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Ceramic Technology for Advanced Heat Engines Project Data Base: September 1988 Summary Report

B. L. P. Booker

CERAMIC TECHNOLOGY PROJECT • DOE/ORNL •

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CERAMIC TECHNOLOGY FOR ADVANCED HEAT ENGINES PROJECT DATA BASE: SEPTEMBER 1988 SUMMARY REPORT

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Oak Ridge National Laboratory
Oak Ridge, Tennessee

Date Published: March 1989

NOTICE: This document contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report.

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ABSTRACT

A large volume and wide variety of data on the behavior of advanced ceramic materials are currently being generated within the Ceramic Technology for Advanced Heat Engines project (CTAHE). This is the second in a series of reports summarizing the data stored in the microcomputer-based CTAHE data base . Each report features a different class of ceramics, with as much information on materials in that class as has then been processed. This report concentrates on zirconia-based ceramics.

INTRODUCTION

The purpose of the CTAHE data base is to provide the technical community access to the data generated under the CTAHE project. This document reports progress on developing the database and presents a selected sample of the type and format of the data presently in storage at Oak Ridge National Laboratory. The data discussed in this report are for zirconia-based ceramics.

Information in this report concentrates on zirconia-based ceramics, currently the largest material class represented in the data base. Some data on alumina-zirconia is also included. The only information repeated from the first summary report[1] is in the Weibull plots in Appendix II, Section 6.

Some material designations have been changed from those used previously[1] to achieve uniformity. We will now report materials by the manufacturers' designation. As a result, ceramics from the Army Materials Technology Laboratory have been renamed to conform with the manufacturers' designations. For example, the ceramic formerly reported as NGK LOCKE is now listed as Z-191; AC SPARKPLUG is now TZP-110; TOSHIBA is now TASZIC; KORANSHA KH is now 1986H, etc. While the suppliers and materials are the same, the information will be more traceable through the manufacturers' designations.

Current goals of this data base system are limited to data storage and retrieval and do not include extensive data manipulation. Data is stored as provided by the testing laboratories. If statistical treatment of the data is provided it will be included, but statistical analysis of unprocessed data will not be provided.

SYSTEM STATUS UPDATE

Since the publication of the previous summary[1], the Ceramic Technology for Advanced Heat Engines data base has been expanded to include additional types of test results and revisions of material characterization information. The system now accommodates results on fracture toughness tests, various types of fatigue tests, modulus of rupture (MOR) four point bend tests, shear stress tests, thermal expansion tests, tensile tests, X-ray diffraction studies, density and elasticity measurements under varying conditions, phase analyses, powder analyses, process and thermal histories, testing methods and apparati, chemical analyses, and microstructural details. Approximately 2500 test results are stored at present, covering 73 different ceramics.

The information currently being processed is provided by several different sources, rather than just from test results supplied directly by the testing laboratories. Most of the information is being taken from previous CTAHE project semiannual and bimonthly reports, as well as associated reports generated by the CTAHE project. The goal of the system is to make readily available as much of the data generated within the CTAHE project as facilities permit. This will include all details on the materials composition, processing history, characterization, test method and test results as provided by the suppliers and laboratories involved.

DATA SUMMARY

The data in this report covers 39 different ceramic materials, 33 of which are zirconia-based. Data was provided on magnetic media direct from the testing laboratory, extracted from the Army Materials Technology Laboratory report <u>Effect of Time and Temperature on Transformation Toughened Zirconias</u>[2] by Liselotte Schioler, and the Ceramic Technology for Advanced Heat Engines Program semiannual and bimonthly progress reports. Results of tensile, stress-rupture, MOR four point bend, fracture toughness, and welded joint shear stress tests have been organized into tables and are in Appendix II of this document. All the material characterization information provided in these sources was included, covering intrinsic properties at room temperature, phase analyses, chemical analyses, X-ray analyses, densities, and elasticities after various heat treatments, as well as material fabricator and fabricator codes, if known. This material characterization and background information can be found in Appendix I. This report does not include data published in the previous summary report, except the data used in the Weibull plot, but does include some of the materials characterization information for those data.

SYSTEM ACCESS

The purpose of the database is to provide a convenient, retrievable storage of the data generated by the CTAHE project. Since most of the engineering/design community has access to microcomputers, and the costs and problems associated with maintaining a data base on a microcomputer are much less than those associated with mainframes, the original system has been set up in Ashton-Tate's dBASE III+ framework on a Bernoulli 20 megabyte cartridge on an IBM PC/AT. All data files can be copied to floppy disks for other dBase III+ users, or converted to a variety of other formats, including flat character files, Lotus 1-2-3 files, Microsoft EXCEL (Apple Macintosh) files, and other formats as needed. There are no plans at present to upload the system to a mainframe accessible offsite. Local and remote users may request copies of the whole set of data files or just on specific parts (certain materials, or all MOR data, or all tensile data on zirconia-based ceramics, for example) to be sent to them on floppy disks in one of the formats listed previously.

Presently, the system consists of fifteen different files, each containing a specific type of information. This number of files will grow as other types of tests are added to the system. Linking the information in the different files together (for example, linking material characteristics records to cyclic fatigue data for a given material) can be confusing to the occasional user. To alleviate this problem, a user-friendly interface is being developed that will do the linking for the user. The interface will work within the dBASE III+ structure, so that users must have dBASE III+ for the interface to work. Once fully tested and documented, this interface will be available to all users. Estimated time of completion is December 1989, although a preliminary version might be be available earlier for user testing.

FUTURE SUMMARY REPORTS

The next summary report, scheduled for completion in March 1989, will feature test results and available material characterization information on silicon nitrides and silicon carbides, including whisker toughened materials. The fourth summary report, scheduled for September 1989, will feature alumina-based ceramics.

REFERENCES

1. M. K. Booker, Ceramic Technology for Advanced Heat Engines Program Data Base: A Summary Report. ORNL/M-462, Oak Ridge National Laboratory, Oak Ridge, Tennessee (April 1988).

2. L. J. Schioler, Effect of Time and Temperature on Transformation Toughened Zirconias. MTL 87-29. U. S. Army Materials Technology Laboratory, Watertown, Massachusetts (June 1987).

APPENDIX CONTENTS

APPENDIX I. MATERIAL CHARACTERIZATION AND BACKGROUND INFORMATION

SECTION 1. BACKGROUND AND GENERAL MATERIAL INFORMATION

CHARACTERISTICS OF MATERIALS TESTED BY
THE ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	MATERIAL CLASS	BATCH CODE	SUPPLIER	PROCESS	VINTAGE	MATRIX	STABILIZER	AS RECEIVED, ROOM TEMPERATURE PROPERTIES DENSITY g/cc	MOE GPa	MOR MPa	HARDNESS TEST	HARDNESS GPa	WEIBULL MODULUS
1985	ZIRCONIA TTZ	HIT1985/MTL	HITACHI	HOT-PRESSED	1985	ZrO2	2 mole% Y2O3	6.038	213	1169	Knoop	12.4	3.6
1986H	ZIRCONIA TTZ	KOR1986H/MTL	KORANSHA	HIPED	1986	ZrO2	3 mole% Y2O3	6.045	214	1261			8.8
1986S	ZIRCONIA TTZ	KOR1986S/MTL	KORANSHA	SINTERED	1985	ZrO2	3 mole% Y2O3	5.966	210	640	Knoop	10.8	9.5
AC-SENSOR	ZIRCONIA PSZ	AMTL-A/ACS82	AC SPARKPLUG		1982	ZrO2	Y2O3	5.670	213		Vickers	10.71	10.2
AFC-TTZ	ZIRCONIA TTZ	AMTL-K/AFCK	AMER. FELDMUEHLE		?	ZrO2	MgO	0.000	215				
CERAD-FSZ	ZIRCONIA FSZ	AMTL-F/CERAD82	CERADYNE	HOT PRESSED	1982	ZrO2	Y2O3	5.600	180				
COORS-TZP	ZIRCONIA TZP	AMTL-I/COORS84	COORS PORCELAIN		1984	ZrO2	Y2O3	5.940	211		Vickers	12.08	4.5
COORS-ZDM	ZIRCONIA TTZ	AMTL-G/COORS81	COORS PORCELAIN		1981	ZrO2	MgO	5.290	149				21.4
COORS-ZDM	ZIRCONIA TTZ	AMTL-H/COORS81	COORS PORCELAIN		1983	ZrO2	MgO	5.650	199		Vickers	8.99	4.2
COORS-ZDY	ZIRCONIA FSZ	AMTL-J/COORS81	COORS PORCELAIN		1981	ZrO2	Y2O3	5.530	189				16.0
CZ-203	ZIRCONIA TTZ	CERAM-CZ203/MTL	CERAMATEC	SINTERED	1987	ZrO2	12 mole% CeO2						
MS-TTZ	ZIRCONIA TTZ	AMTL-E/NILSEN82	NILSEN, USA		1982	ZrO2	MgO	5.650	208		Vickers	9.69	13.4
NGK-TZP	ZIRCONIA TZP	AMTL-M/NGKM	NGK SPARKPLUG		?	ZrO2	Y2O3	0.000	198		Vickers	12.82	
NGK-TZP	ZIRCONIA TZP	AMTL-N/NGKN	NGK SPARKPLUG		?	ZrO2	Y2O3	5.770	198		Vickers	11.42	13.5
NILSEN-TTZ	ZIRCONIA TTZ	AMTL-C/NILSENC	NILSEN, USA		?	ZrO2	MgO	0.000	227		Vickers	9.78	
NRL-TZP	ZIRCONIA TZP	AMTL-B/NRL82	NAVAL RESEARCH LAB.		1982	ZrO2	Y2O3	5.770	202		Vickers	10.93	
TASZIC	ZIRCONIA TTZ	TOSTASZIC/MTL	TOSHIBA CERAMICS	SINTERED	1985	ZrO2	2-3 mole% Y2O:	5.880	200	633	Knoop	10.1	6.2
TOR-TZPHP	ZIRCONIA TZP	AMTL-Q/TORAY83	TORAY CO.	HOT PRESSED	1983	ZrO2	Y2O3	5.950	215		Vickers	12.55	
TOR-TZPSIN	ZIRCONIA TZP	AMTL-R/TORAY83	TORAY CO.	SINTERED	1983	ZrO2	Y2O3	5.900	213		Vickers	11.34	
TOSH-TZP	ZIRCONIA TZP	AMTL-P/TOSHBA83	TOSHIBA CERAMICS		1983	ZrO2	Y2O3	5.930	209		Vickers	11.56	10.2
TS-TTZ	ZIRCONIA TTZ	AMTL-D/NILSEN82	NILSEN, USA		1982	ZrO2	MgO	5.660	227		Vickers	9.12	14.1
TZP-110	ZIRCONIA TZP	ACTZP110/MTL	AC SPARKPLUG	SINTERED	1985	ZrO2	2.6 mole% Y2O:	5.835	204	753	Knoop	11.1	12.2
Z-191	ZIRCONIA TZP	AMTL-O/NGK84	NGK SPARKPLUG		1984	ZrO2	Y2O3	5.770					13.5
Z-191	ZIRCONIA TZP	NGKZ191/MTL	NGK-LOCKE	SINTERED	1985	ZrO2	3 mole% Y2O3	5.869	208	873	Knoop	10.9	15.2
Z-201	ZIRCONIA TTZ	KYOZ201/MTL	KYOCERA	SINTERED	1985	ZrO2	2.8 mole% Y2O:	5.853	201	745	Knoop	10.5	8.8
Z-701	ZIRCONIZ TTZ	KYOZ701/MTL	KYOCERA	HIPED	1988	ZrO2	Y2O3						
ZIRCOA2120	ZIRCONIA TTZ	AMTL-S/CGW	CORNING GLASS WRKS		1982	ZrO2	MgO	5.580	194		Vickers	9.0	7.7
ZT-35	ZIRCONIA PSZ	AMTL-L/AFC82	AMER. FELDMUEHLE		1982	ZrO2	MgO	5.510	215		Vickers	9.32	5.9

CHARACTERISTICS OF MATERIALS TESTED BY
THE ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	MATERIAL CLASS	BATCH CODE	FABRICATOR	MATRIX	DENSITY g/cc	MOE GPa	HARDNESS TEST	HARDNESS 2Kg load, GPa	MOLE % CHROMIA IN ALUMINA *	MOLE% HAFNIA IN ZIRCONIA **
UM-ZTA1	ALUMINA ZTA	AMTL-U1/MTLLS	UNIV. OF MICHIGAN	Al2O3+ZrO2	4.330	363	Vickers	16.64	10	10
UM-ZTA2/HI	ALUMINA ZTA	AMTL-U2H/MTLLS	UNIV. OF MICHIGAN	Al2O3+ZrO2	4.370	351	Vickers	15.97	10	20
UM-ZTA2/ME	ALUMINA ZTA	AMTL-U2M/MTLLS	UNIV. OF MICHIGAN	Al2O3+ZrO2	4.370	-	Vickers	-	10	20
UM-ZTA2/LO	ALUMINA ZTA	AMTL-U2L/MTLLS	UNIV. OF MICHIGAN	Al2O3+ZrO2	4.370	241	Vickers	spalled	10	20
UM-ZTA3/HI	ALUMINA ZTA	AMTL-U3H/MTLLS	UNIV. OF MICHIGAN	Al2O3+ZrO2	4.400	352		spalled	20	10
UM-ZTA3/LO	ALUMINA ZTA	AMTL-U3L/MTLLS	UNIV. OF MICHIGAN	Al2O3+ZrO2	4.400	248		-	20	10
UM-ZTA4	ALUMINA ZTA	AMTL-U4/MTLLS	UNIV. OF MICHIGAN	Al2O3+ZrO2	4.300	361	Vickers	15.95	20	20
UM-ZTM5	ALUMINA-ZTM	AMTL-U5/MTLLS	UNIV. OF MICHIGAN	Al2O3+ZrO2	3.390	182	Vickers	9.15		
UM-ZTM6	ALUMINA ZTM	AMTL-U6/MTLLS	UNIV. OF MICHIGAN	Al2O3+ZrO2	3.420	169	Vickers	6.26		

* Chromia was added to alumina to reduce thermal conductivity.
** Hafnia was added to zirconia to increase stable transformation temperature

MATERIAL CHARACTERISTIC INFORMATION FOR ZIRCONIA AND ALUMINA-BASED CERAMICS TESTED BY
THE UNIVERSITY OF DAYTON RESEARCH INSTITUTE
TEST DATA REPORTED IN PREVIOUS SUMMARY REPORT (REF. 1)

MATERIAL	MATERIAL CLASS	SUPPLIER	PROCESS	MATRIX	STABILIZER	DENSITY (g/cc)	VICKER'S HARDNESS (kg/mm^2)	THERMAL EXPANSION COEFFICIENT (x10e-6/ C)	KIC MICRO-INDENT (MPa m^.5)
MS-PSZ	ZIRCONIA PSZ	NILCRA CERAMIC		ZrO2	3wt%MgO	5.69	1099	10.3	7.6
PSZ-Z201	ZIRCONIA PSZ	KYOCERA	Sintered	ZrO2	5.4wt%Y2O3	5.90	1282	11.0	8.8
TS-PSZ	ZIRCONIA PSZ	NILCRA CERAMIC		ZrO2	3wt%MgO	5.78	1025	9.5	6.0
Z191	ZIRCONIA TZP	NGK-LOCKE	Sintered	ZrO2	5wt% Y2O3	5.90	1292	10.1	7.4
CTZP	ZIRCONIA TZP	CERAMATEC		ZrO2	CeO2 + Al2O3	5.70	1099	10.3	7.0
YTZP-XS241	ZIRCONIA TZP	CERAMATEC		ZrO2	5wt% Y2O3	5.56	1120	9.9	6.6
DTA-AZ301	ALUMINA ZTA	KYOCERA		Al2O3 w/19%ZrO2		4.20	1939	8.4	11.1
ZTA-XS121	ALUMINA ZTA	CERAMATEC		Al2O3 w/ZrO2		4.40	1172	9.4	6.9

SECTION 2. CHEMICAL ANALYSES

CHEMISTRIES OF MATERIALS IN AS RECEIVED STATE
TESTED BY THE ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	BATCH CODE	Weight % Al	Ca	Cr	Fe	Mg	Si	Ti	Y	Zr	Zn
AC-SENSOR	AMTL-A/ACS82	1.83	0.00	0.02	0.06	0.00	0.02	0.05	6.10	0.00	0.06
NRL-TZP	AMTL-B/NRL82	0.10	0.05	0.00	0.07	0.02	0.05	0.07	6.50	0.00	-
NILSEN-TTZ	AMTL-C/NILSENC	0.15	0.01	0.00	0.00	1.88	0.00	0.07	0.05	0.00	0.04
TS-TTZ	AMTL-D/NILSEN82	0.03	0.00	0.00	0.04	1.98	0.00	0.08	0.04	0.00	0.08
MS-TTZ	AMTL-E/NILSEN82	0.10	0.04	0.00	0.08	1.94	0.05	0.13	0.00	0.00	-
CERAD-FSZ	AMTL-F/CERAD82	0.01	0.00	0.01	0.02	0.01	0.00	0.08	11.10	0.00	0.03
COORS-ZDM	AMTL-G/COORS81	0.11	0.07	0.03	0.01	1.48	0.06	0.04	0.08	0.00	0.04
COORS-ZDM	AMTL-H/COORS81	0.05	0.00	0.00	0.00	1.71	0.00	0.04	0.01	0.00	0.00
COORS-TZP	AMTL-I/COORS84	0.68	0.00	0.02	0.03	0.01	0.09	0.08	4.20	0.00	-
COORS-ZDY	AMTL-J/COORS81	0.36	0.68	0.01	0.02	0.03	0.43	0.05	7.10	0.00	0.02
AFC-TTZ	AMTL-K/AFCK	0.09	0.02	0.02	0.01	2.29	0.02	0.04	0.03	0.00	0.02
ZT-35	AMTL-L/AFC82	0.03	0.02	0.00	0.00	2.09	0.00	0.04	0.03	0.00	0.01
NGK-TZP	AMTL-M/NGKM	0.54	0.03	0.08	0.01	0.01	0.72	0.09	6.70	0.00	0.03
NGK-TZP	AMTL-N/NGKN	0.54	0.03	0.01	0.01	0.01	0.72	0.09	6.70	0.00	0.03
Z-191	AMTL-O/NGK84	0.43	0.00	0.01	0.16	0.01	0.52	0.03	4.00	0.00	0.17
TOSH-TZP	AMTL-P/TOSHBA83	0.10	0.00	0.00	0.10	0.01	0.17	0.04	3.50	0.00	-
TOR-TZPHP	AMTL-Q/TORAY83	0.52	0.00	0.00	0.08	0.01	0.00	0.01	3.50	0.00	-
TOR-TZPSIN	AMTL-R/TORAY83	0.66	0.03	0.00	0.08	0.02	0.08	0.01	3.80	0.00	-
ZIRCOA2120	AMTL-S/CGW	0.06	0.13	0.02	0.07	1.65	0.01	0.03	0.36	0.00	0.54
UM-ZTA1	AMTL-U1/MTLLS	38.00	0.05	7.50	0.15	0.02	0.13	0.09	0.03	6.90	-
UM-ZTA2	AMTL-U2/MTLLS	34.20	0.04	14.30	0.05	0.01	0.11	0.01	0.00	7.40	-
UM-ZTA3	AMTL-U3/MTLLS	35.90	0.02	14.90	0.01	0.01	0.11	0.01	0.00	7.90	-
UM-ZTA4	AMTL-U4/MTLLS	40.30	0.02	7.80	0.06	0.02	0.11	0.01	0.00	7.90	-
UM-ZTM5	AMTL-U5/MTLLS	26.20	0.03	0.00	0.01	0.01	10.10	0.01	0.00	14.20	-
UM-ZTM6	AMTL-U6/MTLLS	22.20	0.00	5.00	0.16	0.01	10.30	0.01	0.00	13.80	-

SECTION 3. MICROSTRUCTURAL AND PHASE ANALYSES

PART 3A. Microstructure information

MICROSTRUCTURAL INFORMATION* ON ZIRCONIA AND ALUMINA-BASED CERAMICS
TESTED BY THE UNIVERSITY OF DAYTON RESEARCH INSTITUTE
FOR DATA REPORTED IN THE PREVIOUS SUMMARY (REF. 1)

MATERIAL	MICROSTRUCTURE
CTZP	Fine grained multiphase material (1 to 4 microns). Uniform distribution of pores.
DTA-AZ301	Dense two phase material with grains about .3 to 2. microns.
MS-PSZ	Porous coarse grained (30-60 microns) material.
PSZ-Z201	Dense fine grained material (0.2 to 0.5 microns, average about .3 microns).
TS-PSZ	Porous coarse grained (30-60 microns) material.
YTZP-XS241	Fine grained multiphase material (2 to 4 microns). Uniform distribution of pores, 0.5 to 4 microns.
Z191	Dense fine grained material (0.2 to 0.4 microns)
ZTA-XS121	Fine grained multiphase material (0.5 to 2.5 microns, avg. 1.5 microns). Uniform distribution of pores, 0.2 to 2 microns.

MATERIAL	CRYSTAL STRUCTURE
CTZP	1% monoclinic phase in as received state.
ZTA-XS121	30% monoclinic phase in as received state.
YTZP-XS241	11% monoclinic phase in as received state.
PSZ-Z201	3% monoclinic phase in as received state.
Z191	7% monoclinic phase in as received state.
MS-PSZ	23% monoclinic phase in as received state
TS-PSZ	33% monoclinic phase in as received state
DTA-AZ301	28% monoclinic phase in as received state

* See reference 8 for the source of this information.

PART 3B. Phase analyses

PHASE ANALYSES OF VARIOUS MATERIALS
TESTED BY THE ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	BATCH CODE	PHASE	HEAT TREATMENT	MATRIX	QUANTITY vol%	ANALYTICAL METHOD
1985	HIT1985/MTL	MONOCLINIC	100h@1000C	ZrO2	2.42	X-RAY DIFF
1985	HIT1985/MTL	TETRAGONAL+CUBIC	100h@1000C	ZrO2	97.58	X-RAY DIFF
1985	HIT1985/MTL	MONOCLINIC	500h@1000C	ZrO2	20.06	X-RAY DIFF
1985	HIT1985/MTL	TETRAGONAL+CUBIC	500h@1000C	ZrO2	79.94	X-RAY DIFF
1985	HIT1985/MTL	MONOCLINIC	AS RECEIVED	ZrO2	10.51	X-RAY DIFF
1985	HIT1985/MTL	TETRAGONAL+CUBIC	AS RECEIVED	ZrO2	89.49	X-RAY DIFF
1986H	KOR1986H/MTL	TETRAGONAL+CUBIC	100h@1000C	ZrO2	100.00	X-RAY DIFF
1986H	KOR1986H/MTL	MONOCLINIC	500h@1000C	ZrO2	91.82	X-RAY DIFF
1986H	KOR1986H/MTL	TETRAGONAL+CUBIC	500h@1000C	ZrO2	8.18	X-RAY DIFF
1986H	KOR1986H/MTL	MONOCLINIC	AS RECEIVED	ZrO2	13.47	X-RAY DIFF
1986H	KOR1986H/MTL	TETRAGONAL+CUBIC	AS RECEIVED	ZrO2	86.53	X-RAY DIFF
1986S	KOR1986S/MTL	TETRAGONAL+CUBIC	100h@1000C	ZrO2	100.00	X-RAY DIFF
1986S	KOR1986S/MTL	MONOCLINIC	500h@1000C	ZrO2	34.70	X-RAY DIFF
1986S	KOR1986S/MTL	TETRAGONAL+CUBIC	500h@1000C	ZrO2	65.30	X-RAY DIFF
1986S	KOR1986S/MTL	MONOCLINIC	AS RECEIVED	ZrO2	9.48	X-RAY DIFF
1986S	KOR1986S/MTL	TETRAGONAL+CUBIC	AS RECEIVED	ZrO2	90.52	X-RAY DIFF
AC-SENSOR	AMTL-A/ACS82	MONOCLINIC	100h@1000C	ZrO2	34.00	X-RAY DIFF
AC-SENSOR	AMTL-A/ACS82	MONOCLINIC	500h@1000C	ZrO2	29.00	X-RAY DIFF
AC-SENSOR	AMTL-A/ACS82	MONOCLINIC	AS RECEIVED	ZrO2	35.20	X-RAY DIFF
NRL-TZP	AMTL-B/NRL82	MONOCLINIC	100h@1000C	ZrO2	0.00	X-RAY DIFF
NRL-TZP	AMTL-B/NRL82	MONOCLINIC	500h@1000C	ZrO2	0.00	X-RAY DIFF
NRL-TZP	AMTL-B/NRL82	MONOCLINIC	AS RECEIVED	ZrO2	0.00	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	100h@1000C	ZrO2	56.70	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	100h@1100C	ZrO2	72.50	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	100h@1200C	ZrO2	100.00	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	100h@1300C	ZrO2	100.00	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	100h@900C	ZrO2	20.70	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	250h@1000C	ZrO2	61.40	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	250h@1100C	ZrO2	93.10	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	250h@1200C	ZrO2	96.50	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	250h@1300C	ZrO2	99.20	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	250h@900C	ZrO2	34.10	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	500h@1000C	ZrO2	71.50	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	500h@1100C	ZrO2	100.00	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	500h@1200C	ZrO2	100.00	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	500h@1300C	ZrO2	100.00	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	500h@900C	ZrO2	32.10	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	50h@1000C	ZrO2	38.70	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	50h@1100C	ZrO2	59.50	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	50h@1200C	ZrO2	82.80	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	50h@1300C	ZrO2	97.80	X-RAY DIFF
NILSEN-TTZ	AMTL-C/NILSENC	MONOCLINIC	50h@900C	ZrO2	34.20	X-RAY DIFF
TS-TTZ	AMTL-D/NILSEN82	MONOCLINIC	100h@1000C	ZrO2	57.70	X-RAY DIFF
TS-TTZ	AMTL-D/NILSEN82	MONOCLINIC	500h@1000C	ZrO2	80.40	X-RAY DIFF
TS-TTZ	AMTL-D/NILSEN82	MONOCLINIC	AS RECEIVED	ZrO2	27.70	X-RAY DIFF
MS-TTZ	AMTL-E/NILSEN82	MONOCLINIC	100h@1000C	ZrO2	34.80	X-RAY DIFF
MS-TTZ	AMTL-E/NILSEN82	MONOCLINIC	500h@1000C	ZrO2	79.10	X-RAY DIFF
MS-TTZ	AMTL-E/NILSEN82	MONOCLINIC	AS RECEIVED	ZrO2	23.90	X-RAY DIFF

PHASE ANALYSES OF VARIOUS MATERIALS
TESTED BY THE ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	BATCH CODE	PHASE	HEAT TREATMENT	MATRIX	QUANTITY vol%	ANALYTICAL METHOD
CERAD-FSZ	AMTL-F/CERAD82	MONOCLINIC	AS RECEIVED	ZrO2	0.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	100h@1000C	ZrO2	96.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	100h@1100C	ZrO2	100.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	100h@1200C	ZrO2	100.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	100h@1300C	ZrO2	100.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	100h@900C	ZrO2	83.60	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	250h@1000C	ZrO2	100.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	250h@1100C	ZrO2	100.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	250h@1200C	ZrO2	97.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	250h@1300C	ZrO2	100.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	250h@900C	ZrO2	92.20	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	500h@1000C	ZrO2	100.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	500h@1100C	ZrO2	100.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	500h@1200C	ZrO2	100.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	500h@1300C	ZrO2	100.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	500h@900C	ZrO2	99.70	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	50h@1000C	ZrO2	100.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	50h@1100C	ZrO2	100.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	50h@1200C	ZrO2	100.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	50h@1300C	ZrO2	100.00	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	50h@900C	ZrO2	77.30	X-RAY DIFF
COORS-ZDM	AMTL-G/COORS81	MONOCLINIC	AS RECEIVED	ZrO2	66.20	X-RAY DIFF
COORS-ZDM	AMTL-H/COORS81	MONOCLINIC	100h@1000C	ZrO2	62.30	X-RAY DIFF
COORS-ZDM	AMTL-H/COORS81	MONOCLINIC	500h@1000C	ZrO2	93.20	X-RAY DIFF
COORS-ZDM	AMTL-H/COORS81	MONOCLINIC	AS RECEIVED	ZrO2	14.00	X-RAY DIFF
COORS-TZP	AMTL-I/COORS84	MONOCLINIC	100h@1000C	ZrO2	0.00	X-RAY DIFF
COORS-TZP	AMTL-I/COORS84	MONOCLINIC	500h@1000C	ZrO2	0.00	X-RAY DIFF
COORS-TZP	AMTL-I/COORS84	MONOCLINIC	AS RECEIVED	ZrO2	0.00	X-RAY DIFF
COORS-ZDY	AMTL-J/COORS81	MONOCLINIC	AS RECEIVED	ZrO2	0.00	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	100h@1000C	ZrO2	35.10	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	100h@1100C	ZrO2	79.40	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	100h@1200C	ZrO2	99.40	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	100h@1300C	ZrO2	98.40	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	100h@900C	ZrO2	15.30	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	250h@1000C	ZrO2	50.90	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	250h@1100C	ZrO2	100.00	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	250h@1200C	ZrO2	99.40	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	250h@1300C	ZrO2	98.80	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	250h@900C	ZrO2	6.00	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	500h@1000C	ZrO2	91.50	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	500h@1100C	ZrO2	100.00	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	500h@1200C	ZrO2	99.20	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	500h@1300C	ZrO2	99.30	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	500h@900C	ZrO2	19.40	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	50h@1000C	ZrO2	15.60	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	50h@1100C	ZrO2	63.90	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	50h@1200C	ZrO2	64.10	X-RAY DIFF

PHASE ANALYSES OF VARIOUS MATERIALS
TESTED BY THE ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	BATCH CODE	PHASE	HEAT TREATMENT	MATRIX	QUANTITY vol%	ANALYTICAL METHOD
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	50h@1300C	ZrO2	75.70	X-RAY DIFF
AFC-TTZ	AMTL-K/AFCK	MONOCLINIC	50h@900C	ZrO2	15.20	X-RAY DIFF
ZT-35	AMTL-L/AFC82	MONOCLINIC	100h@1000C	ZrO2	14.70	X-RAY DIFF
ZT-35	AMTL-L/AFC82	MONOCLINIC	500h@1000C	ZrO2	70.30	X-RAY DIFF
ZT-35	AMTL-L/AFC82	MONOCLINIC	AS RECEIVED	ZrO2	6.40	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	100h@1000C	ZrO2	9.80	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	100h@1100C	ZrO2	1.40	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	100h@1200C	ZrO2	21.30	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	100h@1300C	ZrO2	34.40	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	100h@900C	ZrO2	16.00	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	250h@1000C	ZrO2	5.30	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	250h@1100C	ZrO2	11.10	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	250h@1200C	ZrO2	34.80	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	250h@1300C	ZrO2	37.50	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	250h@900C	ZrO2	9.30	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	500h@1000C	ZrO2	1.00	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	500h@1100C	ZrO2	24.10	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	500h@1200C	ZrO2	39.20	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	500h@1300C	ZrO2	47.00	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	500h@900C	ZrO2	3.20	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	50h@1000C	ZrO2	3.40	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	50h@1100C	ZrO2	4.00	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	50h@1200C	ZrO2	17.80	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	50h@1300C	ZrO2	34.00	X-RAY DIFF
NGK-TZP	AMTL-M/NGKM	MONOCLINIC	50h@900C	ZrO2	5.00	X-RAY DIFF
NGK-TZP	AMTL-N/NGKN	MONOCLINIC	AS RECEIVED	ZrO2	7.00	X-RAY DIFF
Z-191	AMTL-O/NGK84	MONOCLINIC	500h@1000C	ZrO2	0.00	X-RAY DIFF
TOSH-TZP	AMTL-P/TOSHBA83	MONOCLINIC	100h@1000C	ZrO2	0.00	X-RAY DIFF
TOSH-TZP	AMTL-P/TOSHBA83	MONOCLINIC	500h@1000C	ZrO2	0.00	X-RAY DIFF
TOSH-TZP	AMTL-P/TOSHBA83	MONOCLINIC	AS RECEIVED	ZrO2	0.00	X-RAY DIFF
TOR-TZPHP	AMTL-Q/TORAY83	MONOCLINIC	100h@1000C	ZrO2	0.00	X-RAY DIFF
TOR-TZPHP	AMTL-Q/TORAY83	MONOCLINIC	500h@1000C	ZrO2	0.00	X-RAY DIFF
TOR-TZPHP	AMTL-Q/TORAY83	MONOCLINIC	AS RECEIVED	ZrO2	0.00	X-RAY DIFF
TOR-TZPSIN	AMTL-R/TORAY83	MONOCLINIC	500h@1000C	ZrO2	61.10	X-RAY DIFF
TOR-TZPSIN	AMTL-R/TORAY83	MONOCLINIC	AS RECEIVED	ZrO2	3.80	X-RAY DIFF
ZIRCOA2120	AMTL-S/CGW	MONOCLINIC	100h@1000C	ZrO2	69.60	X-RAY DIFF
ZIRCOA2120	AMTL-S/CGW	MONOCLINIC	500h@1000C	ZrO2	76.00	X-RAY DIFF
ZIRCOA2120	AMTL-S/CGW	MONOCLINIC	AS RECEIVED	ZrO2	35.90	X-RAY DIFF
TASZIC	TOSTASZIC/MTL	MONOCLINIC	100h@1000C	ZrO2	26.66	X-RAY DIFF
TASZIC	TOSTASZIC/MTL	TETRAGONAL+CUBIC	100h@1000C	ZrO2	73.34	X-RAY DIFF
TASZIC	TOSTASZIC/MTL	MONOCLINIC	500h@1000C	ZrO2	44.05	X-RAY DIFF
TASZIC	TOSTASZIC/MTL	TETRAGONAL+CUBIC	500h@1000C	ZrO2	55.95	X-RAY DIFF
TASZIC	TOSTASZIC/MTL	MONOCLINIC	AS RECEIVED	ZrO2	32.35	X-RAY DIFF
TASZIC	TOSTASZIC/MTL	TETRAGONAL+CUBIC	AS RECEIVED	ZrO2	67.65	X-RAY DIFF
TZP-110	ACTZP110/MTL	MONOCLINIC	100h@1000C	ZrO2	38.26	X-RAY DIFF
TZP-110	ACTZP110/MTL	TETRAGONAL+CUBIC	100h@1000C	ZrO2	61.74	X-RAY DIFF
TZP-110	ACTZP110/MTL	MONOCLINIC	500h@1000C	ZrO2	29.36	X-RAY DIFF
TZP-110	ACTZP110/MTL	TETRAGONAL+CUBIC	500h@1000C	ZrO2	70.64	X-RAY DIFF

PHASE ANALYSES OF VARIOUS MATERIALS
TESTED BY THE ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	BATCH CODE	PHASE	HEAT TREATMENT	MATRIX	QUANTITY vol%	ANALYTICAL METHOD
TZP-110	ACTZP110/MTL	MONOCLINIC	AS RECEIVED	ZrO2	29.95	X-RAY DIFF
TZP-110	ACTZP110/MTL	TETRAGONAL+CUBIC	AS RECEIVED	ZrO2	70.05	X-RAY DIFF
Z-191	NGKZ191/MTL	MONOCLINIC	100h@1000C	ZrO2	10.66	X-RAY DIFF
Z-191	NGKZ191/MTL	MONOCLINIC	500h@1000C	ZrO2	21.26	X-RAY DIFF
Z-191	NGKZ191/MTL	MONOCLINIC	AS RECEIVED	ZrO2	31.17	X-RAY DIFF
Z-191	NGKZ191/MTL	TETRAGONAL+CUBIC	AS RECEIVED	ZrO2	68.83	X-RAY DIFF
Z-201	KYOZ201/MTL	MONOCLINIC	100h@1000C	ZrO2	65.77	X-RAY DIFF
Z-201	KYOZ201/MTL	MONOCLINIC	100h@1000C	ZrO2	55.03*	X-RAY DIFF
Z-201	KYOZ201/MTL	TETRAGONAL+CUBIC	100h@1000C	ZrO2	44.97*	X-RAY DIFF
Z-201	KYOZ201/MTL	TETRAGONAL+CUBIC	100h@1000C	ZrO2	34.23	X-RAY DIFF
Z-201	KYOZ201/MTL	MONOCLINIC	500h@1000C	ZrO2	65.44	X-RAY DIFF
Z-201	KYOZ201/MTL	MONOCLINIC	500h@1000C	ZrO2	68.58*	X-RAY DIFF
Z-201	KYOZ201/MTL	TETRAGONAL+CUBIC	500h@1000C	ZrO2	34.56	X-RAY DIFF
Z-201	KYOZ201/MTL	TETRAGONAL+CUBIC	500h@1000C	ZrO2	31.42*	X-RAY DIFF
Z-201	KYOZ201/MTL	MONOCLINIC	AS RECEIVED	ZrO2	24.50	X-RAY DIFF
Z-201	KYOZ201/MTL	TETRAGONAL+CUBIC	AS RECEIVED	ZrO2	75.50	X-RAY DIFF

* These values are from a second set of specimens.

PART 3C. X-Ray diffraction data

X-RAY DIFFRACTION ANALYSIS FOR VARIOUS ZIRCONIA MATERIALS
DATA FROM THE ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	SPECIMEN NUMBER	HEAT TREATMENT	2 THETA (degrees)	D SPACE (Angstroms)	INTEGRATED INTENSITY	PHASE	WAVE-LENGTH
1985	HIT-41	100h@1000C	28.11	3.172	239.60	MONOCLINIC	1.5418
1985	HIT-41	100h@1000C	28.30	3.151	381.15	MONOCLINIC	1.5418
1985	HIT-41	100h@1000C	30.18	2.959	56112.89	TETRAGONAL+CUBIC	1.5418
1985	HIT-41	100h@1000C	30.97	2.885	365.72	TETRAGONAL+CUBIC	1.5418
1985	HIT-41	100h@1000C	31.28	2.857	197.36	MONOCLINIC	1.5418
1985	HIT-6	500h@1000C	28.29	3.153	6144.10	MONOCLINIC	1.5418
1985	HIT-6	500h@1000C	30.30	2.947	60322.21	TETRAGONAL+CUBIC	1.5418
1985	HIT-6	500h@1000C	31.19	2.865	1427.84	MONOCLINIC	1.5418
1985	HIT-6	500h@1000C	31.63	2.827	1011.94	MONOCLINIC	1.5418
1985	HIT-6	500h@1000C	31.89	2.804	269.47	MONOCLINIC	1.5418
1985	HIT-72	AS RECEIVED	29.39	3.141	1161.85	MONOCLINIC	1.5418
1985	HIT-72	AS RECEIVED	30.26	2.951	23828.37	TETRAGONAL+CUBIC	1.5418
1985	HIT-72	AS RECEIVED	31.20	2.864	286.80	MONOCLINIC	1.5418
1985	HIT-72	AS RECEIVED	31.86	2.806	187.17	MONOCLINIC	1.5418
1986H	KH-1	500h@1000C	28.35	3.148	80.56	MONOCLINIC	1.5418
1986H	KH-1	500h@1000C	30.40	2.940	1547.36	TETRAGONAL+CUBIC	1.5418
1986H	KH-40	100h@1000C	30.50	2.941	1649.13	TETRAGONAL+CUBIC	1.5418
1986H	KH-75	AS RECEIVED	28.42	3.140	80.93	MONOCLINIC	1.5418
1986H	KH-75	AS RECEIVED	30.34	2.946	889.49	TETRAGONAL+CUBIC	1.5418
1986S	KS-13	500h@1000C	28.20	3.162	4107.89	MONOCLINIC	1.5418
1986S	KS-13	500h@1000C	30.24	2.953	116633.88	TETRAGONAL+CUBIC	1.5418
1986S	KS-13	500h@1000C	31.46	2.841	1060.31	MONOCLINIC	1.5418
1986S	KS-41	100h@1000C	30.27	2.951	25112.48	TETRAGONAL+CUBIC	1.5418
1986S	KS-72	AS RECEIVED	28.46	3.134	1468.56	MONOCLINIC	1.5418
1986S	KS-72	AS RECEIVED	30.35	2.943	23969.66	TETRAGONAL+CUBIC	1.5418
TASZIC	TOSH-41	100h@1000C	28.31	3.150	3698.74	MONOCLINIC	1.5418
TASZIC	TOSH-41	100h@1000C	30.28	2.949	21543.85	TETRAGONAL+CUBIC	1.5418
TASZIC	TOSH-41	100h@1000C	31.45	2.842	880.93	MONOCLINIC	1.5418
TASZIC	TOSH-6	500h@1000C	28.13	3.169	14259.39	MONOCLINIC	1.5418
TASZIC	TOSH-6	500h@1000C	30.12	2.965	37547.78	TETRAGONAL+CUBIC	1.5418
TASZIC	TOSH-6	500h@1000C	31.25	2.965	3024.12	MONOCLINIC	1.5418
TASZIC	TOSH-76	AS RECEIVED	28.26	3.155	4809.69	MONOCLINIC	1.5418
TASZIC	TOSH-76	AS RECEIVED	30.17	2.960	21366.10	TETRAGONAL+CUBIC	1.5418

X-RAY DIFFRACTION ANALYSIS FOR VARIOUS ZIRCONIA MATERIALS
DATA FROM THE ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	SPECIMEN NUMBER	HEAT TREATMENT	2 THETA (degrees)	D SPACE (Angstroms)	INTEGRATED INTENSITY	PHASE	WAVE-LENGTH
TASZIC	TOSH-76	AS RECEIVED	31.26	2.859	1164.17	MONOCLINIC	1.5418
TZP-110	AC-13	500h@1000C	28.13	3.170	2811.32	MONOCLINIC	1.5418
TZP-110	AC-13	500h@1000C	30.13	2.964	11569.08	TETRAGONAL+CUBIC	1.5418
TZP-110	AC-38	100h@1000C	28.13	3.169	3313.53	MONOCLINIC	1.5418
TZP-110	AC-38	100h@1000C	30.11	2.965	10938.41	TETRAGONAL+CUBIC	1.5418
TZP-110	AC-38	100h@1000C	30.79	2.902	135.53	TETRAGONAL+CUBIC	1.5418
TZP-110	AC-38	100h@1000C	31.33	2.853	698.43	MONOCLINIC	1.5418
TZP-110	AC-77	AS RECEIVED	28.16	3.166	2728.22	MONOCLINIC	1.5418
TZP-110	AC-77	AS RECEIVED	30.08	2.969	13192.11	TETRAGONAL+CUBIC	1.5418
TZP-110	AC-77	AS RECEIVED	31.23	2.862	413.23	MONOCLINIC	1.5418
TZP-110	AC-77	AS RECEIVED	31.53	2.835	156.42	MONOCLINIC	1.5418
Z-191	NGK-30	500h@1000C	28.24	3.158	4520.31	MONOCLINIC	1.5418
Z-191	NGK-30	500h@1000C	30.24	2.953	36616.61	TETRAGONAL+CUBIC	1.5418
Z-191	NGK-30	500h@1000C	31.19	2.865	1259.95	MONOCLINIC	1.5418
Z-191	NGK-53	100h@1000C	28.16	3.166	1988.86	MONOCLINIC	1.5418
Z-191	NGK-53	100h@1000C	30.08	2.968	35308.49	TETRAGONAL+CUBIC	1.5418
Z-191	NGK-53	100h@1000C	31.33	2.853	475.63	MONOCLINIC	1.5418
Z-191	NGK-83	AS RECEIVED	28.49	3.130	9764.44	MONOCLINIC	1.5418
Z-191	NGK-83	AS RECEIVED	30.23	2.954	51318.17	TETRAGONAL+CUBIC	1.5418
Z-191	NGK-83	AS RECEIVED	31.05	2.878	1045.46	MONOCLINIC	1.5418
Z-191	NGK-83	AS RECEIVED	31.40	2.847	1803.67	MONOCLINIC	1.5418
Z-191	NGK-83	AS RECEIVED	31.70	2.821	972.91	MONOCLINIC	1.5418
Z-201	KY-19	500h@1000C	28.24	3.157	8544.97	MONOCLINIC	1.5418
Z-201	KY-19	500h@1000C	30.21	2.956	11038.22	TETRAGONAL+CUBIC	1.5418
Z-201	KY-19	500h@1000C	31.44	2.843	3678.51	MONOCLINIC	1.5418
Z-201	KY-3	500h@1000C	28.18	3.164	12305.22	MONOCLINIC	1.5418
Z-201	KY-3	500h@1000C	30.13	2.963	14045.15	TETRAGONAL+CUBIC	1.5418
Z-201	KY-3	500h@1000C	31.35	2.851	5618.21	MONOCLINIC	1.5418
Z-201	KY-42	100h@1000C	28.15	3.167	10369.26	MONOCLINIC	1.5418
Z-201	KY-42	100h@1000C	30.13	2.964	12813.97	TETRAGONAL+CUBIC	1.5418
Z-201	KY-42	100h@1000C	31.34	2.852	4026.69	MONOCLINIC	1.5418
Z-201	KY-47	100h@1000C	27.87	3.198	7358.55	MONOCLINIC	1.5418
Z-201	KY-47	100h@1000C	29.82	2.994	12409.69	TETRAGONAL+CUBIC	1.5418

X-RAY DIFFRACTION ANALYSIS FOR VARIOUS ZIRCONIA MATERIALS
DATA FROM THE ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	SPECIMEN NUMBER	HEAT TREATMENT	2 THETA (degrees)	D SPACE (Angstroms)	INTEGRATED INTENSITY	PHASE	WAVE-LENGTH
Z-201	KY-47	100h@1000C	31.02	2.881	1520.27	MONOCLINIC	1.5418
Z-201	KY-73	AS RECEIVED	28.03	3.181	4495.68	MONOCLINIC	1.5418
Z-201	KY-73	AS RECEIVED	29.92	2.984	25690.67	TETRAGONAL+CUBIC	1.5418
Z-201	KY-73	AS RECEIVED	30.81	2.900	449.02	TETRAGONAL+CUBIC	1.5418
Z-201	KY-73	AS RECEIVED	31.06	2.877	239.33	MONOCLINIC	1.5418
Z-201	KY-73	AS RECEIVED	31.26	2.859	224.16	MONOCLINIC	1.5418

SECTION 4. OTHER INTRINSIC PROPERTIES

PART 4A. Elasticity

ROOM TEMPERATURE SONIC MODULI OF ELASTICITY
FOR DIFFERENT HEAT TREATMENTS OF VARIOUS ZIRCONIAS AND ALUMINAS

MATERIAL	BATCH CODE	HEAT TREATMENT	MOD. OF ELASTICITY (GPa)
AC-SENSOR	AMTL-A/ACS82	100h@1000C	214
AC-SENSOR	AMTL-A/ACS82	500h@1000C	215
AC-SENSOR	AMTL-A/ACS82	AS RECEIVED	213
NRL-TZP	AMTL-B/NRL82	100h@1000C	202
NRL-TZP	AMTL-B/NRL82	500h@1000C	202
NRL-TZP	AMTL-B/NRL82	AS RECEIVED	202
NILSEN-TTZ	AMTL-C/NILSENC	100h@1000C	209
NILSEN-TTZ	AMTL-C/NILSENC	100h@1100C	202
NILSEN-TTZ	AMTL-C/NILSENC	100h@1200C	194
NILSEN-TTZ	AMTL-C/NILSENC	100h@1300C	173
NILSEN-TTZ	AMTL-C/NILSENC	250h@1000C	208
NILSEN-TTZ	AMTL-C/NILSENC	250h@1100C	204
NILSEN-TTZ	AMTL-C/NILSENC	250h@1200C	195
NILSEN-TTZ	AMTL-C/NILSENC	250h@1300C	159
NILSEN-TTZ	AMTL-C/NILSENC	500h@1000C	217
NILSEN-TTZ	AMTL-C/NILSENC	500h@1000C	212
NILSEN-TTZ	AMTL-C/NILSENC	500h@1100C	163
NILSEN-TTZ	AMTL-C/NILSENC	500h@1200C	193
NILSEN-TTZ	AMTL-C/NILSENC	500h@1300C	135
NILSEN-TTZ	AMTL-C/NILSENC	500h@900C	202
NILSEN-TTZ	AMTL-C/NILSENC	50h@1100C	214
NILSEN-TTZ	AMTL-C/NILSENC	50h@1200C	205
NILSEN-TTZ	AMTL-C/NILSENC	50h@900C	206
NILSEN-TTZ	AMTL-C/NILSENC	AS RECEIVED	227
TS-TTZ	AMTL-D/NILSEN82	100h@1000C	213
TS-TTZ	AMTL-D/NILSEN82	500h@1000C	210
TS-TTZ	AMTL-D/NILSEN82	AS RECEIVED	227
MS-TTZ	AMTL-E/NILSEN82	100h@1000C	208
MS-TTZ	AMTL-E/NILSEN82	500h@1000C	208
MS-TTZ	AMTL-E/NILSEN82	AS RECEIVED	208
CERAD-FSZ	AMTL-F/CERAD82	AS RECEIVED	180
COORS-ZDM	AMTL-G/COORS81	100h@1000C	168
COORS-ZDM	AMTL-G/COORS81	100h@1100C	128
COORS-ZDM	AMTL-G/COORS81	100h@1200C	96
COORS-ZDM	AMTL-G/COORS81	100h@1300C	110
COORS-ZDM	AMTL-G/COORS81	100h@900C	152
COORS-ZDM	AMTL-G/COORS81	250h@1000C	161
COORS-ZDM	AMTL-G/COORS81	250h@1100C	115
COORS-ZDM	AMTL-G/COORS81	250h@1200C	106
COORS-ZDM	AMTL-G/COORS81	250h@900C	150
COORS-ZDM	AMTL-G/COORS81	500h@1000C	156
COORS-ZDM	AMTL-G/COORS81	500h@1100C	115
COORS-ZDM	AMTL-G/COORS81	500h@900C	151
COORS-ZDM	AMTL-G/COORS81	50h@1000C	174
COORS-ZDM	AMTL-G/COORS81	50h@1100C	156
COORS-ZDM	AMTL-G/COORS81	50h@1200C	124
COORS-ZDM	AMTL-G/COORS81	50h@900C	155

ROOM TEMPERATURE SONIC MODULI OF ELASTICITY
FOR DIFFERENT HEAT TREATMENTS OF VARIOUS ZIRCONIAS AND ALUMINAS

MATERIAL	BATCH CODE	HEAT TREATMENT	MOD. OF ELASTICITY (GPa)
COORS-ZDM	AMTL-G/COORS81	AS RECEIVED	149
COORS-ZDM	AMTL-H/COORS81	100h@1000C	188
COORS-ZDM	AMTL-H/COORS81	500h@1000C	203
COORS-ZDM	AMTL-H/COORS81	AS RECEIVED	119
COORS-TZP	COORS-ZDY	100h@1000C	212
COORS-TZP	COORS-ZDY	500h@1000C	213
COORS-TZP	COORS-ZDY	AS RECEIVED	211
COORS-ZDY	AMTL-J/COORS81	100h@1000	186
COORS-ZDY	AMTL-J/COORS81	100h@1100	184
COORS-ZDY	AMTL-J/COORS81	100h@1200	190
COORS-ZDY	AMTL-J/COORS81	100h@1300	197
COORS-ZDY	AMTL-J/COORS81	100h@900	185
COORS-ZDY	AMTL-J/COORS81	250h@1000	185
COORS-ZDY	AMTL-J/COORS81	250h@1100	185
COORS-ZDY	AMTL-J/COORS81	250h@1200	186
COORS-ZDY	AMTL-J/COORS81	250h@1300	186
COORS-ZDY	AMTL-J/COORS81	250h@900	182
COORS-ZDY	AMTL-J/COORS81	500h@1000	183
COORS-ZDY	AMTL-J/COORS81	500h@1100	185
COORS-ZDY	AMTL-J/COORS81	500h@1200	185
COORS-ZDY	AMTL-J/COORS81	500h@1300	199
COORS-ZDY	AMTL-J/COORS81	500h@900	184
COORS-ZDY	AMTL-J/COORS81	50h@1000	189
COORS-ZDY	AMTL-J/COORS81	50h@1100	188
COORS-ZDY	AMTL-J/COORS81	50h@1200	188
COORS-ZDY	AMTL-J/COORS81	50h@900	186
COORS-ZDY	AMTL-J/COORS81	AS RECEIVED	189
AFC-TTZ	AMTL-K/AFCK	100h@1000C	207
AFC-TTZ	AMTL-K/AFCK	100h@1100C	204
AFC-TTZ	AMTL-K/AFCK	100h@1200C	190
AFC-TTZ	AMTL-K/AFCK	100h@1300C	201
AFC-TTZ	AMTL-K/AFCK	100h@900C	204
AFC-TTZ	AMTL-K/AFCK	250h@1000C	205
AFC-TTZ	AMTL-K/AFCK	250h@1100C	204
AFC-TTZ	AMTL-K/AFCK	250h@1200C	195
AFC-TTZ	AMTL-K/AFCK	250h@1300C	192
AFC-TTZ	AMTL-K/AFCK	250h@900C	206
AFC-TTZ	AMTL-K/AFCK	500h@1000C	207
AFC-TTZ	AMTL-K/AFCK	500h@1100C	211
AFC-TTZ	AMTL-K/AFCK	500h@1200C	183
AFC-TTZ	AMTL-K/AFCK	500h@1300C	188
AFC-TTZ	AMTL-K/AFCK	500h@900C	205
AFC-TTZ	AMTL-K/AFCK	50h@1000C	209
AFC-TTZ	AMTL-K/AFCK	50h@1100C	207
AFC-TTZ	AMTL-K/AFCK	50h@1200C	203
AFC-TTZ	AMTL-K/AFCK	50h@900C	206
ZT-35	AMTL-L/AFC82	100h@1000C	196

ROOM TEMPERATURE SONIC MODULI OF ELASTICITY
FOR DIFFERENT HEAT TREATMENTS OF VARIOUS ZIRCONIAS AND ALUMINAS

MATERIAL	BATCH CODE	HEAT TREATMENT	MOD. OF ELASTICITY (GPa)
ZT-35	AMTL-L/AFC82	500h@1000C	193
ZT-35	AMTL-L/AFC82	AS RECEIVED	215
NGK-TZP	AMTL-M/NGKM	100h@1000C	198
NGK-TZP	AMTL-M/NGKM	100h@1100C	202
NGK-TZP	AMTL-M/NGKM	100h@1200C	207
NGK-TZP	AMTL-M/NGKM	100h@1300C	212
NGK-TZP	AMTL-M/NGKM	100h@900C	207
NGK-TZP	AMTL-M/NGKM	250h@1000C	203
NGK-TZP	AMTL-M/NGKM	250h@1100C	199
NGK-TZP	AMTL-M/NGKM	250h@1200C	205
NGK-TZP	AMTL-M/NGKM	250h@1300C	214
NGK-TZP	AMTL-M/NGKM	250h@900C	199
NGK-TZP	AMTL-M/NGKM	500h@1000C	203
NGK-TZP	AMTL-M/NGKM	500h@1100C	204
NGK-TZP	AMTL-M/NGKM	500h@1200C	210
NGK-TZP	AMTL-M/NGKM	500h@900C	205
NGK-TZP	AMTL-M/NGKM	50h@1000C	203
NGK-TZP	AMTL-M/NGKM	50h@1100C	198
NGK-TZP	AMTL-M/NGKM	50h@1200C	205
NGK-TZP	AMTL-M/NGKM	50h@900C	206
NGK-TZP	AMTL-N/NGKN	AS RECEIVED	198
TOSH-TZP	AMTL-P/TOSHBA83	100h@1000C	210
TOSH-TZP	AMTL-P/TOSHBA83	500h@1000C	209
TOSH-TZP	AMTL-P/TOSHBA83	AS RECEIVED	209
TOR-TZPHP	AMTL-Q/TORAY83	100h@1000C	214
TOR-TZPHP	AMTL-Q/TORAY83	500h@1000C	213
TOR-TZPHP	AMTL-Q/TORAY83	AS RECEIVED	215
TOR-TZPSIN	AMTL-R/TORAY83	500h@1000C	218
TOR-TZPSIN	AMTL-R/TORAY83	AS RECEIVED	213
ZIRCOA2120	AMTL-S/CGW	100h@1000C	197
ZIRCOA2120	AMTL-S/CGW	500h@1000C	203
ZIRCOA2120	AMTL-S/CGW	AS RECEIVED	194
UM-ZTA1	AMTL-U1/MTLLS	100h@1000C	364
UM-ZTA1	AMTL-U1/MTLLS	500h@1000C	363
UM-ZTA1	AMTL-U1/MTLLS	AS RECEIVED	363
UM-ZTA2HI	AMTL-U2/MTLLS	500h@1000C	350
UM-ZTA2HI	AMTL-U2/MTLLS	AS RECEIVED	351
UM-ZTA2LO	AMTL-U2/MTLLS	500h@1000C	322
UM-ZTA2LO	AMTL-U2/MTLLS	AS RECEIVED	241
UM-ZTA2ME	AMTL-U2/MTLLS	500h@1000C	322
UM-ZTA3HI	AMTL-U3/MTLLS	500h@1000C	350
UM-ZTA3HI	AMTL-U3/MTLLS	AS RECEIVED	352
UM-ZTA3LO	AMTL-U3/MTLLS	AS RECEIVED	248
UM-ZTA3ME	AMTL-U3/MTLLS	500h@1000C	324
UM-ZTA4	AMTL-U4/MTLLS	100h@1000C	263

ROOM TEMPERATURE SONIC MODULI OF ELASTICITY
FOR DIFFERENT HEAT TREATMENTS OF VARIOUS ZIRCONIAS AND ALUMINAS

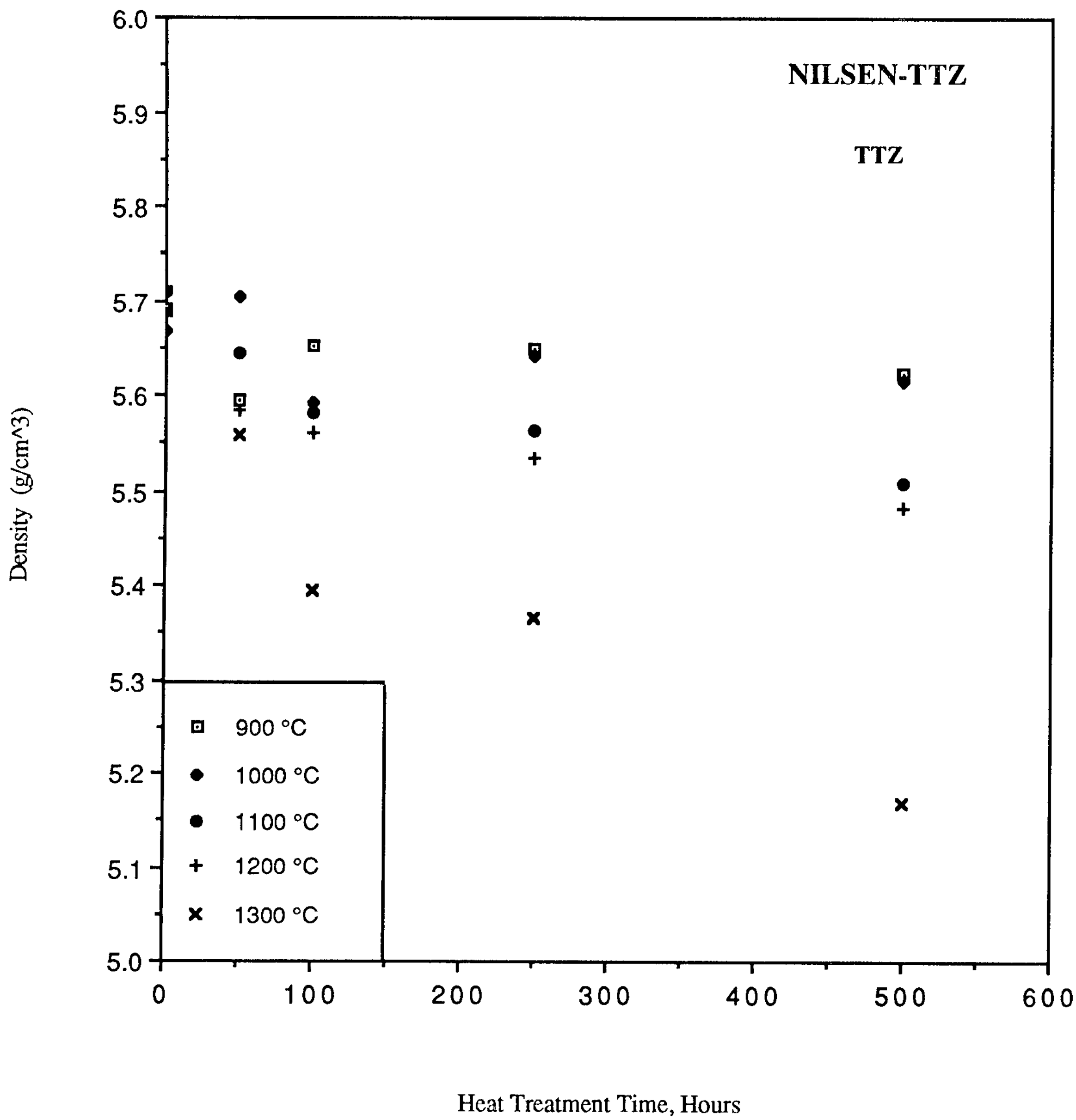
MATERIAL	BATCH CODE	HEAT TREATMENT	MOD. OF ELASTICITY (GPa)
UM-ZTA4	AMTL-U4/MTLLS	500h@1000C	362
UM-ZTA4	AMTL-U4/MTLLS	AS RECEIVED	361
UM-ZTM5	AMTL-U5/MTLLS	500h@1000C	175
UM-ZTM5	AMTL-U5/MTLLS	AS RECEIVED	182
UM-ZTM6	AMTL-U6MTLLS	500h@1000C	158
UM-ZTM6	AMTL-U6MTLLS	AS RECEIVED	169

PART 4B. Density

DENSITY DATA FOR VARIOUS ZIRCONIA-BASED CERAMICS
FROM MTL 87-29, JUNE, 1987

MATERIAL	BATCH CODE	HEAT TREATMENT	DENSITY (g/cc)	MATERIAL	BATCH CODE	HEAT TREATMENT	DENSITY (g/cc)
AC-SENSOR	AMTL-A/ACS82	100h@1000C	5.628	COORS-ZDM	AMTL-G/COORS81	250h@900C	5.030
AC-SENSOR	AMTL-A/ACS82	500h@1000C	5.668	COORS-ZDM	AMTL-G/COORS81	500h@1000C	5.093
AC-SENSOR	AMTL-A/ACS82	AS RECEIVED	5.667	COORS-ZDM	AMTL-G/COORS81	500h@1100C	4.890
NRL-TZP	AMTL-B/NRL82	100h@1000C	5.785	COORS-ZDM	AMTL-G/COORS81	500h@900C	5.023
NRL-TZP	AMTL-B/NRL82	500h@1000C	5.763	COORS-ZDM	AMTL-G/COORS81	50h@1000C	5.136
NRL-TZP	AMTL-B/NRL82	AS RECEIVED	5.774	COORS-ZDM	AMTL-G/COORS81	50h@1100C	5.051
NILSEN-TTZ	AMTL-C/NILSENC	0h@1000C	5.668	COORS-ZDM	AMTL-G/COORS81	50h@1200C	4.908
NILSEN-TTZ	AMTL-C/NILSENC	0h@1100C	5.709	COORS-ZDM	AMTL-G/COORS81	50h@900C	5.095
NILSEN-TTZ	AMTL-C/NILSENC	0h@1200C	5.713	COORS-ZDM	AMTL-G/COORS81	AS RECEIVED	5.294
NILSEN TTZ	AMTL-C/NILSENC	0h@1300C	5.689	COORS-ZDM	AMTL-H/COORS81	100h@1000C	5.548
NILSEN-TTZ	AMTL-C/NILSENC	100h@1000C	5.591	COORS-ZDM	AMTL-H/COORS81	500h@1000C	5.537
NILSEN-TTZ	AMTL-C/NILSENC	100h@1100C	5.581	COORS-ZDM	AMTL-H/COORS81	AS RECEIVED	5.649
NILSEN-TTZ	AMTL-C/NILSENC	100h@1200C	5.562	COORS-TZP	AMTL-I/COORS84	100h@1000C	5.986
NILSEN-TTZ	AMTL-C/NILSENC	100h@1300C	5.394	COORS-TZP	AMTL-I/COORS84	500h@1000C	5.979
NILSEN-TTZ	AMTL-C/NILSENC	100h@900C	5.652	COORS-TZP	AMTL-I/COORS84	AS RECEIVED	5.939
NILSEN-TTZ	AMTL-C/NILSENC	250h@1000C	5.642	COORS-ZDY	AMTL-J/COORS81	0h@1000C	5.522
NILSEN-TTZ	AMTL-C/NILSENC	250h@1100C	5.563	COORS-ZDY	AMTL-J/COORS81	0h@1100C	5.552
NILSEN-TTZ	AMTL-C/NILSENC	250h@1200C	5.535	COORS-ZDY	AMTL-J/COORS81	0h@1200C	5.503
NILSEN-TTZ	AMTL-C/NILSENC	250h@1300C	5.365	COORS-ZDY	AMTL-J/COORS81	0h@1300C	5.494
NILSEN-TTZ	AMTL-C/NILSENC	250h@900C	5.650	COORS-ZDY	AMTL-J/COORS81	0h@900C	5.504
NILSEN-TTZ	AMTL-C/NILSENC	500h@1000C	5.615	COORS-ZDY	AMTL-J/COORS81	100h@1000C	5.484
NILSEN-TTZ	AMTL-C/NILSENC	500h@1100C	5.508	COORS-ZDY	AMTL-J/COORS81	100h@1100C	5.478
NILSEN-TTZ	AMTL-C/NILSENC	500h@1200C	5.482	COORS-ZDY	AMTL-J/COORS81	100h@1200C	5.435
NILSEN-TTZ	AMTL-C/NILSENC	500h@1300C	5.170	COORS-ZDY	AMTL-J/COORS81	100h@1300C	5.419
NILSEN-TTZ	AMTL-C/NILSENC	500h@900C	5.623	COORS-ZDY	AMTL-J/COORS81	100h@900C	5.502
NILSEN-TTZ	AMTL-C/NILSENC	50h@1000C	5.704	COORS-ZDY	AMTL-J/COORS81	250h@1000C	5.495
NILSEN-TTZ	AMTL-C/NILSENC	50h@1100C	5.644	COORS-ZDY	AMTL-J/COORS81	250h@1100C	5.478
NILSEN-TTZ	AMTL-C/NILSENC	50h@1200C	5.584	COORS-ZDY	AMTL-J/COORS81	250h@1200C	5.400
NILSEN-TTZ	AMTL-C/NILSENC	50h@1300C	5.559	COORS-ZDY	AMTL-J/COORS81	250h@1300C	5.377
NILSEN-TTZ	AMTL-C/NILSENC	50h@900C	5.596	COORS-ZDY	AMTL-J/COORS81	250h@900C	5.460
NILSEN-TTZ	AMTL-C/NILSENC	AS RECEIVED	5.692	COORS-ZDY	AMTL-J/COORS81	500h@1000C	5.473
TS-TTZ	AMTL-D/NILSEN82	100h@1000C	5.643	COORS-ZDY	AMTL-J/COORS81	500h@1100C	5.443
TS-TTZ	AMTL-D/NILSEN82	500h@1000C	5.629	COORS-ZDY	AMTL-J/COORS81	500h@1200C	5.380
TS-TTZ	AMTL-D/NILSEN82	AS RECEIVED	5.660	COORS-ZDY	AMTL-J/COORS81	500h@1300C	5.236
MS-TTZ	AMTL-E/NILSEN82	100h@1000C	5.632	COORS-ZDY	AMTL-J/COORS81	500h@900C	5.406
MS-TTZ	AMTL-E/NILSEN82	500h@1000C	5.553	COORS-ZDY	AMTL-J/COORS81	50h@1000C	5.526
MS-TTZ	AMTL-E/NILSEN82	AS RECEIVED	5.646	COORS-ZDY	AMTL-J/COORS81	50h@1100C	5.540
CERAD-FSZ	AMTL-F/CERAD82	AS RECEIVED	5.599	COORS-ZDY	AMTL-J/COORS81	50h@1200C	5.479
COORS-ZDM	AMTL-G/COORS81	0h@1000C	5.166	COORS-ZDY	AMTL-J/COORS81	50h@1300C	5.475
COORS-ZDM	AMTL-G/COORS81	0h@1100C	5.078	COORS-ZDY	AMTL-J/COORS81	50h@900C	5.488
COORS-ZDM	AMTL-G/COORS81	0h@1200C	5.051	COORS-ZDY	AMTL-J/COORS81	AS RECEIVED	5.534
COORS-ZDM	AMTL-G/COORS81	0h@1300C	5.059	AFC-TTZ	AMTL-K/AFCK	0h@1000C	5.737
COORS-ZDM	AMTL-G/COORS81	0h@900C	5.125	AFC-TTZ	AMTL-K/AFCK	0h@1100C	5.723
COORS-ZDM	AMTL-G/COORS81	100h@1000C	5.073	AFC-TTZ	AMTL-K/AFCK	0h@1200C	5.717
COORS-ZDM	AMTL-G/COORS81	100h@1100C	5.824	AFC-TTZ	AMTL-K/AFCK	0h@1300C	5.720
COORS-ZDM	AMTL-G/COORS81	100h@1200C	4.808	AFC-TTZ	AMTL-K/AFCK	0h@900C	5.705
COORS ZDM	AMTL-G/COORS81	100h@900C	5.067	AFC-TTZ	AMTL-K/AFCK	100h@1000C	5.649
COORS-ZDM	AMTL-G/COORS81	250h@1000C	5.134	AFC-TTZ	AMTL-K/AFCK	100h@1100C	5.556
COORS-ZDM	AMTL-G/COORS81	250h@1100C	4.936	AFC-TTZ	AMTL-K/AFCK	100h@1200C	5.550
COORS-ZDM	AMTL-G/COORS81	250h@1200C	4.790	AFC-TTZ	AMTL-K/AFCK	100h@1300C	5.392

ORNL-DWG 88-16423



PART 4C.

Figure 1. Density vs heat treatment time for NILSEN-TTZ, a transformation-toughened zirconia-based ceramic.

ORNL-DWG 88-16424

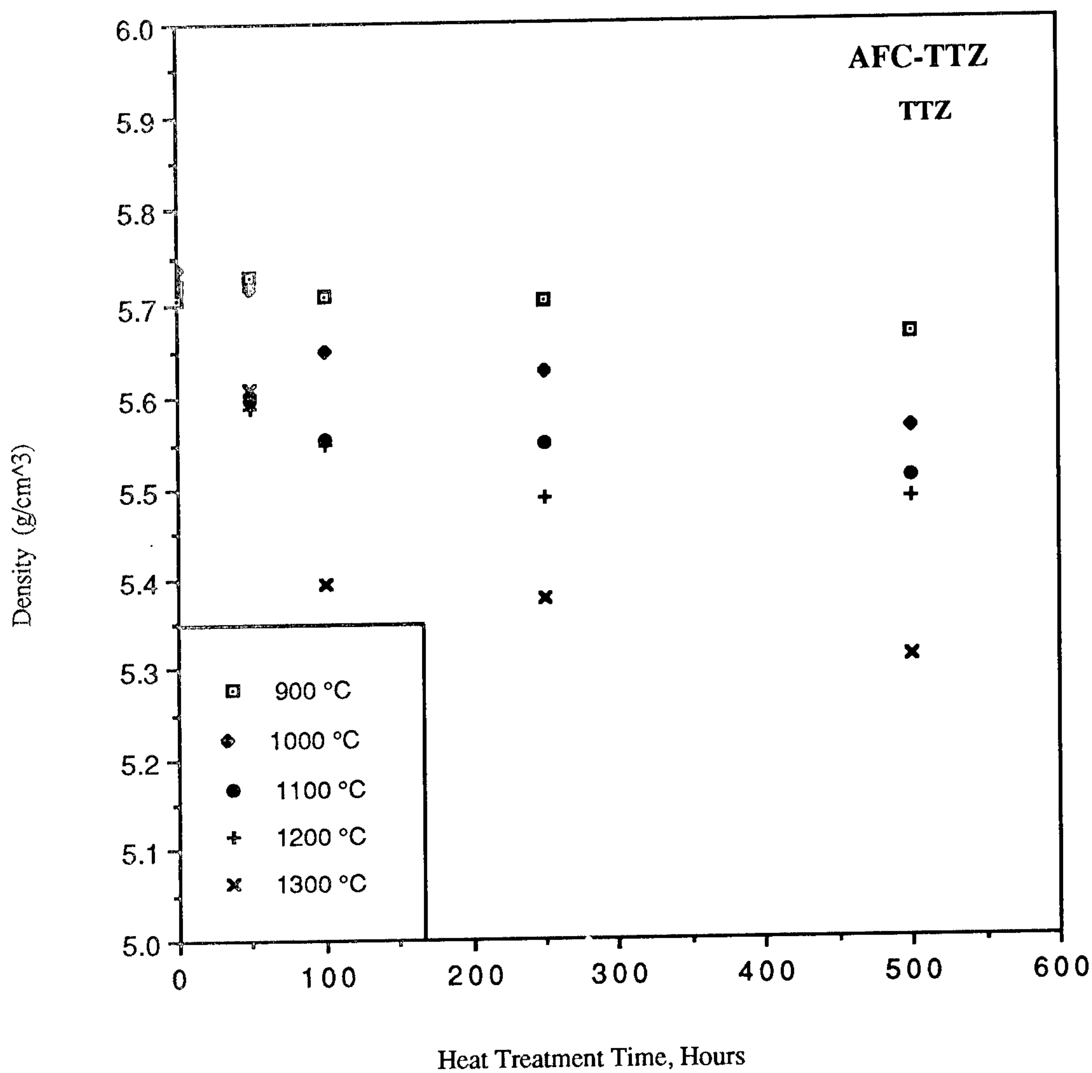


Figure 2. Density vs heat treatment time for AFC-TTZ, a transormation toughened zirconia-based ceramic.

ORNL-DWG 88-16425

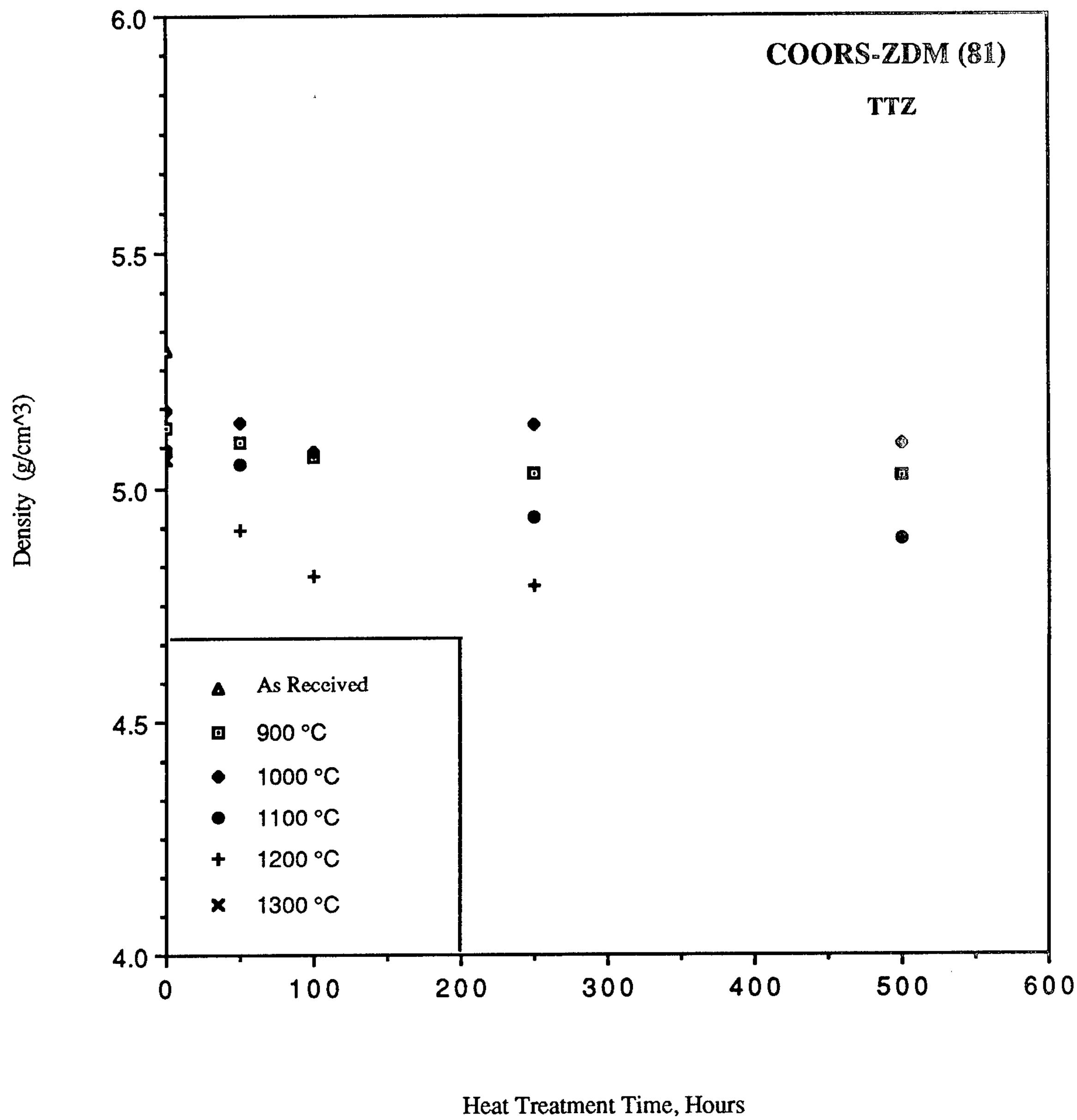


Figure 3. Density vs heat treatment time for COORS-ZDM, a transformation-toughened zirconia-based ceramic.

ORNL-DWG 88-16426

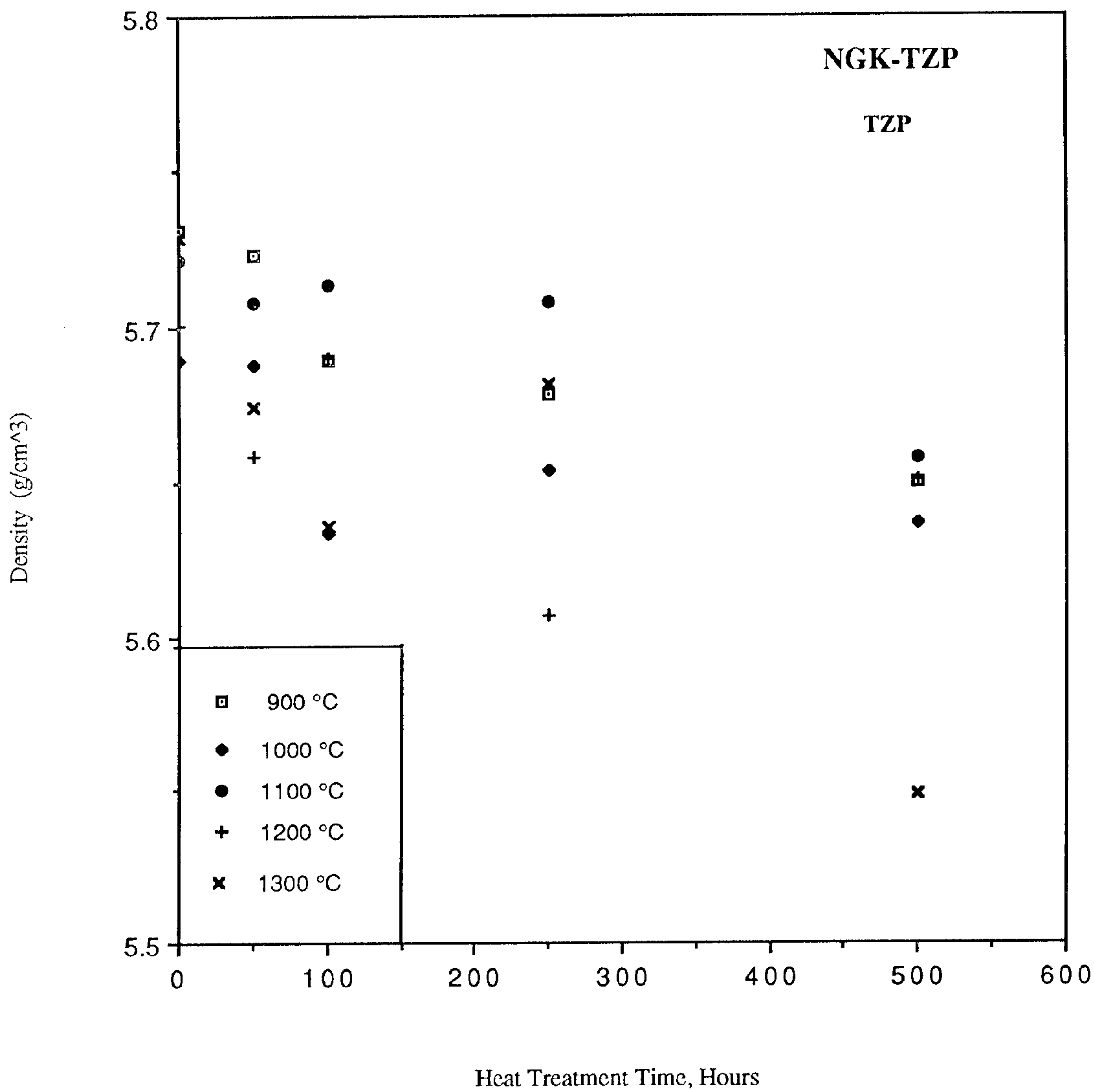


Figure 4. Density vs heat treatment time for NGK-TZP, a tetragonal polycrystalline zirconia.

ORNL-DWG 88-16427

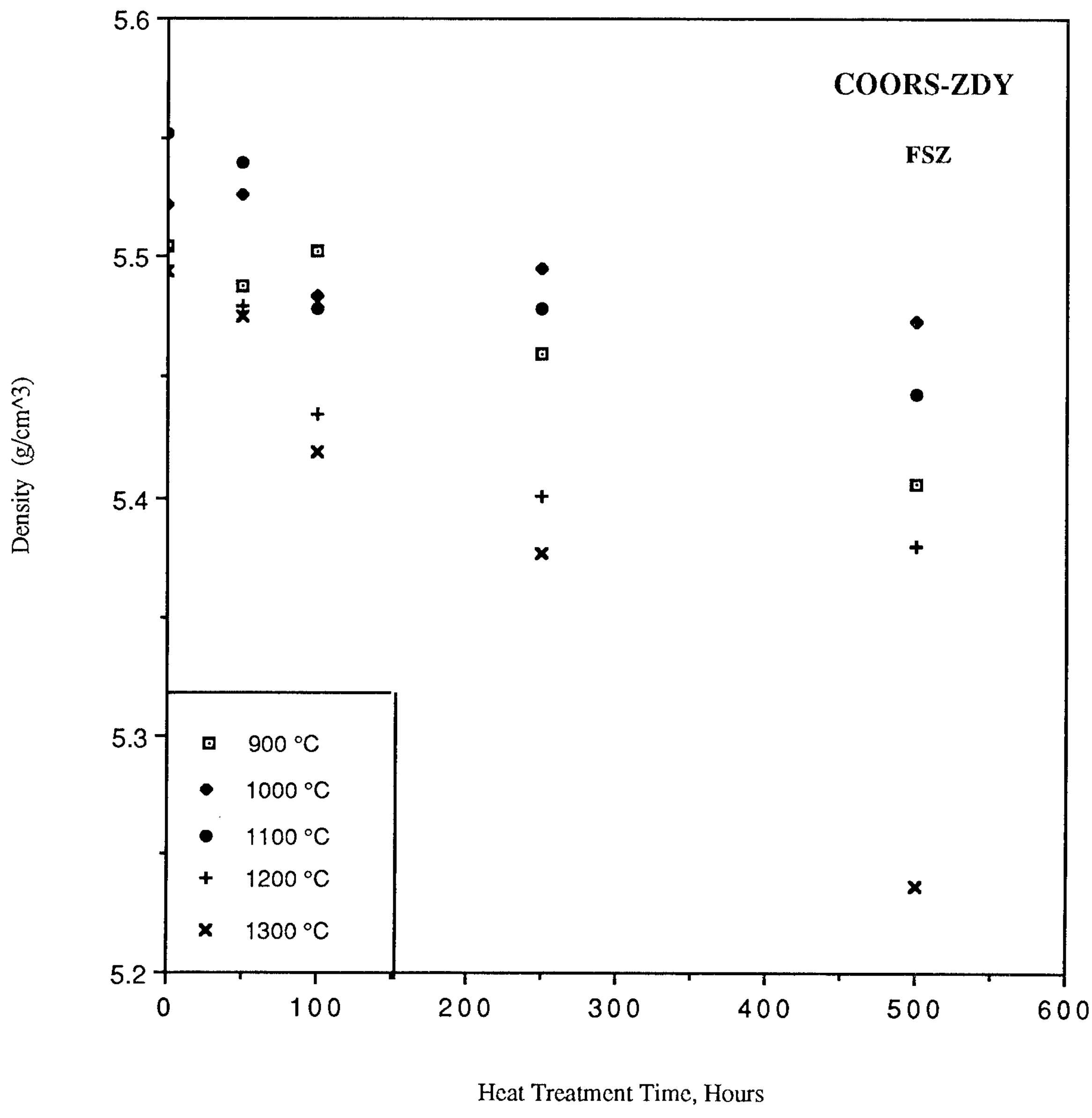


Figure 5. Density vs heat treatment time for COORS-ZDY, a fully stabilized zirconia-based ceramic .

DENSITY DATA FOR VARIOUS ZIRCONIA-BASED CERAMICS
FROM MTL 87-29, JUNE, 1987

MATERIAL	BATCH CODE	HEAT TREATMENT	DENSITY (g/cc)	MATERIAL	BATCH CODE	HEAT TREATMENT	DENSITY (g/cc)
AFC-TTZ	AMTL-K/AFCK	100h@900C	5.709	NGK-TZP	AMTL-M/NGKM	250h@1000C	5.654
AFC-TTZ	AMTL-K/AFCK	250h@1000C	5.628	NGK-TZP	AMTL-M/NGKM	250h@1100C	5.708
AFC-TTZ	AMTL-K/AFCK	250h@1100C	5.550	NGK-TZP	AMTL-M/NGKM	250h@1200C	5.607
AFC-TTZ	AMTL-K/AFCK	250h@1200C	5.487	NGK-TZP	AMTL-M/NGKM	250h@1300C	5.682
AFC-TTZ	AMTL-K/AFCK	250h@1300C	5.376	NGK-TZP	AMTL-M/NGKM	250h@900C	5.679
AFC-TTZ	AMTL-K/AFCK	250h@900C	5.701	NGK-TZP	AMTL-M/NGKM	500h@1000C	5.637
AFC-TTZ	AMTL-K/AFCK	500h@1000C	5.565	NGK-TZP	AMTL-M/NGKM	500h@1100C	5.658
AFC-TTZ	AMTL-K/AFCK	500h@1100C	5.509	NGK-TZP	AMTL-M/NGKM	500h@1200C	5.651
AFC-TTZ	AMTL-K/AFCK	500h@1200C	5.485	NGK-TZP	AMTL-M/NGKM	500h@1300C	5.548
AFC-TTZ	AMTL-K/AFCK	500h@1300C	5.310	NGK-TZP	AMTL-M/NGKM	500h@900C	5.650
AFC-TTZ	AMTL-K/AFCK	500h@900C	5.664	NGK-TZP	AMTL-M/NGKM	50h@1000C	5.688
AFC-TTZ	AMTL-K/AFCK	50h@1000C	5.718	NGK-TZP	AMTL-M/NGKM	50h@1100C	5.708
AFC-TTZ	AMTL-K/AFCK	50h@1100C	5.598	NGK-TZP	AMTL-M/NGKM	50h@1200C	5.659
AFC-TTZ	AMTL-K/AFCK	50h@1200C	5.591	NGK-TZP	AMTL-M/NGKM	50h@1300C	5.675
AFC-TTZ	AMTL-K/AFCK	50h@1300C	5.610	NGK-TZP	AMTL-M/NGKM	50h@900C	5.723
AFC-TTZ	AMTL-K/AFCK	50h@900C	5.727	NGK-TZP	AMTL-N/NGKN	AS RECEIVED	5.771
ZT-35	AMTL-L/AFC82	100h@1000C	5.512	Z-191	AMTL-O/NGK84	AS RECEIVED	5.770
ZT-35	AMTL-L/AFC82	500h@1000C	5.450	TOSH-TZP	AMTL-P/TOSHBA83	100h@1000C	5.937
ZT-35	AMTL-L/AFC82	AS RECEIVED	5.506	TOSH-TZP	AMTL-P/TOSHBA83	500h@1000C	5.920
NGK-TZP	AMTL-M/NGKM	0h@1000C	5.690	TOSH-TZP	AMTL-P/TOSHBA83	AS RECEIVED	5.928
NGK-TZP	AMTL-M/NGKM	0h@1100C	5.722	TOR-TZPHP	AMTL-Q/TORAY83	100h@1000C	5.943
NGK-TZP	AMTL-M/NGKM	0h@1200C	5.701	TOR-TZPHP	AMTL-Q/TORAY83	100h@1000C	5.943
NGK-TZP	AMTL-M/NGKM	0h@1300C	5.729	TOR-TZPHP	AMTL-Q/TORAY83	500h@1000C	5.956
NGK-TZP	AMTL-M/NGKM	0h@900C	5.731	TOR-TZPHP	AMTL-Q/TORAY83	AS RECEIVED	5.950
NGK-TZP	AMTL-M/NGKM	100h@1000C	5.634	TOR-TZPSIN	AMTL-R/TORAY83	500h@1000C	5.714
NGK-TZP	AMTL-M/NGKM	100h@1100C	5.714	TOR-TZPSIN	AMTL-R/TORAY83	AS RECEIVED	5.897
NGK-TZP	AMTL-M/NGKM	100h@1200C	5.691	ZIRCOA2120	AMTL-S/CGW	100h@1000C	5.469
NGK-TZP	AMTL-M/NGKM	100h@1300C	5.636	ZIRCOA2120	AMTL-S/CGW	500h@1000C	5.472
NGK-TZP	AMTL-M/NGKM	100h@900C	5.690	ZIRCOA2120	AMTL-S/CGW	AS RECEIVED	5.576

APPENDIX II. TEST RESULTS

SECTION 1. STRESS RUPTURE DATA

STRESS RUPTURE DATA FROM MTL87-29, JUNE 1987
ZIRCONIAS AND ZIRCONIA-TOUGHENED ALUMINAS

MATERIAL	TYPE	TEMP C	STRESS MPa	RUPTURE TIME HOURS	TIME DISC. HOURS	STRAIN %	RETAINED STRENGTH MPa	COMMENTS
ZT-35	PSZ	900	200	>500	0	0.090	561	
AC-SENSOR	PSZ	1000	100	>500	0	0.010	0	
ZT-35	PSZ	1000	200	>500	0	0.420	0	
AC-SENSOR	PSZ	1100	100	0	313	3.130	0	Microswitch trip ended run.
ZT-35	PSZ	1100	200	0	0	0.000	0	Rupture time=4.8min.
AC-SENSOR	PSZ	1200	100	0	2	1.010	0	Microswitch trip ended run.
ZT-35	PSZ	1200	200	0	0	0.000	0	Rupture time=9 min.
TS-TTZ	TTZ	900	200	>500	0	0.040	400	
COORS-ZDM	TTZ	900	200	>500	0	0.000	324	
TS-TTZ	TTZ	1000	200	>500	0	0.230	343	
COORS-ZDM	TTZ	1000	200	>500	0	0.580	221	
ZIRCOA2120	TTZ	1000	200	500	0	1.190	0	
TS-TTZ	TTZ	1100	200	0	125	1.030	0	Microswitch trip ended run.
COORS-ZDM	TTZ	1100	200	74	0	1.600	0	
TS-TTZ	TTZ	1200	200	26	0	0.960	0	
COORS-TZP	TZP	1000	175	>500	0	0.660	6	
COORS-TZP	TZP	1100	175	0	0	0.000	0	Rupture time=2.8 sec
COORS-TZP	TZP	1100	175	0	0	0.000	0	Rupture time=8.6 sec
COORS-TZP	TZP	1200	175	0	0	0.000	0	Rupture time=14.2 min.
COORS-TZP	TZP	1200	175	0	0	0.000	0	Rupture time=5.2 sec.
UM-ZTA1	ZTA	900	100	>500	0	0.050	511	
UM-ZTA2/LO	ZTA	900	150	0	0	0.050	0	
UM-ZTA4	ZTA	900	100	>500	0	0.000	431	
UM-ZTA1	ZTA	1000	100	>500	0	0.160	325	
UM-ZTA3/LO	ZTA	1000	75	>500	0	0.320	0	
UM-ZTA3/HI	ZTA	1000	75	>500	0	0.170	331	
UM-ZTA4	ZTA	1000	100	>500	0	0.080	380	
UM-ZTA1	ZTA	1100	100	>500	0	0.450	258	
UM-ZTA2/HI	ZTA	1100	150	262	0	0.680	0	
UM-ZTA4	ZTA	1100	100	>500	0	0.550	270	
UM-ZTA1	ZTA	1200	100	0	127	1.690	223	Microswitch trip ended run.
UM-ZTA2/HI	ZTA	1200	150	1	0	0.430	0	
UM-ZTA4	ZTA	1200	100	2	0	0.690	0	

SECTION 2. CYCLIC FATIGUE DATA

CYCLIC FATIGUE DATA ON MgO-PSZ FROM OAK RIDGE NATIONAL LABORATORY

MATERIAL	REFERENCE CODE	SPEC. NO.	TEMP. (C)	MOE (GPa)	STRESS (MPa)	CYCLES AT STRESS	CYCLES TO FAILURE	TEST TIME,h	COMMENTS
TS-PSZ	SA9ORNL242	9	400	0	336	1209	1209	1	CONSTANT LOAD
TS-PSZ	SA9ORNL242	10	400	150	328	13	13	0	CONSTANT LOAD
TS-PSZ	SA9ORNL242	11	400	156	314	5	5	0	CONSTANT LOAD
TS-PSZ	SA9ORNL242	4	800	148	279	3	3	0	CONSTANT LOAD
TS-PSZ	SA9ORNL242	5	800	156	254	2	2	0	CONSTANT LOAD
TS-PSZ	SA9ORNL242	6	800	160	241	45126	0	0	STEP-LOAD, STEP 1
TS-PSZ	SA9ORNL242	6	800	160	260	124946	0	0	STEP-LOAD, STEP 2
TS-PSZ	SA9ORNL242	6	800	160	279	88970	0	0	STEP-LOAD, STEP 3
TS-PSZ	SA9ORNL242	6	800	160	295	90837	349879	194	STEP-LOAD, STEP 4 FAIL
TS-PSZ	SA9ORNL242	1	800	159	235	77071	0	0	STEP-LOAD, STEP 1
TS-PSZ	SA9ORNL242	1	800	159	256	48709	0	0	STEP-LOAD, STEP 2
TS-PSZ	SA9ORNL242	1	800	159	271	132555	0	0	STEP-LOAD, STEP 3
TS-PSZ	SA9ORNL242	1	800	159	287	88970	0	0	STEP-LOAD, STEP 4
TS-PSZ	SA9ORNL242	1	800	159	300	30	347335	193	STEP-LOAD, STEP 5 FAIL
TS-PSZ	SA9ORNL242	14	1000	147	212	49120	0	0	STEP-LOAD, STEP 1
TS-PSZ	SA9ORNL242	14	1000	147	228	82315	0	0	STEP-LOAD, STEP 2
TS-PSZ	SA9ORNL242	14	1000	147	242	129036	0	0	STEP-LOAD, STEP 3
TS-PSZ	SA9ORNL242	14	1000	147	257	43725	0	0	STEP-LOAD, STEP 4
TS-PSZ	SA9ORNL242	14	1000	147	270	40979	345175	192	STEP-LOAD, STEP 5 FAIL
MS-PSZ	ORBM8-88P24	39	25	0	284	30	0	0	STEP-LOAD, STEP 1
MS-PSZ	ORBM8-88P24	39	25	0	353	7621	0	0	STEP-LOAD, STEP 2
MS-PSZ	ORBM8-88P24	39	25	0	388	2986	0	0	STEP-LOAD, STEP 3
MS-PSZ	ORBM8-88P24	39	25	0	421	155	10799	0	STEP-LOAD, STEP 4 FAIL
MS-PSZ	ORBM8-88P24	40	400	0	238	1103	1103	0	CONSTANT LOAD
MS-PSZ	ORBM8-88P24	41	400	0	240	54135	0	0	STEP-LOAD, STEP 1
MS-PSZ	ORBM8-88P24	41	400	0	257	44278	0	0	STEP-LOAD, STEP 2
MS-PSZ	ORBM8-88P24	41	400	0	271	32487	0	0	STEP-LOAD, STEP 3
MS-PSZ	ORBM8-88P24	41	400	0	283	132491	0	0	STEP-LOAD, STEP 4
MS-PSZ	ORBM8-88P24	41	400	0	297	44129	0	0	STEP-LOAD, STEP 5
MS-PSZ	ORBM8-88P24	41	400	0	311	44505	0	0	STEP-LOAD, STEP 6
MS-PSZ	ORBM8-88P24	41	400	0	325	44685	0	0	STEP-LOAD, STEP 7
MS-PSZ	ORBM8-88P24	41	400	0	336	135	407489	0	STEP-LOAD, STEP 8 FAIL
MS-PSZ	ORBM8-88P24	37	800	0	192	46641	0	0	STEP-LOAD, STEP 1

Specimen geometry: uniform gaged buttonhead with 6.3 x 25.4mm gage section.
All MS-PSZ and TS_PSZ material are from batches labeled NILCRA/ORNL1.
ORBM8-88P24 = See reference 5.
SA9ORNL242 = See reference 3.

CYCLIC FATIGUE DATA FROM OAK RIDGE NATIONAL LABORATORY

MATERIAL	REFERENCE CODE	SPEC. NO.	TEMP. (C)	MOE (GPa)	STRESS (MPa)	CYCLES AT STRESS	CYCLES TO FAILURE	TEST TIME,h	COMMENTS
MS-PSZ	ORBM8-88P24	37	800	0	210	88308	0	0	STEP-LOAD, STEP 2
MS-PSZ	ORBM8-88P24	37	800	0	221	225600	0	0	STEP-LOAD, STEP 3
MS-PSZ	ORBM8-88P24	37	800	0	233	44263	0	0	STEP-LOAD, STEP 4
MS-PSZ	ORBM8-88P24	37	800	0	244	44769	0	0	STEP-LOAD, STEP 5
MS-PSZ	ORBM8-88P24	37	800	0	258	130466	0	0	STEP-LOAD, STEP 6
MS-PSZ	ORBM8-88P24	37	800	0	271	144444	0	0	STEP-LOAD, STEP 7
MS-PSZ	ORBM8-88P24	37	800	0	286	352	724843	0	STEP-LOAD, STEP 8 FAIL
MS-PSZ	ORBM8-88P24	38	800	0	190	1	1	0	CONSTANT LOAD
MS-PSZ	ORBM8-88P24	36	1000	0	180	49172	0	0	STEP-LOAD, STEP 1
MS-PSZ	ORBM8-88P24	36	1000	0	195	25918	75090	0	STEP-LOAD, STEP 2 FAIL

Specimen geometry: uniform gaged buttonhead with 6.3 x 25.4mm gage section.
All MS-PSZ and TS_PSZ material are from batches labeled NILCRA/ORNL1.
ORBM8-88P24 = See reference 5.

SECTION 3. WELDED JOINT SHEAR STRESS DATA

SHEAR STRESS TEST DATA ON WELDED SPECIMENS FROM OAK RIDGE NATIONAL LABORATORY

MATERIAL A	MATERIAL B	MATERIAL B LOT	FILLER MATERIAL	JOINT PROCESS	JOINT	SPEC. NUMBER	HEAT TREATMENT	TEMP C	LOAD N	SHEAR STRESS MPa	WIDTH mm	HEIGHT mm
MS-PSZ	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-72	100h@400C	25	22.70	114	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-178	100h@400C	25	22.70	202	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-179	100h@400C	25	22.70	43	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-244	120h@400C	25	22.70	229	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-245	120h@400C	25	22.70	246	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-246	120h@400C	25	22.70	261	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-247	120h@400C	25	22.70	213	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-248	120h@400C	25	22.70	251	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-99	100h@400C	25	22.70	123	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-169	100h@400C	25	22.70	210	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-170	100h@400C	25	22.70	117	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-249	120h@400C	25	22.70	216	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-250	120h@400C	25	22.70	299	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-251	120h@400C	25	22.70	267	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-252	120h@400C	25	22.70	255	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	BR604	AS	BRAZED IN VAC@735C	MCB-253	120h@400C	25	22.70	332	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-95	100h@400C	25	22.70	61	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-182	100h@400C	25	22.70	180	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-183	100h@400C	25	22.70	150	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-234	120h@400C	25	22.70	57	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-235	120h@400C	25	22.70	226	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-236	120h@400C	25	22.70	123	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-237	120h@400C	25	22.70	252	2.50	2.00
MS-PSZ	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-238	120h@400C	25	22.70	190	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-110	100h@400C	25	22.70	103	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-184	100h@400C	25	22.70	118	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-185	100h@400C	25	22.70	87	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-239	120h@400C	25	22.70	150	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-240	120h@400C	25	22.70	19	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-241	120h@400C	25	22.70	24	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-242	120h@400C	25	22.70	50	2.50	2.00
MS-PSZ/TI*	CAST IRON	CEC-8003	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-243	120h@400C	25	22.70	71	2.50	2.00
MS-PSZ	A286	-	LithoBT	AS	BRAZED IN VAC@790C	MCB-211	AS RECEIVED	25	22.70	67	2.50	2.00
MS-PSZ	A286	-	LithoBT	AS	BRAZED IN VAC@790C	MCB-212	AS RECEIVED	25	22.70	62	2.50	2.00
MS-PSZ	A286	-	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-199	AS RECEIVED	25	22.70	254	2.50	2.00
MS-PSZ	A286	-	INCUSIL-15ABA	AF	BRAZED IN VAC@775C	MCB-200	AS RECEIVED	25	22.70	340	2.50	2.00
MS-PSZ/TI*	Titanium	ASTM/B265g1	BR604	AS	BRAZED IN VAC@735C	MCB-298	AS BRAZED	25	22.70	375	2.50	2.00
MS-PSZ/TI*	Titanium	ASTM/B265g1	BR604	AS	BRAZED IN VAC@735C	MCB-298	AS BRAZED	25	22.70	469	2.50	2.00
MS-PSZ/TI*	Titanium	ASTM/B265g1	BR604	AS	BRAZED IN VAC@735C	MCB-298	AS BRAZED	25	22.70	343	2.50	2.00

SHEAR STRESS TEST DATA ON WELDED SPECIMENS FROM OAK RIDGE NATIONAL LABORATORY

MATERIAL A	MATERIAL B	MATERIAL B LOT	FILLER MATERIAL	JOINT PROCESS	JOINT	SPEC. NUMBER	HEAT TREATMENT	TEMP C	LOAD N	SHEAR STRESS MPa	WIDTH mm	HEIGHT mm
MS-PSZ	MS-PSZ	ORNL-1	BR604	AS	BRAZED IN VAC@735C	MCB-175	AS BRAZED	25	22.70	365	2.50	2.00
MS-PSZ	MS-PSZ	ORNL-1	BR604	AS	BRAZED IN VAC@735C	MCB-175	AS BRAZED	25	22.70	493	2.50	2.00
MS-PSZ	MS-PSZ	ORNL-1	BR604	AS	BRAZED IN VAC@735C	MCB-175	AS BRAZED	25	22.70	508	2.50	2.00
MS-PSZ	MS-PSZ	ORNL-1	BR604	AS	BRAZED IN VAC@735C	MCB-175	AS BRAZED	25	22.70	462	2.50	2.00
MS-PSZ	MS-PSZ	ORNL-1	BR604	AS	BRAZED IN VAC@735C	MCB-175	AS BRAZED	25	22.70	483	2.50	2.00
MS-PSZ	MS-PSZ	ORNL-1	BR604	AS	BRAZED IN VAC@735C	MCB-267	AS BRAZED	200	22.70	483	2.50	2.00
MS-PSZ	MS-PSZ	ORNL-1	BR604	AS	BRAZED IN VAC@735C	MCB-267	AS BRAZED	200	22.70	347	2.50	2.00
MS-PSZ	MS-PSZ	ORNL-1	BR604	AS	BRAZED IN VAC@735C	MCB-267	AS BRAZED	400	22.70	298	2.50	2.00
MS-PSZ	MS-PSZ	ORNL-1	BR604	AS	BRAZED IN VAC@735C	MCB-267	AS BRAZED	400	22.70	268	2.50	2.00
MS-PSZ	MS-PSZ	ORNL-1	BR604	AS	BRAZED IN VAC@735C	MCB-267	AS BRAZED	400	22.70	361	2.50	2.00
MS-PSZ	CAST IRON	CEC8003	BR604	AS	BRAZED IN VAC@735C	MCB-300	AS BRAZED	25	22.70	380	2.50	2.00
MS-PSZ	CAST IRON	CEC8003	BR604	AS	BRAZED IN VAC@735C	MCB-300	AS BRAZED	25	22.70	356	2.50	2.00
MS-PSZ	CAST IRON	CEC8003	BR604	AS	BRAZED IN VAC@735C	MCB-300	AS BRAZED	25	22.70	399	2.50	2.00
MS-PSZ	CAST IRON	CEC8003	BR604	AS	BRAZED IN VAC@735C	MCB-300	AS BRAZED	25	22.70	354	2.50	2.00
MS-PSZ	CAST IRON	CEC8003	BR604	AS	BRAZED IN VAC@735C	MCB-300	AS BRAZED	25	22.70	369	2.50	2.00

* Material is coated with .6 micrometers of titanium.
All MS-PSZ is from batch coded ORNL-1.

SECTION 4. FRACTURE TOUGHNESS DATA

FRACTURE TOUGHNESS DATA FROM MTL87-29, JUNE 1987
ZIRCONIAS AND ZIRCONIA-TOUGHENED ALUMINAS

MATERIAL	TYPE	HEAT TREATMENT	SPECIMEN ID	TYPE of KIC	TEMP C	LOAD N	STRESS MPa	KIC MPa m
COORS-ZDY	FSZ	AS RECD	SUMOF7	INDENT+4PTB	25	20	0	3.010
AC-SENSOR	PSZ	100h@1000C	SUMOF2	INDENT+4PTB	25	200	0	4.090
AC-SENSOR	PSZ	100h@1000C	SUMOF12	INDENT+4PTB	25	0	0	3.930
AC-SENSOR	PSZ	500h@1000C	SUMOF3	INDENT+4PTB	25	100	0	3.840
AC-SENSOR	PSZ	500h@1000C	SUMOF8	INDENT+4PTB	25	20	0	4.100
AC-SENSOR	PSZ	500h@1000C	SUMOF2	INDENT+4PTB	25	150	0	3.800
AC-SENSOR	PSZ	AS RECD	SUMOF6	INDENT+4PTB	25	100	0	4.100
ZT-35	PSZ	100h@1000C	SUMOF2	INDENT+4PTB	25	200	0	8.960
ZT-35	PSZ	100h@1000C	SUMOF11	INDENT+4PTB	25	100	0	9.440
ZT-35	PSZ	500h@1000C	SUMOF3	INDENT+4PTB	25	150	0	6.900
ZT-35	PSZ	500h@1000C	SUMOF3	INDENT+4PTB	25	200	0	6.990
ZT-35	PSZ	500h@1000C	SUMOF1	INDENT+4PTB	25	20	0	5.490
ZT-35	PSZ	500h@1000C	SUMOF2	INDENT+4PTB	25	250	0	7.220
ZT-35	PSZ	500h@1000C	SUMOF3	INDENT+4PTB	25	100	0	6.660
ZT-35	PSZ	AS RECD	SUMOF5	INDENT+4PTB	25	100	0	5.260
ZT-35	PSZ	AS RECD	SUMOF4	INDENT+4PTB	25	150	0	5.080
ZT-35	PSZ	AS RECD	SUMOF5	INDENT+4PTB	25	50	0	5.310
TS-TTZ	TTZ	100h@1000C	SUMOF12	INDENT+4PTB	25	100	0	6.520
TS-TTZ	TTZ	500h@1000C	SUMOF3	INDENT+4PTB	25	150	0	6.400
TS-TTZ	TTZ	500h@1000C	SUMOF4	INDENT+4PTB	25	100	0	6.060
TS-TTZ	TTZ	500h@1000C	SUMOF3	INDENT+4PTB	25	50	0	5.870
TS-TTZ	TTZ	AS RECD	SUMOF4	INDENT+4PTB	25	100	0	7.880
MS-TTZ	TTZ	100h@1000C	SUMOF7	INDENT+4PTB	25	100	0	8.870
MS-TTZ	TTZ	500h@1000C	SUMOF7	INDENT+4PTB	25	100	0	5.610
MS-TTZ	TTZ	AS RECD	SUMOF9	INDENT+4PTB	25	100	0	10.400
COORS-ZDM	TTZ	100h@1000C	SUMOF5	INDENT+4PTB	25	100	0	6.120
COORS-ZDM	TTZ	100h@1000C	SUMOF6	INDENT+4PTB	25	150	0	6.230
COORS-ZDM	TTZ	500h@1000C	SUMOF3	INDENT+4PTB	25	150	0	5.320
COORS-ZDM	TTZ	500h@1000C	SUMOF3	INDENT+4PTB	25	100	0	4.510
COORS-ZDM	TTZ	500h@1000C	SUMOF3	INDENT+4PTB	25	250	0	5.960
COORS-ZDM	TTZ	AS RECD	SUMOF4	INDENT+4PTB	25	150	0	10.690
COORS-ZDM	TTZ	AS RECD	SUMOF4	INDENT+4PTB	25	250	0	11.570
COORS-ZDM	TTZ	AS RECD	SUMOF4	INDENT+4PTB	25	100	0	10.190
ZIRCOA2120	TTZ	100h@1000C	SUMOF3	INDENT+4PTB	25	150	0	5.470
ZIRCOA2120	TTZ	100h@1000C	SUMOF3	INDENT+4PTB	25	100	0	5.360
ZIRCOA2120	TTZ	100h@1000C	SUMOF1	INDENT+4PTB	25	30	0	4.530
ZIRCOA2120	TTZ	500h@1000C	SUMOF3	INDENT+4PTB	25	50	0	5.150
ZIRCOA2120	TTZ	500h@1000C	SUMOF3	INDENT+4PTB	25	150	0	5.490
ZIRCOA2120	TTZ	500h@1000C	SUMOF3	INDENT+4PTB	25	100	0	5.580
ZIRCOA2120	TTZ	AS RECD	SUMOF2	INDENT+4PTB	25	150	0	10.510
ZIRCOA2120	TTZ	AS RECD	SUMOF8	INDENT+4PTB	25	100	0	8.730
ZIRCOA2120	TTZ	AS RECD	SUMOF1	INDENT+4PTB	25	20	0	5.540
NRL-TZP	TZP	100h@1000C	SUMOF3	INDENT+4PTB	25	100	0	4.630
NRL-TZP	TZP	500h@1000C	SUMOF3	INDENT+4PTB	25	100	0	4.880
NRL-TZP	TZP	AS RECD	SUMOF2	INDENT+4PTB	25	100	0	5.030
COORS-TZP	TZP	100h@1000C	SUMOF17	INDENT+4PTB	25	100	0	6.830
COORS-TZP	TZP	500h@1000C	SUMOF17	INDENT+4PTB	25	100	0	8.380
COORS-TZP	TZP	AS RECD	SUMOF14	INDENT+4PTB	25	100	0	6.810
Z-191	TZP	500h@1000C	SUMOF2	INDENT+4PTB	25	100	0	8.680
TOSH-TZP	TZP	100h@1000C	SUMOF8	INDENT+4PTB	25	150	0	6.840
TOSH-TZP	TZP	500h@1000C	SUMOF6	INDENT+4PTB	25	150	0	6.730
TOSH-TZP	TZP	AS RECD	SUMOF8	INDENT+4PTB	25	150	0	7.040

FRACTURE TOUGHNESS DATA FROM MTL87-29, JUNE 1987
ZIRCONIAS AND ZIRCONIA-TOUGHENED ALUMINAS

MATERIAL	TYPE	HEAT TREATMENT	SPECIMEN ID	TYPE of KIC	TEMP C	LOAD N	STRESS MPa	KIC MPa m
TOSH-TZP	TZP	AS RECD	SUMOF1	INDENT+4PTB	25	100	0	8.190
TOR-TZPSIN	TZP	AS RECD	SUMOF1	INDENT+4PTB	25	100	0	11.630
UM-ZTA1	ZTA	100h@1000C	SUMMARY	INDENT+4PTB	25	100	371	4.850
UM-ZTA1	ZTA	500h@1000C	SUMMARY	INDENT+4PTB	25	100	450	4.560
UM-ZTA1	ZTA	AS RECD	SUMMARY	INDENT+4PTB	25	100	436	4.860
UM-ZTA2/HI	ZTA	500h@1000C	SUMMARY	INDENT+4PTB	25	100	410	4.930
UM-ZTA2/HI	ZTA	AS RECD	SUMMARY	INDENT+4PTB	25	100	457	4.970
UM-ZTA2/LO	ZTA	AS RECD	SUMMARY	INDENT+4PTB	25	100	122	3.520
UM-ZTA2/ME	ZTA	500h@1000C	SUMMARY	INDENT+4PTB	25	100	286	0.000
UM-ZTA3/HI	ZTA	500h@1000C	SUMMARY	INDENT+4PTB	25	100	413	3.940
UM-ZTA3/HI	ZTA	AS RECD	SUMMARY	INDENT+4PTB	25	100	386	4.980
UM-ZTA3/ME	ZTA	500h@1000C	SUMMARY	INDENT+4PTB	25	100	373	3.470
UM-ZTA4	ZTA	100h@1000C	SUMMARY	INDENT+4PTB	25	100	398	4.950
UM-ZTA4	ZTA	500h@1000C	SUMMARY	INDENT+4PTB	25	100	456	4.700
UM-ZTA4	ZTA	AS RECD	SUMMARY	INDENT+4PTB	25	100	0	5.290
UM-ZTM5	ZTM	500h@1000C	SUMMARY	INDENT+4PTB	25	100	296	0.000
UM-ZTM5	ZTM	AS RECD	SUMMARY	INDENT+4PTB	25	100	260	0.000
UM-ZTM6	ZTM	500h@1000C	SUMMARY	INDENT+4PTB	25	100	292	0.000
UM-ZTM6	ZTM	AS RECD	SUMMARY	INDENT+4PTB	25	100	286	0.000

SECTION 5. TENSILE DATA

PART 5A. Tensile data table

TENSILE DATA FROM OAK RIDGE NATIONAL LABORATORY*

MATERIAL	BATCH CODE	SPECIMEN NUMBER	TEMP (C)	TENSILE STRENGTH (MPa)	YOUNG'S MODULUS (GPa)
TS-PSZ	NILCRA/ORNL-1	15	25	326	0
TS-PSZ	NILCRA/ORNL-1	16	25	448	0
TS-PSZ	NILCRA/ORNL-1	7	400	376	0
TS-PSZ	NILCRA/ORNL-1	8	400	314	0
TS-PSZ	NILCRA/ORNL-1	2	800	292	167
TS-PSZ	NILCRA/ORNL-1	3	800	269	156
TS-PSZ	NILCRA/ORNL-1	13	1000	253	145
TS-PSZ	NILCRA/ORNL-1	12	1000	244	148

* This data came from reference 3.

PART 5B. Tensile graph

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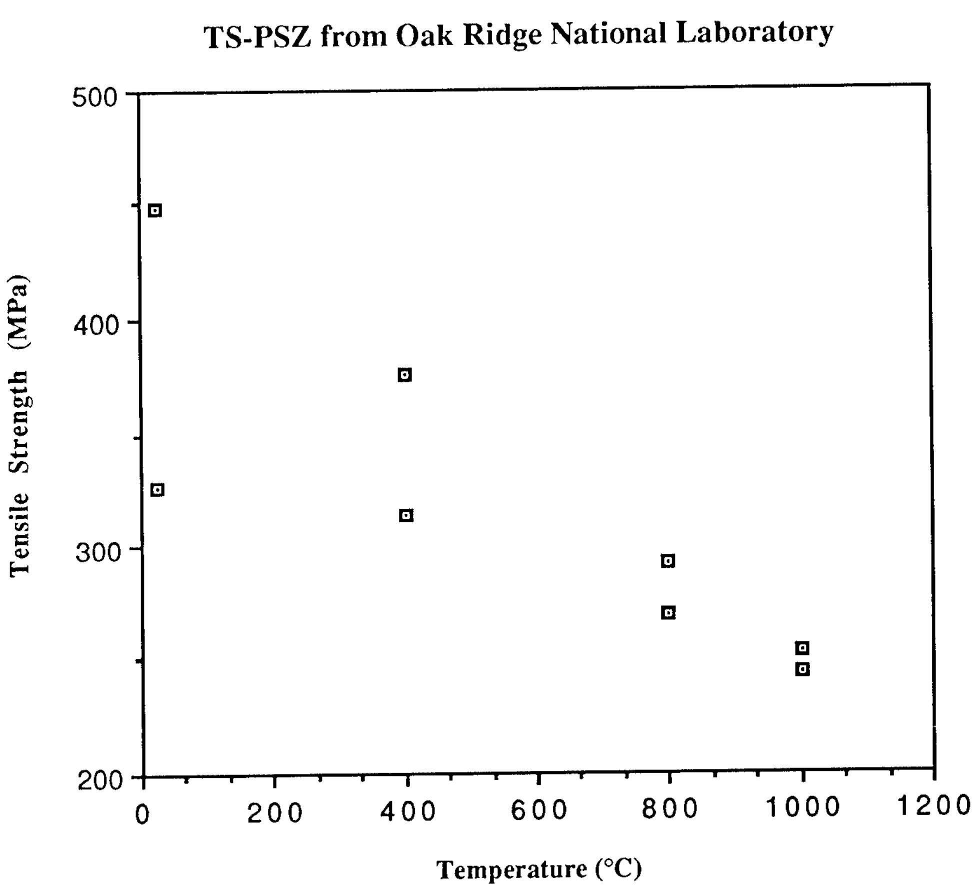

Figure 6. Tensile strength vs temperature for Nilcra's MgO partially stabilized zirconia, thermal shock grade.

SECTION 6. WEIBULL INFORMATION

PART 6A. Weibull data

WEIBULL INFORMATION FOR MATERIALS REPORTED IN MTL87-29

MATERIAL	BATCH CODE	HEAT TREATMENT	NUMBER OF TESTS	AVERAGE STRENGTH MPa	WEIBULL INTERCEPT	WEIBULL MODULUS
AC-SENSOR	AMTL-A/ACS82	AS RECD	8	309	324	10.20
AC-SENSOR	AMTL-A/ACS82	500h@1000C	12	274	303	4.30
AC-SENSOR	AMTL-A/ACS82	100h@1000C	12	314	342	5.60
NRL-TZP	AMTL-B/NRL82	AS RECD	2	708	0	0.00
NRL-TZP	AMTL-B/NRL82	500h@1000C	2	624	0	0.00
NRL-TZP	AMTL-B/NRL82	100h@1000C	3	659	0	0.00
TS-TTZ	AMTL-D/NILSEN82	AS RECD	10	588	609	14.10
TS-TTZ	AMTL-D/NILSEN82	500h@1000C	9	392	405	15.60
TS-TTZ	AMTL-D/NILSEN82	100h@1000C	13	385	409	7.80
MS-TTZ	AMTL-E/NILSEN82	AS RECD	14	640	665	13.40
MS-TTZ	AMTL-E/NILSEN82	500h@1000C	9	288	307	7.40
MS-TTZ	AMTL-E/NILSEN82	100h@1000C	8	493	505	21.40
CERAD-FSZ	AMTL-F/CERAD82	AS RECD	4	207	0	0.00
COORS-ZDM	AMTL-G/COORS81	AS RECD	13	186	190	21.40
COORS-ZDM	AMTL-H/COORS83	AS RECD	12	534	596	4.20
COORS-ZDM	AMTL-H/COORS83	500h@1000C	11	240	252	9.90
COORS-ZDM	AMTL-H/COORS83	100h@1000C	12	320	327	24.60
COORS-TZP	AMTL-I/COORS84	AS RECD	14	921	1010	4.50
COORS-TZP	AMTL-I/COORS84	500h@1000C	16	998	1154	2.90
COORS-TZP	AMTL-I/COORS84	100h@1000C	15	920	1026	2.40
COORS-ZDY	AMTL-J/COORS81	AS RECD	10	242	250	16.00
ZT-35	AMTL-L/AFC82	AS RECD	10	445	483	5.90
ZT-35	AMTL-L/AFC82	500h@1000C	12	314	328	11.40
ZT-35	AMTL-L/AFC82	100h@1000C	13	592	624	9.50
NGK-TZP	AMTL-N/NGKN	AS RECD	5	758	827	13.50
TOSH-TZP	AMTL-P/TOSHBA83	AS RECD	9	518	544	10.20
TOSH-TZP	AMTL-P/TOSHBA83	500h@1000C	7	457	488	6.80
TOSH-TZP	AMTL-P/TOSHBA83	100h@1000C	8	560	597	7.50
TOR-TZPHP	AMTL-Q/TORAY83	AS RECD	3	1159	0	0.00
TOR-TZPHP	AMTL-Q/TORAY83	500h@1000C	3	237	0	0.00
TOR-TZPSIN	AMTL-R/TORAY83	AS RECD	1	954	0	0.00
TOR-TZPSIN	AMTL-R/TORAY83	500h@1000C	2	212	0	0.00
ZIRCOA2120	AMTL-S/CGW	AS RECD	20	511	543	7.70
ZIRCOA2120	AMTL-S/CGW	500h@1000C	11	327	341	11.60
ZIRCOA2120	AMTL-S/CGW	100h@1000C	15	312	324	13.60

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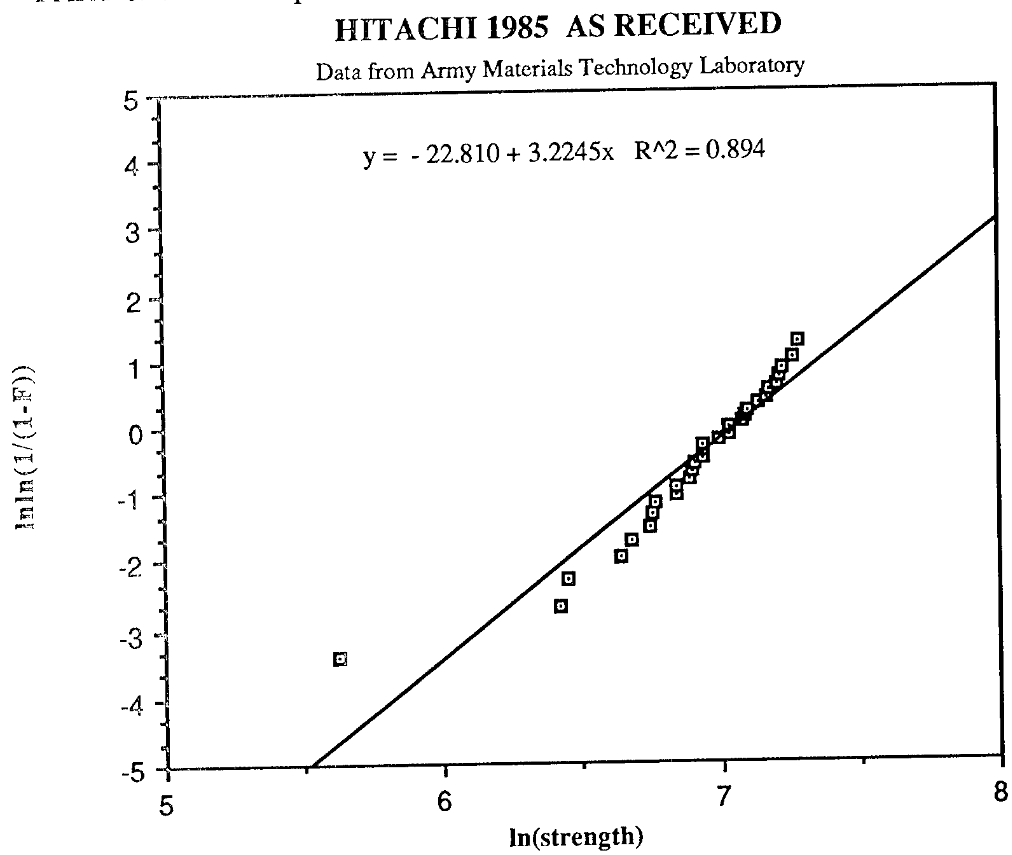

Figure 8. Weibull plot for Hitacchi 1985 in as received condition.

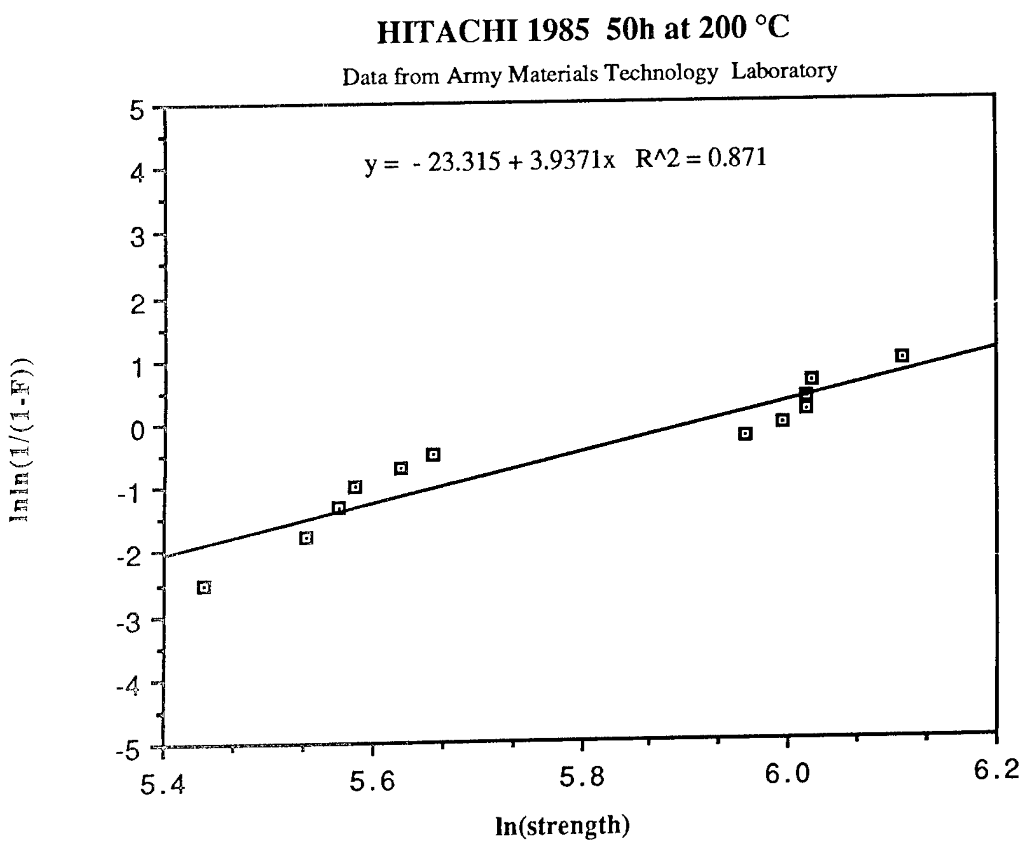

Figure 9. Weibull plot for Hitachi 1985 after 50 hours at 200°C.

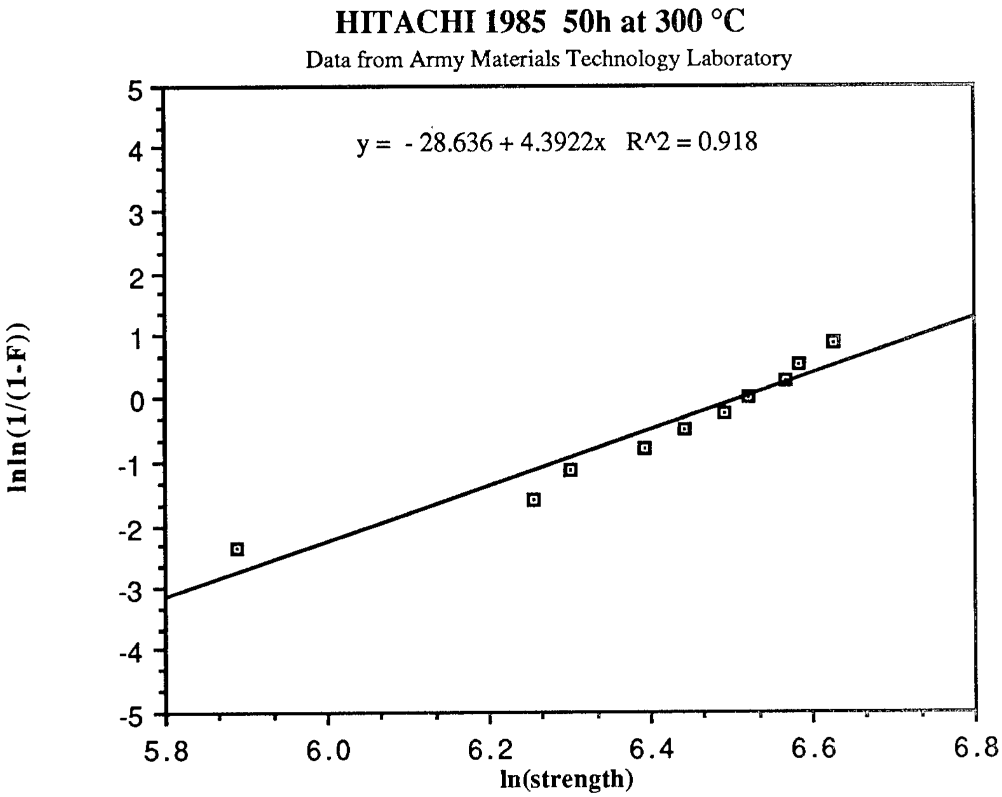

Figure 9. Weibull plot for Hitachi 1985 after 50 hours at 300°C.

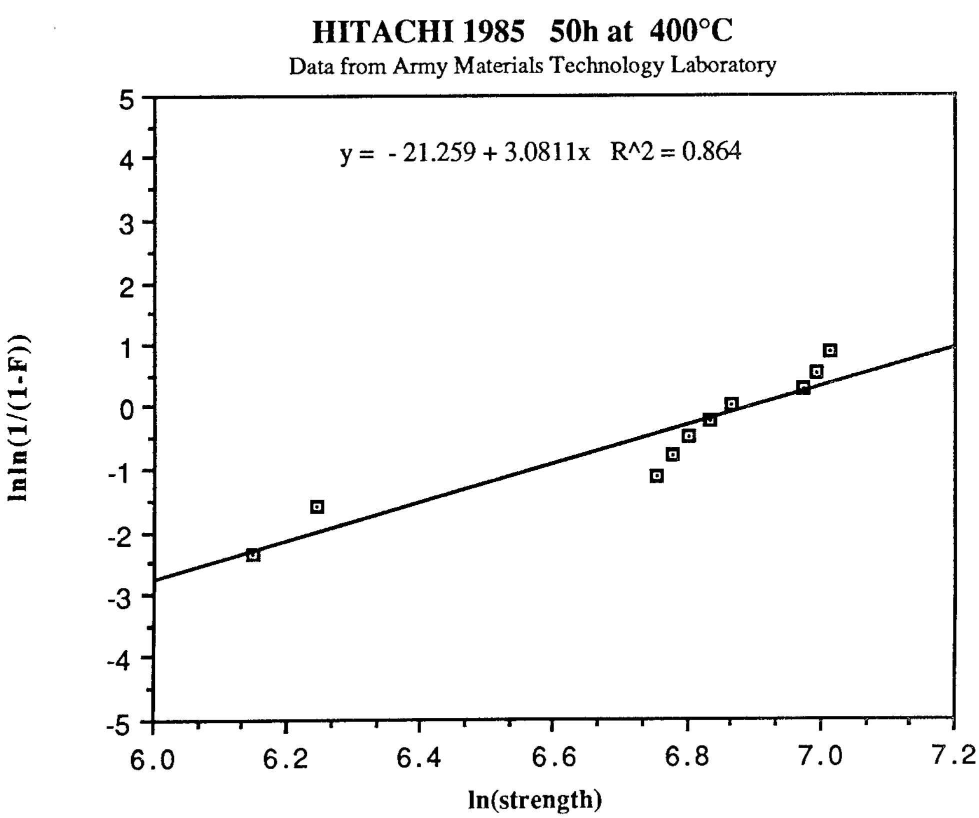

Figure 10. Weibull plot for Hitachi 1985 after 50 hours at 400°C.

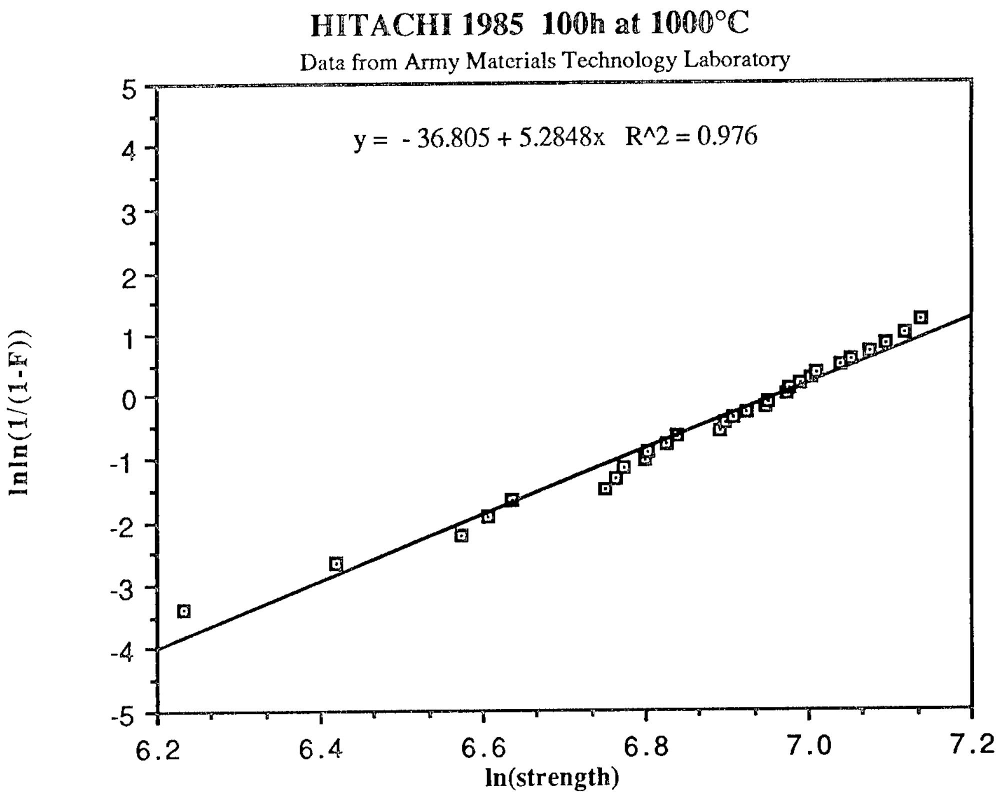

Figure 11. Weibull plot for Hitachi 1985 after 100 hours at 1000°C.

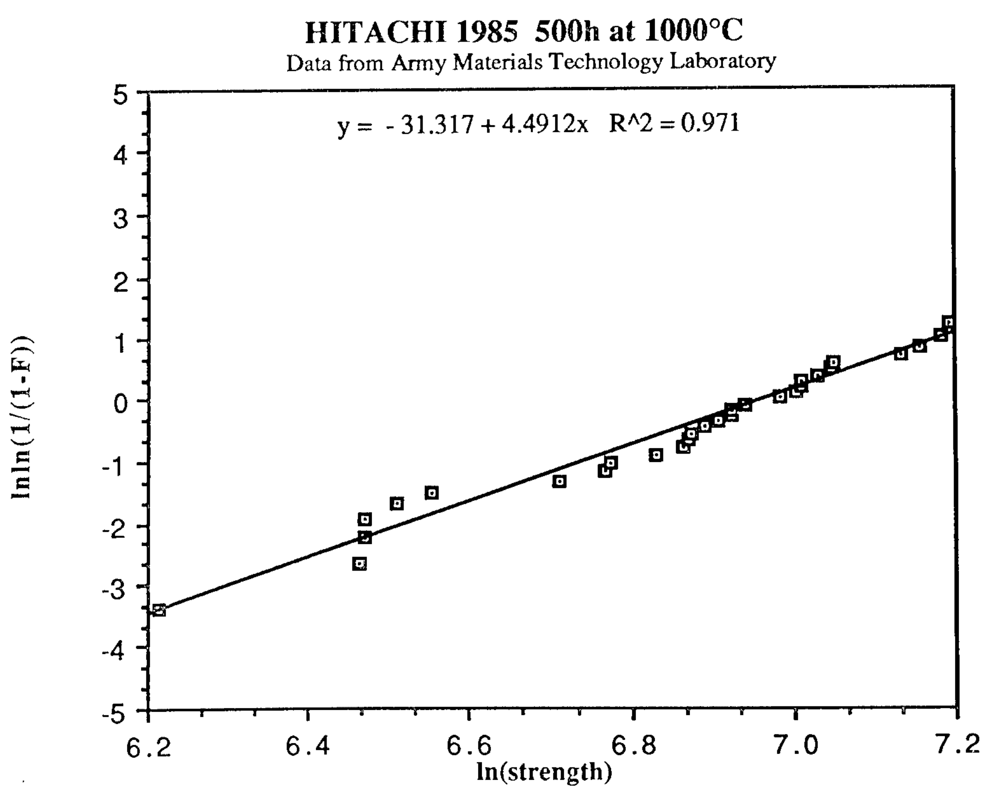

Figure 12. Weibull plot for Hitachi 1985 after 500 hours at 1000°C.

ORNL-DWG 88-16432

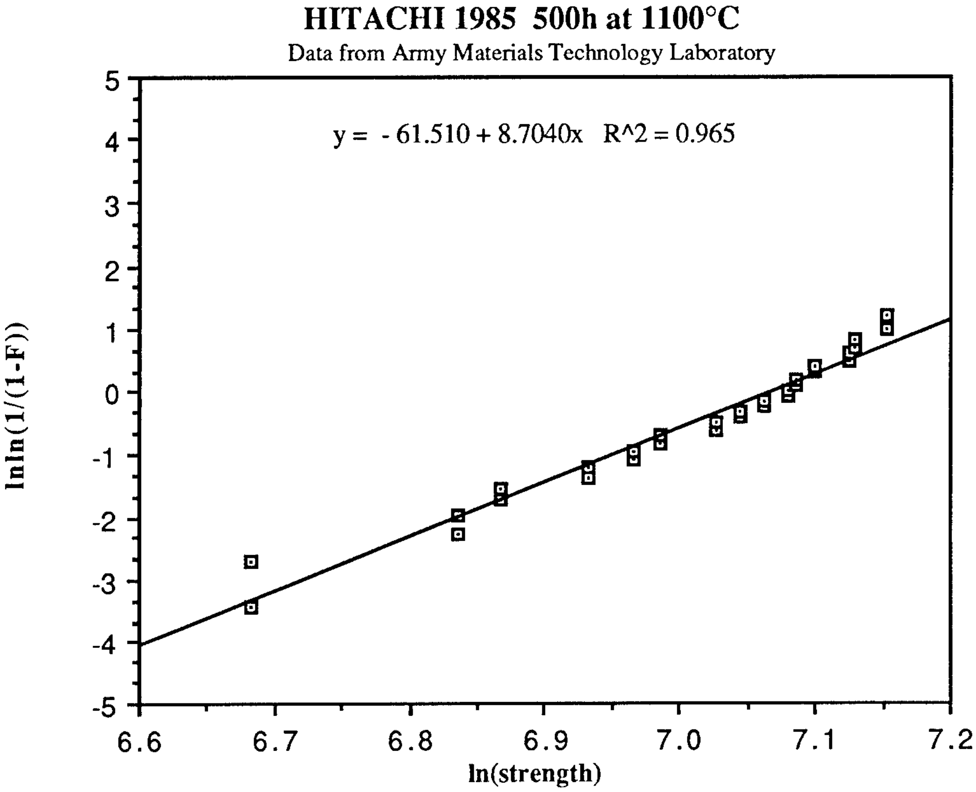

Figure 13. Weibull plot for Hitachi 1985 after 500 hours at 1100°C.

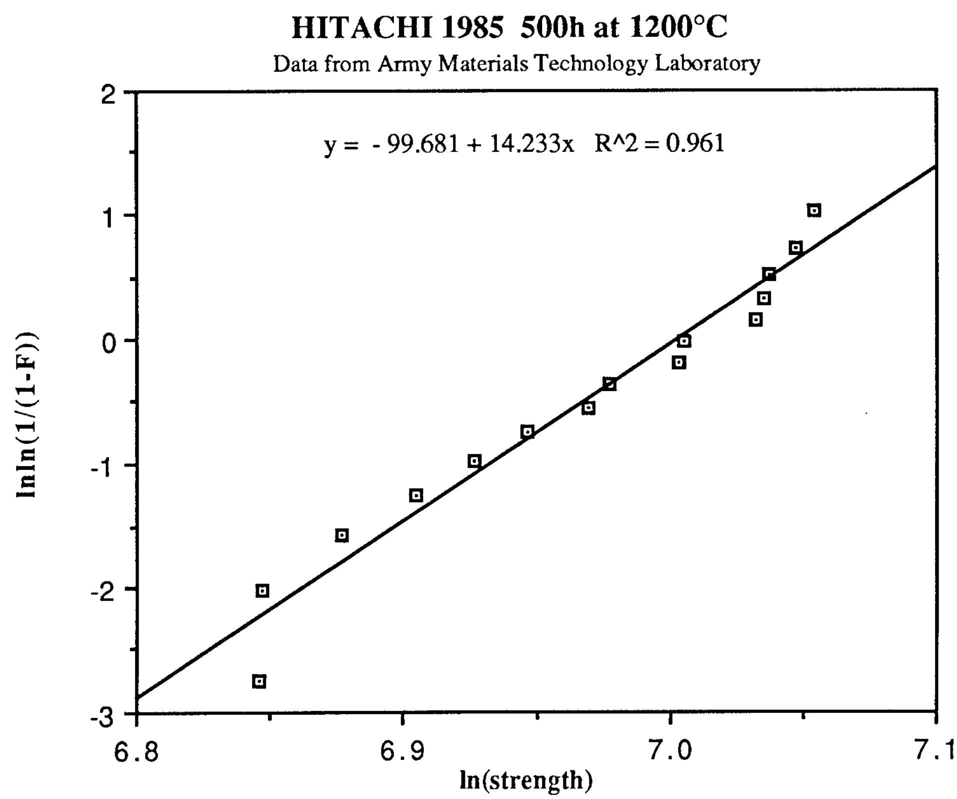

Figure 14. Weibull plot for Hitachi 1985 after 500 hours at 1200°C.

ORNL-DWG 88-16433

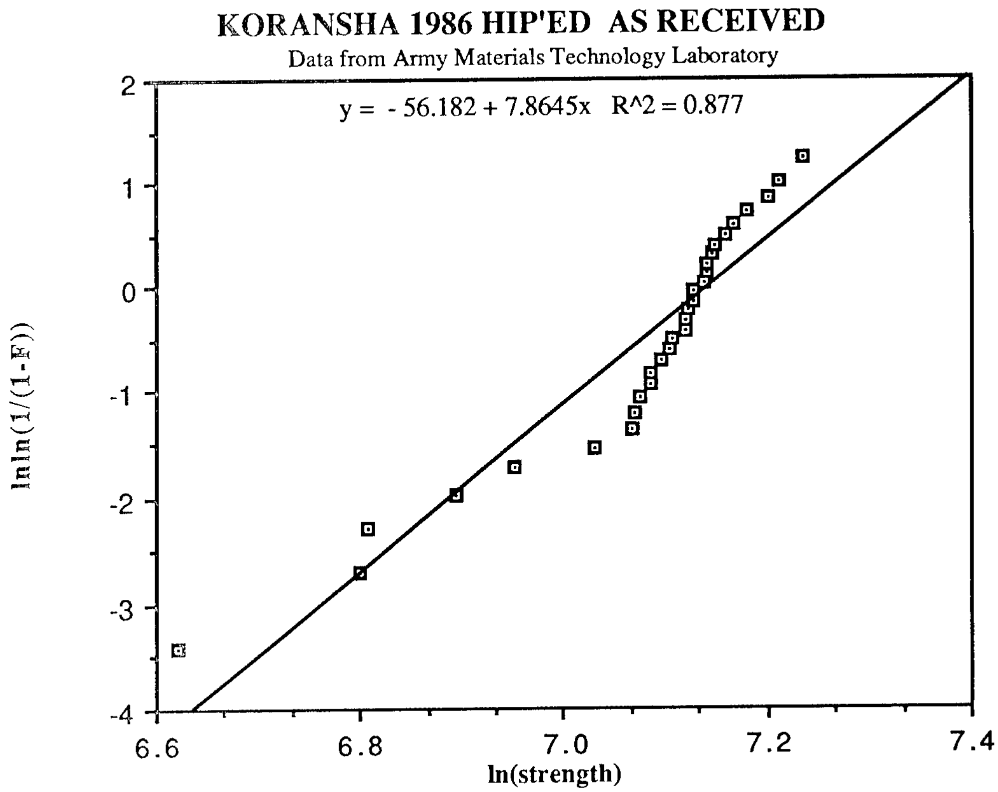

Figure 15. Weibull plot for Koransha 1986H in as received condition.

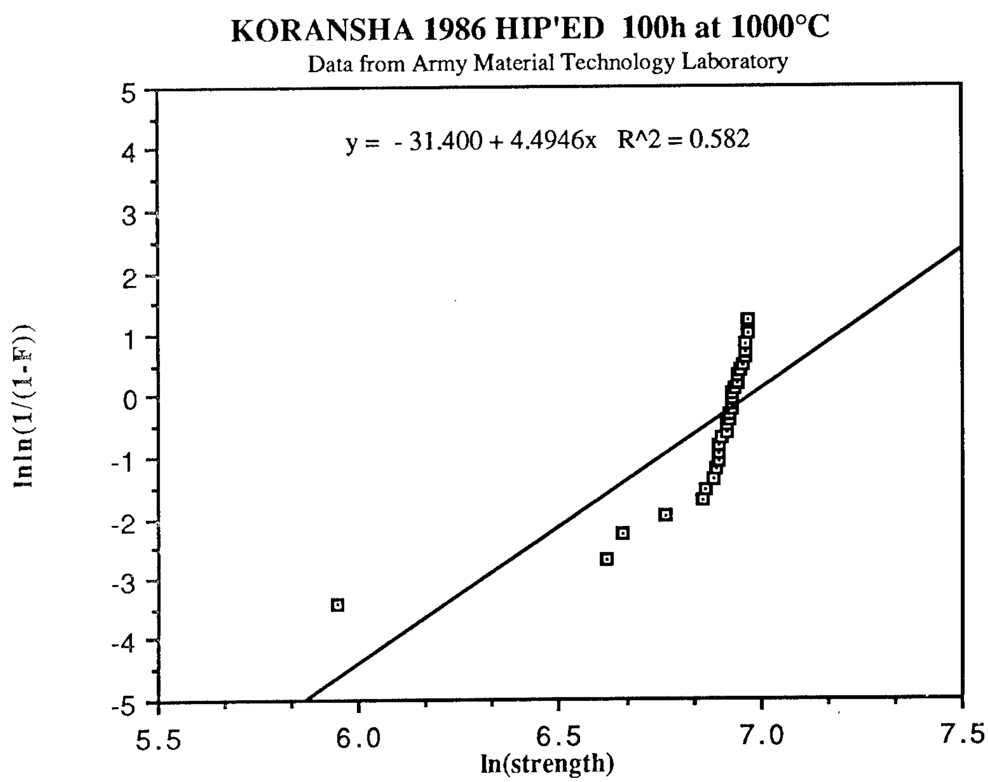

Figure 16. Weibull plot for Koransha 1986H after 100 hours at 1000°C.

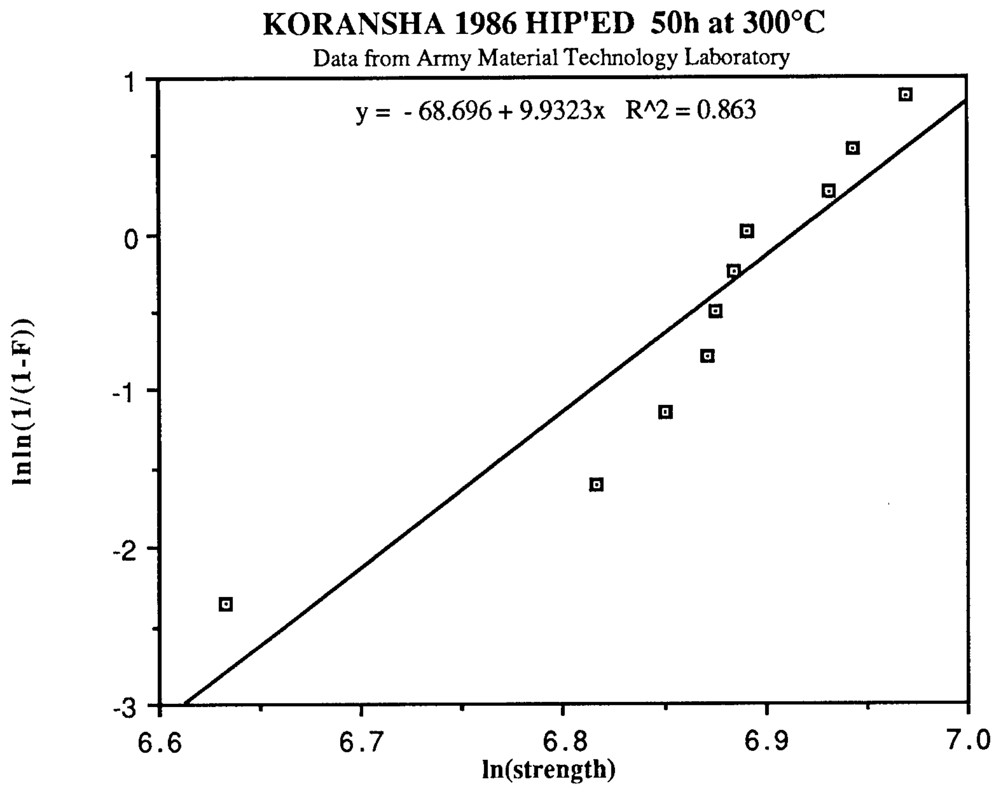

Figure 17. Weibull plot for Koransha 1986H after 50 hours at 300°C.

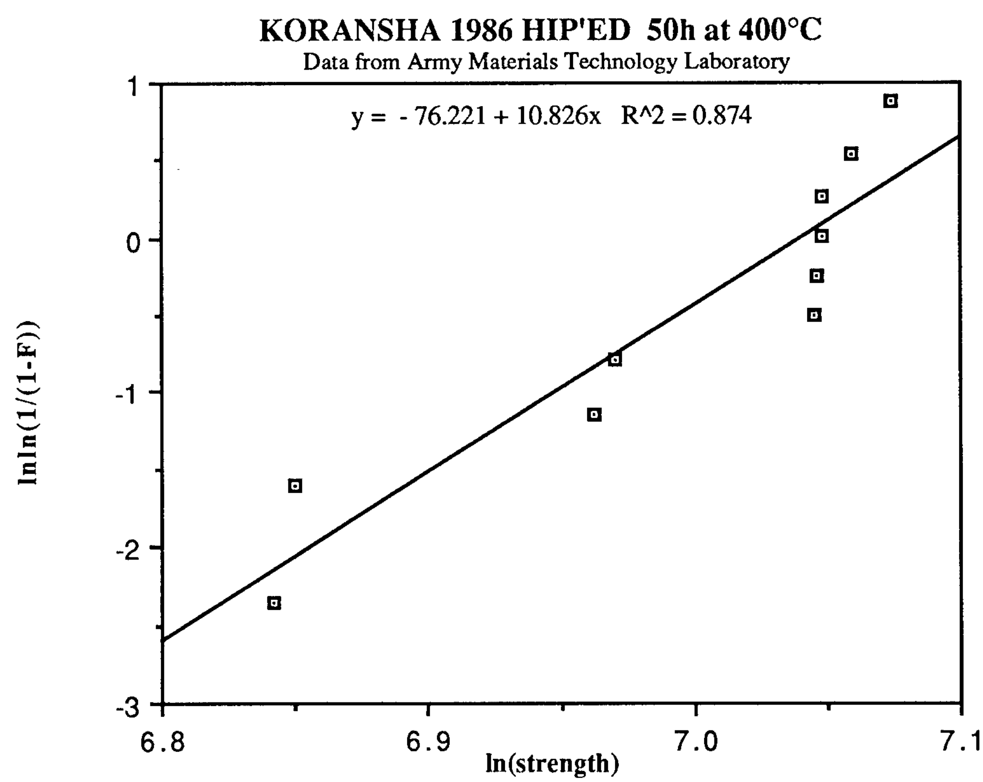

Figure 18. Weibull plot for Koransha 1986H after 50 hours at 400°C.

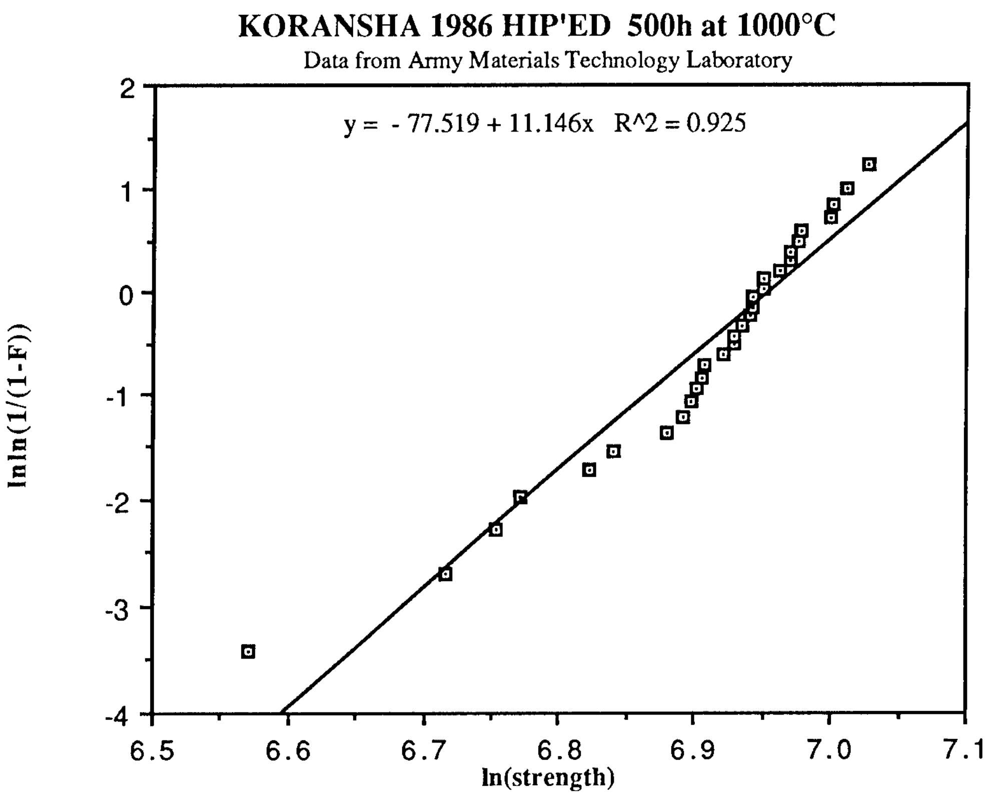

Figure 19. Weibull plot for Koransha 1986H after 500 hours at 1000°C.

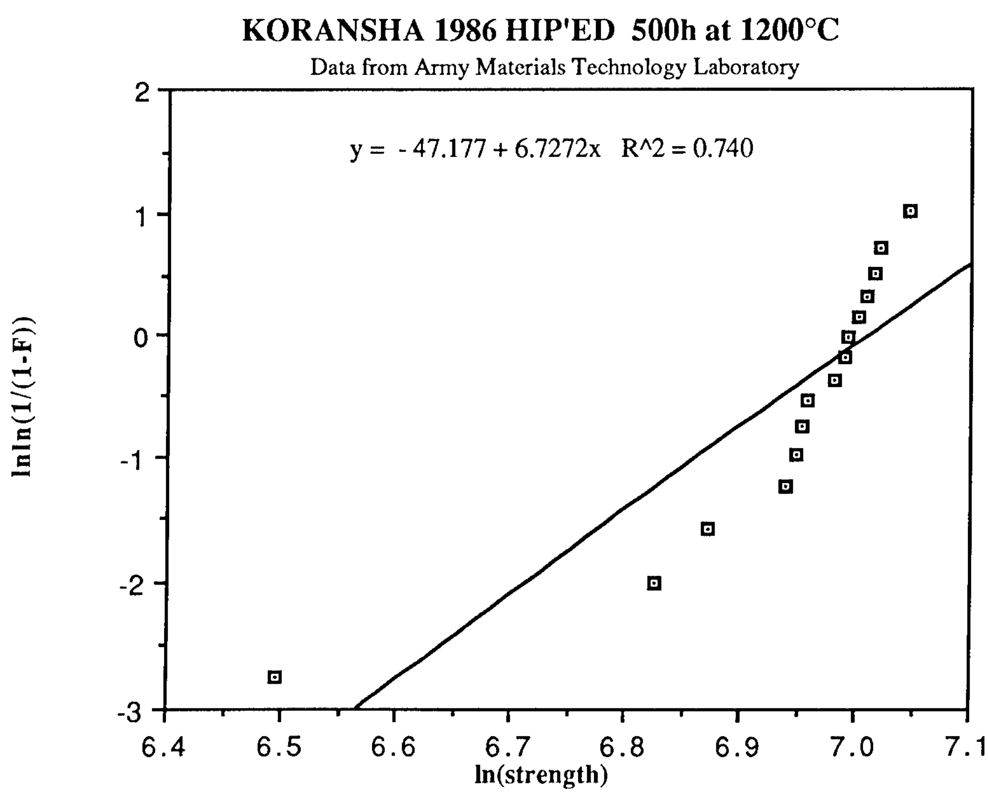

Figure 20. Weibull plot for Koransha 1986H after 500 hours at 1200°C.

ORNL-DWG 88-16436

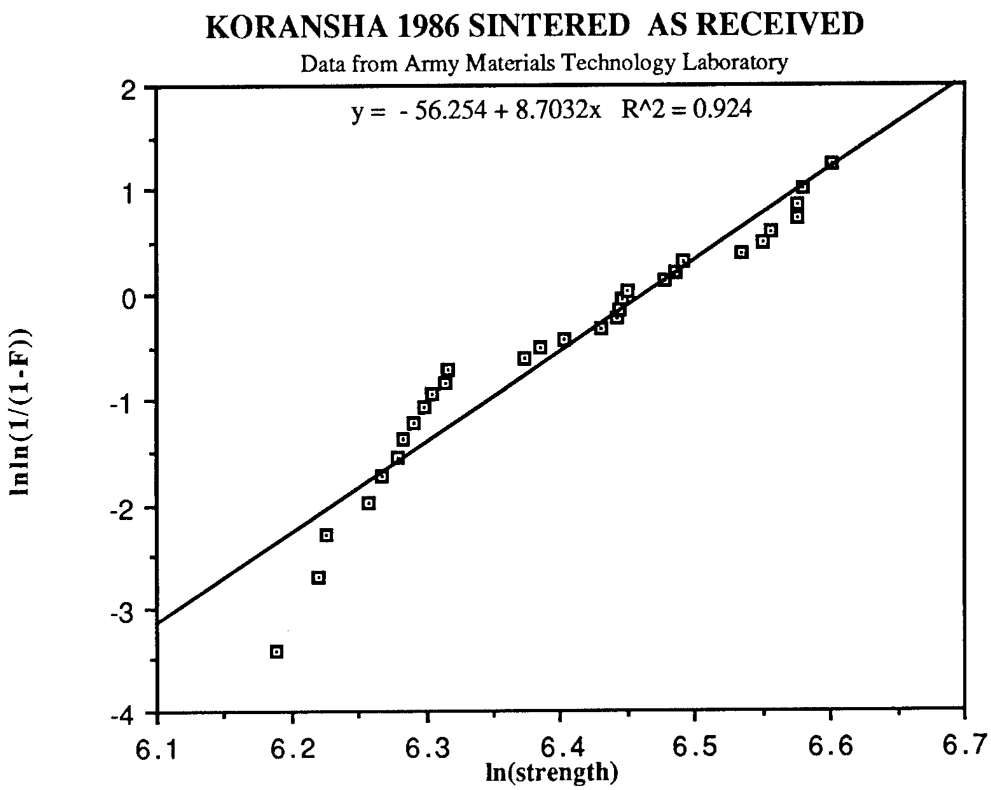

Figure 21. Weibull plot for Koransha 1986S in as received condition.

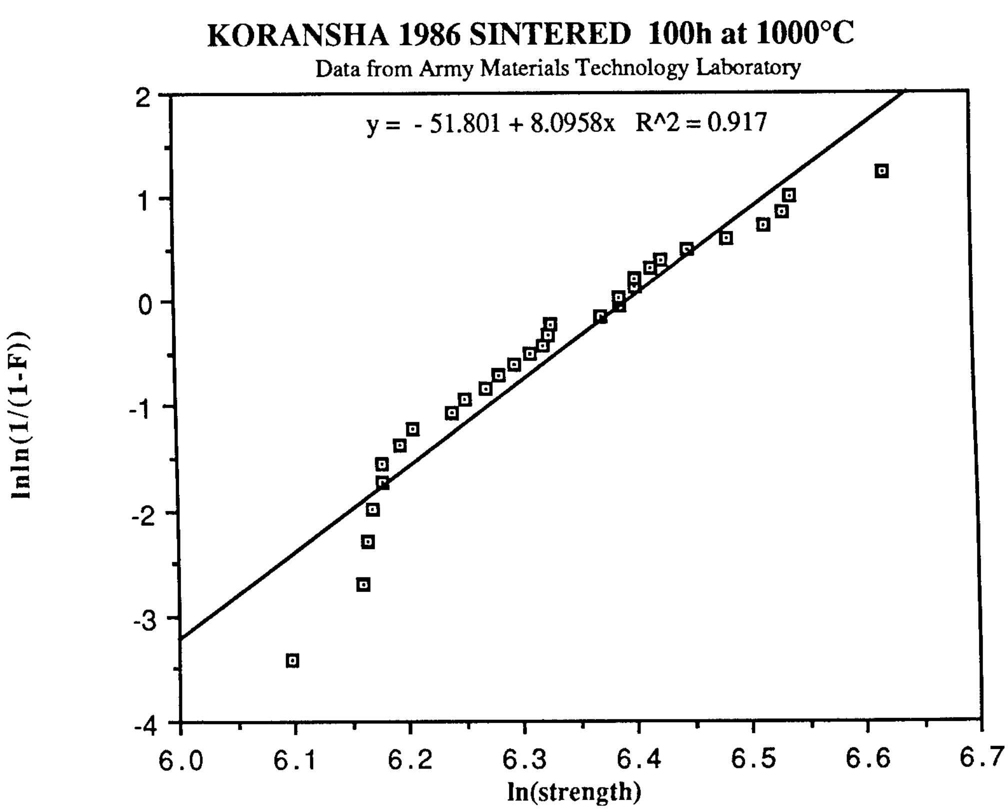

Figure 22. Weibull plot for Koransha 1986S after 100 hours at 1000°C.

ORNL-DWG 88-16437

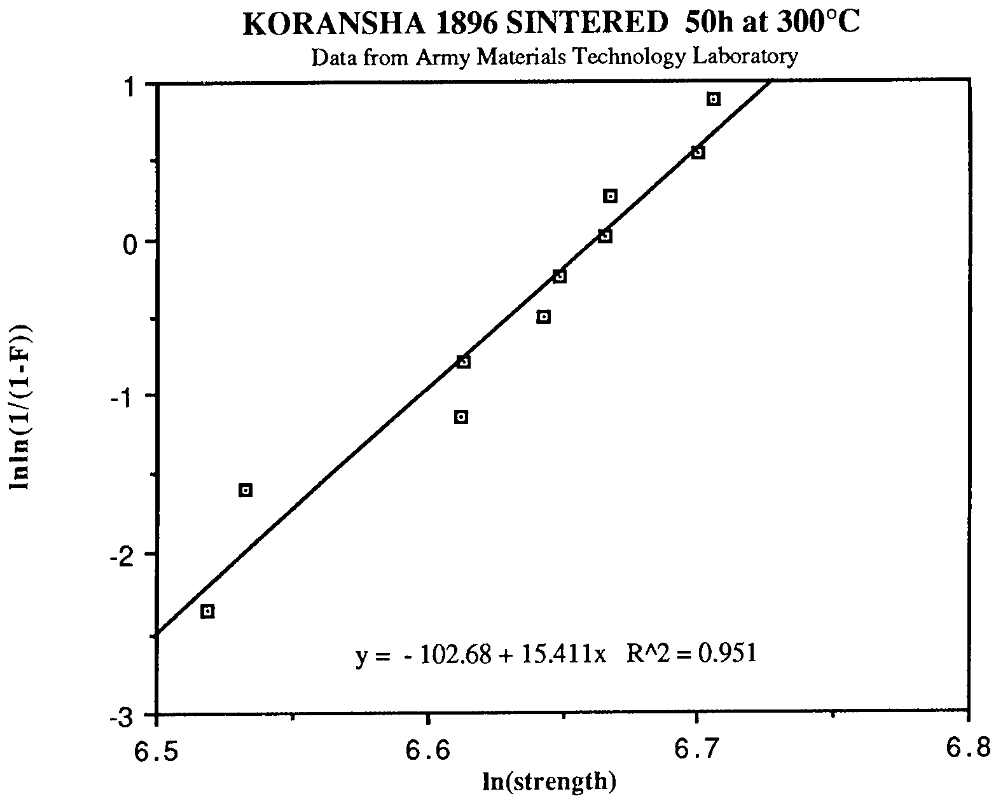

Figure 23. Weibull plot for Koransha 1986S after 50 hours at 300°C.

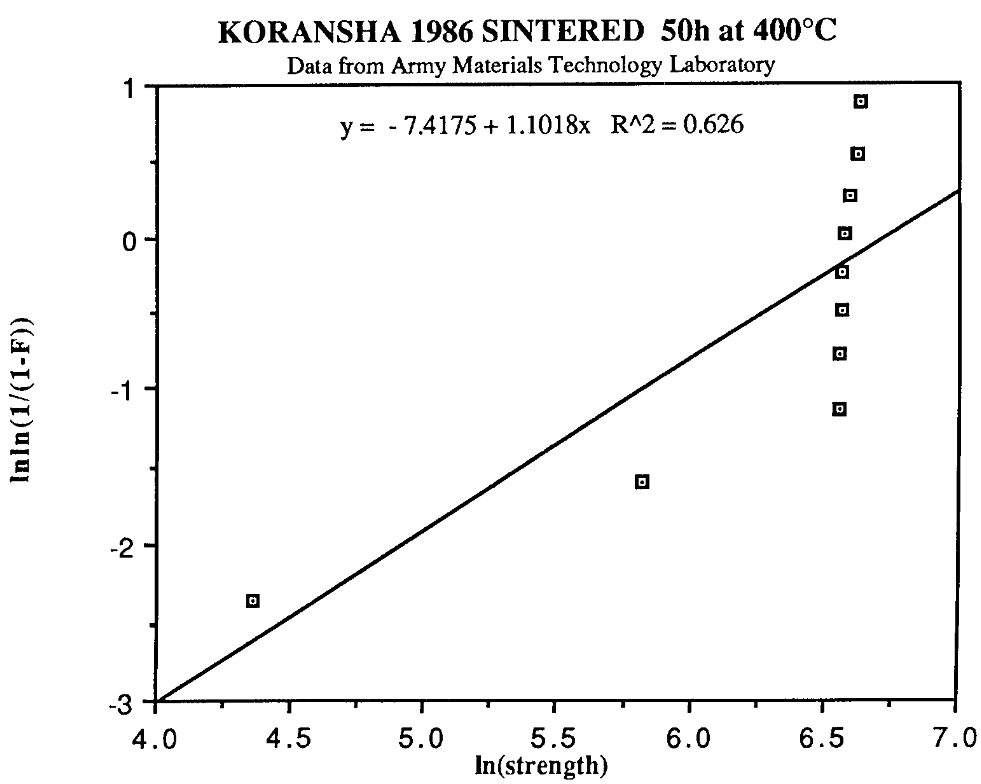

Figure 24. Weibull plot for Koransha 1986S after 50 hours at 400°C.

ORNL-DWG 88-16438

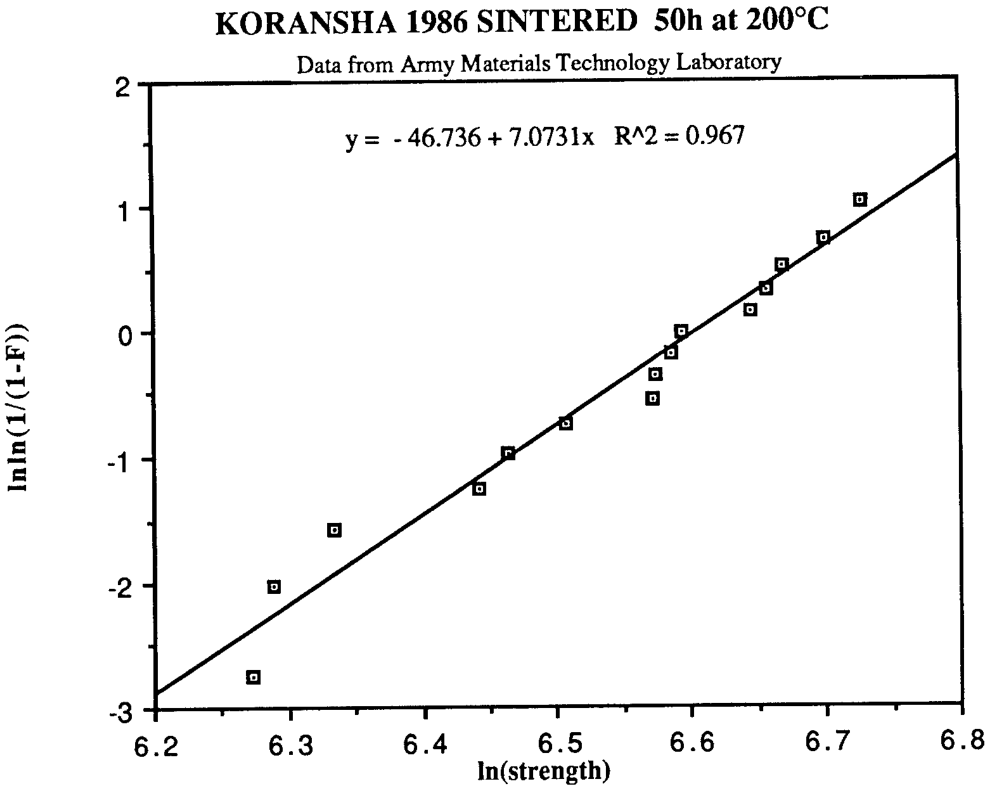

Figure 25. Weibull plot for Koransha 1986S after 50 hours at 200 °C.

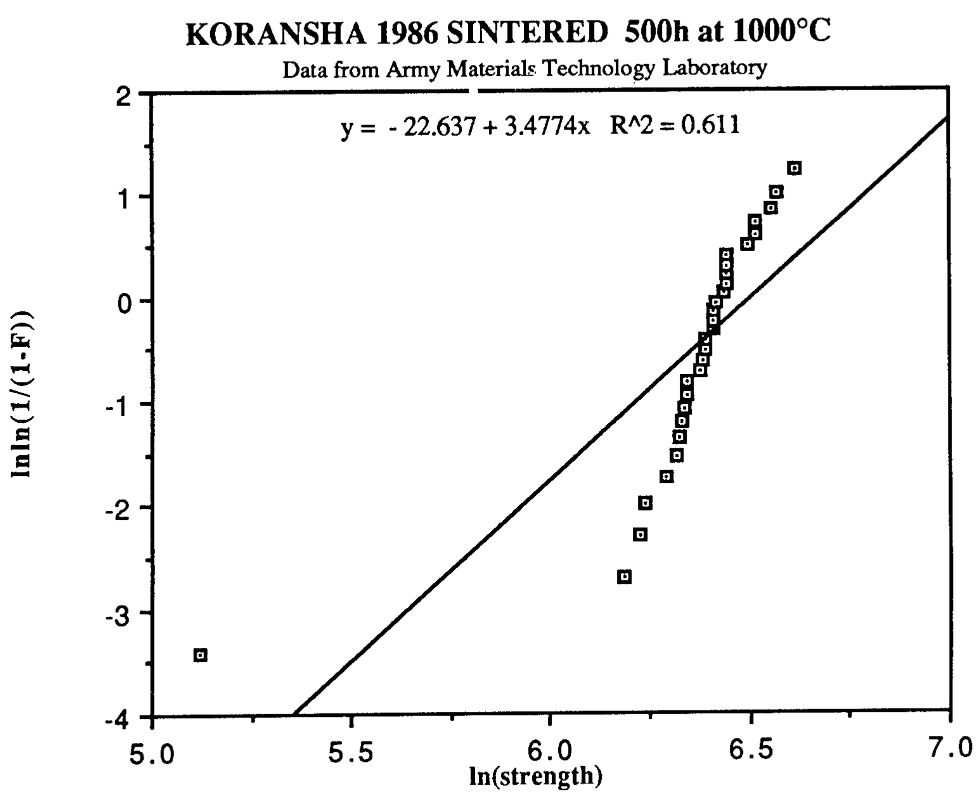

Figure 26. Weibull plot for Koransha 1986S after 500 hours at 1000°C.

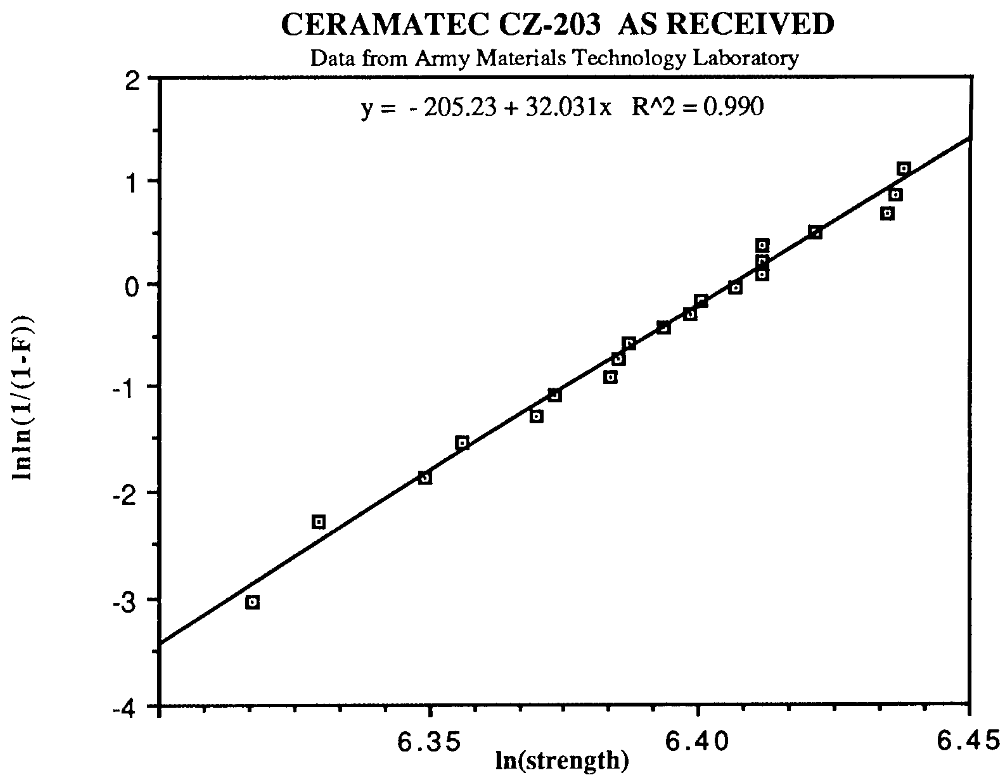

Figure 27. Weibull plot for Ceramatec CZ-203 in as received condition.

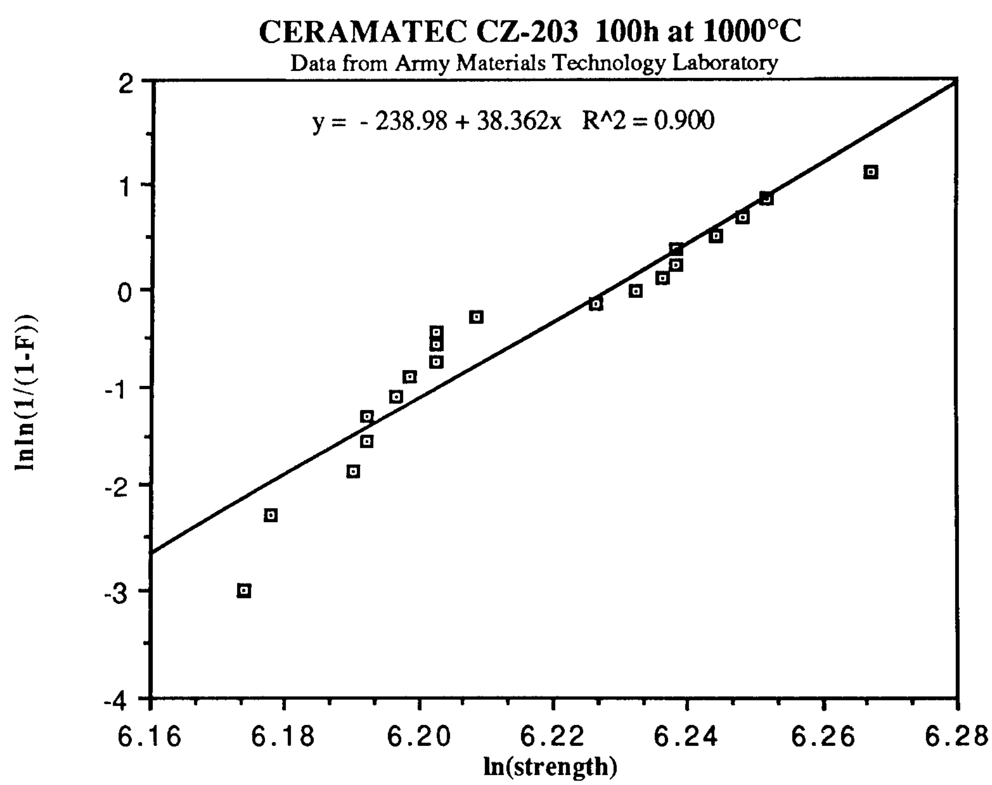

Figure 28. Weibull plot for Ceramatec CZ-203 after 100 hours at 1000°C.

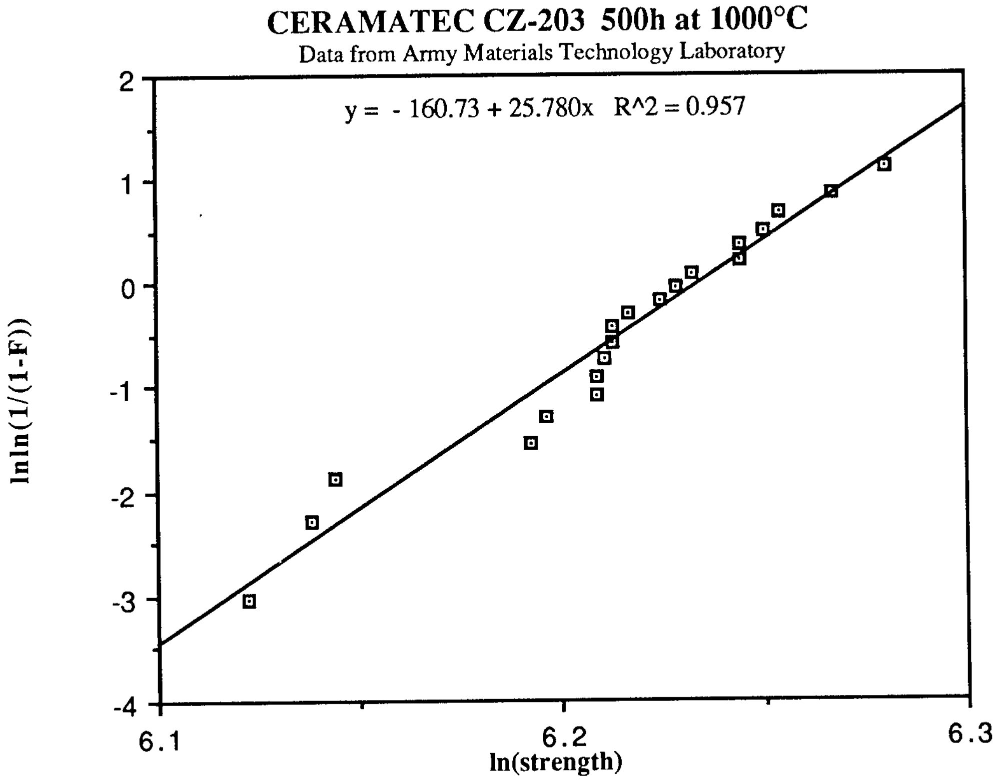

Figure 29. Weibull plot for Ceramatec CZ-203 after 500 hours at 1000°C.

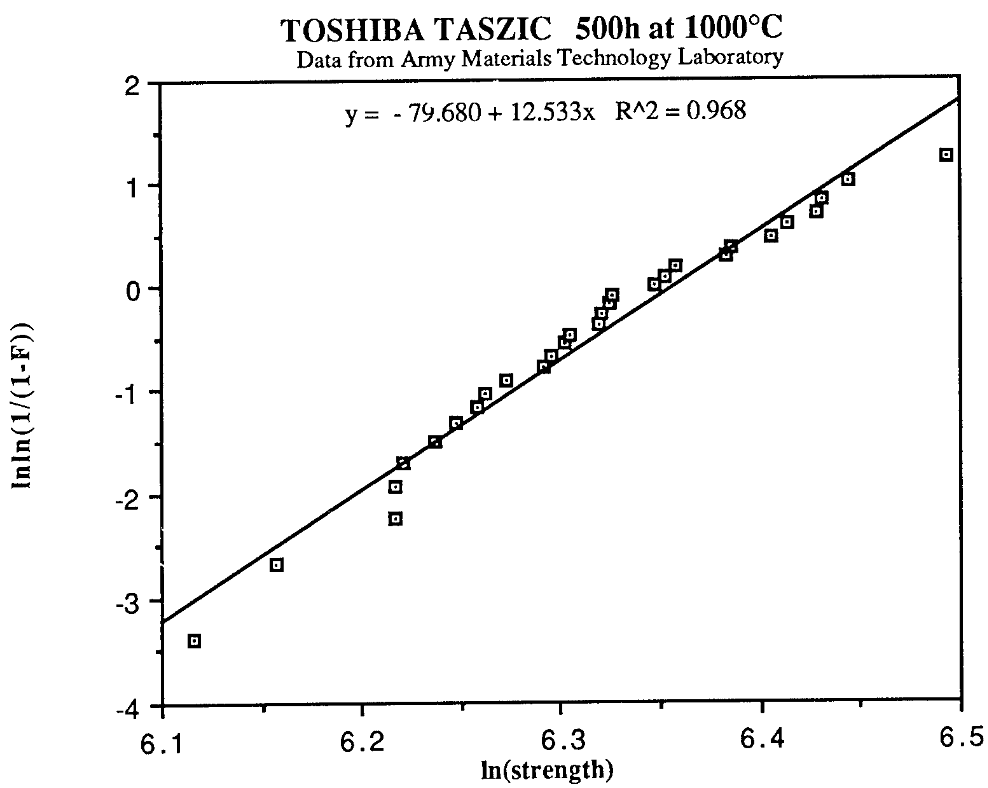

Figure 30. Weibull plot for Toshiba TASZIC after 500 hours at 1000°C.

ORNL-DWG 88-16441

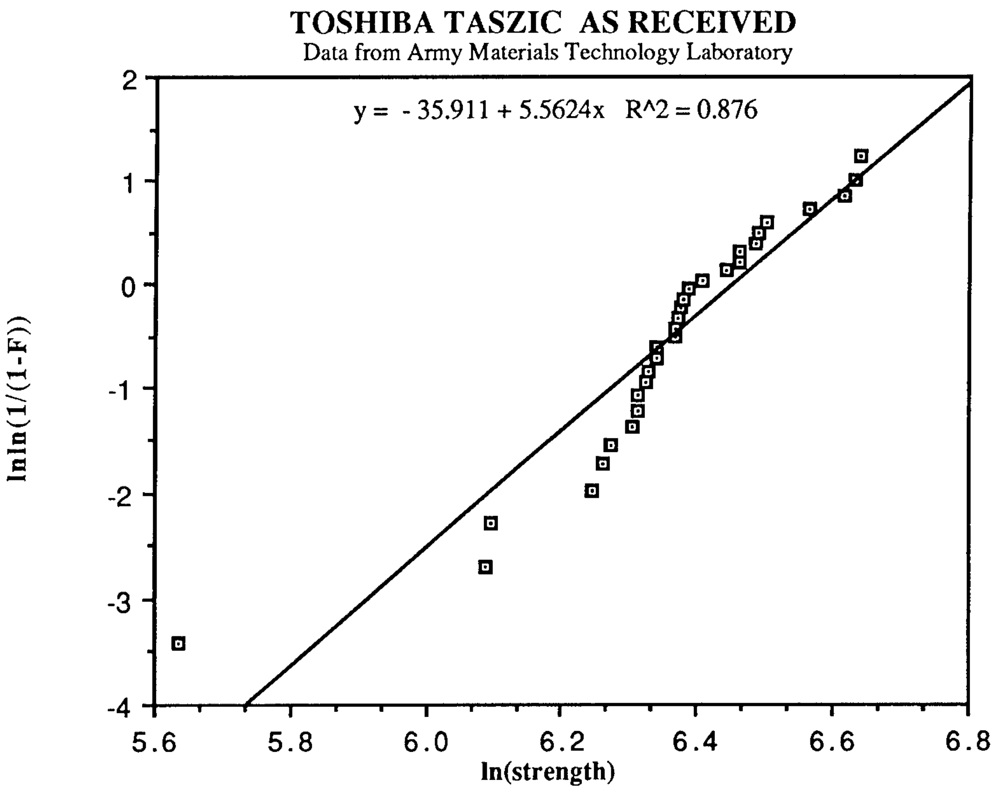

Figure 31. Weibull plot for Toshiba TASZIC in as received condition.

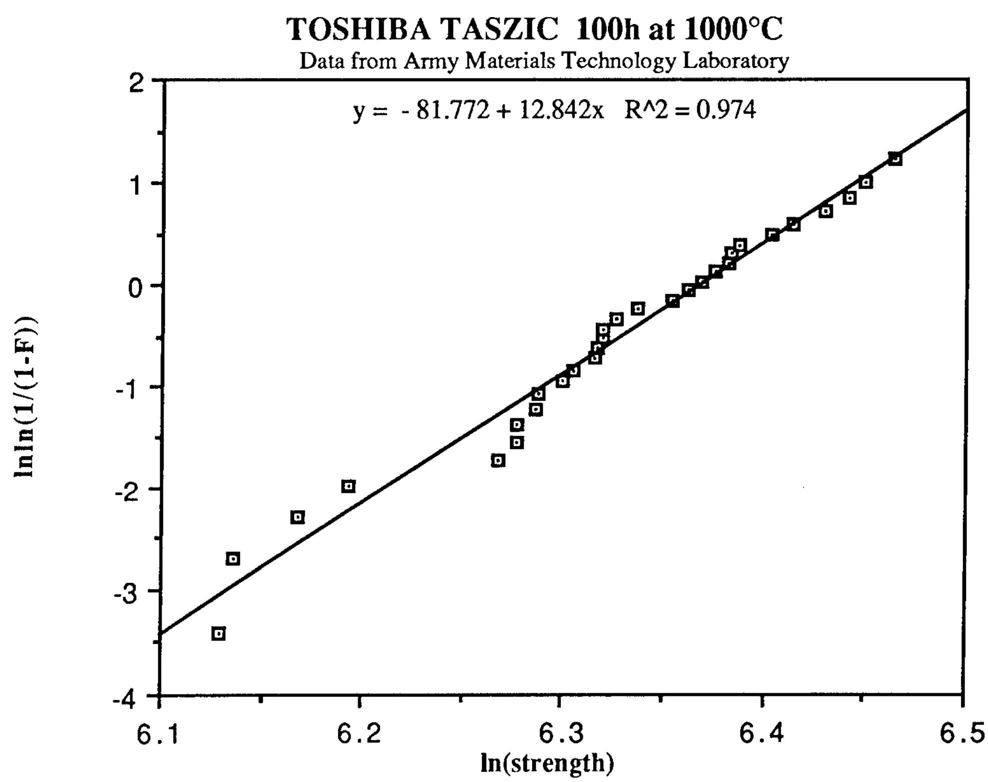

Figure 32. Weibull plot for Toshiba TASZIC after 100 hours at 1000°C.

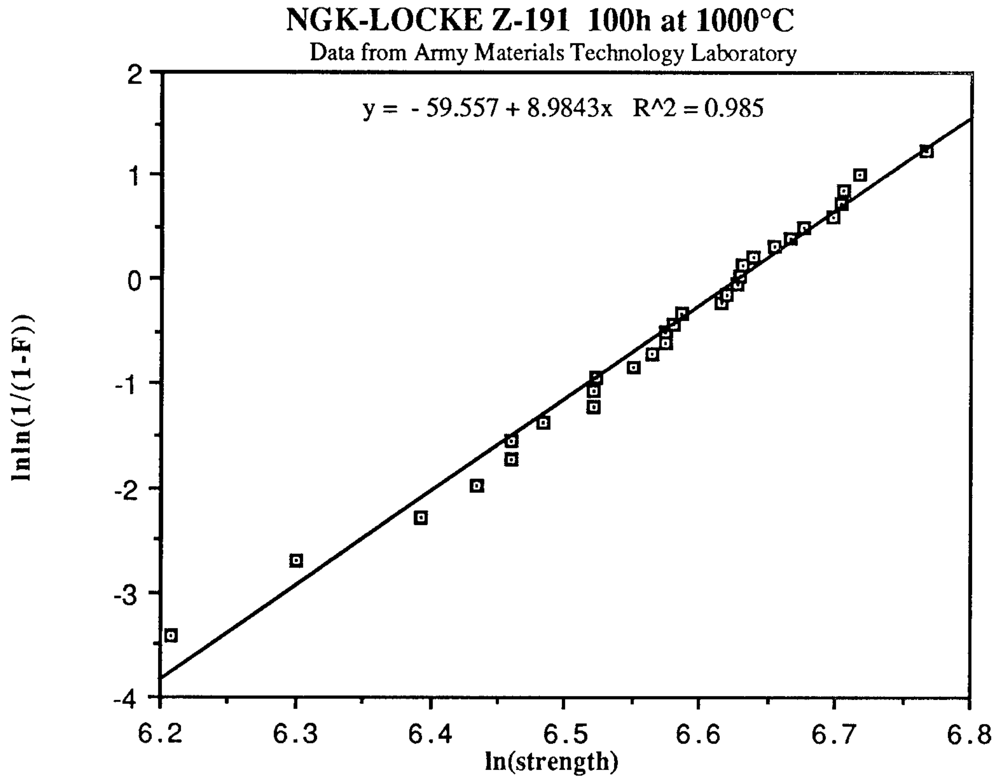

Figure 34. Weibull plot for NGK-Locke Z-191 after 100 hours at 1000°C.

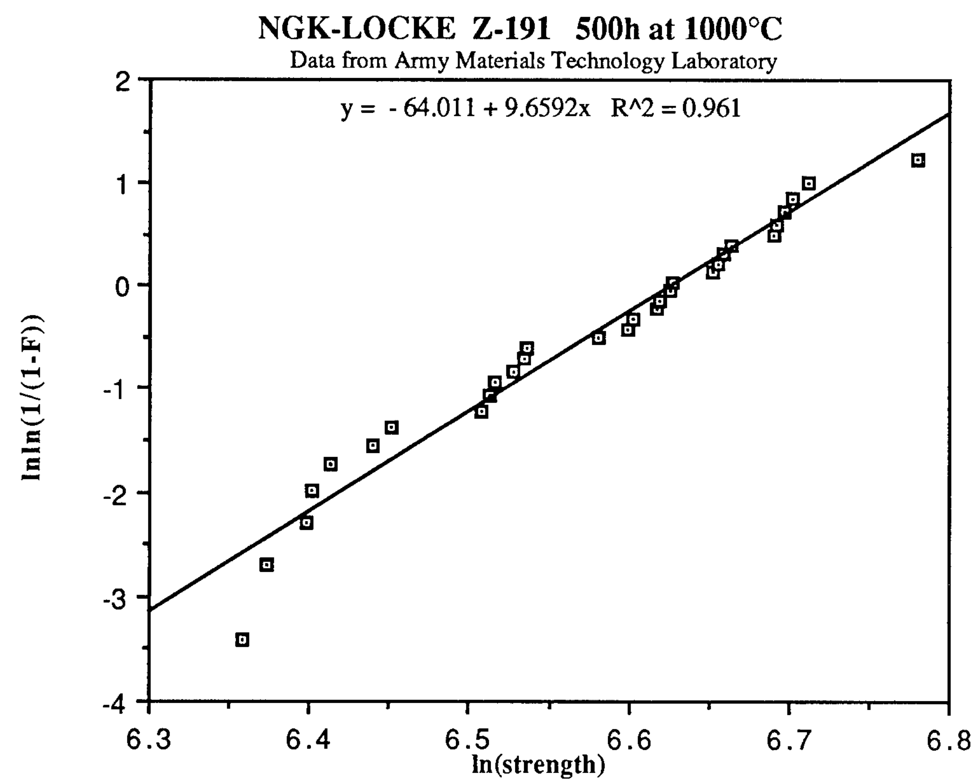

Figure 34. Weibull plot for NGK Locke Z-191 after 500 hours at 1000°C.

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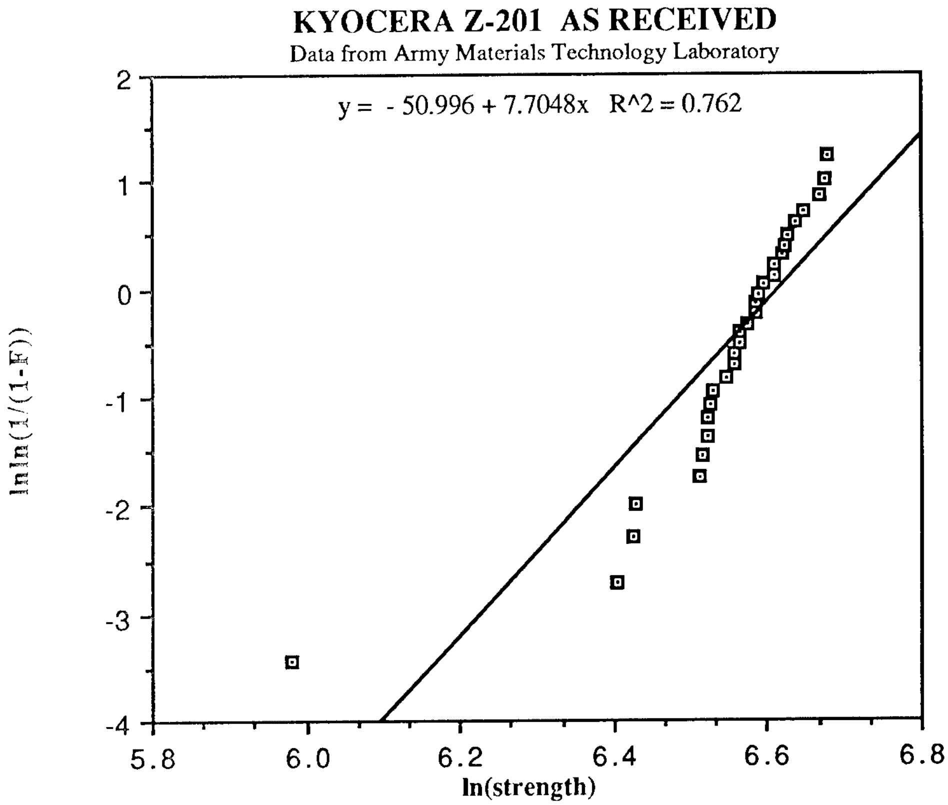

Figure 35. Weibull plot for Kyocera Z-201 in as received condition.

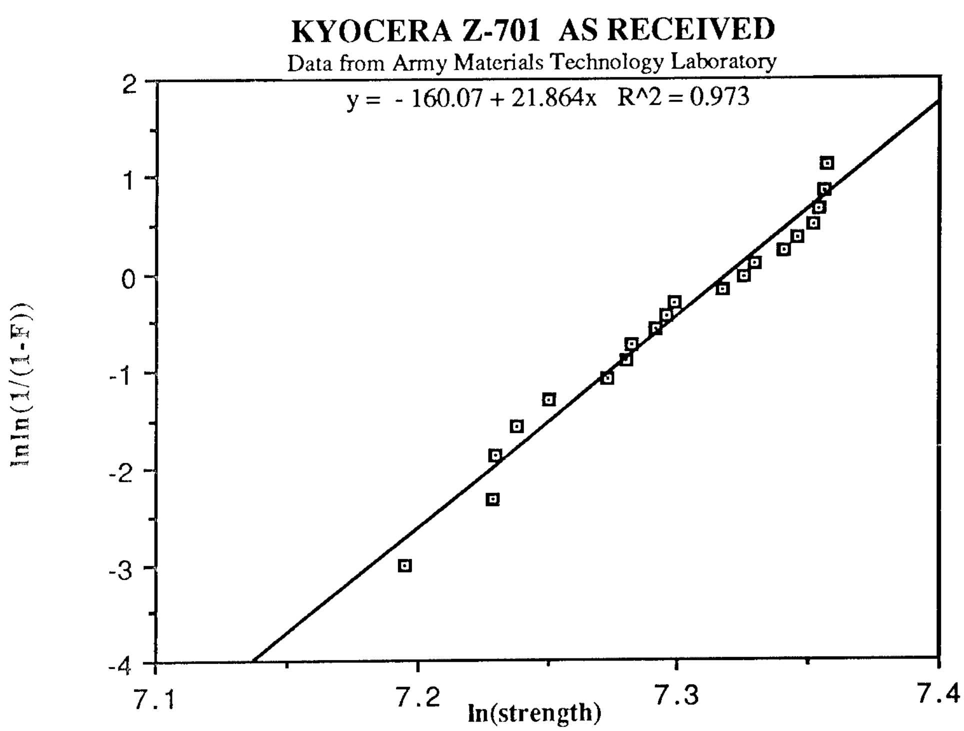

Figure 36. Weibull plot for Kyocera Z-701 in as received condition.

ORNL-DWG 88-16444

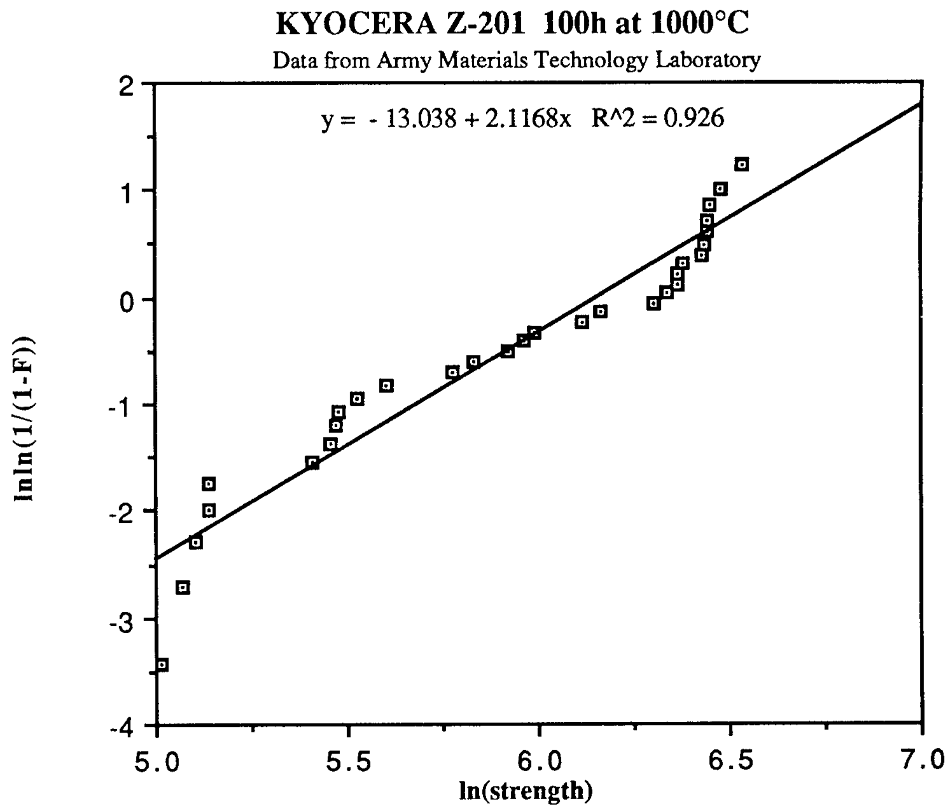

Figure 37. Weibull plot for Kyocera Z-201 after 100 hours at 1000 °C.

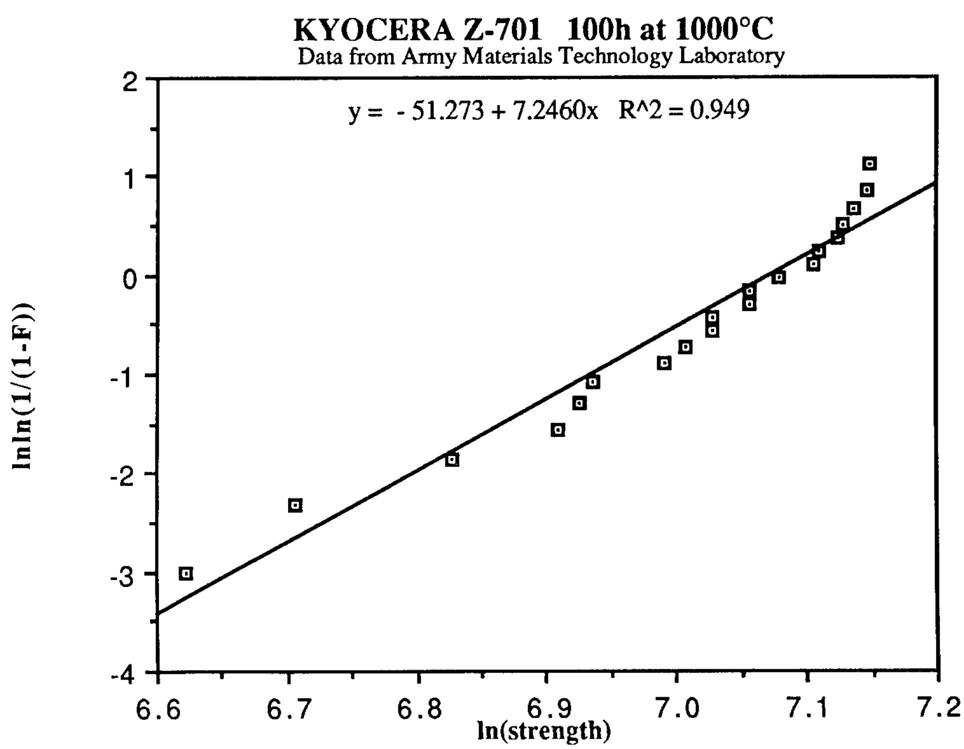

Figure 38. Weibull plot for Kyocera Z-701 after 100 hours at 1000°C.

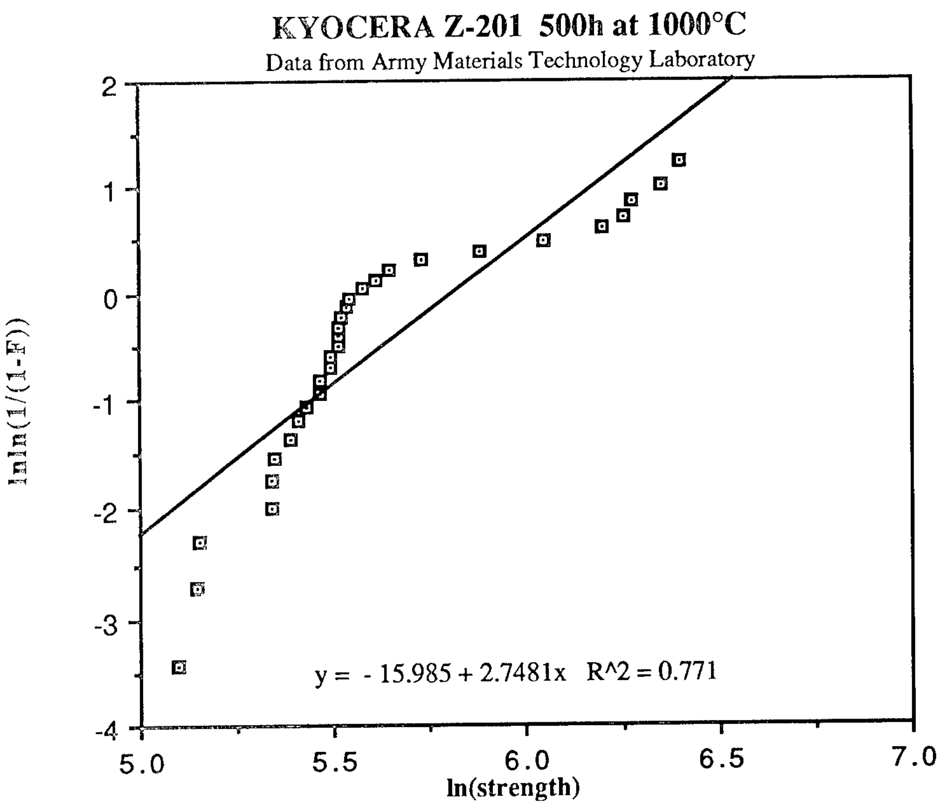

Figure 39. Weibull plot for Kyocera Z-201 aafter 500 hours at 1000°C.

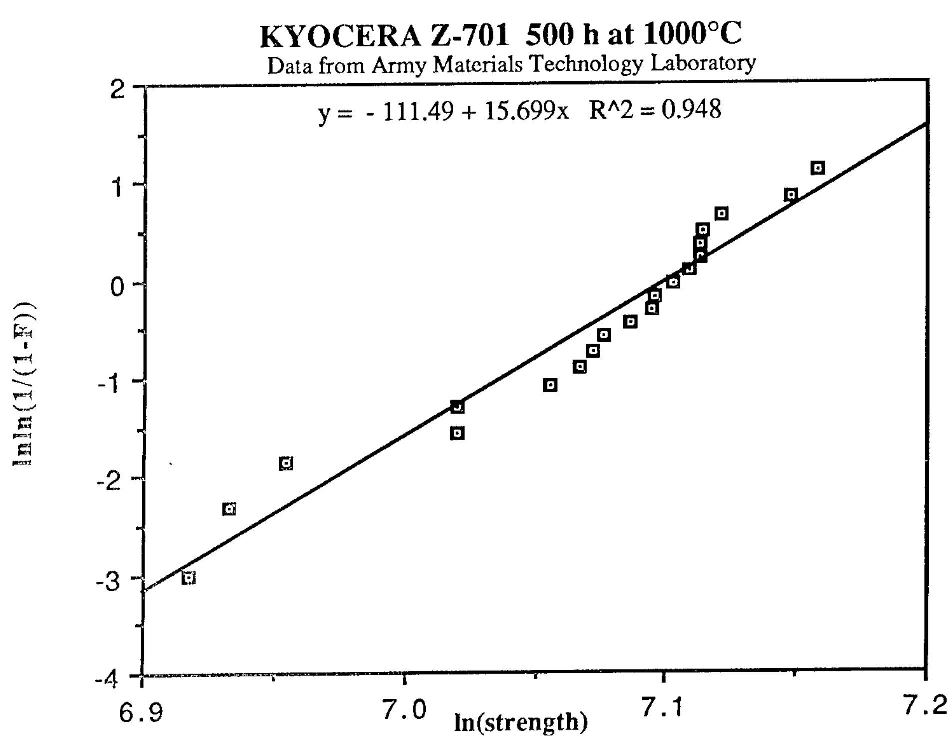

Figure 40. Weibull plot for Kyocera Z-701 after 500 hours at 1000°C.

SECTION 7. MODULUS OF RUPTURE - FOUR POINT BEND DATA

MOR 4 POINT BEND TEST DATA FROM MTL87-29

MATERIAL	TYPE	SPECIMEN ID	TEMP C	HEAT TREATMENT	STRESS MPa
AMTL-F	FSZ	SUMOF4	25	AS RECEIVED	207
AMTL-J	FSZ	SUMOF10	25	AS RECEIVED	242
AMTL-A	PSZ	SUMOF12	25	100h@1000C	314
AMTL-A	PSZ	SUMOF12	25	500h@1000C	274
AMTL-A	PSZ	SUMOF 8	25	AS RECEIVED	309
AMTL-L	PSZ	SUMOF13	25	100h@1000C	592
AMTL-L	PSZ	SUMOF12	25	500h@1000C	314
AMTL-L	PSZ	SUMOF10	25	AS RECEIVED	445
AMTL-D	TTZ	SUMOF13	25	100h@1000C	385
AMTL-D	TTZ	SUMOF9	25	500h@1000C	392
AMTL-D	TTZ	SUMOF10	25	AS RECEIVED	588
AMTL-E	TTZ	SUMOF8	25	100h@1000C	493
AMTL-E	TTZ	SUMOF9	25	500h@1000C	288
AMTL-E	TTZ	SUMOF14	25	AS RECEIVED	640
AMTL-G	TTZ	SUMOF13	25	AS RECEIVED	186
AMTL-H	TTZ	SUMOF12	25	100h@1000C	320
AMTL-H	TTZ	SUMOF11	25	500h@1000C	240
AMTL-H	TTZ	SUMOF12	25	AS RECEIVED	534
AMTL-S	TTZ	SUMOF15	25	100h@1000C	312
AMTL-S	TTZ	SUMOF11	25	500h@1000C	327
AMTL-S	TTZ	SUMOF20	25	AS RECEIVED	511
AMTL-B	TZP	SUMOF3	25	100h@1000C	659
AMTL-B	TZP	SUMOF2	25	500h@1000C	624
AMTL-B	TZP	SUMOF2	25	AS RECEIVED	708
AMTL-I	TZP	SUMOF15	25	100h@1000C	920
AMTL-I	TZP	SUMOF16	25	500h@1000C	998
AMTL-I	TZP	SUMOF14	25	AS RECEIVED	921
AMTL-N	TZP	SUMOF5	25	AS RECEIVED	758
AMTL-P	TZP	SUMOF8	25	100h@1000C	560
AMTL-P	TZP	SUMOF7	25	500h@1000C	457
AMTL-P	TZP	SUMOF9	25	AS RECEIVED	518
AMTL-Q	TZP	SUMOF3	25	AS RECEIVED	1159
AMTL-R	TZP	SUMOF1	25	AS RECEIVED	954

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	1985	HEAT TREAT.	50 HRS @ 300C
FABRICATOR	HITACHI	DATE	3/19/87
VINTAGE	1985	METHOD	MIL STD 4-PT BEND
C.H SPEED	0.5 mm/min	SPECIMEN SIZE	MIL STD "B"
CHART SPEED	100 mm/min	SLOPE	5.44
HUMIDITY, %	25.0	TESTER	T. STEFANICK
TEMPERATURE	25 C	MOMENT ARM	10 mm

SPEC	LOAD	WIDTH	HEIGHT	STRESS		FLAW	PHOTO	SEM	COMMENTS
ID	N	mm	mm	MPA	KSI	TYPE	Y/N	Y/N	
196	438	4.0300	3.0040	361	52	LARGE VOID	NO	NO	BROKE AT L.L.P.
197	630	4.0280	3.0020	521	76	?	YES	NO	
204	660	4.0300	3.0020	545	79	MACHINING DAMAGI	YES	YES	
199	724	4.0280	3.0040	598	87	?	NO	NO	
200	760	4.0300	3.0020	628	91	VOID?	YES	YES	
203	794	4.0240	2.9960	659	96	VOID ON CHAMFER	NO	NO	
201	816	4.0260	2.9920	679	99	VOID	NO	NO	
198	860	4.0240	3.0000	712	103	POROUS SEAM	YES	YES	
202	874	4.0280	3.0000	723	105	SINTERING AGGLOME	YES	YES	
205	912	4.0280	3.0000	755	109	?	YES	NO	

NOTE: R.L.P. = Right Load Pin, L.L.P. = Left Load Pin, L.P. = Load Pin.

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	1985	HEAT TREAT.	50 HRS @ 400C
FABRICATOR	HITACHI	DATE	3/19/87
VINTAGE	1985	METHOD	MIL STD 4-PT BEND
C.H SPEED	.5 mm/min	SPECIMEN SIZE	MIL STD "B"
CHART SPEED	100 mm/min	SLOPE	3.781
HUMIDITY, %	25	TESTER	T. STEFANICK
TEMPERATURE	25 C	MOMENT ARM	10mm

SPEC ID	LOAD N	WIDTH mm	HEIGHT mm	STRESS MPA	STRESS KSI	FLAW TYPE	PHOTO Y/N	SEM Y/N	COMMENTS
207	564	4.0280	3.0000	467	68	VOID	YES	YES	
210	620	4.0280	2.9980	514	75	SUBSURFACE S.A.	YES	YES	
208	1028	4.0240	2.9920	856	124	POROUS SEAM	NO	NO	
206	1058	4.0260	2.9940	879	128	M.D. ON CHAMFER	NO	NO	
211	1086	4.0280	3.0020	898	130	POROUS SEAM	YES	YES	
215	1120	4.0280	3.0000	927	134	?	NO	NO	BROKE AT L.L.P.
212	1158	4.0280	3.0020	957	139	?	YES	YES	BROKE AT L.L.P.
214	1288	4.0280	3.0000	1066	155	M.D. ON CHAMFER	YES	YES	BROKE AT R.L.P.
213	1316	4.0280	3.0020	1088	158	PORE	YES	NO	BROKE AT R.L.P.
209	1338	4.0260	2.9960	1111	161	?	NO	NO	

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	1985	HEAT TREAT.	500HRS @1100C
FABRICATOR	HITACHI	DATE	6/11/86
VINTAGE	1985	METHOD	MIL STD 4-PT BEND
C.H SPEED	.5 mm/min	SPECIMEN SIZE	MIL STD "B"
CHART SPEED	100 mm/min	SLOPE	9.41
HUMIDITY, %	65	TESTER	T. STEFANICK
TEMPERATURE	25 C	MOMENT ARM	10 mm

SPEC ID	LOAD N	WIDTH mm	HEIGHT mm	STRESS MPA	STRESS KSI	FLAW TYPE	PHOTO Y/N	SEM Y/N	COMMENTS
119	946	4.0180	2.9740	799	116	PORES	YES	YES	
120	1104	4.0160	2.9760	931	135	MACHINING DAMAGE	NO	NO	
111	1128	4.0120	2.9620	961	139	POSSIBLE M.D.	NO	NO	PIECE MISSING
112	1208	4.0140	2.9660	1026	149	PORE	YES	YES	
109	1240	4.0000	2.9640	1059	154	M.D. ALONG SURFACE	NO	NO	
116	1274	4.0180	2.9680	1080	157	LARGE S.A.	NO	NO	
117	1326	4.0140	2.9660	1127	163	?	NO	NO	PIECE MISSING
110	1346	4.0140	2.9620	1147	166	CRACK OR VOID UND SURF	YES	NO	
113	1370	4.0100	2.9640	1167	169	POSSIBLE M.D. ON SURF	NO	NO	BROKE AT R.L.P.
114	1392	4.0100	2.9600	1189	172	SINTERING AGGL. ?	NO	NO	
108	1436	4.0040	3.0000	1195	173	INCLUSION	YES	YES	3 BREAKS,1 OUTSIDE L.L.P
107	1454	4.0020	3.0000	1211	176	SINTERING AGGLOMERATE	NO	NO	BROKE AT L.L.P.
106	1492	4.0020	3.0000	1243	180	M.D. ON CHAMFER	NO	NO	
115	1472	4.0200	2.9660	1249	181	SUSSURFACE S.A.	YES	YES	
118	1516	4.0180	2.9760	1278	185	?	NO	NO	

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	1986, HIP'ed	HEAT TREAT.	50 HRS @ 200C
FABRICATOR	KORANSHA	DATE	1/5/87
VINTAGE	1986	METHOD	MIL STD 4-PT BEND
C.H SPEED	.5 mm/min	SPECIMEN SIZE	MIL STD "B"
CHART SPEED	100 mm/min	SLOPE	5.511 MPa
HUMIDITY, %	28	TESTER	T. STEFANICK
TEMPERATURE	25 C	MOMENT ARM	10 mm

SPEC	LOAD	WIDTH	HEIGHT	STRESS		FLAW	PHOTO	SEM	COMMENTS
ID	N	mm	mm	MPA	KSI	TYPE	Y/N	Y/N	
97	614	4.0100	2.9920	513	74	M.D. ON CHAMFER	NO	NO	BROKE AT L.L.P.
102	1120	4.0200	3.0000	929	135	WHITE INCLUSION	YES	YES	2 BREAKS, 1@RLP, LFT PRI
91	1124	4.0160	3.0040	930	135	?	NO	NO	2 BREAKS, 1@LLP, RT PRI
98	1132	4.0180	3.0060	935	136	MACHINING DAMAGE	NO	NO	2 L.P. BREAKS
103	1156	4.0200	3.0080	953	138	?	NO	NO	
96	1158	4.0180	3.0060	957	139	?	YES	YES	
105	1152	4.0160	2.9960	959	139	MD?-?	NO	NO	2 BREAKS, 1 @ L.L.P.
94	1166	4.0200	3.0100	960	139	?	NO	NO	2 LP BREAKS, LFT PRIM?
92	1174	4.0180	3.0040	971	141	MACHINING DAMAGE ?	YES	YES	2 LP BREAKS, LEFT PRIM?
101	1174	4.0220	3.0000	973	141	MACHINING DAMAGE?	YES	YES	
93	1178	4.0180	2.9980	979	142	PORE OR VOID	YES	NO	2 BRKS, 1@LLP, RT PRIM
99	1184	4.0240	3.0000	981	142	M.D. ON CHAMFER	YES	YES	
100	1186	4.0220	2.9980	984	143	M.D. ON CHAMFER	NO	NO	
95	1186	4.0160	2.9980	986	143	M.D. ON CHAMFER	NO	NO	2 BRKS, 1@RLP, LFT PRIM
104	1228	4.0220	3.0060	1014	147	M.D. ON CHAMFER (RT	NO	NO	

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	1986, HIP'ed	HEAT TREAT.	HIP'ed 50HR @ 300C
FABRICATOR	KORANSHA	DATE	3/19/87
VINTAGE	1986	METHOD	MIL STD 4-PT BEND
C.H SPEED	.5 mm/min	SPECIMEN SIZ	MIL STD "B"
CHART SPEED	100 mm/min	SLOPE	12.38
HUMIDITY, %	25	TESTER	T. STEFANICK
TEMPERATURE	25 C	MOMENT ARM	10 mm

SPEC ID	LOAD N	WIDTH mm	HEIGHT mm	STRESS MPA	STRESS KSI	FLAW TYPE	PHOTO Y/N	SEM Y/N	COMMENTS
206	916	4.0180	3.0000	760	110	VOID ?	YES	YES	
202	1110	4.0240	3.0100	913	132	POROUS SEAM	YES	YES	BROKE AT L.L.P.
200	1144	4.0240	3.0060	944	137	?	NO	NO	2BRKS, 1@LLP, RGHT PRMRY
201	1170	4.0260	3.0080	964	140	M.D. ON CHAMFER ?	NO	NO	
208	1168	4.0240	3.0000	968	140	M.D. ON CHAMFER ?	YES	YES	
203	1174	4.0160	2.9960	977	142	PORE	NO	NO	BROKE AT R.L.P.
205	1186	4.0200	3.0000	983	143	M.D. ON CHAMFER	YES	YES	
199	1236	4.0240	3.0000	1024	148	IMPURITY	YES	YES	2BRKS, 1@LLP, RGHT PRMRY
204	1240	4.0180	2.9900	1036	150	?	NO	NO	2 L.P. BRKS, LEFT PRMRY
207	1298	4.0280	3.0140	1064	154	PORE	NO	NO	2 L.P. BRKS, LEFT PRMRY

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	1986, HIP'ed	HEAT TREAT.	50HR @ 400C
FABRICATOR	KORANSHA	DATE	3/20/87
VINTAGE	1986	METHOD	MIL STD 4-PT BEND
C.H SPEED	.5 mm/min	SPECIMEN SIZE	MIL STD "B"
CHART SPEED	100 mm/min	SLOPE	13.180
HUMIDITY, %	25	TESTER	T. STEFANICK MPa
TEMPERATURE	25 C	MOMENT ARM	10 mm

SPEC	LOAD	WIDTH	HEIGHT	STRESS		FLAW	PHOTO	SEM	COMMENTS
ID	N	mm	mm	MPA	KSI	TYPE	Y/N	Y/N	
191	1138	4.0220	3.0120	936	136	MACHINING DAMAGI	NO	NO	
196	1142	4.0180	3.0060	944	137	MACHINING DAMAGE	YES	NO	BROKE AT R.L.P.
190	1276	4.0180	3.0040	1056	153	POROUS SEAM	YES	YES	
194	1296	4.0280	3.0100	1065	155	?	NO	NO	
195	1394	4.0240	3.0100	1147	166	M.D. ON CHAMFER ?	YES	YES	
193	1392	4.0220	3.0080	1148	166	M.D. ON CHAMFER	NO	NO	
197	1382	4.0180	2.9940	1151	167	?	NO	NO	2 L.P. BRKS, RGHT PRMRY
192	1388	4.0180	3.0000	1151	167	MACHINING DAMAGI	YES	NO	
198	1406	4.0140	3.0060	1163	169	M.D. ON CHAMFER ?	YES	YES	2 L.P. BRKS, RGHT PRMRY
189	1432	4.0220	3.0080	1181	171	?	YES	YES	

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	1986, SINTERED	HEAT TREAT.	50HR @300C
FABRICATOR	KORANSHA	DATE	3/19/87
VINTAGE	1985	METHOD	MIL STD 4-PT BEND
C.H SPEED	.5 mm/min	SPECIMEN SIZE	MIL STD "B"
CHART SPEED	100 mm/min	SLOPE	18.726
HUMIDITY, %	25	TESTER	T STEFANICK
TEMPERATURE	25 C	MOMENT ARM	10 mm

SPEC ID	LOAD N	WIDTH mm	HEIGHT mm	STRESS MPA	STRESS KSI	FLAW TYPE	PHOTO Y/N	SEM Y/N	COMMENTS
189	804	4.0120	2.9780	678	98	M.D. ON CHAMFER	NO	NO	
187	810	4.0120	2.9700	687	100	POROUS SEAM	YES	YES	BROKE AT R.L.P.
186	878	4.0040	2.9740	744	108	M.D.? ON CHAMFER	YES	NO	
182	882	4.0140	2.9740	745	108	POROUS SEAM	NO	NO	2 LP BREAKS, RIGHT PRMRY
181	910	4.0120	2.9780	767	111	PORE	YES	YES	
185	914	4.0020	2.9800	772	112	PORE	NO	NO	
190	930	4.0080	2.9780	785	114	PORE	YES	NO	
184	932	4.0120	2.9780	786	114	M.D.? ON CHAMFER	NO	NO	2 LP BREAKS, RIGHT PRMRY
183	970	4.0200	2.9860	812	118	M.D. ON CHAMFER	YES	YES	
188	974	4.0180	2.9840	817	118	PORE	NO	NO	2 BRKS,1@LLP,RIGHT PRMRY

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	1986, SINTERED	HEAT TREAT.	SINTERED 50HR @400C
FABRICATOR	KORANSHA	DATE	3/19/87
VINTAGE	1985	METHOD	MIL STD 4-PT BEND
C.H SPEED	100 mm/min	SPECIMEN SIZE	MIL STD "B"
CHART SPEED	100 mm/min	SLOPE	1.401
HUMIDITY, %	25	TESTER	T. STEFANICK
TEMPERATURE	25 C	MOMENT ARM	10 mm

SPEC ID	LOAD N	WIDTH mm	HEIGHT mm	STRESS MPA	STRESS KSI	FLAW TYPE	PHOTO Y/N	SEM Y/N	COMMENTS
175	92	4.0140	2.9720	78	11	MACHINING DAMAGE ?	YES	YES	
178	400	4.0220	2.9780	336	49	LARGE VOID	YES	YES	
171	826	4.0120	2.9720	699	101	SINTERING AGGLOMERATE	YES	YES	
177	834	4.0200	2.9780	702	102	POROUS SEAM	NO	NO	
179	842	4.0180	2.9800	708	103	SINTERING AGGLOMERATE	NO	NO	
176	838	4.0100	2.9740	709	103	SINTERING AGGLOMERATE	NO	NO	
174	850	4.0140	2.9800	715	104	SINTERING AGGLOMERATE	YES	NO	
180	864	4.0140	2.9700	732	106	POROUS SEAM	YES	YES	
173	890	4.0080	2.9760	752	109	POROUS SEAM	NO	NO	2 LP BREAKS, RIGHT PRMRY
172	892	4.0080	2.9620	761	110	SINTERING AGGLOMERATE	YES	NO	

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	TZP-110	HEAT TREAT.	50HRS @ 200C
REF. CODE	MTL2AC52	DATE	10/24/86
FABRICATOR	AC SPARKPLUG	METHOD	MIL STD 4-PT BEND
VINTAGE	1985	SPECIMEN SIZE	MIL STD "B"
C.H SPEED	.5 mm/min	SLOPE	31.104
CHART SPEED	100 mm/min	TESTER	T. STEFANICK
HUMIDITY, %	42	MOMENT ARM	10 mm
TEMPERATURE	25 C		

SPEC ID	LOAD N	WIDTH mm	HEIGHT mm	STRESS MPA	STRESS KSI	FLAW TYPE	PHOTO Y/N	SEM Y/N	COMMENTS
105	642	3.9900	2.9800	544	79	PORES	YES	YES	
104	680	3.9920	2.9820	575	83	PORE ON CHAMFER	YES	NO	
103	692	4.0080	2.9960	577	84	DAMAGE ON CHAMFER	YES	YES	
107	705	3.9960	2.9900	592	86	PORES	NO	NO	2 BRKS, 1@RLP, LFT PRIM
106	714	4.0000	2.9920	598	87	PORES ON CHAMFER	YES	YES	

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	CZ203	HEAT TREAT.	AS RECEIVED
FABRICATOR	CERAMATEC	DATE	7/20/87
VINTAGE	1986	METHOD	MIL STD 4-PT BEND
C.H SPEED	0.5 mm/min	SPECIMEN SIZE	MIL STD "B"
CHART SPEED	100 mm/min	SLOPE	36.52
HUMIDITY, %	55.0	TESTER	T. STEFANICK
TEMPERATURE	25 C	MOMENT ARM	10 mm

SPEC	LOAD	WIDTH	HEIGHT	STRESS		PHOTO	SEM	COMMENTS
ID	N	mm	mm	MPA	KSI	Y/N	Y/N	
65	652	3.9950	2.9720	554	80	NO	NO	2 BRKS, 1 @ R.L.P.
63	664	4.0040	2.9780	561	81	NO	NO	2 BREAKS
67	678	4.0040	2.9800	572	83	NO	NO	
61	682	4.0040	2.9780	576	84	NO	NO	
54	694	4.0080	2.9820	584	85	NO	NO	2 BREAKS
60	692	4.0080	2.9740	586	85	NO	NO	
66	700	4.0030	2.9780	592	86	NO	NO	2 BRKS, 1 @ R.L.P.
59	704	4.0060	2.9820	593	86	NO	NO	
58	704	4.0060	2.9800	594	86	NO	NO	2 BREAKS, 1 @ R.L.P.
57	708	4.0060	2.9780	598	87	NO	NO	2 L.P. BREAKS
70	704	3.9940	2.9660	601	87	NO	NO	2 BREAKS
53	706	3.9970	2.9660	602	87	NO	NO	
52	712	4.0000	2.9680	606	88	NO	NO	2 BREAKS
69	718	4.0020	2.9740	609	88	NO	NO	
64	716	3.9960	2.9720	609	88	NO	NO	2 BRKS, 1 @ R.L.P.
68	722	4.0040	2.9800	609	88	NO	NO	
55	728	4.0040	2.9770	615	89	NO	NO	2 BRKS, 1 @ R.L.P.
56	730	3.9920	2.9680	623	90	NO	NO	2 BREAKS
62	738	4.0060	2.9760	624	91	NO	NO	
51	737	4.0020	2.9740	625	91	NO	NO	

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	CZ203	HEAT TREAT.	100 HRS @1000C
FABRICATOR	CERAMATEC	DATE	7/24/87
VINTAGE	1987	METHOD	MIL STD 4-PT BEND
C.H SPEED	0.5 mm/min	SPECIMEN SIZE	MIL STD "B"
CHART SPEED	100mm/min	SLOPE	43.150
HUMIDITY, %	59.0	TESTER	T. STEFANICK
TEMPERATURE	25 C	MOMENT ARM	10 mm

SPEC	LOAD	WIDTH	HEIGHT	STRESS		PHOTO	SEM	COMMENTS
ID	N	mm	mm	MPA	KSI	Y/N	Y/N	
14	565	3.9970	2.9720	480	70	NO	NO	
16	566	3.9940	2.9700	482	70	NO	NO	
13	567	3.9890	2.9560	488	71	NO	NO	
11	574	3.9950	2.9700	489	71	NO	NO	
19	574	3.9930	2.9700	489	71	NO	NO	2 BRKS, 1 @ L.L.P.
17	576	3.9960	2.9680	491	71	NO	NO	2 L.P. BREAKS
8	575	3.9880	2.9640	492	71	NO	NO	2 L.P. BREAKS
3	576	3.9910	2.9620	494	72	NO	NO	2 BRKS, 1 @ L.L.P.
5	581	3.9970	2.9720	494	72	NO	NO	2 L.P. BREAKS
12	580	3.9930	2.9700	494	72	NO	NO	BROKE AT L.L.P.
10	580	3.9920	2.9600	497	72	NO	NO	2 L.P. BREAKS
6	599	4.0040	2.9780	506	73	NO	NO	
9	603	4.0060	2.9790	509	74	NO	NO	
2	599	3.9930	2.9690	511	74	NO	NO	2 BRKS, 1 @ R.L.P.
15	603	3.9960	2.9730	512	74	NO	NO	
1	600	3.9940	2.9660	512	74	NO	NO	
4	605	3.9960	2.9710	515	75	NO	NO	
20	607	3.9940	2.9700	517	75	NO	NO	
18	606	3.9960	2.9620	519	75	NO	NO	2 BRKS, 1 @ L.L.P.
7	622	4.0040	2.9730	527	76	NO	NO	2 BRKS, 1 @ R.L.P.

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	CZ203	HEAT TREAT.	500 HRS AT 1000 C
FABRICATOR	CERAMATEC	DATE	9/8/87
VINTAGE	1987	METHOD	MIL-STD 4-PT BEND
C.H SPEED	0.5 mm/min	SPECIMEN SIZE	MIL-STD "B"
CHART SPEED	100 mm/min	SLOPE	29.38
HUMIDITY, %	54.0	TESTER	JEFF SWAB
TEMPERATURE	25C	MOMENT ARM	10 mm

SPEC ID	LOAD N	WIDTH mm	HEIGHT mm	STRESS MPA	KSI	PHOTO Y/N	SEM Y/N	MISC.
28	539	4.0000	2.9770	456	66	NO	NO	
34	543	3.9920	2.9680	463	67	NO	NO	
35	545	3.9910	2.9650	466	68	NO	NO	
45	578	4.0070	2.9750	489	71	NO	NO	2 L.P. BREAKS
42	582	4.0080	2.9790	491	71	NO	NO	2 BRKS, 1 AT R.L.P.
26	583	3.9950	2.9690	497	72	NO	NO	
37	591	4.0090	2.9840	497	72	NO	NO	2 L.P. BREAKS
33	581	3.9910	2.9610	498	72	NO	NO	
40	588	3.9980	2.9750	499	72	NO	NO	
39	584	3.9880	2.9680	499	72	NO	NO	2 BREAKS
41	593	4.0050	2.9780	501	73	NO	NO	
29	591	3.9940	2.9640	505	73	NO	NO	
27	596	3.9940	2.9710	507	74	NO	NO	2 BREAKS
38	598	3.9990	2.9680	509	74	NO	NO	
31	612	4.0050	2.9840	515	75	NO	NO	
30	606	3.9930	2.9720	515	75	NO	NO	2 L.P. BREAKS
44	616	4.0060	2.9850	518	75	NO	NO	
32	609	3.9830	2.9690	520	75	NO	NO	
43	625	4.0060	2.9790	527	76	NO	NO	
36	631	4.0040	2.9750	534	77	NO	NO	

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	Z201	HEAT TREAT.	50 HRS @ 200C
FABRICATOR	KYOCERA	DATE	10/24/86
VINTAGE	1985	METHOD	MIL STD 4-PT BEND
C.H SPEED	.5 mm/min	SPECIMEN SIZE	MIL STD "B"
CHART SPEED	100 mm/min	SLOPE	114.29
HUMIDITY, %	42	TESTER	T. STEFANICK
TEMPERATURE	25 C	MOMENT ARM	10 mm

SPEC	LOAD	WIDTH	HEIGHT	STRESS		FLAW	PHOTO	SEM	COMMENTS
ID	N	mm	mm	MPA	KSI	TYPE	Y/N	Y/N	
95	460	4.0720	3.0420	366	53	AGGLOM OR L.G.	YES	YES	2 BRKS, 1 @ R.L.P.
96	458	4.0520	3.0220	371	54	LARGE GRAIN	YES	YES	2 L.P. BRKS

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	Z191	HEAT TREAT.	50 HRS @200 C
FABRICATOR	NGK-LOCKE	DATE	1/5/87
VINTAGE	1985	METHOD	MIL STD 4-PT BEND
C.H SPEED	.5 mm/min	SPECIMEN SIZE	MIL STD "B"
CHART SPEED	100 mm/min	SLOPE	16.469
HUMIDITY, %	28	TESTER	T. STEFANICK
TEMPERATURE	25 C	MOMENT ARM	10 mm

SPEC ID	LOAD N	WIDTH mm	HEIGHT mm	STRESS MPA	STRESS KSI	FLAW TYPE	PHOTO Y/N	SEM Y/N	COMMENTS
100	856	4.0100	2.9900	716	104	IMPURITY?	NO	NO	
99	972	4.0080	2.9860	816	118	SINTERING AGGLOMERATE	NO	NO	
91	982	4.0040	2.9860	825	120	MACHINING DAMAGE?	NO	NO	BROKE NEAR L.L.P.
104	1010	4.0060	3.0080	836	121	VOID	YES	NO	
92	1038	4.0040	3.0100	858	125	SINTERING AGGLOMERATE	NO	NO	
105	1026	4.0100	2.9900	859	125	VOID	YES	YES	AREA NEAR VOID IS ORANGI
103	1064	4.0080	3.0120	878	127	?	NO	NO	
96	1054	4.0120	2.9840	885	128	SINTERING AGGLOMERATE	NO	NO	
102	1060	4.0120	2.9880	888	129	INCLUSION	YES	YES	BROKE AT L.L.P.
97	1078	4.0060	3.0120	890	129	SINTERING AGGLOMERATE	NO	NO	
98	1094	4.0080	2.9840	920	133	SINTERING AGGLOMERATE	YES	YES	
94	1128	4.0060	3.0120	931	135	?	NO	NO	2 L.P. BREAKS
93	1132	4.0040	3.0080	937	136	?	NO	NO	ORIGIN NEAR CHAMFER
101	1120	4.0000	2.9880	941	136	SINTERING AGGLOMERATE	YES	YES	2 LP BRKS, LEFT PRIMARY
95	1140	4.0140	2.9880	954	138	?	YES	YES	

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	Z191	HEAT TREAT.	50 HRS @ 300C
FABRICATOR	NGK	DATE	3/19/87
VINTAGE	1985	METHOD	MIL STD 4-PT BEND
C.H SPEED	.5 mm/min	SPECIMEN SIZE	MIL STD "B"
CHART SPEED	100 mm/min	SLOPE	15.802
HUMIDITY, %	25	TESTER	T. STEFANICK
TEMPERATURE	25 C	MOMENT ARM	10mm

SPEC ID	LOAD N	WIDTH mm	HEIGHT mm	STRESS MPA	STRESS KSI	FLAW TYPE	PHOTO Y/N	SEM Y/N	COMMENTS
178	874	4.0140	2.9880	732	106	?	NO	NO	BROKE AT R.L.P.
173	918	4.0040	2.9820	773	112	SINTERING AGGLOMERATE	NO	NO	
172	962	4.0000	3.0020	801	116	SINTERING AGGLOMERATE	YES	YES	BROKE AT R.L.P.
180	1020	4.0040	2.9880	856	124	POROUS REGION	YES	NO	
175	1022	4.0000	2.9860	860	125	PORE OR S.A.	NO	NO	
179	1054	4.0020	2.9840	887	129	POROUS SEAM	YES	YES	
176	1068	4.0100	2.9900	894	130	?	YES	YES	
174	1080	4.0000	3.0100	894	130	SINTERING AGGLOMERATE	YES	YES	2 BREAKS, LEFT PRIMARY
177	1088	3.9960	3.0140	899	130	S.A. ON CHAMFER	NO	NO	
171	1092	4.0060	2.9920	914	132	SINTERING AGGLOMERATE	NO	NO	

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	Z191	HEAT TREAT.	50 HRS @ 400 C
FABRICATOR	NGK-LOCKE	DATE	3/19/87
VINTAGE	1985	METHOD	MIL STD 4-PT BEND
C.H SPEED	.5 mm/min	SPECIMEN SIZE	MIL STD "B"
CHART SPEED	100 mm/min	SLOPE	4.510
HUMIDITY, %	25	TESTER	T. STEFANICK
TEMPERATURE	25 C	MOMENT ARM	10 mm

SPEC ID	LOAD N	WIDTH mm	HEIGHT mm	STRESS MPA	STRESS KSI	FLAW TYPE	PHOTO Y/N	SEM Y/N	COMMENTS
188	516	4.0120	3.0140	425	62	IMPURITY	YES	YES	BROKE AT L.L.P.
190	926	4.0060	3.0120	764	111	MACHINING DAMAGE	YES	YES	
187	984	4.0100	2.9860	826	120	PORE	NO	NO	BROKE AT L.L.P.
189	990	4.0040	2.9840	833	121	SINTERING AGGLOMERATE	NO	NO	
183	1024	4.0100	3.0120	844	122	SINTERING AGGLOMERATE	YES	NO	BROKE AT R.L.P.
182	1024	4.0080	3.0120	845	123	MACHINING DAMAGE ?	NO	NO	
181	1062	4.0060	2.9900	890	129	MACHINING DAMAGE ?	NO	NO	
185	1064	4.0040	2.9900	892	129	MACHINING DAMAGE ?	NO	NO	BLACK DOT AT FAILURE
184	1114	4.0060	3.0100	921	134	?	YES	YES	
186	1114	4.0120	2.9880	933	135	POROUS SEAM	YES	YES	2 BREAKS, 1 AT R.L.P.

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	Z701	HEAT TREAT.	AS RECEIVED
FABRICATOR	KYOCERA	DATE	2/5/88
VINTAGE	1988	METHOD	MIL STD 1942
C.H SPEED	0.5 mm/min	SPECIMEN SIZE	MIL STD "B"
CHART SPEED	50 mm/min	SLOPE	24.706
HUMIDITY, %	27.0	TESTER	T. STEFANICK
TEMPERATURE	25 C	MOMENT ARM	10 mm

SPEC	LOAD	WIDTH	HEIGHT	STRESS		PHOTO	SEM	COMMENTS
6.4	N	mm	mm	MPA	KSI	Y/N	Y/N	
64	1610	4.0000	3.0100	1333	193	NO	NO	
71	1672	4.0100	3.0120	1379	200	NO	NO	
80	1668	4.0090	3.0080	1380	200	NO	NO	
63	1684	4.0080	3.0100	1391	202	NO	NO	
69	1704	4.0000	3.0120	1409	204	NO	NO	
61	1744	4.0080	3.0100	1441	209	NO	NO	
66	1756	4.0090	3.0090	1451	210	NO	NO	
72	1768	4.0100	3.0150	1455	211	NO	NO	
67	1766	4.0100	3.0000	1468	213	NO	NO	
70	1778	4.0000	3.0090	1473	214	NO	NO	
79	1790	4.0090	3.0100	1478	214	NO	NO	
76	1822	4.0100	3.0090	1506	218	NO	NO	
77	1836	4.0100	3.0080	1518	220	NO	NO	
62	1848	4.0120	3.0100	1525	221	NO	NO	
68	1866	4.0100	3.0100	1541	223	NO	NO	
65	1870	4.0010	3.0090	1549	225	NO	NO	
78	1886	4.0100	3.0080	1559	226	NO	NO	
73	1892	4.0100	3.0100	1562	227	NO	NO	
75	1894	4.0100	3.0090	1565	227	NO	NO	
74	1898	4.0100	3.0100	1567	227	NO	NO	

MATERIAL	Z701	HEAT TREAT.	100 HRS @ 1000C
REF. CODE	MTL2KY71	DATE	02/22/88
FABRICATOR	KYOCERA	METHOD	MIL STD 1942
VINTAGE	1988	SPECIMEN SIZE	MIL STD B
C.H SPEED	0.5 mm/min	SLOPE	8.316
CHART SPEED	unknown	TESTER	E. HOLZLE
HUMIDITY, %	21.0	MOMENT ARM	10 mm
TEMPERATURE	25 C		

SPEC ID	LOAD N	WIDTH mm	HEIGHT mm	STRESS MPa	STRESS KSI	PHOTO Y/N	SEM Y/N	COMMENTS
43	914	4.0120	3.0140	752	109	NO	NO	
44	992	4.0100	3.0120	818	119	NO	NO	
40	1118	4.0090	3.0120	922	134	NO	NO	
48	1208	4.0080	3.0050	1001	145	NO	NO	
42	1234	4.0090	3.0120	1018	148	NO	NO	
49	1246	4.0100	3.0110	1028	149	NO	NO	
37	1316	4.0070	3.0100	1087	158	NO	NO	
34	1342	4.0160	3.0100	1106	160	NO	NO	
36	1364	4.0090	3.0090	1127	164	NO	NO	
46	1362	4.0090	3.0060	1128	164	NO	NO	
50	1404	4.0100	3.0090	1160	168	NO	NO	
45	1408	4.0090	3.0130	1161	168	NO	NO	
39	1438	4.0080	3.0100	1188	172	NO	NO	
38	1478	4.0100	3.0100	1220	177	NO	NO	
35	1480	4.0090	3.0090	1223	177	NO	NO	
33	1502	4.0090	3.0080	1242	180	NO	NO	
47	1506	4.0090	3.0050	1248	181	NO	NO	
41	1524	4.0070	3.0130	1257	182	NO	NO	
31	1536	4.0080	3.0100	1269	184	NO	NO	
32	1540	4.0120	3.0080	1273	185	NO	NO	

DATA FROM ARMY MATERIALS TECHNOLOGY LABORATORY

MATERIAL	Z701	HEAT TREAT.	500h @ 1000C
FABRICATOR	KYOCERA	DATE	3/17/88
VINTAGE	1988	METHOD	MIL STD 1942
C.H SPEED	0.5 mm/min	SPECIMEN SIZE	MIL STD B
CHART SPEED	unknown	SLOPE	17.912
HUMIDITY, %	19.0	TESTER	J. SWAB
TEMPERATURE	25 C	MOMENT ARM	10 mm

SPEC ID	LOAD N	WIDTH mm	HEIGHT mm	STRESS MPA	STRESS KSI	PHOTO Y/N	SEM Y/N	COMMENTS
KY7-13	1220	4.0060	3.0070	1010	147	NO	NO	LEFT L.P. BREAK
KY7-11	1240	4.0100	3.0090	1025	149	NO	NO	
KY7-18	1272	4.0120	3.0130	1048	152	NO	NO	LEFT L.P. BREAK
KY7-20	1344	4.0070	3.0000	1118	162	NO	NO	
KY7-19	1346	4.0080	3.0010	1119	162	NO	NO	
KY7-10	1396	4.0050	3.0040	1159	168	NO	NO	
KY7-17	1422	4.0110	3.0130	1172	170	NO	NO	
KY7-1	1422	4.0040	3.0060	1179	171	NO	NO	
KY7-15	1428	4.0080	3.0060	1183	172	NO	NO	
KY7-7	1446	4.0090	3.0080	1196	173	NO	NO	
KY7-5	1454	4.0040	3.0070	1205	175	NO	NO	
KY7-6	1456	4.0080	3.0060	1206	175	NO	NO	RIGHT L.P. BREAK
KY7-4	1464	4.0040	3.0050	1215	176	NO	NO	LEFT L.P. BREAK
KY7-8	1474	4.0070	3.0040	1223	177	NO	NO	LEFT L.P. BREAK
KY7-2	1482	4.0040	3.0070	1228	178	NO	NO	
KY7-3	1486	4.0060	3.0100	1228	178	NO	NO	
KY7-9	1482	4.0050	3.0050	1229	178	NO	NO	LEFT L.P. BREAK
KY7-16	1502	4.0130	3.0120	1238	180	NO	NO	
KY7-14	1538	4.0100	3.0090	1271	184	NO	NO	
KY7-12	1552	4.0070	3.0070	1285	186	NO	NO	

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