SAFETY ANALYSIS REPORT

UPDATE AND REVIEW

for

University of Oklahoma

AGN-211P Reactor

License R-53

Docket 50-112

April 30, 1982

TABLE OF CONTENTS

I Introduction

The Univerisity of Oklahoma, as a part of the application for renewal of its operating license R-53, has completed a review of its original Safety Analysis Report (SAR). This review has been conducted by the reactor staff, nuclear engineering faculty members and Reactor Safety Committee members. The application for renewal has received the proper internal approvals as attested by the signatures of the Vice President for Administrative Affairs and the Director of the School of Aerospace, Mechanical and Nuclear Engineering, a component of the College of Engineering, on the renewal application.

The Safety review logically comes down to three basic questions:

1. The facility has operated very successfully for 20 years. Can the facility be operated for the renewal period (20 years) with equal safety?
2. Are there Safety questions related to the increase in power from 15 watts to 100 watts?
3. What Safety questions are connected with operating the core in a flux trap configurations?

Our Safety review will focus on ideas associated with these three question. Other general information about the facility is also included.

It is noted that the AGN-211 reactor series, designed and built by Aerojet General Nucleonics, is a standard class system. A complete description of the reactor system, associated potential hazards and AEC Hazards Evaluation Report, is on file (Docket 50-88). We request that all prior Aerojet General Nucleonics documents submitted, as well as all prior University of Oklahoma documents submitted, be incorporated by reference.

The University of Oklahoma's AGN 211P (pool type) is now the only remaining 211 in operation in the U.S. West Virginia University at Morgantown

operated a 211 for a number of years at 75 watts. The University of Basel (Switzerland) operated a 211 at 1kw (for short periods) but has now switched from AGN polyethylene fuel to metal clad UO_2 elements in order to operate at powers above 1kw.

The University of Oklahoma continues to consider its AGN-211P to be a valuable and highly versatile training and low flux research reactor. The reactor is used as an integral part of the nuclear engineering program (B.S., M.S. and Ph.D.).

II Description of the Facility

The reactor is located in the Nuclear Engineering Laboratory Building (NEL) and is physically in exactly the same position since the initial installation. The pool is sunk into the floor surrounded by concrete blocks. Beam tubes energe from the concrete shield into a experimental area, the floor of which is ~ 10 feet below the reactor room floor. A fuel storaged pit, on the opposite end, allows for storage of spare fuel elements.

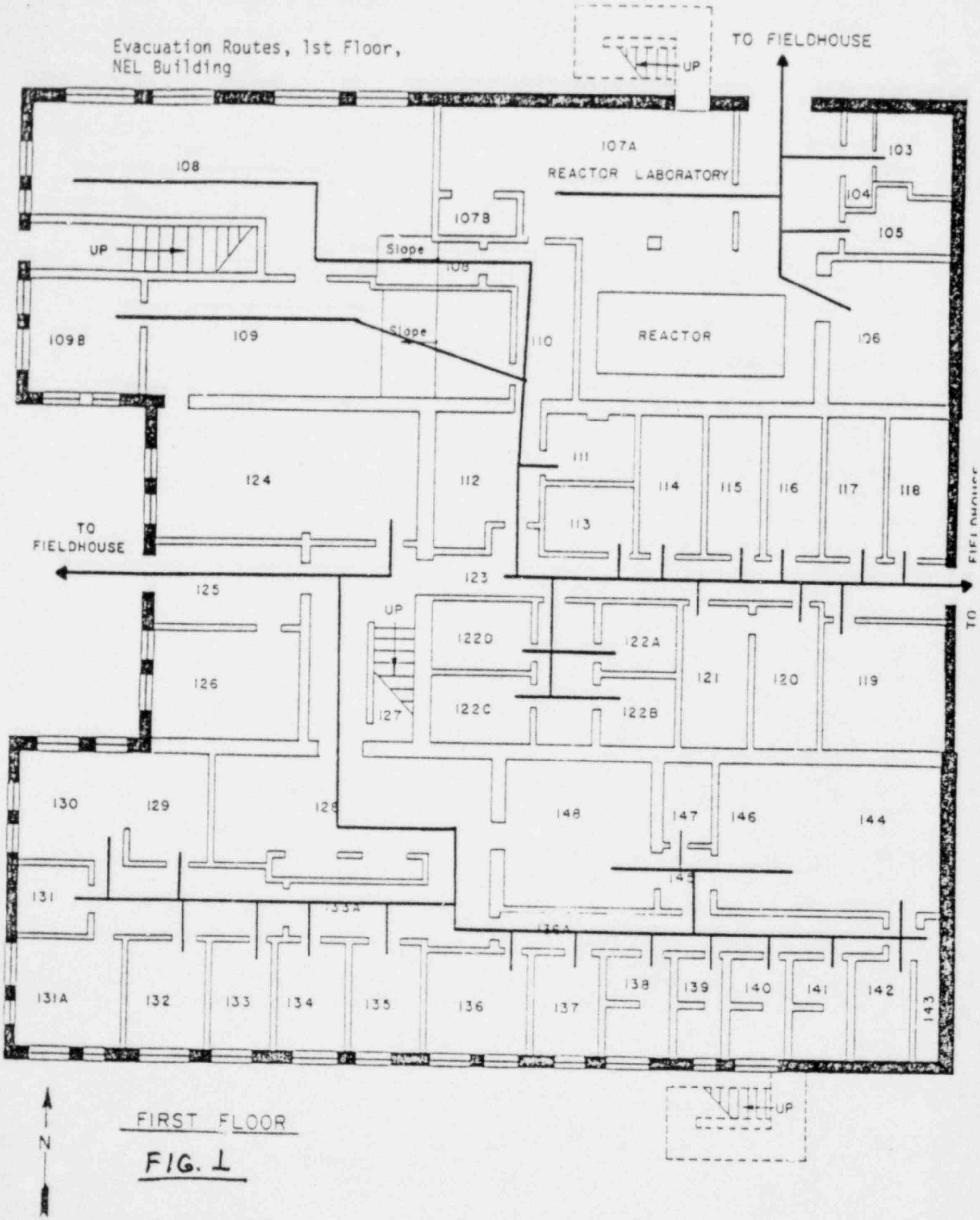
The room in which the reactor is located is a restricted area. Only members of the reactor staff have keys. All persons entering the room during reactor operations are required to wear a TLD or a PIC.

The pool and location of all components of the reactor system in the labs are as they were in 1958. The reactor room did undergo a major redecoration in 1979.

Outside the reactor room and immediately adjacent to it (see Fig. 1) are graduate student offices (Rooms 113, 114, 115) and nuclear engineering labs (Rooms 108, 109, 124). These activities occupy the entire north half of the first floor. The south half of the first floor is occupied by Computer and Personnel Department employees.

The second floor of the building is also occupied by Personnel Department employees.

Evacuation Routes, 1st Floor,
NEL Building



FIRST FLOOR

FIG. 1

A second floor room, which is directly over the reactor pool, is controlled by the reactor staff and is used for storage. The purpose of this is simply a precausion. At 15 watts, the measured gamma-ray dose rate is about 0.09 mr/hr in the center of this second floor room. At 100 watts we, therefore, anticipate a gamma-ray level of

$$0.09 \times 100/15 = 0.6 \text{ mr/hr}.$$

No neutron dose is measurable in the room. Operating procedures require the room be locked prior to startup. In the event of a power excursion it woulb be best to have this second floor room empty.

Radiation surveys in all areas immediately adjacent to the reactor room have been conducted repeatedly over the years. With the reactor at 15 watts measurable increases over background have been detected in two graduate student rooms 114 and 115 (the value is about 3 times background) which are occupied an estimated 20% of the working day.

Our conclusion is that, in its present location in the NEL Building, the reactor will continue to operate safely and in full compliance with federal regulations regards radiation doses to non-occupational and occupational personnel. We consider all personnel in the building to be non-occupational if they are not associated with the reactor staff or the nuclear labs. We note also that <u>all</u> persons employed in the building know about the reactor and have gone through building evacuation rehersals. Thus, in the event of a possible or actual radiation hazard, we have confidence that our training program and emergency preparedness would protect the building employees.

III Site Description

The NEL Building is located on the Norman Campus of the University of Oklahoma. The NEL Building is constructed of brick and reinforced concrete. It has been modernized several times over the past 20 years. The building is

bordered by a street on the west, parking areas on the north, east and south. There are no known plans to introduce any form of construction around the NEL Building.

The population of Norman has grown to approximately 50,000 with an additional 22,000 students on campus. It is noted that no liquid or gaseous effluents are released as a consequence of the operation of an AGN-211P. No cooling of the pool water is necessary at 100 watts as the temperature rise of the 800 gallons of pool water is neglible.

The Norman area is subject to tornadoes. A city wide tornado alert system (sirens) operates very effectively. The reactor is not operated if a tornado alert is in effect.

There are no known factors which have altered the climatology or meteorology of the region from the descriptions given in the original license submission.

We note two additional points. The NEL Building now has a light and horn warning system on <u>every</u> entrance of the building. Signs clearly state the building is not to be entered if the lights are flashing and the University Police are present to ensure compliance. This is by emergency procedure. Once each year a full scale simulated emergency building evacuation is done in order to ensure that all personnel in the building are familiar with the evacuation procedure. Evacuation horns sound throughout the entire building. Evacuation routes are posted in various areas throughout the building.

IV <u>Operation of the Facility over the Renewal Period</u>

The University fo Oklahoma's reactor has been in operation since 1959. The staff has now completed a review of all components of the system. Our review was cast in the framework, is there a possible safety related question relative to the reactor system or one of its component, since it is to

function for the period of the license renewal (20 years)?

The evaluation concluded that there were four components of the system which had the potential to affect safety or result in license violation.

1. Failure of the control and safety rods system.
2. Failure of the gamma compensated neutron ionization chambers.
3. Corrosion of the pool tank resulting in a loss of pool water thereby, exposing the core.
4. Fuel deterioration.

In addition, we have considered a Maximum Hypothetical Accident (MHA), as opposed to a Design Basic Accident (DBA) which does not seem appropriate for an AGN type reactor.

A. Failure of the Control and Safety Rod System

The AGN-211P operates with 2 safety blades worth about 1.5% reactivity and 2 control rods, one worth ~ 1.5% and the orther ~ 0.45%. The four together constitute a shutdown reactivity of about 5%.

Each year the rod mechanism is disassembled and inspected. Some rubbing of the rods on the rod guides has shown up but hs not affected rod drop times which are also measured each year.

In 1980, we were fortunate to procure from West Virginia University a complete duplicate of the rod system. We thus have a spare system which could replace the present system or components of the spare system may be used to affect repairs. We consider the presence of this complete spare control and safety system as a totally adequate assurance of the ability of the system to operate safely over the renewal period.

B. Gamma Compensated Neutron Chamber

The reactor operates with two conventional gamma compensated neutron

ionization chambers. These drive standard linear and log calibrated power channels, the output being displayed on recorders. Both of these chambers have been replaced recently due to failure of their seals (moisture in the connectors). Replacement units are readily available. Thus, should the two chambers require replacement (which is likely), we are in a position to accomplish the replacement with little difficulty.

We note that our license requires us to confirm the power calibration once each year.

In order to achieve a power reading of 100 watts, the log N chamber will need to be physically moved back from the surface of the graphite reflector. This will be done opon receipt of NRC approval to go to 100 watts. We see nc safety related questions associated with replacement of the ion chambers or the power calibration.

C. Corrosion of the Pool Tank

The AGN-211P reactor core sits on an grid plate in the bottom of an 800 gallon pool. Approximately five feet of water covers the top of the core. Each fuel element has (permanently attached) five inches of graphite and two inches of lead on the top end. At 15 watts the gamma level at the surface of the pool water is 15 mr/hr. At 100 watts we expect

$$\frac{100}{15} \times 15 = 100 \text{ mr/hr}$$

A person standing, looking down into the pool, would be in a gamma field of about 20 mr/hr at 100 watts.

We have considered the question of corrosion of the aluminum tank. Should corrosion-failure of the tank wall occur below the top of the core, the water would drain, exposing the top of the core.

If the reactor were operating when the leak occurred, it would scram because of the low pool water interlock. Loss of pool water, with the reactor down, could be investigated by emptying the pool water down until the top of the core was exposed. The radiation level will depend on the duration of the last run and the length of the decay time. Such a measurement, however, would assured us that a leak exposing the core would not result in a hazardous radiation condition. The reason is quire clear. Operation at 15 watts or 100 watts results in a small fission product inventory which rapidly decays to very low levels (it is possible to physically handle a fuel element one day after shutdown from a 15 watt run.

The measurement was made by taking a gamma-ray reading at the surface of the water. The reactor had been shutdown 15 days. This reading was ~ 0.03 mr/hr (normal background). The pool water was then emptied until the top of the core was exposed. The reading measured ~ 0.09 mr/hr (three times background). Had this measurement been made around one day after shutdown, the reading from the exposed core would be ≈ 10-50 mr/hr. This is a very satisfying result. We, therefore, conclude that should the aluminum tank leak, exposing the core (loss of the five feet of water normally over the core), no serious radiation hazard exists, even if the leak occurred a short time after shutdown from a 100 watt run.

D. Fuel Deterioration

The core of the AGN-211P consists of homogeneous fuel arranged in a series of elements. The fuel consists of polyethylene clad UO_2 in the form of fine particles. Each fuel element appears as a homogeneous, unclad, solid polyethylene block.

The University of Oklahoma reactor has always operated with its fuel

elements painted with a special epoxy to keep the pool water from contacting the fuel surface. Every several years this epoxy is replaced as needed. The spare fuel elements to be received from West Virginia University will be simliarly painted with epoxy. The UWV did not cover their elements.

The epoxy has one other advantage. It reduces the amount of gaseous fission products which escape the fuel surfaces into the pool water. The pool water is continuously monitored by circulating the water past a shielded 2 x 2 NaI (Tℓ) detector. This higly sensitive system allows us to observe the very slow growth of gaseous fission products in the water. Indication of the presence of fission products appears about an hour after reaching 15 watts. A slow growth is observed over the balance of the run. Water analysis has established the presence of Kr-87, Kr-88, Xe 137 and Xe 138 in the water. At 100 watts we anticipate that fission product levels in the water will be higher by the ratio 100/15. This water fission product activity will be monitored carefully after first reaching 100 watts.

To ensure the fission product gases are not leaving the water in dangerous quantities, entering the air in the reactor room, a new air monitor will be made operational. This sampling system takes air directly from the surface of the pool water into a sensitive air-ionization chamber. At 15 watts this system does not normally record the presence of any gaseous fission products in the air drawn from over the water.

We, therefore, conclude that the air monitoring system will be quite satisfactory to detect the presence of gaseous fission products at a power level of 100 watts. Through calibration, the concentration of any measured activity can be determined.

Further, the fuel has been used for twenty years and shows no deterioration. It is important to bear in mind that clad corrosion or clad

rupture is not a problem. The AGN fuel is unclad.

E. Operation at 100 Watts

Operation of the reactor at 100 watts has been discussed and considered throughout the various sections of the SAR. In remains, perhaps, to be stated that we find no impediment to increasing the power from 15 to 100 watts. The UWV reactor operated at 75 watts for a period of years without problems to our knowledge. In order to keep the gamma-ray level at or below 0.1 mr/hr at the operator's console, quarter inch iron plates will be layed across the pool at power levels above 50 watts. We have always used a very conservative exposure policy because of the presence of students.

Additionally, neutron and gamma radiation surveys around the reactor clearly establish that the concrete shielding is fully adequate for 100 watt operation. The power increase will be undertaken in several steps with a period of operation at each power step (25, 50, 75, 100) to allow time to observe any unforseen effects.

F. Maximum Hypothetical Accident (MHA)

The University of Oklahoma AGN-211P is a homogeneous, thermal reactor, using 20 w/o U-235 oxide. The maximum permitted positive excess reactivity is limited to 0.65%. The effective beta for the reactor is estimated to be around 0.75%. Control of the excess is through a fuel loading limitation. To reach an excess of 0.65 will require that the pool water be lowered substantially below 20°C. Thus, excess reactivity is controlled by a loading limitation as well as administrative procedure.

We are not able to define a design basis accident (DBA) for an AGN-211 reactor. No insertion or moderation or fuel into the reactor (anywhere) can result in much more than a scram on period. Jerking a small piece of cadmium

from the glory hole will result in an instantaneous period of 5 second (period scram setting). This is with an excess of 0.45%.

We can, however, define a maximum hypothetical accident (MHA). Our license renewal asks for approval to operate in more than one core configuration. This is important in the training of students in that several different critical experiments may be run. Changes in rod worths among different cores could now be demonstrated.

We have asked for approval to operate in two basic core configurations. These are shown in Figure 2. The standard core is a 12 element parallelepiped with a graphite reflector. The flux trap core will be either a 15, 16, 17 or 18 element core depending on the excess reactivity needed. The missing element at the center produces a neutron pileup which results in a thermal flux of about a factor of two over that in the standard core. (Both ANISN And EXTERMINATOR computer codes have been used to compute the flux in the hole.) Such flexibility in core configuration is highly beneficial to the nuclear engineering program, both research and teaching.

Studies of the flux trap configuration have, however, pointed to what we feel make define the MHA.

Consider: The flux trap configuration is present. The pool water is at 20°C, the glory hole is empty and the excess reactivity is measured to be, say 0.4%. The reactor is shutdown by -4.6% (all four rods in). We now postulate the accident senario.

Unbeknown to the operator, a student loads a plastic rod in the GH (absolute violation of operative procedure). This has a positive worth of ~ 0.1%. The reactor is now shutdown by -4.5%.

A new operator takes over and is told to change to a standard core. In absolute violation of procedure he loads a fuel element into the empty flux

FIGURE 2

R	R	R	R	R	R
R	R	R	R	R	R
R	F	F	F	F	R
R	F	F	F	F	R
R	F	F	F	F	R
R	R	R	R	R	R
R	R	R	R	R	R

F = FUEL ELEMENT
R = GRAPHITE REFLECTOR ELEMENT

A. Standard Core Configuration

R	R	R	R	R	R
R	R	F	F	R	R
R	F	F	F	F	R
F	F	W	W	F	F
R	F	F	F	F	R
R	R	F	F	R	R
R	R	R	R	R	R

W = WATER FILLED

B. Flux Trap Core Configuration

trap. That element is estimated to be worth 4.6% (three group EXTERMINATOR CALCULATIONS). The reactor, with all four rods in, is now delayed critical, having a 0.1 excess. The resulting period will be about 60 seconds. This means that if the operator does not take an emergency corrective action within about 7 minutes, the reactor power will have reached 1000 watts. The large negative temperature coefficient ($-3.0 \times 10^{-4}/°C$) will simply shut the system down. The reactor operator would be expected to shove a cadmium sleeve in the glory hole or pour boric acid in the pool to secure a shutdown.

This accident is the only possible way we can postulate any large reactivity addition to an AGN-211P.

The result of a 2% step input was calculated by AEROJECT General in the original hazards analysis for the AGN. In summary, a 2% step would result in a period of 5-10 milliseconds. The excursion would last about 100 milliseconds. The core temperature would have reached 70°C -80°C, distorting the polyethylene fuel and terminating the reaction. The total energy release is estimated to be about 4 megajoules. Since a temperature of at least 200°C is required to melt the polythylene, no large fission product release would occur. The excursion would result in a dose of 1 to 2 R should a person be standing looking down into the pool. We note also that the 2% step would produce about 100 milliscuries of I-131.

While the consequences of these accident are relatively mild, steps must be taken to ensure that they do not occur. Such steps encompass both administrative and physical assurances.

By procedure, to effect a change in a core configuration (flux trap to standard or reverse)

1. A SRO will be present
2. A second person will be present
3. A cadmium sleeve will be placed in the glory hole prior to the start of the core change-over resulting in a large additional negative reactivity (therefore, preventing the MHA postulated).
4. The change-over will be conducted form a written procedure.

Finally, it is noted that the greatest safety feature of the AGN polythylene fuel is its large negative temperature coefficient (3.6×10^{-4}°C).