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LOOSE-PARTS MONITORING: PRESENT STATUS OF THE TECHNOLOGY, ITS IMPLEMENTATION IN U.S. REACTORS, AND SOME RECOMMENDATIONS FOR ACHIEVING IMPROVED PERFORMANCE^a

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ABSTRACT

MASTER

At the request of the U.S. Nuclear Regulatory Commission (NRC), an assessment of the technical development status of loose-parts monitoring systems (LPMS) and their performance record to date in commercial light-water-cooled nuclear reactor plants was made during the spring of 1977, using an on-site personal interview and equipment demonstration approach. Our study revealed that while presently demonstrated LPMS technology does indeed provide a capability for detecting the *presence* of those relatively massive loose parts that would likely constitute a serious operational or safety hazard to the plant, it unfortunately affords little information useful to the determination of the parts' safety significance and has not yet attained the levels of sophistication and reliability ordinarily associated with safety systems. We also found a definite need for specification of the functional requirements for LPMS, in the form of a clear and comprehensive statement of NRC policy regarding the formulation and implementation of safety-oriented, yet operationally practicable, loose-parts monitoring *programs* for both existing and future nuclear generating stations so that overall objectives of both the utilities and the regulatory agency might be satisfied simultaneously.

While it is our best technical judgment that loose-parts monitoring programs providing reliable *detection* (but not *characterization*) capabilities could be implemented with today's technology, the path on which the nuclear utility industry should proceed in order to meet NRC expectations is not completely clear. A Regulatory Guide entitled "Loose Part Detection Program for the Primary System of Light-Water-Cooled Reactors," soon to be issued for public comment, constitutes a first step towards satisfying this need for guidance and goal establishment.

INTRODUCTION AND PURPOSE

Under the combined sponsorship of the U.S. Nuclear Regulatory Commission Offices of Nuclear Reactor Regulation, Nuclear Regulatory Research, and Standards Development, an assessment of the technical development status of loose-parts monitoring systems and their performance record to date in commercial light-water-cooled reactor plants was made during the spring of 1977. Specific goals of this assessment were (1) to understand the reasons for the nonuniform application experience being reported to the NRC by the utility users of LPMS, (2) to identify possible generic deficiencies in hardware designs and operational procedures, (3) to identify technical development needs (if any), and (4) to provide recommendations to the NRC for their establishment of more precise licensing and regulatory positions with regard to LPMS.

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SURVEY METHODS

Our assessment was based primarily on on-site personal interviews with the technical and first-line managerial personnel responsible for designing, marketing, procuring, using, and maintaining commercially produced LPMS. Coupled with these interviews were demonstrations of the system hardware, both in the laboratory and during normal plant operation.

^a Work performed for the U.S. Nuclear Regulatory Commission under interagency agreement with the U.S. Energy Research and Development Administration and under contract with the Union Carbide Corporation. The opinions expressed within this report are those of the authors and do not necessarily reflect those of the U.S. Nuclear Regulatory Commission.

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Six vendors offering commercial LPMS were identified, and five of these consented to being interviewed with regard to their detailed technical approach to loose-parts monitoring. Since the utilities having operational LPMS were too numerous to permit visits to all, a representative sample of ten users was selected on the bases of (1) positive and negative performance experiences to date, (2) positive and negative apparent attitudes towards a plant's need for an LPMS, (3) relative scope and sophistication of the equipment, (4) reactor type (i.e., pressurized- and boiling-water) and manufacturer, and (5) LPMS manufacturer. In the utility interviews, attention was focused on performance record, reasons for purchasing an LPMS and for selecting a particular equipment vendor, apparent level of technical understanding by operations and maintenance personnel, post-sale followup provided by the LPMS vendor, and degree of confidence in and acceptance by technical and managerial personnel of the LPMS and related vendor services.

SURVEY FINDINGS

Nonuniform Application Experience

As reactor noise instrumentation specialists, we were disappointed with the status of current LPMS technology development and implementation revealed by these interviews. We had expected that either (1) the instrumentation would be automated to such a degree that detecting, sizing, and locating a loose part would be accomplished automatically by the hardware, without need for human interpretation, or (2) the utilities would have sufficient in-house expertise in loose-parts monitoring so that these same functions could be accomplished with less sophisticated hardware supported by human interpretive skills. However, our studies revealed that for many plants a more attractive option was the use of an unsophisticated LPMS that served only to detect the probable presence of a loose part, backed up by an off-site, on-call team of loose-parts diagnostic experts replete with specialized equipment. In some cases this choice had been made as a result of a cost-benefit analysis but, more often, such reliance on others (often unidentified) was judged to reflect a basic disbelief in the plant's need for the information which could be provided by a well-founded system. Utilities that had experienced damaging loose parts in the past were found to be consistently positive in their attitude towards LPMS, whereas those lacking a loose-parts history seemed to maintain an "it-can't-happen-to-us" viewpoint. Many of the LPMS now in service were acknowledged to have been purchased on a basis of coercion, not self-recognized need.

We also found many utilities presently under-utilizing their LPMS, i.e., neglecting to take full advantage of the capabilities provided by the LPMS vendor. In most cases, baseline information was not being accumulated, record keeping was inadequate, and personnel understanding of the LPMS principles was minimal. Operating procedures for the LPMS often made no reference to the important subjects of loose-part confirmation and subsequent characterization.

In our judgment, the nonuniform application experience reported to the NRC by the utility users of LPMS results chiefly from the varying degrees to which the utilities accept monitoring for loose parts as being a useful endeavor and not from the particular instrumentation selected for the job, or the type, construction, and age of the plant.

The less-than-enthusiastic acceptance given LPMS by today's utility industry is not unique; other surveillance and diagnostic systems for which there is no presently established, clearly justifiable, self-recognized need or about which plant designers, architect-engineers (A-Es), and operating personnel are ill-informed have been similarly received. Utilities have been confused by conflicting information from designers, nuclear steam supply system vendors, the NRC, and LPMS vendors regarding the need for and the performance capabilities of LPMS, and this confusion has been compounded by a lack of practical guidance from the Commission staff regarding their expectations for LPMS performance and for action plans to be taken when indications of a loose part are received.

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Generic Deficiencies

Our survey revealed that, with few exceptions, LPMS presently in operation produce too many false alarms. This is most unfortunate, because in many cases utility response to such malfunctioning, nonsafety-grade surveillance equipment is not to identify the cause and correct it but is rather to reduce the LPMS sensitivity to the point where the false alarms disappear. This action, of course, defeats the purpose of the instrumentation.

Moreover, present-day LPMS are operated, in the main, as qualitative (not quantitative) devices; i.e., even though the several information channels of a given installation may be balanced with respect to each other, no attempt is ordinarily made to establish an absolute system calibration that is meaningful to other installations. This all but precludes the

use of loose-parts data from one plant in diagnosing similar problems in another, but does not seriously compromise detection capability within a single plant. Also, such practice often leads to the use of completely arbitrary alarm level settings.

Since loose-part *characterization* (i.e., sizing, locating and estimating point of loose part origin) is still in its developmental infancy, present LPMS have only limited built-in capability for estimating the nature of loose parts. This deficiency diminishes the usefulness of the LPMS because, in the event a loose part is detected, no further information relevant to the subsequent assessment of the safety significance of the part is available.

Finally, we judged that many present-day LPMS are marginally conceived and engineered, in the sense that signal amplitude information serves as the principal indicator, whereas other signal characteristics (risetime, duration, frequency content) that could prove valuable in minimizing false alarms are underutilized. Also, the total number of sensors employed, their mounting positions, and mounting methods used have often been specified more on a basis of convenience than optimality (in many cases this is attributable to the retrofitted nature of the LPMS). Moreover, at their present state of development, many LPMS are simply ill-suited to the typical utility environment from a human engineering point of view, owing to a requirement for considerable interpretation and judgment on the part of the LPMS operator in distinguishing genuine loose-part signals from spurious signals.

Technical Development Needs

Our study revealed that while presently *demonstrated* LPMS technology has a documented capability for detecting the presence of those relatively massive loose parts that would likely constitute a serious operational or safety hazard to the plant, it unfortunately affords little of the additional information that could be helpful in determining the parts' safety significance and has not yet attained those levels of sophistication and reliability ordinarily associated with safety systems. Accordingly, we single out decreased false alarm rate (i.e., highly selective response to metal-on-metal impacts) and loose-part characterization capabilities (i.e., size, location, and point-of-origin estimation) as the most needed technical developments, and believe that modest development programs could yield significant performance improvements in these areas.

RECOMMENDATIONS

For NRC Implementation

1. Reexamine the technical justification for loose-parts monitoring programs on a basis of plant *safety*, not plant *operability* and *economics*; if such safety justification cannot be clearly established, then relieve present and future nuclear plants of further loose-parts monitoring program requirements.

Based on the information available to us, it is our judgment that *clear-cut*, documented technical justification, on a basis of safety to the plant operating personnel and the public, for loose-parts monitoring programs is presently lacking. It has been claimed that monitoring for the presence of loose parts is beneficial because (1) the presence of unsecured, detached, and drifting parts in the reactor's primary coolant system raises serious questions regarding the advisability of continued plant operation; (2) even the somewhat limited technology now in use has proved effective in several

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However, if safety justification for loose-part monitoring can be firmly established, then proceed to cultivate industry acceptance by giving LPMS legitimacy and stature through creation of a strong technical foundation and a carefully formulated implementation policy. Continuation of present and encouragement of new development of monitoring techniques, release of new and improved Regulatory Guides, formulation of consistent Branch Positions, inclusion of LPMS in Standard Technical Specifications, and in-plant demonstrations of the latest LPMS technology are all to be encouraged.

2. Clarify and document the Commission staff's *long-term* expectations for the technical performance of LPMS, both for presently operating and future plants; then broadcast this position to the LPMS vendors, A-Es, and utilities. The new Regulatory Guide 1.133, "Loose Part Detection Program for the Primary System of Light-Water-Cooled Reactors,"

which is expected to be issued soon, constitutes a first step in this direction but, in our opinion, provides insufficient indication of future expectations for LPMS. We strongly believe that any attempt to step the technology forward (through increased regulatory requirements) in a piecemeal fashion, without clearly defined ultimate objectives, is unlikely to produce a satisfactory final product.

3. Reexamine the Commission staff's present definition of a loose part as being one that is "disengaged and drifting"; such definition may be too narrow, in that it does not cover the *incipient* loose part, i.e., one that is impacting in place but is still partially secured. Likewise, reexamine the historical precedent that instrumentation be confined to so-called natural collection areas within the primary coolant system, since we believe that knowledge of the loose part's point of origin may be just as important from a standpoint of safety significance as its present resting place. Innovative approaches should be encouraged.
4. Under the proviso that a clear-cut, *safety-related* need for LPMS is established, encourage the utility industry to formulate monitoring *programs*, not just acquire additional hardware. The foremost goal of such programs is to assure prompt and reliable *detection* of all sonically active, primary system loose parts exceeding a threshold of detectability;^a this threshold should be based on both technical "best efforts" and a criterion of impact severity that is derived from a likelihood of reactor system damage or malfunction. [Note: "reliable" detection implies an acceptably low incidence rate of false indications.]

Key elements of such programs include quality-assured equipment, comprehensive calibration and operating procedures, sufficient and well-documented baseline information, and continued attention by knowledgeable utility staff to data interpretation, record keeping, and observation of background signal trends. The relationships among these elements are clarified in Fig. 1. To be maximally effective, such programs must be integrated into the total scheme of plant operations. The Commission staff might encourage such a farsighted, integrated approach by requesting that licensees state how they plan to do so in their mandatory design-phase safety analyses.

5. Provide utilities with a *choice* regarding both the general approach and the endpoint performance requirements of their LPMS, so that monitoring programs might be formulated that satisfy the overall objectives of both utilities and the NRC and yet reflect the operational preferences of the particular plant. To be meaningful, this choice must be tightly coupled with action plans that permit increased operational latitude commensurate with the additional information that is made available through more comprehensive programs. We suggest in Fig. 1 that one possible implementation plan meriting consideration might consist of two distinct phases (denoted Phase I and Phase II), yielding quite different endpoint performance capabilities, which could be pursued serially or in parallel; while attainment of Phase II would be highly commended, indefinite postponement of this added-capability phase would be provided as a perpetual option, if the utility were willing to implement an attendant, limited-option action plan in the event of a loose part.

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For Industry Implementation

1. Examine the *economic* (plant availability) justification for loose-parts monitoring by performing a thorough cost-benefit analysis based on the numerous types of loose-part incidents recorded to date. Utilities may well find that loose-parts monitoring programs can be extremely attractive, based solely on economic considerations, independent from any NRC requirements. Presuming, however, that the NRC will continue in the future to require some degree of loose-parts monitoring on all nuclear plants, utility acceptance would also be significantly enhanced if the potential economic benefits of early detection and ameliorative action were more widely appreciated.
2. Under the proviso that a clear-cut, economics-related need for LPMS is established, carry out the technical development needed to achieve both reliable *detection* and a sufficient degree of loose-part *characterization* capability to allow the operability

^aBased on the expected mass range of primary coolant system loose parts that have been detected in the past, their potential safety significance, and typical coolant flow velocities Regulatory Guide 1.133 is expected to suggest that an acceptable threshold of detectability would be a metal-on-metal impact that imparts an energy of 0.5 ft-lb or more to the inner surface of the primary coolant pressure boundary at a distance of 3 ft from a sensor. We have not examined the suitability of this level in detail, but it appears reasonable and is likely to be achievable in practice.

Fig. 1. Implementation plan.

significance of the part to be assessed with some assurance. Demonstrate the newly developed technology in-plant, and widely disseminate the results, both within the nuclear industry and to the NRC.

3. In conjunction with the two preceding recommendations, postulate various potential loose-part occurrences and examine both their safety and economic implications. Formulate appropriate action plans that identify precisely those steps that would be taken to gather corroborative information for ascertaining the significance of any loose parts that might be detected. Propose time frames for responding with ameliorative and corrective plant actions. Such preplanned responses can only benefit plant internal operations and help to answer questions posed by the NRC.

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For All Affected Parties

Open channels of communication. Our survey revealed that feedback from the utilities to the A-Es (who typically bear the responsibility for specifying the LPMS technical requirements) is lacking at present; information exchange among the utilities at the LPMS user level is likewise deficient and, as cited earlier, so are other channels (NRC to the industry, LPMS vendors to the utilities, etc.).

It should also be acknowledged that the attitudes, policies, and the (oft-times opposing) incentives of the utilities, the Nuclear Regulatory Commission, the Advisory Committee on Reactor Safeguards, the LPMS vendors, and the A-Es are all part of the total LPMS picture; i.e., there are institutional, political, and economic aspects as well as purely technical ones. Thus, the degenerative-feedback situation now prevailing is, in our opinion, unlikely to improve until a more cooperative and venturesome approach is adopted by all five affected groups.

CONCLUSIONS

The present status of loose-parts monitoring programs in U.S. commercial reactors leaves much to be desired, from the viewpoints of all affected parties--the NRC, the utilities, and the LPMS vendors--and all parties must bear some portion of responsibility for having created it. We think the present unsatisfactory status is a predictable outgrowth of the atmosphere of confusion, coercion, and inadequately established need in which this technology was born, coupled with hastily conceived and shallow technical development carried out with too little attention to ultimate performance goals. Nonetheless, we believe that order

and a sense of value-impact balance can be established if carefully selected and appropriately executed technical *and* regulatory improvements are instituted by the nuclear industry and the NRC.

The *technical* improvements that we have suggested may be the easier of the two to achieve because, even though LPMS having both adequate sensitivity and reliability have not been, in our opinion, fully demonstrated at present, it is our best technical judgment that such systems are not only feasible but could, in fact, be implemented today using state-of-the-art technology.

The *regulatory* improvements that we have suggested, on the other hand, are likely to be more difficult to achieve because, in our opinion, a complete reassessment of the basic safety justifications underlying the current regulatory requirement for loose-parts monitoring programs as well as a clear and concise policy statement of NRC staff's expectations for future performance of LPMS are required before any more detailed plans for industry implementation of better loose-parts programs can be made.

Prompt attention to the above issues by NRC staff, research and development personnel, and industry spokesmen alike would serve the best interests of all affected parties, and is strongly recommended.