May 26, 1982

RECEIVED
JUN 02 1982
US NUCLEAR REGULATORY COMMISSION
DOCUMENT MANAGEMENT BR
TIDC

Docket No. 50-237
LS05-82-05-062

Mr. L. DelGeorge
Director of Nuclear Licensing
Commonwealth Edison Company
Post Office Box 767
Chicago, Illinois 60690

Dear Mr. DelGeorge:

SUBJECT: SEP TOPIC III-4.B, TURBINE MISSILES - DRESDEN 2

Enclosed is our draft evaluation of SEP Topic III-4.B. The evaluation concludes that the turbine missile risk is acceptably low with the addition of inservice inspections described in the SER.

You are requested to examine the facts upon which the staff has based its evaluation and respond either by confirming that the facts are correct or by identifying errors and supplying the corrected information. We encourage you to supply any other material that might affect the staffs evaluation of this topic or be significant in the integrated assessment of your facility.

Your response is requested within 30 days of receipt of this letter. If no response is received within that time, we will assume that you have no comments or corrections.

Sincerely,

Original signed by:

Paul W. O'Connor, Project Manager
Operating Reactors Branch No. 5
Division of Licensing

SE04
1/1
DS4 USE (16)
ADD:
G. Staley
G. Cwalina

Enclosure:
As stated

cc w/enclosure:
See next page

8206030244 820526
PDR ADOCK 05000237
P PDR

SEPB
GCwalina
5/20/82

5/24/82

OFFICE	SEPB	SEPB	SEPB	ORB#5	ORB#5	AD:SA:DL	
SURNAME	DPersinko:bl	RHermann	WRussell	PO'Connor	DCrutchfield	GLainas	
DATE	5/20/82	5/21/82	5/21/82	~~5/24/82~~	5/26/82	5/25/82	

Mr. L. DelGeorge

cc
Robert G. Fitzgibbons Jr.
Isham, Lincoln & Beale
Counselors at Law
Three First National Plaza
Suite 5200
Chicago, Illinois 60602

Mr. B. B. Stephenson
Plant Superintendent
Dresden Nuclear Power Station
Rural Route #1
Morris, Illinois 60450

The Honorable Tom Corcoran
United States House of Representatives
Washington, D. C. 20515

U. S. Nuclear Regulatory Commission
Resident Inspectors Office
Dresden Station
RR #1
Morris, Illinois 60450

Mary Jo Murray
Assistant Attorney General
Environmental Control Division
188 W. Randolph Street
Suite 2315
Chicago, Illinois 60601

Chairman
Board of Supervisors of
Grundy County
Grundy County Courthouse
Morris, Illinois 60450

John F. Wolf, Esquire
3409 Shepherd Street
Chevy Chase, Maryland 20015

Dr. Linda W. Little
500 Hermitage Drive
Raleigh, North Carolina 27612

Judge Forrest J. Remick
The Carriage House - Apartment 205
2201 L Street, N. W.
Washington, D. C. 20037

Illinois Department of Nuclear Safety
1035 Outer Park Drive, 5th Floor
Springfield, Illinois 62704

U. S. Environmental Protection Agency
Federal Activities Branch
Region V Office
ATTN: Regional Radiation Representati
230 South Dearborn Street
Chicago, Illinois 60604

James G. Keppler, Regional Administrat
Nuclear Regulatory Commission, Region
799 Roosevelt Street
Glen Ellyn, Illinois 60137

SEP REVIEW

OF

TURBINE MISSILES

TOPIC III - 4.B

FOR THE

DRESDEN NUCLEAR POWER PLANT UNIT 2

DRESDEN NUCLEAR POWER PLANT, UNIT NO. 2

TABLE OF CONTENTS

I. INTRODUCTION

The safety objective of Topic III - 4.B is to assure that structures, systems, and components important to safety are adequately protected from potential turbine missiles. Of those systems important to safety, this topic is primarily concerned with safety-related systems; i.e., those structures, systems, or components necessary to perform required safety functions and to ensure:

1. The integrity of the reactor coolant pressure boundry,
2. The capability to shut down the reactor and maintain it in a safe shutdown condition, or
3. The capability to prevent accidents that could result in potential offsite exposures that are a significant fraction of the guideline exposures of 10 CFR Part 100, "Reactor Site Criteria" (Ref.1).

II. REVIEW CRITERIA

According to General Design Criterion 4, of Appendix A to 10 CFR Part 50 (Ref. 2), nuclear power plant structures, systems and components important to safety shall be appropriately protected against dynamic effects, including the effects of missiles. Failures that could occur in large steam turbines of the main turbine-generator have the potential for ejecting large high-energy missiles that can damage plant structures, systems and components. Typical safety - related systems are listed in Regulatory Guide (RG) 1.117 (Ref. 3). RG 1.115 (Ref. 4) describes methods for protecting safety related systems against low trajectory missiles (LTMs) resulting from turbine failure, and outlines methods for evaluating and calculating the probability of unacceptable damage to these systems. Turbine missile safety evaluations are prepared with the aid of the above Regulatory Guides and Standard Review Plan (SRP) Sections 3.5.1.3 (Ref. 5) and 2.2.3 (Ref. 6).

III. RELATED SAFETY TOPICS AND INTERFACES

The scope of review for this topic was limited to avoid duplication of effort since some aspects of the review were performed under related topics. The related topics and their subject matter are identified in Table I. Each of the related topic reports contains the acceptance criteria and review guidance for its subject matter. The review for this topic makes specific and direct use of information provided in reviews of Topics VII-3, and XV-18. Topic XV-18 is particularly significant since turbine failure resulting in the rupture of the turbine casing is approximately equivalent to a main steam line failure outside containment, which for a BWR releases primary coolant steam and radioactivity to the environment. Hence, regardless of the probability of turbine missiles striking safety related structures, systems, or components, the criteria of Topic XV-18 must be satisfied in order to meet the criteria of this topic.

IV. REVIEW GUIDELINES

Evaluation of the risk associated with turbine missiles involves (1) identification of safety related structures systems and components, (2) definition of potential missiles and their probability of occurrence, (3) quantitative and qualitative descriptions of strike probabilities, and

TABLE I

RELATED SAFETY TOPICS AND INTERFACES

TOPIC #	TITLE
VII-3	Systems Required for Safe Shutdown
IX-3	Station Service and Cooling Water Systems
IX-5	Ventilation Systems
XV-3	Loss of External Load, Turbine Trip, Loss of Condenser Vacuum, Closure of Main Steam Isolation Valve (BWR), and Steam Pressure Regulation Failure (Closed)
XV-7	Reactor Coolant Pump Rotor Seizure and Reactor Coolant Pump Shaft Break
XV-18	Radiological Consequences of Main Steam Line Failure Outside Containment (BWR)

4) specification of unacceptable damage to safety related structures, systems, and components.

1. RG 1.117 (Ref. 3) and the SEP Review of Safe Shutdown Systems for the plant (Ref. 7) are used to identify safety related targets. Target location coordinates relative to missile origins can usually be obtained from plant layout drawings (plan and evaluation views) to within about $\pm$ 3 ft. Obtaining a "complete" list of safety related targets with their locations is always a concern. It should be noted that plant layout drawings undergo changes with time, and are generally not complete, in that not all safety related targets are shown on them. For example, most safety related piping (which does not appear on layout drawings), and vital power lines and buses are difficult to locate and take into account precisely in an analysis. Hence, the estimation of "equivalent target areas and locations" is frequently required.

2. Fragments from low pressure turbine wheels are considered the primary missiles produced during turbine failure. There are basically two modes of turbine failure that can result in the ejection of missiles; a) a design overspeed failure, caused by flaw induced failure of turbine wheel material at approximately the normal operating speed, and b) a destructive overspeed failure, due to failure of the overspeed control system. With few exceptions, for other turbine failures, broken parts are relatively small and contained within the turbine casing. The turbine vendor provides the licensee with the turbine information required for an evaluation. This information consists of rotor shaft rotational speeds, wheel characteristic (weights, locations, etc.),

kinetic properties of potential missiles, missile generation probabilities, and steam valve characteristics. In the absence of NRC reviewed and accepted plant specific data on missile generation probabilities [P_1 (design) and P_1 (destructive)] historical data (Ref's 8 and 9) are used to estimate the likehood of missile-producing turbine failure. Should the vendor present data only on destructive overspeed failure, an analysis of strike and damage probabilities for destructive overspeed may be used to obtain a total probability of unacceptable damage provided the value of $P_1 = 10^{-4}$ per turbine year is used for the total probability of missile generation.

3. Missile collisions with barriers and targets are acceptably estimated with the methods described in the SRP Section 3.5.1.3 (Ref. 5) and RG 1.115 (Ref. 4). As with targets, barrier location coordinates, relative to the origin of the missiles, can be obtained from plant layout drawings. The barrier perforation formulae currently used by the NRC in reviewing concrete barrier adequacy is the CEA-EDF formula (Ref. 10). The approach presented in References 4 and 5 differentiates between high and low trajectory missiles.

   a) High trajectory missiles (HTMs) are characterized by their nearly vertical trajectories. Missiles ejected more than a few degrees from the vertical are approximated to either have sufficent speed such that they land offsite, or have speeds low enough so that their impact on most plant structures is not a significant hazard. Currently, the NRC accepts, for a given failure mode (k), the following formula for approximating the HTM strike probability for each missile (i) from each wheel (j):

$$^{ij*}P_2(\mathrm{HTM}) = \frac{g^2 A}{12\ {}^{j}\Omega_t\ ({}^{i}V_M - {}^{i}V_m)} \left[\frac{1}{{}^{i}V_m^3} - \frac{1}{{}^{i}V_M^3} \right]$$

where ${}^{i}V_M$ = maximum missile ejection velocity [ft/sec],

${}^{i}V_m$ = minimum missile - barrier perforation velocity [ft/sec],

g = acceleration of gravity [32.2 ft/sec^2],

A = total horizontal target area [ft^2],

${}^{j}\Omega_t$ = total solid angle into which the missile can emerge

[= 1.10 steradians, for missiles from interior wheels (azimuthal angle range $\pm$ 5°).

= 2.66 steradians, for missiles from end wheels (aximuthal angle range, 0 to $\pm$ 25°).]

Hence, the total HTM strike probability for N wheels, each of which produces n missiles, is:

$$^{k}P_2\ (\mathrm{HTM}) = \frac{1}{4N} \sum_{j}^{N} \sum_{i}^{n} {}^{ij*}P_2\ (\mathrm{HTM})$$

b) In estimating the strike probability for low trajectory missiles (LTMs), i.e., $^{k}P_2$ (LTM), the missiles may be assumed to originate at the turbine shaft centerline and have straight line trajectories (Ref. 5). According to the model described in Reference 5, safety-related targets and barriers are approximated as planes parallel to the turbine axis. That is, the model presented does not take into account the complex geometric configurations of targets or barriers, the probability of barriers deflecting missiles toward or away from targets, or the actual parabolic trajectory of the missiles, hence, the definition of eqivalent target areas or missile trajectories may sometimes be required. Targets which are located outside the LTM strike zone (Ref. 4) are considered protected from LTMs.

Therefore, the total strike probability for a given failure mode is acceptably estimated by the above procedures as

$$^{k}P_2 = {}^{k}P_2 \ \text{(HTM)} + {}^{k}P_2 \ \text{(LTM)}$$

If the target is electronic equipment, electrical cables, or buses, then scabbing velocities should be used in place of perforation velocities in evaluation the final barrier to allow for the damaging effects of secondary missiles.

4. In general, any missile which perforates the portion of the final barrier between the turbine and the target is assumed to cause unacceptable damage to the target. Therefore, when a missile is estimated to perforate the final barrier, the probability of damaging a struck target ($^{*}P_3$) is assumed to be $^{*}P_3 = 1.$, unless data or analyses are presented to justify some other valve.

Based on the above defined probabilities, the proability of unacceptable damage to a plant due to turbine failure is

$$P_4 = \sum_{k=1}^{2} {}^{k}P_1 \ {}^{k}P_2 \ {}^{k}P_3 \ \text{per turbine year.}$$

Standard Review Plant Section 2.2.3 (Ref. 6) is employed to evaluate the calculated probability of unacceptable target damage. Because of the difficulty of assigning accurate numerical values to parameters which define the expected rate of occurrence of unacceptable damage to safety-related structures, systems or components, the probability of approximately 10^{-6} per year is currently considered acceptable if, when combined with reasonable qualitative arguments, the actual probability can be shown to be lower.

V. EVALUATION

1. Target Information

This topic is primarily concerned with ensuring a) the integrity of the reactor coolant pressure boundary, b) the capability to shutdown the reactor and maintain it in a safe shutdown condition, and c) the prevention of significant radioactive release to the environment (Ref. 1). The class 1E electrical ~~systems~~, including the auxiliary systems for the onsite electric power supplies, that provide the emergency electrical power needed for the function of safety related systems are taken into consideration in this evaluation. Those structures, systems, and components whose continued functioning is not required but whose failure could reduce to an unacceptable safety level the functional capability of any safety related system or could result in incapacitating injury to occupants of the control room are also taken into consideration.

a) Reactor Coolant Pressure Boundary

The Dresden Unit 2 reactor coolant pressure boundary consists of the pressure vessel, the recirculation loops and pumps, the high pressure and low pressure coolant injection (ie., HPCI and LPCI) and isolation condenser (ie., IC) piping, and the feedwater and

and main steam systems up to and including the outermost containment isolation valves in system piping which penetrates primary reactor containment. Due to the complexity of the reactor coolant pressure boundary geometry, this target area is taken to be the cross sectional area of the drywell interior. The cross sectional area of the steam tunnel is also considered a safety related target since a missile entering this area could prevent closure of the main steam isolation valves.

b) Safe Shutdown Systems

The staff and the licensee have developed a "minimum list" of systems necessary to take the reactor from operating conditions to cold shutdown (Ref. 7). Although other systems may be used to perform shutdown and cooldown functions, the following list is the minimum number of systems required to fulfill the BTP RSB 5-1 criteria: Reactor Control and Protection Systems; Electromatic Relief valves; LPCI System; HPCI System; Emergency Service Water (ESW) System; Instrumentation for shutdown and cooldown; and Emergency Power (AC and DC) and Control Power for the above systems and equipment.

The entire reactor control room is considered the prime target area for the Reactor Control and Protection System. Although the control room is, by location, adequately protected for LTMs, being outside the LTM strike zone, it is a target for HTMs. The reactor control and protection buses behind the Reactor Building Closed Cooling Water

(RBCCW) pumps are considered LTM targets. Also, the electrical cable tunnel leading from Unit 3 to the control room is a target for LTMs.

The LPCI System is considered adequately protected from all turbine missiles, being located below ground level along the reactor building (RB) wall farthest from the turbine and behind the dry-well.

The HPCI system is below ground level, located in the HPCI building behind the Unit 3 reactor building (ie. along the RB wall farthest from the turbine) and, hence, adequately protected from LTMs, although it is a target for HTMs.

The ESW System, also called the Containment Cooling Water (CCW) System, consist of four pumps (located in the turbine building) and two heat exchanges (located below ground level in the far corners of the RB, relative to the turbine) which draw water from two contaminated condensite storage tanks. Only the pumps and storage tanks are so located as to be considered turbine missile targets.

The torus shaped pressure suppression chamber, the hydraulic control rod drive (HCRD) system, and the standby Liquid control (SLC) system are the only instruments for shutdown and cooldown which have not been included in one or more of the above systems. The pressure suppression chamber is not considered a turbine missiles target since it is shadowed from turbine missiles by the turbine pedestal and the RB and drywell super-structure. However, the HCRD system and the SLC system are considered targets, although the former is at least partially shadowed by the turbine pedestal and the RB superstructure and the latter is viewed as a back up system.

Station batteries and diesel generators are the control power and emergency power sources for safe shutdown and cooldown systems and equipment. The battery room is located over the control room and, hence is a target only for HTMs. There are two diesel generators available to Dresden Unit 2 (as well as Unit 3); one is located at ground floor level of the turbine building outside the LTM strike zone, and the other - shared by Units 2 and 3 - is located below ground level in the HPCI building. Therefore, neither are LTM targets, and, although they could be struck by HTMs, neither are considered HTM targets since, due to their physical separation and the fact that only one generator is required for safe shutdown, one missile cannot strike both generators, and the probability of two missiles from a single failure event each hitting a different generator is considered negligible.

The IC system was added to the safe shutdown and cooldown systems list since it would normally be relied on as the first choice of the operator for cooling the plant upon loss of the main condenser (which is, of course, not available during a turbine failure). While the IC system is on the side of the dry well opposite the turbine and therefore, protected from LTMs, the IC condenser, located in the RB at the 589 ft level, is considered a target for HTMs.

The entire Crib House, which contains pumps for the diesel generator cooling water (needed to cool the diesel generations and the HPCI and LPCI room coolers), the service water supply, and the fire protection water system, is a target for turbine missiles.

Note, for the reasons discussed in SEP Topic IX-3, the RBCCW system is not considered a target for turbine missiles.

c) Sources of Radioactive Release

Outside the reactor coolant pressure boundary the only significant sources of radioactivity are the ~~spent~~ fuel in the spent fuel storage pool, and liquid and gaseous radioactive waste stored in the offgas filter building and in-and-around the radwaste building. Since it is necessary not only to protect the spent fuel from direct missile strike, but also preclude significant loss of watertight integrity of the storage pool, either of which could result in the release of radioactivity and offsite exposures that are a significant fraction of the guideline exposures of 10 CFR Part 100, the entire spent fuel pool is taken as a turbine missile target. Similarily, the offgas filter building is considered a turbine missile target; however, since the charcoal adsorber beds and most vital equipment are below ground level, the building is considered a target only for HTMs. The radwaste building and associated radioactive waste storage tanks were not considered turbine missile targets. According to Technical Specification 3.8, the activity of material stored there is below the limits specified in 10 CFR Part 20; it was assumed that it could not contribute to the 10 CFR Part 100 specified limits at the enclusion area boundary or the low population zone. It should be noted that a turbine failure which results in turbine casing rupture is roughly equivalent to a main steam line failure outside containment. For a BWR, rupture of the pressure boundary outside containment will allow radioactivity contained in the coolant to escape to the environment. Hence, a turbine failure with turbine casing rupture, in itself, constitutes a potential hazard to public health and safety, regardless of missile ejection. The radiological consequences of such a failure are reviewed under Topic XV - 18. Targets considered in the analysis of unacceptable damage due to potential ejection of high and low trajectory missiles during turbine failure are summarized in Table II. Note that, except for the Electric Cable Tunnel (Unit 3) and the Contaminated Condensate Storage Tanks, safety related systems for Unit 3 do not lie in the Unit 2 LTM strike zone. However, safety related systems associated with Unit 3 that are potentially susceptible to HTMs were taken into account in this evaluation, as indicated in the table. Unit 1 safety related systems were ignored.

2. Turbine Data

Dresden Unit 2 has a condensing 1800 RPM, General Electic Company, code type N1 turbine with 38" long last stage buckets. This is a tandem compound unit with three 2-flow low pressure (LP) hoods and one 2-flow high pressure (HP) section. Each of the three, similar, low pressure turbines has 8 wheels at each end, and each wheel carries a single row of buckets. Steam from the high pressure turbine is sent through a moisture separator for removel of entrained water before entering the LP turbines, steam is exhausted from the three LP turbines into a three section condenser.

TABLE II

POTENTIAL TURBINE MISSILE TARGETS *

Structures, Systems and components	HTM ** Units 2	3	LTM ** Units 2	3
a) Reactor Coolant Pressure Boundary				
Drywell Interior	x	x	x	
Steam Tunnel	x	x	x	
b) Safe Shutdown				
Control Room	- x -			
Reactor Control and Protection Buses			x	
Electrical Cable Tunnel (Unit 3)				x
HPCI pumps and heat exchanges	x	x		
ESW (ie., CCW) pumps	~~x~~	x	x	
Contaminated CSTs	- x -		- x -	
HCRD System			x	
SLC System	x	x	x	
Battery Room	x	x		
IC System	x	x		
Crib House	- x -		- x -	
c) Sources of Radioactive Release				
Spent fuel Pool	x	x	x	
Offgas filter Building	- x -			

* These targets were considered sufficently vulnerable to warrant a detailed barrier analysis to determine whether or not they can be struck.

** A x under a given unit number indicates that the target for that unit is considered potentially vulnerable to HTMs (or LTMs) from Unit 2. The notation - x - indicates that a particular target (i.e. safety related system) which serves both units is potentially vulnerable.

This unit is not a current production "38 inch last stage bucket" unit. The vane pitch diameter is smaller and, consequently, the wheel stresses are lower, resulting in a smaller wheel than is used on current units. Wheels are designated by their stage number and wheel location number; Table III shows the Dresden Unit 2 LP turbine wheel weights and locations with stage and wheel location numbers. Correspondingly, vendor estimated, wheel fragment projected areas and exit velocities for a postulated destructive overspeed failure are presented in Table IV, assuming wheels burst into 120 degree segments at approximately 180 percent of normal operating speed.

3. Analysis

In general, the total strike probability ~~P_2~~ is estimated as a sum, over all missile-target combinations, of products of geometric and perforation probabilities. For this purpose, the geometric probability is defined as the ratio of the solid angle subtended by the target to the maximum possible solid angle associated with the ejected missile (see Section IV of this Topical, and Ref. 5). Correspondingly, the perforation probability is defined as the probability that the missile will perforate intervening barriers and hit the final barrier in front of the target with sufficient energy to either perforate it and strike the target or cause scabbing, in which case secondary missiles are assumed to strike the target.

TABLE III

LOW PRESSURE TURBINE WHEEL WEIGHTS

AND LOCATIONS

Order No.	Stage No.	Wheel No.	Weight (lbs)	Location * (ft)
1	14	L-0	12438	-7.29
2	13	L-1	8098	-5.96
3	12	L-2	7288	-4.94
4	11	L-3	6606	-4.06
5	10	L-4	5721	-3.23
6	9	L-5	5613	-2.46
7	8	L-6	5424	-1.67
8	7	L-7	4397	- .67

* This is the distance along the turbine shaft from the center line of the steam inlet to the center line of the wheel.

TABLE IV

POSTULATED TURBINE MISSILE DATA FOR

DESTRUCTIVE OVERSPEED

FAILURE

WHEEL NO.	WEIGHT	AREA	MIN.	MAX.
1	4146.0	557.0	334.7	510.0
	"	906.5	"	"
	"	1256.0	"	"
2	2699.0	298.0	20.0	550.0
	"	495.4	"	"
	"	692.8	"	"
3	2429.0	298.0	"	"
	"	495.4	"	"
	"	692.8	"	"
4	2202.0	298.0	"	"
	"	495.4	"	"
	"	692.8	"	"
5	1907.0	213.0	"	470.0
	"	368.9	"	"
	"	524.8	"	"
6	1871.0	213.0	"	"
	"	368.9	"	"
	"	524.8	"	"
7	1808.0	213.0	"	"
	"	368.9	"	"
	"	524.8	"	"
8	1466.0	213.0	"	"
	"	368.9	"	"
	"	524.8	"	"

The evaluation performed for this SER involved an analysis of the geometric strike probability for the targets listed in Table II, a separate analysis of the perforability of intervening barriers, and an integrated assessment of the resulting turbine missile risk.

a) Geometric Strike Probability

The procedure used to calculate the LTM geometric strike probability is described in Ref. 5. Following this procedure, the LTM strike probability for the targets listed in Table II, based on the postulated turbine missile data presented in Tables III and IV, is about 8×10^{-2}, if no credit is taken for intervening barriers, i.e., structural members, radiation shields, and non-safety related equipment between the turbine and the targets. Based on this strike probability, the probability of unacceptable damage to safety related structures, systems, and components would be unacceptable according to RG 1.115 and SRP Sections 3.5.1.3 and 2.2.3. However, there are numerous barriers between these targets and the turbine which must be taken into account.

b) Barrier Analysis

The method of analysis employed involves the computation of residual velocities for the pertinent missiles in the turbine missile spectrum acting on the structural barriers between the turbine and the various targets. Residual velocities were computed in accordance with the recommendations contained in a paper by George E. Sliter (Ref. 10). The CEA-EDF formulas for perforation and residual velocity were used. A calculation was also made with the NDRC formula which was found to be overly conservative based on the results reported by Sliter in the above mentioned paper and in reports of full scale tests.

(i) Low Trajectory Missiles

In general, targets outside of the turbine building and below the main floor (elevation 561'-6") are not vulnerable to low-trajectory turbine missiles because of the number and size of structural barriers. The CCWS Pumps are partially protected from low-trajectory turbine missiles by the turbine supports, as is the electrical cable tunnel (Unit 3); however, adequate shielding does not completely shadow the effective target areas; therefore, these targets are vulnerable even though the pedestal and supports, which partially shield them, cannot be perforated by any of the postulated missiles.

For low-trajectory turbine missiles ejected above the main floor, the only targets which are vulnerable are the contaminated condensate storage tanks and the standby liquid control system. Table V summarizes the results of the barrier analysis for low trajectory turbine missiles.

TABLE V

TARGET VULNERABILITY

LOW TRAJECTORY TURBINE MISSILES

TARGET	POSSIBLE MISSILES*	BARRIERS**	CONCLUSION
1. Drywell Interior	Wheel Nos. 1 through 8	78" Drywell Wall, 39" Reactor Building Wall, 24" Radiation Shield	Not Vulnerable to any missiles
2. Spent Fuel Storage Pool	"	62" Fuel Pool Wall, 39" Reactor Building Wall	Not Vulnerable to any missiles
3. Electrical Cable Tunnel (Unit 3)	"	24" Radiation Shield, (132" Turbine Pedestal)	Vulnerable to all missiles, however, partially shadowed
4. Steam Pipe Tunnel	"	132" Turbine Pedestal, 39" Reactor Building Wall	Not Vulnerable to any missiles
5. Stand-by Liquid Control System	"	None	Vulnerable to all missiles
6. Reactor Control and Protection Buses	"	24" Radiation Shield, 39" Reactor Building Wall, 48" Reactor Building Wall	Not Vulnerable to any missiles
7. HCRD System	"	24" Radiation Shield, 39" Reactor Building Wall, 48" Reactor Building, Wall	Not Vulnerable to any missiles

TABLE V (CONTINUED)

TARGET	POSSIBLE MISSILES*	BARRIERS**	CONCLUSION
8. CCWS Pumps	"	(132" Turbine Pedestal)	Vulnerable to all missiles, however, partially shadowed
9. Crib House	"	132" Turbine Pedestal	Not Vulnerable to all missiles.
10. Contaminated Condensate Storage Tanks	"	None	Vulnerable to all missiles, however, partially shadowed

* See tabulation of missile spectrum, Table IV

** Assumed f'c=4000 psi, for concrete barriers; those closest to target listed first.

( ) Indicate a barrier that partially shadows the target.

(ii) High Trajectory Missiles

For high-trajectory turbine missiles virtually any target in the plant is vulnerable except the following:

- The drywell is not vulnerable to any high-trajectory turbine missiles. This includes the drywell head although the radiation shield above the drywell head could be penetrated to a depth of approximately four feet by the worst case high-trajectory missile.
- Equipment in the reactor building outside the drywell and below the 517'-6" level is not vulnerable to high-trajectory missiles from wheels 5 through 8.

As shown in Section IV of this SEP Topic, the HTM strike probability is a function of the perforation velocity for the ceiling or roof covering the target. For convenience in analysis, each safety related target, on the average, is conservatively assumed to be covered by a ceiling 18 inches thick. According to the methods employed here (Ref. 10), the mean perforation velocity for the most energetic postulated turbine missiles incident on a 18 inches thick reinforced concrete barrier with a compressive strength of 4000 psi is 158 ft/sec.

c) Discussion

(i) Low Trajectory Missiles

Of the ten potential targets for low trajectory missiles (see Table II), our barrier analysis showed that only the following four are vulnerable: the Electrical Cable Tunnel

(Unit 3); the Stand-by Liquid Control System; the CCWS Pumps; the Contaminated Condensate Storage Tanks. That is, by the staff's calculations, the postulated maximum energy missiles from all wheels can perforate intervening barriers and strike these targets. For the maximum energy missiles, the resulting total strike probability for LTMs is 1.6×10^{-2}; the largest contributions to the total are associated with the Electrical Cable Tunnel, 8×10^{-3}, and the Contaminated Condensate Storage Tanks, 7×10^{-3}, With regard to the Electrical Cable Tunnel, credit was not taken for the high angle of incidence (greater than 45 degrees from normal) for turbine missiles on the tunnel wall, which would tend to result in missile deflection rather than perforation. Also, for none of the targets was credit taken for the fact that existing missiles would have a velocity distribution ranging from near zero to maximum, which could be reasonably expected to decrease the resulting strike probability by a factor of about two. In the staff's opinion, these conservatisms indicate that the actual strike probability is well within the range 10^{-3} to 10^{-2}.

(ii) High Trajectory Missiles

Of the twenty potential targets for high trajectory missiles (see Table II) our barrier analysis showed that all but the two drywells are vulnerable. For estimating the strike probability, the entire floor area of the room containing a given safety related system was taken in some cases as the effective area of the system. The total horizontal area of all targets vulnerable to HTMs was approximated to be 32600 ft^2. For a uniform distribution of missile velocities, from the ceiling perforation velocity to the maximum missile velocity, the resulting total strike probability for HTMs was calculated to be 1.7×10^{-3}. Furthermore, due to conservatisms involved in estimating the target area and ceiling thickness, we believe the actual HTM strike probability is below 10^{-3}.

As a result, based on a missile generation rate P_1 of 10^{-4} per year, the staff estimates that total probability of unacceptable damage P_4 (see Section IV) from low and high trajectory missiles is less than 10^{-6} per year.

(iii) Other Factors

We have also reviewed other factors that have a bearing on the probability of missile generation at both design and destructive overspeed.

Protection against destructive overspeed failure is accomplished by three independent systems; i.e., a normal speed governor, and mechanical and electrical backup overspeed control systems. Assuming 100% steam flow and 100% on the load selector, the control valves will throttle to try to limit overspeed to a setpoint of 105% of turbine speed. Due to large quantities of steam contained in the turbine and separators, turbine speed may increase even after control valves have closed. Upon which the intercept valves will throttle closed at 105% to a setpoint of 107% of turbine speed. If turbine speed increased to 110%, a mechanical turbine trip would occur, closing the main stop valves as well as the control and intercept valves. As backup protection for the 110% mechanical trip, there is an electrical overspeed trip of 112%. Every refueling outage the turbine is tested for a mechanical overspeed trip of 110% turbine speed and an electrical overspeed trip of 112% turbine speed (Ref. 11).

The following Dresden Station procedures (Ref. 12) are used to assure reliability of the turbine overspeed protection system: (a) Each of the main stop valves, the extraction valves for the D, C, and B extractions, and each of the six intercept stop valves and intercept valves are exercised daily; (b) the control valves and 24-volt Master Trip Solenoid valves are exercised weekly; and (c) the turbine auxiliary system is tested weekly. While the staff finds these procedures acceptable, we recommend addition of the following: At approximately 3-1/3-year intervals, during refueling or maintenance shutdowns coinciding with the inservice inspection schedule required by Section XI of the ASME Code for reactor components, at least one main steam stop valve, one main steam control valve, one reheat stop valve, and one reheat intercept valve should be dismantled and visual and surface examinations conducted of valve seats, disks, and stems. If unacceptable flaws or excessive corrosion are found in a valve, all other valves of that type should be dismantled and inspected. Valve bushings should be inspected and cleaned, and bore diameters should be checked for proper clearance. The staff concludes that the Dresden Station procedures, together with our recommendation, constitute adequate assurance of turbine overspeed control system reliability.

The Dresden Station Unit No. 2 turbine-generator was manufactured by General Electric. During the past several years the results of turbine inspections at operating nuclear facilities indicate that cracking to various degrees has occurred at the inner radius of turbine disks or wheels. Some of the turbines in which wheel bore cracks have been identified are of General Electric design. The staff has been following this development closely and, together with the respective turbine manufacturers, is in the process of developing new criteria and procedures for establishing turbine wheel inspection frequencies, as well as guidance for turbine overspeed control system maintenance and testing to preclude wheel failures.

As a result of the cracks found recently, General Electric has provided specific inspection recommendations to utility owners for each LP turbine not yet inspected, which will have been in service for six years or more as of the end of 1982. Included are both machines operating in BWR and PWR plants. These recommendations involve inspecting each machine within a period of one year or less.

With regard to the Dresden Station Unit No. 2 L.P. turbines, a January 1981 wheel bore ultrasonic examination by General Electric detected indications on the bore surfaces of numerous wheels. All of these indications were shallow and not expected to affect the structural integrity of the wheels. Keyway indications were also detected. These indications varied from less than .03 inches to a maximum of .29 inches. In performing calculations to determine the reinspection interval for these L. P. turbines, General Electric conservatively assumed that either stress corrosion cracks were present or that they initiated as soon as the unit was put back on line. The reinspection interval was based on the current NRC criteria which states that a wheel which contains indications must be reinspected in one half the calculated time required to reach one half the critical crack size. With this criteria, General Electric estimates that these turbines should be reinspected within six years. The NRC staff currently accepts this wheel reinspection schedule.

VI. Summary

We conclude that, provided the criteria of Topic XV-18 are satisfied and the inservice inspection schedules discussed in this report are followed, the total turbine missile risk from high and low trajectory missiles for the Dresden Station Unit No. 2 design is acceptably low so that the plant structure, systems, and components important to safety are adequately protected against potential turbine missiles.

VII. REFERENCES

1. Volume 10, Code of Federal Regulations, Part 100, "Reactor Site Criteria."

2. Volume 10, Code of Federal Regulations, Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants."

3. Regulatory Guide 1.117, "Tornado Design Classification," June 1976.

4. Regulatory Guide 1.115, "Protection Against Low-Trajectory Turbine Missiles," Rev. 1, July 1977.

5. Standard Review Plan Section 3.5.1.3, "Turbine Missiles," Rev. 1.

6. Standard Review Plan Section 2.2.3, "Evaluation of Potential Accidents," Rev. 1.

7. Topic VII-3, SEP Review of Safe Shutdown Systems for the Dresden Unit 2 Nuclear Plant, Rev. 1, September 1980.

8. Bush, S. H., "Probability of Damage to Nuclear Components Due to Turbine Failure," Nuclear Safety, Vol. 14, No. 3, May-June 1973.

9. Bush, S. H., "A Reassessment of Turbine-Generator-Failure Probability," Nuclear Safety, Vol. 19, No. 6, Nov.-Dec. 1978.

10. Sliter, G. E., "Residual Velocity of Missiles Perforating Concrete," Second ASCE Conference on Civil Engineering and Nuclear Power, Knoxville, Tennessee, Vol. IV, 1980, p. 5-3-1.

11. Dresden Operating Surveillance Procedure DOS 5600-1, Rev. 0, April 1976.

12. Dresden Operating Surveillance Procedure DOS 5600-2, Rev. 4, February 1978.