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CONCEPTUAL DESIGN OF PUSPATI TRIGA REACTOR (RTP) SPENT FUEL STORAGE RACK

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ABSTARCT

PUSPATI TRIGA Reactor (RTP) is a pool type research reactor with 1MW thermal power. It has been safely operated since 28 June 1982. During 28 years of safe operation, there are several systems and components of the RTP that have been maintained, repaired, upgraded and replaced in order to maintain its function and safety conditions. RTP has been proposed to be upgraded so that optimum operation of RTP could be achieved as well as fulfill the future needs. Thus, competencies and technical capabilities were needed to design and develop the reactor system. In the meantime, there is system or component need to be maintained such as fuel elements. Since early operation, most of the fuel elements still can be used and none of the fuel elements was replaced or sent for reprocessing and final disposal. Towards the power upgrading, preparation of spent fuel storage is needed for temporary storing of the fuels discharged from the reactor core. The spent fuel storage rack will be located in the spent fuel pool to accommodate the spent fuels before it is send to reprocessing or final disposal. This paper proposes the conceptual design of the spent fuel storage rack. The output of this paper focused on the physical and engineering design of the spent fuel storage.

Keywords : Spent fuel storage rack ,Spent Fuel

ABSTRAK

Reaktor TRIGA PUSPATI (RTP) merupakan reaktor jenis kolam dengan kuasa 1-MW terma. Ia telah selamat dikendalikan semenjak 28 Jun 1982.Sepanjang kendalian selama 28 tahun, terdapat beberapa sistem dan komponen yang terdapat pada RTP telah diselenggara,dibaiki, dinaiktaraf dan juga ditukar bagi menjamin kefungsian dan keselamatan reaktor.RTP telah disyorkan untuk dinaiktaraf bagi mencapai keadaan kendalian yang optimum dan seterusnya memenuhi keperluan masa depan.Oleh itu, kompetensi dan keupayaan teknikal adalah diperlukan bagi merekabentuk dan membangunkan sistem reaktor yang baru.Dalam masa yang sama, terdapat juga beberapa sistem atau komponen yang perlu dikekalkan seperti elemen bahan api.Semenjak awal kendalian, kebanyakan elemen bahan api masih boleh terus digunakan dan tidak ada elemen bahan api yang ditukar atau dihantar untuk diproses semula dan pelupusan terakhir. Menuju ke arah menaiktaraf reaktor, penyedian tempat simpanan elemen bahan api terpakai untuk penyimpanan sementara elemen bahan api yang dikeluarkan dari teras reaktor.Tempat simpanan ini akan ditempatkan dalam kolam simpanan bahan api terpakai. Penulisan ini mencadangkan rekabentuk konsep rak penyimpanan bahan api terpakai . Penulisan ini memfokus kepada rekabentuk fizikal dan kejuruteraan rak penyimpanan bahan api terpakai.

Katakunci : Rak penyimpanan bahan api terpakai, Bahan api terpakai

INTRODUCTION

PUSPATI TRIGA Reactor (RTP) is the only research reactor in Malaysia.RTP, a pool type reactor with 1-MW thermal power was operated since 28 June 1982. RTP uses the TRIGA type fuel element supplied by General Atomic. RTP's fuel elements consist of 8.5 wt%, 12 wt% and 20 wt% with 20% enrichment. Figure 1 and Table 2 show the physical design of the RTP's fuel element and the characteristic of the RTP's Fuel Element taken from Safety Analysis Report respectively [1].

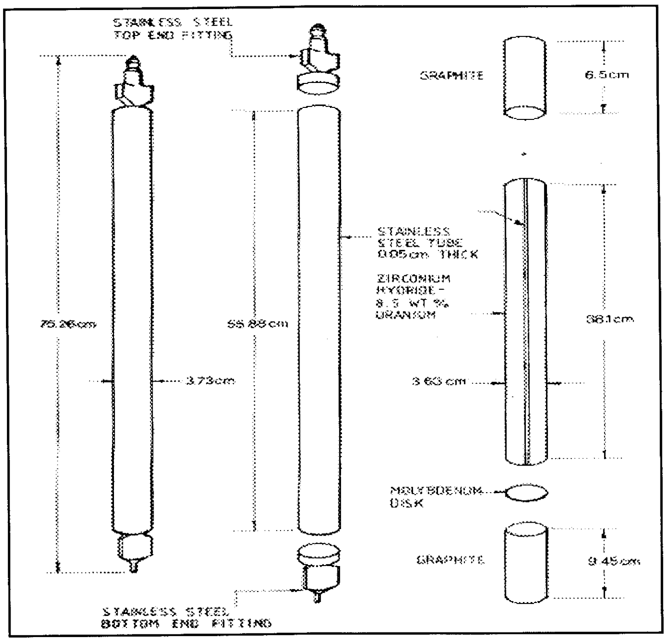

Figure 1: RTP's Fuel Element

There are 129 fuel elements available at RTP. Details of RTP's fuel elements properties and the characteristic of the RTP's Fuel Elements are tabulated in table 1 and table 2 correspondingly.

Table 1: Details of Reactor Fuel Element

Location	Enrichment	Wt %	Amount
Fresh fuel	20 %	8.5	4
		12	1
		20	1
Reactor Core		8.5	86
		12	16
		20	10
Irradiated fuel storage		8.5	8
		12	3
		20	-

Table 2: The Characteristic of the RTP Fuel Element

Parameter		Nominal value
Thickness, inch(cm)		
Fuel meat ($U\text{-}ZrH_{1.6}$)		1.43 (3.63)
Cladding (SS 304)		0.02 (0.051)
Cross section Area, inch2 (cm2)		
Water flow		0.83 (5.38)
Length, Inch (cm)		
Total fuel element		29.6 (75.26)
Active height (fuelled part)		15.0 (38.1)
Top graphite section		2.6 (6.5)
Bottom graphite section		3.7 (9.45)
Nominal U content		
Weight, g	8.5 wt%	190
	12 wt%	275
	20 wt%	495
U-235 content		
Enrichment, %		20
Weight, g	8.5 wt%	40
	12 wt%	55
	20 wt%	100

PROBLEMS STATEMENT

Since first criticality, nuclear fuel was undergo fission process and produce heat as well as fission products. Even after the reactor shutdown, the heat is still being produced by means of radioactive decay of fission product itself. The irradiated fuel elements were highly radioactive. Safety aspects were strictly applied during handling the irradiated fuels in order to avoid the radiation exposure and ensure the radiation level according to the ALARA principle.

In most research reactor, the spent fuels discharged from the reactor core were stored in the spent fuel pond for temporary storing. This allows dissipation and fission product decay. The spent fuels discharged from the reactor core needs to be secured in the safe storage before sent to reprocess or final disposal. Thus, spent fuel storage rack is the appropriate component to accommodate the spent fuels. It will be located and immersed in the spent fuel pond.

DESIGN OBJECTIVE

Towards the reactor power upgrading from 1-MW to 3-MW, the preparation to discharge and store spent fuels from the reactor core will be the crucial issue. Therefore, spent fuel storage rack was proposed to be designed to accommodate the discharged fuel elements. The proposed design was based on physical and engineering design only.

SPECIFIC DESIGN REQUIREMENTS

The IAEA Safety series No.116 [2] states that the wet storage of spent fuel should fulfill the specific design requirements;

i. **Subcriticality**

- *For those designs of wet storage facilities where pool water boiling during abnormal operating conditions is permitted, specific allowances shall be provided in the design evaluations for the change in water moderator density during such operational states and accident conditions*

ii. **Structure and layout**

- *The boundaries of the storage pool and other components important to the retention of the cooling water shall be designed to withstand operational states and accident conditions (and, in particular, impacts from collisions or dropped loads) without significant leakage of water.*

iii. **Radiation protection**

- *Wet storage facilities shall be designed to provide effective control of radioactive materials which may be released into the water medium.*

iv. **Heat removal**

- *Heat removal systems for spent fuel storage facilities shall be designed to ensure the safe operation of the facility. The primary concern shall be to ensure that no temperature limit set to protect the components, systems and the inventory from damage shall be exceeded. Thus, heat removal systems of wet storage facilities shall ensure that the bulk temperatures of the pool water remains within safe limits during normal operation and anticipated operational occurrences. Accordingly, the design should ensure that variations and rates in change of the temperatures of the pool medium and affected facility components can be maintained within acceptable limits during operations, as identified and specified during the design process.*

v. **Material**

- *The materials of the storage rack shall be compatible with the pool water or shall be effectively protected against undue degradation or corrosion. The storage racks or containers shall not contaminate the pool water. Ease of decontamination of equipment* *exposed or in contact with pool water is related to the surface condition and properties of the materials of component fabrication. The designer shall consider the requirements for decontamination when specifying the materials for such equipment.*

vi. **Handling**

- *Hollow handling tools intended for use under water should be designed so that they fill with water upon submergence (to maintain water shielding) and drain upon removal. Over-raising of fuel or other components shall be prevented by incorporating interlocks designed to inhibit hoist motion in the event that high radiation fields are detected.*

DESIGN CRITERIA

The design of the spent fuel storage rack includes engineering and safety design to ensure the design is reliable, practical and safe. Therefore, some criteria such as dimension, shape, material and capacity were taken into consideration when designing the rack. Table 3 shows the proposed design criteria of the spent fuel storage racks.

Table 3: Proposed design criteria of spent fuel storage rack

Criteria	Design 1	Design 2	Design 3
Type	Rectangular (Closed)	Rectangular (Opened)	Rectangular (Channel)
Physical Dimension (L x W x H)	(72 X 72 X 73) cm	(72 X 72 X 73) cm	(72 X 72 X 73) cm
Material	Stainless steel	Stainless steel	Stainless steel
Fuel distance (center to center)	10 cm	10 cm	10 cm
Capacity	49 fuels	49 fuels	49 fuels
Fabrication	Moderate	Easy	Difficult
Water sampling	Average inside the rack	Pool average	By Channel

From the Table 3, three designs were proposed with the same dimension, material, fuel distance and capacity. The option to choose the stainless steel as the material is due to the advantages on mechanical properties especially for strength for the high temperature environment. Table 4 shows the mechanical properties of stainless steel [5] and Figure 2 shows the strength of Type-304 Stainless Steel as a function of temperature [1].

Table 4 : Mechanical Properties of Stainless Steel 304

Mechanical Properties of Stainless Steel 304	
Hardness, Brinell	123
Hardness, Knoop	138
Hardness, Rockwell B	70
Hardness, Vickers	129
Tensile Strength, Ultimate	505 MPa
Tensile Strength, Yield	215 MPa
Elongation at Break	70 %
Modulus of Elasticity	193 - 200 GPa
Poisson's Ratio	0.29
Charpy Impact	325 J
Shear Modulus	86 GPa

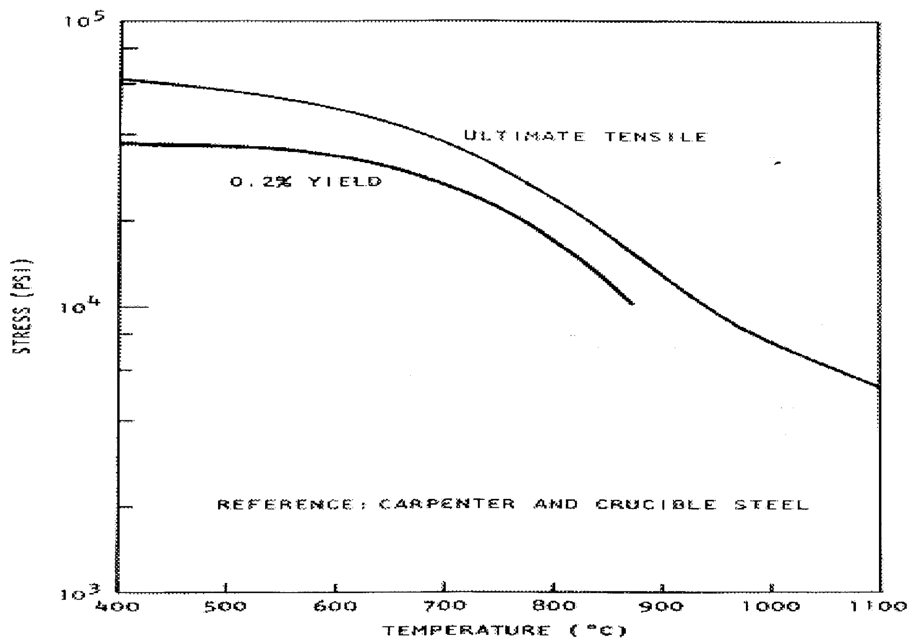

Figure 2: Strength of Type-304 Stainless Steel as a function of temperature

Each rack capable to accommodate 49 spent fuel elements. Three racks were needed to store all 129 spent fuels and assume that the entire fuel elements were discharged from the reactor core. The distance between the centers of fuel elements is 100 mm as criticality consideration.

However, the designs were different in the fabrication consideration which Design 2 wills contributes the simplest process during fabrication. The rectangular (channel) shape was proposed which is benefit to allow and simplify the water sampling in each channel in the rack especially when undesired leakage occurs in the spent fuel element. This will assist to detect which of the fuel element is leaking. Besides, radioactive decay of the fission product in the spent fuel will produced heat. The coolant flow was required to remove the generated heat. In order to allow the coolant flow through the channel, the design of the top and the bottom plates were refer to the design of the top and bottom grid plate of the reactor core. Figure 3a to 5b shows the details of proposed design of the rack while Figure 6 to 11 shows the design details.

PHYSICAL AND ENGINEERING DESIGN OF PROPOSED SPENT FUEL STORAGE RACK

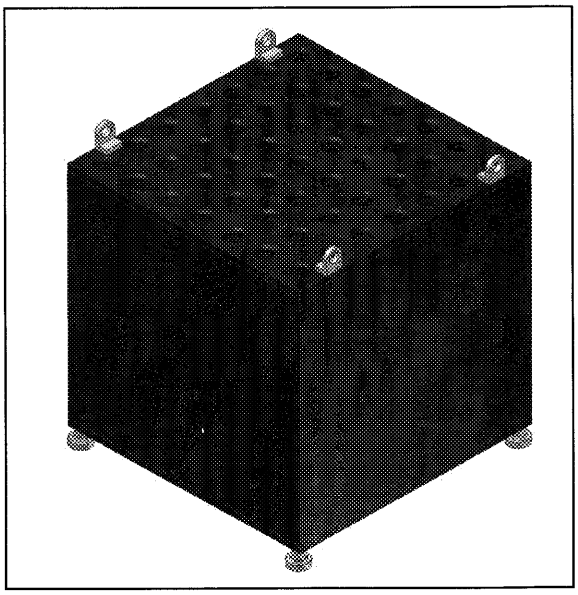

Figure 3a: Design 1

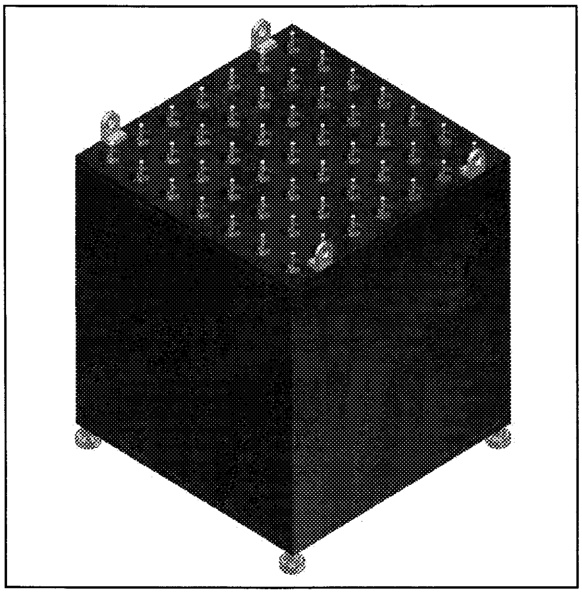

Figure 3b: Design 1 (with fuels)

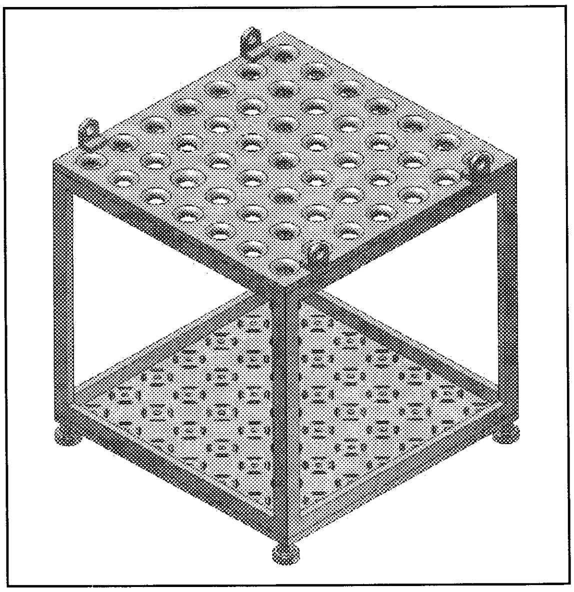

Figure 4a: Design 2

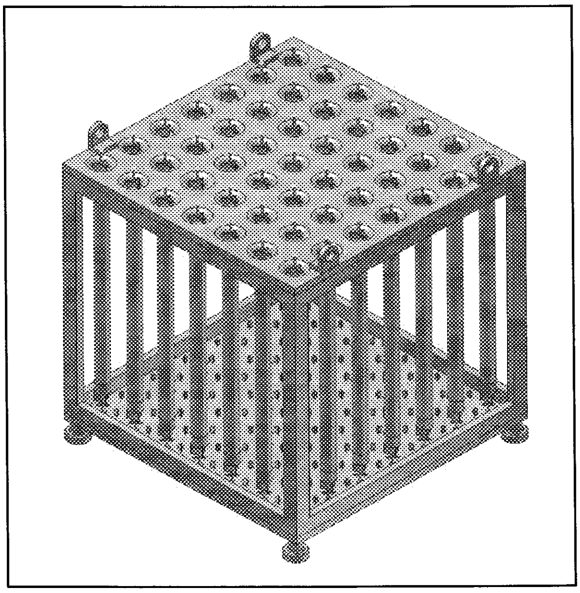

Figure 4b: Design 2 (with fuels)

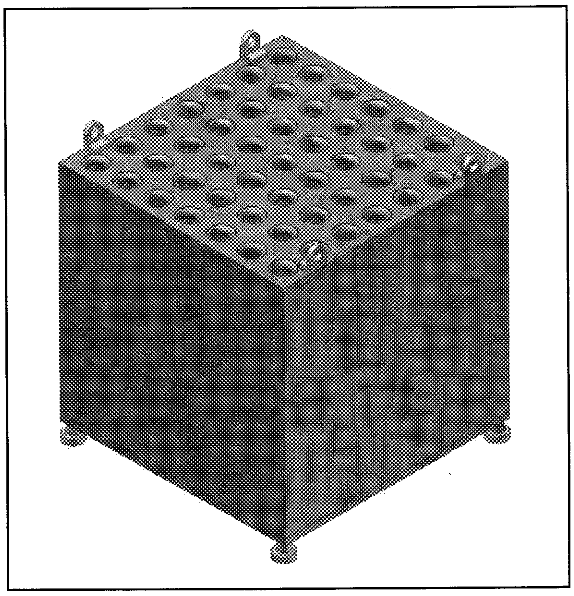

Figure 5a: Design 3

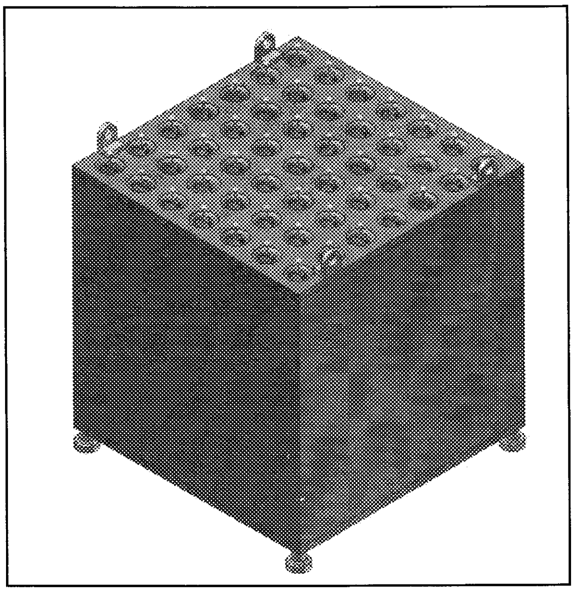

Figure 5b: Design 3 (with fuels)

DESIGN DETAILS

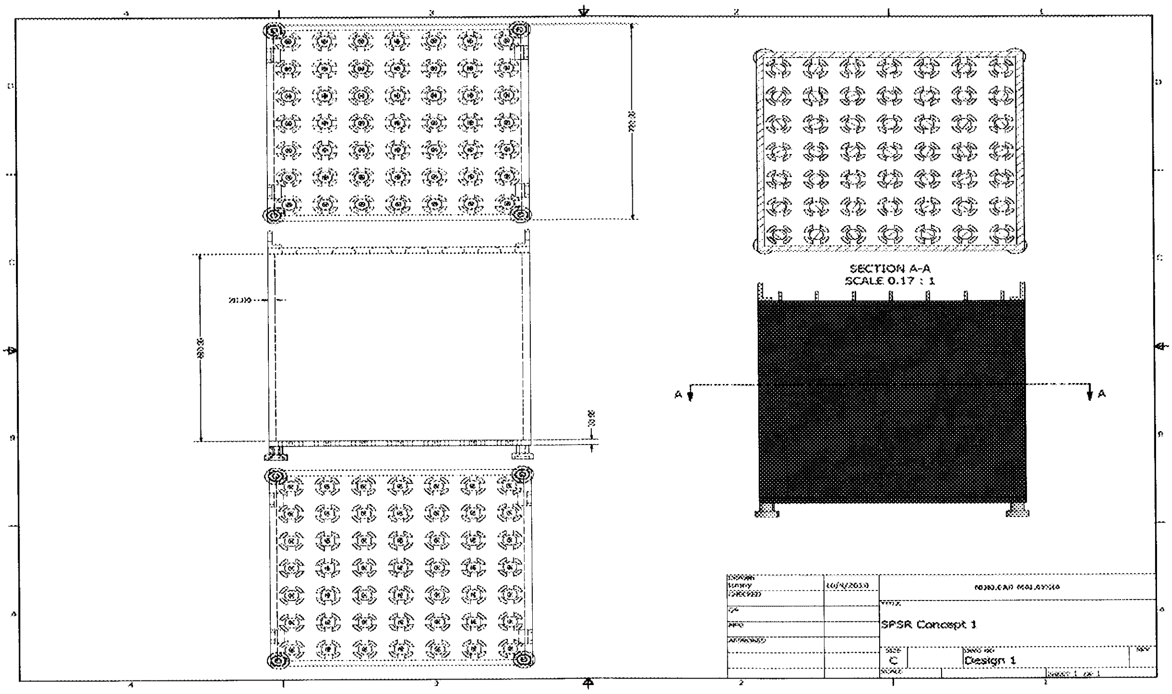

Figure 6: Details of Design 1

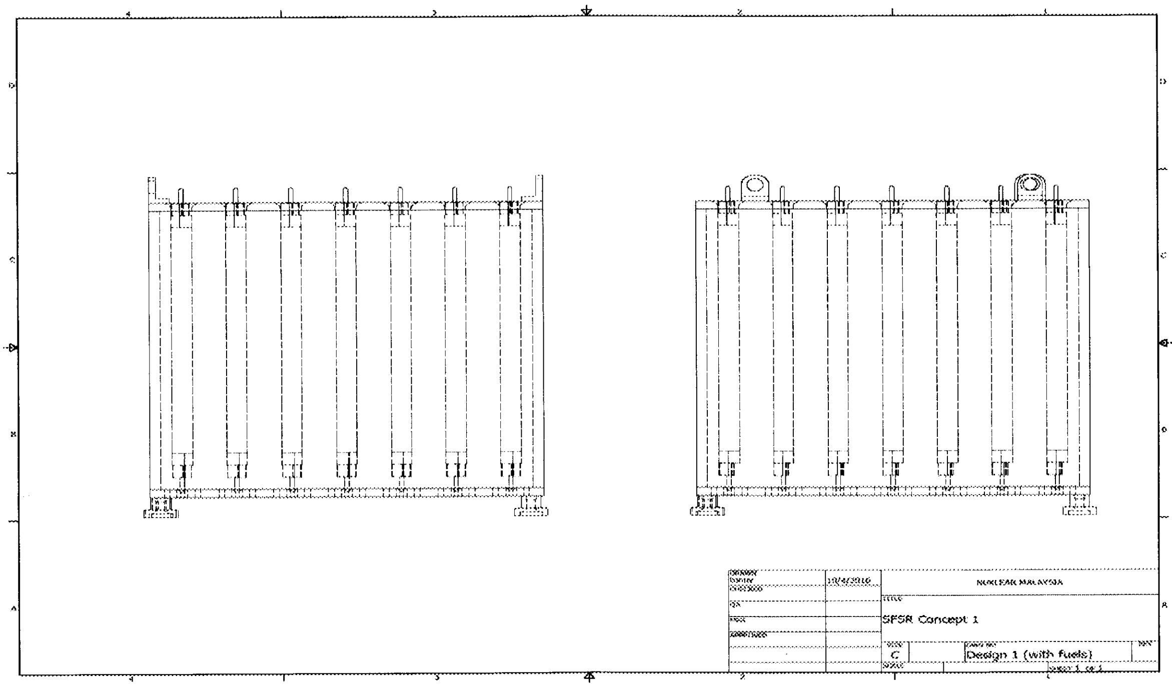

Figure 7: Details of Design 1(with fuels)

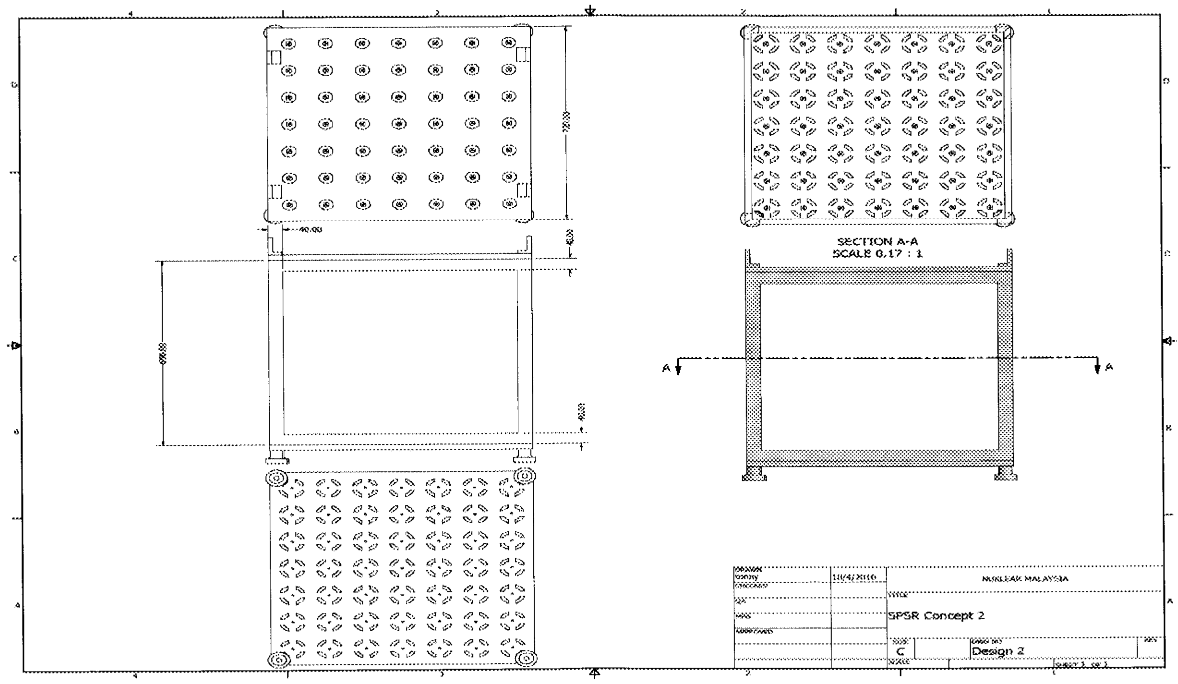

Figure 8: Details of Design 2

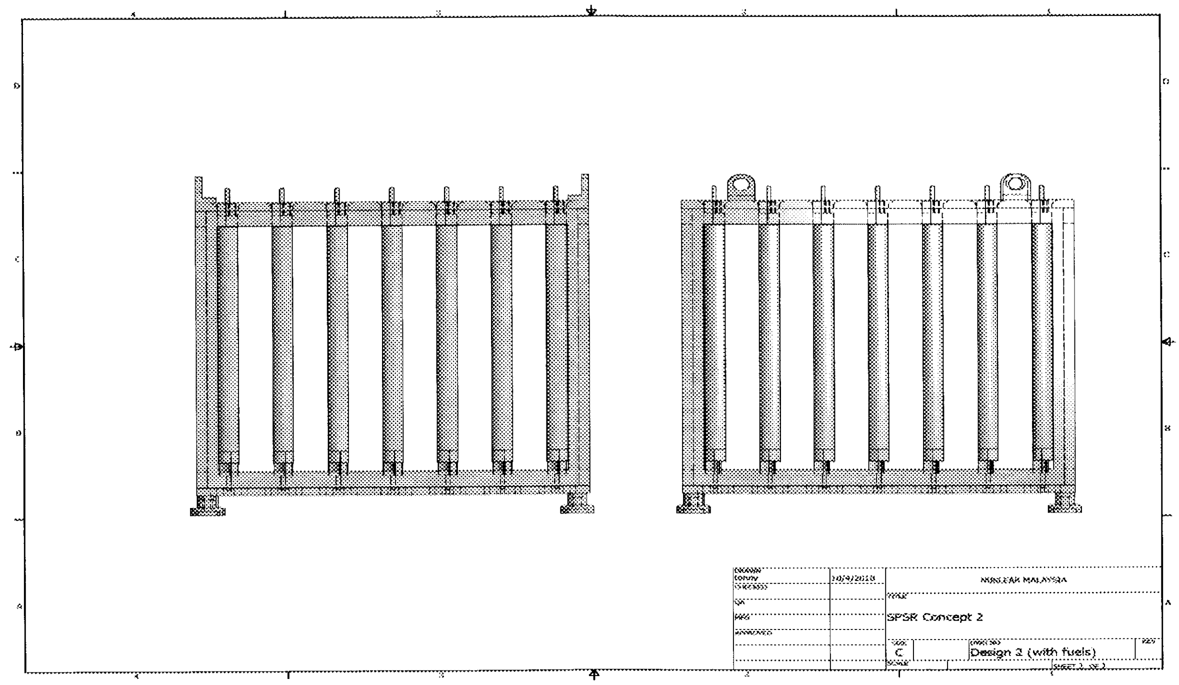

Figure 9: Details of Design 2 (with fuel)

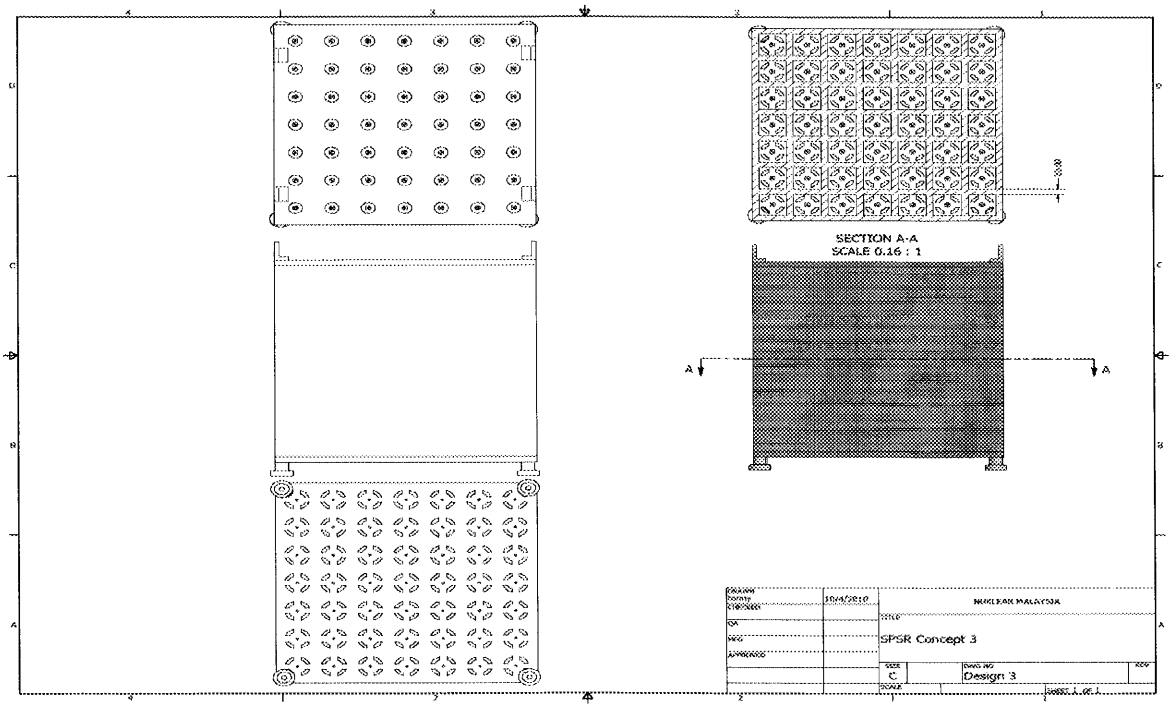

Figure 10: Details of Design 3

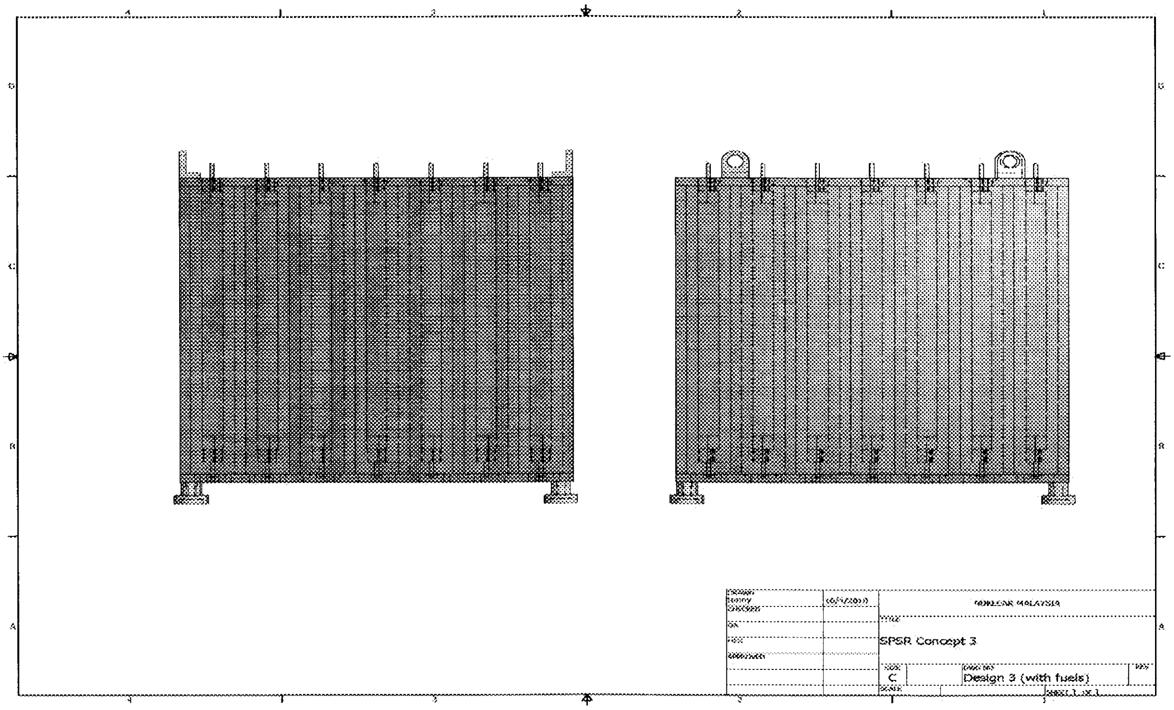

Figure 11: Details of Design 3 (with fuels)

CONCLUSION

The proposed conceptual designs of spent fuel storage rack for the RTP was successfully done. Three designs of storage racks with dimension 720 mm x 720 mm x 730 mm were proposed to accommodate 129 fuel elements. The selected material is stainless steel. The selection of the final design will be after the further analysis on the design including engineering, thermalhydraulic and neutronic analysis.

RECOMMENDATION

This design is still in review. Therefore, to improve the design some analysis should be done such as stress analysis, coolant flow analysis, thermal hydraulic analysis and neutronic analysis. The costs of the fabrication also need to be considered to determine the affordable design.

ACKNOWLEGMENT

I would like to appraise my special thanks to all collogues that involve directly or indirectly in completing this paper. All the information, comments and advices given were appreciated.

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