Docket No. 50-255

MAR 2 3 1973

Consumers Power Company
ATTN: Mr. R. C. Youngdahl
Senior Vice President
212 West Michigan Avenue
Jackson, Michigan 49201

Change No. 5
License No. DPR-20

Gentlemen:

On December 8, 1972, we changed the Interim Special Technical Specifications (Appendix B) of Provisional Operating License No. DPR-20 (Amendment No. 4) for the Palisades Plant. This change authorized a temporary power increase up to 85% of full power (1870 MWt) for an operating period not to exceed 750 effective full power hours (about 6 weeks of operation at 85% of full power). After further analysis, on March 2, 1973, we approved continued operation of Palisades at 85% of full power (1870 MWt), for an operating period not to exceed 1500 effective full power hours after December 8, 1973.

Our letters to you of December 8, 1972, and March 2, 1973, indicated that as a result of our continuing review of fuel densification, an increase in linear power density might be allowed in the future. We have used information submitted by you and our analytical methods to reevaluate this matter and have concluded that Palisades can be operated at higher power levels than those presently authorized under the March 2, 1973, change to License No. DPR-20. The bases for this conclusion are presented in the enclosed safety evaluation entitled, "Supplement No. 5 to Safety Evaluation, By the Directorate of Licensing, U. S. Atomic Energy Commission, In the Matter of Consumers Power Company, Palisades Plant, Docket No. 50-255". Based on this evaluation, we approve a power increase up to 2200 MWt for an operating period such that the core average fuel exposure does not exceed 6000 MWD/MTU. This increase is subject to the enclosed revisions to Appendix B of your Operating License and is designated Change No. 5 to License No. DPR-20.

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We conclude that the approved change does not involve significant hazard considerations not described or implicit in the Final Safety Analysis Report and that there is reasonable assurance that the health and safety of the public will not be endangered. Accordingly, pursuant to Section 50.59 of 10 CFR Part 50, the Technical Specifications of Facility Operating License No. DPR-20 are hereby changed as set forth in revised pages, copies of which are enclosed.

Sincerely,

A. Schwencer for

R. C. DeYoung, Assistant Director
for Pressurized Water Reactors
Directorate of Licensing

Enclosures:
1. Supplement No. 5 to Safety Evaluation
2. Revised Tech Spec Pages

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SUPPLEMENT NO. 5

TO

SAFETY EVALUATION

BY THE DIRECTORATE OF LICENSING

U. S. ATOMIC ENERGY COMMISSION

IN THE MATTER OF

CONSUMERS POWER COMPANY

PALISADES PLANT

DOCKET NO. 50-255

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1.0 INTRODUCTION

Consumers Power Company was issued a Provisional Operating License to operate the Palisades Plant at levels up to 2200 MWt on October 16, 1972. Appendix B to the operating license restricted plant operation to 1320 MWt while the effects of fuel densification on reactor operation were further studied.

On October 12, 1973, Consumers Power Company submitted their analysis of the effects of operation of the Palisades Plant with densified fuel with consideration also given to the consequences of collapsed fuel. Consumers felt they had justified full power operation of Palisades for the first fuel cycle. Supporting Tech Specs and additional analytical work were also provided. Significant parameters that received close scrutiny included the local peaking augmentation factors due to nearby gaps, the creep collpase and gap conductance models and the effects of densified fuel on the LOCA and other accidents. Additional information was submitted on November 13, 1972, in response to staff questions on times to first clad collapse and fuel cladding temperatures following a loss of coolant accident.

On November 14, 1972, the Regulatory Staff issued a report entitled "Technical Report on Densification of Light Water Reactor Fuels," (the Densification Report, Ref. 1.1) and on November 20, 1972, the Regulatory Staff requested that the applicant provided analyses and relevant bases for determining the effects of fuel densification on normal operation, transients and accidents for the Palisades Plant for a core average burnup of greater than 6000 MWD/MTU.

On November 21, 1972, Consumers Power Company provided at the request of the staff, further additional information with respect to loss of coolant accident analysis. On December 8, 1972, information was submitted regarding plans to reduce the operating pressure at the Palisades Plant from 2100 to 1900 psia and the predicted clad collapse times.

Based on the evaluation of the information submitted above and values of gap conductance from the staff computer code, GAPCON, the Interim Special Technical Specifications were changed on December 8, 1972, to allow operation at power levels not exceeded 1870 MWt for 750 EFPH at an operating pressure of 1900 psia. We agreed that collapse of rods was not predicted to occur during this time period.

Subsequent to the December 8, 1972, Technical Specification change, Consumers Power Company submitted a change request that would allow further reduction of the primary system operating pressure to 1800 psia (December 18, 1972) and further analyses of steady state operation, operating transients and postulated accidents taking into account the effects of densification and reduced operating pressure (January 3, 1973). Additional information was provided by Consumers Power Company with respect to the effect of varying gap conductivity on cladding temperatures during a loss of coolant accident on January 16 and February 12, 1973.

In subsequent sections of this Safety Evaluation, our technical review of fuel densification, as it applies to the Palisades Plant, and our technical evaluation of the Consumers Power Company's safety analyses of steady state operation, operating transients and postulated accidents taking into account the effects of densification are presented. Comparisons of the Consumer's calculations with our independent analyses are also presented.

The Regulatory Staff has concluded that operation of the Palisades Plant as now proposed at power levels up to 100% of full power, in accordance with the Special Interim Technical Specifications will not present an undue risk to the health and safety of the public.

1.1 Scope of Review

The applicant stated that the determination of reactor power capability was based on the premise that the fuel cladding in the regions of the fuel column gaps will not flatten until after the first refueling outage. The staff concludes that "no collapse or flattening" is an appropriate assumption for core average burnups of 6000 MWD/MTU and used it as the basis for our evaluation.

Our evaluation of Palisades is described in the following chapters where calculations, made by both the applicant and the Regulatory Staff, are discussed.

The essential elements that must be considered in evaluating the effects of densification have been set forth in our Densification Report. The effects of fuel densification on the course of postulated plant transients and accidents were reviewed by the applicant and evaluated by the Staff. Since the performance of the facility in steady state operation, and during various postulated transients and accidents had been established previously and reported in the application (FSAR), it was only necessary to evaluate those changes in analyses or results resulting from the effects of densification.

A detailed evaluation by the Staff of the methods used by CE to evaluate the effects of densification on unpressurized fuel was carried out for the Maine Yankee reactor and our results were published in an addendum to the safety evaluation dated March 15, 1973. Pertinent conclusions reached as a result of that review are that the flux peaking augmentation model prepared by CE is acceptable, the time for clad collapse is not expected during the first 6000 MWD/MTU of core average burnup, an acceptable and conservative calculational method has been used to describe the creepdown effect that tends to increase gap conductance with lifetime, and the applicant's calculation of stored energy for non-pressurized fuel rods cannot be accepted at this time. However, we used an interim stored energy model which we conclude is conservative for evaluating this fuel rod design. We have also used this interim model to evaluate further operation of Palisades.

2.0 DISCUSSION OF DENSIFICATION EFFECTS

2.1 Densification Effects

Densification of fuel causes a decrease in the volume of the fuel pellet with corresponding changes in the pellet radius and length. There are three principal effects associated with fuel densification:

(a) A decrease in the pellet length will cause the linear heat generation rate to increase by an amount in direct proportion to the percentage decrease in pellet length.

(b) A decrease in the pellet length can lead to generation of axial gaps within the fuel column, resulting in increased local neutron flux and the generation of local power spikes.

(c) A decrease in the pellet radius increases the radial clearance between the fuel pellet and fuel rod cladding causing a decrease in the gap thermal conductance, and consequencely in the capability to transfer heat across the radial gap. This decrease in heat transfer capability will cause the stored energy in the fuel pellet to increase. A decrease in radial gap conductance also will degrade the heat transfer capability of the fuel rod during various transient and accident conditions.

In summary, the effects of fuel densification cause the fuel rod to contain more stored energy, increase the linear heat generation rate of the pellet, decrease the heat transfer capability of the fuel rod and create the potential for a local power spike in any fuel rod. To assess the safety implications of fuel densification, all of these effects have been evaluated for the Palisades Plant reactor under all modes to reactor operation.

2.2 Calculations of the Effects of Densification

2.2.1 Clad Creepdown

Cladding creepdown is the term used to indicate the phenomenon which affects the geometry of the gap between the fuel pellets and the cladding.

The staff reviewed the applicant's model and concluded that it would predict creepdown rates accurately enough for evaluation of time-dependent gap conductance. The staff made independent calculations of the gap closure rate utilizing clad midwall strain and in-reactor creep data. A comparison of these calculations show that the applicant's creepdown rate is conservative.

2.2.2 Time to Collapse

Time-to-collapse is the term used to indicate the calculations to determine the time required for an unsupported clad tubing to flatten into the axial gap volume caused by the fuel pellet densification.

The Palisades accident analysis was based on the assumption of uncollapsed cladding. The staff has reviewed the model used by the applicant to calculate the time at which fuel rod collapse would be expected. Because several steps in the model were not fully substantiated at the time of review, the staff performed an independent calculation using the computer code BUCKLE (described in reference 2.1).

The staff's calculations indicate that the time to cladding collapse exceeds the proposed period of operation with adequate margin. The period of operation includes approximately 3000 hours during which the reactor operated with a primary pressure of 2100 psia, approximately 1000 hours during which the reactor operated with a primary pressure of 1900 psia and a period of approximately 4000 hours with a primary pressure reduced to 1800 psia.

2.2.3 Gap Conductance

The ability to transfer heat from the fuel pellet to the cladding is governed by the thermal conductance of the radial gap between the pellet and the cladding. The effect of densification is to increase the size of the radial gap, which decreases the gap conductance and results in an increase in the fuel pellet stored energy.

Although gap conductance is an important factor in establishing fuel pin stored energy, other factors (including flux depression factors, fuel conductivity, and surface effects) must also be considered.

2.2.3.1 Calculation of Gap Conduction

The applicant uses the FATES computer code to calculate the gap conductance. We reviewed the CE model and input and concluded that certain portions of that model were not suitably conservative or justified. The staff used its own code, GAPCON, to evaluate densification effects.

The staff made a GAPCON calculation for the Palisades reactor fuel using the following assumptions:

(1) Fission gas release - The fission gas release rate was based on data by Hoffman and Coplin (Reference 2.2) which is a correlation based on volumetric average temperature.

(2) Power history - The peak power density was varied between 9 and 13 kW/ft, but was held constant for each calculation through a core burnup of 6000 MWD/MTU.

(3) Peak/average Power - The fission gas release rates were approximated by the volumetric average temperatures associated with the peak power density divided by the axial peaking factor. This approach is consistent with Hoffman and Coplin's data. The axial peaking factor used for these analyses was 1.36.

(4) Densification Rate - Instantaneous densification was assumed to occur as specified in the Densification Report.

(5) Gap closure rates: The gap closure rates were presented by the applicant as a psuedo fuel swelling rate in terms of volume percent per MWD/MTU. The gap closure rate contained contributions from fuel cracking, fuel swelling, and cladding creepdown. The staff believes the applicant has used a conservative estimate of the gap closure rate associated with fuel cracking. Therefore it subtracted the contribution due to cladding creep and modified the swelling equation in GAPCON to utilize the CE rate. A cladding creepdown rate was inferred from BUCKLE calculations wherein the actual and intended operating history were simulated. The creepdown rates were selected from a case that used a nominal wall thickness and ovality to reduce the creepdown effect. The BUCKLE calculations did not consider the effects of fission gas buildup; consequently actual creepdown rates

may be less than those used for GAPCON calculations.

(6) UO_2 thermal conductivity integral - an integral of 93 w/cm was used instead of the applicant's 97 w/cm.

The results of these calculations are presented in Table 2.1.

Our preceding review of the CE analysis indicates that most of the models appear reasonable. Comparison of predictions with experiments indicated good agreement with data that apparently had been used to calibrate various models. Comparison with independent data, specifically from Chalk River (Bain) and General Electric Prototype rods indicated that predicted temperatures were lower than those inferred from the experiment.

This may be due in particular to the two features of the model open to some question; the psuedo contact model, and the relatively high UO_2 conductivity. The staff recognizes that a strictly annular model is probably conservative, and some modification to account for asymmetry, cracking, and other phenomena as they contribute to contact may eventually be acceptable. However, at this time it is felt that existing data does not warrant this credit. Rather than "subtract" these effects from the applicant's model, the staff performed calculations to independently assess the fuel rod stored energy. These calculations were made with the previously described GAPCON Code.

As noted, the applicant's fuel swelling model was utilized in the GAPCON calculations. In general, agreement between GAPCON and the vendors calculations was good when the "pseudo" contact was suppressed.

Since stored energy is the parameter of interest and since UO_2 conductivity and flux depression factors as well as gap conductance contribute to stored energy, a more appropriate parameter is volumetric average temperature.

To evaluate the level of operation for Palisades, CE provided a plot of allowable peak linear heat rate as a function of average fuel temperature. The limit line is based on a peak cladding temperature of 2300°F for the LOCA calculation. As was discussed earlier, fuel pellet average temperature as a function of exposure was calculated for several linear heat rates. The values plotted on Figure 2.1 of average temperature for the instantaneously densified fuel were reduced by 100°F prior to plotting to account for elastic deformation of the cladding.

The CE LOCA limit plot is overlaid on Figure 2.1. The intersection of the limit line with temperature curve for the appropriate temperature and linear heat rate are plotted on Figure 2.2. This curve will form the basis for Technical Specifications limiting operation of the Palisades plant.

2.3 Conclusions

The staff has concluded that:

(1) The direct effects of fuel densification have been adequately accounted for,

(2) The time to collapse as calculated by the applicant is beyond the proposed period of operation, 6000 MWD/MTU of core average burnup. The staff made calculations independently and reached the same conclusion.

(3) An acceptable and conservative calculational method has been used to describe the creepdown effect that tends to increase gap conductance with lifetime.

(4) The applicant's calculation of stored energy for non-pressurized fuel rods cannot be accepted at this time. However, the staff has used an interim model which it concludes is conservative for evaluating the stored energy for this fuel rod design.

3.0 EFFECTS OF DENSIFICATION ON STEADY-STATE OPERATION AND TRANSIENTS

3.1 General

Fuel densification can affect steady-state operation by virtue of its effect on local neutron flux (due to gaps in the fuel column) and the resulting slightly shorter fuel stack length. An additional effect occurs in the transient analyses where, due to a lower gap conductance, the fuel has a higher initial stored energy and a slower heat release rate during the transient.

In order to offset the effects of fuel densification, the Palisades reactor will be operated with added restrictions on the peak linear heat generation rate, primary coolant pressure, and control rod patterns. Another condition that will increase the thermal margin is the increased primary coolant flow rate that is based on flow measurements taken during initial startup of the plant. All of these changes in operating conditions together will provide greater margins of safety for steady state and transient operations than had been provided in the original design.

TABLE 2 -1

GAPON Calculations For Palisades

Time (Days)	Heat Rating (kW/ft) 9.0		10.0		11.0		12.0		13.0	
	H_{Gap} *	Temp.(°F)	H_{Gap} *	Temp.(°F)	H_{Gap} *	Temp.(°F)	H_{Gap} *	Temp.(°F)	H_{Gap} *	Temp.
0	401	2270	425	2425	453	2565	485	2694	514	2827
60	239	2921	227	3279	241	3451	260	3569	281	3676
120	243	2894	253	3105	285	3177	328	3199	390	3173
180	294	2626	333	2710	421	2648	549	2562	760	2447
240	428	2208	590	2124	934	1979	1725	1838	2127	1893
300	1042	1634	2052	1543	2151	1648	2115	1772	2083	1900
360	2426	1399	2167	1531	2107	1653	2080	1777	2059	1904
420	2345	1405	2123	1535	2075	1657	2053	1781	2038	1907
130	248	2866	259	3066	295	3119	348	3114	411	3108
150	261	2791	281	2946	335	2939	408	2899	511	2833

* in BTU/hr. ft^2°F

FIGURE 2.1
AVERAGE FUEL TEMPERATURE VS. KW/FT
ASSUMING INSTANTANEOUS DENSIFICATION

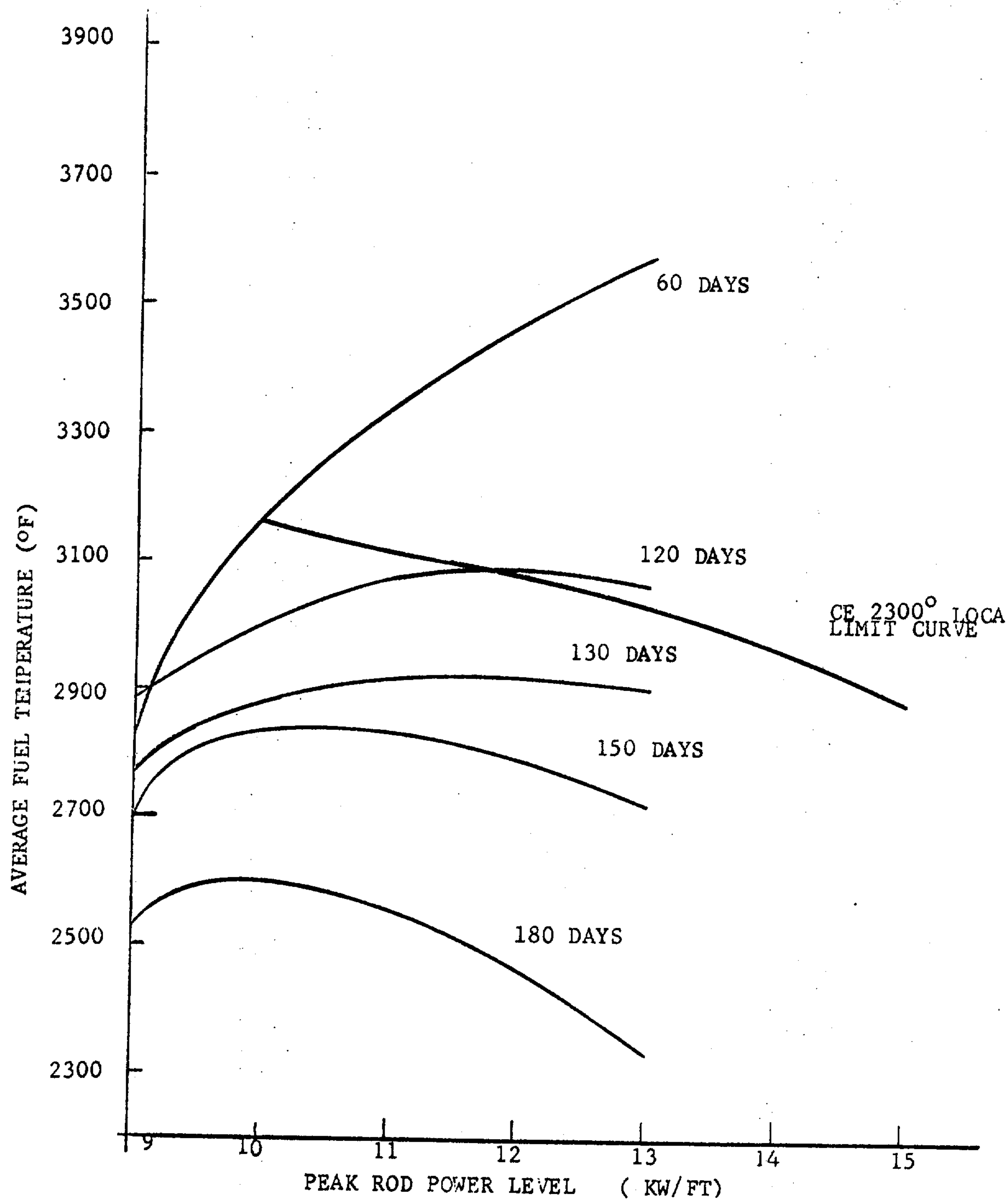
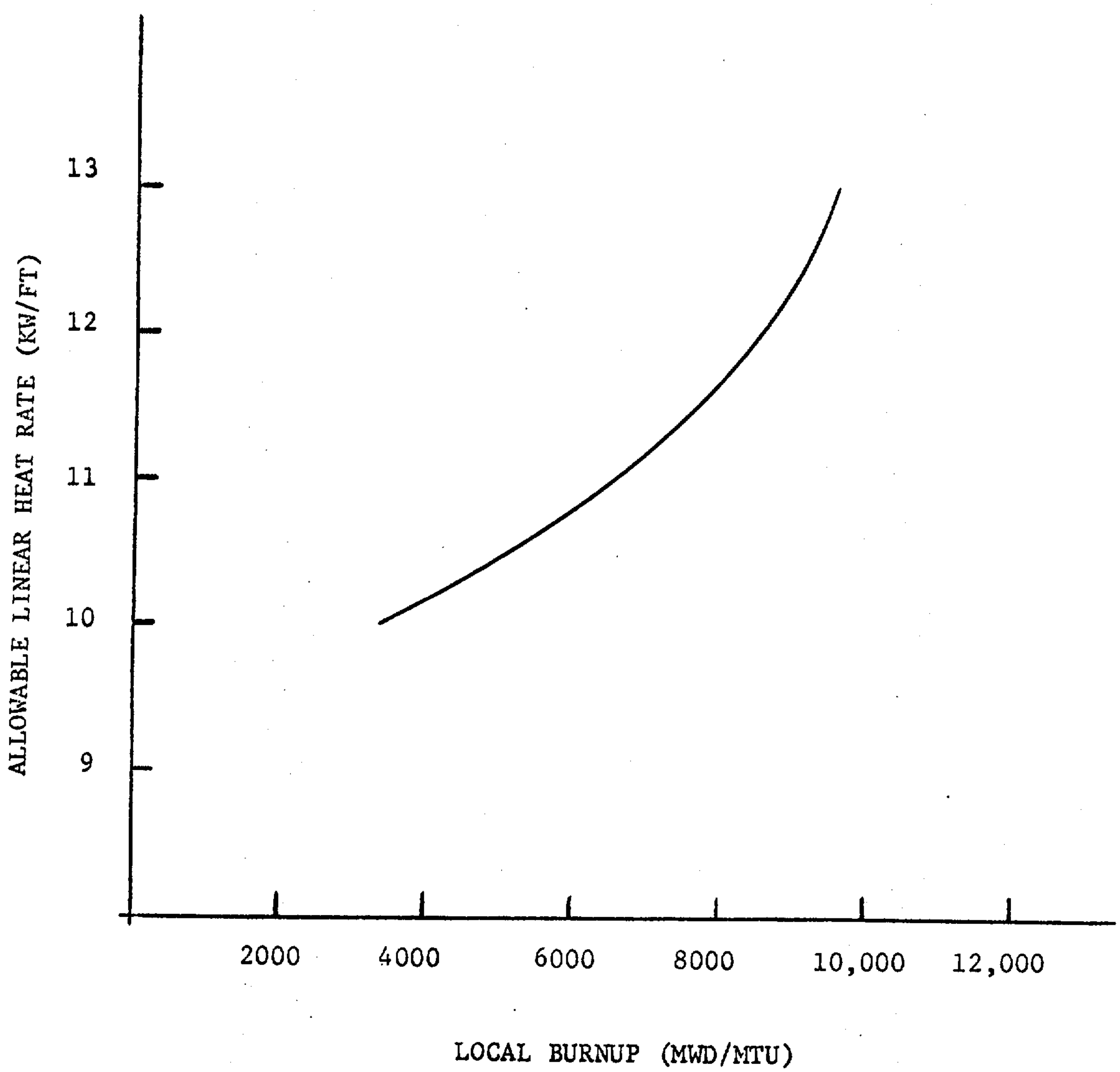


FIGURE 2.2
ALLOWABLE LINEAR HEAT RATES
IN PALISADES REACTOR



On the basis of calculations of the effects of fuel densification, the Palisades reactor will be operated with more restrictive limits on control rod patterns and motion than originally proposed, and with a reduced design total peaking factor. The changes consider the effect of local peaking caused by gaps in the fuel pellet stack and changes in the gross peaking factors, primarily axial, which can be controlled by more restrictive operation of control rods.

The effects of densification on power density distributions have been calculated by the applicant using models in general conformance with those discussed in Section 4 of the Staff densification report (Ref. 1.1). These calculations by the applicant take into account the peaking due to a given gap, the probability distribution of peaking due to the distribution of gaps, and the convolution of the peaking probability with the design radial power distribution and are acceptable.

The applicant's calculations result in a peaking augmentation factor which varies almost linearly with core height and reaches a value of 1.10 at the top of the core.

In order to ensure that the reactor is not operated with a peak linear density in excess of the limiting value necessary for LOCA considerations, the applicant will be required by Technical Specifications to employ his fixed in-core detector system to periodically determine the allowable power level.

This is accomplished by requiring that the allowed average linear power density (kW/ft) and peaking factor determined from an incore detector map be appropriately adjusted by a measurement error factor of

1.10, a flux peaking augmentation factor varying from 1.0 at the bottom of the core to 1.10 at the top of the core, an engineering factor of 1.03, a factor of 1.0175 that accounts for axial fuel densification, and power measurement factor of 1.02 such that the peak linear power density is less than that necessary to meet the Interim Acceptance Criteria regarding the LOCA. Alarms are set to activate if any local detector readings increase over the values used for the incore map by the amount that the peak linear power density is less than the LOCA limit. If four alarms are received, and validated (immediately), the reactor power is reduced below the alarm setpoint. This system in effect employs the fixed incore detector system as a continuously operating peak linear power density meter, and will prevent the LOCA limit from being exceeded.

3.2 Conclusions

The effects of fuel densification on steady state and transient operation have been evaluated by the applicant and reviewed by the staff.

The effect on steady state operation, mostly due to local increases in thermal neutron flux and heat generation, is compensated for by the improved thermal-hydraulic conditions in the reactor core, that is: the reduced permissible linear heat generation rate, and the increased primary coolant flow rate.

The staff concludes on the basis of its review that the potential effects of fuel densification on the steady state and postulated transient operation have been evaluated in an appropriate manner and are acceptable for the period of operation proposed.

4.0 ACCIDENT ANALYSIS

The effect of fuel densification in the analysis of postulated accidents has been considered by the applicant and reviewed by the staff. The assumed occurrence of densification affected the analysis of the LOCA, the control rod ejection, the steam-line rupture, and locked-rotor accidents.

Consideration of the LOCA analysis by the applicant resulted in a limitation on the peak linear heat generation rate as a function of burnup based on instantaneous densification as shown on Figure 2.2. For the rates shown, the calculated peak cladding temperature is limited to 2300°F.

The effects of densification changed the results of the rod ejection accident; however the results are still within acceptable staff limits.

The consequences of a steam line break accident in the Palisades reactor for operation up to 6000 MDW/MTU would be less severe than previously analyzed and shown in the FSAR.

The loss of flow accident (locked rotor) is less severe than previously reported in the FSAR when densification is included and credit is given for the new operating conditions.

5.0 SUMMARY AND CONCLUSIONS

The effects of fuel densification have been considered in analyses of normal operation, operation during transient conditions, and postulated accident conditions. On the basis of the staff review of the applicant's calculations, and calculations performed by the staff and its consultants, the staff concludes that for the period of operation proposed:

(1) The effects of densification during steady state and transient operation of the Palisades reactor will not cause the limits on DNBR, or cladding strain, or centerline temperatures, to become less conservative than values previously established in the FSAR.

(2) The effects of densification were included in the calculation of fuel rod behavior during postulated loss-of-coolant accidents. The LOCA analysis is acceptable and complies with the June 1971 Interim Policy Statement.

(3) A conservative calculational method has been used by the applicant to describe the creepdown effect that tends to increase gap conductance with lifetime.

(4) Our Technical Specifications will limit power operation to a core average burnup of less than 6000 MWD/MTU to assure that cladding collapse will not occur during this period of operation.

(5) Operating restrictions are necessary to assure compliance with paragraphs 1-4, and will be incorporated into the Technical Specifications.

On the basis of the about five conclusions the applicant is in compliance with the staff densification report; on this basis the staff concludes that Palisades Reactor can be operated at power levels up to 100% of rated power with no undue risk to the health and safety of the public.

REFERENCES

1.1 "Technical Report on Densification of Light Water Fuels" by USAEC Regulatory Staff, November 14, 1972.

2.1 P. J. Pankaskie "BUCKLE, An Analytical Computer Code for Calculating Creep Buckling of an Initially Oval Tube" BNWL-B-253, March 1973.

2.2 J. P. Hoffman and D. H. Coplin, "The Release of Fission Gases from Uranium Dioxide Pellet Fuel Operated at High Tmperatures," GEAP-4596, September 1974.

APPENDIX B

TO

PROVISIONAL OPERATING LICENSE DPR-20

INTERIM SPECIAL TECHNICAL SPECIFICATIONS

FOR THE

PALISADES PLANT

CONSUMERS POWER COMPANY

DOCKET NO. 50-255

Date of Issuance: March 23, 1973

INTERIM SPECIAL TECHNICAL SPECIFICATIONS

FOR OPERATION OF THE PALISADES PLANT

DOCKET NO. 50-255

1. The maximum steady state core power level shall not exceed 2200 MWt.

2. The primary to secondary leakage in a steam generator shall not exceed 0.3 gpm for any period greater than 24 consecutive hours.

3. For a core average burnup of less than 6000 MWD/MTU:

   a. The peak linear power with appropriate consideration of normal flux peaking, flux peaking augmentation factors, measurement-calculational uncertainty (10%), engineering factor (3%), increase in linear heat rate due to axial fuel densification (1.75%) and power measurement uncertainty (2%), shall not exceed the kW/ft limit shown in Figure B-1.

   b. Flux peaking augmentation factors used will be assumed to vary linearly from 1.0 at the bottom of the core to 1.10 at the top of the core.

   c. For power operation above a power level of 85% of the level permitted by 3.a, incore detector alarms generated by the data logger shall be set, based on the latest power distribution obtained, such that the peak linear power including appropriate consideration of flux peaking augmentation factors does not exceed the kW/ft limit defined in 3.a at the alarm set point. If four or more coincident alarms are received, the validity of the alarms shall be immediately determined and, if valid, power shall be immediately decreased below alarm set point and a power distribution map obtained. If a power distribution is not obtained within 24 hours of the alarm condition power shall be reduced to 85% of the value defined in 3.a.

   d. The incore detector alarm set points shall be established based on the latest power distribution maps, normalized to the kW/ft limit defined in 3.a.

   e. Power distributions shall be evaluated every week or more often as required by plant operations.

   f. Primary coolant gross gamma radioactivity shall be monitored continuously by the fission product monitor. If the fission product monitor is not operating, the primary coolant gross radioactivity shall be measured at least once per day.

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g. Secondary coolant gas radioactivity shall be monitored continuously by the air ejector gas monitor.

Secondary coolant gross radioactivity shall be measured at least twice per week. If the air ejector monitor is not operating, the secondary coolant gross radioactivity shall be measured at least once per day to evaluate steam generator leak tightness.

h. A monthly report of primary and secondary activity measurements, effluent discharge radioactivity levels and core average fuel burnup shall be made to the Directorate of Licensing.

i. Rates of power increase shall not exceed 10% power/hour.

4. Nominal primary system operating pressure shall not exceed 1800 psia.

5. If at the end of a core average burnup of 6000 MWD/MTU additional information has not been submitted and approved by the Directorate of Licensing, the reactor will be placed in a cold shutdown condition.

6. The data logger can be inoperable for two hours. If at the end of two hours, it is not available, the power level shall not exceed 85% of the kW/ft limit defined in 3.a.

7. Control rod insertion limits will be in accordance with Figure B-2, except for physics tests and CRDM exercises.

8. The reactor coolant temperature at the inlet to the reactor vessel shall be no greater than 525 ^{o}F during steady state operation above 80% of full power.

FIGURE B-1
ALLOWABLE LINEAR HEAT RATES
IN PALISADES REACTOR

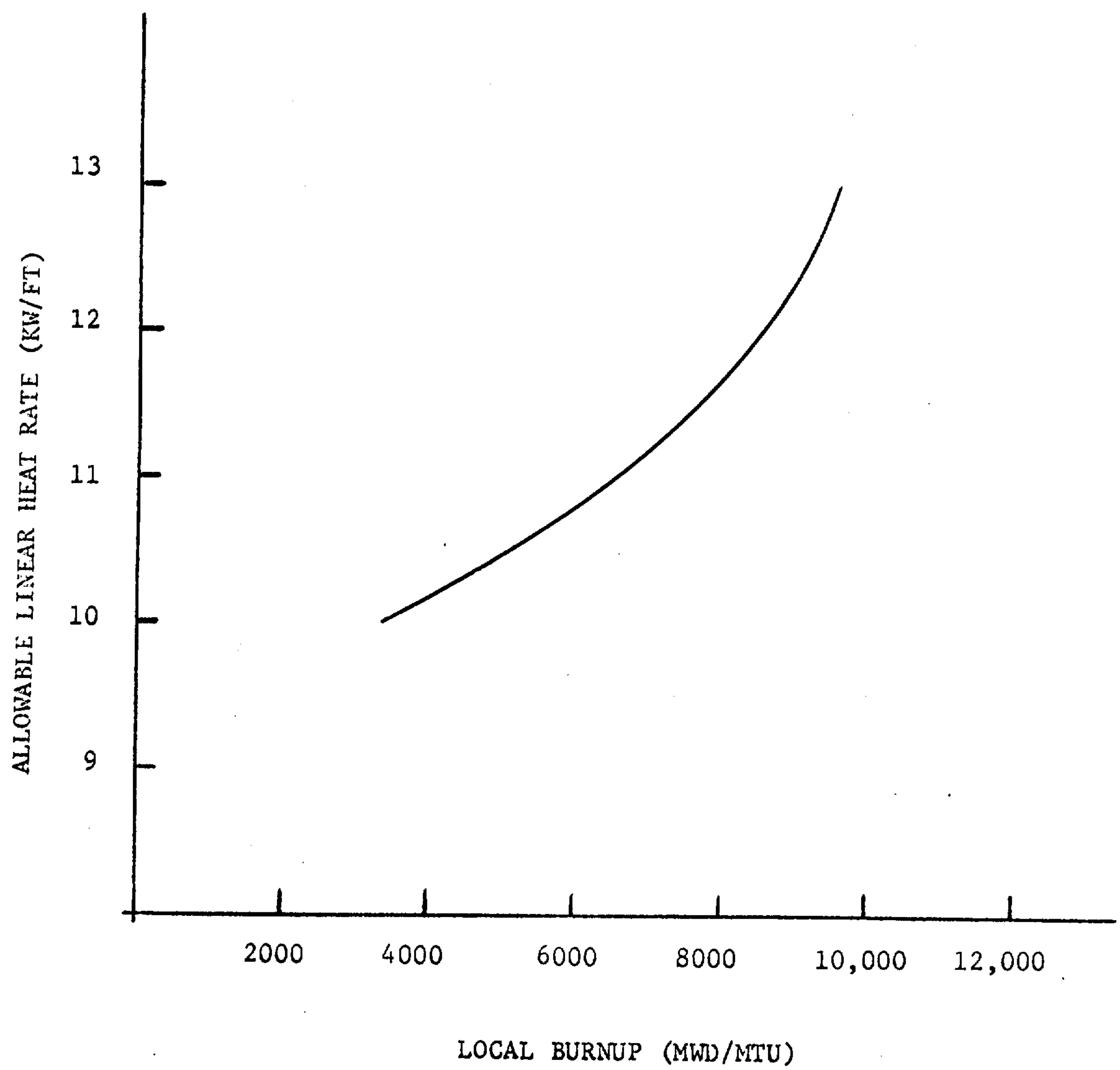
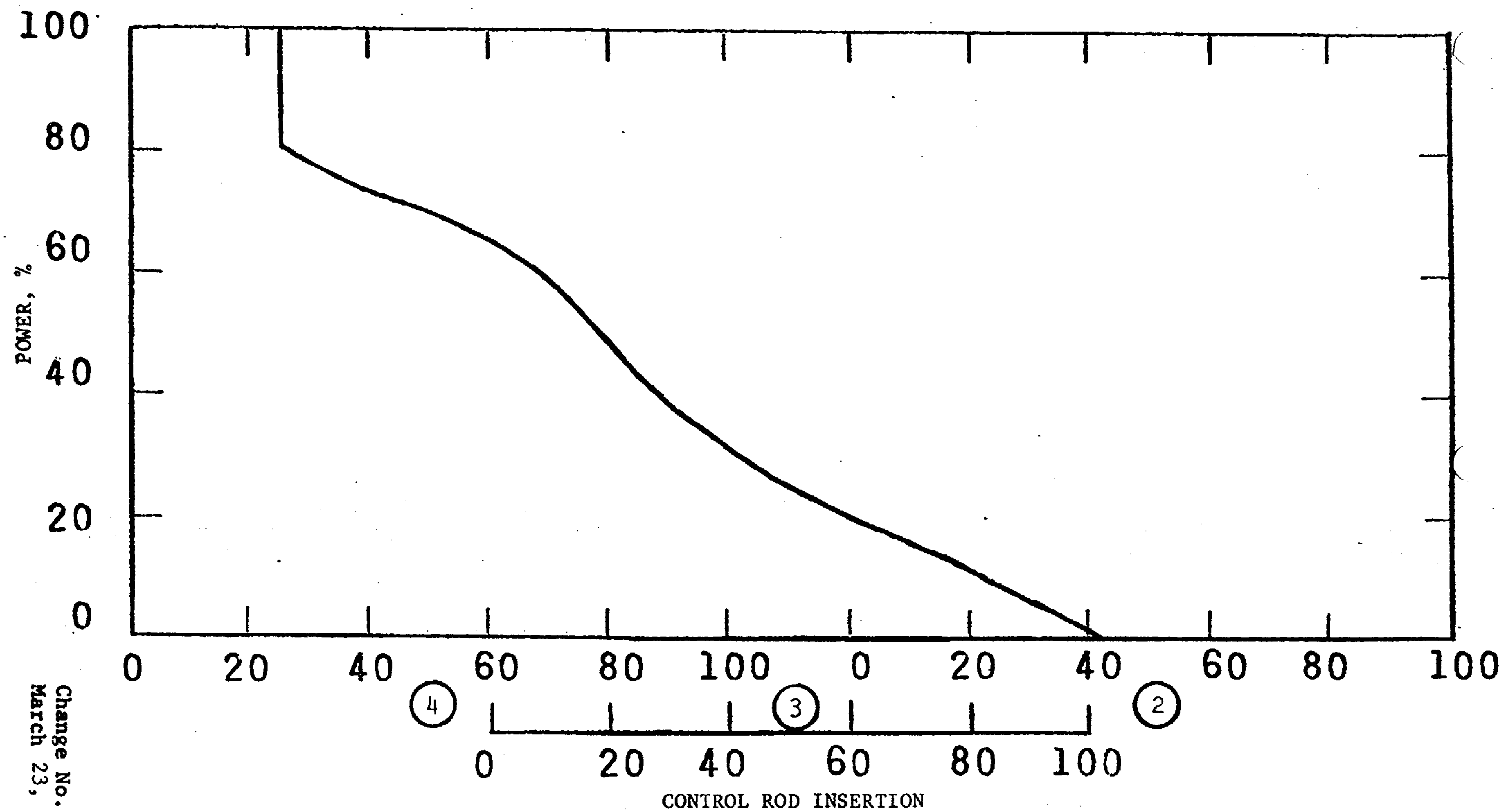


FIGURE B-2

PALISADES PLANT
CONTROL ROD INSERTION LIMITS
ALLOWED POWER LEVEL (% OF 2200 Mwt) VS CONTROL ROD INSERTION (%) BY ROD GROUP



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March 23, 1973