3.10 CORE LIMITS

Applicability: Applies to core conditions required to meet the Final Acceptance Criteria for Emergency Core Cooling Performance.

Objective: To assure conformance to the peak clad temperature limitations during a postulated loss-of-coolant accident as specified in 10 CFR 50.46 (January 4, 1974) and to assure conformance to the 14.5 KW/ft (for V and VB fuel and 13.4 KW/ft (for P8x8R and GE8x8EB fuel) operating limits for local linear heat generation rate.

Specification: A. Average Planar LHGR

During power operation, the average linear heat generation rate (LHGR) of all the rods in any fuel assembly, as a function of average planar exposure, at any axial location shall not exceed:

A.1 Fuel Types V and VB

The product of the maximum average planar LHGR (MAPLHGR) limit shown in Figures 3.10-1 (for 5-loop operation) and 3.10-2 (for 4-loop operation) and the axial MAPLHGR multiplier in Figure 3.10-3.

A.2 Fuel Types P8x8R and GE8x8EB

The maximum average planar LHGR (MAPLHGR) limit shown in Figure 3.10-4 and 3.10-5 for both 5-loop and 4-loop operation.

A.3 If at any time during power operation it is determined by normal surveillance that the limiting value for APLHGR is being exceeded, action shall be initiated to restore operation to within the prescribed limits. If the APLHGR is not returned to within the prescribed limits within two (2) hours, action shall be initiated to bring the reactor to the cold shutdown condition within 36 hours. During this period surveillance and corresponding action shall continue until reactor operation is within the prescribed limits at which time power operation may be continued.

B. Local LHGR

During power operation, the linear heat generation rate (LHGR) of any rod in any fuel assembly, at any axial location shall not exceed the maximum allowable LHGR:

B.1 Fuel Types V and VB

As calculated by the following equation;

$$LHGR \leq LHGR_d \left[1 - \frac{\Delta P}{P} \max \left(\frac{L}{LT} \right) \right]$$

Where: $LHGR_d$ = Limiting LHGR (=14.5)

$\frac{\Delta P}{P}$ = Maximum Power Spiking Penalty (=0.033 and 0.039 for fuel Types V and VB respectively)

LT = Total Core Length - 144 inches
L = Axial position above bottom of core

B.2 Fuel Type P8x8R and GE8x8EB

$LHGR \leq 13.4$ KW/ft.

B.3 If at any time during operation it is determined by normal surveillance that the limiting value of LHGR is being exceeded, action shall be initiated to restore operation to within the prescribed limits. If the LHGR is not returned to within the prescribed limits within two (2) hours, action shall be initiated to bring the reactor to the cold shutdown condition within 36 hours. During this period, surveillance and corresponding action shall continue until reactor operation is within the prescribed limits at which time power operation may be continued.

C. Minimum Critical Power Ratio (MCPR)

During steady state power operation, MCPR shall be greater than or equal to the following:

	APRM STATUS	MCPR Limit
1.	If any two (2) LPRM assemblies which are input to the APRM system and are separated in distance by less than three (3) times the control rod pitch contain a combination of three (3) out of four (4) detectors located in either the A and B or C and D levels which are failed or bypassed i.e., APRM channel or LPRM input bypassed or inoperable.	1.51

	APRM STATUS	MCPR Limit
2.	If any LPRM input to the APRM system at the B, C, or D level is failed or bypassed or any APRM channel is inoperable (or bypassed).	1.51
3.	All B, C, and D LPRM inputs to the APRM system are operating and no APRM channels are inoperable or by passed.	1.51

When APRM status changes due to instrument failure (APRM or LPRM input failure), the MCPR requirement for the degraded condition shall be met within a time interval of eight (8) hours, provided that the control rod block is placed in operation during this interval.

For core flows other than rated, the nominal value for MCPR shall be increased by a factor of k_f, where k_f is as shown in Figure 3.10-6.

If at any time during power operation it is determined by normal surveillance that the limiting value for MCPR is being exceeded for reasons other than instrument failure, action shall be initiated to restore operation to within the prescribed limits. If the steady state MCPR is not returned to within the prescribed limits within two [2] hours, action shall be initiated to bring the reactor to the cold shutdown condition within 36 hours. During this period, surveillance and corresponding action shall continue until reactor operation is within the prescribed limit at which time power operation may be continued.

Bases:

The Specification for average planar LHGR assures that the peak cladding temperature following the postulated design basis loss-of-coolant accident will not exceed the 2200°F limit specified in 10 CFR 50.46 (January 4, 1974) considering the postulated effects of fuel pellet densification.

The peak cladding temperature following a postulated loss-of-coolant accident is primarily a function of the average heat generation rate of all the rods of a fuel assembly at any axial location and is only dependent secondarily on the rod to rod power distribution within an assembly. Since expected location variations in power distribution within a fuel assembly affect the calculated peak clad temperature by less than ± 20°F relative to the peak temperature for a typical fuel design, the limit on the average linear heat generation rate is sufficient to assure that calculated temperatures are below the limits specified in 10 CFR 50.46 (January 4, 1974).

The maximum average planar LHGR limits of fuel types V and VB are shown in Figure 3.10-1 for five loop operation and in Figure 3.10-2 for four loop operation, and are the result of LOCA analyses performed by Exxon Nuclear Company utilizing an evaluation model developed by Exxon Nuclear Company in compliance with Appendix K to 10 CFR 50 (1). Operation is permitted with the four-loop limits of Figure 3.10-2 provided the fifth loop has its discharge valve closed and its bypass and suction valves open. In addition, the maximum average planar LHGR limits shown in Figures 3.10-1 and 3.10-2 for Type V and VB fuel were analyzed with 100% of the spray cooling coefficients specified in Appendix K to 10 CFR Part 50 for 7 x 7 fuel. These spray heat transfer coefficients were justified in the ENC Spray Cooling Heat Transfer Test Program (2).

The maximum average planar LHGR limits of fuel types P8x8R and GE8x8EB are shown in Figure 3.10-4 and Figure 3.10-5, for both 5-loop and 4-loop operation, and are based on calculations employing the models described in Reference 4. Power operation with LHGR's at or below those shown in Figures 3.10-4 and 3.10-5 assures that the peak cladding temperature following a postulated loss-of-coolant accident will not exceed the 2200°F limit.

The effect of axial power profile peak location for fuel types V and VB is evaluated for the worst break size by performing a series of fuel heat-up calculations. A set of multipliers is devised to reduce the allowable bottom skewed axial power peaks relative to center or above center peaked profiles. The major factors which lead to the lower MAPLHGR limits with bottom skewed axial power profiles are the change in canister quench time at the axial peak location and a deterioration in heat transfer during the extended downward flow period during blowdown. The MAPLHGR multiplier in Figure 3.10-3 shall only be applied to MAPLHGR determined by the evaluation model described in reference 1.

The possible effects of fuel pellet densification are:

1) creep collapse of the cladding due to axial gap formation;
2) increase in the LHGR because of pellet column shortening;
3) power spikes due to axial gap formation; and
4) changes in stored energy due to increased radial gap size.

Calculations show that clad collapse is conservatively predicted not to occur during the exposure lifetime of the fuel. Therefore, clad collapse is not considered in the analyses.

Since axial thermal expansion of the fuel pellets is greater than axial shrinkage due to densification, the analyses of peak clad temperatures do not consider any change in LHGR due to pellet column shortening. Although the formation of axial gaps might produce a local power spike at one location on any one rod in a fuel assembly the increase in local density would be on the order of only 2% at the axial midplane. Since small local variations in power distribution have a small effect on peak clad temperature, power spikes were not considered in the analysis of loss-of-coolant accidents(1).

Changes in gap size affect the peak clad temperatures by their effect on pellet clad thermal conductance and fuel pellet stored energy. Treatment of this effect combined with the effects of pellet cracking, relocation and subsequent gap closure are discussed in XN-174. Pellet-clad thermal conductance for Type V and VB fuel was calculated using the GAPEX model (XN-174).

The specification for local LHGR assures that the linear heat generation rate in any rod is less than the limiting linear heat generation rate even if fuel pellet densification is postulated. The power spike penalty for Type V and VB fuel is based on analyses presented in Facility Change Request No.6 and FDSAR Amendment No.76, respectively. The analysis assumes a linearly increasing variation in axial gaps between core bottom and top, and assures with 95% confidence that no more than one fuel rod exceeds the design linear heat generation rate due to power spiking.

The power spike penalty for GE fuel is described in Reference 3.

The loss of coolant accident (LOCA) analyses are performed using an initial core flow that is 70% of the rated value. The rationale for use of this value of flow is based on the possibility of achieving full power (100% rate power) at a reduced flow condition. The magnitude of the reduced flow is limited by the flow relationship for overpower scram. The low flow condition for the LOCA analysis ensures a conservative analysis because this initial condition is associated with a higher initial quality in the core relative to higher flow-lower quality conditions at full power. The high quality-low flow condition for the steady-state core operation results in rapid voiding of the core during the blowdown period of the LOCA. The rapid degradation of the coolant conditions due to voiding results in a decrease in the time to boiling transition and thus degradation of heat transfer with consequent higher peak cladding temperatures. Thus, analysis of the LOCA using 70% flow and 102% power provides a conservative basis for evaluation of the peak cladding temperature and the maximum average planar linear heat generation rate (MAPLHGR) for the reactor.

The APRM response is used to predict when the rod block occurs in the analysis of the rod withdrawal error transient. The transient rod position at the rod block and corresponding MCPR can be determined. The MCPR has been evaluated for different APRM responses which would result from changes in the APRM status as a consequence of bypassed APRM channel and/or failed/bypassed LPRM inputs. The steady state MCPR required to protect the minimum transient CPR of 1.07 for the worst case APRM status condition (APRM Status 1) is determined in the rod withdrawal error transient analysis. The steady state MCPR valves for APRM status conditions 1, 2, and 3 will be evaluated each cycle.

The time interval of eight (8) hours to adjust the steady state of MCPR to account for a degradation in the APRM status is justified on the basis of instituting a control rod block which precludes the possibility of experiencing a rod withdrawal error transient since rod withdrawal is physically prevented. This time interval is adequate to allow the operator to either increase the MCPR to the appropriate value or to upgrade the status of the APRM system while in a condition which prevents the possibility of this transient occurring.

The steady-state MCPR limit was selected to provide margin to accommodate transients and uncertainties in monitoring the core operating state, manufacturing, and in the critical power correlation itself(3). This limit was derived by addition of the CPR for the most limiting abnormal operational transient caused by a single operator error or equipment malfunction to the fuel cladding integrity MCPR limit designated in Specification 2.1.

Transients analyzed each fuel cycle will be evaluated with respect to the steady-state MCPR limit specified in this specification.

The purpose of the K_f factor is to define operating limits at other than rated flow conditions. At less than 100% flow the required MCPR is the product of the operating limit MCPR and the K_f factor. Specifically, the K_f factor provides the required thermal margin to protect against a flow increase transient.

The K_f factor curves shown in Figure 3.10-6 were developed generically using the flow control line corresponding to rated thermal power at rated core flow and are applicable to all BWR/2, BWR/3 and BWR/4 reactors. For the manual flow control mode, the K_f factors were calculated such that at the maximum flow state (as limited by the pump scoop tube set point) and the corresponding core power (along the rated flow control line), the limiting bundle's relative power was adjusted until the MCPR was slightly above the Safety Limit. Using this relative bundle power, the MCPR's were calculated at different points along the rated flow control line corresponding to different core flows. The ratio of the MCPR calculated at a given point of core flow, divided by the operating limit MCPR determines the value of K_f.

REFERENCES

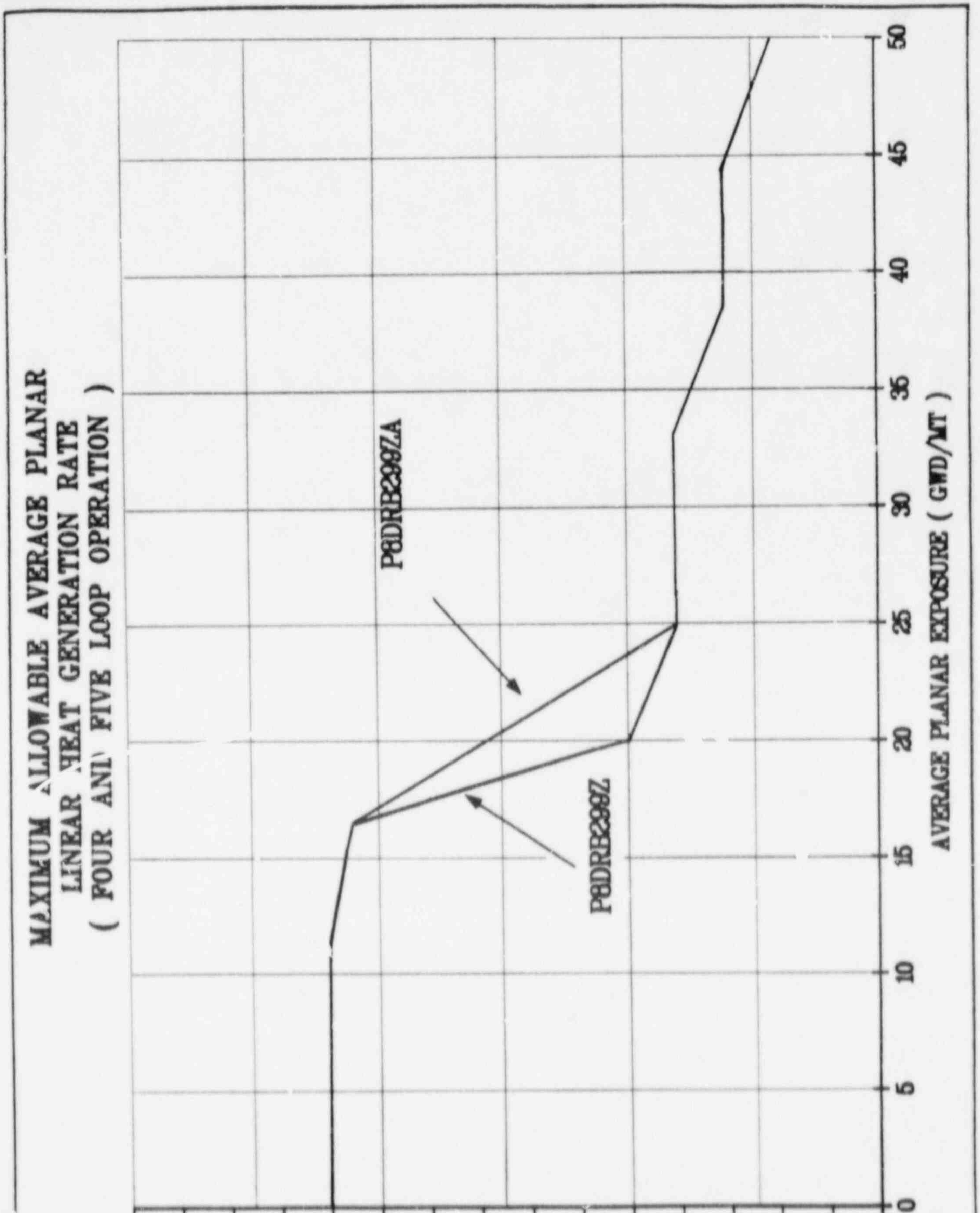
(1) XN-75-55-(A), XN-75-55, Supplement 1-(A), XN-75-55. Supplement 2-(A), Revision 2, "Exxon Nuclear Company WREM-Based NJP-BWR ECCS Evaluation Model and Application to the Oyster Creek plant," April 1977.

(2) XN-75-36 (NP)-(A), XN-75-36 (NP) Supplement 1-(A), "Spray Cooling Heat Transfer phase Test Results, ENC - 8 x 8 BWR Fuel 60 and 63 Active Rods, Interim Report," October 1975.

(3) NEDE-24195; General Electric Reload Fuel Application for Oyster Creek.

(4) NEDE-31462P; "OYSTER CREEK NUCLEAR GENERATING STATION SAFER/CORECOOL/GESTR-LOCA LOSS-OF-COOLANT ACCIDENT ANALYSIS," August 1987.

FIGURE 3.10-4



MAXIMUM ALLOWABLE AVERAGE PLANAR LINEAR HEAT GENERATION RATE (FOUR AND FIVE LOOP OPERATION)

MAXIMUN ALLOWABLE AVERAGE PLANAR LINEAR HEAT GENERATION RATE (FOUR AND FIVE LOOP OPERATION)

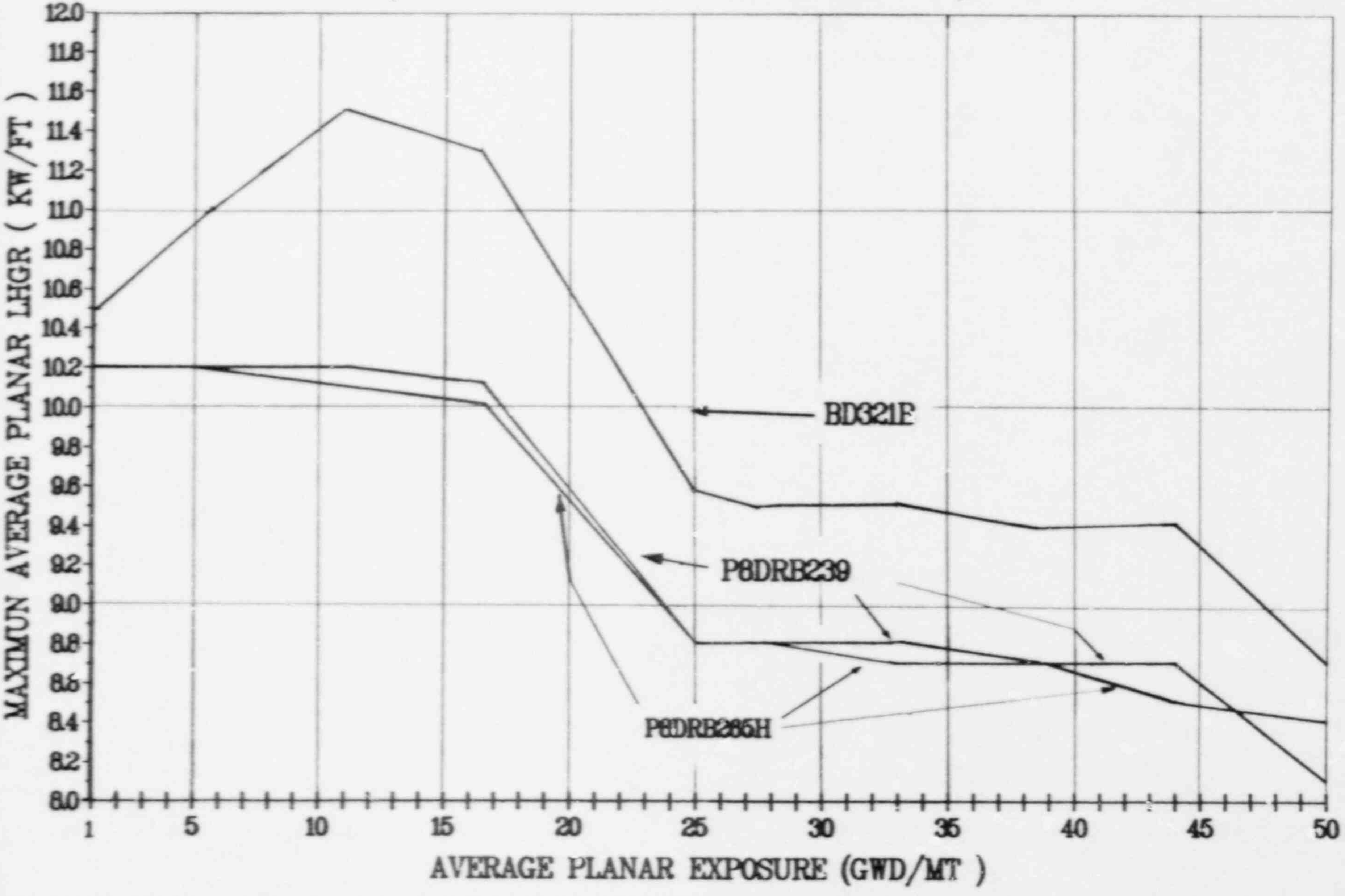


FIGURE 3.10-5