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Item 14

ATOMIC ENERGY COMMISSION
LOCKLAND AIRCRAFT REACTORS OPERATIONS OFFICE

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SUBJECT: MEDICINE, HEALTH AND SAFETY

7-1.14 ACT

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Memorandum

TO : Manager, LAROO

DATE: JAN 13 1961

FROM : Brig. General Irving L. Branch
Assistant Director (Aircraft Reactors), DRD

SUBJECT: DIRECT CYCLE ADVANCED CORE TEST (ACT) HAZARDS REVIEW

RD:AIR:AP

As a result of the ACT hazards review on December 8, 1960, the Advisory Committee on Reactor Safeguards has submitted the following comments:

"This proposed reactor will have an unusual property in that it will continuously omit fission products through the test period. Calculations and experiments made up to this time indicate that the release of fission products during normal operation will be sufficiently low so that persons off-site can be protected from receiving more than the non-occupational tolerance doses. This protection relies to a large extent upon the meteorological and monitoring services provided by the Atomic Energy Commission from its Idaho Operations Office. The applicant proposes to monitor the gases which will be released so that in the event that the rate of gross-fission-product release should show a rapid rise, the facility can be shut down to avoid excessive off-site doses. It should be emphasized that the proposed operation is on the basis that it will be continued up to the point where the off-site dose will equal the non-occupational tolerance dose.

"In the event of an accident or maloperation, the rate of fission product release could increase greatly, depending upon the severity of the accident. Even though the applicant proposes to provide safety controls, exhaust gas monitoring, and emergency cooling so that an incipient accident can probably be controlled to avoid any significant increase in the fission products, the ACRS believes that additional protection should be provided for the public as follows:

"1. The exhaust gases from the reactor and engine, together with air from the buildings surrounding the Advanced Core Test, should be released through a stack at least 250 feet high. This increase in stack height over that proposed will reduce significantly the concentration of any release of radioactivity reaching the public.

"2. An emergency filter system should be provided which will give adequate protection to the public in the case of an

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accident. It is imperative that this system can be activated in a sufficiently short time to prevent excessive off-site exposure. The ACRS desires to review this filter system before reactor operation. This system should be tested routinely in order to establish its reliability.

"3. The presently proposed control rod system should be given additional study. Consideration should be given to the use of individual drives for rapid insertion for each control rod.

"4. Further study should be given to a secondary shutdown device of a simple and reliable nature and preferably operating by a different mechanism than that used in the primary control system.

"5. The Committee recommends that the proposed tests of the ceramic fuel elements - both in-pile and out of pile - be carried out on the schedule proposed. These tests will serve as quality control on the fuel elements being fabricated. The Committee also endorses the proposed hot critical experiment after all the actual fuel elements are available.

"The Committee would generally advise against an operation such as the ACT which intentionally exposes the off-site public to maximum permissible non-occupational doses. However, in view of the short duration of the ACT experiment, the Committee believes that this operation can be carried out without undue hazard to the health and safety of the public - provided that the design work is successful and the proposed material testing, fuel element testing and hot critical experiments all turn out favorably."

The Division of Licensing and Regulation, AEC, is in general accord with the ACRS comments; however, they have taken exception to the specified stack height. The DLR comments on this point are as follows:

"The ACRS has recommended that the effluent stack height be increased to 250 feet and has stated that "this increase in stack height over that proposed will reduce significantly the concentration of any release of radioactivity reaching the public." We are not convinced, however, that the recommended increase in stack height would result in a substantial increase in safety to the public. Release of radioactive gaseous effluents at increased elevation would, for average weather conditions, reduce the concentration of these gases at ground level in the areas immediately around the stack, - out to distances of 10 or

so stack lengths. In particular but infrequent weather situations, the ground concentration from a higher stack would be reduced even at large distances. Conversely, under some conditions, even near the stack, there would be little or no practical difference. On the average, and particularly under the weather conditions for which operations of the ACT are contemplated, at distances larger than a mile or so and certainly in off-site areas, an increase in stack height from 150 to 250 would result in no practical difference in air concentration of stack effluents. Furthermore, increasing the stack height would decrease the reliability and effectiveness of close-in field measurements of air concentrations which is a key ingredient of the controlled operation plan of the ACT."

"Thus, it is our opinion that the stack height should be sufficient to give protection to the ACT facility itself and the immediately adjacent areas but that any increase beyond this would give no substantial protection to people at large distances and would make it more difficult to carry out the close-in field monitoring-operational control scheme now planned. We plan to discuss this again with the ACRS and will advise you of any further developments."

It is requested that LAROO take the following action:

1. Inform GE-ANPD of the ACRS and DLR comments.

2. Obtain comments from GE-ANPD regarding the specified stack height as soon as possible.

3. As soon as GE-ANPD has formulated firm plans for complying with the comments on the emergency filter system, the primary control rod system and the secondary shutdown system, please advise us so that arrangements can be made for an interim discussion with the ACRS.

APPENDIX I

THIS DOCUMENT CONSISTS OF ___ PAGES

I. INTRODUCTION

This appendix contains a general review of APEX 573 which presents the design features of the D140-E1 Advanced Core Test (ACT) assembly and possible biological hazards resulting from the release of radioactive materials during power operation of the assembly. The report was reviewed for accuracy of presentation and from the standpoint of overall philosophy of the ACT operation in relation to test schedules and air cleaning facility requirements. As a result of the review several comments and discussions have arisen and will be presented in this Appendix I. In the presentations we will not endeavor to be detailed in regard to particular page and paragraph (this will be done in Appendix II) but instead will present comments as general comments in areas of particular significance and on philosophy.

In general the analysis of the biological hazards was based on the following set of assumptions:

1. Normal Operation

   a. Acceptable low level release of fission products from fuel elements. (Here ~~we understand~~ "acceptable" to be used in reference to dose limits at the site boundary).

2. Abnormal Operations

   a. Local overheating of one or more fuel tubes as a result of coolant air blockage.

   b. A reactor meltdown caused by failure of after heat removal mechanisms.

   c. A nuclear excursion caused by control failures or core deformation resulting from meltdown.

II. DISCUSSIONS

The comments on the review have been separated into five areas of significance to hazards of operation of the ACT. These areas are discussed in the following:

a. Core and Materials Integrity

Since the reactor core design and materials content are essentially new and unproven from the standpoint of core integrity and fission product release it becomes important to review those factors which will lend confidence to a safe operation.

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A series of out-of-pile tests have been run to determine at what stress levels individual fuel tube failures first appear. These ZrO_2 clad tubes were tested at heat flux levels 2 to 5 times higher than ACT conditions and at temperatures of 2300°F to 2750°F for times up to 1000 hours. The results of the tests indicate that no failures appear if the combined stress levels are maintained below 27,000 psi. The P140E cruise stress level design is 15,000 psi. Thermal cycling tests including 2 tests of 1000 hours duration at 2500°F with cycles at 20 hour intervals and other cycle tests at temperatures to 2600°F in the MTR, HTRE-2, LITR and ORR have shown no failures which can be attributed to thermal cycling.

Tests run to evaluate fuel retention at 2500°F and 2600°F and at various dewpoints indicate approximately 2% loss over 1000 hours. In pile tests indicate that the application of the ZrO_2 clad to the I-D of the fuel tube reduces water vapor corrosion essentially to zero. This fact probably represents in addition to the reduction of corrosion, a reduction in the increase of release of long lived fission products that would be carried away in the corrosion of unclad tubes.

A number of two and three tier mockup tests have been run wherein the assemblies were loaded and operated at temperature. Results of these tests indicate no gross core damage and also that local voids are bridged by surrounding tubes.

With the successful completion of the LIME test (HTRE-2/LZE-4) data pertinent to the understanding of core integrity as a result of local fuel tube over temperature, due to coolant blockage, has become available. In the LIME experiment the coolant flow to 18 fueled tubes in a specially designed insert cartridge were blocked and the tubes were allowed to operate at power densities comparable to those of the ACT for a period of ten minutes. Results of the test indicate that though fuel tube material was displaced within the plugged region boundary, at an estimated temperature of 4500°F, the damage did not propagate to fueled tubes surrounding the plugged region. This result indicates that no catastrophic failure of the ACT core should be expected due to blockage of a reasonable number of fuel tubes, e.g., 19 to 37. Other HTRE-2 insert tests run over the past two years have resulted in an accumulation of data on the operating characteristics of ceramic fuel elements. In general the information collected indicates that for the temperatures, times, powers, and stresses that are anticipated for ACT operation, core integrity will be maintained.

Concerning the control system the ACT core is fitted with 48 control rods located in the side reflector. The control rod drive and scram mechanisms are of a new design making use of chain and sprocket buried

in the front shield assembly and driven by a power head assembly through gears and shafts. The power head is external to the engine. The power head is driven by a pneumatic motor and scram is provided by clock type springs wound up and latched by means of an electro-mechanical clutch.

This system is new to ANP reactors and at the present little is known of the system operating characteristics. However, it is expected that program of checkout will be established to prove the design and establish reliability particularly with regard to scram.

b. Meterological Control of ACT Tests

The low level normal radioactivity release of fission products from the ACT operation has been estimated at 6800 - 10 minute curies per hour and has been used to calculate the doses to the nearest off-site reciptor at various circumferentral sectors, for usual meterological conditions. The calculations presented in the APEX report indicate for a given quarter of a year assuming 200 hours of ACT operation at a maximum power of 50 megawatts, a maximum thyroid dose of 20 millirad will result. ~~This dose is a factor of 150 below the established dose limits~~. Should fission product storage in the core or should meterological conditions exist during a particular operation that would result in a calculation of a dose to the reciptor in excess of the limit the operation would be curtailed.

Much reactor test data are available to substantiate the predicted modes and magnitudes of fission product release. The LIME tests indicate that the maximum release of fission products, during the 10 minute operation, would be of sufficient magnitude to be detectable above the steady state release of the ACT core (predicted ACT release 6800 - 10 minute curies per hour; maximum release during the LIME test 37,000 - 10 minute curies per hour, representing a factor of approximately 6 above steady state ACT release.). The LIME tests adds confidence to the predictions and understanding of local core melting and indicates that releases are of sufficiently low a magnitude such that, should a local melt occur the doses to the site boundary, under meterological control, would remain within limits.

Other HTRE-2 reactor tests with ceramic inserts wherein continuous release was the normal occurence have resulted in the accumulation of much data on the fractional releases of the various isotopes, the release as a function of time, and the dispersion of this activity over the NRTS area as a function of various meterology. These data show that doses resulting from release of fission products can be controlled and also shows that modes of release from the ceramic materials are predictable.

In general all of the data and calculations show that for all normal operations and minor abnormal operations (local melts) that the release of fission products can be maintained within acceptable off side dose limits using meterological controls.

c. Design Data for an Electrostatic Precipitator

In the consideration of the electrostatic precipitator as a means of effluent cleaning for the FET exhaust system, design data were needed before final specifications could be written. The MTRE-2 FEET (insert L2A-2) tests were implemented to provide these design data. The test involved the use of the MTRE-2 reactor and a specially designed side loop containing an electrostatic precipitator capable of handling 6 pounds per second of air. In essence the tests have shown that, for short periods of time (2 to 4 hours) efficiencies for the removal of the halogens of 90 percent can be achieved and the data accumulated are of such a quality as to form the basis for establishing design specifications for the FET precipitator. It has been estimated that the design, fabrication and installation of the FET filter system will require from 16 to 20 months and cost from 3 to 4 million dollars.

d. Precipitator Philosophy

A considerable amount of time has been spent over the past several months in the evaluation of an electrostatic precipitator as a gross air cleaning device for the FET. The FEET tests resulted in data which indicates the precipitator can be designed and fabricated to remove 90% of the halogens. However there are several factors involving the use of a precipitator of the size anticipated for FET use (60 feet high, 40 feet deep, and 150 feet wide) that show that such a system would be undesirable from an operations standpoint. These factors such as:

1. Maintenance of the mechanical components of the system, in some cases under high radiation fields.

2. Periodic cleaning of the plates of the precipitator to insure that efficiencies will be maintained.

3. Drainage and storage of large quantities of contaminated waste

represent time delays to the ACT operation which could be of sufficient magnitude to render the precipitator operation, the limiting item in the ACT test program.

It appears that there are two primary reasons for incorporating the electrostatic precipitator into the FET stack system, these are:

1. To remove at least 90 percent of the halogen fission products from the effluent gas during normal operations.

2. To remove at least 90 percent of the fission products and particulate resulting from minor core accidents, e.g., accidents not of sufficient energy release to cause pressure shell rupture such as local melts. (It has been assumed that a filter system would be ineffective in the case of a major accident.)

It has been shown in the preceeding discussions that the normal release of fission products represents doses to the nearest receptor, beyond the site boundary, of a maximum of 20 millirads to the thyroid. This dose is a factor of 150 below the specified limit of 3 rads. Here, also, we are talking about the maximum dose; on the average the dose is more like 8 millirads representing a further reduction in the normal release to a factor of 370 below the limit. The factor of 10 reduction gained by including a precipitator in the FET stack system therefore represents, relatively speaking, an additional reduction to doses, which are at the outset far below the limit.

Indications are that accidents of a minor nature such as local melts result in increases in release by a factor of 6 above normal ACT steady state release with the resultant maximum calculated dose being a factor of approximately 10 below the off site limit. This release is immediately detectable and would result in reactor scram thereby strongly limiting the time duration of such a release.

An additional factor which bears consideration in regard to release is the fact that reductions in the halogen content of the effluent gas are achieved using a stack exhaust system, through plate out in the ducts and through the changes in effective stack height by gas temperature. It is possible that these reductions could approach a factor of 10.

In general it appears that fission product releases resulting from normal reactor operations can be limited by meterological control to acceptable off site limits and that minor core accidents do not result in off site dose limits being exceeded wherein no special air cleaning devices are involved.

e. The Maximum Accident

The ACT reactor will be designed and operated in such a manner such that a multiplicity of control system and/or operator failures must occur before major reactor excursions will result. The design of the control system and particularly the safety system will be consistent with a fail safe philosophy in which component failure will produce actions which would shut the reactor down. These safety and control systems will be extensively checked to establish reliability and confidence factors.

The maximum accident is certainly a feature associated with all reactor operations and it is pointed out that maximum effort is made to recognize possible causes of such accidents and to take every precaution to insure that such accidents have a minimum probability of occurence.

III. CONCLUSIONS

From the review of the APEX report and within the scope of the report

and other data and information available, the following are concluded of the proposed ACT operation in the Flight Engine Test Facility:

1. The mechanical design and materials properties of the ACT reactor are sufficiently well known such as to indicate that the reactor can be operated at the design power level, temperature and for the test time involved, without significant core damage.

2. The proposed ACT operation can be conducted in a safe manner wherein normal low level fission product release can be maintained within acceptable safe dose limits, by using meterological controls and with a standard stack exhaust system.

3. Sufficient data are now available from FEET tests to form the basis for a set of design specifications for an electrostatic precipitator for the reduction of the halogen content of the ACT effluent by a factor of 10 (90% efficient). The precipitator can be built within the time alloted.

   However, it is pointed out that factors involving the maintenance of the precipitator system of the size required for the FET could represent time delays to the ACT test program of sufficient magnitude to render the precipitator operation the limiting item in the performance of the test program. In addition the cost of such a system would be extremely high.

4. The material presented in the APEX report on the hazards of operation and the analysis of accidents was adequate and reasonably thorough and the assumed maximum accidents are of sufficiently low probability to be an acceptable risk.

Material for Appendix II is now being collected and evaluated and will be forwarded as soon as possible.