March 1978

VALUE-IMPACT STATEMENT FOR PROPOSED REGULATORY GUIDE 1.133, "LOOSE-PART DETECTION PROGRAM FOR THE PRIMARY SYSTEM OF LIGHT-WATER-COOLED REACTORS"

Technical Issue

There have been a large number of cases, see Table 1, where loose parts have occurred in the primary system of operating pressurized water (PWR) and boiling water (BWR) reactors. These loose parts have resulted from:

1. Component structural failures
2. Objects being inadvertently left in the system at the time of construction, routine maintenance, refueling and repair operations.

Loose parts have the potential for causing or being the result of safety related damage in both PWR and BWR light-water-cooled reactors, see Table 2. Such damage relates primarily to:

1. Damage to fuel cladding resulting from overheating or mechanical penetration.
2. Jamming of control rods.
3. Component which is source of loose part may be degraded to where it cannot properly perform its safety related function.

Value

Issuance and implementation of the subject guide will:

1. Extended the structural evaluation programs associated with the design, manufacturing, construction and preoperational phases of nuclear power plants, to the normal operating service life of these facilities.
2. Permit early detection of a loose part which can provide the time required to avoid or mitigate safety related damage or malfunctions of primary system components.
3. Permit early detection of structural conditions that are less conservative than those assumed in the accident analyses or are not considered in the safety analysis report.

ENCLOSURE 2

4. Through early detection of structural damage be beneficial in maintaining occupational radiation exposure "as low as is reasonably achievable" (ALARA) by minimizing wear generated crud buildup and limiting the need for extensive repair.

5. Provide guidelines for applicants and licensees to follow in developing and implementing an integrated loose part detection program and for the staff to follow in developing specific review guidelines for Section 4.4 of the Standard Review Plan and for establishing an enforceable program.

6. Partially satisfy ACRS generic item 5, Group II, titled "Monitoring for Excessive Vibration or Loose Parts Inside the Pressure Vessel".

7. Provide a baseline program by which NRC might evaluate, based upon operating experiences, the need for future technical and administrative revisions to the loose part detection program.

Impact

The effect of the proposed regulatory guide on applicants and licensees will be limited because:

1. The NRC staff is now requiring a commitment to a loose part detection system from all applicants applying for a construction permit or an operating license. A description of the loose part detection system is requested in Section 4.4.6, "Instrumentation Requirements", of Regulatory Guide 1.70, Revision 2, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants".

   Previously, at the request of the ACRS and the NRC staff, many applicants were voluntarily committing to the installation of a loose part detection system. Of the 67 operating reactors (all figures are as of February 17, 1978), 20 have a loose part detection system (i.e., 19 PWRs and 1 BWR). Of the 86 plants presently under construction, 70 are committed to a loose part detection system (i.e., all 59 PWRs and 11[1] of the 27 BWRs).

2. The proposed regulatory guide was developed recognizing that for surveillance programs to be utilized effectively, they must result in a minimum of interference with normal operation and be sufficiently

[1] Although applicants for the remaining BWR plants are not presently committed to installation of a loose part detection system, it is the intent of the NRC staff to obtain such a commitment from these applicants at the time of the OL review.

simple so that results can normally be interpreted by on-site operating personnel. The proposed regulatory guide addresses the preceding concerns and limits the impact to the licensees by:

a. Recommending that instrumentation be kept to an acceptable minimum.

b. Recommending that special provisions be incorporated for minimizing the potential for false alert signals.

c. Specifying procedures that require little attention by control room personnel and minimum reporting by the licensee.

d. Noting in the proposed regulatory guide that no action is recommended with respect to reactor operation based on information obtained from the loose part detection system alone.

3. Recommended reporting procedures are within the framework of established guidelines. Of the three reporting procedures specified, one (item a below) is consistent with the guidelines of Regulatory Guide 1.70 (i.e., the Standard Format). Another (item b below) is consistent with Regulatory Guide 1.16, "Reporting of Operating Information - Appendix A Technical Specification". Neither constitutes a new generic reporting requirement. The third (item c below) is part of a limiting condition of operation in a proposed technical specification that is consistent with that of similar programs. The bases for these reporting procedures are detailed below.

a. Providing a program description (Regulatory Position 4), including specification or modification of the alert level (Regulatory Position 3.a), is consistent with the request for information in Section 4.4.6 of the Standard Format.

b. Notifying the Commission of a loose part (Regulatory Position 6) is consistent with the request for "prompt notitication with written followup" in Regulatory Position 2.a(9) of Regulatory Guide 1.16.

c. The proposed guide establishs a reporting procedure as part of the technical specification limiting condition of operation (Regulatory Position 5.b(2)). In the event any one of the required instrumentation channels is inoperable for more than 30 days, the limiting condition of operation specifies that a special report be submitted to the Commission within 10 days outlining the cause of the malfunction and the plans for restoring the channel(s) to an operable status. The reporting procedure within the limiting condition of operation is consistent with similar requirements for seismic and meteorological instrumentation. Incorporating the reporting requirement into the limiting condition of operation reduces the impact to the licensee by linking operability of the plant to the reporting requirement rather than directly to operability of the loose part detection system. This is desirable since it would be unreasonable to shut down the plant for loss of instrumentation that monitors only random malfunctions of structural components without first reviewing the plant's operating history.

The proposed regulatory guide will, however, have an effect on applicants and licensees due to the following provisions in the guide which have not heretofore been addressed in previous loose part detection programs:

1. Periodic testing for operability, including calibration.

2. Need to demonstrate operability of system for all earthquakes up to and including the Operational Basis Earthquake.

3. Need to demonstrate that the system is adequate for the normal operating environmental conditions of radiation, vibration, temperature and humidity.

In addition, an improperly developed and poorly implemented loose part detection program has the potential for increasing radiation exposure to station personnel by causing increased amounts of primary system inspections.

It is estimated that the total installed cost to a utility for a loose part detection system that satisfies the regulatory guide recommendations would be $100K. The estimated costs for generically qualifying the system for the specified seismic incident ($25K) and for the specified environmental conditions ($10K) are incorporated into the total cost of the program on a pro rate basis. It is estimated that the annual recurring cost to the utility for periodic operability checks and maintenance would be $15K. For comparison, the cost to a utility of an unscheduled shutdown is, depending on the specific plant, $100K to $300K per day.

Alternatives Considered

The purpose of the loose part detection program is to detect the presence of loose parts before they cause safety related damage. From this point of view, there is no true alternative to the loose part detection program specified in the proposed guide. All the available "alternatives" are dependent upon safety related damage having occurred (e.g, gross blockage of flow to the core can be detected in a PWR by thermocouples which exist at the outlet to the core). For this reason, the use of the word "alternative" in this section is replaced by the phrase "other available methods". These other available methods should in fact be used in conjunction with the loose part detection program to assist in determining the safety significance of a loose part alert signal.

A summary of the advantages and disadvantages of the loose part detection program compared with that of other available methods is presented in Table 2 for both PWRs and BWRs. The particular safety issues identified in the table are those that can credibly be caused by a loose part in the primary system. It was concluded from discussions with the NRC staff that with regard to the presence of a loose part in the primary system, fuel rod damage and control rod jamming were the primary safety concerns and that a loose part in the primary system could not credibly affect proper operation of the emergency core cooling system for either a PWR or BWR.

The impact to the licensee of the tabulated "other available methods" would be minimal, unless there was an attempt to reduce some of the disadvantages of these other methods, because the associated instrumentation or procedures already exist for the reactor system. The greatest benefit of these other methods would be derived when used as a diagnostic tool in conjunction with the loose part detection program.

The loose part detection program is unique (i.e., relative to the other available methods) in its ability to extend the defense-in-depth concept to detection of certain abnormal structural conditions before the occurrence of abnormal operational conditions. It is worthy of note, although the data is limited, that in the two instances where loose parts were detected by means of a loose part detection system (Table 1 items 12 and 19), there was no additional damage to primary system components. Where loose parts were detected by other methods (i.e., the remainder of the individual incidents in Table 1), in approximately 40 percent of the cases there was some loose part induced damage or malfunction with the primary system.

The proposed regulatory guide provides general guidelines for a loose part detection program. The choice of alternative solutions to satisfy the general guidelines is left with the applicants and licensees. Short of satisfying the minimum recommendations specified in the guide, the type, extent, and location of instrumentation, the type of recording and data reduction systems, procedures for minimizing false alert signals, operability and calibration checks, procedures for establishing alert levels are all elements of the program which have alternate forms of solution and for which the applicants and licensees have the freedom to establish their own procedures and methods.

Discussion

The loose part detection program proposed in this guide is a continuous inservice surveillance program for components within the primary coolant pressure boundary. In a sense, it complements the present ASME Section XI program that requires periodic inservice inspection of the primary coolant pressure boundary.

Although the NRC staff now requires applicants to implement a loose part detection program, no specific guidance is provided by the staff regarding the content of such a program. This has resulted in somewhat varied system abilities and implementation programs. This makes evaluation and comparison of present programs and operating experience very difficult. The proposed regulatory guide outlines the minimum system characteristics which the NRC staff feels are necessary for a workable system and combines this with technical specifications and reporting procedures for a complete and enforceable loose part detection program.

Table 1 provides a summary of representative loose part incidents in PWR and BWR power reactors. One incident (Table 1 item 30), however, is included for a liquid metal reactor. The following conclusions are derived from this summary.

1. Occurrences. There have been numerous instances to date where loose parts have occurred in the primary system of both PWRs and BWRS.

2. Source and size of loose parts. Mechanical connections (e.g. threaded) and misplaced parts and tools are the major sources of loose parts. Loose parts are generally of a size that may be easily hand-held.

3. Operational problems. A stuck control rod (Table 1 item 3, 4b, 7, 10c, 11a, 16, 17, and 21) is the most often repeated potentially safety related incident that has resulted from loose parts (debris) in the primary system. The most significant incident that has occurred to date from a loose part is the partial meltdown of two fuel assemblies in the Fermi-1 liquid metal reactor (Table 1 item 30).

4. Reliability and safety. Operating experience shows that loose parts from failed components can be reliable precursors of major structural damage. The expeditious detection of these loose parts can provide the time requird to mitigate structural damage and thereby reduce the need for extended downtimes for repairs (Table 1 items 6 and 7). Reliability is of course a major consideration to utilities. Inasmuch as loose part detection programs can reduce downtime, such programs are desirable to utilities[2]. Closely related although of lesser probability is the potential of a loose part being the cause or result of safety related damage. Inasmuch as loose part detection programs can detect safety related structural damage, and in particular can detect the presence of a loose part that can block flow to the core, such programs are considered necessary to the NRC staff.

5. Methods of detection. Experience shows that in most instances loose parts and any associated detrimental effects are detected during inspections made at refueling or other special inspections (Table 1 items 2 4a 6, 7, 8 9, 10b, 11, 14, 15, 21, and 22). Most often prior to shutdown there are no obvious indications of a loose part. Personnel are often alerted to the possibility of a loose part only after detecting a stuck control rod at the time of refueling (Table 1 items 3, 4b, 10c, 11a, 16 17, and 21b). On occasion, the presence of a loose part is determined by means of a loose part detection system (Table 1 items 12, 19, and 31), coolant activity measurements (Table 1 items 1 and 13), audible noise (Table 1 items 5a, 8b, and 18) or by indications from other plant measurements.

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[2]Pecently a questionnaire was sent by the NRC staff to utilities with loose part detection systems in an attempt to gather the operating history of and experience with such systems. In responding to this questionnaire one utility noted that it felt that the original investment of a loose part detection system would be recovered if during the lifetime of the plant, the system increased plant operability by one day.

6. Limitations and value of loose part detection program. As noted in item 5 above (i.e., methods of detection), most loose parts are detected during refueling inspections. The loose part detection program can contribute greatly to alerting station presonnel to the presence of many of these loose parts, thereby increasing the probability that such parts will be found and as necessary removed. The loose part detection program can detect the presence of those parts that can cause significant blockage of core flow. The loose part detection program cannot, however, detect the presence of those very small loose parts that can cause the jamming of control rods. In addition, although the loose part detection system provides an alert function for many types of loose parts, its ability to provide diagnostic information is at this time somewhat limited. The true value of the loose part detection program rests in its ability to complement and reinforce other existing or available procedures for detection of abnormal primary system conditions.

Summary

1. The loose part detection progam can provide a measurable increase to the in-depth-defense for reactor safety with little impact to the licensee.

2. The proposed regulatory guide provides guidelines for the development, implementation and enforcement of a workable loose part detection program.

Implementation

It is recommended that this guide be used in the evaluation of submittals for operating license or construction permit applications docketed after October 15, 1978.

TABLE 1

Summary Of Representative Loose Parts Incidents

U.S. and Foreign Power Reactors

	Reactor	Type	Loose Part			System Damage	Detection		
			Source	Mode*	Description		Operation	Method	Date
1.	San Onofre	PWR	Fuel rod	F	18" section	None	Commercial	Coolant Activity	1/72
2.	Obrigheim	PWR	Fuel rod	F	End plug	None	Refueling	Inspection	1970
3.	Ginna	PWR	Fuel rod	F	End plug	Stuck control rod	Refueling	Stuck Control rod	10/72
4.	Robinson 2	PWR	a) Fuel assembly spring grid clips,	F	Fragments	None	Shut down	Special inspection of steam generator	11/73
			Steam generator nozzle cover	L	Bolt head				
			b) Weld spatter	L	0.090"x0.060"	Stuck control rod	Commercial	Stuck control rod	11/70
5.	Oconee 1	PWR	a) Incore instrumentation tubes	F	21 (3/4" dia.) nozzles	Extensive damage to 2 steam generator tube sheets and tube sheet welds	Precritical	Audible noise, inspection	3/72
					4 guide tubes	Massive damage to reactor internals, including fracture of core support barrel bolts (~ 8 mo. downtime)			
			b) Reactor internals	L	Bolts, 3"x1/2" dia.	None			11/74

* F: Failed part, L: Lost during construction, refueling or maintenance.

TABLE 1 (continued)

			Loose Part				Detection		
	Reactor	Type	Source	Mode	Description	System Damage	Operation	Method	Date
6.	Trino	PWR	Thermal shield,	F	Bolts, tubes,	Massive damage to reactor materials, including fracture of core support barrel bolts and specimen holders (~ 3 yr. shutdown)	Refueling	Inspection	4/67
			Incore instrumentation	F	metal chips				
7.	Sena	PWR	Thermal shield	F	Bolts, pieces of metal	Stuck control rod, broken core support barrel bolts (~ 2 yr. shutdown)	Shutdown	Special inspection	~1967
8.	Palisades	PWR	a) Compensating ring	F	Bolt head (3/4"x7/8" dia.)	None	Shutdown	Inspection of Steam generator	5/72
			b) Reactor coolant pump	F	Suction deflector (34 lb.)	Light impeller and casing damage	Precritical	Audible noise	5/71
					Capscrew (10"x1/2" dia.)				
9.	Shippingport	PWR	Unknown		1/4" ss nut	None	Refueling	Inspection	4/69
10.	Yankee Rowe	PWR	a) Specimen lifting bails		1/8" dia. wire in 1-3/4" dia. circle (8)				10/63
			b) Assorted, includes surveillance holders and charpy V-notch specimens,	F	60 individual pieces from fabricated parts	Reactor vessel wear: two small holes 0.020" through 0.109" cladding. Shroud tube tie bar sheared by loose specimen holder	Refueling	Inspection	11/65
					Hanger rods (3/4" dia.) sharpened into spears				
			Thermal shield,	F	cap screw				
			Shroud	F	cap screw				
			c) Control rod shroud mounting bolts	F	7 bolts, 4 mounting cups	Stuck control rod	Refueling	Stuck control rod	11/72

TABLE 1 (continued)

			Loose Part				Detection		
	Reactor	Type	Source	Mode	Description	System Damage	Operation	Method	Date
11.	Indian Pt. 1	PWR	a) Unknown		Tapered ss pin (1-3/4" long x 5/32" - 9/32")	Stuck control rod	Shutdown testing	Stuck control rod	2/65
			b) Surveill. holders	F	3 balance levers	None	Refueling	Inspection	11/65
			c) Surveill. holder	F	1 balance lever (1/4" dia. x 1") 5/32" - 9/32")	None	Refueling	Inspection	3/70
12.	Oconee 2	PWR	Reactor coolant pump impeller		Locking nut cap screw, cylindrical metal bar (bolt, nut?) set screw	None	Commercial	Loose Part Detection System	1/74
13.	Stade	PWR	Fuel assembly drop preventer	F	Bolts	Fuel damage (~ 44 fuel assemblies)	Commercial	Coolant activity	1973
14.	3 Mile Is.-1	PWR	a) Unknown	L	Carbon steel nut	None	Precritical	Inspection	1974
			b) Unknown	L	1.29" x 0.55 dia. pin	None	Refueling	Inspection	1976
15.	Arkansas-1	PWR	Surveillance holder	F	Two spring cartridges, 1 push rod, journal bearing, portion of holder tube	None	Refueling	Special inspection	3/76
16.	Indian Pt. 2	PWR	Machining operation	L	Metal chip	2 stuck control rods	Precritical	Stuck control rod	5/72
			Unknown		Debris	None		Inspection	
17.	Pt. Beach 1	PWR	Reactor coolant pump volute	F	20 small chips, 1 chip caused control rod to stick	1 stuck control rod	Precritical	Stuck control rod	10/70
18.	Maine Yankee	PWR	Reactor coolant pump	F	Metal chips (~ 3 cups in steam generator cold leg). Some metal chips	Significant damage to pipe cladding between steam generator and pump	Precritical	Noise and leakage	7/72

TABLE 1 (continued)

	Reactor	Type	Loose Part: Source	Mode	Description	System Damage	Detection: Operation	Method	Date
18.	Maine Yankee	(continued)			in hot leg, pump guide vane (26 lbs., 7"x10"x1/2")				
			RTD instrumentation	F	4 wells 3" long	Loss of coolant through RTD wells			
19.	Calvert Cliffs-1	PWR	Steam generator		Siphon tube (6" long x 5/8" O.D.)	None	Precritical	Loose Part Detection System	9/73
20.	GKN	PWR	Unknown		2-1/2 oz. nut				
21.	Dresden-1	BWR	a) Fuel assembly	F	7 cap screws	None	Refueling	Inspection	1/67
			b) Fuel assembly	F	1 cap screw	Stuck control rod (full in)	Commercial	Control rod malfunction	4/74
22.	Tarapur-1	BWR	Fuel assembly	F	4 fuel assemblies, from 2 out of 20 loose guide tube assemblies	Wear through 4 fuel channels and 3 fuel rods	Refueling	Inspection	8/71
23.	Dresden-3	BWR	Welding purge dam from LPCI	L	3/8" plywood, rubber sheets, 1-1/4" x 1/4" dia. stove bolts, 4 nut-screw combination, 1 washer, 1 nut	None	Precritical	Low flow indication on jet pump	3/7
24.	Quad-Cities-2	BWR	Jet pump holddown assembly	F	Beam bolt assembly, 2-1/4" dia. insert washer, retainer and 1/2" dia. connecting bolt	None to remainder of system	Commercial	Abnormal jet pump readings	8/72

TABLE 1 (continued)

	Reactor	Type	Loose Part: Source	Loose Part: Mode	Loose Part: Description	System Damage	Detection: Operation	Detection: Method	Detection: Date
24.	Quad-Cities-2	(cont'd)	Jet pump holddown assembly	F	Beam and bolt retainer clips and 1/2" dia. cap screw missing on two pumps, 1 restrainer adjusting screw missing	None to remainder of system	Refueling	Inspection	2/75
			Assorted	L	Missing dosimeter screws, clips, wire, wrench, rag grinding burr				
25.	Quad-Cities-1	BWR	Jet pumps	F	3 restrainer gate bolt heads and 3 gate bolt head keepers, 1 restrainer gate wedge and 1 wedge spring, 1 retainer for beam bolt (L shape, 2" long x 3" long x 2" wide x 1/8" wide), 2 bolts for retainer (3/4" x 1/2" dia.)	None to remainder of system	Refueling	Inspection	4/74
			LPRM		Spring reel guide (2" long x 1" dia.)				
			Refueling shield	L	(3/4" x 1/2" long)				
			Welding rod	L	6" long				
26.	Dresden 2	BWR	Steam flow restrictor	F	Restrictor cone	None	Commercial	Instrumentation abnormalities	8/72

TABLE 1 (continued)

			Loose Part				Detection		
	Reactor	Type	Source	Mode	Description	System Damage	Operation	Method	Date
27.	Cooper	BWR	Fuel channel box	F	Pieces from 4 channel boxes: 1"x1-1/2", 2"x3-1/8", 3-1/2"x5" 1-1/2"x1-3/4" (not retrieved)	None	Shutdown	Inspection	10/75
28.	Pathfinder	BWR	Steam separator	F	Pieces of vanes lodged in recirculation loop				1967
29.	Big Rock Point	BWR	a) Thermal shield	F	1/2" bolt, 3" long minus head	Stuck control rod	Commercial	Control rod malfunction	12/67
			b) Thermal shield	F	1/2 bolt head	Stuck control rod	Commercial	Control rod malfunction	4/68
30.	Fermi-1	LM	Flow deflector	F	Six 40 mil thick zirconium segments	Partial meltdown of two fuel assemblies	Shutdown	Inspection	10/66
31.	Crystal River-3	PWR	Burnable poison rod assembly	F	Poison rod spider (7 lbs.)	Moderate impact damage to steam generator tube sheet and tube ends	Commerical	Loose-part detection system	1/78

TABLE 2

POTENTIAL SAFETY RELATED INCIDENTS FROM LOOSE PARTS IN THE PRIMARY SYSTEM OF LIGHT-WATER-COOLED REACTORS

Incident	Type of Loose Part	Loose Part Detection System: Advantage	Loose Part Detection System: Disadvantage	Available Alternative: Advantage	Available Alternative: Disadvantage
				Exercising of control rods	
Stuck control rod	Small chip or weld slag	Detects larger parts that can shed smaller chips	Cannot detect parts of size that jam control rods	Direct check on operability of control rod	Tech spec requires exercising for PWRs 10 notches every 31 days and for BWRs 1 notch every 7 days
				Thermocouples at core outlet and/or Incore neutron detectors	
Flow blockage to core resulting in overheating	Flat plate (PWR); curved plate, bolt (BWR)	Can detect impact of part that can cause significant flow blockage	Unless part chatters its presence will not be detected	Uses available instrumentation (Incore neutron detectors on PWRs and BWRs and T/C on PWRs)	Relatively few fuel assemblies instrumented. Detection requires gross blockage of core or blockage near instrumentation. No requirement for monitoring of thermocouples.
				Primary coolant specific activity measurement	
Fuel cladding mechanical damage	Marble size object	Impacts may be detected in primary system prior to parts entering core	Cannot detect parts already in core	Uses available instrumentation on PWRs and BWRs and is tech. spec. surveillance requirement. Can detect small perforations in fuel cladding	Detection made only after failure of fuel cladding occurs.

(Continued next page)

TABLE 2 (continued)

POTENTIAL SAFETY RELATED INCIDENTS FROM LOOSE PARTS IN THE PRIMARY SYSTEM OF LIGHT-WATER-COOLED REACTORS

Incident	Type of Loose Part	Loose Part Detection System: Advantage	Loose Part Detection System: Disadvantage	Available Alternative: Advantage	Available Alternative: Disadvantage
				Periodic inspection of components within primary coolant boundary	
Degraded component	Of detectable size from failed component	Good early warning system	Requires further diagnoses or inspection	Direct check for degraded components	Increases station personnel radiation exposure. Longtime between inspections
				Periodic inspection inside reactor and steam generator vessels	
Long term wear of reactor vessel or PWR steam generator cladding	Bolt or nut size parts	Ideal for this situation	None	Direct check for loose parts	Increases station personnel radiation exposure. Longtime between inspections.

IMPLEMENTATION EVALUATION REPORT

REGULATORY GUIDE 1.133

LOOSE PART DETECTION PROGRAM

FOR

THE PRIMARY SYSTEM OF LIGHT WATER COOLED REACTORS

TABLE OF CONTENTS

IMPLEMENTATION EVALUATION REPORT
REGULATORY GUIDE 1.133

LOOSE PARTS DETECTION PROGRAM
FOR
THE PRIMARY SYSTEM OF LIGHT WATER COOLED REACTORS

1.0 Safety Assessment

A loose parts detection program provides a means for early detection of loose metallic parts in the primary system. By providing for the early detection and general location of abnormal structural conditions, a loose parts detection program may also minimize radiation exposure to station personnel involved in maintenance and repair. A review of operating experience indicates that loose parts events can be expected about once every 10 reactor years. Thus, about 4 loose parts events can be expected in the 40-year plant lifetime. It should be noted that, in most of the loose parts events which have occurred, indications of the loose object were often detected by other instrumentation. Furthermore, relatively few of these events were of direct safety significance and in no case was there an actual radioactive release.

Failure to detect loose parts can directly or indirectly affect safety in any of the following ways:

a. Direct mechanical damage to the pressure boundary

b. Direct mechanical damage to the reactor or steam generator internals.

c. Mechanical interference with control rods, valves, pump impellers, and other moving parts.

d. Coolant flow blockage

e. Coolant chemistry upset

f. Abrasive effects

g. Excessive coolant radioactivity

h. Missing part (the presence of a loose part of internal origin implies that some component of the system has been degraded).

The Standard Review Plan, Section 4.4, identifies the requirement that an adequate system for detecting loose parts be provided. The loose parts system will add a level of defense in depth to plants in the primary coolant by providing early detection of metallic parts and will minimize radiation exposure to station personnel. Regulatory Guide 1.133, Loose Parts Detection Program for the Primary Systems of Light Water Reactors describes a loose parts detection program acceptable to the staff.

2. <u>Proposed Implementation</u>

For the purpose of implementation of Regulatory Guide 1.133, four groups of plants have been identified as follows:

Group 1 - All plants for which the operating license applications are docketed ~~on or~~ after January 1978.

Group 2 - Plants which are currently being reviewed for an operating license and for which the operating license applications are docketed before January 1, 1978.

Group 3 - Currently operating reactors which have previously committed to installing a loose parts detection system.

Group 4 - Currently operating reactors which have not previously committed to installing a loose parts detection system.

It is recommended that Regulatory Guide 1.133 be applied to all Group 1 plants. Table 1 identifies the Group 1 plants including those applications which are currently being reviewed for an operating license and whose application was docketed on or after January 1978. For Group 1 plants, the Analysis Branch, Division of Systems Safety is including as part of its review, requirements for a commitment to Regulatory Guide 1.133 (construction permit review) or insuring that the requirements of Regulatory Guide 1.133 are met (operating license review) or that an acceptable alternative will be (CP)/is (OL) provided. It is recommended that Group 1 plants which are in the post construction permit stage be notified of the requirement to provide a loose parts monitoring system as recommended by Regulatory Guide 1.133, or an acceptable alternative in their FSAR.

It is recommended that Regulatory Guide 1.133 not be imposed as a backfit for Group 2 plants. The Analysis Branch will review Group 2 plants to insure that an adequate system for detecting loose parts is provided in accordance with Standard Review Plan Section 4.4. The review will verify that commitments made as part of the Construction Permit are met and that programatic aspects of Regulatory Guide 1.133 are implemented. Table 2 lists the Group 2 plants and the status of the review of their loose parts monitoring system.

It is recommended that Regulatory Guide 1.133 not be imposed as a backfit for Group 3 plants. The Reactor Safety Branch, Division of Operating

Reactors is evaluating the loose parts detecting systems being implemented by the Group 3 plants in accordance with their operating license commitments. The evaluation includes an assessment of the loose parts monitoring program for conformance to the programmatic aspects of Regulatory Guide 1.133. Thus, a programmatic (and possibly some hardware) backfit could be imposed on the Group 3 plants. The extent of backfitting will be decided on a case-by-case basis.

It is recommended that Regulatory Guide 1.133 not be imposed as a backfit for Group 4 plants. The Reactor Safety Branch, Division of Operating Reactors is monitoring operation of Group 4 plants. Should cases arise where an existing loose part is known to be present, or a minor design defect be identified which would lead to a higher than normal probability of loose parts, it may be determined that a loose-part detection program be implemented. This safety analysis and justification will be done by the Division of Operating Reactors as required.

3.0 Implementation Evaluation for Construction Permit, Post Construction Permit and Operating License Applications, (Group 1 and Group 2 plants)

The requirements for a loose parts detection program are identified in Regulatory Guide 1.70, Revision 2, Section 4.4.6 and Standard Review Plan Section 4.4. However, no specific guidance is provided by the staff regarding the content of such a program. This has resulted in somewhat varied system abilities and implementation programs. Thus, considerable staff effort has been required on each license application to evaluate the proposed loose parts detection program. Regulatory Guide 1.133 outlines minimum requirements which the staff feels are necessary for a complete and enforceable loose part detection program. Thus, following the recommendations of the guide will reduce the staff resources required to review and evaluate an applicant's loose parts detection program.

3.1 Construction Permit, Post Construction Permit, and Operating License Applications ~~Fuel Load Date~~ Docketed on~~/or~~ After January 1, 1978 ~~1980~~ (Group 1)

It is our judgement that all Group 1 plants should be able to implement a loose parts monitoring system that meets the recommendations of Regulatory Guide 1.133 without affecting their current estimated fuel load dates. Providing a loose parts detection program will add a level of defense in depth for these plants. The use of the regulatory guide in the review of these plants will reduce the staff resources required to review those current applications identified in Table 1. On these bases, it is recommended that Regulatory Guide 1.133 be implemented in the review of all Group 1 plants including those currently under review for a construction permit or operating license and those currently holding construction permits. Furthermore, based on the fact that those plants currently under operating license review or post construction permit have committed to implementation of a loose parts detection system acceptable to the staff, the requirement to meet Regulatory Guide 1.133 is not considered as a backfit as identified in 10 CFR Part 50.109.

Docketed before January 1978.

3.2 Operating License Applications * ~~Fuel Load Date Be~~fore January ~~1980~~ (Group 2)

It is our judgement that all Group 2 plants would not necessarily be able to implement a loose parts monitoring system that meets the recommendations of Regulatory Guide 1.133 without affecting their current estimated fuel load date. Considering that these plants will have an acceptable loose parts detection program based on a review in accordance with Standard Review Plan Section 4.4, the only apparent advantage of applying Regulatory Guide 1.133 would be to reduce the staff's resources required to complete the review of these plants. However, for these plants, the staff review has progressed to the point that a significant portion of the review has been completed. Thus, there would not be an appreciable savings in staff resources by implementing the guide in the review of Group 2 plants. On these bases, it is recommended that Regulatory Guide 1.133 not be imposed in the review of those plants currently being reviewed for an operating license and for which the operating license application was docketed ~~and whose fuel load date is~~ before January 1, 1980 78. The Analysis Branch will complete the review of these plants to insure that an adequate system for detecting loose parts is provided in accordance with Standard Review Plan Section 4.4. The review will verify that commitments made as part of the construction permit are met and that deviations from the recommendations of the regulatory guide are acceptable.

4.0 Implementation Evaluation for Operating Plants with Existing Loose Parts Detection System Commitments (Group 3)

Recent licensees have been required during their OL reviews to commit to installing a loose-parts detection system. No specifications for these systems were imposed. Two alternatives exist for the loose parts detection system for these plants. First, they could be required to supplement their existing commitment including backfitting of hardware to meet the recommendations of Regulatory Guide 1.33. Alternatively, the existing or planned systems could be evaluated on a case-by-case basis for acceptability and conformance to their operating license commitment.

4.1 Effectiveness of Backfitted Systems

A backfitted LPDS is generally not as effective as a system which was included in the original design of the unit. The two major reasons for this are sensor placement and calibration.

An ideal system would have its sensors attached directly to the vessel wall (or on nozzles immediately adjacent to the vessel wall) and distributed to provide maximum coverage. A backfitted system will not, for example, have the benefit of threaded studs built into the vessel. Instead, a backfitted system must use either magnetic or adhesive mounting on the vessel wall (neither has met with complete success); or strap clamps on piping and/or structural members attached to the vessel. (This latter method is more common.) Some sensors are attached at distances as much as 12 feet from the vessel wall. Because sensor locations are based upon accessibility, considerations rather than uniformity of acoustic coverage, the resulting array may be far from optimum.

The response of an LPDS sensor to an impact at a given location cannot be readily calculated. Such a calculation would have to consider waves (of three polarizations) propagating through a complex inhomogeneous three-dimensional structure involving diffraction at each vessel penetration and considerable mutual interference and resonance effects. Also, the acoustic energy generated at the point of impact is not linearly related to the kinetic energy of the impacting object. Therefore, it is necessary to empirically calibrate any LPDS by a series of impacts of various energies at each of many locations on the vessel (and steam generator) walls. Because of probelems with both accessibility and personnel exposure, backfitted systems are generally not as thoroughly calibrated as are "original equipment" systems. Moreover, it is necessary to measure the background noise of the unit as a function of coolant flow and core power. Background noise is more readily measured during the initial startup testing than after any commerical operations.

Installation of any LPDS does not guarantee knowledge of all loose objects. These systems are impact detectors and will not detect a loose object that is not sonically active. Moreover, the rather high false alarm rate, especially in backfitted systems, mandates varification of each alarm before any mitigating action by the operator is taken. Thus, hours or days may pass before an alarm results in any change in the plant status.

4.2 Conclusion

Operating plants which have previously committed to installing a loose parts detection system (Group 3 Plants) will find it difficult to install a system or upgrade an existing system to meet the requirements of Regulatory Guide 1.133. Furthermore, it is not apparent that backfitting hardware would improve the effectiveness of the loose parts detection system for these plants. Therefore, it is recommended that Regulatory Guide 1.133 not be imposed as a backfit for Group 3 plants. Rather, the loose parts detection systems being implemented will be evaluated for conformance with their operating license commitment. It is recommended that the evaluation include an assessment of the loose parts monitoring program for conformance to the programmatic asepcts of Regulatory Guide 1.133. Thus, a programmatic (and possibly some hardware) backfit could be imposed on the Group 2 plants. The extent of backfitting will be decided on a case-by-case basis.

5.0 Implemntation Evaluation for Operating Reactors Without Loose Parts Detection Commitments (Group 4)

5.1 Need for Loose-Parts Detection

5.1.1 Flow Blockage in Unmonitored Areas

Examples of such blockage include small objects jammed within the fuel lattice, larger objects blocking flow at the lower surface of the core, and, in the case of BWR, objects blocking flow in the orifice areas. Safety analysis of such situations, which take credit for decreased neturon moderation, crossflow, and void feedback, have in the past shown that margin to DNB still existed. One vendor has written a generic topical report on the subject and concluded that 79% blockage in one orifice could be tolerated without transition boiling. No DNB-related fuel failure in a commercial LWR has ever been traced to flow blockage due to a loose part in 348 reactor-years. It is not certain that a loose-parts detection system would detect such objects, since they possibly would not impact against any surface with a direct acoustic path to an LPDS sensor.

5.1.2 Missing Parts

Of the loose-part events on file, roughly three-quarters of those which occurred in commercial operation were internal NSSS parts which had become detached. The presence of such a loose part implies that an internal component has been degraded. However, the high redundancy of the various designs generally permits the loss of one non-testable or exercisable component without significant safety consequences. The only exception to this presently on file was the loss of a lock bolt on a reactor coolant pump, which led to seal failure. Most other events on file (capscrews, surveillance capsules, fuel pin parts, etc.) had no immediate safety consequences because they were missing. The remainder (e.g., burnable poison pins, pieces of channel boxes) were detectable by means other than a loos-parts detection system.

5.1.3 Mechanical Damage to the Pressure Boundary

Direct mechanical damage by an impacting loose part to the reactor coolant pressure boundary is possible and has happended. It must be emphasized, however, that such "damage" has never degraded the immediate safety integrity of the pressure boundary. This damage involves either the removal of a portion of the stainless steel inner liner, allowing the primary coolant to corrode the base metal of a vessel wall, or the rupture of a component which is connected to a lower pressure area (steam generator tubes or nuclear instrumentation tubes) resulting in a very small isolable leak. It is doubtful that any loose part of credible size and velocity could cause significant leakage. The events observed, although resulting in a plant shutdown in some cases, were relatively slowly-acting and were readily detectable where leakage occurred.

5.1.4 Direct Mechanical Damage to the NSSS Internals

Direct mechanical damage to the NSSS internals is probably the most obvious safety concern resulting from a loss-part event. Generally, a relatively massive object is required to do significant damage. Even a relatively simple LPDS should detect such an object.

Currently, impact damage due to a loose part is not considered in the structural design of the NSSS. However, it is most unlikely that the massive, seismically analyzed internal support structures will be damaged to the point of being unable to function as intended. Fuel cladding damage is possible, but is unlikely to be extensive because of the modest coolant velocity (about 15 feet/second, equivalent to a fall of 3-1/2 feet), the longitudinal direction of the flow, and the relatively easy detectability of such failures. Any such damage would, in all likelihood, require a period of time equivalent to the greater part of a fuel cycle to become severe (e.g., the instrument tube vibration in BWRs and the guide tube wear in PWRs).

The potential for cladding failure due to loose part impacts can be assessed more quantitatively using existing impact data. Of the four NSSS vendors, GE has assessed the amount of impact energy necessary to cause cladding failure. GE uses this assessment in the radiological analysis of a fuel handling accident where a fuel assembly is dropped upon the reactor core at 40 ft/second. (Other vendors analyze the dropping of an assembly on a concrete floor and conservatively assume all the rods fail in one assembly. Although the other vendors do not use impact damage data, it is expected that their fuel behavior will not differ greatly.)

GE has concluded (and the staff has accepted) that one fuel rod can absorb about 1 foot-pound of bending energy, or about 250 foot-pound of compression loading prior to cladding failure. Obviously, a small object striking a fuel rod from the side can have as much potential for damage as a far larger object striking from above or below.

For an object traveling with the coolant at 15 ft/sec, 1 ft-lb of kinetic energy implies a weight of 4.6 ounces. If it were made of stainless steel, this object would need a volume of approximately 1 cubic inch. It does not appear that there is a significant probability that such an object would have a shape which would permit entry into the fuel lattice with sufficient transverse velocity to cause cladding failure.

A more realistic event would be a heavy object striking the core from above or below. Cladding failure would require 250 ft-lbs. of kinetic energy, corresponding to a 72-pound object moving at 15 ft/sec with the coolant. In reality, the tie plantes and other structural components would spread the impact energy over many fuel rods. Consequently, a very massive object would be needed to fail cladding by impacting the core inlet or outlet. Such objects are not anticipated based upon operating experience to date.

Damage to control rods is also possible, but is unlikely. Control rods are protected by guide tubes when withdraw, and have already performed their shutdown function when inserted. It is instructive to note that a Westinghouse plant can tolerate up to 1-3/4 inches deflection of the guide tubes with no loss of function.

5.1.5 Synergistic Effects

A relatively massive impacting loose part has significance in addition to the direct mechanical damage. This extra significance is due to the fact that high impact energies can break up the loose object or otherwise generate many loose objects. Thus, the hazard associated with all eight areas of safety significance is multipled by the number of loose parts present.

The only area which becomes significantly more hazardous in the presence of a multitude of small loss objects is area 3, mechanical interference with moving parts, the control rods in particular. It is possible in such circumstances to jam more than one control rod (transient and accident analyses always assume one stuck rod) in a time period shorter than the control rod exercise surveillance period.

Boiling water reactors are relatively immune to this problem. Coolant velocities in the lower plenum are low, generally allowing loose objects to settle out. Should an object enter a control rod guide tube and not be carried into a fuel channel, it will drop to the velocity limiter, where exercise programs should detect it. In the event of a scram, the shape of the velocity limiter plus the very large upward force exerted by the hydraulic control rod drive should enable the rod to scram, even though the velocity limiter may be damaged in the process.

Westinghouse pressurized water reactors are somewhat more vulnerable in that a loose object may be cast up and come to rest on top of an RCCA guide plate. Exercise programs would probably not detect such an object, but the object could still prevent complete insertion by preventing the spider from passing that guide plate. Although the loose object would have to be light enough to be carried up to the plate, yet heavy enough to remain in place in the presence of cross-flow, such an event is credible if many loose objects are present.

Thus, there is a possibility of a transient followed by an incomplete scram. It should be remembered that much of the shutdown margin in PWRs is needed to support the assumptions used in the analysis of the steam line break accident. For each anticipated transient, much less negative reactivity is necessary. For a four-loop Westinghouse at end of equilibrium cycle (worst case), the plant will maintain sufficient shutdown margin with five clustered RCCAs failing to insert, or as many as 18 or more RCCAs in a distributed pattern failing to insert. (These numbers take no credit for partial insertion.) Therefore, even multiple loose parts are unlikely to prevent the reactor from shutting down safety in the event of an anticipated transient.

Similar arguments could be made for B&W and CE plants. However, all of these plants (except Palisades) are already equipped with loose-part detection systems. Thus, the question is moot for these plants.

5.1.6 Alternative Instrumentation

Although a loose-parts detection system can contribute to safety in all of these areas, it is not the only contributing system. Interference with moving control components (by one loose part) will be detected by exercising programs for this purpose already in every licensee's Technical Specifications. Bulk flow as well as local flow in certain places (e.g., jet pumps) are monitored directly. Coolant chemistry and coolant activity are sampled periodically. Abrasive effects can be observed by the surveillance of total suspended solids and primarily by seal leakage (monitored directly).

Therefore, a loose part detection system must be regarded as an additional system which only provides defense in depth by earlier warning.

5.2 Conclusion

At this point, all 8 items of safety significance associated with a loose-part event have been considered. None of them have been sufficient to meet the criteria of 10 CFR Part 50.109. It is concluded that backfitting should not be imposed on Group 4 plants. However, this conclusion rests partly upon probabilistic bases. Cases may arise where an existing loose part is known to be present, or a minor design defect is identified which leads to a higher than normal probability of loose-part events. In such individual cases, it would be justified to require a loose-part detection program in conjunction with the appropriate safety analyses.

TABLE 1

GROUP 1 PLANTS - FOR FULL IMPLEMENTATION OF

REGULATORY GUIDE 1.133

1. All plants under CP review
2. All plants in post-CP stage
3. Plants Currently under Operating License Review docketed on or after January 1978.
    - Braidwood Units 1 and 2
    - Comanche Peak Units 1 and 2
    - South Texas
    - Grand Gulf Units 1 and 2
    - WPPSS Nuclear Unit 2
    - Susquehanna
    - Bellefonte

TABLE 2

GROUP 2 PLANTS FOR PARTIAL IMPLEMENTATION OF

REGULATORY GUIDE 1.133 or ACCEPTABLE ALTERNATIVE

- Farley Unit 2
- Fermi Unit 2
- Salem Unit 2
- McGuire Units 1 and 2
- Sequoyah Units 1 and 2
- Summer
- Shoreham
- Midland Units 1 and 2
- Watts Bar Units 1 and 2
- San Onofre Units 2 and 3

REFERENCES

1. Regulatory Guide 1.133, "Loose-Part Detection Program for the Primary System of Light-Water-Cooled Reactors," Revision, 1, Draft 2, dated May 1979.

2. "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," NUREG-75-087, September 1975.

3. "Value-Impact Statement for Proposed Regulatory Guide 1.133, 'Loose-Part Detection Program for the Primary System of Light-Water-Cooled Reactors,'" dated March 1978.

4. "Operational Experience with Commercially Marketed Loose-Part Monitoring Systems," dated

5. "Consequences of a Postulated Flow Blockage Incident in a Boiling Water Reactor," NEDO-10174, October 1977.

6. "Generic Reload Fuel Application," NEDE-24011 dated May 1977.

7. "RESAR 34," Westinghouse Reference Safety Analysis Report, dated July 1975.

8. "Anticipated Transients Without Reactor Trip in Westinghouse Pressurized Water Reactors," WCAP-8096, April 1973.

9. B. Siegel and H. H. Hage, "Fuel Failure Detection in Operating Reactors," NUREG-0401, March 1978.