General Description and Production Lines Of The Egyptian Fuel Manufacturing Pilot Plant

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ABSTRACT

The Egyptian Fuel Manufacturing Pilot Plant, FMPP, is a new facility, producing an MTR-type fuel elements required for the Egyptian Second Research Reactor, ETRR-2, as well as other plates or elements for an external clients with the same type and enrichment percent or lower, (LEU). General description is presented. The production lines in FMPP, which begin from uranium hexaflouride (UF_6, 19.7±0.2 % U^{235} by wt), aluminum powder , and nuclear grade 6061 aluminium alloy in sheets, bars, and rods with the different heat treatments and dimensions as a raw materials, are processed through a series of the manufacturing, inspection, and quality control plan to produce the final specified MTR-type fuel elements. All these processes and the product control in each step are presented. The specifications of the final product are presented.

1. INTRODUCTION

The Egyptian Fuel Manufacturing Pilot Plant, FMPP, is an installation for MTR-type fuel elements production enriched to 20%, to be used in operation of ETRR-2 reactor. MTR-type fuel elements manufacturing involves managing and organizing very different technological activities.

The FMPP plant has been conceived integrally regarding production, this means it comprises all activities for obtaining MTR-type fuel elements from UF_6 and aluminum consumables. All these activities require specific spaces with constructive characteristics defined by the type of processes that take place in them. The areas must be linked by a corridors system, which allows an optimized flow of persons and materials and ensures an appropriate physical and radiological control of the productive activities.

Given the quality requirements of this type of manufacturing, it is necessary for productive activities to be developed in very good cleanness conditions and under strict quality control. It must also be born in mind that this is an installation where fissile materials are processed, with all the radiological, nuclear, conventional and physical safety this implies for workers and environment protection.

The plant has been designed and built by INVAP SE, with cooperation both the Argentine Atomic Energy Commission (CNEA), and Atomic Energy Authority of Egypt (AEA).

The FMPP project started in 1995, different commissioning stages were applied, beginning with plant systems pre-operational tests in 1997, integrated performance tests, process qualifications, training with natural uranium, and finally a complete production with low enriched uranium (19.75 %) on December, 1998.

2. PRODUCTION CAPACITY

The nominal production capacity is 40 fuel elements per year with a total content of U at about 20 % of 2054 grams each. The estimated annual working time is 220 days, in two - 8 hrs - shifts.

3. GENERAL DESCRIPTION

The building is divided into four sectors, each one with specific environmental characteristics and working conditions. All penetrations, ducts and pipes that are sealed continuation of the containment fulfill the same safety requirements of the containment system. As the following:

Sector I
Area A – Administration
Area B – dining room

Sector II
Area C – Locker rooms
Area D – General services

Sector III
Area E – Metrology
Area F – Laboratories
Area G – Fuel elements manufacturing
Area H – Powders manufacturing and core compact manufacturing

Sector IV
Area I – Maintenance
Area J – Services

The powder, fuel core compact, and preplate manufacturing, is the area with the highest risk regarding radioactive material handing. Special care is therefore necessary regarding closing and ventilation. Epoxy paint shall be used for floor and walls, so as to make eventual decontamination easier. The plates and assembly area has similar though less strict requirements and construction is therefore conventional.

All fissile material storerooms are inside the plant. A different room is defined for storing each of the fissile materials on the basis of their physical – chemical forms, moderation and packing in each process stage: UF_6, solutions, powders, and core compact, preplates, plate, fuel elements.

In case of any emergency situation, the maximum distance from any place in the plant to the nearest emergency exit is less than 20 m. The safety doors, which must not be used daily, must open towards the outside with fast opening mechanisms. Low fire load materials are used in operative sectors.

<u>Process Area Definition</u>

The following is another way to define the plant by relating the activities to be performed to the architecture requirements. By observing the manufacturing flow sheet and considering the remaining supporting activities the plant requires for operation it is possible to define conceptually the tasks areas the plant have:

1. Administration
2. Non technological services
3. Physical – chemical, metallographic, and metrologic control services
4. Powders and compacts manufacturing area
5. Mechanical shaping area
6. Fuel plates manufacturing and assembly area
7. Maintenance and auxiliary services

Controlled Zone is the area in which powders, compacts, and preplate are produced in this area a radiological safety program is conduced, including areas and sector workers monitoring as in the code of practices, which is controls the working with radioactive material in all the plant.

Supervised Zone is the area in which fuel plates and final elements assembly are produced, also Physical – chemical laboratory. In this area a radiological safety program is conduced, including only areas monitoring as in the code of practices.

4. GENERAL DESIGN CRITERIA

- The building has been designed and builded to protect FMPP systems, equipment, and structures from external events originated by human activities and natural phenomena.
- The installation has been builded to protect the environment from chemical and radioactive contamination.
- The installation has been builded to fulfill the nuclear criticality safety principles
- The productive areas are separated from the non-productive ones.
- The processes areas with radiological risk are separated from the process areas without that risk to provide radiological safety for workers and environment.
- The areas with radiological risk are differenciated and sorted out physically and operatively according to the basis of their hazard degree.
- The equipment has been designed intrinsically criticality safe as much as it has been compatible with the process operation requirements. Strict and

redundant administrative controls have been defined where the save design has nor been possible.

- Those zones of the FMPP where radiological risks exist are kept at pressure depression relative to the atmospheric value as a barrier to protect the environment.
- The air in the different process areas is treated in order to protect the environment.
- The radiological and chemical liquids generated in the installation are handled in different lines.
- The movement of all person in the installation is controlled.
- The decontamination devices are included.
- Elements for persons for decontamination are provided.

5. PRODUCTION LINES

The production lines are deviled as the following lines:

1. Powder Conversion Line
2. Compact and Preplate Manufacturing Line
3. Fuel Plates Manufacturing and Fuel Element Assembly Line
4. Structural Components Manufacturing Line

5.1. Powder Conversion Line

The purpose of this line is to obtain the U_3O_8 powder from UF_6.

Design Criteria

Due to the enrichment used, the using of water solutions that might act as moderators and UF_6 handling, the sector layout was ruled by nuclear and conventional safety conditions and they include equipment sizes, controls, operating procedures, batch sizes as well as physical barriers introduced to avoid any kind of incidents.

According to the kind of manipulated material, this sector was divided in two sections:

- ***Section1 Precipitation:*** The obtained of ammonium diurinate, ADU, from UF_6 through a wet process.
- ***Section2* calcination:** from ADU, specified U_3O_8 is obtained by means of calcination and sizing operation.

Process Description

- ***Evaporation:*** TheUF$_6$ is solid at room temperature must be heated over its liquefaction point to increase its vapor pressure.
- ***Hydrolysis:*** when the gaseous UF_6 is added to the water in a closed agitated vessel a solution of uranyl fluoride and hydrofluoric acid is formed :

$$UF_6\,(v) + 2H_2O\,(l) \rightarrow UO_2F_2\,(sol.) + 4HF(sol.)$$

- ***Precipitation and Filtration of ADU*:** Precipitate the solution of F2UO2, obtained during the process of hydrolysis by addition of ammonia solution 25% in special condition of temperature and flow rate of ammonia solution, according this reaction:

$$2UO_2F_2 + 6\,NH_4OH \rightarrow (NH_4)2U_2O_7(solid) + 4NH_4F(sol.) + 3H_2O$$

Filtration of the ADU in suspension, washed with ammonia solution 1%, and dried with alcohol in order to obtain the final ADU.

- ***U_3O_8Transformation:*** The ADU obtained is calcinated at 800 ^oC to U_3O_8 in an oxidant atmosphere. The product is then milled, the bigger particles broken and smaller agglomerated. After wards it is sized between 44 and 150 microns.
- ***Grain growth:*** A treatment at 1400^{o}C is made to obtain the high density U_3O_8 required. Subsequently the material is treated in a mortar, milled and sieved keeping the particles between 44 and 90 microns obtaining the desired product.

Description of the Sector

- ***Ventilation and glove boxes system***

⇒Section 1. Precipitation

The UF_6 reacts with moisture in air forming a white fog which consists of hydrofluoric acid and uranyl fluoride, which are both highly toxic and corrosive, the last also being radioactive contamination. With the purpose of preventing the contaimaintion of the personal in case of UF_6 release, all the equipment of this section are located inside a glove box which is under atmospheric pressure.

The gaseous material released is extracted through scrubbers (scrubber's spry towers) and highly efficient particle air filter (HEPA).

⇒**Section 2 Calcination**

Due to the manipulation with dusty materials, the operations are made in three interconnected glove boxes under depression, the extracted air runs through HEAP filter.

U_3O_8 Powder control

1. Uranium content: must be above 84.5% according to specification.
2. Impurities content: should be equal or lower as the specified limit.
3. Particle size distribution.
4. Density: should be above lower limit of 8,0 g/cm3.
5. Stochiometric Ratio: should be within the specified limits.

5.2. Compact and Preplate Manufacturing Line

The objective and scope of the present line is the fuel core compact for the FMPP fuel plate manufacturing, MTR-type fuel elements. According to the kind of manipulated material, this line was divided in two sections:

⇒**Section 1 Compact Manufacturing**

⇒**Section2: Preplate Assembly and Welding**

Compact Manufacturing Section

The process consists of weighting the quantities of the U_3O_8 powder and Al powder, which is 48%by volume of U_3O_8, mixing both powders, pressing by 4.5 Ton /cm^2, cleaning, and quality control of the fuel core compacts.

Product Control

Dimensional control of fuel core compact
According to drawings:
100 % control

Weight: 171.6 (+/- 1,5 g). Calculated on the base of 19,7±0.2% U^{235} enrichment.

Length a = 69,0 + 0 /- 0,3 mm

Width b = 60,5 + 0 /- 0,3 mm

Thickness t = 8,50 ± 0,2 mm

Flatness and Squareness shall be within dimension tolerances of drawing.

Preplate Assembly and Welding Section

The objective and scope of the present process is the assembled of tow covers, Frame, and core compact and the welding of the assembled fuel pre plates, previous to the fuel plate rolling, which will be used in the manufacturing of the MTR-type fuel elements.

5.3. Fuel Plates Manufacturing and Fuel Element Assembly Line

Fuel Plates Manufacturing Section

The process consists of heating up the preplates welded assemblies, hot roll, trim the ends, heat treatment, blister test, and cold rolling. After that X-ray is done to make the cutting of fuel plate according to the radiographs and fuel plate drawing. There are two type of fuel plate, outer fuel plate and inner fuel plate, these types are the same of uranium total content and the length of the meat, but the deference are in the length and window in the outer fuel plate.

Fuel Plate Control

1. Dimensional control: Thickness, core length 100 % control
2. Geometry control: straightness
3. Visual aspect of fuel plates: Surface defects, Marking shall be clearly visible
4. Fuel core homogeneity by X ray

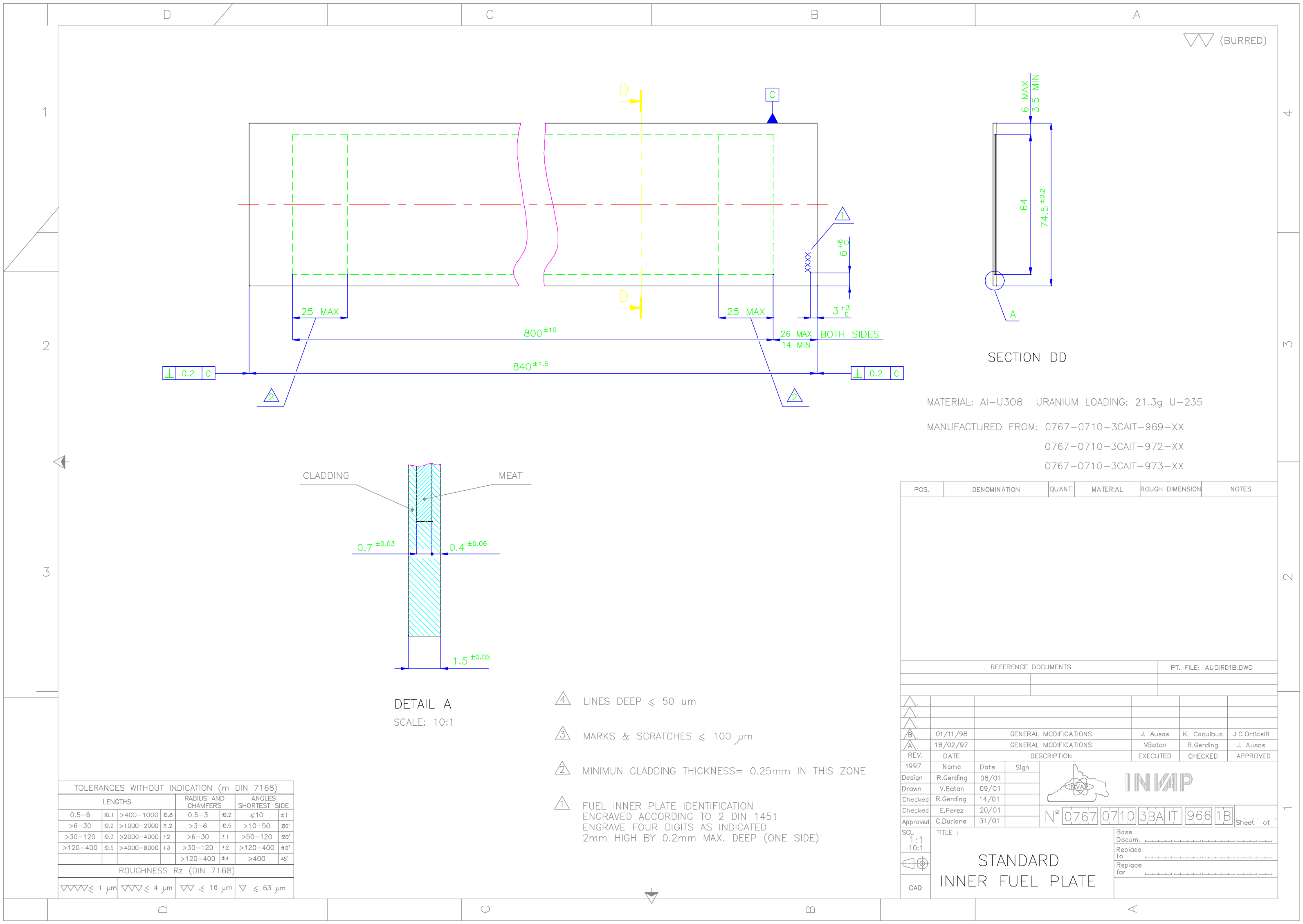
Fuel Plate Specifications

Fuel meat thickness	0.70 mm
Fuel meat width	64.5 mm
Fuel meat length	800 mm
Plate thickness	1.5 mm
U^{235} content per plate	21.3 g
Cladding thickness	0.40 mm
Cladding material	6061 Al alloy

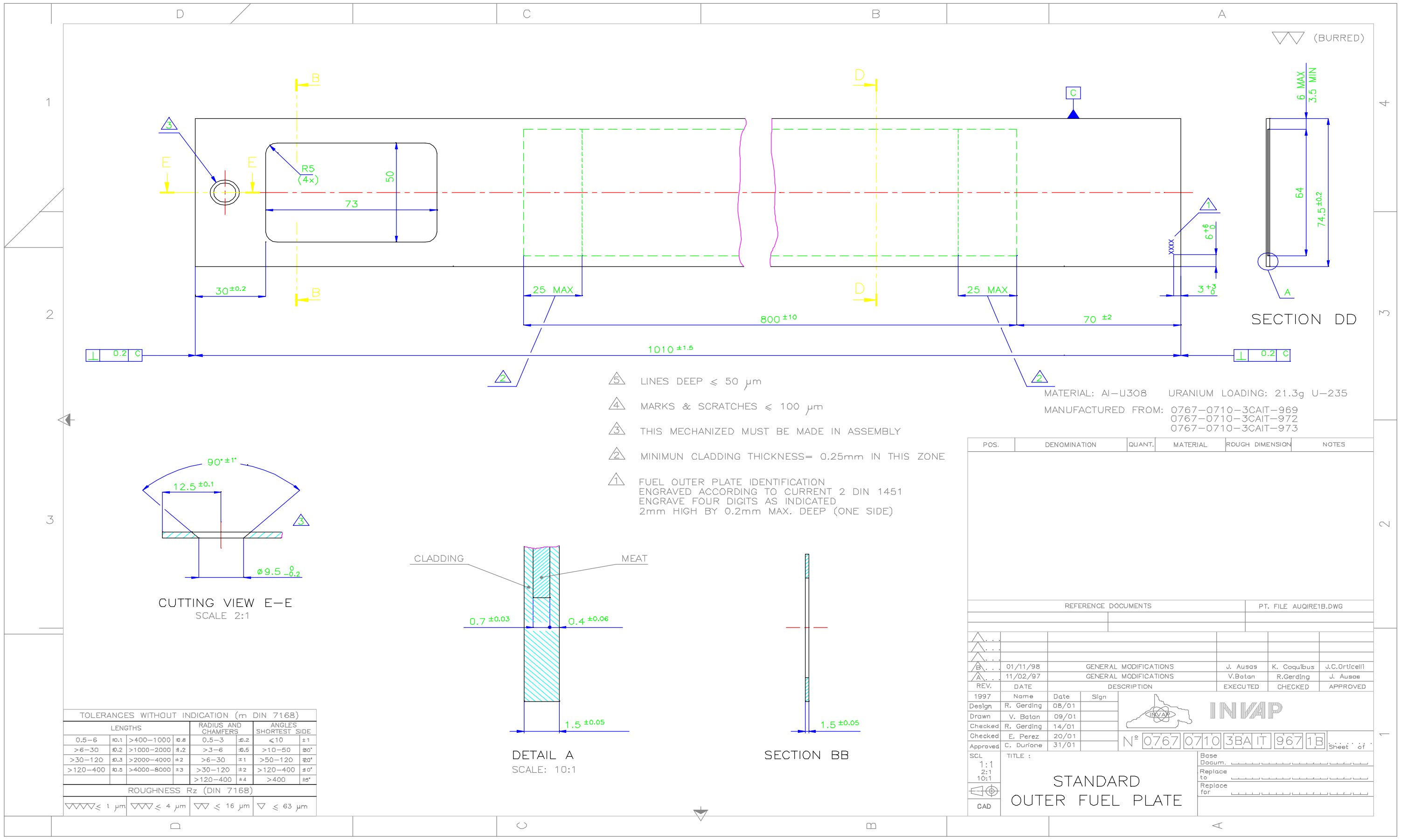
See the attached drawing for inner and outer fuel plate.

Fuel Element Assembly Section

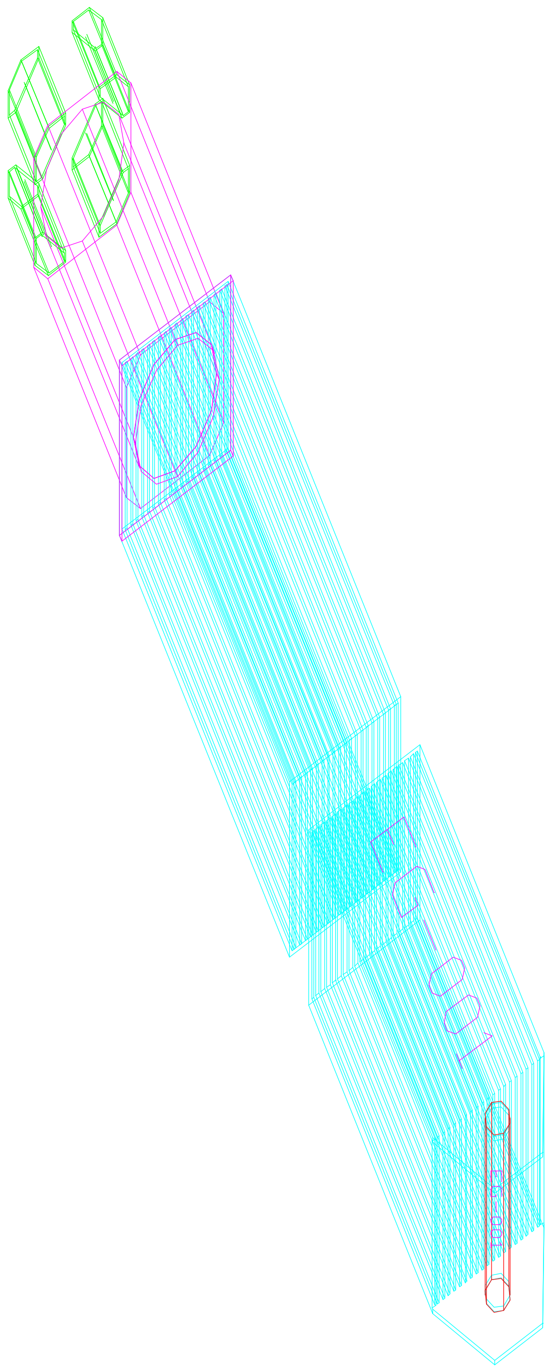
The process consists of assembling the components to the finished Fuel Element



Inner Fuel Plate



Outer Fuel Plate



View of Fuel Element Assembly

Assembly, mainly with a milling machine by a roll of swaging technique.

Fuel Element Components

1. 2 Side plates with FE-Identification Code
2. 17 Inner Fuel Plates
3. 2 Outer Fuel Plates
4. 1 End Box
5. 6 Screws M6 x 9
6. 1 Handling pin, with FE-Identification Code

Fuel Element Assembly Control

1. Dimensional, geometrical and visual control of the fuel element assembly is performed according to the Quality Control.
2. Visual aspect of fuel element assembly: assure that no surface defects are present.
3. Fuel element assembly should be clean, without scratches or other surface defects.
4. Identification markings on Side plates, handling pin and fuel plates shall be clearly visible.

Surface Treatment of Structure Components Section

The produced fuel plates, as well as, the structural Al-6061 components are passed through different steps in order to remove the lubricants, oils, greases, or any other materials, and the oxide film which may attack the aluminium on the surface, as follows:

1- cleaning with TCDE (tricloro diethylene)
2- pickling in an alkaline hot NAOH solution
3- washing with normal water
4- neutralization by cold HNO_3
5- washing with normal water
6- final washing with hot demineralized water
7- repeating, if necessary, from step 3, one or two times
8- drying in air stove

5.4. Structural Components Manufacturing Line

The Egyptian Fuel Manufacturing Pilot Plant has work shop which have computerized machines which able to machining any shape of metals. In this line, are beginning with nuclear grade 6061 aluminium alloy in sheets, bars, and rods with the different heat treatments and dimensions as a raw materials to manufacture these components as the following:

1. Side plates with FE-Identification Code
2. End Box
3. Screws M6 x 9
4. Handling pin, with FE-Identification Code
5. Cover
6. Frame

After all quality control steps of these components, transfer to Fuel Plate manufacturing and Fuel Element Assembly Line to be used in manufacturing of fuel plates and assembling of the fuel elements after surface treatment.

6. FUEL ELEMENT ASSEMBLY SPECIFICATION

In FMPP aluminium base U_3O_8 dispersion was used as meat of fuel material. FMPP is able to produce different types of MTR-type fuel elements, as the following:

Standard Fuel Element

For using as a fuel for the Egyptian second research reactor (ETRR2) with the following specification:

Number of plates	19 (17inner plates and 2 outer plates)
Fuel meat thickness	0.70 mm
Fuel meat width	64.5 mm
Fuel meat length	800 mm
Plate thickness	1.5 mm
Coolant channel	2.7 mm
U^{235} content per plate	21.3 g
Cladding material	6061 Al alloy
Square section	80*80 mm

Requested fuel elements

FMPP can produce plates and fuel elements, as the following:

Flat plates
All cross-section geometries
With enrichments< 20% U^{235}

See the attached drawing for view of fuel element assembly.

7. QUALITY ASSURANCE SECTOR

FMPP has especial laboratories which have especial equipment and devices for quality control, verify, and ensure the specifications of all products which produced inside the plant (U_3O_8 powder, fuel core compact, …etc.), as well as the raw materials which coming from out side the plant (aluminum powder, nuclear grade 6061 aluminium alloy, …etc.). All the quality control tasks take place inside the plant.

8. CONCLUSION

- The Egyptian Fuel Manufacturing Pilot Plant is a new MTR-type fuel element facility. It produces the required fuel assemblies for the Egyptian Second Research Reactor, ETRR-2.
- FMPP passed all the above mentioned commissioning steps for produce the specified fuel element for the ETRR-2.
- The plant has a capacity to produce fuel assemblies for any other customers, with the same type, and enrichment percent or lower, as well as, the conventional tasks in the industry, mainly due to the advanced computerized machines and quality control laboratories.

9. REFERENCES

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