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Rapid Heating Tensile Tests of High-Energy-Rate-Forged 316L Stainless Steel Containing Internal Helium from Radioactive Decay of Absorbed Tritium

by

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DISCLAIMER

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316L stainless steel is a candidate material for construction of equipment that will be exposed to tritium. This austenitic stainless steel is frequently used in the high-energy-rate-forged (HERF) metallurgical condition to take advantage of increased strength produced by cold work introduced by this process. Proper design of tritium-handling equipment will require an understanding of how helium-3, the product of radioactive decay of tritium, affects mechanical properties. This report describes results of elevated-temperature tensile testing of HERF 316L stainless steel specimens containing helium concentrations of 171 (calculated) atomic parts per million (appm). Results are compared with those reported previously for specimens containing 0 and 94 (measured) appm helium.[1]

Tests were performed on round bar specimens with gage diameters of 0.11 inch (2.9 mm) and gage lengths of 0.87 inch (22 mm). Rapid heating tensile tests up to about 1200°C were performed on an Instron tensile testing machine equipped with an environmental chamber connected to an off-gas exhaust system to remove evolved tritium. A quartz lamp heater in the environmental chamber was used to heat the specimens. Temperatures were controlled and monitored with small thermocouples spot-welded to the specimens. Specimens were heated in air to the desired test temperatures within about a minute and held at constant temperature (within 20°C) for testing. Tests were conducted at an extension rate of 0.5 inch per minute (0.21 mm/sec). Ultimate tensile strength, 0.2% offset yield strength, total elongation, uniform elongation and nonuniform elongation were determined from load-time recordings. Uniform elongation was considered to occur under uniaxial tension up to the point of maximum load where necking usually begins. Reduction-in-area values were determined from measurements of specimen diameters at the point of fracture made with an optical microscope or from scanning electron microscope (SEM) images.

Results of these rapid heating tensile tests are shown in Figure 1. Changes in mechanical behavior are attributed to effects of internal helium rather than tritium since testing of hydrogen-charged specimens yielded results similar to those for uncharged specimens. The most pronounced effect of internal helium is the severe reduction of ductility at temperatures above about 600 °C. At these temperatures, specimens containing internal helium failed by mixed-mode shear or intergranular brittle fracture compared to ductile transgranular fractures, cup-and-cone failures and plastic attenuation exhibited by specimens with no internal helium. Nonuniform elongation (9-33%), which is the principal contributor to total elongation at temperatures above 800 °C for specimens containing no internal helium, is greatly reduced (to less than 5%) by internal helium. (Uniform elongation, which normally has low values of about 7% above 800 °C, is reduced to below 2% by internal helium.) This loss of ductility at elevated temperatures is also reflected in greatly reduced values for reduction-in-area from near 100% to below 10%. Internal helium apparently interferes with

Derivative Classifier

the necking process which influences these two ductility parameters. Thus, embrittlement may involve interactions between the internal helium and the complex triaxial stress state that arises when necking starts. This type of embrittlement apparently occurs only at elevated temperatures during straining since specimens containing internal helium that were heated for five minutes at 1000 ^{o}C retained their ductility in subsequent tests at room temperature. Similar embrittlement has been observed for 304 stainless steel containing as little as 0.07 appm helium generated by neutron irradiation. [2] Thus, it appears that small concentrations of internal helium greatly reduce the high temperature ductility of austenitic stainless steels with increasing concentrations having decreasing effect.

Effects of internal helium on other mechanical properties of HERF 316L stainless steel are less drastic than loss of ductility at elevated temperatures. Offset yield strengths at 20-600 ^{o}C increased by about 10 and 30 ksi for specimens containing helium concentrations of 94 and 177 appm, respectively. No effects on ultimate tensile strength were observed for specimens containing 94 appm helium but an increase of about 10 ksi was observed in tests at 20-500 ^{o}C for specimens containing 171 appm helium. Also, no effects on uniform elongation were observed in 20-500 ^{o}C tests of specimens containing 94 appm helium but tests of specimens containing 171 appm helium at 200-500 ^{o}C yielded uniform elongation values of about 13% compared to values of about 18% determined for specimens containing 0 and 94 appm helium. These results suggest that the rate of change of these mechanical properties with helium concentration increases with helium concentration. No effects of internal helium on nonuniform elongation (6-9%) were observed in tests at 20-600 ^{o}C. Tests of specimens containing 94 appm helium at 20-400 ^{o}C yielded the same values for reduction-in-area (about 80%) as determined for specimens with no internal helium. (Reduction-in-area values for specimens containing 171 appm helium will be determined in future SEM examinations.) All specimens tested at 20-400 ^{o}C failed by ductile cup-and-cone fracture.

Additional rapid heating tensile tests will be performed on tritium-charged specimens of HERF 316L stainless steel after they have been aged to produce internal helium concentrations of greater than 250 appm.

ACKNOWLEDGEMENT

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REFERENCES

1. Mosley, W. C., Rapid Heating Tensile Tests of High-Energy-Rate-Forged 316L Stainless Steel Charged with Hydrogen and Tritium, Presented at IMS-AIME 1989 Fall Meeting, Indianapolis, Indiana, October 1-5, 1989, DP-MS-89-9

2. Cunningham, J. W., Shogan, R. P., Jacko, R. J., and Wood, S., SRP Reactor Operability Assurance Program--Tensile Properties of Savannah River Materials, WSRP-005 (1987).

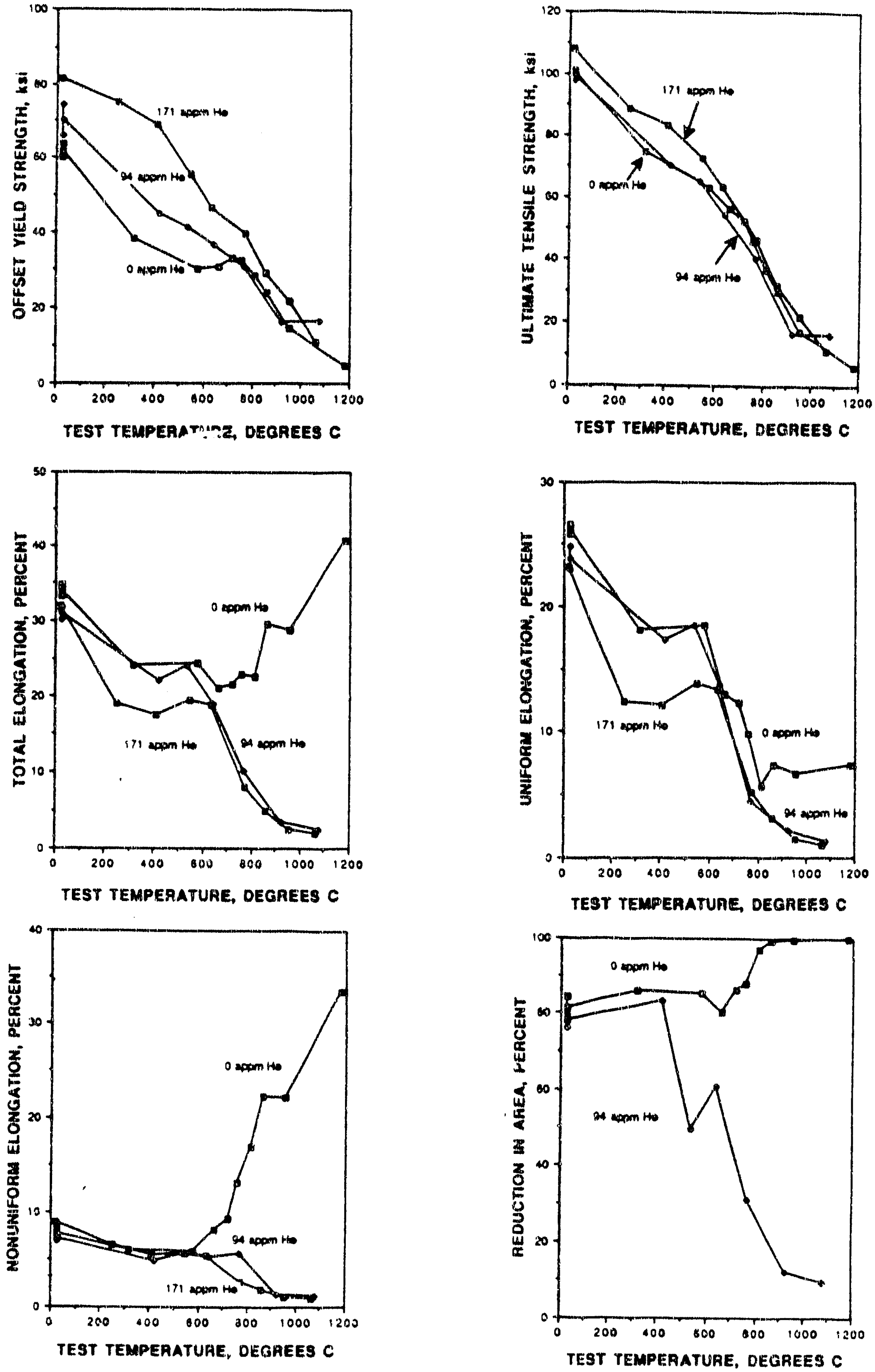
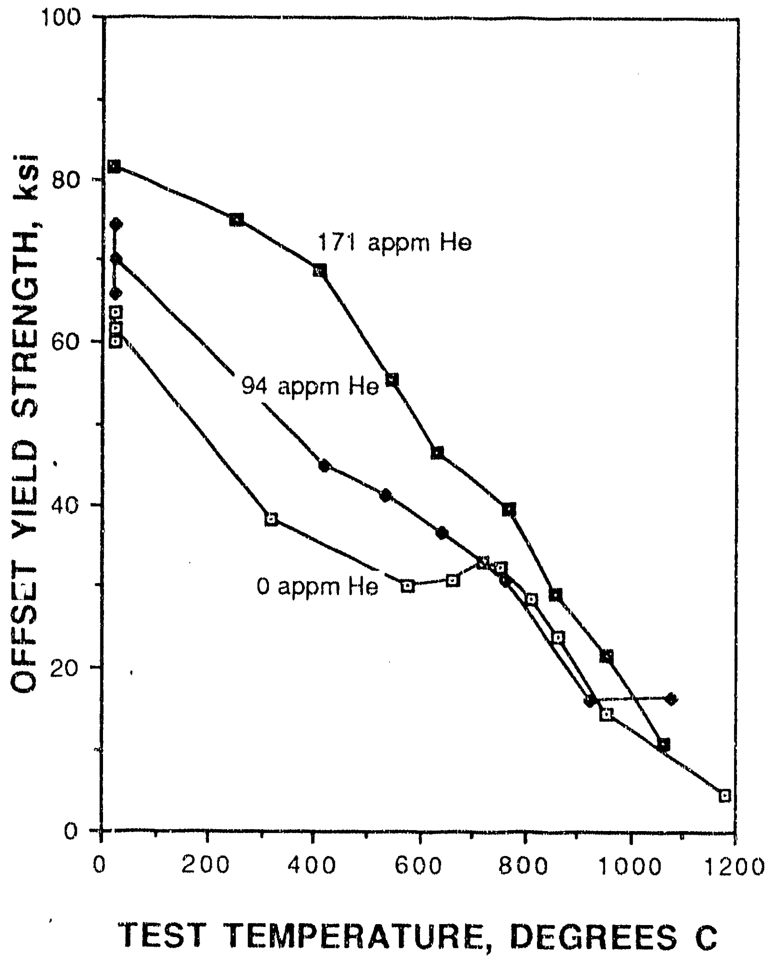
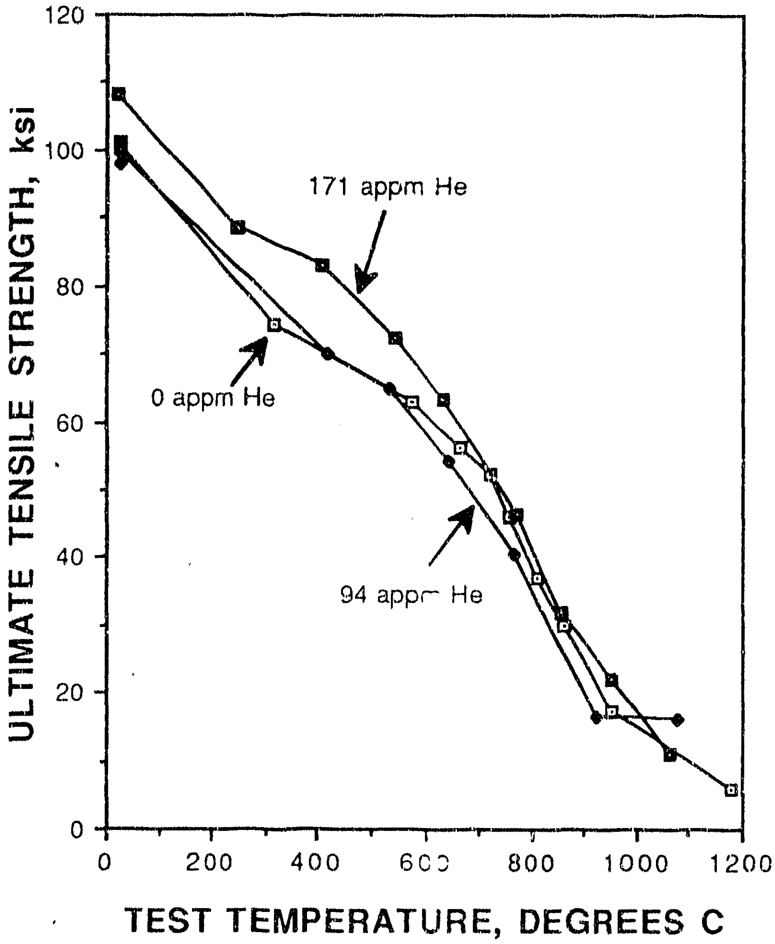


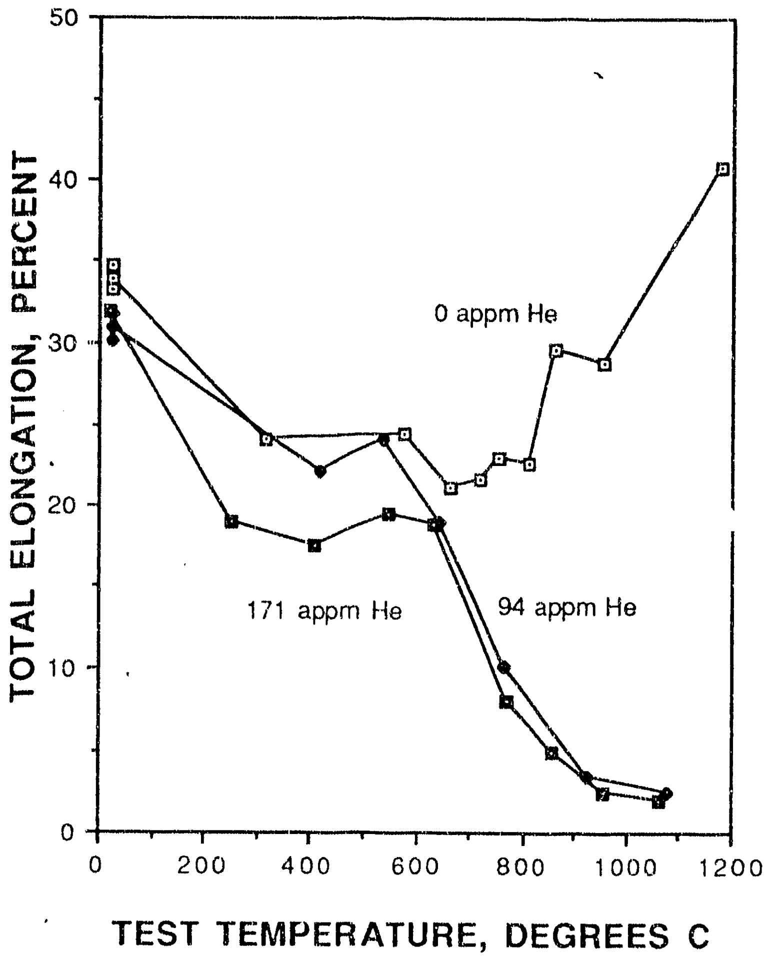
Fig. 1. Results of rapid heating tensile tests of HERF 316L stainless steel containing 0, 94 and 171 appm helium-3 from radioactive decay of absorbed tritium.



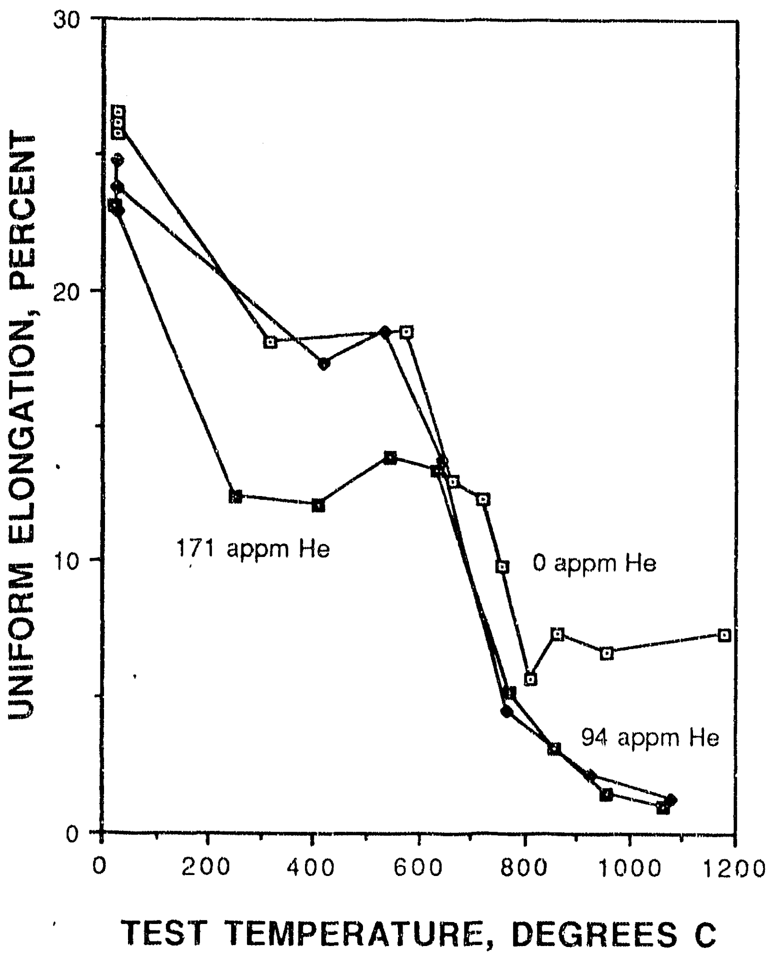
OFFSET YIELD STRENGTH, ksi
100
80
60
40
20
0
0
200
400
600
800
1000
1200
TEST TEMPERATURE, DEGREES C
171 appm He
94 appm He
0 appm He

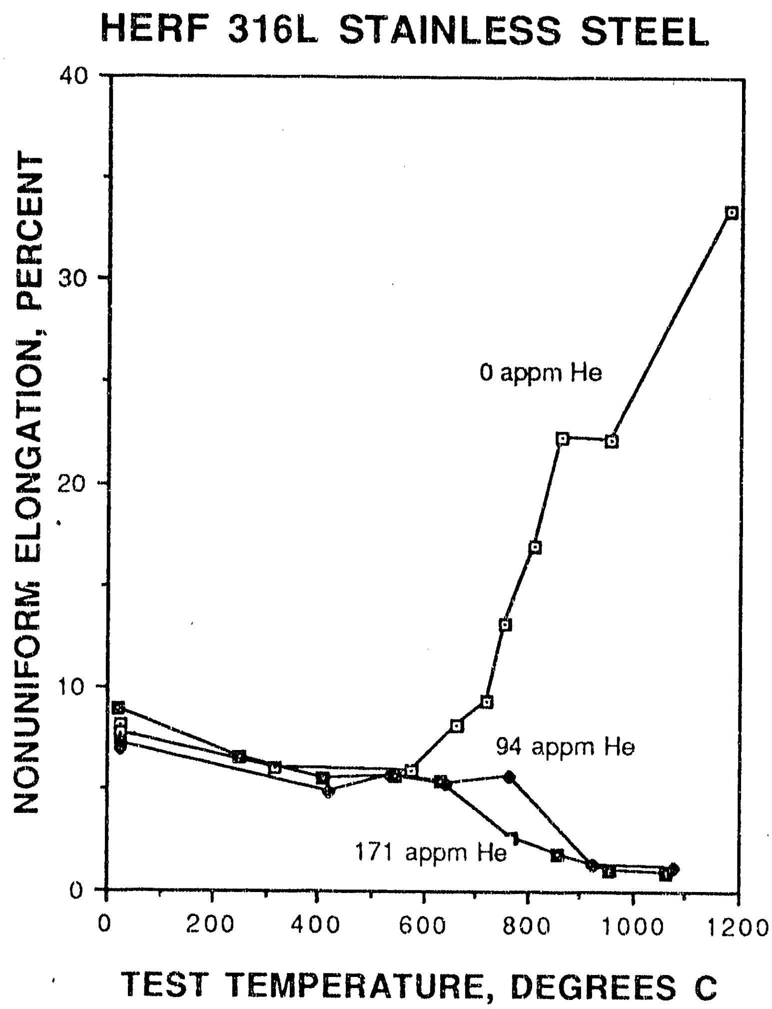


ULTIMATE TENSILE STRENGTH, ksi
120
100
80
60
40
20
0
0
200
400
800
1000
1200
TEST TEMPERATURE, DEGREES C
171 appm He
0 appm He
94 app He

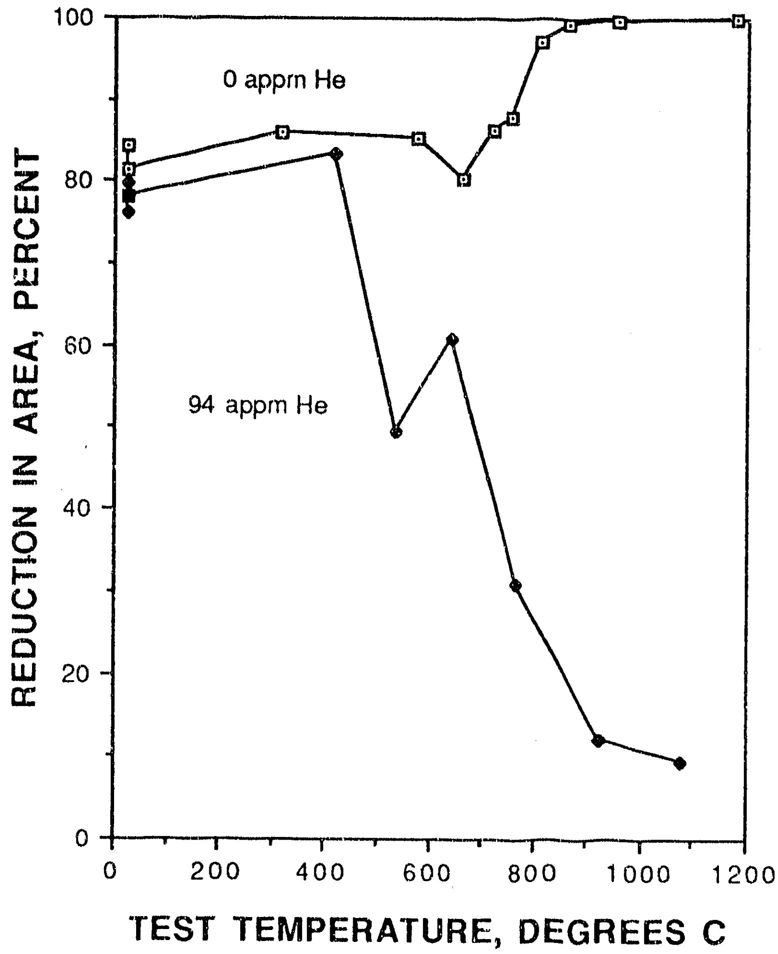


TOTAL ELONGATION, PERCENT
0
10
20
30
40
50
0
200
400
600
800
1000
1200
TEST TEMPERATURE, DEGREES C
0 appm He
171 appm He
94 appm He


30
20
10
0
UNIFORM ELONGATION, PERCENT
0
200
400
600
800
1000
1200
TEST TEMPERATURE, DEGREES C
171 appm He
0 appm He
94 appm He



HERF 316L STAINLESS STEEL
NONUNIFORM ELONGATION, PERCENT
0 appm He
94 appm He
171 appm He
0
10
20
30
40
0
200
400
600
800
1000
1200
TEST TEMPERATURE, DEGREES C



100
80
60
40
20
0
REDUCTION IN AREA, PERCENT
0 apprn He
94 appm He
0
200
400
600
800
1000
1200
TEST TEMPERATURE, DEGREES C

THE SIXTEENTH DOE COMPATIBILITY, AGING AND SERVICE LIFE CONFERENCE

FIRST CALL FOR PAPERS

MEETING LOCATION

The Sixteenth DOE Compatibility, Aging and Service Life Conference will be hosted by Lawrence Livermore National Laboratory on Tuesday, Wednesday and Thursday, April 24-26, 1990.

PURPOSE OF CONFERENCE

Reliability of a weapon system implies that no important chemical reactions or physical changes occur in its materials or components such that its performance during stockpile life is compromised. Acheiving this goal requires confident predictions of the effects of aging on the materials and assurances that important incompatibilities between the various materials do not exist. In light of the trend towards much longer service life for new weapons systems and service life extensions for older systems, aging and compatibility of materials becomes an even more important concern. The purpose of this Conference is to address these issues by bringing together experts from throughout the weapons complex.

EXAMPLE TOPICS

Given the goals of the Conference, there are many topics of potential interest and relevance to the weapons complex. Examples include

1. Material aging and compatibilty studies in environments of interest in weapons systems.
2. Metals compatibility- oxidation, hydriding and other reactions with weapons environments and materials.
3. New or novel analytical techniques applied or potentially applicable to aging and/or compatibility concerns.
4. Studies on new materials which may be useful in future weapons systems.
5. Compatibility considerations associated with studies on complete systems and how to address them.
6. SLT (Stockpile laboratory tests) evaluations- test philosophy, results and use of information.
7. Studies on the importance of processing variables, such as cleaning, handling and packaging.
8. Impact on compatibility and aging of new Environmental Safety and Health regulations.

Because of the increasing interest in stockpile refurbishment and modernization, it should be emphasized that presentations dealing with compatibility and aging problems on older systems are encouraged.

PAPER DETAILS

Short papers, submitted prior to the Conference, are required of anyone wishing to present work at the Sixteenth DOE Compatibility, Aging and Service Life Conference. It is important that these papers be as informative as possible. They must contain 500 words minimum of text and be a maximum of three pages in length, including any figures, tables and references. For uniformity of the Conference Proceedings, which will be based on photocopies of the submitted paper, a standardized paper format is required. Papers must be typed on 8 inch by 11 inch sheets using a one inch left margin (for binding ease) and a minimum of 3/4 inch for the other three margins. A single column format should be used, together with single spacing between lines and elite typeface. An example abstract will be provided in the second (and final) call for papers to be distributed in late 1989. The due date for receipt of papers at Sandia-Albuquerque will be February 23, 1990. Papers must be submitted through your representative (listed below). The Conference will have oral (20 or 30 minute) and poster sessions and authors will be requested to state a preference. Since the length of the meeting limits the number of oral presentation slots available, review of the submitted papers by the four laboratory representatives will be used to choose the papers accepted for oral presentation. All papers (classified and unclassified) will be bound into a Conference Proceedings which will be available at the Conference. In addition, copies of the unclassified papers will be given to all attendees at the beginning of the Conference.

REPRESENTATIVES

Bendix	Erich Grotheer
GEND	Bill Brown
Los Alamos	Gene Taylor
LLNL	Hy Golopol
Mound	Gary Miller
Pantex	Bob Spray
RFP	Jerry Stakebake
SNLA	Ken Gillen
SNLL	Duane Lindner
SRL	Mike Morgan 773A, C117
Y-12	Ron Keyser

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