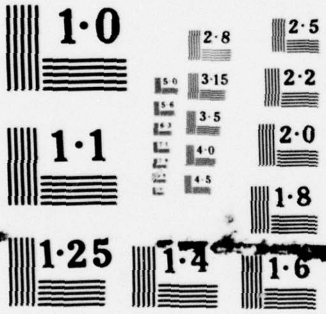
AD-A072 773 CARNEGIE-MELLON UNIV PITTSBURGH PA DEPT OF MECHANICA--ETC F/G 20/12
RECOMMENDED PLAN FOR PROJECT FRACT: A CRITICAL EVALUATION OF FR--ETC(U)
JUL 79 J L SWEDLOW, S E BENZLEY, W E HAISLER N00014-78-C-0528
UNCLASSIFIED SM-79-3A NL

1 OF 1
AD
A072773

END
DATE
FILMED
9 - 79
DDC



NATIONAL BUREAU OF STANDARDS

Carnegie-Mellon University
PITTSBURGH, PENNSYLVANIA 15213

DEPARTMENT OF
MECHANICAL ENGINEERING

Recommended Plan for Project FRACT

A Critical Evaluation of
FRACTURE RELATED ANALYTICAL AND COMPUTATIONAL TECHNIQUES

Report SM 79-3A July 1979

Planning Committee:

S. E. Benzley, Sandia
W. E. Haisler, Texas A&M University
A. S. Kobayashi, University of Washington
H. J. Konish, Westinghouse ARD
J. C. Newman, Langley Research Center, NASA
C. H. Parr, Lord Kinematics
J. S. Solecki, CMU
J. L. Swedlow, CMU (chmn)
W. K. Wilson, Westinghouse R&D

Department of Mechanical Engineering
Carnegie Institute of Technology
Carnegie-Mellon University
Pittsburgh, Pennsylvania

Accession For
NTIS GRA&I ☒
DDC TAB ☐
Unannounced ☐
Justification______

By______

Distribution/

Availability Codes

Dist.	Avail and/or special
A	

LEVEL II

12

6 Recommended Plan for Project FRACT:
A Critical Evaluation of
FRACTURE RELATED ANALYTICAL AND COMPUTATIONAL TECHNIQUES.

14 [redacted] SM-79-3A

12 49p'

11 Jul~~y 19~~79

~~Planning Committee:~~

10 J. L. /Swedlow,
S. E./Benzley, [redacted]
W. E./Haisler, [redacted]
A. S./Kobayashi, [redacted]
H. J./Konish, ~~Westinghouse ARD~~
J. C. Newman, Langley Research Center, NASA
C. H. Parr, Lord Kinematics
J. S. Solecki, CMU
J. L. Swedlow, CMU (chmn)
W. K. Wilson, Westinghouse R&D

9 Rept. for Jun 78-Jun 79,

15 N00014-78-C-0528

DDC
RECEIVED
AUG 14 1979
D

Department of Mechanical Engineering
Carnegie Institute of Technology
Carnegie-Mellon University
Pittsburgh, Pennsylvania

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

405 494

PREFACE

This report outlines a recommended plan for critical evaluation of Fracture Related Analytical and Computational Techniques, Project FRACT. The report includes suggestions and commentary from many members of the Advisory Group (Appendix B), who were given a preliminary draft for review. Wherever feasible, we provide both the initial text and these responses in this version of the report. We note also that most of the responses were quite supportive of the broad concept of Project FRACT, and that suggestions were aimed toward its improvement.

INTRODUCTION

It has been well over half a century since the first elastic analyses [1] of stress in the vicinity of a crack were performed, but somewhat less than two decades since meaningful results [2] for elastic-plastic problems have become available. Since the late 1960s the latter type of calculation has grown to be routine in many establishments. Unlike elastic analyses for which careful evaluations and cross-checks have long since been completed - see, e.g., Peterson [3] - elastic-plastic procedures have not been subject to a wide-scale scrutiny. Thus, while there is a growing number of sources for such analysis, there is no standard or set of standards whereby these results may be evaluated in terms of their accuracy and resolution. This is troubling both intellectually and in terms of specific applications involving fracture related configurations and which demand good answers.

The case of particular interest here is one involving fracture-related configurations. These include a variety of cracked laboratory testpieces, sharply notched test specimens used in screening tests [4], and - of great import - their counterparts in service structures. The reason for concern, of course, is that there is increasing demand for structural integrity and, at the same time that the technology for dealing with elastic-plastic fracture grows, so must the primary mechanics base. It is of little use, for example, to define a fracture criterion if there is doubt as to the quality of the (computationally) predicted stress and strain fields.[1*]

None of this should be inferred as a criticism of analysts or developers of code. Indeed, such workers have made important contributions that now and in the future will stand as being of great value in our overall effort to unravel, however slowly, the problem of elastic-plastic fracture. Rather

---

*Superscripts refer to notes taken from the comments of the Advisory Group, beginning on page 15.

the difficulty lies in not having pulled together the essence of each of these many contributions so that the great power that is their potential may be wisely used.

A window on the need for such effort was given by the comparative study done under ASTM auspices and reported by Wilson and Osias [5]. Using the "round robin" format for a well-defined problem, the study showed that ten solutions compared very favorably in the elastic range but, at a high level of excitation, "...the difference[s] between solutions is [are] major."

It must be true that great minds run in the same channel, for other groups have begun to contemplate some action on this problem*. We describe here an effort lasting approximately two years, and involving ten to twelve investigators as participants. The objectives are

- to replicate physical behavior of elastic-plastic flow in fracture related configurations, using computational and/or analytical means;
- to provide the technical community a firm basis for such analyses, by broad dissemination of the results;
- to establish benchmark problems and solutions for future investigators to check their own work;
- to establish thereby a basis for evaluating the quality of any pertinent analysis; and
- to move the state of the art of elastic-plastic analysis to a position of greater certainty.

This effort thus has high aims; it responds to what by an apparent consensus is a considerable need. How we have proceeded to plan for Project FRACT is

---

*See Appendix A.

outlined in Appendix B; what appears in the main report is an overall procedure, an outline of specific problems to solve, and an indication of the anticipated phasing of the Project.

PROCEDURE

FRACT is a recommended program of activities whose potential participants "solve" a sequence of problems using quite different approaches: experimental, computational and, where appropriate, analytical. Each problem in the sequence is carefully defined, and each one is intended to test one or another aspect of the solution method(s). Of particular concern is modeling, whether it be of load application, material behavior, or geometry. Thus the solutions to each problem are to be closely compared and, as differences are identified, their sources found. Ultimately, these solutions must be brought closely into register. In this manner, it is expected that the art we term modeling is enhanced and at the same time the quality of the solutions is improved.

The specific problems are chosen to fall into a sequence, from those involving a uniform stress or strain field to those engendered by a crack or notch. A progression of problems is intentionally chosen so that the degree of stress concentration increases. The reasons for not dealing exclusively with crack problems are quite simple: A crack is such a dominant geometric feature that it may mask inadvertant modeling errors which, while perhaps unimportant in simple laboratory specimens, become essential in more complex service configurations. In addition, crack-tip stress analyses necessarily incur numerically large strains - which outrun the usual type of stress-strain material data - but it is not clear whether these strain values are meaningful and/or capable of corroboration. As a result, some of the problems chosen for study will involve intermediate levels of stress concentration which may at first appear to be conservative. This feature is expected to pay off in the long run, however, especially as there is afforded an opportunity to evaluate critically the modeling techniques used by the various participants.

It is assumed for purposes of this discussion that the participants in Project FRACT would work on a contractual basis; should such funding become available, it may derive from either a single or combined sources. Whatever the mode, funding is needed to guarantee timely performance, reporting on schedule, and other aspects of each participant's work such that the overall Project is neither impeded nor thwarted by the exigencies any one participant may face within his/her organization. It is intended that support is for solving the problems within the sequence, and not for development of code or equipment, nor for extensive amounts of education, nor for incidentals (e.g., travel, reporting) beyond those used directly in the Project. Materials, computer time, and manpower are expected to be the primary direct costs.

Monitoring of the Project involves two aspects, administrative and technical, and it could well require the talents of two or more people working in a close partnership. The administrative monitoring will be in a form settled by the sponsor(s). The technical monitor(s) need not be employed by the sponsor(s), but may be drawn from the technical community. No such person can be both a monitor and a participant, and the monitor(s) must be qualified to perform as needed, i.e., credible; free to act; unencumbered by lack of funds or special relationships to participants; and closely in tune with the objectives and process involved in this Project. It is after all the monitor who says that a set of results is "good," in some sense, and he/she must have the standing in the technical community to do so.[2]

A protocol for the Project may be established at this stage, at least in outline. Since the problems to be treated are sequential, there is an order both in which they are to be solved and in which results may become generally available. In some cases this may require deferral of publication, and all participants must recognize this need.

It is essential that each problem in the sequence be uniquely defined and comprehensively understood by each participant. It is believed that the problems as now conceived meet such a requirement but, should there be changes in the problem definition, all participants must be fully informed.

All participants would be expected to progress from simpler problems to more difficult ones, results being gauged closely by the technical monitor(s). Correspondence of experimental, computational, and analytical results is the signal for moving to the next, more difficult problem in a sequence. Discrepancies must be addressed; the participant should be allowed to repeat his/her work with the technical monitor's aid, the target being close replication on the computer of experimental data. In this manner, findings for each problem would be released jointly, with all participants contributing to any publication. It is expected that each such publication would include information in support of the Project's objectives, e.g., the modeling lore required for a benchmark problem, the quality of result, and a new definition of the state of the art.[3]

Criteria for selecting participants are easily stated but subtle in their implementation. Participants should be experimentalists and analysts (computational or otherwise) of the highest calibre, people who can be relied upon to deliver the best solutions to each problem in the sequence, as delineated in a subsequent section. As a group, they should represent the range of techniques and approaches now in use so that, for example, the Project does not wind up with a half dozen people using the same code for analysis*. Apart from quality and breadth, the issue of criteria for selection of participants is largely empirical. A process outlined in the next section provides means for effecting such a result, and we anticipate that it will be followed as a part of the review of the preliminary draft of this report. Results of that process will be appended to the final form of the report.

In summary, this section defines Project FRACT and outlines the rationale chosen whereby its objectives are to be met. The structure is described briefly, together with an outline of the protocol for its operation. Criteria for selection of participants is touched upon, and is picked up in another context, below.

PARTICIPANTS

It would be altruistic to conceive Project FRACT in terms of a large number of participants. While such a scale of activity would have great impact on the technical community, it would also necessitate an excessive concentration of funds for this work. Hence a balance must be struck between what is desirable and what is realistic to do, and great care must be exercised in selecting the participants in the Project. Most certainly, we seek

---

*While differences in the procedures various candidates for participation might use must be taken into account, there is no intent here to "qualify" or to "disqualify" any given procedure. There certainly are differences to be found from one procedure to the next; we believe these to be far less important than the manner in which the procedure is used. It is nonetheless sensible to test this as a working hypothesis, so to speak, by ensuring that alternative procedures, computational or otherwise, are included in the Project.

success and, thereby, we should focus on those candidates for participation who are most likely to contribute to that success. That usually implies people who have established their abilities through prior work. Typically one infers the need for some generally acknowledged reputation, but there may also be good candidates who are less widely known or recognized.

As a result, we rely on two points. The first, noted above, is the explicit statement of need for participants of the highest calibre who can be relied upon to deliver the best solutions to each problem in the sequence. The second point is a simple procedure which is believed to give the information needed.

This report has been reviewed by a large segment of the pertinent technical community*, and the commentary and reactions of these people were solicited. In addition, we have asked all such readers to nominate candidates for participation, bearing in mind the character and objectives of Project FRACT. As a result, several people have been suggested, and their names transmitted with this report to the sponsoring agency. However, anyone in the technical community is potentially a participant, should Project FRACT become funded.

---

*Refer to Appendix B.

PROBLEMS

The problems to be solved can be defined in one or both of two manners. One could, in the context of elasto-plastic or incremental theory, delineate a set of initial- and boundary-value problems. The physical or experimental counterparts would then be inferential. To the extent that satisfactory comparison between the two types of solution is the key to success, and that modeling is a clear target of the Project, this form of definition is inappropriate. The preferred approach is to describe the problems in physical terms, and to minimize or eliminate ambiguity. We follow that approach here. The central issue is modeling per se, and the specifics of load representation, material characterization, and geometric matters are left to the analyst, computational or otherwise.[4] The analyst will of course be provided with precise detail of the experimental arrangement and certain key information, e.g., tensile data.

Certain general comments are in order with respect to all problems defined below. First, it is anticipated that 6061-0 aluminum will be used[5] in all experiments and that all test specimens will be made from the same original pieces of material*. The specimens are to be annealed after machining so as to avoid localized regions of work-hardening which would lead to a spatial variation of material properties. For comment on this effect, see [6] and the ensuing discussion [7, pg. 891]. Abusive machining [8] is to be avoided as well.

Data to be extracted from each test will fall into three categories. First, there is overall structural response, e.g., load *vs* deflection at a well-defined position. While this may seem a rather crude measure, it is

---

*It will be useful to make an excess number of specimens, of course, and care must be taken to maintain any directionality which is determined to exist in the (preferably single) product form from which the specimens are cut.

typically used in fracture characterization and must therefore be accurate.[6] Second, one may describe coarse interior data such as might be used to check for load alignment and specimen symmetry; such information should also be corroborated by analysis. Third, fine-scale data, as determined in the vicinity of a stress concentration, may be extracted. The specific data to be extracted from any one problem are of course peculiar to that problem. We note, however, that all problems or tests within Project FRACT should produce results of the first two types described. Fine-scale data should also be obtained and used in direct form so that there is no risk of compromise from the process of reducing experimental data.

Clearly, fine-scale data are available in two forms: strains, as from (small) strain gauges carefully placed and oriented, and displacements as determined by several techniques. Local displacements (either relative or absolute) can be measured via:

1. clip gauges placed across the faces of a notch or crack, at various distances from the root of the stress raiser;
2. silhouette photography of the profile of a specimen, as it changes with load progression;
3. moiré techniques; and
4. holographic methods, including speckle photography [9].

Note that strain gauges and clip gauges give point values of quantities they measure, silhouettes provide information along a boundary, and that the last two techniques yield field data. A hierarchy thus exists in the fine-scale data which may be obtained, in terms both of the effort needed to extract the data and the degree to which detailed comparisons can be made. The general approach for problems in Project FRACT is to make judicious use of these techniques, obtaining as much information as is economically feasible.

The load cycle for all problems is expected to range from nil to a level where general yield is under way, followed by load removal*. It is anticipated as a minimum that data in each of the three categories (above) will be obtained: when the specimen is wholly (or very nearly so) elastic, at two or three intermediate levels of excitation, at peak load, and following load removal. In addition, structural response and certain of the coarse interior data should be recorded continuously throughout the load cycle. For much of this information, it is necessary to record data automatically. The most desirable arrangement would allow continuous recording and storage of the test data on magnetic tape with software for retrieval and both analogue and digital presentation of the data. This software should be sufficiently flexible for plotting specific measurements (e.g., a given strain) as a function of either time or another measurement. It is recognized that a data system with these capabilities may be unobtainable and other approaches may be required. An acceptable approach might be to create automatically generated plots of all strain and displacement data as functions of applied load and/or time. If applied load is chosen as the independent variable, a plot of applied load *vs* time must be generated during testing. As a last resort, data scans at discrete time or load intervals during the test are a marginally acceptable means of obtaining response data. Regardless of the specific data acquisition system used, all response data must be stored in a form permitting subsequent retrieval and use.

The overall sequence of problems comprises three sets, four thin plate (or nearly plane stress) geometries, five round (or axisymmetric) shapes, and at least one thick (or nearly plane strain) specimen. The sense of a sequence

---

*In some instances at least, it is appropriate to go through a load reversal as well. Whether this is to be incorporated into analysis may be decided at a later stage.

obtains from the following list:[7]

1. Thin plate
    a. smooth, no stress concentrator
    b. circular perforation
    c. symmetric U notches
    d. center crack
2. Round
    a. smooth, no stress concentrator
    b. reduced cross-section
    c. mild U notch
    d. intermediate U notch
    e. V notch
3. Thick
    a. edge crack, four-point bend
    (b. same geometry, other load configuration)

Obviously the two smooth specimens (1a and 2a) provide necessary tensile data. They also serve as a cross-check on both the loading mechanism used in the laboratory and the basics of any analysis. The hole radius (1b) is chosen to be in proportion to that of the mild U notch (2c), and the other two U notch cases (1c and 2d) are the same geometry (within a scale factor). The center cracked thin plate (1d) is not covered by an ASTM standard, as is the V notched round [4,10], but it is a familiar configuration in certain types of less formal fracture testing. The same is true of the four-point bend specimen in plane strain.

It should be apparent that the progression from tensile testing to fracture related specimens has been chosen carefully with an effort to facilitate both experimentation and modeling, and with an eye on opportunities for isolating any difficulty that may arise in pursuing the sequence of problems. Explicit description of the individual problems appears in Appendix C.

PHASING

As indicated above, a considerable amount of review of the planning for Project FRACT is anticipated, and other preparations (notably funding arrangements) must be made before the Project may be implemented. Assuming that those aspects have been completed, it is relatively straightforward to devise an ordering for the various phases of the Project. Reference to Table 1 shows that material acquisition and specimen fabrication proceed in parallel with establishing the necessary contractual relations so that, by the end of the sixth month, tensile data are to be in hand and the more substantive parts of the Project may proceed. Note that both experimentation and analysis have initial portions, during which test fixtures and procedures may be checked out, and any necessary start-up for analysis may be done. Reporting (of an interim nature) is called for during this period so that, where any changes are made to the original problem definitions owing, say, to laboratory requirements, there is opportunity to assimilate this information. The schedule or pacing of problem solution is implied by the subsequent interim reports, and final reporting is indicated. If this schedule proves to be too tight, some loosening may be achieved by deferring the final report slightly. Should the pacing be slow, additional problems - especially ones dealing with thick sections - may be contemplated. Note that technical monitoring proceeds throughout the Project.

CONCLUDING REMARKS

This planning document is intended to be terse so that no extensive summary is in order. The overall procedure is described so that the scope and the approach are clear. We touch the issues of participants and how they are to be selected, the actual problems in their sequence - much the technical centerpiece of the Project - are outlined in a manner designed to bring out the conceptual underpinnings of the Project, and phasing is outlined. We believe that pursuit of this effort will meet the objectives stated in the Introduction, and that its successful conclusion will advance the art to a degree and for its many practitioners that will prove valuable.[8]

ACKNOWLEDGMENTS

This planning effort was sponsored by the Office of Naval Research, and this initial vote of confidence is appreciated. The members of the Planning Committee also express their gratitude to their respective organizations for making time available to participate. The Planning Committee is, in addition, in debt to the Advisory Group whose commentary and thoughtful contributions helped to consolidate this activity.

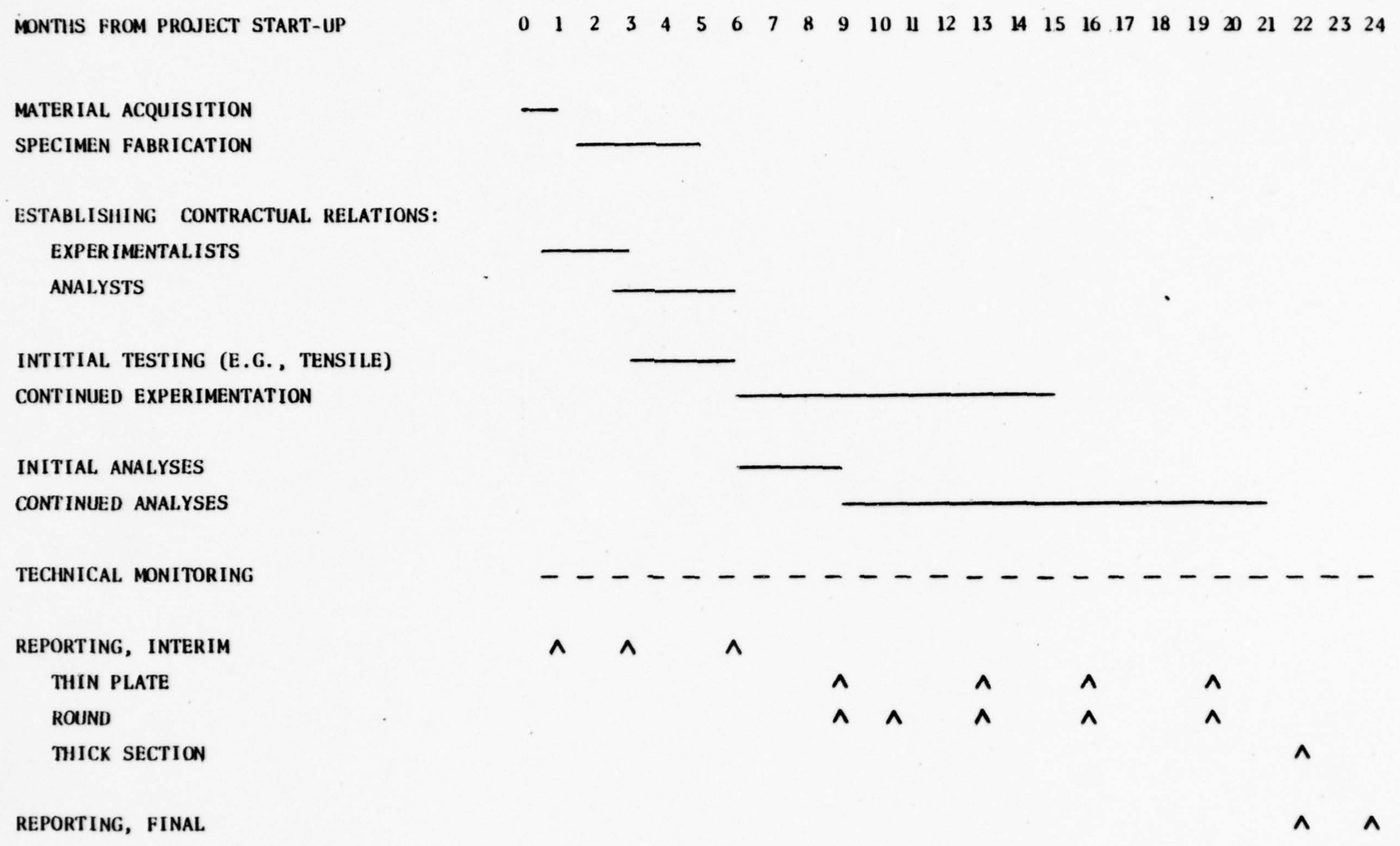


TABLE 1. ESTIMATED PHASING FOR PROJECT FRACT

NOTES FROM ADVISORY GROUP RESPONSE

1. "The reason for undertaking such an exercise...needs to be stated in terms of the cost and safety of structures." Concern here is that the basis of Project FRACT is more academic than pragmatic. The seemingly academic character of the Project derives largely from its progression from (geometrically) simple to difficult problems, to be sure. This does not detract from its objective of obtaining accurate results, on a reliable basis. This is essential if the analyst is to be able to accommodate arbitrary configurations, materials, and loadings.
2. The organizational structure, especially with respect to the technical monitor not also being a participant, has been noted. The intent here is to avoid any potential for conflict. Certainly, were all parties to agree, this constraint could be lifted.
3. There are suggestions to the effect that Project FRACT be merged with similar efforts being developed within professional societies, in particular, ASTM Committee E-24. Were this to be done, the opportunity for funding (page 4) could be lost in that the usual "round-robin" procedure provides participants with anonymity, whereas public reporting is a requirement for federally funded work.
4. Comments on this point included: "...there is relatively little [discussion] on the range of computational procedures..." especially special or singularity elements, that might be used; "...the same analytical formulation of the stress-strain curve be used by all participants..." the preference being expressed for the Ramberg-Osgood equation; "...that several...plasticity models be employed..." with four suggested specifically; and that insufficient credit is given to "...methods of analysis based on closed form approximations." We believe it would run counter to the entire spirit of

the Project to control modeling too closely. Certainly, the selection of participants would proceed so that there is no significant duplication of methodology - see footnote, page 6 - but to do more could easily bias the Project with respect to identifying modeling problems precisely and then resolving them.

5. This material choice has been criticized. The 0 temper is too soft and exhibits some strain rate sensitivity, and aluminum does not replicate behavior found in ferrous alloys, especially pressure vessel steels. The selection of material will require further investigation and, as some comments have indicated, specimen preparation must proceed with considerable care.
6. Care must be taken to check for specimen distortion at the grips. Coarse interior data will compensate where this could be problematic.
7. Additional specimens have been suggested, including: center-loaded, simply supported beam; a pressurized, thick-walled pressure vessel; an uncracked beam to precede 3a; and additional thickness (0.2 and 0.25 in) for 1d. It has been noted that the round specimens are possibly too small, and that thick specimen performance will vary from the interior to the surface where observations are perforce made. Finally, the thread relief on 2a (Figure 5) is noted to be non-standard. Certainly it will be in order to refine the specimen design but, at this stage, it is not evident that additional specimen types can be assimilated into the Project without creating difficulty in terms of additional cost.
8. Support for the conceptual basis and the technical objectives of this Project were evident throughout the responses received from the Advisory Group. It is reasonable to infer that the respondents saw that the Project addresses a real need, and that it is planned in a manner to meet that requirement.

REFERENCES

1. C. E. Inglis, *Transactions of the Institution of Naval Architects* (London), 60 (1913) 219-230. See also the ensuing discussion.

2. J. H. Argyris and D. W. Scharpf, *ZAMP*, 23 (1972) 517-552; P. V. Marcal and I. P. King, *International Journal of Mechanical Sciences*, 9 (1967) 143-155; J. L. Swedlow, M. L. Williams, and W. H. Yang, *Proceedings of the First International Conference on Fracture*, 1 (1965) 259-282.

3. R. E. Peterson, *Stress Concentration Factors*, 2nd ed., John Wiley, New York (1974), 1st ed. (1953).

4. *Rapid Inexpensive Tests for Determining Fracture Toughness*, National Materials Advisory Board Report NMAB-328 (1976).

5. W. K. Wilson and J. R. Osias, *International Journal of Fracture*, 14 (1978) R95-R108.

6. J. L. Swedlow, *International Journal of Fracture*, 5 (1969) 25-31; See also J. H. Underwood et al., *Engineering Fracture Mechanics*, 2 (1971) 183-196.

7. J. L. Swedlow, *Computers and Structures*, 3 (1973) 879-898.

8. W. A. Thomas, Recognition and Control of Abusive Machining Effects on Helicopter Components, American Helicopter Society National Forum (1973), preprint 750.

9. K. A. Stetson, *Optical Engineering*, 14 (1975) 482-489.

10. ASTM Standard E602-76T.

APPENDIX A

Other groups contemplating an effort similar to Project FRACT have been identified during the course of its planning phase. It so far would appear that two or three proprietary activities are in progress. They tend to be specific to one application or another, and information as to status and results have yet to appear in the open literature. At least three voluntary efforts under the aegis of one professional society or another are being planned. To date they appear more limited in scope than Project FRACT but that is not to say that more extensive plans will not emerge. The groups are

1. ASTM: Committee E-24 on Fracture Testing, Task Group E-24.08.02 on Computational Techniques and Procedures. Co-chairmen are D. M. Parks and W. K. Wilson.
2. EGF (European Group on Fracture): Chairman is J. D. Harrison, and funding is being sought from Euratom.
3. SESA: Fracture Committee, Subcommittee on Numerical Modeling. Chairman is F. W. Smith.

There may also be a similar interest within ASME, but definite word has yet to be received. The point is nonetheless clear that the issues raised here are of general interest so that a significant fraction of the technical community seeks to address them.

APPENDIX B

It was deemed important from the very outset that this planning effort not proceed in a vacuum. Apart from the chance of duplicating work that might begin elsewhere, there is a clear need to tap as broad a resource as was feasible to develop. Accordingly, an Advisory Group was identified, and people have now agreed to serve in that capacity. As planning went forward, these people were notified of progress in outline rather than detail form. It is to this Group that the preliminary draft of this report was sent for comment and critique. It is also from this Group that nominations for participation were solicited. The membership of the Advisory Group follows; it is clear that overlap with other activities is established so that, were there to be some duplication of effort, it could be made useful rather than inadvertant.

The Planning Committee was drawn from the larger technical community to represent the expertise needed for the planning phase of the Project. It has met three times (13 September and 31 October 1978, 17 January 1979) as well as having developed much of the written material upon which this report is based. Dr. Alan Kushner served on the Planning Committee through the end of 1978, as the ONR representative; his professional association then changed and he did not participate in the completion of this work. The Committee is grateful for his contribution.

Project FRACT

Listing of Advisory Group

Professor J. E. Akin
University of Tennessee

Dr. D. M. Anderson (AIAA)
General Dynamics

Dr. Harry Armen
Grumman Aerospace Corp.

Professor Satya N. Atluri
Georgia Institute of Technology

Professor Zdenek P. Bazant (SMIRT)
Northwestern University

Professor James A. Begley
Ohio State University

Dr. Steven E. Benzley*
Sandia Laboratories

Dr. Michael J. Buckley
Defense Advanced Research Projects Agency

Dr. C. I. (Jim) Chang
Naval Research Laboratory

Dr. T. A. Cruse
Pratt & Whitney Aircraft

Dr. R. T. Fenner (IMechE)
Imperial College of Science and Technology

Dr. George J. Fix
Carnegie-Mellon University

Professor Walter E. Haisler*
Texas A&M University

Dr. John Harrison
The Welding Institute

Mr. J. G. Kaufman (ASTM E24)
Aluminum Co. of America

Professor Albert S. Kobayashi*
University of Washington

Dr. H. J. Konish*
Westinghouse Electric Corp.

Professor Erhard Krempl (Matls. Div. ASME)
Renssalaer Polytechnic Institute

Dr. John D. Landes (ASTM E24.08)
Westinghouse Electric Corp.

Dean H. Liebowitz *(Eng. Frac. Mech.)*
George Washington University

Professor H. W. Liu
Syracuse University

Dr. Pedro V. Marcal
Marc Analysis Research Corp.

Professor K. J. Miller *(Fatigue Engr. Matls. Structures)*
University of Sheffield

Professor H. Miyamoto (JSME)
Science University of Tokyo

Lt. Col. J. D. Morgan
Air Force Office of Scientific Research

Dr. J. C. Newman*
NASA Langley Research Center

Mr. Charles Parr*
Lord Kinematics Corp.

Dr. N. Perrone
Office of Naval Research

Dr. Owen Richmond
U.S. Steel Research

Dr. Edward Saibel
Army Research Office

Professor George C. Sih
Lehigh University

---

*Planning Committee member.
**Pending

Dr. G. B. Sinclair
Carnegie-Mellon University

Professor R. Skalak**(Appl. Mech. Div., ASME)
Columbia University

Professor C. W. Smith (SESA Fracture Committee)
Virginia Polytechnic Institute

Mr. J. S. Solecki*
Carnegie-Mellon University

Dr. E. Sommer
Institut für Festkörpermechanik

Dr. John E. Srawley
NASA Lewis Research Center

Professor A. W. Thompson
Carnegie-Mellon University

Professor C. E. Turner (ICF)
Imperial College of Science and Technology

Dr. W. R. Tyson (CFRC)
CANMET

Dr. H. C. van Elst
Metaalinstituut TNO

Mr. Donald B. Van Fossen (PVP Div., ASME)
Babcock & Wilcox

Mr. E. T. Wessel (ASTM E24.08)
Westinghouse Electric Corp.

Dean M. L. Williams *(Int. J. Fracture)*
University of Pittsburgh

Dr. W. K. Wilson* (ASTM E24.08.02)
Westinghouse Electric Corp.

Professor Takeo Yokobori
Tohoku University

APPENDIX C

Thin Plate Problems

This set of problems shares the common structural basis shown schematically as a test specimen in Figure 1. It consists of a rectangular thin plate gauge section, subjected to remote, in-plane, uniaxial tension introduced through thickened end tabs. These end tabs are to be integral parts of the specimen; separately fabricated pieces attached to a plate of uniform thickness are not acceptable.

The four distinct problem types of interest are differentiated according to the structural stress concentration contained in the specimen. Type 1a specimens have no such concentration and are thus unnotched tensile specimens of the type shown in Figure 1. Type 1b specimens contain a single circular hole at the center of the gauge section (Figure 2), and Type 1c specimens contain two opposed edge notches tranverse to the applied loading (Figure 3). Type 1d specimens contain a fatigue-sharpened crack placed normal to the applied loading (Figure 4). The principal dimensions of all notches are the same, regardless of notch type. Thus, the hole diameter D in Type 1b specimens, the total notch depth 2ℓ in Type 1c specimens, and the total crack length 2a in type 1d specimens are equal. The principal notch dimension (D, 2ℓ, 2a) for any notched specimen is indicated by λ.

The thickness B of the gauge section must be small enough to warrant plane stress modeling of specimen behavior, so that experimental measurements on the surface of the specimen can be meaningfully compared with computational results. At the same time, it is necessary that B be significantly larger (e.g., an order of magnitude) than the microstructural dimensions, such as grain size, of the specimen material. A satisfactory gauge section thickness is thus somewhat dependent on the material of interest. A gauge section thickness of 0.10 inch, which is at least marginally adequate for materials as coarse as ASTM grain size number 1, is chosen for the purposes of this discussion. It is assumed that this choice is justified by microstructural examination of the actual specimen material prior to testing. If such examination indicates that alteration of the proposed gauge section thickness is warranted with regard to microstructural considerations, the consequences of such a change on specimen fabricability and susceptibility to handling damage must be assessed. All specimen types must have the same gauge section thickness.

All other gauge section dimensions are directly or indirectly related to gauge section thickness. See Table 1. In the notched specimens (Types 1b,1c), the principal notch dimension λ must equal or exceed ten times the gauge section thickness, while the gauge section width W must be from 2.5λ to 5.0λ. Other notch dimensions are as indicated in Figures 3 and 4. Unnotched Type 1a specimens must have the same gauge section width as notched specimen types. Lower bounds on λ and W (i.e., λ=1.0 inch, W=2.5 inch) are chosen for this discussion to avoid any unnecessary requirements on testing machine capacity. The gauge section length L is chosen equal to five times the specimen width. It is assumed that this length is large enough to provide an axial separation of 0.5W or more between the local stress and strain perturbations induced at the end tabs and the notch (if any). The validity of this assumption must be continuously addressed throughout the course of the experimental and analytical phases of this work; instrumentation and data acquisition are to be designed to meet this requirement*.

---

*Internal Planning Committee correspondence provides further detail on these points; the overall objectives are described on pp. 8-10 of the main part of this report.

Configuration of the loading end tabs is indicated in Figure 1. End tab width is chosen to be identical to gauge section width to simplify specimen fabrication and to eliminate any potential difficulties in a width transition region. Other loading tab dimensions are chosen to assure adequate loading capability for unnotched Type I specimens. End tabs sized on this basis are adequate for loading of notched specimen types. Total end tab length L_T is chosen equal to 1.5W. A single loading pin hole with a nominal diameter D_T of 1.0 inch is located as shown in each end tab. In actuality, these holes must be slightly larger than indicated to avoid binding between the specimen and the loading pins. Based on this loading pin size, the end tab thickness B_T is chosen equal to 7.5B.

Axisymmetric (Round) Problems

This set of problems is also predicated on a common shape. In order to fabricate the specimens from a product form of reasonable thickness, however, the dimensions are scaled down somewhat from those of the Thin Plate series, and we assume the basic structural shape of a 1-inch diameter rod. The end fittings are depicted here as standard, to fit threaded grips. If it should develop that an alternative is both available and preferable it will of course be used. Apart from that, configuration of the specimens follows the considerations outlined above.

The smooth (Type 2a) specimen is shown in Figure 5; it should serve a source for tensile data as well as being a check on the loading systems, given proper instrumentation. The Type 2b specimen allows extensive local straining without risk of failure at the grips, and it will serve as a significant check on computation. Specimens 2c and 2d are related to 1b and 1c, as noted above; specimen 2e is as close to a cracked configuration as is feasible while preserving axisymmetry. It also relates to fracture testing, as discussed in the text of this report [4] (see Figures 6, 7, and 8)*.

Thick (Plane Strain) Problems(s)

This is a four-point bend specimen with an edge crack halfway through the thickness. Thickness should be as great as the product form allows, probably 1.5 inch, and the cross-section is square. Loading is generated by opposing pairs of rollers, half the specimen's thickness in diameter, spaced at 6 inch and 12 inch, respectively. Thus no roller is immediately opposite the crack front, and loading is introduced at a distance of four times the crack depth. (It is assumed that the crack is generated by a fatigue process, following usual practice, and that the specimen is annealed after fabrication.)

Depending on progress of the work, we may wish to use the same specimen in three-point bend as well. This is a variant of the standard K_{Ic} test in that the span/width ratio is eight rather than four (see Figure 9).

---

*The notch angle shown in Figure 8 may be reduced from 90 deg to 60 deg.

TABLE 1

Nominal Specimen Dimensions

Dimension[1]	Bounds	Assumed Value
B	——[2]	0.10 inch
$\lambda = D$ (type 1b)	$\lambda \geq 10B$	0.25 inch
$\lambda = 2\ell$ (type 1c)	$\lambda \geq 10B$	1.5 inch
r (type 1c)	--	0.3125 inch
$\lambda = 2a$ (type 1d)	$\lambda \geq 10B$	1.0 inch
W	$2.5\lambda \leq W \leq 5$	2.50 inch
L	$L \geq 5W$	12.50 inch
B_T	$D_T B_T \geq 3WB$	0.75 inch
D_T	$D_T B_T \geq 5(W-\lambda)B$	1.00 inch
L_T	$L_1 \geq 1.5W$	3.75 inch

---

[1] See Figures 1-4.

[2] Gauge section thickness is bounded from below by microstructural dimensions of material, and from above by plane stress considerations.

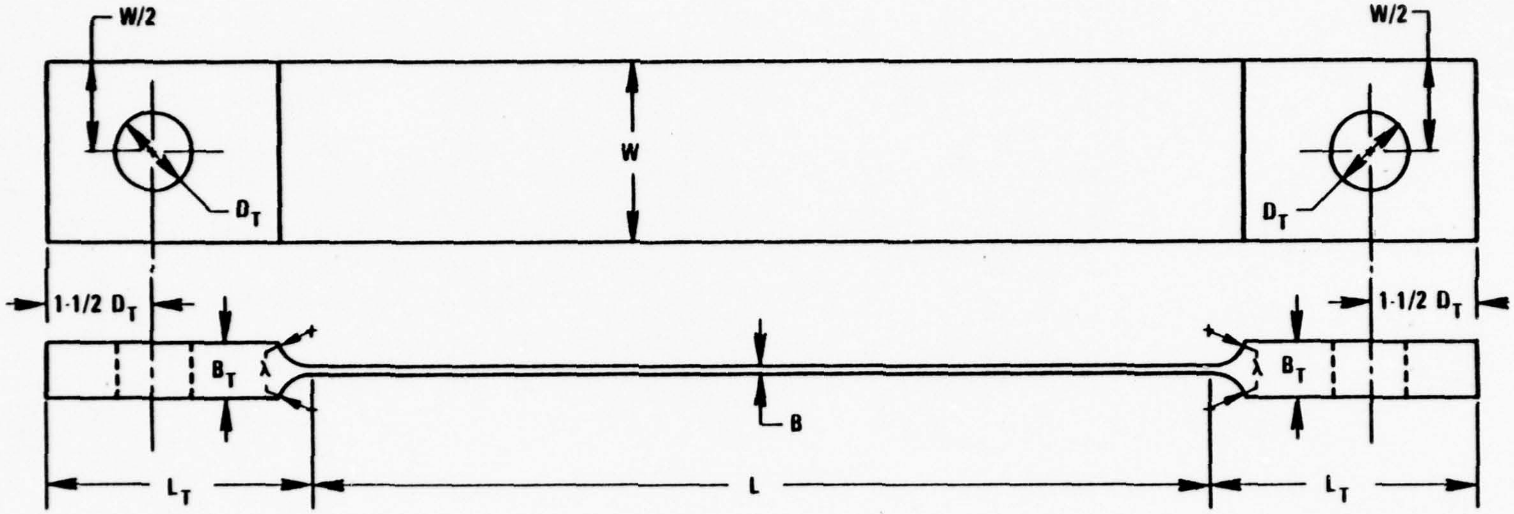


Figure 1. Schematic Configuration of Type 1a Specimen

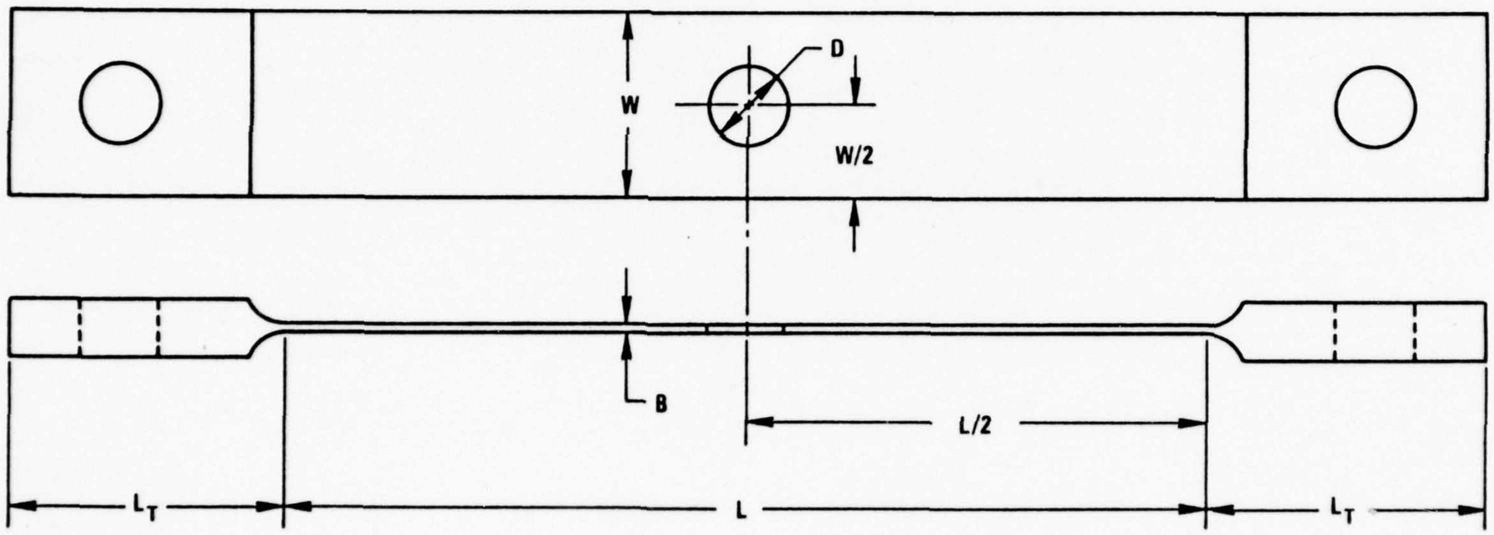


Figure 2. Schematic Configuration of Type 1b Specimen

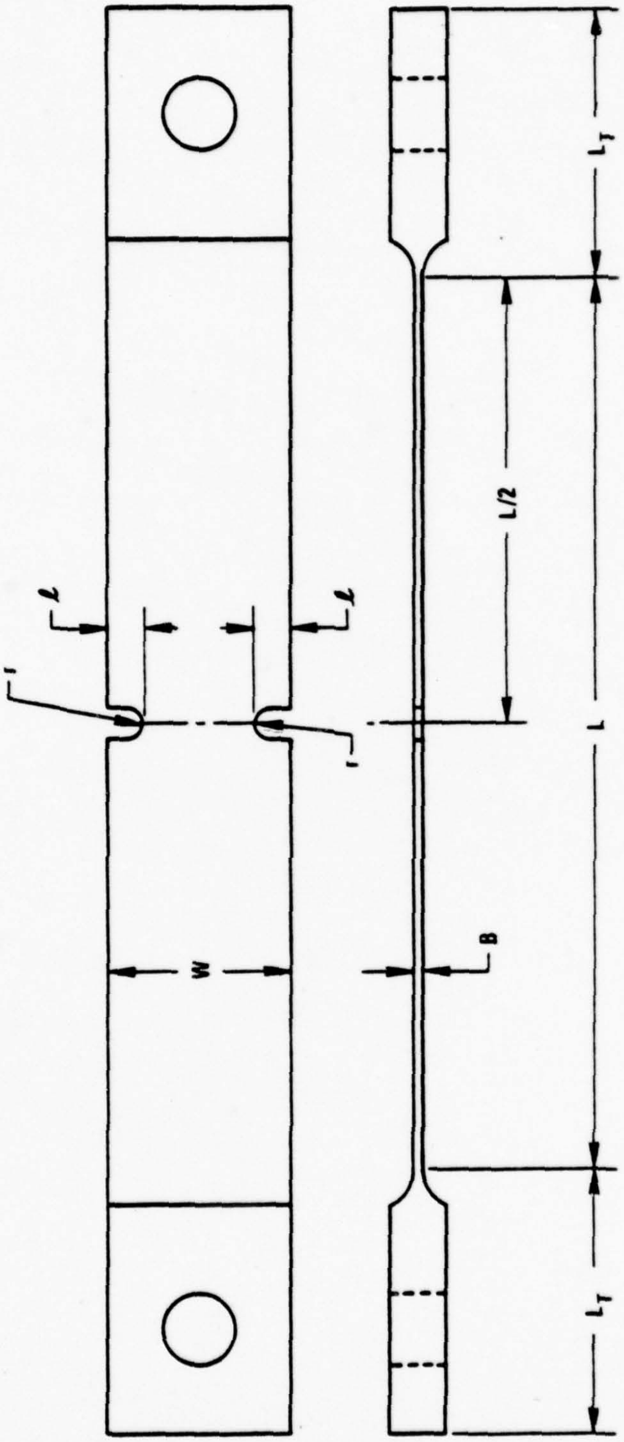


Figure 3. Schematic Configuration of Type 1c Specimen

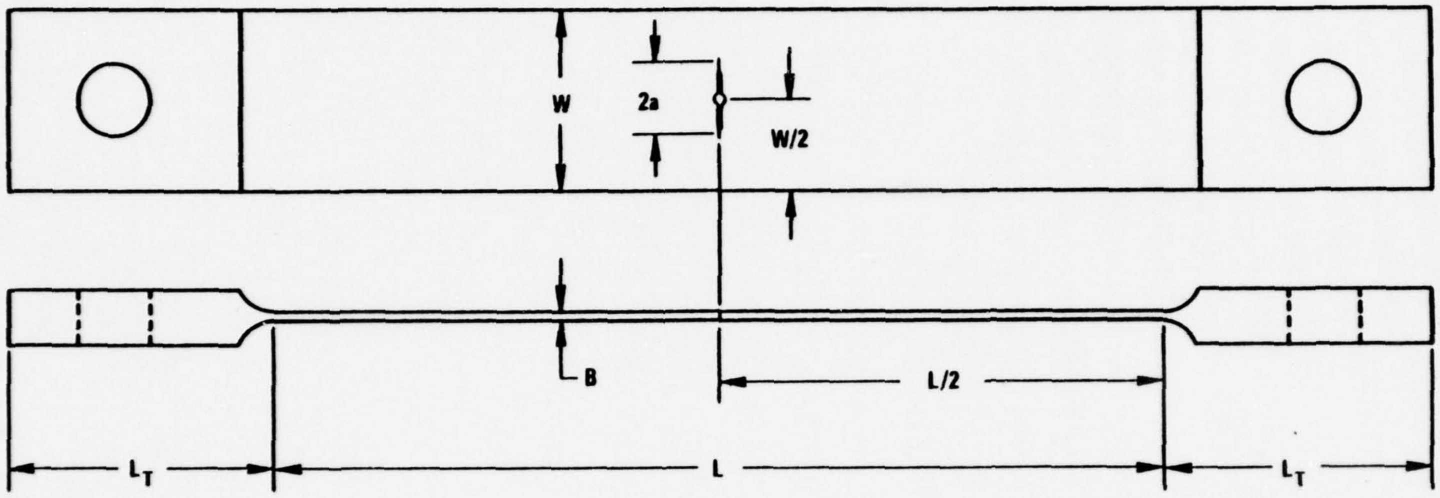


Figure 4. Schematic Configuration of Type Id Specimen

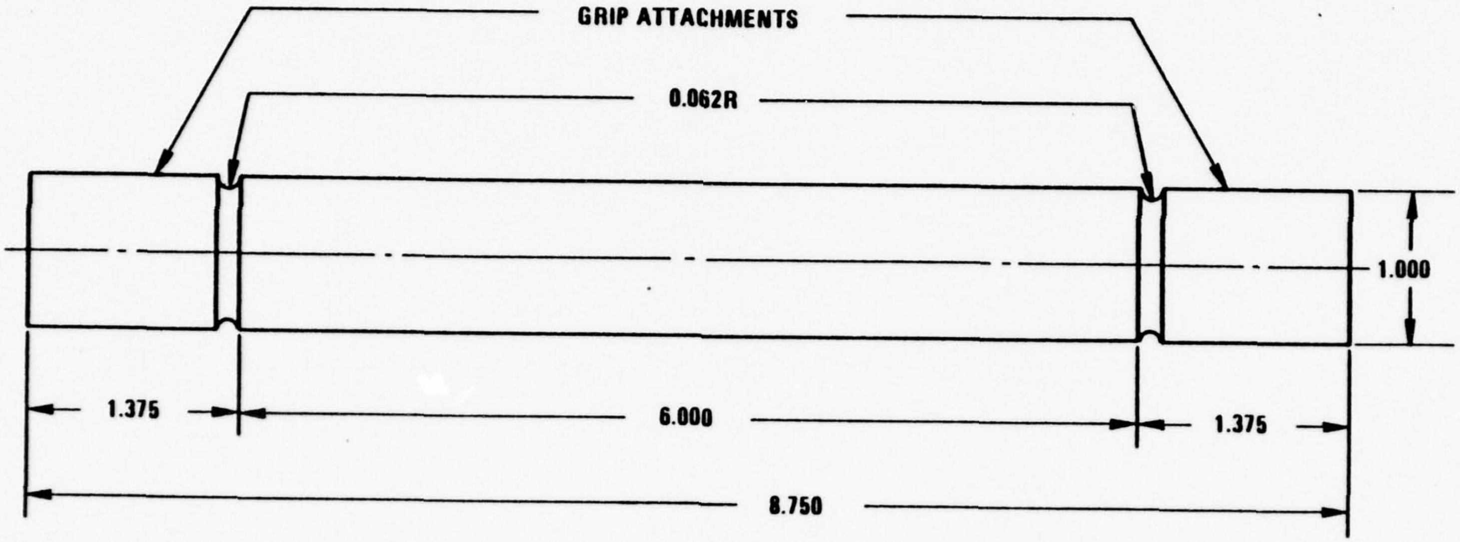


Figure 5. Schematic Configuration of Type 2a Specimen

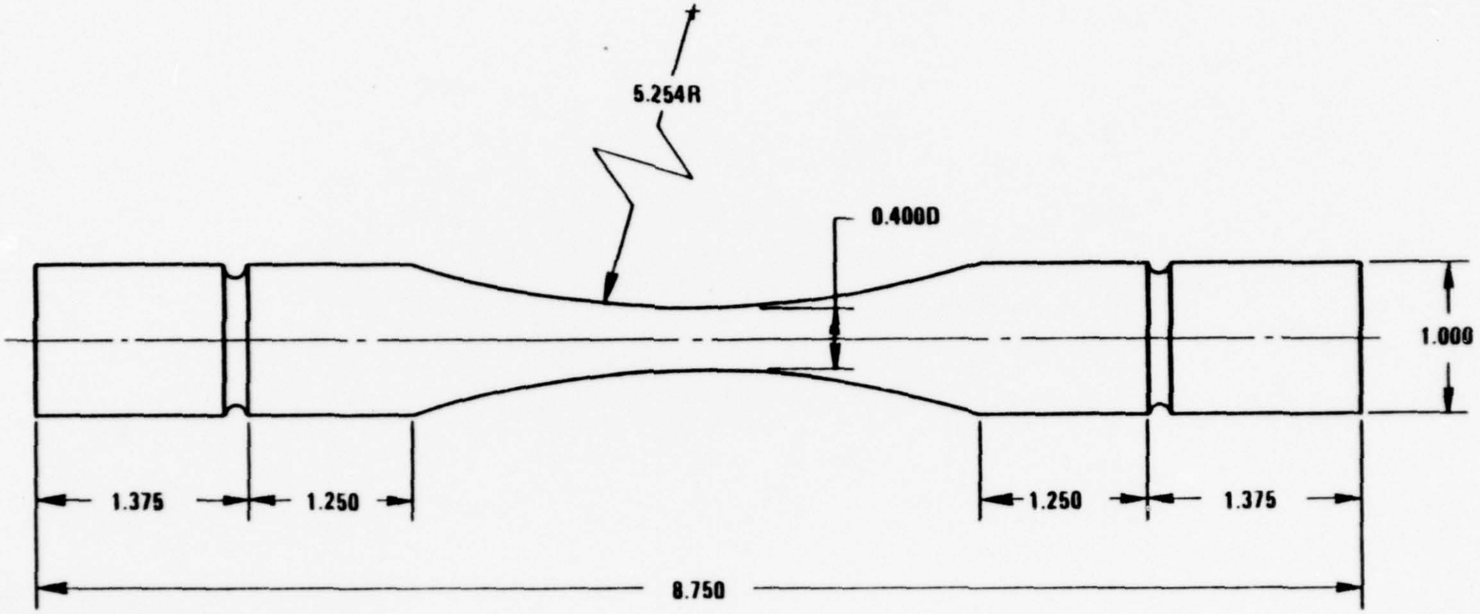
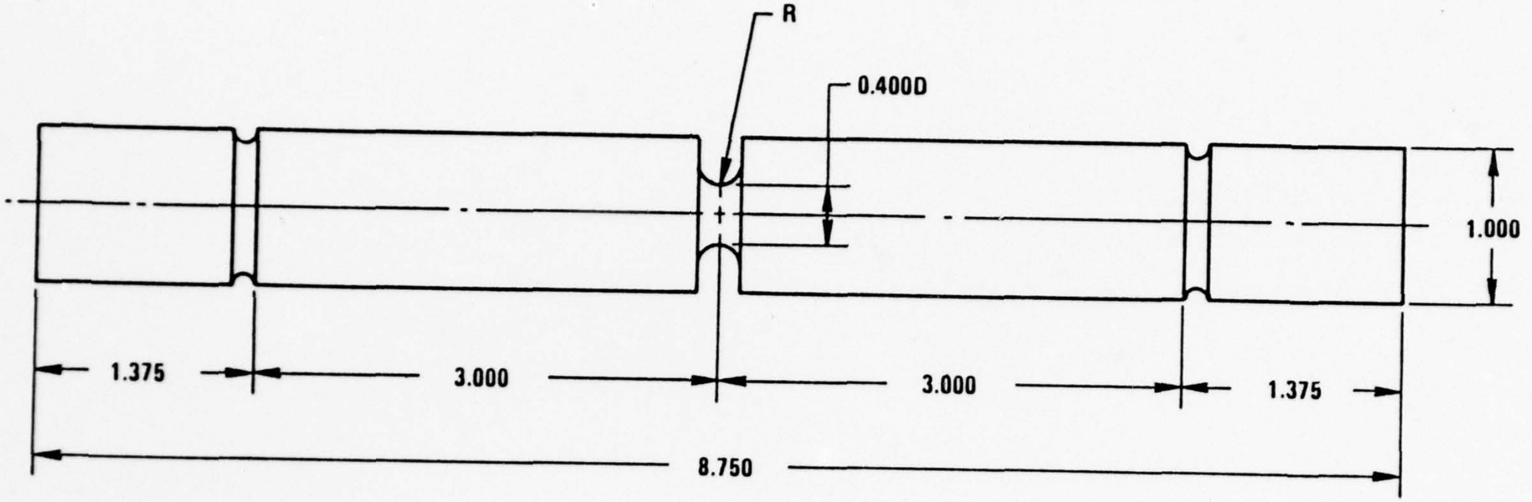


Figure 6. Schematic Configuration of Type 2b Specimens



SPEC. TYPE	R
2c	0.125
2d	0.250

Figure 7. Schematic Configuration of Type 2c and Type 2d Specimens

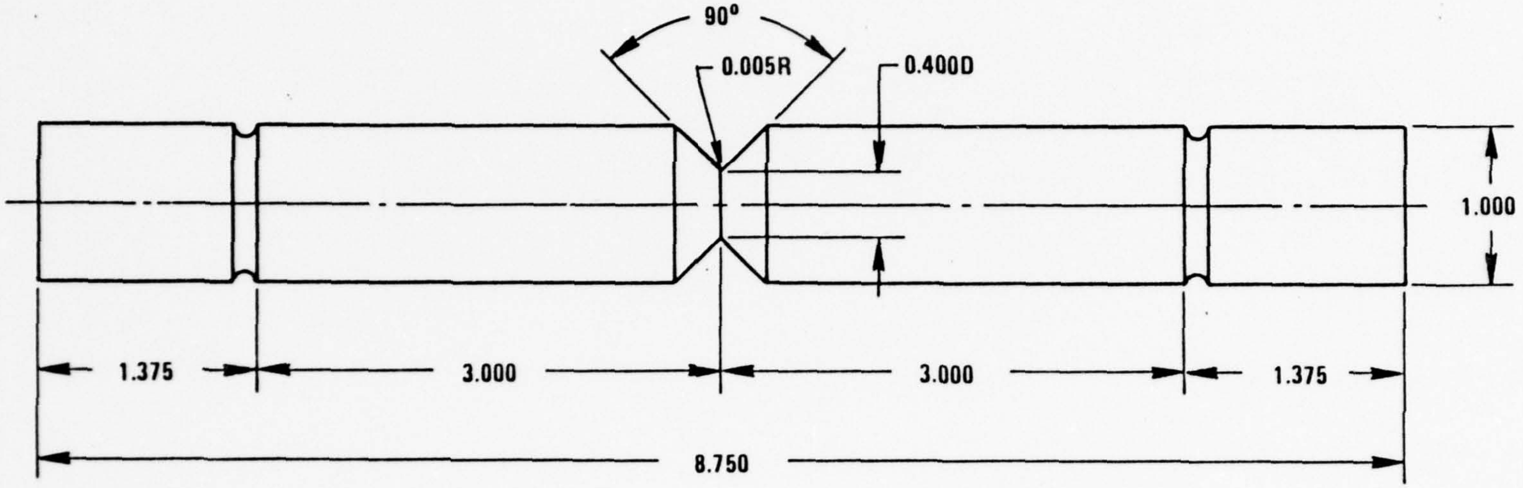


Figure 8. Schematic Configuration of Type 2e Specimen

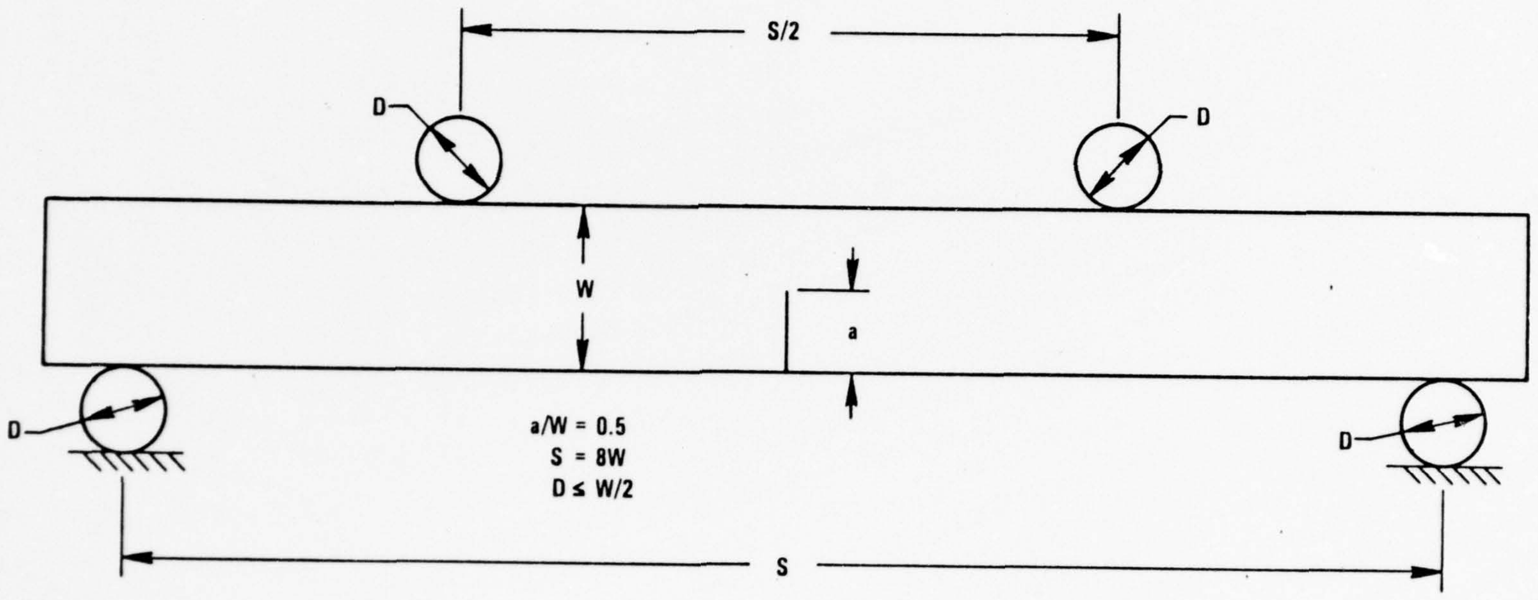


Figure 9. Schematic Configuration of Type 3a Specimen

PART 1 - Government

Administrative and Liaison Activities

Office of Naval Research
Department of the Navy
Arlington, VA 22217
Attn: Code 474 (2)
Code 471
Code 200

Director
Office of Naval Research
Branch Office
666 Summer Street
Boston, MA 02210

Director
Office of Naval Research
Branch Office
536 South Clark Street
Chicago, IL 60605

Director
Office of Naval Research
New York Area Office
715 Broadway - 5th Floor
New York, NY 10003

Director
Office of Naval Research
Branch Office
1030 East Green Street
Pasadena, CA 91106

Naval Research Laboratory (6)
Code 2627
Washington, DC 20375

Defense Documentation Center (12)
Cameron Station
Alexandria, VA 22314

Navy

Undersea Explosion Research Division
Naval Ship Research and Development Center
Norfolk Naval Shipyard
Portsmouth, VA 23709
Attn: Dr. E. Palmer, Code 177

Navy (Con't.)

Naval Research Laboratory
Washington, DC 20375
Attn: Code 8400
8410
8430
8440
6300
6390
6380

David W. Taylor Naval Ship Research and Development Center
Annapolis, MD 21402
Attn: Code 2740
28
281

U.S. Naval Weapons Center
China Lake, CA 93555
Attn: Code 4062
4520

Commanding Officer
U.S. Naval Civil Engineering Laboratory
Code L31
Port Hueneme, CA 93041

Naval Surface Weapons Center
White Oak
Silver Spring, MD 20910
Attn: Code R-10
G-402
K-82

Technical Director
Naval Ocean Systems Center
San Diego, CA 92152

Supervisor of Shipbuilding
U.S. Navy
Newport News, VA 23607

U.S. Navy Underwater Sound Reference Division
Naval Research Laboratory
P.O. Box 8337
Orlando, FL 32806

Navy (Con't.)

Chief of Naval Operations
Department of the Navy
Washington, DC 20350
Attn: Code OP-098

Strategic Systems Project Office
Department of the Navy
Washington, DC 20376
Attn: NSP-200

Naval Air Systems Command
Department of the Navy
Washington, DC 20361
Attn: Code 5302 (Aerospace and Structures)
604 (Technical Library)
320B (Structures)

Naval Air Development Center
Director, Aerospace Mechanics
Warminster, PA 18974

U.S. Naval Academy
Engineering Department
Annapolis, MD 21402

Naval Facilities Engineering Command
200 Stovall Street
Alexandria, VA 22332
Attn: Code 03 (Research and Development)
04B
045
14114 (Technical Library)

Naval Sea Systems Command
Department of the Navy
Washington, DC 20362
Attn: Code 03 (Research and Technology)
037 (Ship Silencing Division)
035 (Mechanics and Materials)

Naval Ship Engineering Center
Department of the Navy
Washington, DC 20362
Attn: Code 6105G
6114
6120D
6128
6129

Commanding Officer and Director
David W. Taylor Naval Ship
Research and Development Center
Bethesda, MD 20084
Attn: Code 042
17
172
173
174
1800
1844
1102.1
1900
1901
1945
1960
1962

Naval Underwater Systems Center
Newport, RI 02840
Attn: Dr. R. Trainor

Naval Surface Weapons Center
Dahlgren Laboratory
Dahlgren, VA 22448
Attn: Code G04
G20

Technical Director
Mare Island Naval Shipyard
Vallejo, CA 94592

U.S. Naval Postgraduate School
Library
Code 0384
Monterey, CA 93940

Webb Institute of Naval Architecture
Attn: Librarian
Crescent Beach Road, Glen Cove
Long Island, NY 11542

Army

Commanding Officer (2)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709
Attn: Mr. J. J. Murray,
CRD-AA-IP

Watervliet Arsenal
MAGGS Research Center
Watervliet, NY 12189
Attn: Director of Research

U.S. Army Materials and Mechanics
Research Center
Watertown, MA 02172
Attn: Dr. R. Shea, DRXMR-T

U.S. Army Missile Research and
Development Center
Redstone Scientific Information
Center
Chief, Document Section
Redstone Arsenal, AL 35809

Army Research and Development
Center
Fort Belvoir, VA 22060

NASA

National Aeronautics and Space Administration
Structures Research Division
Langley Research Center
Langley Station
Hampton, VA 23365

National Aeronautics and Space Administration
Associate Administrator for Advanced
Research and Technology
Washington, DC 20546

Scientific and Technical Information Facility
NASA Representative (S-AK/DL)
P.O. Box 5700
Bethesda, MD 20014

Air Force

Commander WADD
Wright-Patterson Air Force Base
Dayton, OH 45433
Attn: Code WWRMDD
AFFDL (FDDS)
Structures Division
AFLC (MCEEA)

Chief Applied Mechanics Group
U.S. Air Force Institute of Technology
Wright-Patterson Air Force Base
Dayton, OH 45433

Chief, Civil Engineering Branch
WLRC, Research Division
Air Force Weapons Laboratory
Kirtland Air Force Base
Albuquerque, NM 87117

Air Force Office of Scientific Research
Bolling Air Force Base
Washington, DC 20332
Attn: Mechanics Division

Department of the Air Force
Air University Library
Maxwell Air Force Base
Montgomery, AL 36112

Other Government Activities

Commandant
Chief, Testing and Development Division
U.S. Coast Guard
1300 E Street, NW
Washington, DC 20226

Technical Director
Marine Corps Development
and Education Command
Quantico, VA 22134

Director Defense Research
and Engineering
Technical Library
Room 3C128
The Pentagon
Washington, DC 20301

Director
National Bureau of Standards
Washington, DC 20034
Attn: Mr. B. L. Wilson, EM 219

Dr. M. Gaus
National Science Foundation
Environmental Research Division
Washington, DC 20550

Library of Congress
Science and Technology Division
Washington, DC 20540

Director
Defense Nuclear Agency
Washington, DC 20305
Attn: SPSS

Mr. Jerome Persh
Staff Specialist for Materials
and Structures
OUSDR&E, The Pentagon
Room 3D1089
Washington, DC 20301

Chief, Airframe and Equipment Branch
FS-120
Office of Flight Standards
Federal Aviation Agency
Washington, DC 20553

National Academy of Sciences
National Research Council
Ship Hull Research Committee
2101 Constitution Avenue
Washington, DC 20418
Attn: Mr. A. R. Lytle

National Science Foundation
Engineering Mechanics Section
Division of Engineering
Washington, DC 20550

Picatinny Arsenal
Plastics Technical Evaluation Center
Attn: Technical Information Section
Dover, NJ 07801

Maritime Administration
Office of Maritime Technology
14th and Constitution Ave., NW
Washington, DC 20230

Maritime Administration
Office of Ship Construction
14th and Constitution Ave., NW
Washington, DC 20230

PART 2 - Contractors and Other Technical Collaborators

Universities

Dr. J. Tinsley Oden
University of Texas at Austin
345 Engineering Science Building
Austin, TX 78712

Professor Julius Miklowitz
California Institute of Technology
Division of Engineering
and Applied Sciences
Pasadena, CA 91109

Dr. Harold Liebowitz, Dean
School of Engineering and
Applied Science
George Washington University

Professor Eli Sternberg
California Institute of Technology
Division of Engineering and
Applied Sciences
Pasadena, CA 91109

Professor Paul M. Naghdi
University of California
Department of Mechanical Engineering
Berkeley, CA 94720

Professor A. J. Durelli
Oakland University
School of Engineering
Rochester, MI 48063

Professor F. L. DiMaggio
Columbia University
Department of Civil Engineering
New York, NY 10027

Professor Norman Jones
Massachusetts Institute of Technology
Department of Ocean Engineering
Cambridge, MA 02139

Professor E. J. Skudrzyk
Pennsylvania State University
Applied Research Laboratory
Department of Physics
State College, PA 16801

Professor J. Kempner
Polytechnic Institute of New York
Department of Aerospace Engineering and
Applied Mechanics
333 Jay Street
Brooklyn, NY 11201

Professor J. Klosner
Polytechnic Institute of New York
Department of Aerospace Engineering and
Applied Mechanics
333 Jay Street
Brooklyn, NY 11201

Professor R. A. Schapery
Texas A&M University
Department of Civil Engineering
College Station, TX 77843

Professor Walter D. Pilkey
University of Virginia
Research Laboratories for the
Engineering Sciences
School of Engineering and
Applied Sciences
Charlottesville, VA 22901

Professor K. D. Willmert
Clarkson College of Technology
Department of Mechanical Engineering
Potsdam, NY 13676

Dr. Walter E. Haisler
Texas A&M University
Aerospace Engineering Department
College Station, TX 77843

Dr. Hussein A. Kamel
University of Arizona
Department of Aerospace and
Mechanical Engineering
Tucson, AZ 85721

Dr. S. J. Fenves
Carnegie-Mellon University
Department of Civil Engineering
Schenley Park
Pittsburgh, PA 15213

Universities (Con't.)

Dr. Ronald L. Huston
Department of Engineering Analysis
University of Cincinnati
Cincinnati, OH 45221

Professor G. C. M. Sih
Lehigh University
Institute of Fracture and
Solid Mechanics
Bethlehem, PA 18015

Professor Albert S. Kobayashi
University of Washington
Department of Mechanical Engineering
Seattle, WA 98105

Professor Daniel Frederick
Virginia Polytechnic Institute and
State University
Department of Engineering Mechanics
Blacksburg, VA 24061

Professor A. C. Eringen
Princeton University
Department of Aerospace and
Mechanical Sciences
Princeton, NJ 08540

Professor E. H. Lee
Stanford University
Division of Engineering Mechanics
Stanford, CA 94305

Professor Albert I. King
Wayne State University
Biomechanics Research Center
Detroit, MI 48202

Dr. V. R. Hodgson
Wayne State University
School of Medicine
Detroit, MI 48202

Dean B. A. Boley
Northwestern University
Department of Civil Engineering
Evanston, IL 60201

Professor P. G. Hodge, Jr.
University of Minnesota
Department of Aerospace Engineering
and Mechanics
Minneapolis, MN 55455

Dr. D. C. Drucker
University of Illinois
Dean of Engineering
Urbana, IL 61801

Professor N. M. Newmark
University of Illinois
Department of Civil Engineering
Urbana, IL 61803

Professor E. Reissner
University of California, San Diego
Department of Applied Mechanics
La Jolla, CA 92037

Professor William A. Nash
University of Massachusetts
Department of Mechanics and
Aerospace Engineering
Amherst, MA 01002

Professor G. Herrmann
Stanford University
Department of Applied Mechanics
Stanford, CA 94305

Professor J. D. Achenbach
Northwestern University
Department of Civil Engineering
Evanston, IL 60201

Professor S. B. Dong
University of California
Department of Mechanics
Los Angeles, CA 90024

Professor Burt Paul
University of Pennsylvania
Towne School of Civil and
Mechanical Engineering
Philadelphia, PA 19104

Universities (Con't.)

Professor H. W. Liu
Syracuse University
Department of Chemical Engineering
and Metallurgy
Syracuse, NY 13210

Professor S. Bodner
Technion R&D Foundation
Haifa, Israel

Professor Werner Goldsmith
University of California
Department of Mechanical Engineering
Berkeley, CA 94720

Professor R. S. Rivlin
Lehigh University
Center for the Application
of Mathematics
Bethlehem, PA 18015

Professor F. A. Cozzarelli
State University of New York at Buffalo
Division of Interdisciplinary Studies
Karr Parker Engineering Building
Chemistry Road
Buffalo, NY 14214

Professor Joseph L. Rose
Drexel University
Department of Mechanical Engineering
and Mechanics
Philadelphia, PA 19104

Professor B. K. Donaldson
University of Maryland
Aerospace Engineering Department
College Park, MD 20742

Professor Joseph A. Clark
Catholic University of America
Department of Mechanical Engineering
Washington, DC 20064

Professor T. C. Huang
University of Wisconsin-Madison
Department of Engineering Mechanics
Madison, WI 53706

Dr. Samuel B. Batdorf
University of California
School of Engineering
and Applied Science
Los Angeles, CA 90024

Professor Isaac Fried
Boston University
Department of Mathematics
Boston, MA 02215

Professor Michael Pappas
New Jersey Institute of Technology
Newark College of Engineering
323 High Street
Newark, NJ 07102

Professor E. Krempl
Rensselaer Polytechnic Institute
Division of Engineering
Engineering Mechanics
Troy, NY 12181

Dr. Jack R. Vinson
University of Delaware
Department of Mechanical and Aerospace
Engineering and the Center for
Composite Materials
Newark, DL 19711

Dr. Dennis A. Nagy
Princeton University
School of Engineering and Applied Science
Department of Civil Engineering
Princeton, NJ 08540

Dr. J. Duffy
Brown University
Division of Engineering
Providence, RI 02912

Dr. J. L. Swedlow
Carnegie-Mellon University
Department of Mechanical Engineering
Pittsburgh, PA 15213

Dr. V. K. Varadan
Ohio State University Research Foundation
Department of Engineering Mechanics
Columbus, OH 43210

Universities (Con't.)

Dr. Z. Hashin
University of Pennsylvania
Department of Metallurgy and
Materials Science
College of Engineering and
Applied Science
Philadelphia, PA 19104

Dr. Jackson C. S. Yang
University of Maryland
Department of Mechanical Engineering
College Park, MD 20742

Professor T. Y. Chang
University of Akron
Department of Civil Engineering
Akron, OH 44325

Professor Charles W. Bert
University of Oklahoma
School of Aerospace, Mechanical,
and Nuclear Engineering
Norman, OK 73019

Professor Satya N. Atluri
Georgia Institute of Technology
School of Engineering Science and
Mechanics
Atlanta, GA 30332

Professor Graham F. Carey
University of Texas at Austin
Department of Aerospace Engineering
and Engineering Mechanics
Austin, TX 78712

Industry and Research Institutes

Dr. Jackson C. S. Yang
Advanced Technology and Research, Inc.
10006 Green Forest Drive
Adelphi, MD 20783

Dr. Norman Hobbs
Kaman AviDyne
Division of Kaman
Sciences Corp.
Burlington, MA 01803

Industry and Research Institutes (Con't.)

Argonne National Laboratory
Library Services Department
9700 South Cass Avenue
Argonne, IL 60440

Dr. M. C. Junger
Cambridge Acoustical Associates
1033 Massachusetts Avenue
Cambridge, MA 02138

Dr. V. Godino
General Dynamics Corporation
Electric Boat Division
Groton, CT 06340

Dr. J. E. Greenspon
J. G. Engineering Research Associates
3831 Menlo Drive
Baltimore, MD 21215

Dr. K. C. Park
Lockheed Missile and Space Company
3251 Hanover Street
Palo Alto, CA 94304

Newport News Shipbuilding and
Dry Dock Company
Library
Newport News, VA 23607

Dr. W. F. Bozich
McDonnell Douglas Corporation
5301 Bolsa Avenue
Huntington Beach, CA 92647

Dr. H. N. Abramson
Southwest Research Institute
8500 Culebra Road
San Antonio, TX 78284

Dr. R. C. DeHart
Southwest Research Institute
8500 Culebra Road
San Antonio, TX 78284

Dr. M. L. Baron
Weidlinger Associates
110 East 59th Street
New York, NY 10022

Industry and Research Institutes (Con't.)

Dr. T. L. Geers
Lockheed Missiles and Space Company
3251 Hanover Street
Palo Alto, CA 94304

Mr. William Caywood
Applied Physics Laboratory
Johns Hopkins Road
Laurel, MD 20810

Dr. Robert E. Nickell
Pacifica Technology
P.O. Box 148
Del Mar, CA 92014

Dr. M. F. Kanninen
Battelle Columbus Laboratories
505 King Avenue
Columbus, OH 43201

Dr. G. T. Hahn
Battelle Columbus Laboratories
505 King Avenue
Columbus, OH 43201

Dr. A. A. Hochrein
Daedalean Associates, Inc.
Springlake Research Center
15110 Frederick Road
Woodbine, MD 21797

Mr. Richard Y. Dow
National Academy of Sciences
2101 Constitution Avenue
Washington, DC 20418

Mr. H. L. Kington
Airesearch Manufacturing Company
of Arizona
P.O. Box 5217
111 South 34th Street
Phoenix, AZ 85010

Dr. M. H. Rice
Systems, Science, and Software
P.O. Box 1620
La Jolla, CA 92037

REPORT DOCUMENTATION PAGE		**READ INSTRUCTIONS BEFORE COMPLETING FORM**
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Planning Phase for Project FRACT: A Critical Evaluation of Fracture Related Analytical and Computational Techniques		5. TYPE OF REPORT & PERIOD COVERED Contract Report June 1978 - June 1979
		6. PERFORMING ORG. REPORT NUMBER Report SM 79-3A
7. AUTHOR(s) Planning Committee, J. L. Swedlow, Chmn.		8. CONTRACT OR GRANT NUMBER(s) ONR Research Contract No. N00014-78-C-0528
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Mechanical Engineering Carnegie-Mellon University Pittsburgh, Pennsylvania 15213		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Department of the Navy Arlington, Virginia 22217		12. REPORT DATE
		13. NUMBER OF PAGES 46
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution of this report is unlimited.

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report outlines a plan for critical evaluation of fracture related analytical and computational techniques. The plan involves ten to twelve investigators who, by various techniques, "solve" a succession of problems involving elastic and elasto-plastic behavior, followed by residual fields after load removal. Solutions would proceed by analytical, computational, and experimental techniques, applied to closely defined problems. The problems represent a sequence of stress concentrations, from none to mild to sharp - as used

20. in fracture testing. The sequence of problems is intended to identify the essential needs for modeling of such problems to produce accurate results. The plan is described in terms of procedure and phasing over a two-year period, and the problems are described in terms of their experimental set-up. Thin-plate, round, and thick-section configurations are included. The report was prepared by a Planning Committee of experts in the field, and a preliminary draft was reviewed by a larger Advisory Group. Comments received during this review process are incorporated into this report.