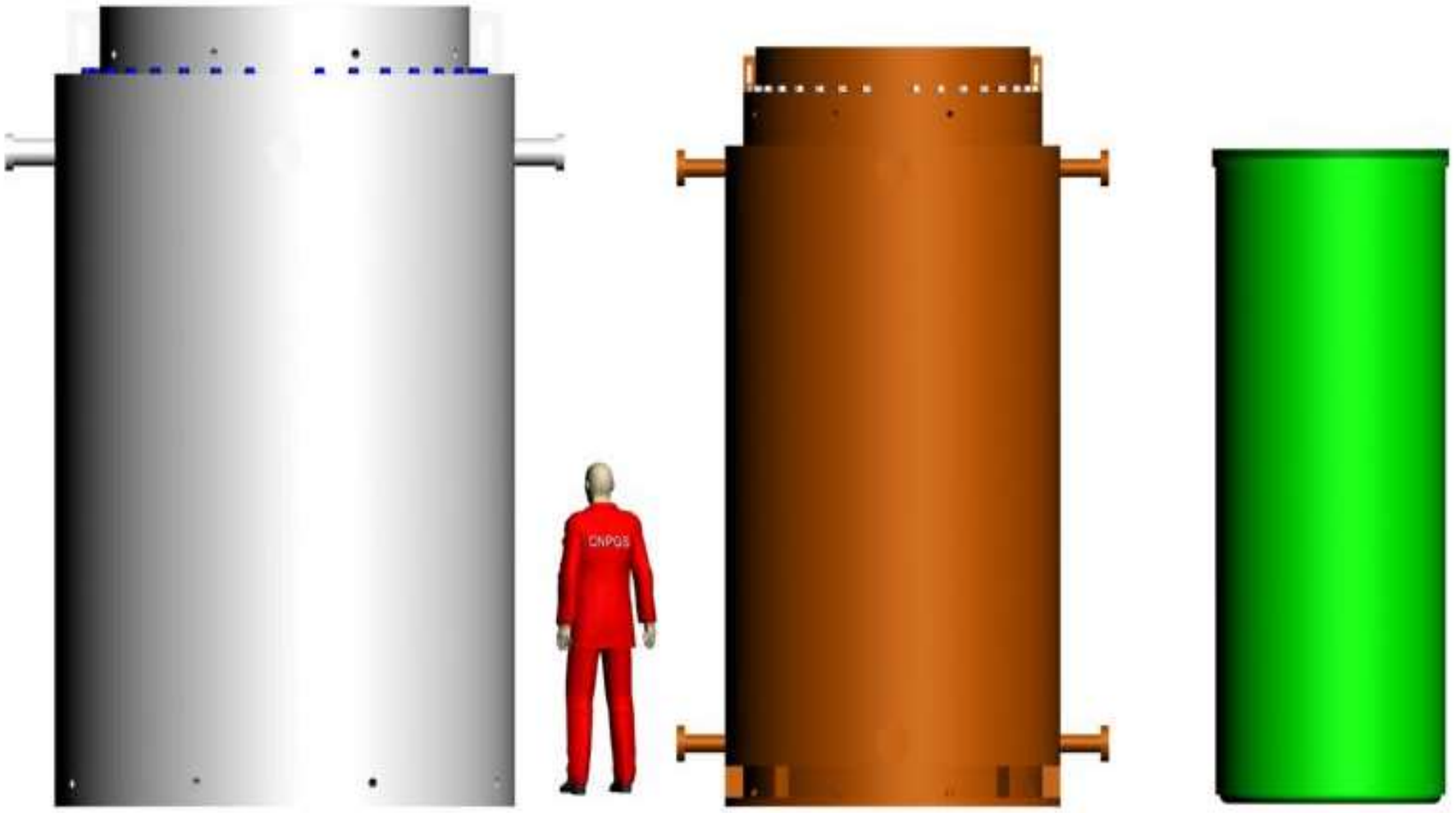
SC21 CASK



DRY PACKAGING
(CONDITIONING)

INTERIM DRY STORAGE

PWR Casks (SC21, TC21) & Canister (Pakistan)

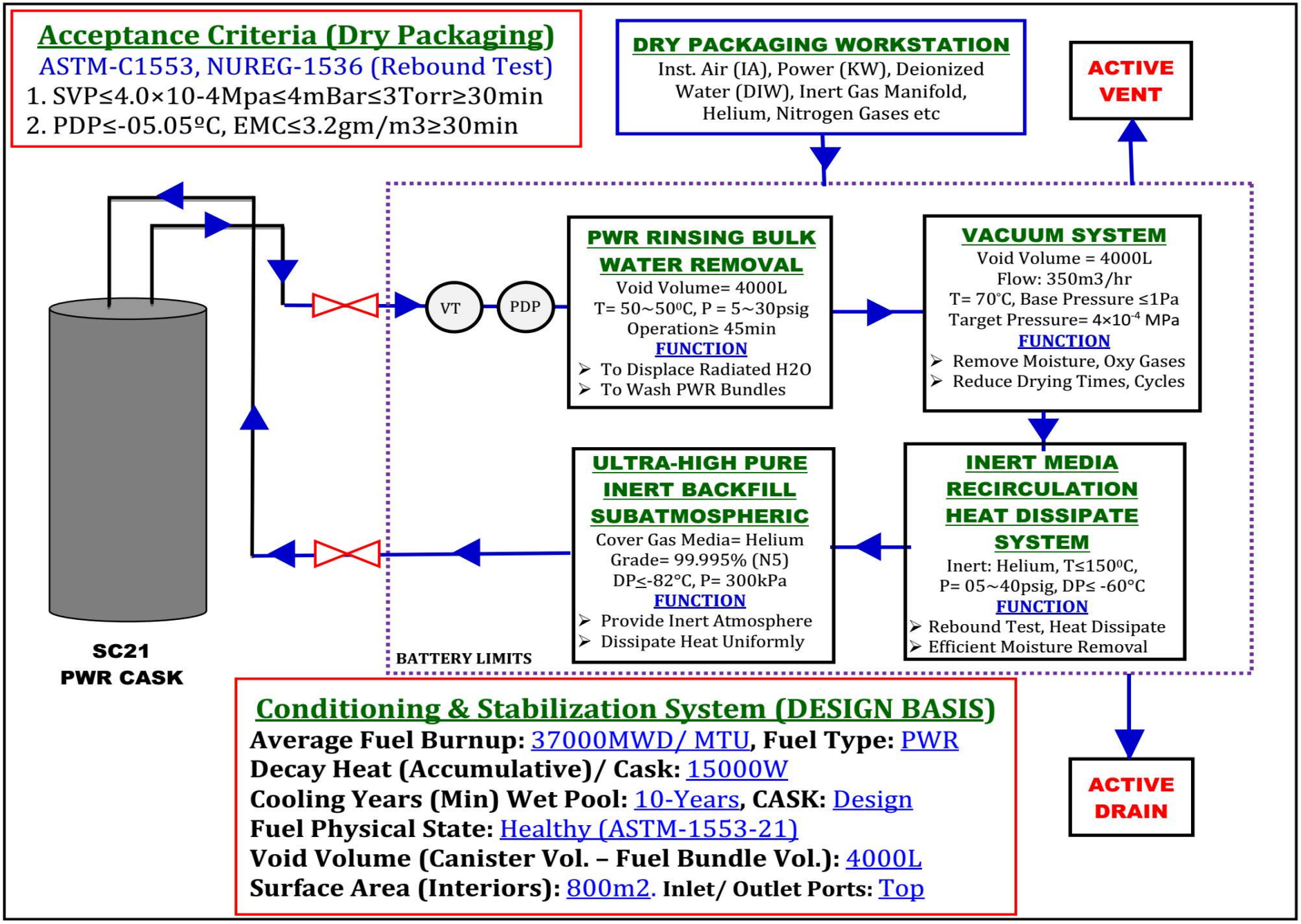


Fuel Storage Cask
(Barite Filled)
Wt : ~100 Ton

Fuel Transfer Cask
(Lead + AlB4C + HDPBr)
Wt : ~70 Ton

Fuel Container
(SS304)
Wt : 16 Ton

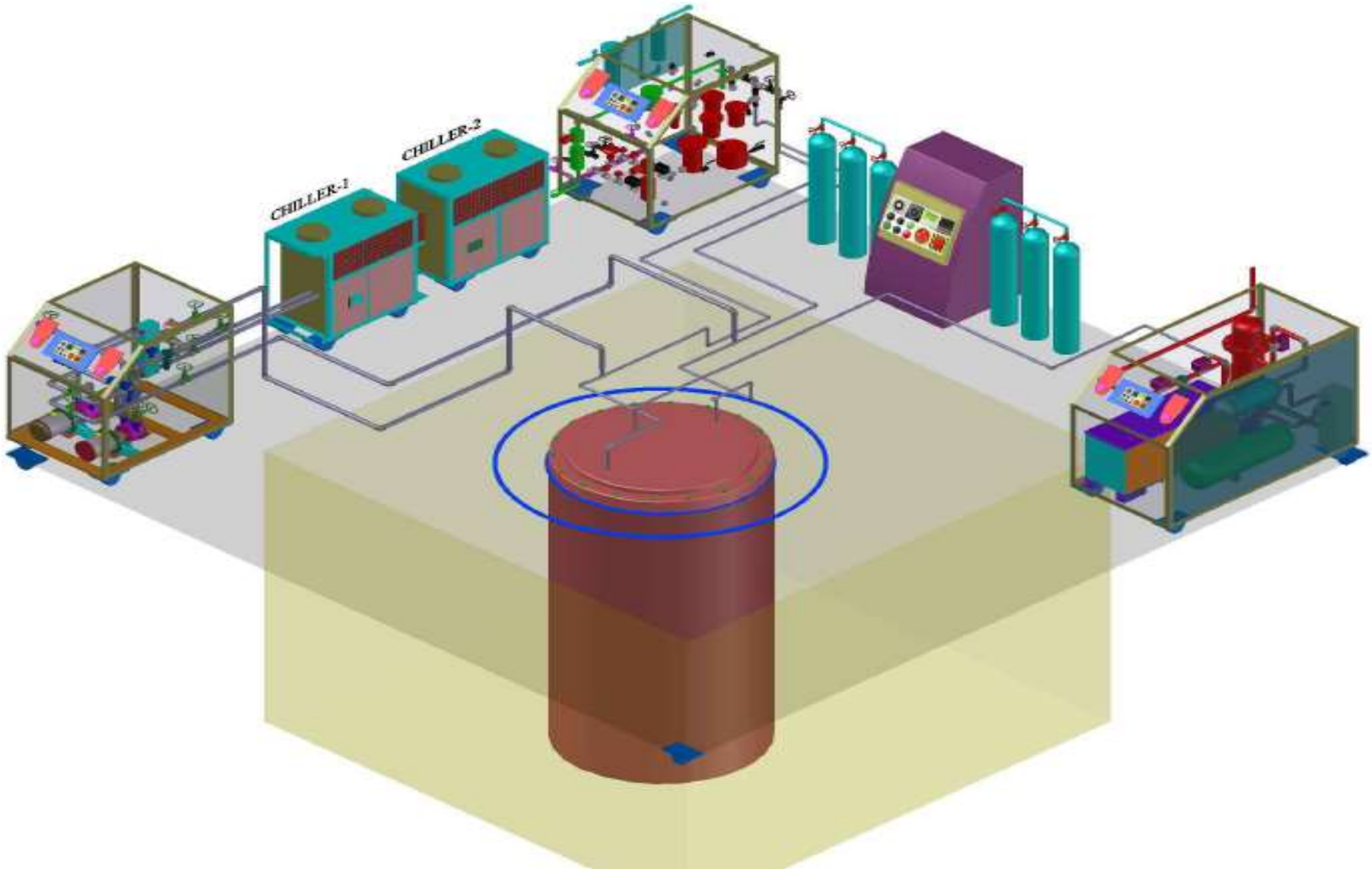
PWR Spent Fuel Dry Packaging System Pakistan

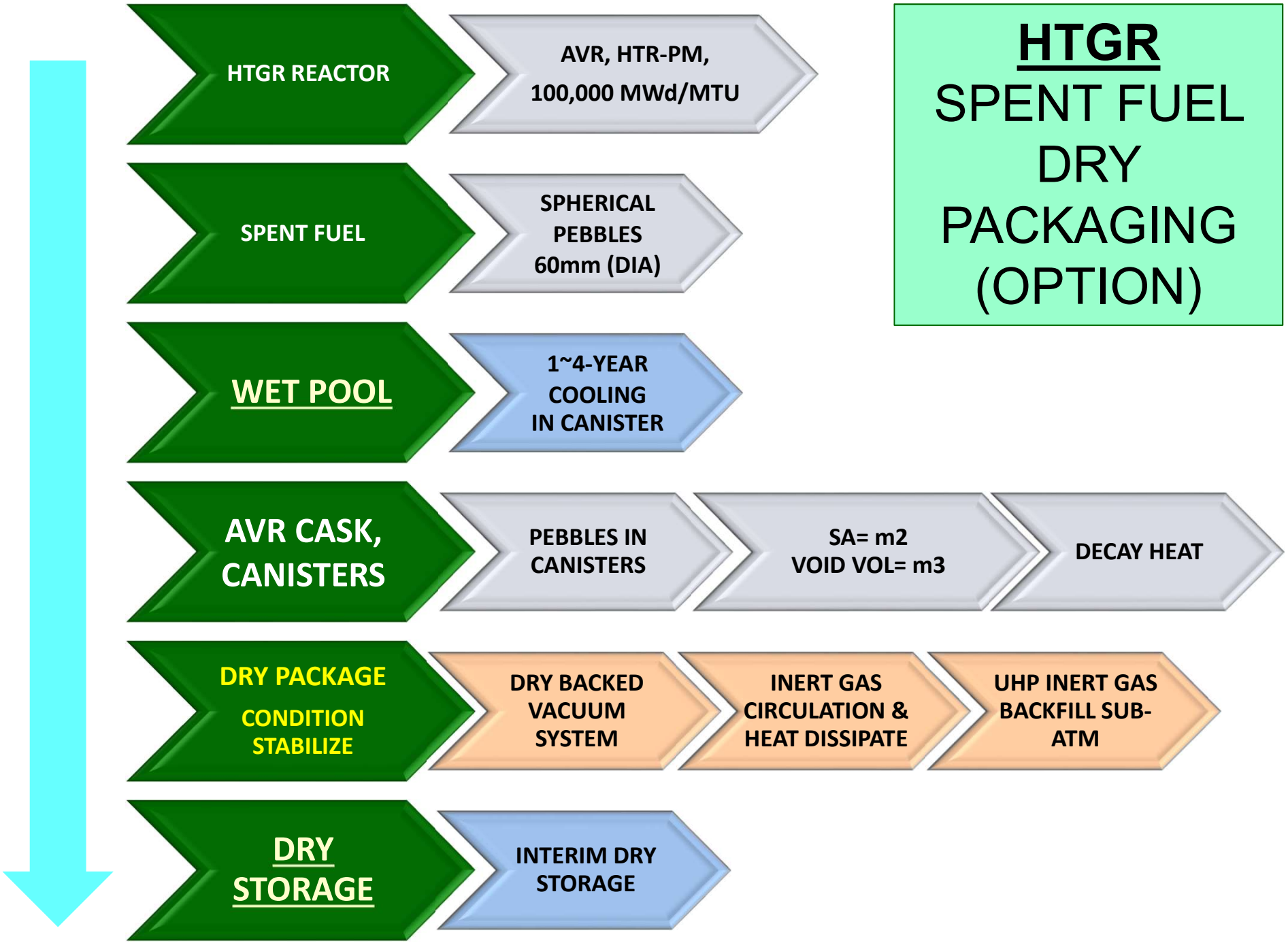


SCHEMATIC

Cond & Stabilization (Dry Packaging)

PWR Spent Fuels

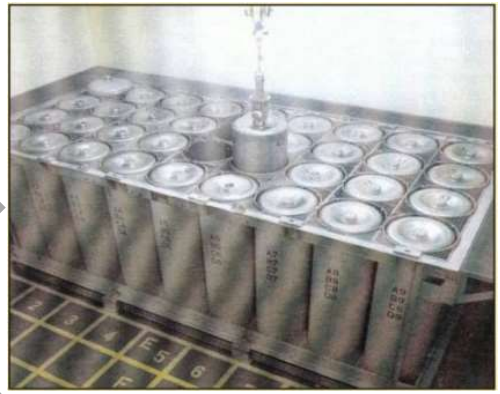



HTGR REACTOR
AVR, HTR-PM,
100,000 MWd/MTU
HTGR
SPENT FUEL DRY PACKAGING (OPTION)
SPENT FUEL
SPHERICAL
PEBBLES
60mm (DIA)
WET POOL
1~4-YEAR
COOLING
IN CANISTER
AVR CASK,
CANISTERS
PEBBLES IN
CANISTERS
SA= m2
VOID VOL= m3
DECAY HEAT
DRY PACKAGE
CONDITION
STABILIZE
DRY BACKED
VACUUM
SYSTEM
INERT GAS
CIRCULATION &
HEAT DISSIPATE
UHP INERT GAS
BACKFILL SUB-
ATM
DRY
STORAGE
INTERIM DRY
STORAGE

TRISO Spherical Pebble SNF Manage (Worldwide)

HTGR REACTOR

TRISO SPHERICAL PEBBLES



SS304 CANISTERS

DRY PACKAGING
CONDIONING
STABILIZATION
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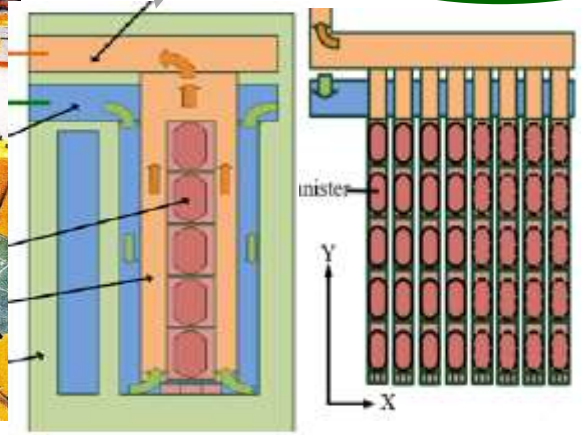
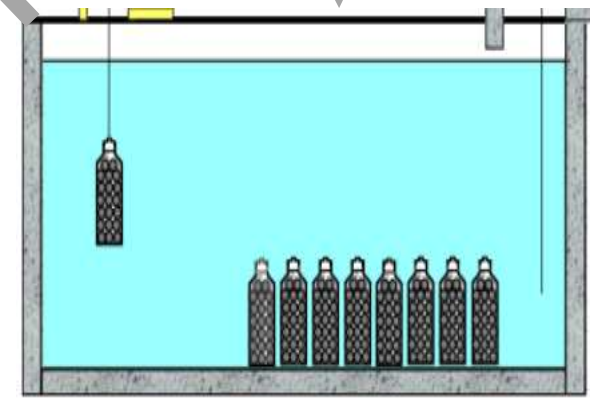
CASK DRY STORAGE

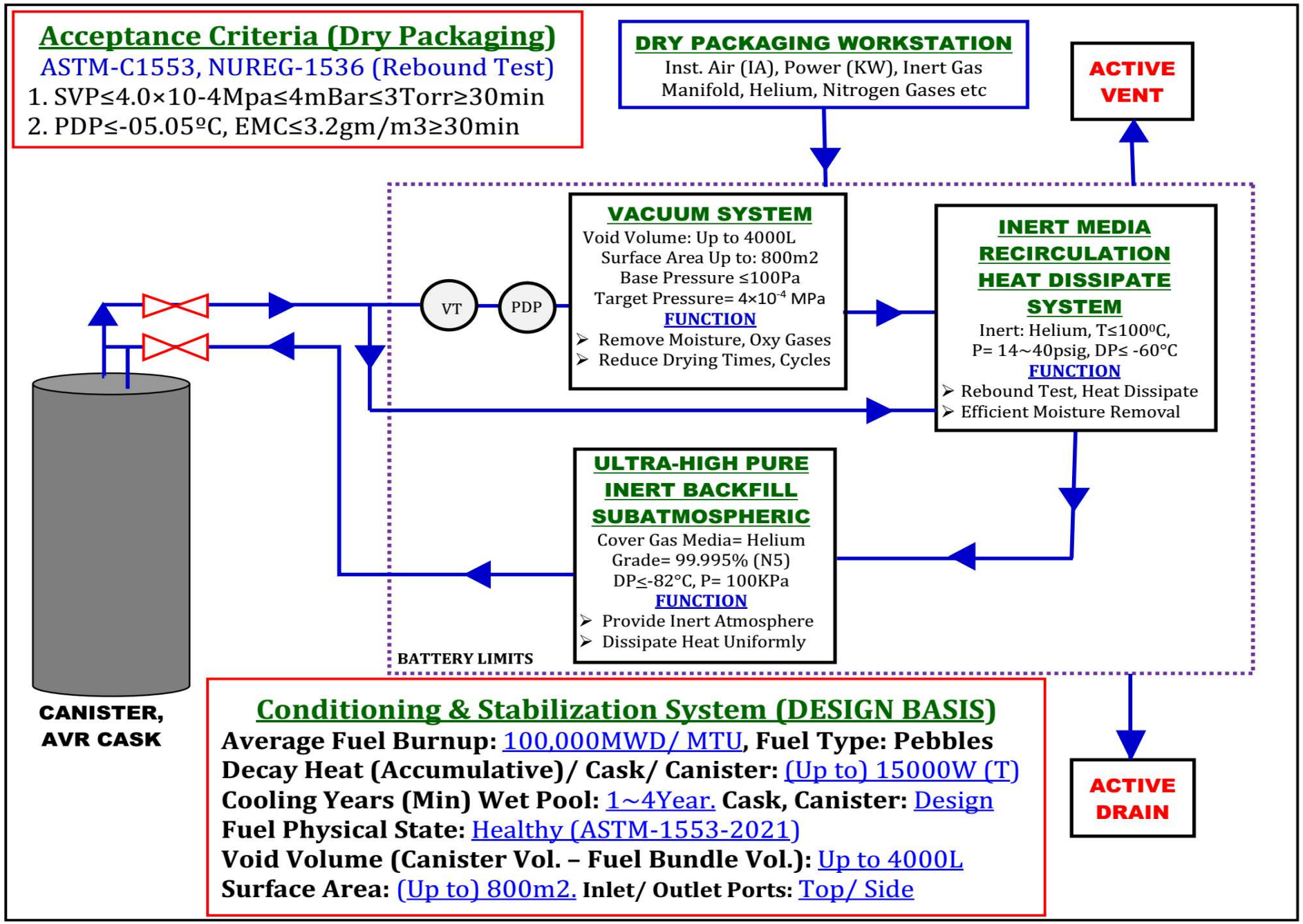


STORAGE WELLS (HTR-PM)



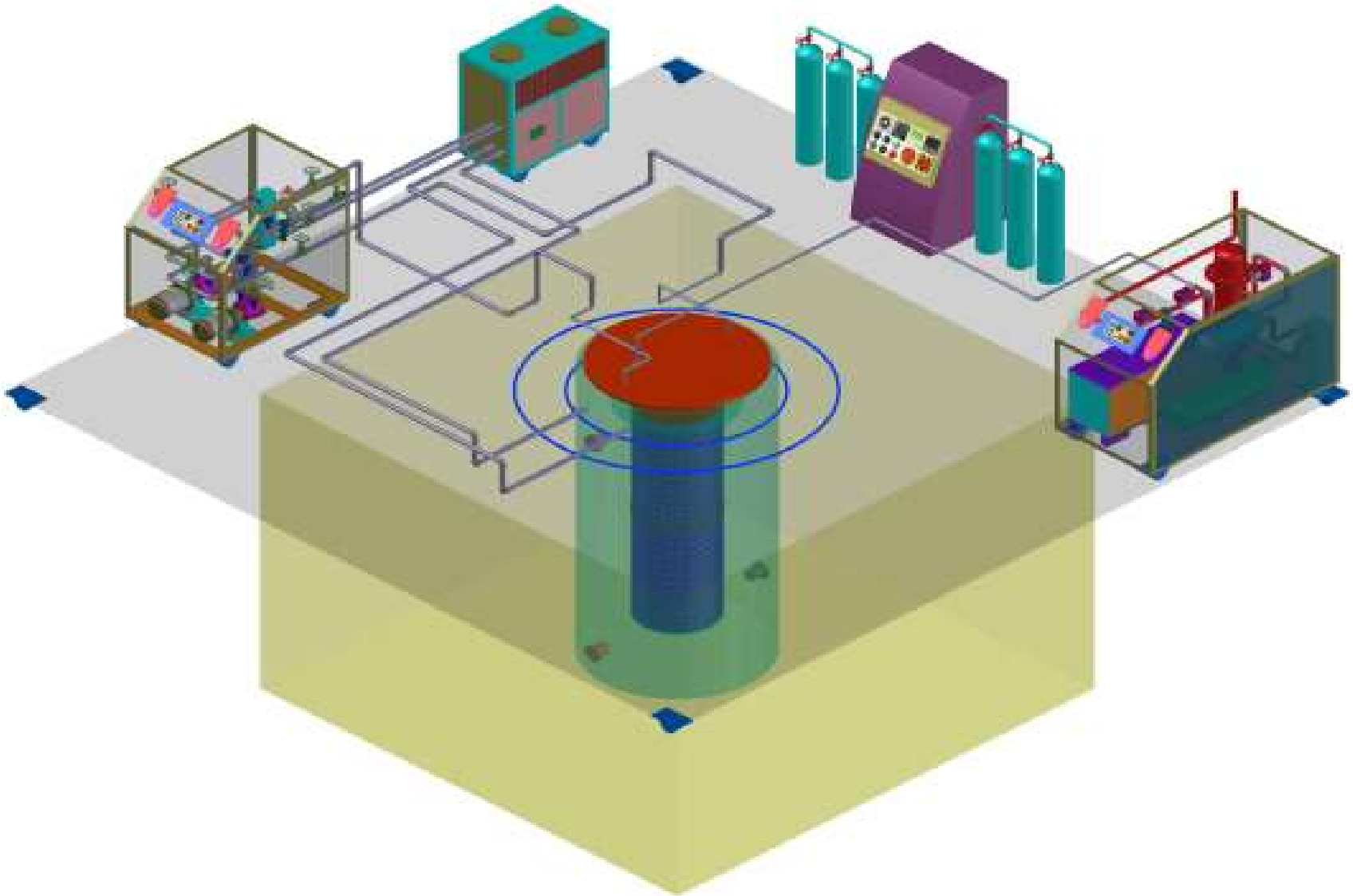
CANISTER WET STORAGE

HTGR Spent Fuel Dry Packaging System (Option)



SCHEMATIC

Canister Conditioning & Dry Packaging Option For TRISO Spent Fuel (Spherical Pebbles) of HTGR



Comparative Aspects

Dry Packaging of (PWR CASK SC21) & (CANDU CASK TC108) & Option For TRISO (HTGR)

Parameter to Consider	CANDU	PWR	HTGR
Fuel Burnup MWD/MTU	9000	37000	≥ *80,000
Decay Heat (W)/ CASK	**400**	**15,000**	**1.3 ~5W/ Element**
Cooling Year Wet Pool (Min)	**10**	**10**	**1~ 4**
Fuel State (ASTM-1553)	**Healthy**	**Healthy**	**Healthy**
Canister Void Volume VV (m3)	**0.250**	**4.0**	*
Interior Surface Area SA (m2)	**100**	**800**	*
In/ Out Ports (Orientation)	**Top/ Bottom**	**Top**	**Top/ Side**
Fuel Peak Cladding Temp. °C	**160**	**400**	**400**

* Comparison (Summary, Conclusion) Next

Comparison HTGR Spent Fuels (Pebbles)
(Canister, Cask, Decay Heat)

Reactor Dry Storage	Spherical Pebbles/ Canister	Decay Heat (KW/ Canister)	Decay Heat (W/ Element)
AVR	*950	7.3	3.8
HTR-PM	40,000	27	1.3
Xe-100	6,000	30	5.0

* AVR CASK (02 Canisters, Total: 1900 Spherical Pebbles)

SUMMARY, CONCLUSION

- *Canister Internal Conditioning & Stabilization System **(Dry Packaging) of PWR for SC21 CASK** (PDS Dry Storage Facility, CNPGS Chashma, With Some Modifications) Be Adopted for TRISO Spent Fuel of HTGR **Up To**
  - Canister Interiors & Spent Fuel Surface Area= **800m2**
  - Canister Void Vol.= **4m3**
  - Canister Decay Heat= **15000W**
- Compliance To Regulatory Requirement **ASTM-1553, NUREG-1536** For Dry Packaging of Spent Nuclear Fuels