ACTIVITY PLAN

PARAMETRIC STUDIES OF METAL DEGRADATION AND MICROSTRUCTURE:
Measurement of Plane-Strain Fracture Toughness.

Sub-Activity E-20-18c of Activity E-20-18 of the scientific investigation 'Metal Barrier Selection and Testing'
WBS # 1.2.2.3.2

Harkirat S. Ahluwalia

Revision 0

July 27, 1989

L. J. Jardine, YMP Project Leader — Date 9/3/89

D. W. Short, YMP QA Manager — Date 9/14/89

W. L. Clarke, Technical Area Leader — Date 7/28/89

R. D. McCright, Task Leader — Date 7/28/89

University of California
Lawrence Livermore National Laboratory

YUCCA MOUNTAIN PROJECT

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CHANGE NOTICE

CN No.: E-20-I8c-0-I

Affected Document: Activity Plan E-20-I8c Rev. 0

Prepared by: Harkirat S. Ahluwalia

Approved by: W. L. Belanz 11/13/89
(Technical Area Leader) (Date)

Approved by: D. O. Short 11/14/89
(YMP QA Manager) (Date)

Approved by: Bill J. Hardy 11/14/89
(YMP Project Leader) (Date)

Training Required: Yes ☐ No ☒

Currently Read as Follows:

Section 3.0 as published.

2. Section 10.0 as published.

Changed to Read:

1. Section 3.0. Add new paragraph, p2.

The parameter J_{Ic} may be used on materials that lack sufficient brittleness or specimens that lack sufficient thickness to be tested for K_{Ic} according to the requirements of ASTM Test Method E 399 [2]. J_{Ic} values can be converted to their equivalent in terms of stress intensity factor, K_I. These K_I values then correspond to toughness near the onset of slow-stable crack extension in a dominant linear elastic stress field that contains a preexisting crack. ASTM Test Method E 813-88, 'Standard Test Method for J_{Ic}, A Measure of Fracture Toughness'[4], should be used for the determination of J_{Ic}. The property J_{Ic} determined by this test method characterizes the toughness of materials near the onset of crack extension from a preexisting fatigue crack. The J_{Ic} value marks the beginning stage of material crack growth resistance development, the full extent of which is not developed by this test method. The value of J_{Ic} as determined by this test method can be used to evaluate materials in terms that can be significant to design.

Section 10.0. Add reference [4], p6.

[4] Standard Test Method for J_{Ic}, A Measure of Fracture Toughness: E 813-88, ASTM Philadelphia, p698-712, 1988.

NOTE: THIS CHANGE NOTICE IS TO BE FILED AT THE FRONT OF THE AFFECTED DOCUMENT

1.0 INTRODUCTION

1.1 Identification of activity

This activity plan is for sub-activity E-20-18c and is written pursuant to quality procedure 033-YMP-QP 3.0, [1]. Sub-activity E-20-18c is part of activity E-20-18 which is known as "Parametric studies of metal degradation and microstructure". Activity E-20-18 is a part of the scientific investigation known as "Metal Barrier Selection and Testing" which is identified with WBS # 1.2.2.3.2. and published in UCID-21262.

1.2 Quality Assurance Level Assignment

A quality assurance level of QA-II has been assigned to this activity (E-20-18).

1.3 Responsibilities

Harkirat S. Ahluwalia, John Estill, Greg E. Gdowski and Joseph C. Farmer are the Principal Investigators for this activity and are responsible for the conduct of this work. R. Daniel McCright is the Task Leader for the Metal Barrier Selection and Testing Investigation. Willis L. Clarke is the Technical Area Leader for Container Materials, Modeling and Testing.

2.0 PURPOSE AND OBJECTIVES

The objective of this sub-activity is to provide specific fracture mechanics data needed for material selection and model development.

3.0 ACTIVITY DESCRIPTION

This activity will be used to access the plane-strain fracture toughness (K_{Ic}) of the candidate materials. This characterizes the resistance of a material to fracture in a inert environment in the presence of a sharp crack under severe tensile constraint, such that the state of stress near the crack front approaches tri-tensile plane strain, and the crack-tip plastic region is small compared with the crack size and specimen dimensions in the constraint direction. A K_{Ic} value is believed to represent a lower value of fracture toughness. The value of K_{Ic} determined by this sub-activity and the value for K_{Iscc} (threshold stress intensity for stress corrosion cracking) determined by activity E-20-18d will be used to rank the candidate alloys in terms of the embrittlement index, K_{Ic}/K_{Iscc}.

This activity involves testing of notched specimens that have been pre-cracked in fatigue by loading in tension. Load versus displacement across the notch at the specimen edge is recorded on a x-y recorder. The load corresponding to a 2% apparent increment of crack extension is established by a specific deviation from the linear portion of the record. The K_{Ic} value is calculated from this load by equations that have been established on the basis of elastic stress analysis of various specimens. The validity of the determination of the K_{Ic} value depends upon the

establishment of a sharp-crack condition at the tip of the fatigue crack, a specimen of adequate size. To establish a suitable crack-tip condition, the stress intensity level at which the fatigue pre-cracking of the specimen is conducted is limited to a relatively low value. During the conduct of this activity ASTM standard E399-83 will be referenced,[2].

3.1 Technical Reviews

A formal surveillance will be held before any experimental work begins. This review will insure that:

1. Measurement and test equipment (M&TE) are properly calibrated as specified in quality procedure 033-YMP-QP-12.0.

2. Test samples are procured as specified in quality procedure 033-YMP-QP-4.0 and controlled as specified in quality procedure 033-YMP-QP-8.0.

3. Collected data will be controlled as specified in quality procedure 033-YMP-QP-8.0.

4. Laboratory notebooks are being maintained as specified in quality procedure 033-YMP-QP-3.4.

After completion of an experiment or a series of experiments, a UCID report will be written. The UCID report will undergo review as specified quality procedure 033-YMP-QP-3.3.

3.2 Hold Points

There are no formal hold points associated with this activity, but the results will be evaluated on a continuous basis by the Principal Investigator to insure that work is proceeding according to plan. If significant unanticipated problems arise, the Principal Investigators will inform the Task Leader. A joint decision will be made about corrective actions.

Progress will be reported to the Task Leader in Monthly reports. If changes in project scope require that experimental work change direction, it is the responsibility of the Task Leader to communicate this to the Principal Investigator in writing.

3.3 Equipment

Required M&TE include: Constant extension rate testing machine (CERT), specifically Cortest Series 34000 Floor Model; Load cell, Sensotec model D/3971-01, identification no: 5015939; Controller, Cortest model SC12, identification no: 4403461. These instruments are found on the list of calibrated equipment (see Appendix I). The Reversing d.c. potential drop instrument is on order. Displacement gages and Caliper or micrometers are also required and are in the process of being acquired. The identification numbers and calibration records of all M&TE used will be identified in the scientific notebook.

3.4 Materials

All samples tested will be procured as specified in quality procedure 033-YMP-QP-4.0. and controlled as specified in quality procedure 033-YMP-QP-8.0.

3.5 Special Environmental Conditions

The tests will be conducted in dry air or in an argon atmosphere. Contact with moisture will be avoided. These tests will be carried out at ambient temperatures.

3.6 Special Training/Qualification Requirements

No special training/qualification are required.

3.7 Activity Closeout

The final product of this sub-activity will be a UCID report documenting all results. Supporting documentation such as laboratory notebooks and technical review comments will be retained by the responsible individual until the document package is transferred to the local records center at the conclusion of the sub-activity.

) PRECISION AND ACCURACY

The precision of a K_{Ic} determination is a function of the accuracy and bias of the various measurements of linear dimensions of the specimen and testing fixtures, the precision of the displacement measurements, and the bias of the load measurement as well as the bias of the recording devices used to produce the load displacement record and the precision of the constructions made on this record. The accuracy of the various measurements will be recorded in the scientific notebook.

4.1 Calibration requirements

All M&TE must be calibrated as specified in quality procedure 033-YMP-QP-12.0 [1]. Identification numbers of equipment used for this sub-activity will be found on the approved list of M&TE for the Yucca Mountain Project.

4.2 Conditions Which May Adversely Affect Results

In order for a result to be considered valid it is required that both the specimen thickness, B, and the crack length, a, exceed $2.5(K_Q/\sigma_{ys})^2$, where σ_{ys} is the 0.2% offset yield strength of the material for the temperature and loading rate of the test and K_Q is the conditional result used to establish if a valid K_{Ic} has been measured.

5.0 IN-PROCESS DOCUMENTATION

In process documentation will include stress-strain curves, optical and electron micrographs. Such records will be kept in a controlled laboratory notebook identified as Metal Barrier Selection and Testing Task Controlled Notebook No.00078. Copies of all in-process documents will be kept by all the principal investigators identified in Section 1.3. Results will be periodically transmitted to the Task Leader in the monthly report and the Task Leader is responsible for transferring the document package to the local records center at the conclusion of this sub-activity..

5.1 Data Recording and Data Reduction

All relevant data for the determination of K_{Ic} shall be kept in a bound, scientific notebook. The data from the x-y recorder and any construction on that record will be pasted in the scientific notebook. Data collected from computers will be stored on magnetic media and a hard copy will also be presented in the scientific notebook.

5.2 Analysis

The interpretation of test records, sensitivity analysis and calculation of K_{Ic} shall be conducted according to the Technical Implementing Procedure, TIP-CM-1.[3].

6.0 INTERFACES

This sub-activity can proceed independent of any other activity, however activity E-20-19 ("Metal Barrier Selection") cannot proceed without this activity.

7.0 SCHEDULE

The readiness review for this sub-activity was scheduled for the 31st July 1989. The final UCID report will summarize all of the data and a draft copy will be completed prior to the first week in April of 1990.

8.0 TECHNICAL IMPLEMENTING PROCEDURES

A TIP for the determination of plane-strain fracture toughness (K_{Ic}) and the threshold stress intensity for stress corrosion cracking (K_{Iscc})[3] will be prepared in accordance with Quality Procedure No. 033-YMP-QP-5.0, "Technical Implementing Procedures". The established ASTM procedure E399-83 [2] will also be used as a guide.

9.0 SPECIAL CASES (PROCUREMENT)

Technical services provided by Hira Ahluwalia are provided by contract and meet the requirements of 033-YMP-QP 4.0 "Procurement Control and Documentation"[1]. All such services will be performed under the LLNL YMP Quality Assurance Plan.

9.1 QA Requirements Specification

Not applicable

9.2 Statement of work

The statement of work for technical support for this activity is to provide technical support for electrochemical corrosion experiments.An example of service contract statement of work is provided in Appendix II.

9.3 Subcontractor Interface Control

The technical contacts at LLNL for the contracts discussed in Section 9.0 are Joseph C. Farmer, William Halsey, R.Daniel McCright and Willis Clarke.

9.4 Materials/Equipment Provided

Access to laboratory space is provided so that work on this sub-activity can be accomplished.

9.5 Deliverables

Deliverables for the technical support contractor will include a UCID report documenting the results and scientific notebooks and data accumulated on magnetic media.

10.0 REFERENCES

[1] Yucca Mountain Project, Quality Procedures Manual.

[2] Standard test method for plane-strain fracture toughness of Metallic Materials: E399-83, ASTM Philadelphia, p680-701. 1983.

[3] Technical Implementing Procedure for K_{Ic} and K_{Iscc}, TIP-CM-1.

11.0 APPENDIXES

[I] Current list of calibrated equipment p2.
[II] Example statement of work.

APPENDIX I

Current list of calibrated equipment p2.

INSTRUMENT	MODEL	MFG	IDENT NO	LAST CAL	CAL EXP	RECALL	ACTIVITY	BLDG	ROOM	TAL	TL
THERMOCOUP	TYPE K	OMEGA	34	8/09/88	8/09/89	6/28/89	B-20-4	281	1160	WILDER	GLASSLEY
T. /COUP	TYPE K	OMEGA	17	8/09/88	8/09/89	6/28/89	B-20-4	281	1160	WILDER	GLASSLEY
STRAIN GAU	5550	PRECISE SE	23479	8/09/88	8/09/89	6/28/89	B-20-4	281	1160	WILDER	GLASSLEY
STRAIN GAU	5550	PRECISE SE	24380	8/09/88	8/09/89	6/28/89	B-20-4	281	1160	WILDER	GLASSLEY
STRAIN GAU	5550 V5	PRECISE SE	23342	8/09/88	8/09/89	6/28/89	B-20-4	281	1160	WILDER	GLASSLEY
STRAIN GAU	5550 V6	PRECISE SE	23341	8/09/88	8/09/89	6/28/89	B-20-4	281	1160	WILDER	GLASSLEY
STRAIN GAU	2105	TABER	721223	8/09/88	8/09/89	6/28/89	B-20-4	281	1160	WILDER	GLASSLEY
WEIGHT SET	NONE	TROEMNER	4935825	9/14/88	9/15/89	6/28/89	B-20-4	281	1160	WILDER	GLASSLEY
WEIGHT SET	6137/1540	TROEMNER	4935832	9/15/88	9/15/89		D-20-31	243	2026	SHAW	RYERSON
CONTROLLER	SC12	CORTEST	4403461	CAL LAB			D-20-31	243	2026	SHAW	RYERSON
STRIP CHAR	585/11/13	OMEGA	4347352	CAL LAB		INITIAL	E-20-23	241	1878	CLARKE	McCRIGHT
STRIP CHAR	585/11/13	OMEGA	4414849	CAL LAB		INITIAL	E-20-23	241	1877	CLARKE	McCRIGHT
STRIP CHAR	585/11/13	OMEGA	4076603	CAL LAB		INITIAL	E-20-23	241	1877	CLARKE	McCRIGHT
STRIP CHAR	585/11/13	OMEGA	4350130	CAL LAB		INITIAL	E-20-23	241	1877	CLARKE	McCRIGHT
POTENTIOST	173	PAR	4015329	4/28/89	10/28/89	INITIAL	E-20-23	241	1877	CLARKE	McCRIGHT
POTENTIOST	173	PAR	4369149	CAL LAB			E-20-23	241	1878	CLARKE	McCRIGHT
CONTROLLER	175	PAR	3676767	4/28/89	10/28/89	INITIAL	E-20-23	241	1877	CLARKE	McCRIGHT
POTENTIOST	273	PAR	4053581	4/21/89	10/20/89		E-20-23	241	1878	CLARKE	McCRIGHT
POTENTIOST	273	PAR	4066826	CAL LAB			E-20-23	241	1877	CLARKE	McCRIGHT
POTENTIOST	362	PAR	4272227	3/13/89	9/13/89	INITIAL	E-20-23	241	1878	CLARKE	McCRIGHT
POTENTIOST	363	PAR	4345822	1/09/89	7/09/89		E-20-23	241	1878	CLARKE	McCRIGHT
POTENTIOST	363	PAR	4277185	3/07/89	9/07/89	6/5/89	E-20-23	241	1878	CLARKE	McCRIGHT
POTENTIOST	363	PAR	3328949	3/07/89	9/07/89		E-20-23	241	1878	CLARKE	McCRIGHT
POTENTIOST	363	PAR	3711963	3/06/89	9/06/89		E-20-23	241	1878	CLARKE	McCRIGHT
POTENTIOST	363	PAR	3329106	CAL LAB			E-20-23	241	1878	CLARKE	McCRIGHT
C RTER	376	PAR	4764128	4/29/89	10/29/89		E-20-23	241	1878	CLARKE	McCRIGHT
LOAD CELL	D/3971-01	SENSOTEC	5015939	4/28/89	10/28/89		E-20-23	241	1878	CLARKE	McCRIGHT
LVDT	351-000	TRANS-TEK	4764111	CAL LAB			E-20-23	241	1878	CLARKE	McCRIGHT
WEIGHT SET	NONE	TROEMNER	4935818	9/15/88	9/15/89	INITIAL	E-20-23	241	1878	CLARKE	McCRIGHT
PROFILECHE	DEKTAK IIA	SLOAN	88503	1/12/89	1/12/90		E-20-23	241	1883	CLARKE	McCRIGHT
OSCILLOSCO	2465	TEKTRONIX	4160616	9/01/88	9/10/89		G-20-3.1	151	1034A	SHAW	RYERSON
WATT TRANS	S73-25-230	AME	4763411	10/07/88	10/07/90		H-20-6	327		CLARKE	RUSSELL
WATT TRANS	S73-25-230	AME	4763428	10/07/88	10/07/90		S-20-1	G	TNL	WILDER	RAMIREZ
DEPTH PROB	501DR	CPN	4737900	7/28/88	7/28/89		S-20-1	G	TNL	WILDER	RAMIREZ
DA CONTROL	3497A	HP	3854172	9/26/88	9/26/89	6/5/89	S-20-1	G	TNL	WILDER	RAMIREZ
PRES TRAN	2279-1	ASHCROFT	5038761	4/12/89	4/12/90		S-20-1	G	TNL	WILDER	RAMIREZ
PRES TRAN	2279-2	ASHCROFT	5038785	4/12/89	4/12/90		S-20-1	G	TNL	WILDER	RAMIREZ
PRES TRAN	2279-3	ASHCROFT	5038792	4/12/89	4/12/90		S-20-1	G	TNL	WILDER	RAMIREZ
PRES TRAN	2279-4	ASHCROFT	5038761	4/12/89	4/12/90		S-20-1	G	TNL	WILDER	RAMIREZ
BALANCE	2404	SARTORIUS	3792559	CAL LAB			S-20-1	G	TNL	WILDER	RAMIREZ
BALANCE	MG5D	METTLER	3559879	CAL LAB		INITIAL	J-20-8	281		AINES	SILVA
OSCILLOSCO	11402	TEKTRONIX	4928490	CAL LAB		INITIAL	J-20-8	281		AINES	SILVA
OSCILLOSCO	2335	TEKTRONIX	4728496	CAL LAB		INITIAL	J-20-8	281		AINES	SILVA
PULSE GEN	DG535	SRS	4778699	CAL LAB		INITIAL	J-20-8	281		AINES	SILVA
:RX THERM	2804A	HP	5038655	CAL LAB		INITIAL	J-20-8	281		AINES	SILVA
VERT AMP	11A34	TEKTRONIX	4921767	CAL LAB		INITIAL	J-20-8	281		AINES	SILVA
THERMOCOUP	TYPE K	OMEGA	3977512	3/15/89	3/15/90	INITIAL	J-20-8	281		AINES	SILVA
THERMOCOUP	TYPE K	OMEGA	3977529	3/15/89	3/15/90		B-20-4	281		WILDER	GLASSLEY
THERMOCOUP	TYPE K	OMEGA	3977536	3/15/89	3/15/90		B-20-4	281		WILDER	GLASSLEY
IOCOUP	TYPE K	OMEGA	3977543	3/15/89	3/15/90		B-20-4	281		WILDER	GLASSLEY
							B-20-4	281		WILDER	GLASSLEY

APPENDIX II.

Example statement of work.

MATERIAL SCIENCE SUPPORT FOR THE
YUCCA MOUNTAIN PROJECT.

STATEMENT OF WORK PROPOSAL.

Introduction

The Metal Barrier Selection and Testing (MBST) Task of the Yucca Mountain Project at Lawrence Livermore National Laboratory (LLNL) is responsible for the selection of the metal barrier material for application in the high-level nuclear waste repository being designed for the Yucca Mountain Site in Nevada. The Scientific Investigation Plan (SIP) for the MBST task includes : (i) development of models for degradation modes, mechanical properties and microstructure (E-20-16); (ii) experimental technique development (E-20-17); (iii) parametric studies of degradation and microstructure (E-20-18); (iv) degradation mode surveys (E-20-13).

It is proposed that Science and Engineering Associates, Inc. continue to provide significant scientific and engineering support to: (i) evaluate existing mechanistically based models of stress corrosion cracking and crevice corrosion in alloy 825 and CDA 715 under repository conditions; (ii) perform constant extension rate testing with simultaneous measurement of acoustic emissions and electrochemical noise; (iii) provide technical support for electrochemical corrosion experiments including accessment of plane-strain fracture toughness (K_{Ic}) and threshold stress intensity for stress corrosion cracking, (K_{Iscc}) of the candidate materials; (iv) complete an evaluation of the suitability of titanium, zirconium and monel as corrosion resistant materials for high-level Nuclear Waste Containers for emplacement at the Yucca Mountain repository.

All of these tasks, which are described in detail below, will be completed in accordance with the Quality Assurance Program Plan for YMP (033-YMP) at the Quality Assurance level assigned in the Scientific Investigation Plan.

This procurement action deals with the acquisition of support personnel only. The scientist, who is required due to his technical expertise, will support the activities of the Yucca Mountain Project. The scientific personnel will work under the direct supervision of LLNL-YMP staff. This work will be completed in accordance with approved QA procedures as defined in the YMP Quality Assurance Program Plan. The qualifications of personnel assigned to work on this subcontract has been documented and submitted to the YMP QA staff.

TECHNICAL SUPPORT OF WORK.

:ller will provide a Ph.D. Scientist to support the Nuclear Waste Management Program at Lawrence Livermore National Laboratory.

Task 1 Complete an evaluation of the availability and applicability of existing mechanistically based models of stress corrosion cracking and crevice corrosion, adapt these models or develop new models to help predict the effects of stress corrosion cracking and crevice corrosion in alloy 825 and CDA 715 under repository conditions. This task includes completion of a survey of the technical literature to identify mechanistically based models of localized corrosion, crevice corrosion, and stress corrosion cracking and modifying these models to aid in the prediction of the effects of crevice corrosion and stress corrosion cracking on alloy 825 and CDA 715 in a repository environment. This task is an important element of activity E-20-16, building upon already existing data and information previously identified in E-20-13. This task, which will provide significant input to activity E-20-19 (metal barrier material selection), will be performed at a quality assurance level QA II.

Task 2 Conduct constant extension rate testing with simultaneous measurement of acoustic emissions and electrochemical noise. Current transients correlated with acoustic emissions can be used to determine repassivation rates at crack tips. Repassivation rates may also be determined with the strained electrode technique. Additionally provide technical assistance with other experimental technique development activities. This task is an element of activity E-20-17, "Experimental :chnique development" and will be performed at a quality assurance level QA III.

Task 3 Provide technical support for electrochemical corrosion experiments including accessment of plane-strain fracture toughness (K_{Ic}) and threshold stress intensity for stress corrosion cracking, (K_{Iscc}) of the candidate materials. The values of K_{Ic} and K_{Iscc} will be used to rank the candidate alloys in terms of the embrittlement index, K_{Ic}/K_{Iscc}. This task is an element of activity E-20-18, "Parametric studies of degradation and microstructure" and will be performed at a quality assurance level of QA I.

Task 4 Complete an evaluation of the suitability of titanium, zirconium and monel as corrosion resistant materials for high-level Nuclear Waste Containers for emplacement at the Yucca Mountain Repository. The overall project schedule is such that the container material must be chosen before the environmental conditions at the site are fully characterized by tests conducted in exploratory shafts. There is, therefore, some potential that the actual site conditions may prove to be too aggressive for successful employment of the alloys currently being evaluated as metal container materials. There is also some potential that performance assessment models will predict metal container degradation rates that are not consistent with meeting the goal of "substantially complete containment" included in the NRC regulations for the repository.

While both of these potentials are small, it is prudent to consider other lloys as a backup to the alloys currently being considered. This tas .ll be performed at a quality assurance level of QA III.

Reports The seller will submit monthly progress reports.