A REVIEW OF
FABRICATION AND INSTALLATION REQUIREMENTS
FOR LMFBR PIPING

TECHNICAL REPORT 220

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LMFBR PIPING
FABRICATION AND INSTALLATION
REQUIREMENTS

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1 INTRODUCTION

C F Braun & Co has been awarded a contract (1) by the US Atomic Energy Commission for the development and verification of a Piping Design Guide for sodium-cooled fast breeder reactor power plants (LMFBR). The work is a Priority 1 Task under the LMFBR Program Plan (2) prepared for the USAEC Division of Reactor Development and Technology (RDT) by the LMFBR Program Office, Argonne National Laboratory. It is identified in the Program Plan as Task 3-8.2, Development of Design Technology for Piping.

This report presents the basic requirements for the fabrication and installation of LMFBR piping systems. These requirements are based on analyses of the requirements used for existing nuclear and/or liquid metal facilities, those present in the latest editions of codes, standards and specifications for nuclear systems, and incorporating the experience and judgment of manufacturers, fabricators, and technical specialists dealing with nuclear systems.

Although an LMFBR piping system may be entirely austenitic stainless steel, at the time of this writing, the inclusion of ferritic materials was thought probable. For this reason the topics of postweld heat treatment and magnetic particle testing are included. This report will cover only the most stringent piping requirements, such as the primary and secondary coolant loops will require. However, it is recognized that there may be systems that can be fabricated and installed to less stringent requirements. This report does not contain any quality assurance procedures or requirements other than those inherent in the fabrication and installation requirements. Quality assurance will be the subject of a separate task and will be factored directly into the preliminary issue of the Design Guide.

A review procedure has been established to ensure consistency between interdependent studies currently being performed under this and other task areas of the LMFBR Program Plan. Under the review procedure, the Liquid Metal Engineering Center (LMEC) is the coordinating agency. Technical reports prepared by Braun under this contract have been distributed by LMEC to appropriate review agencies designated by USAEC. This report, issued in preliminary form on February 28, 1969, has been reviewed under the procedure described above. Pertinent comments have been incorporated and the report has been released by USAEC for final publication.

- (1) AT(04-3)-781, AEC San Francisco Operations Office (SAN)
- (2) Liquid Metal Fast Breeder Reactor Program Plan, LMFBR Program Office, Argonne National Laboratory - AEC R&D Report, Reactor Technology, WASH-1101, August 1968.

2 GENERAL DISCUSSION

2.1 SOURCES

There are three primary source groups for information used in establishing LMFBR fabrication and installation requirements. The first group includes published articles, specifications, and standards used for the fabrication and installation of existing nuclear and/or liquid metal systems. The second group of sources is the most recent codes and standards for nuclear systems, some of which are in the preliminary stage. The third source is the judgment and experience of individual specialists and industrial organizations who have used and can evaluate a majority of the nuclear codes and standards.

The articles in the first group concerned the Dounreay fast breeder reactor, the Dresden nuclear power station, the Southwest Experimental Fast Oxide Reactor (SEFOR), EBR-I, liquid metal cooled reactors in general, and specifications used for the Hallam Nuclear Power Reactor, The Fermi Reactor, and some small liquid sodium systems. These are listed as references (7) and (14) through (30).*

The second group included ASME Boiler and Pressure Vessel Code Sections III, Nuclear Vessels (2) and IX, Welding Qualifications (3), USAS B31.7, Nuclear Power Piping (1), and the applicable specifications of the Reactor Development and Technology Division (RDT) of the US Atomic Energy Commission. Also of interest were the Atomic Energy Commissions "Tentative Regulatory Supplementary Criteria for ASME Code-Constructed Nuclear Pressure Vessels" and the ASME's comments on these criteria. The bulletins on Personnel Qualifications of the Society for Nondestructive Testing were also included in this group, which is listed as References (1) to (6), (8) to (12), and (31) to (45).

The third source group was composed of interviews with specialist employees of C F Braun & Co and Liquid Metal Engineering Center, and of the results of a questionnaire sent to fabricators known to have experience in this field.

*References are listed numerically in Section 15, Bibliography

2.2 METHOD

The published articles, specifications, and standards which were used for existing systems fall short of meeting the needs of the more severe conditions of LMFBR piping. Almost without exception, the specifications cite USAS B31.1, which was then the only applicable piping code. Its examination procedures were amended to include 100 percent X-ray and many jobs called for some degree of liquid penetrant and ultrasonic testing. On the whole, however, the specifications were not as complete and had lower standards than today's USAS B31.7 or ASME Section III. One exception was the use of helium mass spectrometer (HMS) leak tests on all welds at Fermi (25) and SRE (23), and on certain critical welds at Hallam (19). This exception will be discussed in Section 6, Leak Testing.

As USAS B31.7 is more applicable to LMFBR piping than USAS B31.1 or the specifications and standards used for existing systems, most of the older requirements will not be used. A few exceptions are leak testing methods and certain welding procedures which are discussed in Section 3. Thus the task is to choose the strictest yet realistic requirements from USAS B31.7, ASME Section III, and the RDT specifications, or a combination of them. The requirements will then be reviewed in the light of information gathered from interviews, questionnaires, and further comments from other participants in the LMFBR program.

The selection of requirements and standards, in this report, should be considered as tentative as the goal of the RDT standards program is to provide approved standards as mandatory requirements of future LMFBR plants. As RDT standards are developed, they will be applied to replace the currently recommended standards.

3 WELDING

A previous report under this contract was Number 214, A Review of Piping Failure Experience. It concluded that the location of the most likely failure in LMFBR piping ". . . would probably be located in the primary or secondary loop at a weld, or in the heat affected zone adjacent to a weld, in the presence of a notch defect or gross geometric discontinuity." Welding must therefore be given most careful consideration due to its primary place in the safety of LMFBR systems.

3.1 WELDING PROCESSES

In order to achieve the high degree of weld integrity necessary for LMFBR piping systems, welding will have to be done by an electric fusion process. Tungsten inert gas (TIG), consumable metal-arc inert gas (MIG), submerged arc, and manual welding with coated electrodes are the processes most likely to be considered. Pulsed-arc, a recent refinement of the MIG process may also be used. Welds may be a single process or a combination of two or more of the processes.

Liquid sodium may attack weld slag or nonmetallic inclusions in the weld metal. For this reason the weld pass in contact with liquid sodium must be smooth, clean and free of defects and should be made by TIG, MIG, or submerged-arc methods rather than by manual welding with coated electrodes. The root pass of pipewelds in sodium service that are accessible only from the outside must be made by the TIG process with a controlled inert gas purge for inside surface protection.

The use of either short-arc or oxy-acetylene welding will not be allowed. The shortarc process is prohibited by the experience and judgment of welding specialists and fabricators. Helmut Thielsch has stated in a letter (48) to the authors of this report, "Because of our thorough analysis of these welding processes when they were first developed ten years ago, and considerable additional testing since then, we have not permitted short-arc welding on pipe for critical applications." Our specialists and others are in agreement with that policy.

3.2 WELDING QUALIFICATIONS

As has always been done, proof of the welding procedures' ability to produce welds of the desired quality and strength and proof of the operator's ability to use those procedures must be obtained by qualification tests.

3.2.1 PROCEDURE QUALIFICATIONS Essentially all codes or specifications dealing with nuclear piping agree that Section IX, Welding Qualifications, of the ASME Boiler and Pressure Vessel Code (3) is at least the basis for weld procedure qualification. A few specifications have modified the requirements of Section IX, aiming at making test welds that more nearly duplicate the production welds. Some of these additions are indeed worthwhile and will be used for the LMFBR system.

ASME Section IX places no time limit on procedure qualifications. For LMFBR systems, each new installation will require a new and complete set of applicable test-plates to cover each welding process and position. This will prevent the submission and use by the fabricator or installer of outdated procedures which may not have been used for years.

Test plates will be subjected to the same examination criteria that will be imposed upon production welds as given in Paragraph 5.8. They shall meet those requirements before the tensile and bend test specimens are removed from the weld test plate.

ASME Section IX test plates qualify procedures for use on material from 3/16-inch thick to twice the thickness of the test plate. This means that some procedure test plates may not reflect the conditions for production welds. Consequently, for LMFBR welding, the range of thicknesses for which a procedure qualifies will be limited to within plus or minus 25 percent of the plate thickness actually used.

As noted in RDT F 6-1 (6),* ASME Section IX (3) states the dimensions of the welding groove are not essential variables of the procedure. For LMFBR welding the dimensions will be treated as essential variables. The sentence in Q-12(c) of Section IX, "The dimensions of the welding groove are not essential variables of the procedure specification" will be disregarded. Additional essential variables will be those given in RDT F 6-1, Paragraph NV-16, Joint Design. "(a) A decrease in the included angle of the welding groove greater than 20 percent of the angle used for qualification. (b) A decrease in the root opening greater than 35 percent of the opening used for qualification. (c) For joints made with consumable inserts, a change in the nominal size or shape of insert or an increase in the nominal root face. (d) A change in type of welding groove."

*This report will use the new numbers for RDT standards that were assigned early in 1969. As the renumbered issues were not available when writing the preliminary report, both old and new numbers, and the date of the latest issue are given in the bibliography. A cross reference index of old and new RDT standard numbers follows the bibliography.

3.2.2 PERFORMANCE QUALIFICATIONS As in Procedure Qualifications almost all codes refer to ASME Section IX (3) for their welder or welding operator qualifications. For LMFBR welding the same modifications to Section IX stated for Procedure Qualifications will be required for Performance Qualifications. Test plates must be subjected to the same inspection criteria as production welds, and the test plates must be within 25 percent of the production plate thickness. The dimensions of the weld grooves will become essential variables by modifying Paragraphs Q-23 (c) and (d) in ASME Section IX by deleting reference to Figure Q-23 as an alternate for groove dimensions.

3.2.3 QUALIFICATION RECORDS One of the items that the nuclear codes agree on is the manufacturer or contractor shall maintain the welding qualification records as required by Paragraph Q-1(c) of ASME Section IX. This will also be required for LMFBR records.

3.3 WELD PREPARATION

Weld preparation is an aspect of fabrication extremely important to the weld joint integrity. It is of particular importance in large diameter piping. Failures can arise from many aspects of weld preparation. As an example, poor fit-up was partly responsible for a leak in the primary sodium piping system at Dounreay (14).

3.3.1 BEVELS The specifications and standards for nuclear and liquid metal system piping agree that butt welding end preparation should be as shown in USAS B16.25, Butt welding Ends, or as used for the procedure qualification weld or welds. A minor exception to B16.25 will be taken for LMFBR piping. The inside contour of any components except valves will not be allowed to "follow its natural geometry" unless it tapers back from its weld end with a slope not exceeding 1 to 3. This exception is taken care of by Figure 1-727.3.1 in USAS B31.7 which depicts acceptable transition slopes when the mating ID and/or OD are unequal.

Machining is the only acceptable method for the original forming of weld bevels. The use of methods other than machining for modifying or repairing weld bevels is to be kept to an absolute minimum. Other methods such as grinding or thermal cutting present contamination hazards and difficulties in dimensional control. If grinding must be done, only resin-bonded, aluminum oxide wheels may be used.

3.3.2 CLEANING LMFBR systems will be no different from others in this respect as the metallurgical requirements of the welds must be protected by keeping the weld bevel and immediately adjacent area free from contaminants.

3.3.2 CLEANING Continued

When thermal cutting methods, such as oxy-acetylene torch, arc-air gouging, or plasma jet are used, the contaminated or heat damaged material must be mechanically removed from the cut surfaces.

RDT F 6-1 requires that a minimum of 1/8 inch be removed from P-3 material, while B31.7 requires that a minimum of 1/32 inch be removed from P-4 and P-5. However, the amount of material which is necessary to remove is variable and dependent upon the material type and the thermal cutting method used.

3.3.3 FIT-UP The accuracy of fit-up is an area where some disagreement exists. The codes agree that the gap between the two bevels should be the same as the qualified welding procedure. However, the tolerances on the matching of internal diameters vary between specifications. ASME Section III, although strictly applicable only to vessels, allows a variance according to the plate thickness from 1/4 of the wall thickness to 1/8 of the wall or 3/4 inch for sections over 2 inch. The coverage in USAS B31.7 is much more complete and explicit. Its requirements in Paragraph 1-727.3.1 (c) Alignment, of a maximum 1/32 uniform mismatch and a 3/32-inch maximum mismatch at any one point are appropriate for LMFBR systems, while those of Section III would not be strict enough.

There are various methods of achieving the required fit-up. In recent years there has been increasing use of engineered alignment clamps. They are available in all sizes and for both internal and external use. They offer quick setup, properly spaced pressure points, and minimum damage to the pipewall. It is therefore required that such clamps be used whenever possible in fitting up LMFBR piping.

The use of wedges, clamps, hammering, and similar methods is to be kept to an absolute minimum to avoid the creation of stress risers by any resulting damage to the pipewall. Marks and depressions created in the piping during fit-up or handling which exceed the materials examinations acceptance standards in Section 5.4 must be removed or repaired as covered in Section 7.

3.3.4 FIXTURES Although the clamps mentioned above are to be used whenever possible, there will always be times when fixtures must be used to aid the fit-up and alignment of piping joints and to hold the joint in place for tack welding. Although most fixtures are temporary in nature, many are welded to the piping and then cut or knocked off after use. All the specifications agree that the fixtures should be the same material as the piping and welded using qualified procedures and welders. These will also be requirements for the LMFBR system.

3.3.4 FIXTURES Continued

When temporary fixtures that have been welded to the piping system are removed, further requirements are created. It will be necessary to LMFBR systems that the areas from which these attachments have been removed to be ground smooth and examined by a liquid penetrant or magnetic particle method as provided in ASME Section III, Paragraph N-524.3.

3.4 WELDING MATERIALS

A great deal of time and effort will go into the testing and examining of the LMFBR piping material. This time and effort will be lost if the welds are not made with materials having the same degree of careful control over them. These materials consist of wire, electrodes, welding flux, and purge gas.

3.4.1 FILLER METAL USAS B31.7 requires no proof, other than the AWS-ASTM classification marking, that the filler metal is indeed the same used for the qualification welds. ASME Section III requires proof by physical or chemical tests "... for each Lot of covered or flux cored electrodes, for each Heat of base electrodes, and for each combination of Heat of base electrodes and Batch of flux mix to be used for vessel welding," (N-511.3). Physical tests are required for A numbers 1 through 6 (N-511.4) and chemical tests are required for A number 7 and 8 and nickel base alloys (N-511.5). These tests, and the modification to the tests given in RDT F 6-1, Paragraph 14, will be required for LMFBR filler metal. This will amend N-511.5 so that all heats and lots of weld material, regardless of A number, receive chemical analysis. Consumable inserts used in LMFBR welds will also need to meet these same requirements.

3.4.2 FLUX USAS B31.7 does not mention welding flux directly. As indicated by the quotation in the previous paragraph, ASME Section III requires flux to be tested with the filler metal. N-523 in Section III also requires that "Suitable identification, storage, and handling of electrodes, flux, and other welding materials shall be maintained. Precautions shall be taken to minimize absorption of moisture by low-hydrogen electrodes and flux." RDT F 6-1 and the AEC criteria for Section III (4) go even farther. They require that these low-hydrogen materials be stored in ovens for specific times and at specific temperatures. This is not desirable for reasons best expressed in the following ASME comments on the AEC criteria (5).

This proposal is a good example of how an attempt to cover all details of fabrication can defeat its own purpose and jeopardize quality by forbidding practices which are tailored to the actual materials, shop practices, and fabrication conditions.

3.4.2 FLUX Continued

In support of this comment C F Braun's construction people have experienced welding difficulties when low-hydrogen flux was held too long at high temperature and became too dry. This was confirmed by discussion with the weld rod manufacturer. We thus agree that flux storage requirements above those of ASME Section III are not necessary. The fabricator or constructor will be doing his best to avoid flux problems to protect his own interests and the weld examinations required will check his performance.

3.4.3 PURGE GAS There are minor problems associated with using purge gas on large diameter pipe welds or under conditions exposed to any degree of wind. The solution of these problems, as with those of flux storage, are best left to the discretion of the welding contractor for requirements beyond those given in ASME Section IX and the qualified weld procedure. He will be aware of the problems and will know he must solve them to produce sound welds capable of passing the required weld examinations.

3.5 WELDING DETAILS

3.5.1 PREHEAT As ferritic materials are under consideration for portions of LMFBR piping, preheat may be necessary. The preheat temperature requirements of USAS B31.7 and ASME Section III are essentially identical, while those of RDT F 6-1 are much higher for most materials. We feel the temperatures of B31.7 and Section III are adequate. Proper postweld heat treatments cancel any slight advantage to be gained from a higher preheat temperature, and the lower temperature is easier on the welder and decreases problems with shrinkage. Since B31.7 is for piping and Section III is for vessels, the requirements of B31.7 will be used for LMFBR piping.

3.5.2 BACKING RINGS The use of backing rings has often resulted in notch type stress risers, cracks, and poor weld penetration. They would also be undesirable flow restrictions, sources of corrosion, and areas where impurities might settle out, as well as contributors to thermal gradient stresses.

The provisions of USAS B31.7 Paragraph 1-727.2.2, which are similar to Section III's will be required for the LMFBR. Backing rings will be used only if they are removed after welding and the inside root surface is ground smooth and examined by liquid penetrant or magnetic particle methods.

3.5.3 NUMBER OF PASSES To prevent undesirable grain size in the welds the maximum depth of deposit in one pass must be limited. Submerged arc welds in heavy plate may deposit a maximum of 3/8 inch in one pass but all other processes will be limited to a maximum of 1/4 inch. Heavy plate is defined as one inch or thicker.

3.6 WELDING OF MATERIALS

Longitudinal welds in piping made from plate will be a major portion of the LMFBR piping welds. It is vital that their qualification, preparation, materials, and details be to the same requirements as the piping girth welds.

3.7 PIPESPOOL WELDING*

All pipespool welds in sodium service will be girth type butt welds. Socket welding is not permitted. The pipespool fabricator easily controls the fit-up and cleanliness of the welds and the welds can be positioned to allow the use of automatic welding machines, so the required degree of integrity is readily obtained. The shop also is usually free to choose the most economical of several methods.

3.8 INSTALLATION WELDING

The field conditions, in contrast to those in the shop, often limit the welding process selection to the one which will promise the required quality under the circumstances, regardless of cost. The welds may be in any position, sometimes with restricted access, and fit-up may be imperfect. Automatic machines for field use are being developed by Rytech, Airco, Linde, and others although at this time they are not perfected to the point where they may be used for LMFBR welds.

*Pipespool - A unit of pipe and fittings whose dimensional limits are defined by pipe ends prepared for field welding.

4 POSTWELD HEAT TREATMENT

ASME Section III, RDT F 6-1, and USAS B31.7 all have practically identical and acceptable postweld heat treatment requirements. The advantage of B31.7 containing the requirements within a code for piping, rather than for vessels, is thus chosen for the LMFBR. One exception, which would be taken to any of the three codes, will be that the minimum holding temperature for P-5 materials, shown in Table 1-731.3.1, should be 1300 F. Also P-1 through P-5 materials should be limited to a maximum of 1400 F to prevent excessive scaling and to minimize the chance of warpage. As suggested by RDT F 6-1, Note 1 of Table 1-731.3.1, should be prefaced by "When specifically approved by the owner".

In regard to procedure requirements, when performing local heat treatment, which should only be done with resistance heaters, sufficient thermocouples must be included to ensure that all parts of the weld area are under complete control. Thermocouple holders should be attached directly to the work-piece, preferably by welding, and be properly shielded from the heating elements to prevent false readings. When thermocouple holders are welded to the pipe they must be welded using qualified procedures and welders. If they are removed the area must be inspected as required for fixtures in 3.3.4. A temperature recording device shall be used to continuously record temperatures of the pipe during the heating, soaking, and cooling periods.

5 EXAMINATION

In the past, there has been some debate over the use of the terms Examination and Inspection. This report will follow the example of USAS B31.7 which says that an inspector is a person employed and qualified by a state, municipality, or insurance company, and who performs the inspections required by legal enforcement authorities.

On the other hand, an examiner may be an employee of the owner, and engineering organization, an inspection company, or an insurance company. He performs examinations to assure that the facility has met all the construction and design requirements of the applicable codes and specifications. This report will thus discuss examiners and examinations, inspectors, and inspection being up to others.

Examination is perhaps the most important area of requirements for the LMFBR system. We know from experience and investigations that fabrication and installation methods are available which are suitable for the system but it is the examinations which must guarantee that they have been set up and carried out correctly to obtain complete integrity of the system.

5.1 METHODS

In addition to visual examination, there are at present five widely used methods of nondestructive testing - radiograph, liquid penetrant, ultrasonic, magnetic particle, and eddy current. Eddy current will not be used on the LMFBR systems as it is primarily for small-diameter thin-wall materials. Many other methods are currently in the experimental stage, but are not yet usable on a production basis.

5.2 PROCEDURES

Appendix IX of ASME Section III and Appendix B of USAS B31.7 both contain complete procedures for the types of examination to be used on the LMFBR systems. These methods are radiograph, ultrasonic, liquid penetrant, and magnetic particle. There are also RDT standards on these methods but those available at this time are not written specifically for application to LMFBR piping. A comprehensive review of the pertinent RDT standards is contemplated for possible modification and application to the piping design guide. The procedures in USAS B31.7 are presently considered most suitable for LMFBR piping systems since they apply to piping systems rather than to vessels.

In the procedure for visual examination in B31.7, however, a modification should be made. The RDT F 6-1 list in Paragraph 28.1.3 of the minimum items to be visually examined prior to and after, is a necessary addition to B31.7, Paragraph 1-736.5.1. The listing is as follows.

5.2 PROCEDURES Continued

(a) Prior to welding, for:

- (1) Weld end preparation, dimensions and finish.
- (2) Clearance dimensions of backing strips, rings or consumable inserts.
- (3) Alignment and fit-up of the pieces being welded.
- (4) Verification of correct type of material. It is not intended that this require chemical verification provided there is an adequate material marking and control system to permit checking the material type identification marking on the material against material manufacturer's certifications.
- (5) Verification of cleanliness requirements.

(b) After welding, for:

- (1) Size of legs and throat of fillet welds.
- (2) Contour, reinforcement, and surface finish of outside surface of welds. Also,
- (3) Contour, reinforcement, and surface finish of inside surface where possible.
- (4) Degree of undercutting, overlap, etc.
- (5) Evidence of mishandling, arc strikes, center punch or other impression marking, or excessive grinding.

It should also be noted that Appendix B of USAS B31.7 gives a procedure only for the ultrasonic examination of welds. The ultrasonic examination procedures for materials are found in Paragraphs 1-724.1.1, 1-724.3.1, 1-724.4.1, and 1-724.5.1.

5.3 EXAMINATION QUALIFICATIONS

To carry out the examination methods successfully and to interpret the results requires experienced and skilled personnel, as well as qualified methods. Insufficient or improper testing can cause both the rejection of sound material and the acceptance of unsound material. As pointed out in Reference (13), "A test wrongly applied or interpreted is worse than no test because it gives a false sense of security. The factor of ignorance has been increased and the factor of safety decreased." The following paragraphs will describe the required personnel and procedure qualifications to avoid these problems.

5.3.1 PROCEDURE QUALIFICATIONS As for any other systems, the examination procedures for the LMFBR will be considered qualified if they demonstrate the capability to detect defects which are described in the applicable specifications as unacceptable or required to be reported.

5.3.2 OPERATOR QUALIFICATIONS In 1966 the American Society for Nondestructive Testing published its recommended practice, SNT-TC-1A, Nondestructive Testing Personnel Qualification and Certification which is contained in five booklets, A, B, C, D, and E, each treating a different testing method. (8)- (12). These have been adopted as standards by USASI, ASME, and RDT, and will be required for the LMFBR.

5.3.3 EXAMINER QUALIFICATIONS ASME Section III and the RDT specifications discuss only inspector qualifications. For LMFBR systems examiner qualifications must also be stated. Those in USAS B31.7 Paragraph 1-736.2.1 will be used with two modifications. At least 10 percent of the examiners experience is to have been on nuclear systems and he is to be familiar with the meaning and intent of the codes and specifications which will be used.

5.3.4 QUALIFICATION RECORDS ASME Section III, Appendix IX and RDT F 3-6(39) require that the manufacturer maintain records of the examination qualification of personnel, procedures and equipment. The industry has found, however, that this is not the best system for a piping installation. Since many manufacturers may participate in a piping system, it has proved advantageous for the owner to keep such records. The LMFBR requirements will, therefore, be those of USAS B31.7 Paragraph B110.5 that these records be retained by the owner, upon completion of construction.

5.4 ACCEPTANCE STANDARDS

Acceptance standards vary slightly depending on whether pipe materials or welds in pipespools are being examined but in either case the acceptance standards of USAS B31.7 are the most complete and practical and will be acceptable for LMFBR systems with one exception - the ultrasonic examination of plate for welded with filler metal pipe. The only acceptance standards allowed for plate will be those given for seamless and welded (without filler metal) tubular products and fittings in Paragraph 1-724.1.1 in B31.7. Those of ASTM A-435 are not acceptable as they allow defects too large for an LMFBR system. Indeed A-435 itself states that it is for finding "gross internal discontinuities."

It must be noted that the above acceptance standards may change as a result of future design tasks. The allowable size of internal and surface defects may be reduced due to their effect on design stresses.

5.5 RIGHTS OF EXAMINERS

The LMFBR will require, as have past specifications for nuclear service, that "The examiner and/or the inspector shall have access to any place where work concerned with the piping is being performed. This includes places where design, manufacture of materials, fabrication, assembly, erection, installation, or examination and testing are being performed or the piping is being stored. Examiners and/or inspectors shall have access to all records pertaining to the materials, fabrication, examination and testing requirements of this Code, including welding performance and welding procedure qualifications." (1-736.3, USAS B31.7)

5.6 EXAMINATION RESPONSIBILITY

ASME Section III in Paragraph N-611.1 requires that the manufacturer be responsible for the examinations performed on the vessels. RDT specifications, which are based on Section III, do not mention this directly and therefore must agree with Section III. Although this may be practical for a single item or package as in the case of nuclear vessels, it has not been general industry practice for piping systems. Due to the great number and variety of components in the piping system, it has been industry practice, as reflected in USAS piping standards, to make the owner responsible for seeing that the requirements for inspection and examination of the system have been met. Since we are concerned with piping, LMFBR system examination responsibility will therefore fall upon the owner as covered in USAS B31.7, Paragraphs 1-736.1 and 1-727.

5.7 MATERIAL EXAMINATION REQUIREMENTS

These are discussed in USAS B31.7, Chapter 1-III, and are appropriate for LMFBR systems with the exception mentioned in Paragraph 5.4 that the acceptance standards of ASTM A435 are not acceptable.

5.8 PIPESPOOL EXAMINATION REQUIREMENTS

The pipespool examination requirements are limited to the examination of welds made in the course of pipespool fabrication, since the material examinations covered in previous paragraphs will have been carried out prior to spool fabrication. To achieve the proper guarantee of sound welds, the type and extent of weld examinations for LMFBR piping will be those of USAS B31.7, Sections 1-727.4 and 1-736.5.1, as modified in Paragraph 5.2 and by the following. The inside surface of the root pass of all accessible welds shall be liquid penetrant or magnetic particle examined. This includes the root of the second side of double-welded butt joints.

Specifications for SRE, HNPF, and SCTI required dye penetrant inspection of the outside of root passes in stainless steel lines. This inspection is now considered unnecessary and undesirable, as it is a potential source of contamination for the second pass.

5.9 INSTALLATION EXAMINATION REQUIREMENTS

As for pipespool examinations, the installation examinations will consist of weld examinations. They will have to be of the same type, and conform to the same requirements, as those specified for pipespools in Paragraph 5.8.

6 LEAK TESTING

Leak testing can do many jobs - it can provide a pressure proof test, a leak tightness test, a structural support test, and a partial simulation of operating conditions. The method and procedure used will determine how many jobs the test accomplishes. Hydrostatic testing can do all the jobs, but is the least effective test for leak tightness. Pneumatic testing can also be used for all the jobs, and is a much better leak tightness test than hydrostatic. But it presents a great safety hazard from energy buildup in the compressed gas. Halide and helium mass spectrometer tests are usually conducted at low pressure and used only for leak detection.

6.1 METHODS

The four methods of leak testing mentioned above are those most commonly used. The choice for any given installation will be influenced by many factors. A primary consideration is, of course, whether both a pressure and a leak test or just one of the two is desired. Other factors then enter in such as economics, safety, test fluid availability, compatibility of test fluid with the process, the extent and size of system to be tested, the degree of sensitivity required, and whether it is a shop or field test.

6.1.1 HYDROSTATIC There are many advantages to hydrostatic testing. It is simple, attains high pressures easily and with relative safety, combines in one test a pressure proof test, leak detection, and a structural support test. With water the test is economical, the test fluid is easily obtainable and usually presents no contamination or corrosion problems. Unfortunately an LMFBR system is one of those with which water is incompatible, due primarily, of course, to sodium's reactivity with water. As the system will be almost entirely austenitic stainless steel, using water also presents a dual problem of keeping the water chloride content low and not concentrating what chlorides are present upon drying the system. Alcohols compatible with sodium could be utilized for test pressures in the range required for LMFBR systems. The use of fluids other than water, however, results in the additional safety hazards associated with volatile or inflammable fluids.

6.1.2 PNEUMATIC Usually performed with air or nitrogen, pneumatic testing, like hydrostatic, can be used for both a pressure and a leak test. Due to the high energy buildup and consequent danger from the compressed gas, special precautions are always taken when using this method. The pressure is always raised in stages to the final value, which is often lower than that used for hydrostatic testing. Any LMFBR piping that is pneumatically tested will be done to the requirements of USAS B31.7 Section 1-737, as ASME Section III is written for vessels and RDT standards have not yet been written to cover a pneumatic test procedure.

6.1.3 HALIDE Although not used for pressure tests, halide testing is good for finding leaks. A halide gas is usually put into the system and a halogen detector or "sniffer" is passed over the outside of the welds in question. Although better than a pneumatic test for leak testing, most halide gases are not compatible with sodium, the tests are not nearly as sensitive as the next method to be discussed, and they may not be used on systems made from 300 series stainless steel.

6.1.4 HELIUM MASS SPECTROMETER There are four common procedures for using this leak detection instrument. Two use helium on the outside of the piping and two use helium on the inside. The inside of the test piece may be evacuated, hooked to the spectrometer, and a stream of helium played on the outside of the pipe to locate leaks. The second method, a variation of the first, is to enclose the piece in a helium atmosphere using a large bag or other means, while the inside is evacuated and hooked to the spectrometer. This method has the disadvantage of not actually locating the leak.

The third method is the reverse of the first. The inside of the piece is pressurized with helium and a probe or "sniffer" is used to locate leaks. The fourth method, known as "the accumulation method," is extremely sensitive but has two serious drawbacks. The piece to be tested is pressurized with helium and then sealed and placed in an evacuated chamber. After a given time interval, such as five minutes, the chamber atmosphere is tested for helium. However, this does not locate the leak and is not practical for large pieces.

Helium mass spectrometry (HMS) leak detection methods are the best currently available. There have been cases where many leaks were found by HMS in systems which had previously passed both a halogen sniffer and a soap bubble test (46). HMS techniques were used on all welds in the Enrico Fermi fast breeder reactor (25) and on the Hallam reactor (19) for the welds between the reactor vessel and the first valve. The LMFBR systems need this same assurance. The use of HMS techniques will be mandatory for all welds, including any longitudinal welds made in manufacturing the pipe.

The choice of method and the procedure will have to be developed for the various applications and will depend on the test location, size of test pieces, and other considerations. As a minimum standard, all HMS tests will meet the requirements of USAS B31.7, Paragraph 1-737.1.3.

6.2 ACCEPTANCE STANDARDS

As prescribed by USAS B31.7, ASME Section III, and RDT F 3-6 (39), the LMFBR system hydrostatic and pneumatic tests must reveal no leakage for acceptance of the pipespool or system. Examples of HMS acceptance standards used in the past are Hallam's (47) maximum permissible leak rate of 1×10^{-7} cc/sec per leak, at 15 psi differential pressure, and Fermi's 5×10^{-8} cc/sec per weld (28). It is necessary that a research program be started to determine if these or some other HMS acceptance standard will be proper for LMFBR welds.

6.3 MATERIALS LEAK TESTING

To give the material a preliminary pressure proof test, each section of pipe going into an LMFBR system must be hydrostatically tested by the manufacturer to the requirements of B31.7, Section 1-737.

6.4 PIPESPOOL LEAK TESTING

The many welds necessary to fabricate the pipespools must be given either a hydrostatic or pneumatic pressure test. As the pipespools must be cleaned and dried before shipment regardless of the test method, a hydrostatic test would not present any additional difficulties.

A more sensitive leak test than that accomplished by the pressure test must then be given to all the welds. For the LMFBR this will be a helium mass spectrometer test, as discussed in 6.1.4.

6.5 INSTALLATION LEAK TESTING

To ensure the field welds are as leak tight as the pipespool welds, they must also be given a helium mass spectrometer leak test. A decision then remains to be made on whether these systems need a pressure test. As the vessels, pipespools, and valves will have already been tested, all that remains is the field welded joints. If the HMS test will not be sufficient, a choice lies between pneumatic and hydrostatic methods. Pneumatic testing has the tremendous advantage of keeping the system clean. The major objection to pneumatic testing reduces to the energy buildup during the test. On this account we must satisfy the following questions before deciding on the test method.

- 1 Are the leak tightness requirements such that we should make a mass spectrometer test even if hydrotesting has been performed?
- 2 If a failure did occur during pneumatic testing, what would be the extent of plant damage?

6.5 INSTALLATION LEAK TESTING Continued

3 Is the possibility of brittle fracture in austenitic stainless steel systems so remote that it can be ignored?

4 Which is the greater safety hazard (1) pneumatic testing a noncommissioned nuclear system or (2) operating a nuclear sodium system that has been hydrostatically tested?

7 REPAIRS

To maintain the high quality of LMFBR materials, it will be necessary to remove or repair all defects which have caused rejection under the inspection acceptance standards noted in Paragraph 5.4. These repairs must be prepared, carried out, and inspected to the same high standards used for the original material. It follows that welds, like materials, must be repaired using the same high quality techniques used for the original welds. Perhaps the most vital repair factor is proper examination of the area from which a defect has been removed. Whether the area is to be weld repaired or not, proper examination is the only way to ensure complete removal of the defect.

7.1 MAXIMUM DEFECT SIZE

The Nuclear Codes and Standards differ slightly on the maximum allowable defect size. The Reactor Development and Technology Specifications (31-37) treat different classes of material separately by modifying ASTM standards. With one exception, the RDT specifications allow repairs only on defects smaller than $1/4$ of the material thickness in depth and less than four times the thickness of the material in length. Seamless pipe RDT M 3-3 (35), the exception, allows a defect size of $1/3$ the material thickness in depth and four times the material thickness in length. The requirements of ASME Section III are essentially the same as those of RDT.

It is felt that unnecessary and expensive rejects will result by following the requirements of ASME and RDT to limit the size of repairable defects. A proper procedure can ensure a repair with the soundness of the rest of the material or welds. As no restriction is put on weld lengths, and they extend completely through the material, there is rarely reason that defect repairs should not be allowed to do the same. Therefore, the requirements of USAS B31.7, Paragraph 1-724.1.7 regarding repair of defects will be mandatory for LMFBR systems. This will allow the repair of defects larger than those discussed above.

7.2 REPAIR PROCEDURE

The material weld repair procedures given in the RDT specifications are satisfactory for LMFBR materials, but the removal of defects not requiring repair is not discussed in most of the RDT specifications. When it is discussed, only a visual inspection is required after defect removal, which is not adequate for the LMFBR.

7.2 REPAIR PROCEDURE Continued

Repair of welds is not mentioned in the welding standard RDT F 6-1(6), and according to its format, must therefore have the same requirements as ASME Section III. In that case the procedure for repair of welds would be acceptable, however, the procedure for elimination of defects not needing repair is not acceptable in Section III in that it does not specify the type of post removal inspection.

As USAS B31.7 covers all the topics in the necessary manner, its requirements for defect elimination, repair of defects, and repair of welds will be required for LMFBR systems. These are detailed in Paragraphs 1-724.1.6, 1-724.1.7, 1-727.7 and essentially involve the removal of the defect, inspection of the area to ensure complete removal, weld repair, if required, by qualified procedure and operator, and finally inspection of any welding to ensure its soundness.

7.3 REPAIR REQUIREMENTS

Requirements for removal of defects, weld repair of defects, and repair of weld defects will depend on the examination acceptance standards given in Paragraph 5.4. Whether made in materials, pipespool welds, or field welds, the repairs will require the same procedures referred to above.

8 MARKING

To ensure that LMFBR components are made only of properly controlled, treated, and tested materials and to avoid retesting the materials, it is vital that they be adequately marked for identification.

8.1 METHODS

Marking methods is a subject which none of the current codes is considered to treat properly for LMFBR materials. RDT F 7-3 (41) and RDT F 7-1(43) allow the use of marking tools or pens with too small of a minimum tip radius. USAS B31.7 and ASME Section III provisions are good but do not control the maximum indentation depth closely enough. To preserve the LMFBR piping's surface finish requirements, marking methods will be governed by USAS B31.7, Paragraph 1-723.1.3 with the following exception. The maximum indentation depth shall be limited to the depth of acceptable nondestructive examination defects, or 1/32 inch, whichever is smaller.

8.2 PRECAUTIONS

The marking precautions in ASTM A530 and USAS B31.7, Paragraph 1-723.1.3 must be followed by ensuring the marking materials contain no harmful metal or metal salts which could react with the piping at high temperature. In addition there must be no use of acid-type marking inks which may contain harmful halides.

8.3 MATERIAL MARKING REQUIREMENTS

To provide the users of the materials with a more complete listing of information, the requirements of ASTM A530 and USAS B31.7, Paragraph 1-723.1.3 regarding the data put on the pipe will be amended to include nominal size, wall thickness, and hydrostatic test pressure.

It is also important that the admonition found in all the standards - to transfer the markings on the material to all pieces when it is cut up for fabrication - be closely heeded.

8.4 PIPESPOOL MARKING REQUIREMENTS

These requirements will be identical to those for material with the exception that a spool identification number must be added to the data already on the spool.

9 CLEANING

The best discussion of cleaning and cleanliness requirements for sodium systems currently available is the tentative draft of RDT F 5-1(45). Its requirements will be mandatory for LMFBR systems, on the condition that no major changes are made before the first issue. It is a very complete document and should be uniquely qualified, as it is the end product of ideas from the Liquid Metal Engineering Center, RDT, Pacific Northwest Laboratory, Bechtel Corporation, the American Nuclear Society, and Atomic Power Development Associates, and various other sources used by LMEC in preparing the draft.

9.1 MAINTENANCE OF CLEANLINESS

This extremely important job will be the major concern of packaging, handling, and storage, all of which will be discussed in Sections 10 and 11.

9.2 MATERIAL CLEANING

As the pipespools will receive a complete cleaning, material cleaning prior to fabrication is of minor importance except for surfaces to be welded. These surfaces shall be clean of all contaminants as noted in Paragraph 3.3.2. The remainder of the material needs only gross soil removed as defined by "preliminary cleaning" in RDT F 5-1 (45).

9.3 PIPESPOOL CLEANING

All pipespools must be cleaned according to their appropriate class in RDT F 5-1(45). This requirement will be the basis of the cleanliness for the entire system due to the difficulty of cleaning the installed system. Therefore, after cleaning, the pipespools must be packaged, shipped, and stored in a manner that will maintain their cleanliness. If pipespools become contaminated in the field, they might be cleaned there, but it will probably be more expedient to return them to the shop.

9.4 INSTALLATION CLEANING

Since an LMFBR system will be quite complex and have a low tolerance for water or water-based solutions, and thus for any residue of chemical cleaning solutions, the cleaning of an installed system is at this time considered an extremely difficult problem. Presently, there seems to be only one answer to this problem. It is the method used for EBR-I, three large-scale pump test facilities (3), and various other small facilities, as well as the Hallam Nuclear Power Facility.*

*Private correspondence with LMEC personnel.

9.4 INSTALLATION CLEANING Continued

The method consists of circulating sodium through the system and using its deoxidizing properties as a final cleaner of the system. If extreme care is taken in cleaning and installing the spools, this should prevent an unacceptable impurity load for the sodium purifying system. If normal cleaning procedures were used and there were any problems removing the cleaning medium, the impurity level of the sodium might well be higher than if the sodium itself is used as a cleaner. Since conventional cleaning methods seem to present many difficulties and no advantages, the method of final cleaning the installed system with sodium currently seems the best.

10 PACKAGING

Previous sections have discussed the need for LMFBR piping to be free from physical defects and to possess a high degree of cleanliness. Proper packaging is necessary to fulfill these requirements. Additionally it has the advantages of fulfilling a great many storage requirements and providing for ease and safety of handling. From experience we know that crating can pay for its relatively low cost by preventing problems whose solutions could involve much higher labor costs.

Wooden crating of LMFBR pipespools will be required up to the largest practical size, possibly 24-inch diameter. The crating requirements will be those specified in RDT F 7-2(40) as modified by the following exceptions. All of the exceptions are excessive requirements for pipespools or would be negated by unsealing the pipe in the field preparatory to making the fit-up and welds. The use of metal containers will not be required. The two piece metal shipping cap shown in the specifications Figure 6 is not necessary, the other types of caps in the specification are adequate. Purging of the pipespools or containers will not be necessary. RDT F 7-2, Paragraph 9.4 on Preproduction Model Pack and Section 11.3 Tests, will not apply as they are not applicable to this one-of-a-kind crating.

The resultant sealing and crating will maintain the piping cleanliness, and geometry, and will allow storage in the open except under the most severe weather conditions. It will also allow handling of the pipespools by conventional methods without fear of surface finish damage, or the use of special materials.

11 HANDLING AND STORAGE

11.1 METHODS

The main concerns of handling and storage are preventive. The methods used must prevent physical damage in the forms of surface nicks, cuts and scratches or large dents or bends affecting the shape of the pipe or the spool. Storage and handling methods must prevent contamination by the entry of particles into the interior of the piping and must also prevent the pipe from contacting materials which may leave undesirable compounds on the pipe's surface. If the pipespools, or a majority of them, are crated as discussed in the previous section, this will prevent the above problems and allow the use of virtually any handling or storage method.

11.2 MATERIALS

To prevent ferritic contamination of stainless steel and the marking or deforming of the pipe surface, the use of nonmetallic or nonmetallic cushioned fixtures is preferred for handling uncrated materials. When this is not possible, fixtures should be clad with or made of stainless steel.

11.3 PRECAUTIONS

Unprotected materials must be under cover and not be stored in contact with the ground or ground water or where they may come into contact with salt water, or salt water spray.

When material has been shipped either with closures or crated, it should be inspected upon receipt to ensure no damage has been done. If the closures or packaging is damaged, the items must be restored to their original cleanliness, if necessary, and the closures or package repaired.

It must be mentioned that the proper handling and storage must begin with the material manufacturer to avoid the necessity of excessive correction of surface defects by the fabricator.

12 CERTIFICATION

12.1 MATERIALS

It will be a portion of the materials selection task to decide what chemical and physical tests the material must undergo and what the acceptance standards will be. The nuclear codes state unanimously that the performance and passage of these tests will be certified by the manufacturer. An example of this requirement which LMFBR piping must meet is given in USAS B31.7 Paragraph 1-723.1.2. As noted in Paragraph 5.6 of this report, the owner is responsible for seeing that this is done. It is also necessary that these certifications can be positively traced back to the mill tests performed on the heat actually being used or to a check analysis.

12.2 WELDING

As stated in Paragraph 3.2.3, certified records of the welding qualifications must be maintained by each manufacturer or contractor.

12.3 RECORDS

As stated in Paragraph 5.6, the owner will have the ultimate responsibility for examination to assure code compliance. In practice, however, it has often been found difficult for the owner to assemble all the necessary certifications and records to accomplish this final inspection. To alleviate this situation, the manufacturers and contractors will be required to supply the owner of the LMFBR system with copies of all certifications maintained by them applying to his project.

13 DIMENSIONAL AND GEOMETRICAL REQUIREMENTS

13.1 MATERIALS

Determining standard component geometries and geometric considerations will be performed in two future tasks under this contract. When this has been done, fabrication or forming techniques must be selected for pipe and fittings which will result in their being within the desired tolerances. Any deviations in dimensions or geometry will affect the validity of the stress factors used in the design calculations.

A practice which is relatively common for critical service piping must be used on LMFBR pipe. The ends will be mechanically sized for 3 inches back, to an ID dimension plus or minus $1/32$ of an inch as an aid to fit up.

Another consideration affected by stress calculations is the pipewall. Often for considerations of availability, delivery, or standardization heavier pipewalls are substituted for those specified. Due to the high thermal transients and heat conductivity of the sodium, the thermal gradient stresses in the pipewall are very high. By increasing the pipewall, the increase in this thermal gradient stress may be more than the reduction in the pressure stresses, resulting in an overstressed condition, thus pipewall substitutions must be watched very carefully in the LMFBR systems.

13.2 PIPESPOOLS

Since very precise weld bevel preparation will be essential, fit-up type welds involving the field beveling of pipe ends will not be permitted. This will require closer than normal tolerances on spool dimensions or the "closure piece" system. In this system dimensions are taken in the field for the last or "closing" piece in each assembly which is then trimmed and beveled in the shop to fit the field dimensions. This method will probably prove to be the most economical and satisfactory, as the number of pipespools held to tight dimensional tolerances would be a minimum.

13.3 INSTALLATION

If the materials and pipespools are properly made, the installation should go smoothly. Due to the extremely high temperature service of much of the LMFBR piping, there will probably be a great amount of cold-spring used in construction. This must be closely checked to ensure the correct amount is used and that the pipe is not deformed or damaged in bringing the ends together for welding. The proper procedure for bringing the pipe ends together is to calculate the best locations for applying both forces and moments to achieve the necessary prestress and also align the pipe ends. This will assure the rotations of the piping are taken into account.

13.3 INSTALLATION Continued

As much of this piping will be highly stressed, all supports and engineered restraints or guides must also be carefully checked to see that they are located exactly as figured in the stress calculations.

14 PROBLEMS REQUIRING FURTHER STUDY

This report has revealed the following problems which require further study.

- (1) Acceptance standards for helium mass spectrometer leak tests
- (2) The pressure test method to be used for the installed system
- (3) The cleaning method to be used for the installed system
- (4) The allowable size for surface and internal defects

Although there are answers to all of these problems, studies will be required to determine if any of those currently available are acceptable for an LMFBR. If none of the answers are acceptable, further studies must be undertaken to find new ones.

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- 38 RDT F 3-1 Inspection System Requirements.
(RDT S-904) February, 1969
- 39 RDT F 3-6 Nondestructive Examination.
(RDT S-908) March, 1969
(RDT S-934)

- 40 RDT F 7-2 Preparations for Sealing, Packaging, Packing,
(RDT S-910) and Marking of Components for Shipment and Storage.
February, 1969
- 41 RDT F 7-3 Requirements for Identification Marking of Reactor
(RDT S-916) Plant Components and Piping. February, 1969
- 42 RDT F 6-3 Proposed Standard - Material Application and
(RDT S-922) Processing Requirements, June 21, 1967.
- 43 RDT F 7-1 Continuous Identification Marking of Wrought
(RDT S-928) Products. February, 1969
- 44 RDT F 2-2 Quality Control System Requirements
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(RDT S-973) March, 1968.
(RDT S-913)
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CROSS INDEX OF RDT STANDARDS

Old No.	New No.	Old No.	New No.	Old No.	New No.	Old No.	New No.
E-1	E 3-1	MA-240	M 5-1 T	MB-163	M 3-4 T	S-904	F 3-1 T
E-2	E 3-2	MA-249	M 3-5	MB-166	M 7-4 T	S-905	F 3-2 T
E-3	E 4-1 T	MA-276	M 7-1 T	MB-168	M 5-4 T	S-908	F 3-6 T
E-4	E 2-2	MA-298	M 1-1 T	MB-275	M 1-7 T	S-910	F 7-2 T
E-6	E 5-1	MA-312	M 3-6	MB-259	M 1-8 T	S-913	F 5-1
E-7	E 5-2	MA-316	M 1-4 T	MB-260	M 1-9 T	S-915	F 8-1
E-9	E 1-3	MA-320	M 6-1 T	MB-295	M 1-10 T	S-916	F 7-3 T
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E-11	E 1-4	MA-335	M 3-12	MB-350	M 10-1	S-918	E 2-1
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E-22	C 2-3	MA-371	M 1-2 T	MB-407	M 3-9	S-928	F 7-1 T
E-70	E 2-3	MA-376	M 3-3 T	MB-408	M 7-10	S-934	F 3-6 T
E-76	E 4-2	MA-387	M 5-5	MB-409	M 5-7	S-935	M 6-2
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M-700	M 13-1	MA-399	M 1-5 T			S-942	F 3-7 T
M-701	M 14-1	MA-403	M 2-5 T	MM-313	M 12-1 T	S-943	F 2-1
M-702	M 2-2 T	MA-461	M 7-2 T	MM-318	M 11-1 T	S-944	F 2-2
M-703	M 3-2 T	MA-473	M 2-6 T	MM-319	M 11-2 T	S-945	F 2-1
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MA-106	M 3-1 T	MA-516	M 5-2 T	MM-325	M 7-6 T	S-960	E 3-3
MA-155	M 3-11	MA-533	M 5-3 T	MM-335	M 8-1 T	S-970	F 2-1
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MA-213	M 3-2 T	MA-577	F 3-4	MM-373	M 7-8 T	S-973	F 5-1
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MA-217	M 4-4			S-902	F 6-1 T	S-975	F 2-2
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MA-234	M 2-3 T						

C F B R A U N & C O

Engineers

ALHAMBRA CALIFORNIA 91802

SAN-781-220

June 6, 1969

Mr H B Fry
Contracting Officer, Contract AT(04-3)-781
AEC San Francisco
2111 Bancroft Way
Berkeley, California 95704

BAL-65

Dear Mr Fry

FABRICATION AND INSTALLATION REQUIREMENTS
TECHNICAL REPORT 220
LMFBR PIPING DESIGN GUIDE
AEC SAN FRANCISCO
PROJECT 4122-W

Transmitted herewith are two copies of the final report covering studies of Fabrication and Installation Requirements of sodium piping for LMFBR piping systems.

The purpose of the study was to identify the requirements with respect to workmanship, quality of materials, control, and test procedures that will ensure a satisfactory piping installation.

Comments on the report from reviewers will be welcome, but further revision is not contemplated.

Yours very truly

Roger Detman

Roger Detman
Project Manager

RFD LSA

Project 4122-W
AEC Contract AT(04-3)-781
June 6, 1969

Mr H B Fry

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