제 9 회 학술발표회 초록

[특별강연]

원자력발전소의 안전 및 표준화

대우엔지니어링 강 창 순

미국의 원자력산업은 정부의 에너지보존정책과 1980년 대에너지수요의 재평가로 말미아마 매우 침체해왔었다. 건설자들이 끊임없이 일으키는 환경 및 안전에 관한 논쟁도 현상태를 호전시키는 데도움이 되지 못한다. 여기서는 위험의 분석, 군비확산으로부터 재순환 플루토늄의 보호, 고방사선 폐기물의 영구적 처분 및 원자력 발전소의 표준화같은 원자력 산업에 있어서의 주된 요소들을 체계적으로 고찰해 보기로 한다.

최근들어 허가 및 통제당국은 발전소 위험의 분석(RISK ANALYSIS)에 관해 서서히 눈을 돌리기 시작한 것 같다. 위험의 분석(RISK ANALYSIS)에는 환경적 영향의 분석과 안전의 분석 두가지를 동시에 처리하고 있다. 개정된 SAR형 지침은 사고의 분석을 통한 실패의 유형 및 그 영향의 분석(FMEA)을 요구하고 있다 이렇게 하여 산업계는 FMEA와 신뢰도의 체계적인 면밀한 분석이 필요하다고 느낀다. 왜냐하면 발전소의 안전은 개별적 체계나 구성요소의 신뢰도에 직접적으로 의존하기 때문이다. 위험(risk)이란 사건발생의 확률치(발생사건/년)와 환경적 결과 (결과/사고)를 곱한 것으로 정의된다. 따라서 위험은 일상적인 폐기물유출 및 비일상적인 사고가 환경에 미치는 결과를 함께 나타낸다. 안전하고 믿을 수 있는 발전소를 설계하는 데는 FMEA, 신뢰도 및 위험의 분석을 심각히 고려하여야 한다.

카터행정부는 재순환플루토늄의 사용을 무한정 연기했다. 이 정책을 택하게된 주요이유는 다음과 같은 해결되지 못한 문제점들 때문이다.

① 군비확산으로부터 플루토늄의 보호
② 고방사성 폐기물의 영구적 처분
③ 재처리 공장의 가동을 통한 긴 반감기의 방사성 동위원소의 방출

이러한 정책결정은 미국 원자력산업에 큰 영향을 줄 것이다. 그러나 정부는 우라늄 순환을 이용하는 원자력발전이 불가피하다는 것을 인정한다. 이것은 폐기연료의 장기저장이 심각하게 고려되어야 하며 U_3O_8의 공급이 확보되어야 한다는 것을 뜻한다. 재래식 화력발전소에 비교한 원자력발전소 건설의 타당성은 고가의 핵연료 주기비로 인하여 재평가되어야 한다.

원자력발전소의 표준화는 건설공정을 단축시키는 필수적 단계로 인식되어 왔다. 미국에 있어서의 복잡한 허가절차 때문만 아니라 산업계에 있어서도 표준화된 발전소의 설치가 불가피하다고 느끼고 있다. 웨스팅하우스의 RESAR (3S, 41, & 414), 콤바스천의 CESSAR (System 80), B & W의 BSAR, 그리고 GE의 GESSAR(BWR/6)은 이 표준화정책에 따른 NSSS Package들이다. 몇몇 건축 및 설계 회사들이 원자력발전소의 건설에도 광범위한 표준화를 시도하였다. 설계비용과 건설공정상의 상당한 절약에도 불구하고 실용주의자들은 완전히 표준화된 공정방식을 채용하기를 꺼리는데 그것은 지나치게 보수적인 설계로 말미암아 야기될지도 모를 잠재적 경제적 손실의 위험 때문이다. 표준화된 발전소는 일반적으로 모든 엔지니어링 및 설계의 조건을 포괄하며 따라서 가장 최신의 State of the art식 기술의 도입을 허용치 않기 때문이다.

상기 논지에 의거 다음과 같은 추천을 하고자 한다.

① FMEA, 신뢰도 및 위험 분석 능력의 발달
② 한국적 여건에 가장 적합한 믿을 수 있는 표준화된 원자력 발전소의 건설촉진
③ THROW-AWAY CYCLE의 핵연료 순환 및 관리 연구를 통한 한국내 원자력발전소 건설의 경제적 타당성의 재평가
④ 폐기 핵연료의 장기저장시설 계획
⑤ 사업 초기단계에 있어서 U_3O_8의 장기공급 확보

〔제 1 부〕

(1)

Temperature Coefficient in D_2O-Moderated Reactor (Wolsung Unit 1)

원자력연구소 김 성 연

The temperature coefficient has been investigated on the Wolsung power reactor, in which fuel is natural uranium dioxide and moderator heavy water. The numerical computations are carried out in terms of changes of the ef fective neutron multiplication factor with respect to moderator temperature and fuel temperature. Variations due to power changes are also considered on the behavior of the multiplication factor and the results are compared with the computed values of temperature coefficient based on the LATREP computer code.

(2)

Fuel Cost Analysis of CANDU-PHW Wolsung Nuclear Power Plant Unit 1

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양 창 국 (한 국 전 력)
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이 창 건 (원자력연구소)

This study calculated based on the Segel Method and using FACOM 230 OS2/VS computer system, the nuclear fuel cost of zircaloy-4 clan nuclear fueldesign paramter of Wolsung Nuclear Power Plant, CANDU-HW (Unit 1) currently under construction in Korea.

Its result indicated that, when the domestic nuclear fuel production scale is 100 tons-U/r with the early 1984 as the operating year, the nuclear fuel cost not including U_3O_8 purchase cost is estimated as $67.98/kg-U which is $33.05/kg-U in terms of the 1976 price which is cheap by 9% compared with $35.37/kg-U from foreign purchases and that the total nuclear fuel cost including the cost of U_3O_8, based on the early 1984 price, is stimated as $229.94kg-U which means that U_3O_8 accounts for 70% of the total. Of the nuclear fuel cost of $67.98/kg-U in case U_3O_8 is excluded, it was determined to consist of 42% of fabrication cost, 35.9% of material cost of zircaloy-4, etc. (U_3O_8 not included) and 20.7% of process conversion cost.

Analysis was alsomade on the effects of nuclear fuel cost calculation to the lifetime of nuclear fuel manufacturing plant, its load factor, production scale expansion of plant facilities, variations of construction and operating costs, fluctuations of interest rates, extent of uranium oreprice increases and application of learning factor.

The result indicated that the most sensitive area is on uraniumore cost escalation and to a lesser degree on load factor, plant scale increase, learning factor and plant lifetime.

(3)

Mechanical and Thermal Analysis of Nuclear Fuel Rods

황 일 순 (원자력연구소)
이 병 호 (한국과학원)

1. Introduction

Fuel safety aspects usually restrict the core power capability of a pressurized water reactor with respect to departure from nucleate boiling limit, fuel melting, loss of coolant accident and pelletclad interaction (P. C. I), etc. The mechanical and the thermal performance of the fuel rodsloaded in the first core of Ko-ri unit 1 are numerically calculated herein by applying an integral computer code, FROD1.0.

2. Method of Analysis

In the calculation of temperature distribution one dimensional steady-state solutions are aimed. The radial power depression is determined as a function of initial entrichment and fuel burnup.

The thermal conductivity of uranium dioxide is varied with local temperature. The temperature drop across the gap between fuel and clad is evaluated using Newton's Cooling Law with gap conductance adjusted for gas composition in the gap and fuel-clad contact pressure. Neglecting a small amount of heat generated in clad the temperature distribution is calculated according to classical conduction theory. Additional temperature drop occurs across the external Corrosion layer and corrosion product deposits released from inner surface of primary cooling loop. The rate of oxide weight gain on the clad surface is stronly affected by its heat flux, water chemistry and hence fast neutron flux. To calculate the cladsurface temperature a forced convective heat transfer coefficient is obtained from the familiar Dittus-Boelter correlation in the subcooled regime and Tong's or Thom's correlation in the superheated regime. The axial profile of fluid temperature is calculated by energy conservation equation.

The deformation of fuel and clad consists of elastic, plastic. creep, fuel densification, swelling and thermal free expansion components. The creep model for very slow strain rate of importance in nuclear reactors the irrediation-enhanced climbing and irradiation growth as well as thermal creep. Three temperature zones of different grain structures are utilized in treating fuel densification and swelling due to fission gases. In the procedure of solving stress-strain relation the plane strain assumptionis taken for granted in case of pellets which are fabricated with dished and chamferred endfaces. The fuelclad contact pressure is found by elastic analysis. The computer code FROD1.0 provides us with required information for the investigation of fuel rod satety based on the conservative design criteria established by Westinghouse as follows:

Slide 1 1. (T_L) BOL$<$5080°F
2. $P_i < P_s$
3. $\bar{\sigma}$ eff$<\sigma_Y$
4. $\epsilon_\theta < 1\%$ per transient

Slide 2 Two limiting power histories consistent with Conditions 1 and 2 of the ANS criteria are generated as input data of FROD1.0.

3. Results and Discussion

SL 3 Pellet temperature decreases with burnup due to clad creepdown and fuel swelling. On the other hand clad surface temperature shows no significant changes with brunup since the surface area of clad dwindles only a small amount.

Internal pressure of fuel rod increases steadily with burnup and reaches a maximum value at the end of life so far as the design criferion is not violated.

SL 4 The circum ferential component of maximum stress of clad is compressive up until the fuel-clad contact starts to take place. After the fuel-clad contact with incubation burnup of about 20000 MWD/MTU, clad hoop stress increases steadily but does not exceed the yield stress of irradiation-hardened Zircaloy-4.

Overpower ramp history up to 118% of full power with the moderate ramp rate of about 0.2 kw/ft-min or 15%/hris superposed on the normal power hiatory.

SL 5 Fuel melting does not seem to occur even for the worst ckse within two standard deviation level of stochastic design parameters. It is found that the fuel rods loaded in the first core of Kori unit 1 meet all the design criteria up until the end of cycle 1: they do not satisfy the clad stress criterion thereafter owing to the fuel-clad interaction in case of overpower ramp accident.

4. Conclusion

For normal operation fuel rods loaded in the first core of Ko-ri unit 1 meet all the design criteria up until the end of life.

In case of overpower ramp accident the fuel rods may not satisfy the design criteria owing to the fuel-clad interaction.

(4)

핵연료주기의 통계적 분석

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정 창 현 (서 울 대 학 교)
김 창 효 (〃)

금년말에 가동 예정인 고리원자력발전소 1호기와 82년 가동 예정인 동 발전소 2호기에 대한 적정 핵연료 주기정책을 추출할 목적으로 경수형로의 몇가지 전형적인 핵연료 주기방법에 대한 경제성을 통계적인 방법으로 살펴보았다. 핵연료비에 연관된 개개 핵연료주기 성분의 단위 가격들을 통계적인 변수로 취급하여 무작위 표본추출방법으로 요구비용 및 여러가지 핵주기 성분에 대한 breakeven코스트의 히스토그램을 얻었다.

이 히스토그램을 근거로 throw away 핵연료 주기, 사용 후 연료 재처리주기 및 플루토늄 재장전 주기간의 상호 cost-benifit를 통계적으로 검토하였다.

(5)

"TEA N_2레이저의 염가제작"

한양대 **김상훈, 고성실, 정선교***

TEA N_2레이저의 염가제작방법이 설명된다. 사용되는 Blumlein은 O-pinch제작에도 쓰이게끔 설계되었다. 이 레이저에 나오는 Superradient UV Beam은 Dye (물감) Pumping에도 사용될 수 있다.

(6)

Phase Dynamics Analysis of Surface Sputtering

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The experimental sputtering formula can be explained by applying the phase space dynamics to the 3-body sputtering mechanism involving the ion and two surface atoms of the solid. By this theory the theoretical sputtering ratio for uranium has been derived.

(7)

Plasma Ultra Centrifuge for Isotope Separation

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The plasma ultra centrifuge, consisting of an annular cavity filled with a collisionless and relatively quiet rotating plasma between two coaxial electrodes, analyzed in the presence of an axial magnetic field. Within the frame of collisionless magnetohydrodynamics and kinetic equations neglecting the microinstabilities in a stable dielectric medium, the isotope ratio and the radial current are obtained. These quantities show the theretical feasibility of the plasma ultra centrifuge for the production of very pure U^{235}.

〔제 2 부〕

(1)

Preparation of High Specific Activity ^{192}Ir Sources

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High specific activity ^{192}Ir source was manufactured by piled up thin ^{192}Ir discs which were irradiated in the central thimble of the TRIGA Mark Ⅲ reactor.

$\phi 3 \times 0.3$mm and $\phi 2 \times 0.3$mm Ir discs were irradiated

in the reactor. The specific activities of $\phi 3 \times 0.3$ mm and $\phi 2 \times 0.3$mm Ir discs were higher than $\phi 3 \times$ 3mm and $\phi 2 \times 2$mm Ir by 2.2 and 1.8 times respectively.

The ^{192}Ir discs were piled up in the $\phi 3 \times 3$mm and $\phi 2 \times 2$mm capsules. The neutronself absorption factor of $\phi 3 \times 0.3$mm Ir target, in the central thimble of the reactor, was determined. The X-ray self absorption reations of the piled ^{192}Ir discs were determined.

(2)

Radioiodine Labelling of Insulin Using Chloramine-T and Dimethylsulfoxide

한국원자력연구소 김 재 록
김 영 희

Using dimethylsulfoxide (DMSO) as a labelling-aid, insulin ^{125}I of radioimmunoassay use has been effectively prepared. A small amount of DMSO was added to the usual labelling mixture and the reaction time was controled. The labelled insulin obtained in such a way showed improved bindabilities to the antibody and thus expressed larger dose gradients in the plots of standard dose-response curves even though the labelling yield was degenerated to some extent. However, a better yield could also be obtained by extending the reaction time upto 1 min or so.

The results, generally agreed with the Stagg's postulation, will be discussed in view of a competitive oxidation of DMSO withdisulfide linkages of the insulin molecule by the chloramine-T

(3)

Activation Analysis of Human Fingernails

인하대학교 김 석 연

Trace-element concentrations in the human fingernail have been found to be related directly to trace-element concentrations in the blood.

NaI(Ti) gamma-ray spectrometry can be used but the lithiumdrifted germanium(Ge(LI))detectors offers high resolution and detects more number of elements.

In this paper, using this solid-state detection system, quantitative and qualitative determinations of sodium, bromine, gold, zinc and antimony were obtained without chemical separation. Samples were obtained from author's lefthand fingernails. The fingernalis were washed indistilled water and washed in acetone. The sample was packed in poyethylenevials, and irradiated at the M.I.T. 5-MW nuclear reactor. The sample was irradiate for 9 hr in a thermal neutron flux of 2×10^{13}n/sec. After irradiation the sample was transferred to cold poy-vials, and gamma-ray spectra were obtained by Ge(LI) detector. The elementwere identified by using comparator technique.

(4)

Incoherent Holography of Scattered X-ray

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A metallic object which scatters incident X-ray behaves as an incoherent X-ray object, and its optical image can be obtained according to the principles of coherent optics. A zone plate which has a central radius 1.6cm and 35 open zones is made of 30cm×30cm×0.2cm lead (Pb) plate. The xone plate is placed before X-ray film and X-ray is made incident upon the object obliquely, so that scattered X-ray hologram is recorded on the film. This hologram is reduced to the size of 3.5 cm×3.5cm touse in the laboratory and it is used for image reconstruction by using He-Nelaser beam and a Beam expander.

The object used in the present experiment is a

brass ring with three shorter rodsin radial direction and at equal angular distance. The X-ray source used is that for medical radiography. It is found the reconstructed image is satisfactory in all respects expect resolution.

Gamma-ray holography is also attempted by using Imc Co-60 object. However, the holograms obtained show too low contrast, requiring further improvement. The method can be used in recording not only the image of the metallic objects but also any defects in it, so that it may provide a new tool for NDT.

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(5)

X-ray Emission in Wire Explosion Process

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Pulsed Bremsstrahlung X-ray is obtained in wire explosion process. The electric current used is of the order of 10 kiloamperes and the density of the current in the wire is of the order of 10 giga-amperes/cm^2. The copper wire used is 10cm long and has the diameter ranging from 10um to 100um The condenser bank is charged up to 10kilo-volts and is drained via an air spark gap switch. X-ray is detected mainly by using X-ray photographic film. The relations of X-ray intensity with respect to the drained power, voltage and total energy stored in the condenser bank are presented, together with the X-ray pin-hole camera photographs which show spatial distribution of X-ray and X-ray emitting electrons.

It is found wire explosion is useful in metallic film coating on glass and metal surfaces. As the impinging atoms have higher kinetic energy than those in thermal evaporation process, the films obtained are found more sturdy and less effected by the surface molecular layers.

The works on thin film (cross-section$\approx 10^{-12}$cm^2) explosion and the high speed photography using two image converter tubes are under preparation. Also application of radiation of wire explosion process in short wavelength optical pumping is under examination.

(6)

Uranium Quantitative Analysis in Ishige One of the Korean Seaweeds

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An attempt has been made to determine uranium content of Ishige, a specis of the brown seaweeds over the Korean coastal area. Owing to urgent needs for future energy requirement Korea must rely her future energy on nuclear power reactors. Due to low content there are many difficulties to supply uranium ore through the conventional uranium ore smelting method.

Fearing the shortage of uranium ore, the author hasdecided to look for an entirely different method of supplying uranium compounds by employing seaweeds which contain uranium compounds as its constituent.

In order to look for the possibility of whether the seaweed can be used as uranium ingradient the experiments were perofrmed by using seaweeds (Ishige) collected from 13 coastal places along east, west, south coast and Jeju island.

The qualitative uranium content is measured by counting their radioactivity employing Delayed Fission Neutron Counting Method.

The results obtained in these are summarized as follows:

1. Ishige contains uranium element about 8 ppm (mg/kg) in dry body.
2. This amount is about 3 times more than Japanese research.
3. Therefore, we may take an optimistic view

regarding the future for nuclear fuel because of great culturing Ishige on the marine base.

(7)

On the Densification of UO_2 Pellet

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Out-of-pile densification of UO_2 has been investigated for fuels with various microstructures in terms of thermal stability responsed from resintering the pellets of 92 to 94% T. D. in the flowing N_2—H_2—H_2O gas mixture at temperatures between 1300°C and 1500°C.

The observation shows that the stable microstructure without any significant thermal densification contains mostly 20-60um diameter of pores in troduced by additive pore former.