

第8回 超鉄鋼ワークショップ
8th Ultra-Steel Workshop

新構造の提案と求められる材料技術

Proposal of New Constructions with Ultra-Steel



主催 Host

独立行政法人 物質・材料研究機構

National Institute for Materials Science

賛助 : CBMMアジア(株) Auspices: CBMM Asia Co., Ltd.

協賛 Approval

(財)金属系材料研究開発センター	The Japan Research and Development Center for Metals
(社)自動車技術会	Society of Automotive Engineers of Japan, Inc.
(社)土木学会	Japan Society of Civil Engineers
(社)日本機械学会	The Japan Society of Mechanical Engineers
(社)日本金属学会	The Japan Institute of Metals
(社)日本建築学会	Architectural Institute of Japan
(社)日本鋼構造協会	Japanese Society of Steel Construction
(社)日本材料学会	The Society of Materials Science, Japan
(社)日本造船学会	The Society of Naval Architects of Japan
(社)日本塑性加工学会	The Japan Society for Technology of Plasticity
(社)日本鉄鋼協会	The Iron and Steel Institute of Japan
(社)日本熱処理技術協会	The Japan Society for Heat Treatment
(社)日本防錆技術協会	Japan Association of Corrosion Control
(社)日本溶接協会	The Japan Welding Engineering Society
(社)表面技術協会	The Surface Finishing Society of Japan
(社)腐食防食協会	Japan Society of Corrosion Engineering
(社)溶接学会	Japan Welding Society

 土木学会認定CPDプログラム

開催

July 21–22, 2004



独立行政法人 物質・材料研究機構
National Institute for Materials Science (NIMS)

**Proceedings of
the 8th Ultra-Steel Workshop**

**Proposal of New Constructions
with Ultra-Steel**

**July 21 & 22, 2004
Tsukuba International Congress Center
Tsukuba, Japan**

Published by :
Steel Research Center
National Institute for Materials Science
1-2-1 Sengen, Tsukuba 305-0047, Japan
Tel : +81-29-859-2102 Fax : +81-29-859-2101
URL <http://www.nims.go.jp/stx-21/>

Contents

Plenary Session: International Trends in Steel Research and Technology

基調講演（英語）：鉄鋼技術研究の世界動向

1. Networking of Research Linkages for Utilization of Ultra Steels	1
K. Nagai (NIMS, Japan)	
2. Development of Non Heat-Treated Wire Rods Based on SIDT Technology	7
D.L. Lee, S.J. Yoo, W.Y. Choo (POSCO, Korea)	
Y.H. Lee, C.S. Lee (Pohang University of Science and Technology, Korea)	
3. Challenges in Improving the Weldability of Modern Steels	13
B. de Meester (Université catholique de Louvain, Belgium)	

Technical Session 1. Welding of Ultrafine Grained and High Strength Steels

技術討論会1（日本語） 超微細粒鋼・高強度鋼を溶接する

1. 超微細粒高強度鋼のための溶接とその継手特性	22
Characteristics of Welded Joints of UFG Steels	
NIMS 平岡和雄	
2. 環境調和型超微細粒鋼創製基盤技術の開発プロジェクトでの接合研究の取り組み	24
Outline of Bonding&Welding Studies for Ultrafine Grained Steels in PROTEUS Project	
(<i>PROduction Technologies for Environment-conscious Ultrafine grained Steels</i>)	
(株)神戸製鋼所 環境調和型超微細粒鋼創製基盤技術研究体(JRCM) 難波茂信	
3. HAZ軟化を有する細粒鋼溶接継手の実用強度の予測	26
Deformation and Strength in Welded Joints of Fine Grained Steel	
中山製鋼所 新富達也、竹士伊知郎	
大阪大学 大畠充、望月正人、豊田政男	
4. 高強度鋼溶接金属の組織と合金設計	28
Microstructure and Alloy Design of High Strength Steel Welds	
新日本製鐵(株) 大北 茂	
5. 高強度鋼とその溶接継手の破壊性能評価のための破壊靭性評価手順	30
Fracture Toughness Evaluation for Fracture Performance Assessment of High Strength Steel Welds	
大阪大学 南二三吉	

Technical Session 2. Toward Realization of New Structural Systems Using Ultra Steel

(In conjunction with Japanese Society of Steel Construction)

技術討論会2（日本語） 超鉄鋼を活かした新鋼構造の具体化（土木セッション）

（共催：日本鋼構造協会）

1. 土木用微細粒高強度耐候性鋼とその溶接	34
-----------------------	----

Weathering Steel with Ultra-fine Grains and its Weldabilities

NIMS 西村俊弥、平岡和雄

2. 土木建築用超高力ボルト鋼とその成形	36
Ultra High Strength Bolt Steel and Its Forming	
NIMS 木村勇次、津崎兼彰	
3. 土木分野への超鉄鋼の利用	38
Applications to Ultra Steel to Infrastructures	
岐阜大学総合情報メディアセンター 奈良 敬	
4. 超鉄鋼による高力ボルト接合部の高性能化	40
High Performance of High Strength Bolted Joints using Ultra Steel	
大阪市立大学 山口隆司	
5. 超鉄鋼の特性を活用した橋梁構造	42
Bridge Structures Introducing Properties of Ultra Steel	
大阪大学 小野潔	
大日本コンサルタント(株) 堀田 毅	
6. 超鉄鋼による鋼橋の経済性と耐久性の向上	46
Cost Down and Durability Improvement of Steel Bridges Using Ultra Steel	
長崎大学 中村聖三	

Technical Session 3. Toward Realization of New Structural Systems Using Ultra Steel

技術討論会3（日本語） 超鉄鋼を活かした新鋼構造の具体化（建築セッション）

（共催：日本鋼構造協会）

1. 建築構造材料の特徴と超鉄鋼の応用	50
Application of Ultra-steel for Structural Materials in the Architectural Engineering	
東京工業大学 和田 章	
2. 超鉄鋼を利用した建築構造物の提案	58
Design Concepts for Building Structures using Ultra-Steel	
東京工業大学 竹内 徹	
3. 建築構造部材および接合部に関する研究課題	64
Research Needs for Structural Members and Connections of Ultra-steel	
東京工業大学 山田 哲	

Scientific Symposium 1. Advanced Nanoindentation Technique as a Key Technology for Futuristic Steels

研究要素討論会1（英語） 最新ナノインデンテーション技術が先進鉄鋼材料の組織設計に果たす役割

1. A Critical Appraisal of Nanoindentation Techniques and Analyses for Determination of Young's Modulus and Hardness of Bulk Solids, Individual Grains and Thin Solid Films	70
M.M. Chaudhri (University of Cambridge, UK)	

2 . Computational Modeling of Nanoindentation-induced Plastic Deformation	.....	76
Y. Shibutani (Osaka University, Japan)"		
3 . Grain Boundary Phenomena Observed with in situ Nanoindentation in a TEM	.....	82
A.M. Minor, E.A. Stach, M. Jin, J.W. Morris (Lawrence Berkeley National Lab., USA)		
T. Ohmura (NIMS, Japan)		
W.A. Soer, J.Th.M. De Hosson (University of Groningen, The Netherlands)		
4 . Mechanical Properties of the Single-Crystal Iron Surfaces Kept at Passive State in Solution	.....	90
M. Seo, M. Chiba (Hokkaido University, Japan)		
5 . Nano-mechanical Characterization of High-strength Martensitic Steels	.....	96
T. Ohmura, K. Tsuzaki (NIMS, Japan)		

Scientific Symposium 2. Have We Recognized the Merits of Solidification Process for Structural Materials?
研究要素討論会 2（英語） 構造材料製造における凝固プロセスの利点

1 . Ecological Steel Making Processes in China	.....	104
D. Cang, L. Li, H. Cui, P. He, Y. Zong (University of Science and Technology Beijing, China)		
2 . 'Eco-Process' of High-Quality Steels Presupposing Thin Slab Casting	.....	110
H. Yada (Shizuoka Institute of Science and Technology, Japan)		
3 . The Application of Solidification Principles for Near or Net-shaped Casting of Al Alloys	.....	118
R. Ghomashchi (University of Quebec at Chicoutimi, Canada)		
4 . Solidification of High Nitrogen Austenitic Structural Steels	.....	132
G. Porcu, M.R. Ridolfi, F. Ruffini, O. Tassa (Centro Sviluppo Materiali, Italy)		
5 . Microstructure and Mechanical Properties of Strip-Cast Low-Carbon Steels	.....	138
F. Yin (NIMS, Japan)		

Scientific Symposium 3. Research and Development of Advanced Heat Resistant Materials for USC Plants Exceeding 650°C
研究要素討論会 3（英語） 650°C超級 USC プラント用先進耐熱材料の研究開発

2 . Materials for Ultrasupercritical Coal-fired Power Plant Boilers	.....	146
R. Viswanathan (EPRI, USA)		
J.F. Henry (Alstom, USA)		
J. Tanzosh (B & W, USA)		
G. Stanko (Foster Wheeler, USA)		
J. Shingledecker (ORNL, USA)		
B. Vitalis (Riley, USA)		
2 . Materials Development in Thermie Project for 700°C USC Plant	.....	158
R. Blum (Elsam, Denmark)		
R.W. Vanstone (Alstom Power Ltd., UK)		

3 . Steamside Oxidation Behavior of Candidate USC Materials at 650°C and 800°C	178
J.M. Sarver, J.M. Tanzosh (The Babcock & Wilcox Company, USA)	
4 . Ultra-Steel R&D in NIMS for 650°C USC Plant	188
F. Abe (NIMS, Japan)	
5 . Development of High Strength Austenitic Steels for 700°C USC Plant	194
M. Igarashi, H. Semba, H. Okada (Sumitomo Metal Industries, Ltd., Japan)"	
6 . Innovative Steel R&D in NIMS for USC Plants at 700°C and Above	200
S. Muneki (NIMS, Japan)	

Poster Session
Phase Transformation

A-1-1	Microstructure and Mechanical Properties of the Thin-Slab-Cast Low-Carbon Steel *P. Xu, F. Yin, K. Nagai (NIMS)	208
A-1-2	Solidification and Precipitation in the Rapidly Cooled C-Mn Steel *H. S. Kim, Y. Kobayashi, S. Tsukamoto, K. Nagai (NIMS)	210
A-1-3	Precipitation of Copper Sulfide in Strip Casting Low Carbon Steel *Z. Liu, Y. Kobayashi, K. Nagai (NIMS)	212
A-1-4	Phase Transformation in Fe-based Alloys in High Magnetic Fields *X. Hao, H. Ohtsuka (NIMS)	214
A-1-5	Structural Control of Materials through Phase Transformations in a High Magnetic Field *H. Ohtsuka, X.Hao (NIMS)	216
A-1-6	BCC Precipitation on Annealing Twin Boundary and Geometrically Necessary Boundary in Work-Hardened FCC Matrix *Y. Adachi, K. Tsuzaki (NIMS)	218
A-1-7	Substructure of Lenticular Martensite in Fe-Ni based Alloys *A.Shibata, S.Morito, T.Furuuhara, T.Maki (Kyoto University)	220
A-1-8	Effect of Initial Microstructure on Recrystallization Behavior during Annealing *M. Natori, Y. Futamura, T. Tsuchiyama, S. Takaki (Kyushu University)	222

Ultrafine Grained Steel

A-2-1	Multi-Directional Forging of Austenitic Stainless Steel with Second Phase Particles *H. Miura, H. Hamaji, T. Sakai (University of Electro-Communications)	226
A-2-2	Effect of Redundant Shear Strain on Ultrafine Grained Structure in IF Steel Deformed by Accumulative Roll-Bonding *N. Kamikawa, N. Tsuji, T. Sakai, Y. Minamino (Osaka University)	228
A-2-3	Effect of Grain Size on Mechanical Properties of Austenitic Stainless Steel Wire *T. Fukumaru, H. Hidaka, T. Tsuchiyama, S. Takaki (Kyushu University)	230
A-2-4	Effect of Dispersed Oxides on Grain Growth in Submicrocrystalline Fe-O Steels *A. Belyakov, Y. Sakai, T. Hara, Y. Kimura, K. Tsuzaki (NIMS)	232
A-2-5	Microstructural Evolution during Simple Heavy Warm Compression of a 0.15C Steel *S.V.S.N. Murty, S. Torizuka, K. Nagai (NIMS)	234

Welding

B-3-1	Metallurgical and Mechanical Properties of Friction Stir Welded Ultra Fine Grained Steel	238
-------	--	-----

*S. Hirano, K. Aota

B-3-2	Low Heat Input Friction Welding for High Tensile and Super Fine Grained Steels	.....	240
	*M. Kimura, M. Kusaka, K. Seo (University of Hyogo)		
	A. Fuji (National University Corporation-Kitami Institute of Technology)		
B-3-3	Detection of Phase-transformation during Welding -Application of ESPI System-	...	242
	*S. Meguro, Y. Muramatsu, S. Kuroda (NIMS)		
B-3-4	Detection of Phase-transformation during Actual Welding Procedure using Laser Speckle Method		244
	*Y. Muramatsu, S. Kuroda (NIMS)		
	J. Yamamoto (Hitachi Construction and Machinery Co., Ltd.)		
	Y.-C. Kim (Osaka University)		
B-3-5	Evaluation of Hardness in Welded Joints by Numerical Simulation of Weld Thermal Cycle and Microphase		246
	- Challenge to Prediction of Joint Performance of Ultra-High Strength Steel -		
	Y. Mikami, M. Mochizuki, M. Toyoda (Osaka University)		
	T. Nakamura, K. Hiraoka (NIMS)		
B-3-6	Development of Low Transformation - Temperature Welding Wire		248
	-High Quality Welding Technology using New Developed Welding Wire-		
	*T. Nakamura, K. Hiraoka (NIMS)		
B-3-7	Formation Mechanism and Prevention of Hot Cracking in High Power Laser Welding of Thick Steel Plates		250
	*G. Arakane, S. Tsukamoto, H. Honda, I. Kawaguchi, S. Kuroda (NIMS)		
B-3-8	Keyhole Fluctuation and Plasma Emission in High Power Laser Welding		252
	*H. Honda, S. Tsukamoto, I. Kawaguchi, G. Arakane (NIMS)		

Fracture

B-4-1	Charpy Impact Toughness of Weld Bond of Ultra-Fine Grained Steels		256
	*H. Qiu, Y. Hagiwara, K. Hiraoka, K. Nagai (NIMS)		
B-4-2	The Effect of Pearlite Phase on Cleavage Fracture in Ferrite-Pearlite Steel		258
	*K. Enami (NIMS)		
B-4-3	Effect of Effective Grain Size on Ductile-Brittle Transition Temperature in Four Different Microstructures of a Low Carbon Steel		260
	*T. Hanamura, F. Yin, K. Nagai (NIMS)		

High Strength Steel

B-5-1	A Practical and Reliable Method to Determine the Activation Energy for Hydrogen Desorption from Steels		264
	*F.-G. Wei, T. Hara, K. Tsuzaki (NIMS)		

B-5-2	Hydrogen Degradation of Quenched and Tempered Steel for High Strength Bolt	266
	*M. Wang, E. Akiyama, K. Tsuzaki (NIMS)	
B-5-3	Evaluation of the Delayed Fracture and Hydrogen Absorption Properties of High Strength Bolts under Atmospheric Corrosion (Establishment of Performance Evaluation Method for High Strength Bolts -The 1st Term Results-)	268
	*K. Matsukado, E. Akiyama, K. Tsuzaki (NIMS)	
	A. Mukai, H. Yamanouchi (Building Research Institute)	

Corrosion Resistant Steel

C-6-1	Corrosion Resistance of Ultrafine-grained Weathering Steel	272
	*T. Nishimura (NIMS)	
C-6-2	A Mechanism on the Improvement of Localized Corrosion Property of HNS by Nitrogen Alloying	274
	*Y. Katada, N. Washizu, H. Baba (NIMS)	
C-6-3	Evaluation of Pitting Resistance of High Nitrogen Stainless Steels	276
	*H. Yashiro, N. Kumagai (Iwate University)	
C-6-4	Development of the Painted Steel Plate for Bridge Structures	278
	*F. Yuse, S. Okano, N. Furukawa (Kobe Steel, Ltd.)	
C-6-5	Evaluation of Corrosion Rate of Carbon Steel in Atmospheric Environment by ACM Sensor	280
	*T. Shinohara, Y. Hosoya (NIMS)	
	W. Oshikawa (University of the Ryukyus)	
	S. Motoda (Tokyo University of Marine Science and Technology)	

Surface Modification

C-7-1	Innovative Thermal Spray Coatings with Marine Corrosion Resistance	284
	*S. Kuroda, J. Kawakita (NIMS)	
C-7-2	Corrosion Protection of Copper using TiO ₂ Coatings	286
	*R. Subasri, T. Shinohara (NIMS)	
C-7-3	Protective Performance of Lead-free Chromium-free Anticorrosive Coating Film for Steel	288
	*M. Nagai, T. Matsumoto, T. Taki, H. Tanabe (Dai Nippon Toryo Co., Ltd.)	
C-7-4	Wear Property of WC Cermet Coatings for Protection of Steels by Improved HVOF Spraying	290
	*Y. Ishikawa, J. Kawakita, S. Kuroda (NIMS)	
	S. Osawa, T. Itsukaichi (Fujimi Incorporated)	
	Y. Sakamoto, M. Takaya (Chiba Institute of Technology)	
C-7-5	Effects of Retained Austenite and Nitriding on Rotating Bending Fatigue Properties of a Cold Work Tool Steel	292
	*D. Yokoi, Y. Haruna (Sanyo Special Steel Co., Ltd.)	
	Y. Yokoyama, K. Fukaura (University of Hyogo)	

C-7-6	Application of the Pre-oxidation Treatment in Ar Gas to the NIMS High-strength Steels	294
	*H. Kutsumi, H. Haruyama, F. Abe (NIMS)	
C-7-7	Effect of Shot Peening and Pre-oxidation in Air on Steam Oxidation Resistance of Mod.9Cr-1Mo Steel	296
	*H. Haruyama, H. Kutsumi, S. Kuroda, F. Abe (NIMS)	
C-7-8	Influence of Sulfur State on High-Temperature Steam Oxidation Resistance of High Chromium Ferritic Steels	298
	*M. Nakai, Y. Murata, M. Morinaga, K. Nagai (Nagoya University)	

Technology Transfer

C-8-1	Joint-Development of Ultra Steel Products with Industries in Suwa Area and NIMS	302
	Y. Watanabe, F. Takagi, M. Matsuzawa, M. Uematsu, S. Osaka, M. Miyasaka, H. Hama, N. Takagi, K. Hatano, K. Urushido, N. Sakurai, A. Miyasaka, *T. Komatsu (STX-21 Joint Research Group in Suwa) Y. Katada, S. Torizuka (NIMS)	
C-8-2	Mat Navi: Searching through NIMS Materials Databases	304
	*Y. Xu, M. Yamazaki, K. Yagi (NIMS)	

Heat Resistant Steel

D-9-1	300,000 Hours Creep Deformation Property of 0.3C Steel	308
	*K. Kimura, H. Miyazaki, K. Yokokawa, O. Kanemaru (NIMS)	
D-9-2	Influence of Tempering Temperature and Aluminum on Creep Property of Quenched and Tempered 2.25Cr-1Mo Steel	310
	*H. Kushima, K. Sawada, K. Kubo, K. Kimura (NIMS)	
D-9-3	Microstructural Analysis of Welded Joint in Crept 2.25Cr-1Mo Steels by EBSP Method	312
	*F. Yoshida, M. Mitsuhashi, D. Terada, H. Nakashima, H. Abe (Kyushu University)	
	H. Hayakawa (Kyushu Electric Power Co., Ltd.)	
D-9-4	Stress Relaxation Behaviour of High Strength Ferritic Creep Resistant Steel	314
	*T. Ohba, K. Sawada, K. Kimura, F. Abe (NIMS)	
	H. Okada (Sumitomo Metal Industries)	
D-9-5	Effect of Boron on Growth of Precipitates in 9Cr Ferritic Steels During Tempering	316
	*W.S. Jung, J.Y. Byun, K.T. Hong (Korea Institute of Science and Technology, Korea)	
	J.S. On (Korea University, Korea)	
D-9-6	Phase Equilibria between Austenite and (Nb,V)(C,N) in 9Cr-1Mo-V-Nb Steel	318
	*M. Yoshino, Y. Mishima (Tokyo Institute of Technology)	
	K. Sawada, H. Kushima, Y. Toda, K. Kimura (NIMS)	
D-9-7	Creep Deformation Behavior and Microstructure in 9Cr-3W-3Co-V,Nb Steels Containing High Boron	320
	*H. Semba, F. Abe (NIMS)	

D-9-8	Difference in Microstructure Evolution between Fe-8Cr-0.1C-M(M:Mo,W,Re) Quaternary Steels	322
	*T. Kunieda, K. Nishii, Y. Murata, M. Morinaga (Nagoya University)	
	T. Koyama (NIMS)	
D-9-9	Change of Microstructures of the High Cr Ferritic Heat Resistant Steel	324
	*H. Okubo, S. Muneki, F. Abe (NIMS)	
D-9-10	Suppression of Type IV Failure by Boron in 9Cr Heat Resistant Steel Welded Joints	326
	*M. Kondo, M. Tabuchi, S. Tsukamoto, F. Yin, F. Abe (NIMS)	
D-9-11	The Effect of Nitrogen on the Microstructure and Mechanical Properties of 11%CrWMoCo Steels	328
	*J. S. On (Korea University, Korea)	
	W. S. Jung, K. T. Hong (Korea Institute for Science and Technology, Korea)	
D-9-12	Behavior of BN Inclusions in High Cr Heat Resistant Steel at High Temperature Heat Treatment	330
	*K. Sakuraya, H. Sembra, H. Okada, F. Abe (NIMS)	
D-9-13	Observation of Multi-Scale Structure for a Creep-Fatigued Ferritic 12Cr-2W Steel	332
	* M. Kimura, K. Yamaguchi, M. Hayakawa, K. Kobayashi (NIMS)	
	K. Kanazawa (Chuo University)	
D-9-14	Omega Method Analysis of Creep Deformation Behavior for the Life Assessment of W Bearing 9Cr Martensitic Steels	334
	*M. Mitsuhashi, D. Terada, F. Yoshida, H. Nakashima, H. Abe (Kyushu University)	
D-9-15	Modeling of Precipitation in Multi-component, Multi-particle, Multi-phase Systems	336
	E. Kozechnik (Materials Center Leoben, Graz University of Technology, Austria)	
	J. Svoboda (Institute of Physics of Materials, Czech Republic)	
	F.D. Fischer (Materials Center Leoben, Institute of Mechanics, Institute for Materials Science, Austria)	
D-9-16	Simulation of the Thermal History of a Complex 9-12% Cr Steel used in Modern Steam Power Plants	340
	J. Rajek, *H. Cerjak (Graz University of Technology, Austria)	
	E. Kozechnik (Graz University of Technology, Materials Center Leoben, Austria)	
D-9-17	Transformation Behavior and Creep Strength of Gr.91 Steel Heated or Strained at Around Critical Temperature	342
	*F. Masuyama (Kyushu Institute of Technology)	
	N. Nishimura (Mitsubishi Heavy Industries, Ltd.)	
	A. Sasada (Choryo Engineering Co., Ltd.)	
D-9-18	Influence of Heats, Heat-treatments and Testing Methods on High Temperature Fatigue of 2.25Cr-Mo Steels	344
	*K. Yamaguchi, M. Hayakawa, M. Kimura, K. Kobayashi (NIMS)	
D-9-19	Development of High Chromium Steel FBR Grade	346
	*M. Ando, T. Takahashi, T. Wakai, K. Aoto (Japan Nuclear Cycle Development Institute)	
	K. Inoue (Japan Atomic Power Company)	

D-9-20	Mechanical Properties and Micro-structural Change of 0.1C-18Cr-9Ni-3Cu-Nb,N Steel during Long Term Aging	348
	*H. Okada, H. Semba, M. Igarashi, H. Matsuo (Sumitomo Metal Industries, Ltd.)	
D-9-21	Improvement in Creep Strength and Impact Toughness of Solid Solution Treated 15Cr Ferritic Steel	350
	*Y. Toda, H. Kushima, K. Kimura, F. Abe (NIMS)	
D-9-22	High Temperature Strength and Weldability of Alloy617 as a Candidate Material for 700°C USC Boiler Components	352
	*T. Sato, H. Harada (Babcock-Hitachi K. K.)	
D-9-23	High Temperature Strength and Oxidation Resistance of ODS Ferritic Steels	354
	*T.Narita, S. Ukai, S. Ohtsuka, T. Kaito (Japan Nuclear Cycle Development Institute) Y. Matsuda (Sumitomo Metal Technology, Inc.)	
D-9-24	High Cycle Fatigue Properties of Alloy 718 Nickel-base Superalloy	356
	* K. Kobayashi, K. Yamaguchi, M. Hayakawa, M. Kimura (NIMS)	
D-9-25	Degradation of Type R Thermocouples during Creep Test.....	358
	*H. Miyazaki, K. Kimura (NIMS)	