U.S. Department
of Transportation
**Federal Railroad
Administration**

Wheel Failure Mechanisms of Railroad Cars

APPENDICES

Office of Research and
Development
Washington, D.C. 20590

CONTRACT NO. DTFR53-82-C-00282, TASK ORDER #6

ASSOCIATION OF AMERICAN RAILROADS

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DOT 'FRA/ORD-

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APPENDICES

TO

WHEEL FAILURE MECHANISMS OF RAILROAD CARS

INTERIM REPORT

TTC-040(FRA-IR85) January 1986

APPENDIX 2.0

WHEEL FAILURES FOR 1983

(LAST QUARTER)

APPENDIX 2.1

WHEEL FAILURES FOR 1984

FAILED WHEEL FILE 1983

STRAIGHT PLATE						CURVED PLATE					
RR & DATE	NO OH	OH	B	C	U	RR & DATE	NO OH	OH	B	C	U
NAHX12213		1			1	TTX12043	1				1
CRR02163	1				1						
CO06303		1		1							
PC10043		1		1							
CO11053	1				1						
MP12303		1			1						
UP11053	1			1							
UP12213	1				1						
MP12213	1				1						
UP101283	1				1						
MP12293	1				1						
MP12193		1			1						
MP12213	1				1						
MP02093	1				1						
SOU05183	1				1						
ATSF01123	1			1							
TOTAL	11	5	0	4	12	0	1	0	0	0	1

APPENDIX 2.1

FAILED WHEEL FILE **1984** REVISED 4/8/85

STRAIGHT PLATE

	OWNER	NUMBER	DATE	DESIGN	NO OH	OH	B	C	U
	UP	21758	JAN 1	H-36		1			1
	CO	111143	JAN 9	J-33	1				1
	ACFX	48039	JAN 14	B-38	1				1
	CNW	753409	JAN 14	H-36		1			1
@	SP	240641	JAN 19	CM-33		1			1
	SLSF	79602	JAN 19	H-36	1				1
@	TTX	473329	JAN 19	J-33		1			1
@	CO	76433	JAN 20	J-33	1				1
@	MP	711712	JAN 20	J-36	1				1
@	MP	711712	JAN 20	J-36	1				1
	DRGW	15671	JAN 21	H-36	1				1
@	BN	458578	JAN 22	H-36		1		1	
	ACFX	46077	JAN 23	H-36	1			1	
@	IC	61677	JAN 23	H-36		1			1
	UTLX	80359	JAN 24	H-36		1		1	
@	CNW	753409	JAN 30	H-36		1			1
	ACFX	89388	JAN 31	H-36		1		1	
@	ACFX	48008	FEB 3	B-38	1				1
	CELX*	23426	FEB 5	H-36	1			1	
	CELX*	23426	FEB 5	H-36	1			1	
	LN	240632	FEB 8	CH-36		1		1	
	ETTX	900357	FEB 8	A-28	1				1
	UP	71038	FEB 16	H-36		1			1
	NW	648207	MAR 2	CJ-33	1				1
	SBD	432307	MAR 8	H-36	1				1
	CR	273264	MAR 9	J-33	1				1
	CR	273264	MAR 9	J-33	1				1
	ATSF	313143	MAR 13	H-36		1			1
	CN*	700687	MAR 16	D-28		1		1	
	BNFE	9437	MAR 16	J-33	1				1
	CODX	48047	APR 24	CH-36		1		1	
@	NW	176990	APR 28	H-36		1		1	
	CP*	403102	MAY 4	B-36		1			1
	ATSF	290045	MAY 9	CM-33		1		1	
	KCS	5252	MAY 17	K-36		1		1	
@	NW	101074	MAY 25	J-33	1				1
	TTAX	978231	JUN 1	CJ-33		1		1	
	TTX	115282	JUN 24	J-33		1		1	
@	ATSF	622368	JUL 17	CH-36	1			1	
	TTX	153362	AUG 4	R-33	1		1		
	CR	73151	AUG 8	CA-33		1			1
	ATSF	700043	AUG 13	A-28	1			1	
	MP	706003	AUG 14	J-36		1			1
@	ATSF	700065	SEPT 5	D-28	1			1	
@	ATSF	293045	SEPT 14	J-33	1				1
	MP	697068	SEPT 21	J-36	1				1
	BCOL*	17443	SEPT 26	J-33	1				1
@	TTX	159908	OCT 15	M-33	1				1
	KCS	957	OCT 17	H-36		1			1
@	SCL	5723	OCT 20	A-33		1			1
@	OTTX	91730	OCT 22	M-33	1		1		
@	CELX	905022	OCT 26	CH-36	1			1	
@	ATSF	601000	OCT 29	H-36	1				1
	SP	515841	NOV 14	B-28	1		1		
@	CNA	794750	NOV 16	H-36	1			1	
@	SP	240283	NOV 21	CJ-33	1			1	
	LGIX	359	NOV 28	H-36		1			1
	UP	492982	DEC 4	CM-33		1	1		
	TTWX	981746	DEC 5	CJ33	1				1
	UP	72887	DEC 5	H-36		1			1
	DUPX	38424	DEC 6	H-36		1		1	
	NOKL	99017	DEC 6	CH-36	1				1
	TLCX	31818	DEC 18	H-36	1				1
	TLCX	31818	DEC 18	H-36	1				1
	CN*	199319	DEC 19	J-36	1			1	
	TTX	100320	DEC 27	J-33	1				1

CURVED PLATE

	OWNER	NUMBER	DATE	DESIGN	NO OH	OH	B	C	U
	ATSF	297089	FEB 11	CJ-33	1				1
	SP	900637	APR 20	CJ-33	1				1
	CPWX*	600408	MAY 7	CH-36	1			1	
@	RBCS	3136	JUL 1	CH-36	1			1	
	BN	10163	AUG 13	CA-33	1				1
	TTX	476299	NOV 5	CJ-33		1			1
	CN*	682211	NOV 14	CJ-33		1			1
	TTX	153411	NOV 14	CJ-33		1			1
	CP*	54959	DEC 3	CJ-33	1				1
@	TTX	250988	DEC 22	CJ-33	1				1
	XTTX	153144	DEC 30	CJ-33		1		1	

	NO OH	OH	B	C	U
TOTAL	38	28	4	22	40
PERCENT	49.4%	36.4%	5.5%	30.1%	54.8%

TOTAL NUMBER OF WHEELS 77

STRAIGHT PLATE TOTAL....... 85.7%

NON-DISCOLORED TOTAL....... 58.4%

NO OH	OH	B	C	U
7	4	0	3	8
9.1%	5.2%	0.0%	4.1%	11.0%

CURVED PLATE TOTAL......... 14.3%

LIST OF APPENDICES

APPENDIX 2.2

WHEEL FAILURES FOR 1985 (JANUARY-JUNE)

APPENDIX 2.2

FAILED WHEEL FILE 1985

STRAIGHT PLATE

OWNER	NUMBER	DATE	DESIGN	NO OH	OH	B	C	U
TLCX	35042	JAN 1	H-36		1			1
TTX	601512	JAN 7	J-33		1			1
NOKL	99130	JAN 9	CH-36	1				1
MOBX*	75029	JAN 11	H-36		1			1
NAHX*	475537	JAN 11	H-36	1			1	
MMID	1256	JAN 19	J-33	1				1
TTX	101395	JAN 19	CM-33	1				1
NAHX	487055	JAN 20	H-36	1				1
RTMX	8585	JAN 20	H-36		1			1
MP	711680	JAN 20	J-36	1				1
MP	711680	JAN 20	J-36	1				1
UP	73297	JAN 20	H-36	1				1
CNW	135003	JAN 20	H-36		1			1
TLCX	35042	JAN 25	H-36		1			1
NW	139678	JAN 26	J-35		1			1
ATSF	313072	JAN 21	CH-36		1			1
BN	526281	JAN 30	CH-36		1		1	
BNFE	9505	JAN 30	J-33	1				1
TTWX	922090	JAN 31	J-33		1			1
MP	822173	FEB 3	J-36	1				1
TTX	252108	FEB 4	CJ-33		1			1
XTRX	75942	FEB 4	H-36	1				1
SLSF	79711	FEB 4	H-36		1			1
CNW	173204	FEB 7	CH-36	1				1
BN	460014	FEB 9	H-36	1				1
UP	81527	FEB 9	CH-36		1			1
TTGX	911731	FEB 10	N-33	1		1		
WP	65482	FEB 12	J-33	1				1
MP	838183	FEB 23	J-33		1			1
UTLX	58568	FEB 25	H-36	1				1
MP	711271	FEB 27	CH-36	1				1
TTWX	982224	MAR 2	J-33		1			
BN	446780	MAR 9	H-36		1		1	
PTLX	17973	MAR 9	CH-36	1				1
BLE	90747	MAR 20	G-33	1				1
NRS	2021	APRIL 12	H-36	1			1	
GTW	597540	MAY 15	CJ-33	1				1
SP	694260	JUNE 17	J-33		1			1

CURVED PLATE

OWNER	NUMBER	DATE	DESIGN	NO OH	OH	B	C	U
NW	169832	JAN 10	CJ-36	1				1
TTX	473122	FEB 6	CJ-33	1				1
SOU	34205	FEB 8	CJ-33	1				1
WP	64738	FEB 24	CJ-33	1				1
BO	73362	MAR 28	CJ-33	1				1
UPFE	457553	APR 1	CJ-33	1				1
LC	215	APRIL 7	CJ-33		1			1
TTX	156557	APR 14	CJ-33	1				1
GN	138136	APR 15	CJ-33	1				1
TTWX	972808	MAY	CM-33	1				
KCS	966	MAY 30	CJ-36		1		1	

	NO OH	OH	B	C	U	NO OH	OH	B	C	U
TOTAL	21	17	1	4	32	9	2	0	1	9
PERCENT	42.9%	34.7%	5.0%	66.7%	69.6%	18.4%	4.1%	0.0%	2.1%	19.1%

TOTAL NUMBER OF WHEELS 49

STRAIGHT PLATE TOTAL....... 77.6%

NON-DISCOLORED TOTAL....... 61.2%

CURVED PLATE TOTAL......... 22.4%

* CANADIAN DERAILMENT

UNIDENTIFIABLE

CGTX 29062 JAN 8 J-33

APPENDIX 3.1

DESCRIPTION OF VAX-11 DATATRIEVE DATA MANAGEMENT FACILITY

APPENDIX 3.1

VAX-11 DATATRIEVE is a multi-faceted data management facility that can store, update, and retrieve information and generate reports. DATATRIEVE is a product of Digital Equipment Corporation (DEC) and is designed to be used on DEC computer systems in conjunction with other DEC software products.

DATATRIEVE can be used interactively from a terminal or called from an application program. Data can be accessed in VAX-11 RMS (Record Management system) and VAX-11 DBMS (Database Management System) database structures. It features integrated editing and graphic output facilities and it supports the forms management facility of VAX-11 TDMS (Terminal Data Management System).

The DATATRIEVE facility also provides a distributed data access capability using DECnet-VAX communications software. This capability makes it possible to use DATATRIEVE to retrieve data on remote VAX systems, just as if the data were stored locally. A single DATATRIEVE command is capable of accessing data from RMS or DBMS local or remote, simply depending on its definition in the VAX-11 CDD (Common Data Dictionary).

Implementing a DATATRIEVE application is a two-phase process. In the first, and more complex, phase the appropriate statements are used to define all data that will be accessed by the application. This need be done only once to establish the foundation on which to build the application. In the second phase DATATRIEVE statements are used to process the data associated with these definitions.

DATATRIEVE allows store data to be retrieved in an easily understood form regardless of underlying data structure (RMS or DBMS) or location (local or remote via DECnet). The data retrieval statements of DATATRIEVE are simple, and particularly powerful statements with English-like syntax. Ad Hoc information retrieval with it is normally performed as an interactive process using a series of statements to progressively narrow-down the group of records to be retrieved.

DATATRIEVE allows domains to be defined that can subset the fields of a record and can span multiple RMS or DBMS record types. These are called view domains because they provide a user's logical view of the data. View domains can also be used with RMS files for domains containing records related in a hierarchical fashion.

Third party vendors have recently announced software products that interface with DATATRIEVE. One such vendor is SPSS INC., while another is ISSCO INC. The former released a new version of SPSSX2 (Statistical Package for the Social Sciences) to be used with DATATRIEVE. The latter released new versions of TELAGRAPH and TELAPLAN (generalized graphic and planning software) to be used with DATATRIEVE.

Currently, the VAX-11/780 at the TTC supports all of the software mentioned, with the one exception of DBMS.

APPENDIX 3.2

ANNOTATED BIBLIOGRAPHY
(Sorted by File Number)

```
                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   100379*                          DATE  00     78

                              AUTHOR
           ROBERT MARION KIPP, PH. D.

                               TITLE
           INVESTIGATIONS OF CRACK GROWTH IN RAILROAD CAR WHEELS CAUSED
            BY THERMALLY INDUCED RESIDUAL STRESS CHG. & CYC. MEC. LOAD

                             KEY WORDS
  FINITE ELEMENT SIMULATIONS, TASK 10, 33" CURVED PLATE, CLASS U, STRESS
  ANALYSIS, LABORATORY SIMUALTIONS, TASK 8, CRACK PROPAGATION.
------------------------------------------------------------------------

  WHEEL STRESS; THERMAL STRESS; CRACK PROPAGATION, WHEEL WEAR LOADING,
  METALLURGY

                              SYNOPSIS
A PSEUDO-ELASTIC FINITE ELEMENT SIMULATION OF DRAG BRAKING CYCLES PREDICTS
DEVELOPMENT OF RESIDUAL STRESS AND CRACK STRESS INTENSITY, BUT NOT SEVERE ENOUGH
TO PREDICT THE DEGREE OF CRACK GROWTH IN DYNAMOMETER TESTS OR ESPECIALLY IN
SERVICE.  POSSIBLE INTERACTION OF HOT THERMAL STRESSES AND RAIL LOAD STRESSES
CITED AS CAUSE FOR DISCREPANCY

************************************************************************


                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   100542/60*                       DATE  00 SEP 82

                              AUTHOR
           V. ARONOV & M. RONS

                               TITLE
           SECOND INTL. HEAVY HAUL CONF. "THE WEAR MECHANISM OF THE
           RAILROAD WHEEL STEEL IN THE FREE ROLLING & BRAKING COND."

                             KEY WORDS
  FATIGUE MODEL, TASK 10

------------------------------------------------------------------------
  WEAR MECHANISMS, MICROSLIP, CONTACT AREA, ADHESION AREA, FRICTION
  COEFFICIENT, TRANSITION FROM ONE WEAR MECHANISM TO ANOTHER


                              SYNOPSIS
EXPERIMENTAL INVESTIGATION OF WHEEL STEELS ON A SMALL SCALE WEAR RIG; A
REFERENCE PAPER FOR SHELLING & WEAR MECHANISMS



************************************************************************
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FILE PRINTED BY FILE NUMBER

FILE NUMBER 100542/61* DATE 00 SEP 82

AUTHOR

A. J. OPINSKY

TITLE

SECOND INTL. HEAVY HAUL CONF. "RAILROAD WHEEL BACK RIM FACE FAILURES: DATA AND ANALYSIS"

KEY WORDS

FAILURE MODEL, TASK 10

BACK RIM FACE FAILURE (BRFF), CRACK INITIATION & PROPOGATION, PROPOGATION RATE, STRESS INTENSITY FACTOR, SHAPE FACTOR, FAILURE INITIATED AT RIM STAMPING (RS)

SYNOPSIS

A CASE STUDY OF FAILURE REPORTS FROM TWO RAILROADS; FRACTURE MECHANICS APPROACH FOR THE FAILURE EVALUATION

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 100542/62* DATE 00 SEP 82

AUTHOR

R. D. FINCH & W. E. THOMFORD

TITLE

SECOND INTL. HEAVY HAUL CONF. "DESIGN FEATURES FOR OPERATIONAL ACOUSTIC SIGNATURE INSPECTION OF RAILROAD WHEELS"

KEY WORDS

NED, TASK 14

ACOUSTIC SIGNATURE METHOD, DEFECTIVE WHEELS, FALSE ALARMS, TIME DOMAIN ANALYSIS

SYNOPSIS

A BACKGROUND PAPER FOR A PRACTICAL OPERATIONAL SYSTEM OF ACOUSTIC SIGNATURE INSPECTION OF DEFECTIVE WHEELS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 100542/71* DATE 00 SEP 82

AUTHOR

D. G. BLAINE

TITLE

SENCOND INTL. HEAVY HAUL CONF. "EFFECT OF BRAKE EQUIPMENT UPON CAPABILITY AND ROLLING STOCK FOR HEAVY HAUL ROUTES"

KEY WORDS

TTC TRACK TESTS, TASKS 5, 6, 7, & 8

BRAKE EQUIPMENT BRAKING RATIO, BRAKE PIPE, STOPPING AND GRADE HANDLING ABILITY, TRAIN LENGTH, TRAIN SPACING

SYNOPSIS

EXCELLENT REFERENCE MATERIAL FOR TRAIN OPERTAION, AAR & UIC BRAKES, GRADE BRAKING, ENERGY ABSORPTION & DISSIPATION

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 100545* DATE 00 78

AUTHOR

P. STANLEY, APPLIED SCIENCE PUBLISHERS LTD

TITLE

NON-LINEAR PROBLEMS IN STRESS ANALYSIS

KEY WORDS

MATERIAL PROPERTIES, TASK 3, FINITE ELEMENT SIMULATIONS

STRESS ANALYSIS; CRACK-TIP DEFORMATION; PLASTICITY CYCLING; CREEP COLLAPSE; BIAXIAL PLASTIC FLOW; THERMAL RATCHETING

SYNOPSIS

SOME OF THE PAPERS CONTAINED IN THIS BOOK TREAT MATERIAL AND STRESS ANALYSIS NON-LINEARITIES ASSOCIATED WITH ELEVATED TEMPERATURE CREEP AND CYCLIC PLASTICITY THAT MAY HAVE GENERAL APPLICABILITY TO THE ANALYSIS OF STRESS CHANGES AND CRACKING OF WHEELS

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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   100600*                         DATE  00 SEP 75

                              AUTHOR
          THE AIR BRAKE ASSOCIATION

                               TITLE
          ENGINEERING AND DESIGN OF RAILWAY BRAKE SYSTEMS


                            KEY WORDS
  TTC TRACK TESTS & TESTING ON RDU, TASKS 4, 5, 6, 7, & 8
-------------------------------------------------------------------------------
  AIR BRAKE EQUIPMENT, AUTOMATIC AIRBRAKE, SLACK ADJUSER, BRAKE HEAD, BRAKE
  PIPE, BRAKING RATIO, BRAKE CYLINDER, RETARDING FORCE, PRACTICAL ADHESION
  LEVELS

                             SYNOPSIS
AN EXCELLENT PRIMER ON TRAIN BRAKE SYSTEM DESIGN, FREIGHT BRAKE SYSTEMS AND
PRINCIPLES OF RIGGING DESIGN



******************************************************************************


                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   200002*                         DATE  00 SEP 72

                              AUTHOR
          AAR, RESEARCH & TEST, CHICAGO

                               TITLE
          INSTRUMENTED WHEELS FOR MEASUREMENT OF VERTICAL AND LATERAL
          WHEEL FORCES

                            KEY WORDS
  PRELIMINARY TRACK TESTING, TASK T5
-------------------------------------------------------------------------------
  WHEELS; MEASUREMENT OF FORCES; INSTRUMENTED WHEELS; TRUCK CALIBRATION;
  STRAIN OUTPUT FOR GAGES; WHEEL TEMPERATURE/FORCES


                             SYNOPSIS
A BACKGROUND PAPER FOR INSTRUMENTATED WHEELSETS; CALIBRATION PROCEDURES;



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FILE PRINTED BY FILE NUMBER

FILE NUMBER 200028* DATE 00 NOV 66

AUTHOR
IGOR L. PAUL & RANGANATH NAYAK

TITLE
STRESS AND STRAIN IN ROLLING BODIES IN CONTACT

KEY WORDS
TREAD CONTACT STRESS; TASK 10

STRESS & STRAIN AT CONTACT REGION OF ROLLING SHEEL; WHEEL WITH NORMAL, LATERAL & TANGENTIAL LOADS

SYNOPSIS
COMPUTER SOLUTION OF TWO SPHERES OF SIMILAR MATEIRAL ROLLING ON EACH OTHER. RESULTS NEED TO BE EXTENDED TO THE CASE OF WHEEL ROLLING ON RAIL

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 200190* DATE 18 NOV 69

AUTHOR
G. R. WEAVER, P. A. ARCHIBALD, E. B. BRENNEMAN

TITLE
INVESTIGATION OF THE THERMAL CAPACITY OF RAILROAD WHEELS
USING COBRA BRAKE SHOES

KEY WORDS
LABORATORY SIMULATION (FULL SCALE DYNAMOMETER BRAKING WITH COBRA BRAKE SHOES & CAST METAL BRAKE SHOES) RESIDUAL STRESS, TASKS 6 & 7,

---

36 INCH CR WHEELS, TREAD CRACKS, EMERGENCY STOP TESTS

SYNOPSIS
OBJECTIVE EVALUATION OF 36 INCH CR WHEELS BRAKED WITH COBRA SHOES AND CAST METAL SHOES, WHEEL TREAD CONDITONS, MACROSTRUCTURE OF RIM, RESIDUAL STRESS PATTERNS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 200222* DATE 00 00

AUTHOR
HIROSHI TADA, PAUL C. PARIS & GEORGE R. IRWIN

TITLE
STRESS ANALYSIS OF CRACKS HANDBOOK

KEY WORDS
CRACK PROPOGATION, TASK 8,

STRESS ANALYSIS ON CRACK PROBLEMS; FRACTURE MECHANICS CORRELATION PARAMETER COMPLIANCE CALIBRATION ANALYSIS; FUNCTION ANALYSIS, PLASTICITY ANALYSIS; MATERIALS SCIENCE

SYNOPSIS
COMPREHENISVE SOURCE OF FORMULAS AND STRESS ANALYSIS INFORMTAION ON CRACK PROPOGATION THROUGH FRACTURE MECHANICS CORRELATION PARAMETERS AND CURRENT FRACTURE CRITERIA. CLOSED FORM AND NUMERICAL SOLUTIONS.

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 200256/1-2* DATE 00 OCT 78

AUTHOR
A. S. BABB, D. S. HODDINOTT, D. J. NAYLOR

TITLE
SIXTH INTL. WHEELSET CONGRESS, "WHEELSET RESEARCH & DEVELOPMENT IN THE BRITISH STEEL CORPORATION"

KEY WORDS
FINITE ELEMENT ANALYSIS, RESIDUAL STRESSES, MATERIAL PROPERTIES, TASKS 10, 6 & 3

---

36 IN. WROUGHT WHEELS, WHEEL DESIGNS, MECHANICAL STRUCTURAL LOADS, METALURGICAL STUDIES, THERMAL CRACKING BEHAVIOR

SYNOPSIS
FINITE ELEMENT ANALYSIS OF TWO 36 INCH WHEELS SHOWS LOWER STRESSES IN DOUBLE CURVED PLATE WHEELS THAN IN STRAIGHT PLATE WHEELS. RESIDUAL STRESS DETERMINATION OF SERVICE WHEELS. THERMAL CRACKING BEHAVIOR OF WHEEL STEELS IN LABORATORY.

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 200256/1-4* DATE 00 OCT 78

AUTHOR
L. BRAZZODURO, P. BROZZO, R. DEMARTINI,

TITLE
6TH INTL WHEELSET CONG. "FINAL RESULTS OF THE RESEARCH WORK ON A NEW SOLID WHEEL APT TO MOST SEVERE OPER. COND.

KEY WORDS
MATERIAL PROPERTIES, TASK 3, UIC-R/2 AND R/6 STEEL

(ITALIAN PRACTICE) THERMAL CRACKING TESTS, DRAG & STOP BRAKING TESTS

SYNOPSIS
THERMAL CRACKING TESTS, DRAG AND STOP BRAKING TESTS (UIC-R/6 & 5 CR WHEELS) WERE PERFORMED TO INVESTIGATE RESISTANCE TO REPEATED THERMAL LOADING.

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 200256/2-3* DATE 00 OCT 78

AUTHOR
M. R. JOHNSON

TITLE
SIXTH INTL. WHEELSET CONGRESS, "PREDICTED AND MEASURED WHEEL STRAINS RESULTING FROM PROLONGED DRAG BRAKING"

KEY WORDS
FINITE ELEMENT SIMULATION, SERVICE EVALUATION, TASK 5 & 10; J36 WHEEL (WROUGHT STEEL) CLASS U

NONLINEAR FINITE ANALYSIS, FULL SCALE TRACK TESTINGS, PREDICTION & MEASUREMENT OF WHEEL STRAINS, RESIDUAL STRESS MEASUREMENT

SYNOPSIS
BOTH TEST DATA AND COMPUTER ANALYSIS SHOW THAT THE WHEEL STRAINS ACCOMPANYING PROLONGED DRAG BRAKING MAY EXCEED YIELD POINT STRAINS

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                     FILE PRINTED BY FILE NUMBER

FILE NUMBER   200256/2-4*                    DATE  00 OCT 78

                               AUTHOR
            K. NISHIOKA, S. NISHIMURA, K. KIRAKAWA,

                                TITLE
            SIXTH INTL. WHEELSET CONGRESS, "FRACTURE MECHANICS APPROACH
            TO THE STRENGTH OF WHEELSETS"

                              KEY WORDS
  EXPERIMENTAL ANALYSIS BASED ON LINEAR FRACTURE MECHANICS, TASK 10, 4 TYPES
  OF WHEEL STEELS, (JAPANESE PRACTICES)
------------------------------------------------------------------------------

  FRACTURE MECH. STRESS INTENSITY FACTOR, RESID. STRESSES, FRACTURE TOUGHNESS
  FATIGUE CRACK GROWTH PROP. OF WHEEL MATL., CRITICAL COND. FOR CRACK GROWTH

                               SYNOPSIS
FRACTURE MECHANICS APPROACH IS CONDUCTED IN BRITTLE TYPE RIM FRACTURE. CRITICAL
CONDITIONS FOR CRACK GROWTH AND FINAL FAILURE ARE EVALUTRED BY EXPERIMENTAL
ANALYSIS BASED ON LINEAR FRACTURE MECHANICS


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                     FILE PRINTED BY FILE NUMBER

FILE NUMBER   200256/3-3*                    DATE  00 OCT 78

                               AUTHOR
            M. F. HENGEL

                                TITLE
            SIXTH INTL. WHEELSET CONGRESS, "FREIGHT CAR WHEEL PERFORM
            ANCE"

                              KEY WORDS
  SERVICE EVALUATION, TASK 1, ALL TYPES OF WHEEL SIZES & RIM TYPES,
------------------------------------------------------------------------------
  PERFORMANCE OF FREIGHT CAR WHEELS, AAR WHY MADE CODE


                               SYNOPSIS
OVERALL PICTURE OF FREIGHT CAR WHEEL PERFORMANCE IN U. S.  REMOVAL GUIDELINES
FOR DEFECTIVE WHEELS FROM SERVICE; FLANGE WEAR AS AN AREA OF CONCERN


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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   200256/3-5*                      DATE  00 OCT 78

                              AUTHOR
          D. G. BLAINE, F. J. GREJDA, & J. C. KAHR

                               TITLE
          SIXTH INTL WHEELSET CONG. "OPERATION ENVIRONMENT FOR NORTH
          AMERICAN FREIGHT TRAIN WHEELS DURING SPEED & SLACK CON. BRAK

                            KEY WORDS
  SERVICE EVALUATION, TRAIN BRAKE APPLICATION PRACTICES IN U. S. TASKS 5 & 6,
----------------------------------------------------------------------------
  TRAIN BRAKE APPLICATIONS, NET BRAKING RATIOS, COMPOSITION BRAKE SHOES,
  TRAIN SLACK, ACCELERATION, BHP/CAR WHEELS


                              SYNOPSIS
DISCUSSION OF BRAKE APPLICATION PRACTICE IN U. S.; SUGGESTIONS FOR OPTIMIZING
TRACTIVE EFFORT, FUEL SAVINGS AND BRAKE SHOE WEAR



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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   200766*                          DATE  00 NOV 80

                              AUTHOR
          I. KALEV, (NASA CONTRACTOR REPORT)

                               TITLE
          A COMPUTER PROGRAM FOR CYCLIC PLASTICITY AND STRUCTURAL
          FATIGUE ANALYSIS

                            KEY WORDS
  FINITE ELEMENT SIMULATION, TASK 10
----------------------------------------------------------------------------
  CYCLIC PLASTICITY, CRACK INITIATION, CRACK GROWTH, CUMULATIVE DAMAGE
  CRITERIA, FATIGUE ANALYSIS, CYCLIC LOADS, ELASTOPLASTICITY, METAL FATIGUE,
  STRUCTURAL ANALYSIS

                              SYNOPSIS
COMPUTER PROGRAM FOR SMALL STRUCTURAL COMPONENTS, CYCLIC PLASTICITY RESPONSE,
PREDICTION OF LIFE TO CRACK INITIATION & CRACK GROWTH RATE


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FILE PRINTED BY FILE NUMBER

FILE NUMBER 200778* DATE 00 NOV 80

AUTHOR

R. D. FINCH

TITLE

TEST REPORT FOR THE CRACKER PLATE DETECTOR TESTS (SERIES I)

KEY WORDS

TASK 14, NDE TECHNIQUES

SYNOPSIS

EVALUATION OF ACOUSTIC SIGNATURE INSPECTION SYSTEM FOR DETECTION OF FLAWS IN RAILROAD WHEELS DURING A SERIES OF TESTS CONDUCTED AT PUEBLO

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 200784* DATE 00 DEC 81

AUTHOR

M. R. JOHNSON & R. R. ROBINSON

TITLE

IMPROVED SAFETY OF RAILROAD CAR WHEELS

KEY WORDS

WHEEL FAILURES, THERMAL CRACKS, SAFETY

SYNOPSIS

A GENERIC BACKGROUND PAPER (REPORT) ON FACTORS WHICH LEAD TO RAILROD WHEEL FAILURES

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 201047* DATE 00 OCT 75

AUTHOR
S. TANAKA & K. HATSUNO, (ET. AL.)

TITLE
FIFTH INTERNATIONAL WHEELSET CONGRESS, VOL. 2

KEY WORDS

WHEEL/RAIL; AXLES, LOAD FATIGUE; BEARINGS & SPEED; HEAT REFINING;
INSEPCTION & MAINTENANCE; ECONOMICS

SYNOPSIS
GENERAL BACKGROUND REFERENCE

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 201048* DATE 00 OCT 75

AUTHOR
H. TOYOTA, K. KASAI (ET. AL.)

TITLE
FIFTH INTERNATIONAL WHEELSET CONGRESS, VOL. 1

KEY WORDS

WHEEL/RAIL; SHINKANSEN TRAIN & BOGIE; SPEEDS, AXLE LOADS, WHEELS, ADHESION;
SLIDING BLOCKS ON TREADS, WHEEL NOISE, RESILIENT WHEELS; FRICTION & WEAR,
WHEEL METALLURGY, RESIDUAL STRESS, WHEEL DESIGNS

SYNOPSIS
GENERAL BACKGROUND REFERENCE

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 201049* DATE 00 OCT 75

AUTHOR
H. TOYOTA, K. KASAI (ET. AL.)

TITLE
FIFTH INTERNATIONAL WHEELSET CONGRESS, VOL. 3

KEY WORDS

WHEEL/RAIL; SUPPLEMENT TO VOL. 1 & 2; DISCUSSION, ADDITIONS, SUMMARY TO PREVIOUS PAPERS

SYNOPSIS
GENREAL BACKGROUND REFERENCE

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 201050* DATE 00 JUL 69

AUTHOR
T. SUGIYAMA , K. NISHIOKA, (ET. AL.)

TITLE
THIRD INTERNATIONAL WHEELSET CONFERENCE

KEY WORDS

WHEEL/RAIL; TESTING; RESILIENCY; CAST STEEL; THERMAL CRACKING; RESIDUAL STRESS; METALLURGY

SYNOPSIS
GENERAL BACKGROUND REFERENCE

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 201098* DATE 00 JUN 50

AUTHOR
H. R. WETENKAMP, O. M. SIDEBOTTOM, H. J. SCHRADER

TITLE
THE EFFECT OF BRAKE SHOE ACTION ON THERMAL CRACKING AND ON FAILURE OF WROUGHT STEEL RAILWAY CAR WHEELS

KEY WORDS
BRAKE DYNAMOMETER TESTING, TASKS 4, 6, & 8

LABORATORY TESTS, STOP BRAKING, DRAG BRAKING, WROUGHT STEEL WHEELS, THERMAL CRACKS, RESIDUAL STRESSES, FRACTURE, CARBON CONTENT, HEAT TREATMENT, WHEEL DESIGN

SYNOPSIS
WROUGHT STEEL WHEELS SUBJECTED TO A SERIES OF LABORATORY TESTS SUCH AS STOP BRAKING & DRAG BRAKING; STUDY OF EFFECT OF CARBON CONTENT, HEAT TREATMENT, WHEEL DESIGN

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 201109* DATE 00 DEC 76

AUTHOR
S. C. ANAND

TITLE
SHAKEDOWN LOADS IN ROLLING DISKS, CYLINDERS AND SPHERES

KEY WORDS
WHEEL SHELLING

STRESS ANALYSIS; FINITE ELEMENTS; PLASTIC STRESS-STRAIN RELATIONS; SUBSTRUCTURING UNLOADING CRITERIA; ELASTIC-PLASTIC

SYNOPSIS
USEFUL PAPER FOR WHEEL SHELLING

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300074* DATE 09 SEP 72

AUTHOR
N. A. BERG & R. H. ALBER

TITLE
TREAD BRAKING VERSUS THE WHEEL

KEY WORDS

WHEEL TREAD PROBLEMS, SHELLING PHENOMENA, WHEEL STRESSES, SPALLING, THERMAL LOAD DAMAGE TO WHEELS, BRAKING

SYNOPSIS
EXCELLENT PRIMER ON WHEEL THERMAL FAILURE

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300082* DATE 00 SEP 70

AUTHOR
N. A. BERG & W. J. KUCERA

TITLE
"A REVIEW OF THERMAL DAMAGE IN RAILROAD WHEELS"

KEY WORDS

BRAKING, THERMAL DAMAGE TO RAILROAD WHEELS, ADHESION, WHEEL FUNCTIONS; STRESS ON WHEEL PLATE AND RIM, THERMAL FATIGUE CRACKS, SHELLING OF WHEELS,

SYNOPSIS
PRIMER ON WHEEL THERMAL DAMAGE

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                  FILE PRINTED BY FILE NUMBER

FILE NUMBER   300082*                        DATE  00 SEP 70

                              AUTHOR
                 N. A. BERG & W. J. KUCERA

                               TITLE
                 "A REVIEW OF THERMAL DAMAGE IN RAILROAD WHEELS"


                           KEY WORDS

--------------------------------------------------------------------------------

   BRAKING, THERMAL DAMAGE TO RAILROAD WHEELS, ADHESION, WHEEL FUNCTIONS;
   STRESS ON WHEEL PLATE AND RIM

                            SYNOPSIS
PRIMER ON WHEEL THERMAL DAMAGE




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                  FILE PRINTED BY FILE NUMBER

FILE NUMBER   300146*                        DATE  00     75

                              AUTHOR
                 H. MURO, T. TSUSHIMA, M. NAGAFUCHI

                               TITLE
                 "INITIATION AND PROPAGATION OF SURFACE CRACKS IN ROLLING
                 FATIGUE OF HIGH HARDNESS STEEL

                           KEY WORDS

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   CRACK PROPAGATION; FATIGUE ANALYSIS; METALLURGY; STEELS; WEAR

                            SYNOPSIS
APPLICABLE TO SHELLING FAILURES



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FILE PRINTED BY FILE NUMBER

FILE NUMBER 300146* DATE 00 75

AUTHOR
H. MURO, T. TSUSHIMA, M. NAGAFUCHI

TITLE
"INITIATION AND PROPAGATION OF SURFACE CRACKS IN ROLLING
FATIGUE OF HIGH HARDNESS STEEL

KEY WORDS

CRACK PROPAGATION; FATIGUE ANALYSIS; METALLURGY; STEELS; WEAR

SYNOPSIS
APPLICABLE TO SHELLING FAILURES

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300147* DATE 00 76

AUTHOR
T. M. BEAGLEY

TITLE
"SEVERE WEAR OF ROLLING/SLIDING CONTACTS"

KEY WORDS

WEAR OF WHEEL FLANGES; ROLLING/SLIDING WHEEL CONTACTS; SHEAR STRESS;
PRESSURE AND FRICITION FORCES

SYNOPSIS
APPLICABLE TO SHELLING FAILURES

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300167* DATE 00 64

AUTHOR
E. OLLERTON, PAPER 10, PROC. INSTN. MECH. ENGRS.

TITLE
"STRESSES IN THE CONTACT ZONE"

KEY WORDS

CONTACT-STRESS PROBLEMS; ADHESION IN RAIL-WHEEL CONTACT; FROZEN-STRESS PHOTOELASTIC TESTS, SURFACE SHEAR STRESS FROM TANGENTIAL FORCES, CREEP OF ROLLING BODIES, BENDING STRESSES IN RAILS,

SYNOPSIS
APPLICABLE TO SHELLING FAILURES

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300218* DATE 00 SEP 78

AUTHOR
C. O. FREDERICK

TITLE
EFFECT OF WHEEL AND RAIL IRREGULARITIES ON THE TRACK

KEY WORDS

TRACK DEFORMATION; WHEELFLAT IMPACTS CAUSE DYNAMIC INCREMENTS; VEHICLE UNSPRUNG MASS; IRREGULARITIES IN WELDED TRACK

SYNOPSIS
APPLICABLE TO SHELLING FAILURES

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300226* DATE 00 SEP 78

AUTHOR
H. ICHINOSE, J. TAKEHARA, N. IWASAKI, M. UEDA

TITLE
"AN INVESTIGATION ON CONTACT FATIGUE AND WEAR RESISTANCE
BEHAVIOUR IN RAIL STEELS

KEY WORDS

FATIGUE ANALYSIS; LOAD AND SLIP INFLUENCES; MICRO-OBSERVATIONS OF CRACK;
RUBBING/DEFORMATION OF CRACK SURFACE; PLASTIC FLOW

SYNOPSIS
A BACKGROUND PAPER FOR CONTACT FATIGUE AND SHELLING PROBLEM;
JAPANESE TECHNOLOGY

* * *

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300226* DATE 00 SEP 78

AUTHOR
H. ICHINOSE, J. TAKEHARA, N. IWASAKI, M. UEDA

TITLE
"AN INVESTIGATION ON CONTACT FATIGUE AND WEAR RESISTANCE
BEHAVIOUR IN RAIL STEELS

KEY WORDS

FATIGUE ANALYSIS; LOAD AND SLIP INFLUENCES; MICRO-OBSERVATIONS OF CRACK;
RUBBING/DEFORMATION OF CRACK SURFACE; PLASTIC FLOW

SYNOPSIS
A BACKGROUND PAPER FOR CONTACT FATIGUE AND SHELLING PROBLEM;
JAPANESE TECHNOLOGY

* * *

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300308* DATE 00 MAR 78

AUTHOR
M. JAMES & J. COHEN

TITLE
PARS - A PORTABLE X-RAY ANALYZER FOR RESIDUAL STRESSES

KEY WORDS
NDE, TASK 14

X-RAY DEVICE FOR MEASURING RESIDUAL STRESSES; PORTABLE MEASURNG INSTRUMENT;
RESIDUAL STRESS ANALYSIS; POSITION SENSITIVE DETECTOR

SYNOPSIS
A PRIMER ON RESIDUAL STRESS DETERMINATION BY X-RAY ANALYSIS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300387* DATE 00 APR 79

AUTHOR
J. MODRANSKY, W. DONNELLY, S. NOVAK, K. SMITH

TITLE
INSTRUMENTED LOCOMOTIVE WHEELS FOR CONTINUOUS MEASUREMENTS
OF VERTICAL AND LATERAL LOADS

KEY WORDS

VEHICLES/COMPONENTS; INSTRUMENTATION

SYNOPSIS
GENERAL REFERENCE PAPER ON INSTRUMENTED WHEELSET TO MEASURE WHEEL/RAIL FORCES

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300406* DATE 00 NOV 78

AUTHOR
K. NAGY, D. A. DAVIS, & R. D. FINCH

TITLE
DETECTION OF FLAWS IN RAILROAD WHEELS USING ACOUSTIC SIGNATURES

KEY WORDS
NDE, TASK 14

AUTOMATIC INSPECTION USING ACOUSTIC SIGNATURES; DETECTION OF SOUND RADIATED INTO AIR BY MICROPHONE TO OBTAIN ACOUSTIC SIGNATURE FOR FINDING CRACKS IN RIM OR PLATE; DETECT FLAT SPOTS OR SHATTERED RIMS W/ACCEL. MOUNTED ON RAIL

SYNOPSIS
A REFERENCE PAPER FOR NDE OF WHEEL DEFECTS BY ACOUSTIC SIGNATURE ANALYSIS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300436* DATE 00 80

AUTHOR
T. J. THOMAS, V. GARG, D. STONE

TITLE
THERMAL FATIGUE ANALYSIS OF A RAILCAR WHEEL UNDER DRAG BRAKING

KEY WORDS
FINITE ELEMENT ANALYSIS, TASK 10, CH36 WHEELS

FATIGUE ANALYSIS; STRESSES FROM TEMPERATURE; DRAG BRAKING AND CYCLIC THERMAL LOADING; FINITE ELEMNT ANALYSIS

SYNOPSIS
CYCLIC THERMAL LOADING ON THE FATIGUE LIFE OF CH36 WHEEL WAS INVESTIGATED BY FINITE ELEMENT METHOD. CREEP PLAST PROGRAM WAS USED TO ESTIMATE THE STRESS & STRAIN DEVELOPED IN THE WHEEL

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300439* DATE 00 JUL 77

AUTHOR
B. R. AHLBECK, H. D. HARRISON

TITLE
TECHNIQUES FOR MEASURING WHEEL/RAIL FORCES WITH TRACKSIDE INSTRUMENTATION

KEY WORDS

WHEEL/RAIL LOADS AS AN IMPORTANT MEASURE OF VEHICLE/TRACK INTERACTIVE RESPONSE; TECHNIQUES FOR MEASUREMENT OF WHEEL/RAIL LOADS; DATA PRESENTED TO ILLUSTRATE AN APPLICATION OF MEASUREMENT TECHNIQUES

SYNOPSIS
WAYSIDE INSTRUMENTATION FOR THE MEASUREMENT OF DYNAMIC WHEEL/RAIL FORCES FOR FUTURE TRACK TESTS TO INVESTIGATE WHEEL SHELLING

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300562* DATE 00 JAN 80

AUTHOR
P. P. MARCOTTE, K. MATHEWSON, W. CALDWELL

TITLE
IMPROVED WHEEL TREAD PROFILES FOR HEAVY FREIGHT VEHICLES

KEY WORDS

WHEEL TREAD PROFILE, STEADY STATE CURVING BEHAVIOR, NON-LINEAR COMPUTER SIMULATION, COMPARISON WITH FIELD TESTS

SYNOPSIS

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FILE PRINTED BY FILE NUMBER

FILE NUMBER 300598* DATE 00 00

AUTHOR
R. J. COOKE, C. J. BEEVERS

TITLE
SLOW FATIGUE CRACK PROPAGATION IN PEARLITIC STEELS

KEY WORDS
FAILURE MODEL, TASK 10

PEARLITIC STEELS, LOAD RATIO, CRACK GROWTH, CRACK CLOSURE

SYNOPSIS
GENERAL REFERENCE PAPER DESCRIBING FACTORS WHICH CONTROL SLOW FATIGUE CRACK PROPAGATION IN PEARLITIC STEELS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300660* DATE 00 AUG 79

AUTHOR
H. R. WETENKAMP, B. J. ECK, P. E. RHINE

TITLE
THE INFLUENCE OF BRAKE SHOES ON THE TEMPERATURES OF WHEELS IN RAILROAD SERVICE

KEY WORDS
LIMITED INVESTIGATION OF BRAKE SHOES, TASK 7

CONSTANT BRAKE SHOE LOADS, DIFFERENT TYPES OF BRAKE SHOES, LABORATORY TESTS, FIELD TESTS

SYNOPSIS
INVESTIGATION OF HOT SPOT TEMPERATURES & COEFFICIENTS OF FRICTION WITH DIFFERENT KINDS OF BRAKE SHOES

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300665* DATE 00 MAR 80

AUTHOR

ROY A. ALLEN

TITLE

A SUPERIOR INSTRUMENTED WHEELSET

KEY WORDS

TESTING WITH INSTRUMENTED WHEELSETS, TASKS 4 & 5

LOAD MEASURING WHEELS, DATA ACQUISITION

SYNOPSIS

DEVELOPMENT IN THE MESUREMENT OF DYNAMIC WHEEL/RAIL FORCES ON A CONTINUOUS TIME BASIS IS DESCRIBED

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300691* DATE 00 00

AUTHOR

D. E. MOCHA, J. W. JONES, D. M. CORBLY

TITLE

ON THE VARIATION OF FATIGUE - CRACK-OPENING LOAD WITH
MEASUREMENT LOCATION

KEY WORDS

FATIGUE-CRACK-OPENING, CRACK-TIP-OPENING LOAD

SYNOPSIS

LABORATORY INVESTIGATION OF DISPLACEMENT-LOAD BEHAVIOR FOR A FATIGUE CRACKED SPECIMAN

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                        FILE PRINTED BY FILE NUMBER

FILE NUMBER   300716*                          DATE   00 OCT 80

                                  AUTHOR
            B. V. BRICKLE

                                   TITLE
            CREEPAGES AND FORCES ACTING ON A WHEELSET ON ROLLERS, ROLL
            DYNAMICS UNIT (RDU) ANALYSIS STUDY

                                 KEY WORDS

--------------------------------------------------------------------------------
   DYNAMICS ANALYSIS; CREEP; WHEELSET ON ROLLERS; DYNAMIC TESTING; TRACK/TRAIN
   DYNAMICS


                                  SYNOPSIS
ANALYSIS OF WHEELSET FORCES & CREEPAGES ON ROLLERS




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                        FILE PRINTED BY FILE NUMBER

FILE NUMBER   300773*                          DATE   00 JUL 79

                                  AUTHOR
            H. A. TANVIR

                                   TITLE
            TEMPERATURE RISE DUE TO SLIP BETWEEN WHEEL AND RAIL - AN
            ANALYTICAL SOLUTION FOR HERTZIAN CONTACT

                                 KEY WORDS
   WHEEL RAIL ADHESION; BRAKING PERFORMANCE, SLIPPING GENERATES HEAT,
   TEMPERATURE RISE INCREASE WHEEL AND RAIL WEAR
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                                  SYNOPSIS
APPLICABLE TO WHEEL SHELLING




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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   300776*                       DATE  00 JAN 81

                             AUTHOR
          MILTON R. JOHNSON

                              TITLE
          DEVELOPMENT AND USE OF AN INSTRUMENTED WHEELSET FOR THE
          MEASUREMENT OF WHEEL/RAIL INTERACTION FORCES

                            KEY WORDS
  TESTING WITH INSTRUMENTED WHEELSETS, TASKS 4 & 5

------------------------------------------------------------------------------
  WHEELSETS; MESUREMENT; WHEEL/RAIL INTERACTION FORCES; STRAIN GAUGE BRIDGES
  ON PLATE OF WHEEL; ISOLATE VERTICAL, LATERAL LOADS,


                             SYNOPSIS
INSTRUMENTAITON DETAILS OF A LOAD MEASURING WHEEL




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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   300778*                       DATE  00 APR 80

                             AUTHOR
          R. P. JOYCE, M. R. JOHNSON

                              TITLE
          INSTRUMENTING A RAILROAD WHEELSET FOR MEASURING A WHEEL/
          RAIL LOAD

                            KEY WORDS
  TESTING WITH INSTRUMENTED WHEELSETS, TASKS 4 & 5

------------------------------------------------------------------------------
  WHEELSETS; DYNAMICS BETWEEN WHEEL AND RAIL; RESPONSE TO TRACK IRREGULAR
  YAWING AND LATERAL CREEP ON CURVES; HUNTING


                             SYNOPSIS
INSTRUMENTATION DETAILS OF INSTRUMENTED WHEELSET CAPABLE OF MEASURING WHEEL/RAIL
DYNAMIC FORCES



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FILE PRINTED BY FILE NUMBER

FILE NUMBER 300779* DATE 00 00

AUTHOR
A. R. POCKLINGTON

TITLE
B. R. LOAD MEASURING WHEEL

KEY WORDS

WHEEL RAIL DYNAMICS; LOAD MEASURING WHEEL;

SYNOPSIS
DEVELOPMENT AND INSTRUMENTATION OF LOAD MEASURING WHEEL

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300780* DATE 00 JAN 81

AUTHOR
C. A. SWENSON, K. R. SMITH

TITLE
DEVELOPMENT AND USE OF INSTRUMENTED LOCOMOTIVE WHEELSETS

KEY WORDS

WHEELSETS; STRAIN GAGES APPLIED TO WHEEL PLATES; MEASUREMENT OF DATA
ANALYSIS/TIME RESPONSE

SYNOPSIS
A PRIMER ON THE DEVELOPMENT OF INSTRUMENTED WHEELSET

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300824* DATE 00 JUL 74

AUTHOR
D. CANNON & R. ALLEN

TITLE
THE APPLICATION OF FRACTURE MECHANICS TO RAILWAY FAILURES

KEY WORDS
FAILURE MODEL, TASK 10

FRACTURE, PRE-EXISTING DEFECT, FATIGUE CRACKS, TO QUANTIFY FRACTURE PROCESS INVOLVING CRACK PROPOGATION TO CATASTROPHIC FAILURE

SYNOPSIS
APPLICATION OF FRACTURE MECHANICS TO RAILWAY FAILURES IN AXLES, WHEELS, RAILS, TRUCK COMPONENTS ETC.

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300834* DATE 00 76

AUTHOR
K. FUJITA, A. YOSHIDA, & T. YAMAMOTO

TITLE
ROLLING CONTACT FATIGUE IN ANNELAED 0.45% CARBON STEEL ROLLERS

KEY WORDS
FAILURE MODEL, TASK 10

CRACK PROPAGATION, STEEL; MICROSTRUCTURE AT SURFACE AND SUBSURFACE OF ROLLERS

SYNOPSIS
JAPANESE PAPER; ROLLING CONTACT FATIGUE ANALYSIS IN SMALL SIZE 0.45% CARBON STEEL ROLLERS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300843* DATE 00 77

AUTHOR
C. FREDERICK, D. CANNON, S. NEWTON

TITLE
DYNAMIC RAIL STRESSES DUE TO WHEEL FLAT IMPACT

KEY WORDS

WHEELFLATS CAUSE RAIL FRACTURE; WHEELFLAT IMPACT STRESSES; RAIL DEFECTS AND FINAL FRACTURE; IMPACT FORCE

SYNOPSIS
APPLICABLE TO SHELLING PROBLEM

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300868* DATE 00 NOV 80

AUTHOR
S. KUMAR & B. RAJKUMAR

TITLE
LABORATORY INVESTIGATION OF WHEEL RAIL CONTACT STRESSES FOR U. S. FREIGHT CARS

KEY WORDS

STRESS ANALYSIS; WHEEL RAIL DYNAMICS; CONTACT STRESS AND TRACK DEGRADATION SIMULATION FACILITY; FREIGHT CAR STRESS LEVELS;

SYNOPSIS
APPLICABLE TO SHELLING PROBLEM

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                         FILE PRINTED BY FILE NUMBER

FILE NUMBER   300869*                             DATE  00 NOV 80

                                    AUTHOR
                 D. R. AHLBECK

                                     TITLE
                 AN INVESTIGATION OF IMPACT LOADS DUE TO WHEEL FLATS AND RAIL
                 JOINTS

                                  KEY WORDS


--------------------------------------------------------------------------------
   WHEEL RAIL DYNAMICS; IMPACT LOADS; WHEEL FLATS, SURFACE SPALLING ON TREAD,
   SHELLING, WELD DEFECTS; RAIL JOINT DIPS


                                   SYNOPSIS
APPLICABLE TO SHELLING PROBLEM




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                         FILE PRINTED BY FILE NUMBER

FILE NUMBER   300875*                             DATE  00 NOV 80

                                    AUTHOR
                 Y. J. PARK & D. H. STONE

                                     TITLE
                 CYCLIC BEHAVIOR OF CLASS U WHEEL STEEL


                                  KEY WORDS
   MATERIAL PROPERTIES, TASK 3

--------------------------------------------------------------------------------
   WHEEL METALLURGY; MATERIAL PROPERTIES UNDER CYCLIC LOADING; FATIGUE TESTS;
   SOFTENING; FATIGUE; LIFE


                                   SYNOPSIS
PROPERTIES OF CLASS U STEELS AT ROOM TEMPERATURE REPORTED IN THIS PAPER WILL BE
USED IN THE PROGRAM



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FILE PRINTED BY FILE NUMBER

FILE NUMBER 300876* DATE 00 NOV 80

AUTHOR
R. LIECHTY

TITLE
CONSIDERATIONS ON THE USE OF RADIALLY-STEERED WHEELSETS IN RAILWAY TRUCKS

KEY WORDS

WHEELSETS; RADIALLY-STEERABLE TRUCK WHEELSET; ADHESION; ANGLE BETWEEN WHEEL PLANE AND RAIL PLANE; CURVE POSITION

SYNOPSIS
NOT DIRECTLY APPLICABLE TO THE WFM PROGRAM; GENERAL REFERENCE PAPER ON STEERABLE TRUCKS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 300961* DATE 00 NOV 81

AUTHOR
K. HIRAKAWA & H. SAKAMOTO

TITLE
EFFECT OF DESIGN VARIATION ON RAILROAD WHEEL FRACTURE

KEY WORDS
TRACK & DYNAMOMETER TESTING, TASK 6

WHEEL DEFECTS; PREDICTING WHEEL FRACTURE; WHEEL DESIGN FOR IMPROVED FRACTURE RESISTANCE, DYNAMOMETER VERIFICATION; RESIDUAL STRESS

SYNOPSIS
OPTIMUM WHEEL DESIGN TESTED WITH IMPROVED FRACTURE RESISTANCE SUPPORTED BY FINITE ELEMENT ANALYSIS & DYNAMOMETER TESTING (JAPANESE EXPERIENCE)

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301000* DATE 00 70

AUTHOR
T. KUNIKAKE, S. NISHIMURA, & H. TAGASHIRA

TITLE
"THE METALLOGRAPHIC OBSERVATION OF THE TREAD OF WHEELS SUBJECTED TO VARIOUS SERVICE CONDITIONS" (IRON & STEEL INST.)

KEY WORDS
METALLOGRAPHIC ANALYSIS, TASK 3, CRACK INITIATION, TASK 8, NDE, TASK 14

WHEELS; METALLURGY; TREAD REGION HARDENING; ON-TREAD BRAKE; HEAT-CHECKS,
SPALLING, FLAKY SURFACE; SHELLING

SYNOPSIS
AN ANALYSIS AND ATLAS OF METALLURGICAL STRUCTURE CHANGES DUE TO BRAKE HEATING

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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301001* DATE 00 FEB 77

AUTHOR
M. R. JOHNSON, R. E. WELCH, & K. S. YEUNG

TITLE
"ANALYSIS OF THERMAL STRESSES & RESIDUAL STRESS CHANGES IN RR WHEELS CAUSED BY SEVERE DRAG BRAKING (JOR. ENG. FOR IND)

KEY WORDS
FINITE ELEMENT ANALYSIS AND SIMULATION, TASK 10

STRESS ANALYSIS; THERMAL STRESSES; DRAG BRAKING; HEATING FROM TREAD BRAKE;
THERMAL CRACK GROWTH

SYNOPSIS
FINITE ELEMENT DEMONSTRATION OF THE FORMATION OF RESIDUAL STRESSES DUE TO BRAKE HEATING. THE STANDARD BY WHICH ELASTIC-PLASTIC F. E. ANALYSIS ARE JUDGED

* * *

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301001* DATE 00 FEB 77

AUTHOR
M. R. JOHNSON, R. E. WELCH, & K. S. YEUNG

TITLE
"ANALYSIS OF THERMAL STRESSES & RESIDUAL STRESS CHANGES IN RR WHEELS CAUSED BY SEVERE DRAG BRAKING (JOR. ENG. FOR IND)

KEY WORDS
FINITE ELEMENT ANALYSIS AND SIMULATION, TASK 10

STRESS ANALYSIS; THERMAL STRESSES; DRAG BRAKING; HEATING FROM TREAD BRAKE; THERMAL CRACK GROWTH

SYNOPSIS
FINITE ELEMENT DEMONSTRATION OF THE FORMATION OF RESIDUAL STRESSES DUE TO BRAKE HEATING. THE STANDARD BY WHICH ELASTIC-PLASTIC F. E. ANALYSIS ARE JUDGED

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301003* DATE 00 MAY 67

AUTHOR
JOSEF MATHAR

TITLE
"DETERMINATION OF INITIAL STRESSES BY MEASURING THE DEFORMATION AROUND DRILLED HOLES"

KEY WORDS

RESIDUAL STRESS ANALYSIS; DISTURB AREA OF STRESS EQUILIBRIUM AROUND DRILLED HOLE DETERMINES INHERENT STRESSES IN CASTING

SYNOPSIS
AN EXCELLENT BACKGROUND PAPER FOR THE BASIS OF HOLE DRILLING TECHNIQUE FOR RESIDUAL STRESS DETERMINATION

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301003* DATE 00 MAY 67

AUTHOR

JOSEF MATHAR

TITLE

"DETERMINATION OF INITIAL STRESSES BY MEASURING THE DEFORMATION AROUND DRILLED HOLES"

KEY WORDS

RESIDUAL STRESS ANALYSIS; DISTURB AREA OF STRESS EQUILIBRIUM AROUND DRILLED HOLE DETERMINES INHERENT STRESSES IN CASTING

SYNOPSIS

AN EXCELLENT BACKGROUND PAPER FOR THE BASIS OF HOLE DRILLING TECHNIQUE FOR RESIDUAL STRESS DETERMINATION

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301004* DATE 00 MAY 70

AUTHOR

K. NISIOKA, T. KUNITAKE, T. KUNITAKE, T. KAGAWA

TITLE

"THE WHEEL TESTING MACHINE AND SOME EXPERIMENTAL RESULTS OF TREAD DEFECTS" TGHE SUMITOMO SEARCH, NO. 3

KEY WORDS

DYNAMOMETER TESTING, TASK 6

WHEEL DEFECTS; SEVERE REQUIREMENTS FOR WHEELS; WHEEL TESTING MACHINE; BRAKING TEST RESULTS; SHELLING, EXPLOSIVE FAILURE

SYNOPSIS

A SET OF CONDITIONS IS DEFINED TO PRODUCE DYNAMOMETER TEST WHEELS TO FAIL. NEW CARBON (JAPANESE) WHEELS ARE USED

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301006* DATE 00 MAY 76

AUTHOR
S. NISHIMURA & K. TOKIMASA

TITLE
"STUDY OF THE RESIDUAL STRESSES IN RAILROAD SOLID WHEELS AND THEIR EFFECT ON WHEEL FRACTURE (BUL. OF THE JSME) VOL. 19

KEY WORDS
FAILURE MODEL, TASK 10

WHEEL STRESS; WHEEL TESTING MACHINE; WHEEL FRACTURE ANALYZED BY LINEAR FRACTURE MECHANICS; RESIDUAL TENSILE STRESS IN RIM

SYNOPSIS
A DEFINITIVE WORK ON COMBINING RESIDUAL STRESS STATE AND FRACTURE MECHANICS DATA TO PREDICT WHEEL FAILURE

* * *

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301016* DATE 00 JUL 76

AUTHOR
E. BEANEY

TITLE
ACCURATE MEASUREMENT OF RESIDUAL STRESS ON ANY STEEL USING THE CENTRE HOLE METHOD

KEY WORDS
DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

RESIDUAL STRESS ANALYSIS; AIR-ABRASIVE TECHNIQUE FOR FORMNG HOLE;

SYNOPSIS
AN EXCELLENT PAPER ON RESIDUAL STRESS MEASUREMENT BY HOLE DRILLING WITH AIR ABRASIVE UNIT

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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301017* DATE 00 DEC 66

AUTHOR
N. RENDLER & I. VIGNESS

TITLE
HOLE-DRILLING STRAIN-GAGE METHOD OF MEASURING RESIDUAL STRESSES

KEY WORDS
DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

RESIDUAL STRESS ANALYSIS; STRAIN RELAXATION AROUND A DRILLED HOLE

SYNOPSIS
A BACKGROUND PAPER FOR THE DETERMINATION OF RESIDUAL STESSES BY HOLE DRILLING-STRAIN GAGING METHOD

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301018* DATE 00 MAY 78

AUTHOR
J. SANDIFER & G. BOWIE

TITLE
RESIDUAL STRESS BY BLIND-HOLE METHOD WITH OFF-CENTER HOLE

KEY WORDS
DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

STRESS ANALYSIS; BLIND-HOLE DRILLING; STRAIN-GAGE-ROSETTE GEOMETRIES; HAND-DRILLED-HOLE CENTER

SYNOPSIS
APPLICATION OF HOLE DRILLING TECHNIQUE FOR THE DETERMINATION OF RESIDUAL STRESSES IN RESTRICTED AREAS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301019* DATE 00 00

AUTHOR
A. BUSH & F. KROMER

TITLE
SIMPLIFICATION OF THE HOLE-DRILLING METHOD OF RESIDUAL STRESS MEASUREMENT

KEY WORDS
DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

RESIDUAL STRESS ANALYSIS; HOLE DRILLING METHOD; ABRASIVE JET MACHINING

SYNOPSIS
AN EXCELLENT PAPER ON THE DETERMINATION OF RESIDUAL STRESSES BY HOLE DRILLING-STRAIN GAGING METHOD USING ABRASIVE JET MACHINING PROCESS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301020* DATE 00 MAY 67

AUTHOR
J. BRUNER, G. BENJAMIN & D. BENCH

TITLE
ANALYSIS OF RESIDUAL, THERMAL AND LOADING STRESSES IN A B33 WHEEL AND THEIR RELATIONSHIP TO FATIGUE DAMAGE

KEY WORDS
FAILURE MODEL, TASK 10

STRESS ANALYSIS; SIMULATED LOADING CONDITIONS; STRESS PATTERN AND FATIGUE TESTS COMPARED; RIM HEATING

SYNOPSIS
A PRELIMINARY INVESTIGATION OF LOADING & THERMAL STRESSES IN A B-33 WHEEL

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301022* DATE 00 00

AUTHOR
W. SOETE & R. VANCROMBRUGGE

TITLE
AN INDUSTRIAL METHOD FOR THE DETERMINATION OF RESIDUAL STRESSES

KEY WORDS
DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

STRESS ANALYSIS; ELASTIC RECOVERY OF STRESSES; DIAL EXTENSOMETER; TENSILE AND COMPRESSIVE STRESSES

SYNOPSIS
BACKGROUND PAPER FOR THE DEVELOPMENT OF RESIDUAL STRESS DETERMINATION BY HOLE DRILLING - STRAIN GAGING METHOD

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301023* DATE 00 00

AUTHOR
K. MILBRADT

TITLE
RING-METHOD DETERMINATION OF RESIDUAL STRESSES

KEY WORDS
DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

RESIDUAL STRESS ANALYSIS; X-RAY DIFFRACTION; CHANGE IN STRESS DISTRIBUTION DUE TO A DRILLED HOLE

SYNOPSIS
BACKGROUND MATERIAL FOR THE DEVELOPMENT OF RESIDUAL STRESS DETERMINATION BY HOLE-DRILLING - STRAIN GAGING METHOD

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301045* DATE 00 JUN 81

AUTHOR
A. IBRAHIM & S. GIBRAIEL

TITLE
EVALUATION OF DYNAMIC LOAD COMBINATION FATIGUE DAMAGE

KEY WORDS
COMPREHENSIVE FAILURE MODEL, TASK 10

FATIGUE ANALYSIS; FATIGUE DAMAGING CYCLES;

SYNOPSIS
A GENERIC BACKGROUND PAPER FOR FATIGUE ANALYSIS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301084* DATE 00 SEP 81

AUTHOR
T. D. BURTON

TITLE
INFLUENCE OF WHEEL/RAIL CONTACT GEOMETRY ON LARGE AMPLITUDE
WHEELSET EQUATIONS OF MOTION

KEY WORDS

WHEEL RAIL DYNAMICS; LATERAL CREEP VELOCITY, FLANGE CONTACT; DYNAMIC MODEL;
YAW & LATERAL TRANSLATION OF WHEELSET

SYNOPSIS
A BACKGROUND PAPER FOR SHELLING PROBLEM

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301098* DATE 00 79

AUTHOR
C. H. HO & O. TUNCEL

TITLE
INVESTIGATION OF THE INFLUENE OF VARIOUS PARAMETERS ON RESIDUAL-STRESS CALIBRATION

KEY WORDS
DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

RESIDUAL STRESS ANALYSIS; CALIBRATION TESTS OF RESIDUAL STRESS; HOLE DRILLING-STRAIN GAGE METHOD;

SYNOPSIS
A BACKGROUND PAPER FOR THE DETERMINATION OF RESIDUAL STRESS BY HOLE DRILLING - STRAIN GAUGE METHOD

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301137* DATE 00 00

AUTHOR
K. L. JOHNSON & J. A. JEFFERIS,

TITLE
"PLASITC FLOW & RESIDUAL STRESSES IN ROLLING & SLIDING CONTACTS" (INSTN. MECH. ENGRS.)

KEY WORDS
COMPREHENSIVE FAILURE MODEL, TASK 10

DEFORMATION; PLASTIC DEFORMATION DUE TO CYCLIC LOADING; FAILURE IN ROLLING CONTACT; FRACTURE, FATIGUE; CONTACT STRESS;

SYNOPSIS
A DESCRIPTION OF HOW NON-THERMALLY INDUCED SURFACE FAILURE WHICH MAY PROVIDE CRACK INITIATION FOR SUBSEQUENT THERMALLY INDUCED GROWTH AND FAILURE IS PRODUCED

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                         FILE PRINTED BY FILE NUMBER

FILE NUMBER   301146*                            DATE  00 NOV 81

                                    AUTHOR
                 A.  POPISTAS & D STOENESCU

                                     TITLE
                 "METHOD FOR MEASUREMENT OF CONTACT BETWEEN WHEEL AND RAIL"


                                  KEY WORDS

-------------------------------------------------------------------------------
   WHEEL RAIL DYNAMICS; BUCHAREST INSTITUTE METHOD; MEASURING WHEEL SET WITH
   NORMAL & FALSE SPOKES; HORIZONTAL, VERTICAL FORCE


                                   SYNOPSIS
NOT DIRECTLY RELATED TO THE PROGRAM



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                         FILE PRINTED BY FILE NUMBER

FILE NUMBER   301146*                            DATE  00 NOV 81

                                    AUTHOR
                 A.  POPISTAS & D STOENESCU

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                 "METHOD FOR MEASUREMENT OF CONTACT BETWEEN WHEEL AND RAIL"


                                  KEY WORDS

-------------------------------------------------------------------------------
   WHEEL RAIL DYNAMICS; BUCHAREST INSTITUTE METHOD; MEASURING WHEEL SET WITH
   NORMAL & FALSE SPOKES; HORIZONTAL, VERTICAL FORCE


                                   SYNOPSIS
NOT DIRECTLY RELATED TO THE PROGRAM



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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301147* DATE 00 APR 81

AUTHOR
I. Y. ELGINDY & C. A. SCIAMMARELA

TITLE
ANALYSIS OF CYCLIC THERMAL AND RESIDUAL STRESSES IN CH36 WHEELS UNDER SERIES OF SEVERE DRAG BRAKING

KEY WORDS
FINITE ELEMENT ANALYSIS SIMULATION, TASK 10, CH36 WHEEL, CLASS U, CRACK PROPAGATION

STRESS ANALYSIS; ELASTO-PLASTIC BEHAVIOR OF MATERIAL; THERMAL & RESIDUAL STRESS HISTORIES; DRAG BRAKING CYCLES; RESTART

SYNOPSIS
FINITE ELEMENT ANALYSIS DEMONSTRATION (WITH TEMPERATURE DEPENDENT PLASTIC PROPERTIES) THAT REPETITION OF SEVERE DRAG BRAKE CYCLES CAN PRODUCE AN INCREMENTAL INCREASE IN RESIDUAL STRESS TO LEVELS THAT WOULD CAUSE ACCELERATED CRACK PROPAGATION DUE TO THERMAL FATIGUE

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301248* DATE 00 NOV 80

AUTHOR
S. KUMAR & R. MARGASAHAYAM

TITLE
A PARAMETRIC AND EXPERIMENTAL ANALYSIS OF FRICTION, CREEP AND WEAR FOR WHEEL AND RAIL ON TANGENT TRACK

KEY WORDS

WEAR INTERRELATED WITH CREEP AND FRICTION; ROUGHNESS, TOUGHNESS, HARDNESS, WHEEL RAIL SIMULATION, WEAR & LOAD

SYNOPSIS
NOT DIRECTLY APPLICABLE TO THE PROGRAM; GENERAL REFERENCE PAPER ON WHEEL WEAR

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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301258* DATE 00 68

AUTHOR
K. ISHII, N. ODA, K. NISHIOKA

TITLE
WEAR OF HIGH-SPEED RAILWAY WHEELS

KEY WORDS

WHEEL WEAR; ROLLING STOCK; ROLLING CONTACT LOADS; CONTACT PRESSURE; JAPANESE TECHNOLOGY

SYNOPSIS
NOT DIRECTLY APPLICABLE TO THE PROGRAM; GENERAL REFERENCE PAPER ON WHEEL WEAR

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301261* DATE 00 79

AUTHOR
K. IIJIMA, T. KIGAWA, T. YOSHIMURA, K. KUROYANAGI

TITLE
"ROLLING CONTACT FATIGUE FAILURE OF BEARING STEELS, WHEEL STREELS AND CARBURIZED GEAR STEELS" (QTRLY REPORTS)

KEY WORDS

FATIGUE ANALYSIS; FATIGUE BEHAVIOR OF BEARING STEELS; HEAT TREATMENT; ROLLING CONTACT FATIGUE STRENGTH;

SYNOPSIS
PERTINENT TO WHEEL SHELLING FAILURE

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301321* DATE 00 82

AUTHOR
M. R. JOHNSON & R. R. ROBINSON A. J. OPINSKY

TITLE
RESIDUAL STRESS CALCULATINS ON 33 INCH (838 mm) DIAMETER ONE WEAR FREIGHT CAR WHEELS UNDER SIM. UNREL. HAND BRAKE COND.

KEY WORDS
FAILURE MODEL, TASK 10

WHEEL WEAR; TENSILE STRESSES IN RIM OF WHEEL; THERMAL LOAD FROM TREAD BRAKING; CRACKS ON RIM

SYNOPSIS
AN ATTEMPT TO DETERMINE MAGNITUDE OF RESIDUAL STRESS CHANGE IN "LOW STRESS" AND "HIGH STRESS" WHEELS WITH THE SAME THERMAL INPUTS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301331* DATE 00 71

AUTHOR
KUNIO NISHIOKA & Y. MORITA

TITLE
"THE STRENGTH OF RAILROAD WHEELS (3RD REPT. STRESS ANALYSIS ON WHEELS SUBJECTED TO VERTICAL AND LATERAL FORCES) JSME

KEY WORDS
FINITE ELEMENT ANALYSIS, TASK 10

WHEEL WEAR; REACTIONS BETWEEN WHEEL & RAIL; STRENGTH OF WHEEL; VERTICAL FORCRE ON TREAD, LATERAL ON FLANGE

SYNOPSIS
EFFECT OF MECHANICAL LOADS ON WHEEL ELASTIC STRESSES

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301333* DATE 00 76

AUTHOR

A. D. GILCHRIST & B. V. BRICKLE

TITLE

A RE-EXAMINATION OF THE PRONENESS TO DERAILMENT OF A RAILWAY WHEEL-SET, (JOR. MECH. ENGR. SCIENCE)

KEY WORDS

DERAILMENTS; ROLLING-CONTACT THEORY; TANGENTIAL FORCE TO CREEPAGE & SPIN; NADAL'S CLASSICAL FORMULA

SYNOPSIS

NOT DIRECTLY APPLICABLE TO PROGRAM; GENERAL REFERENCE PAPER ON WHEEL DERAILMENT THEORY

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301334* DATE 00 70

AUTHOR

K. NISHIOKA & Y. MORITA

TITLE

"THE STRENGTH OF RAILROAD WHEELS (2ND REPT. THE EFFECT OF WHEEL CONTOURS ON THERMAL STRESSES IN WHEELS) JSME

KEY WORDS

COMPREHENSIVE FAILURE MODEL, TASK 10, F.E.A. OF DIFFERENT WHEEL DESIGNS

WHEEL WEAR; TREAD BRAKE; THERMAL STRESSES IN DIFFERENT WHEEL DESIGNS; CRACKS AT TREAD; RIGIDITY OF FLANGE

SYNOPSIS

FINITE ELEMENT ANALYSIS OF DIFFERENT WHEEL DESIGNS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301336* DATE 00 69

AUTHOR

K. NISHIOKA & Y. MORITA

TITLE

"THE STRENGTH OF RAILROAD WHEELS (1ST REPT. THERMAL STRESSES IN DISK WHEELS)

KEY WORDS

FINITE ELEMENT ANALYSIS, TASKS 6 & 10

WHEEL WEAR; TREAD BRAKE TO WHEEL; RIM TEMPERATURE RAISE
BRAKE TESTS

SYNOPSIS

AN EARLY FINITE ELEMENT ANALYSIS PAPER

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301346* DATE 00 59

AUTHOR

M. S. RIEGEL

TITLE

STRESSES IN WROUGHT-STEEL WHEEL RIMS AND THEIR RELATION TO WHEEL LIFE

KEY WORDS

FINITE ELEMENT ANALYSIS, TASK 10

WHEEL WEAR; RESIDUAL STRESSES OF NEW WHEELS; SIMULATED SERVICE STRESSES;
WHEEL FAILURES; CONTROL

SYNOPSIS

A PRELIMINARY ANALYSIS OF RELATING WHEEL RIM STRESSES & WHEEL LIFE

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                       FILE PRINTED BY FILE NUMBER

FILE NUMBER   301353*                          DATE  00     79

                                AUTHOR
            CAMPBELL LAIRD

                                 TITLE
            "MECHANISMS AND THEORIES OF FATIGUE"

                               KEY WORDS
  COMPREHENSIVE FAILURE MODEL, TASK 10

-------------------------------------------------------------------------------
  FATIGUE ANALYSIS; CYCLIC DEFORMATION & MONOTONIC; DISLOCATION, CRACK
  INITIATION; PLASTIC RUPTURE

                               SYNOPSIS
A GENERIC BACKGROUND MATERIAL FOR PHENOMENON AND MECHANISMS OF FATIGUE



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                       FILE PRINTED BY FILE NUMBER

FILE NUMBER   301353*                          DATE  00     79

                                AUTHOR
            CAMPBELL LAIRD

                                 TITLE
            "MECHANISMS AND THEORIES OF FATIGUE"

                               KEY WORDS
  COMPREHENSIVE FAILURE MODEL, TASK 10

-------------------------------------------------------------------------------
  FATIGUE ANALYSIS; CYCLIC DEFORMATION & MONOTONIC; DISLOCATION, CRACK
  INITIATION; PLASTIC RUPTURE

                               SYNOPSIS
A GENERIC BACKGROUND MATERIAL FOR PHENOMENON AND MECHANISMS OF FATIGUE



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FILE PRINTED BY FILE NUMBER

FILE NUMBER   301361*   DATE 00   79

AUTHOR

P. ENGEL & C. ADAMS

TITLE

ROLLING WEAR STUDY OF MISALIGNED CYLINDRICAL CONTACTS

KEY WORDS

WEAR; MISALIGNMENT IN CONTACT; ROLLING WEAR TESTER; PARTIAL SLIP, RIGID BODY SLIP; WEAR ANALYSIS

SYNOPSIS

NOT DIRECTLY APPLICABLE TO THE PROGRAM; GENERAL REFERENCE PAPER ON WEAR AND MICRO SLIP

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER   301362*   DATE 00   76

AUTHOR

A. D. SARKAR

TITLE

"ROLLING RESISTANCE," WEAR OF METALS

KEY WORDS

WHEEL SHELLING ANALYSIS

WEAR; LOW FRICTION OF ROLLING ELEMENTS; SLIP/CREEP AND ENERGY LOSS; SHAKEDOWN LIMIT; HYSTERESIS

SYNOPSIS

USEFUL FOR WHEEL SHELLING ANALYSIS

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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301379* DATE 00 JUN 77

AUTHOR

FRANK A. MCCLINTOCK

TITLE

"PLASTIC FLOW AROUND A CRACK UNDER FRICTION AND COMBINED STRESS"

KEY WORDS

FAILURE MODEL, TASK 10

FRACTURE ANALYSIS; PLASTICITY AT CRACK TIP IN RAIL HEAD; SLIDING, LOCKING, SQUEEZING, UNLOADING

SYNOPSIS

A CORRECTION FOR CRACK GROWTH IN CONTACT STRESS AFFECTED ZONE

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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301399* DATE 00 SEP 78

AUTHOR

G. LONG

TITLE

"WROUGHT WHEEL DESIGN FOR HEAVY AXLE LOAD UNIT TRAIN OPERATION" (HEAVY HAUL RAILWAY CONF. PROCEEDINGS)

KEY WORDS

FINITE ELEMENT ANALYSIS, TASK 10

WHEELS; ADVANCED WHEEL DESIGN FOR HIGH AXLE LOAD; BOSS STAMPING; RESIDUAL STRESS & WROUGHT STEEL

SYNOPSIS

A FINITE ELEMENT BASED FAILURE PREDICTION FOR STRAIGHT PLATE WHEELS

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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301400*                        DATE  00 SEP 78

                              AUTHOR
           L. G.  KEMENY,

                               TITLE
           "THE COMPUTERIZED MONITORING OF RAILWAY WHEELS IN MOTION
           (HEAVY HAUL RAILWAYS CONF. PROCEEDINGS)

                             KEY WORDS
  NDE, TASK 14

--------------------------------------------------------------------------------
  FLAW DETECTION; WHEEL FAILURES BY THERMAL STRESS & CRACKS; AUTOMATED MONI-
  TOR IN MOTION & DERAILING


                              SYNOPSIS
RELEIGH   WAVE METHOD FOR DETECTING CRACKS AND RESIDUAL STRESS.  ACTUAL SYSTEM
MAY NOT BE IN PLACE.



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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301401*                        DATE  00 SEP 82

                              AUTHOR
           C.  SWENSON

                               TITLE
           WHEEL WEAR ON HIGH ADHESION LOCOMOTIVES


                             KEY WORDS

--------------------------------------------------------------------------------
  WHEEL WEAR; WHEEL CREEP CONTROL ON LOCOMOTIVES; ADHESION CONDITONS & SAND;
  TREAD & FLANGE WEAR


                              SYNOPSIS
BACKGROUND MATERIAL FOR SHELLING



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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301402* DATE 00 SEP 82

AUTHOR
R. D. FINCH & W. E. THOMFORD

TITLE
"DESIGN FEATURES FOR OPERTAIONAL ACOUSTIC SIGNATURE
INSPECTION OF RAILROAD WHEELS

KEY WORDS
NDE, TASK 14

SYNOPSIS
AN ACOUSTIC SIGNATURE METHOD FOR DETECTING CRACKED WHEELS. SYSTEM SEEMS TO LACK SUFFICIENT SENSITIVITY AND DEVELOPMENT - IS UNCERTAIN AT THIS TIME (1984)

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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301402* DATE 00 SEP 82

AUTHOR
R. D. FINCH & W. E. THOMFORD

TITLE
"DESIGN FEATURES FOR OPERTAIONAL ACOUSTIC SIGNATURE
INSPECTION OF RAILROAD WHEELS

KEY WORDS
NDE, TASK 14

SYNOPSIS
AN ACOUSTIC SIGNATURE METHOD FOR DETECTING CRACKED WHEELS. SYSTEM SEEMS TO LACK SUFFICIENT SENSITIVITY AND DEVELOPMENT - IS UNCERTAIN AT THIS TIME (1984)

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                         FILE PRINTED BY FILE NUMBER

FILE NUMBER   301403*                             DATE  00 SEP 82

                                    AUTHOR
                 A. J. OPINSKY

                                     TITLE
                 "RAILROAD WHEEL BACK RIM FACE FAILURES; DATA & ANALYSIS
                 (2ND INTL. HEAVY HAUL CONF. PRE-CONF. PROCEED.)

                                  KEY WORDS
   FAILURE MODEL, TASK 10, STRAIGHT PLATE DESIGN, CLASS B & C,

--------------------------------------------------------------------------------
   CRACK PROPAGATION & CATASTROPIC FAILURE


                                   SYNOPSIS
A COMPARISON OF PERFORMANCE OF WHEEL DESIGN AND REAR RIM FACE FAILURES



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                         FILE PRINTED BY FILE NUMBER

FILE NUMBER   301404*                             DATE  00 SEP 82

                                    AUTHOR
                 V. ARONOV & M. PONS

                                     TITLE
                 THE WEAR MECHANISM OF THE RAILROAD WHEEL STEEL IN THE FREE
                 ROLLING AND BRAKING CONDITIONS

                                  KEY WORDS

--------------------------------------------------------------------------------
   WHEEL WEAR; WHEEL STEEL IN FREE ROLLING & BRAKING; WEAR PARTICLE FORMATION
   SEM ANALYSIS

                                   SYNOPSIS
A BACKGROUND PAPER FOR SHELLING PHENOMENON AND FATIGUE FAILURE; NOT DIRECLY
APPLICABLE TO THE PROGRAM



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                    FILE PRINTED BY FILE NUMBER

[illegible] NUMBER   [illegible]                DATE  00 SEP 82

                              AUTHOR
              K. HIRAKA, K. ATOYAMA, E. SUZUKI & A. HAMAZAKI

                               TITLE
              EFFECTS OF CHEMICAL COMPOSITION AND MICROSTRUCTURE ON WEAR
              PROPERTIES OF STEELS FOR RAILROAD WHEELS

                             KEY WORDS
  MATERIAL PROPERTIES, TASK 3
-----------------------------------------------------------------------------



                              SYNOPSIS
PROPERTIES OF AN ALLOY WHEEL



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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301406*                           DATE  00 SEP 82

                              AUTHOR
              T. DEVINE & R. ALBER

                               TITLE
              WHEEL FLANGE WEAR TEST RESULTS IN HEAVY HAUL SERVICE

                             KEY WORDS

-----------------------------------------------------------------------------
  WHEEL WEAR; CARBON CONTENT REDUCED/THERMAL CRACKS; HARDNESS & FLANGE WEAR;
  LUBRICATION, CURVES, SPEED


                              SYNOPSIS
GENERAL BACKGROUND MATERIAL; NOT DIRECTLY APPLICABLE TO THE PROGRAM



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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301409* DATE 00 82

AUTHOR

H. ARAI

TITLE

THEORETICAL ANALYSIS ON THE DYNAMIC CHARACTERISTICS OF WHEELS

KEY WORDS

DYNAMICS ANALYSIS; COUNTERMEASURES VS. NOISE; ROTARY INERTIA, SHEARING DEFORMATION; RESILIENCE

SYNOPSIS

NOT DIRECTLY RELATED TO THE PROGRAM; GENERAL REFERENCE PAPER ON WHEEL DYNAMIC CHARACTERISTICS

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301415* DATE 00 OCT 82

AUTHOR

L. ROZEANU & D. PNUELI

TITLE

THE MORPHOLOGY OF SURFACE DAMAGE CAUSED BY FRICTION

KEY WORDS

FRICTION, FRICTIONAL HEATING ON SLIDING SYSTEMS, SURFACE DAMAGE; MORPHOLOGY AS DIAGNOSTIC TOOL

SYNOPSIS

BACKGROUND MATERIAL FOR SHELLING PROBLEM

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                         FILE PRINTED BY FILE NUMBER

FILE NUMBER   301423*                             DATE  00     82

                                    AUTHOR
                 M.  MUNJAL & M.  HECKL

                                     TITLE
                 SOME MECHANISMS OF EXCITATION OF A RAILWAY WHEEL


                                  KEY WORDS


---------------------------------------------------------------------------------
   VIBRATION; RAILWAY WHEEL VIBRATION; LOAD ON RIM AND ROUGHNESS AT WHEEL/RAIL
   CONTACT; FREQUENCIES


                                   SYNOPSIS
NOT DIRECTLY APPLICABLE TO THE PROGRAM; GENERAL REFERENCE PAPER ON WHEEL
VIBRATIONAL CHARACTERISTICS




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                         FILE PRINTED BY FILE NUMBER

FILE NUMBER   301431*                             DATE  00     82

                                    AUTHOR
                 T.  J.  THOMAS, V.  K.  GARG, & S.  NAIR

                                     TITLE
                 FATIGUE ANALYSIS OF RAILWAY FREIGHT CAR WHEELS UNDER THERMAL
                 LOADING CONDITIONS

                                  KEY WORDS
   FAILURE ANALYSIS, TASK 10

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   WHEEL WEAR; FATIUGE ANALYSIS; FINITE-ELEMENT ANALYSIS; KINEMATIC HARDENING
   MODEL; THERMAL LOADS


                                   SYNOPSIS
A METHODOLOGY FOR PREDICTING WHEEL FAILURE FROM FINITE ELEMENT ANALYSIS




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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301434* DATE 00 82

AUTHOR
S. KUMAR. Y. ADENWALA, B. RAJKUMAR

TITLE
EXPERIMENTAL INVESTIGATION OF CONTACT STRESSES BETWEEN A U. S. LOCOMOTIVE WHEEL AND RAIL

KEY WORDS

CONTACT STRESS ANALYSIS; PLASTICITY AND WEAR; WHEEL/RAIL SIMULATION; LABORATORY & FIELD RESULTS COMPARED

SYNOPSIS
BACKGROUND MATERIAL FOR SHELLING PROBLEM

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301437* DATE 00 60

AUTHOR
J. M. WANDRISCO & F. J. DEWEZ

TITLE
STUDY OF THE DEFECTS THAT ORIGINATE & DEVELOP IN THE TREADS OF RR WHEELS DURING SERVICE (PAP. NO. 60-RR-1)

KEY WORDS
MATERIAL PROPERTIES; TASK 3

FAILURE ANALYSIS; WHEEL TREAD DEFECT FORMATION; SERVICE DEFECTS; BRAKING DEFECTS; ROLLING LOADS

SYNOPSIS
EFFECTS OF CARBON CONTENT AND HEAT ON WHEEL THERMAL CRACK FORMATION

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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301438*                           DATE  00      00

                           AUTHOR
          W. S. LOVELACE,

                            TITLE
          STUDY OF RIM STRESSES RESULTING FROM STATIC LOADS ON
          DIFFERENT 36-IN. RR WHEEL DESIGNS (PAP. NO. 71-RR-4)

                         KEY WORDS

--------------------------------------------------------------------------------
   WHEEL WEAR; STRESS IN RIM SECTIONS; WHEEL RIM AND FATIGUE FAILURES; STATIC
   LOADS UP TO 75,000 LB.

                          SYNOPSIS
EARLIER EXPERIMENTAL STRESS ANALYSIS



*******************************************************************************


                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301439*                           DATE  00      69

                           AUTHOR
          G. E. NOVAK & B. J. ECK

                            TITLE
          A THREE DIMENSIONAL FINITE DIFFERENCE SOLUTION FOR THE THER-
          MAL STRESSES IN RAILCAR WHEELS (PAP. NO. 69-RR-4)

                         KEY WORDS

--------------------------------------------------------------------------------
   WHEEL WEAR; THERMAL STRESS DISTRIBUTION FROM BRAKE; SHEAR STRESSES; THERMAL
   HISTORY OF WHEEL; FATIGUE

                          SYNOPSIS
EARLY FINITE ELEMENT ANALYSIS OF WHEELS (ELASTIC)



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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301440* DATE 00 67

AUTHOR
J. P. BRUNER, R. D. JONES, S. LEVEY & J. WANDRISCO

TITLE
EFFECT OF DESIGN VARIATION ON SERVICE STRESSES IN RAILROAD WHEELS (PAPER NO. 67-WA/RR-6)

KEY WORDS

WHEEL WEAR; SERVICE BRAKING & LOADING SIMULATED; BRAKING, LOADING STRESSES; FATIGUE

SYNOPSIS
OBSOLETE EARLY COMPUTER BASED STRESS ANALYSIS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301441* DATE 00 00

AUTHOR
M. S. RIEGEL, S. LEVY & J. A. SLITER

TITLE
A COMPUTER PROGRAM FOR DETERMING THE EFFECT OF DESIGN VARIATION ON SERVICE STRESSES IN RR WHEELS (PAP. NO. 65-WA/RR-1)

KEY WORDS

WHEEL WEAR; WHEEL SHAPE & DIMENSIONS; HEAT STRESS BY BRAKE SHOE FRICTION; LATERAL, TRACTIONAL FORCES

SYNOPSIS
OBSOLETE STRESS ANALYSIS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301443* DATE 00 71

AUTHOR
L. A. PETERSON, W. H. GREEMAN, & J. M. WANDRISCO

TITLE
MEASUREMENT AND ANALYSIS OF WHEEL-RAIL FORCES
(PAPER NO. 71-WA/RT-4

KEY WORDS
FAILURE MODEL, TASK 10

DYNAMICS ANALYSIS; LATERAL & VERTICAL FORCES; PERFORMANCE SIGNATURES IN CURVES; APPLICATIONS

SYNOPSIS
EXPERIMENTAL DETERMINATION OF MECHANICAL SERVICE LOADS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301445* DATE 00 72

AUTHOR
G. M. CABBLE

TITLE
EFFECT OF WHEEL DIAMETER ON TREAD TEMPERATURE IN GRADE
OPERATION (PAPER NO. 72-WA/RT-10)

KEY WORDS
DYNAMOMETER TESTING, TASK 8

TEMPERATURE CONTROL; WHEEL SIZE AND TREAD TEMPERATURE; BRAKING ON GRADES; EQUIPMENT & PROCEDURES

SYNOPSIS
DYNAMOMETER STUDY OF WHEEL TEMPERATURE. USEFUL BUT OLD INSTRUMENTATION TECHNIQUES

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301446* DATE 00 72

AUTHOR
G. E. NOVAK & B. J. ECK

TITLE
ASYMMETRICAL WHEEL STRESSES CAUSED BY SIMULATED THERMAL AND MECHANICAL SERVICE LOADS (PAPER NO. 72-WA/RT-13)

KEY WORDS
FINITE ELEMENT ANALYSIS, TASK 10

STRESS ANALYSIS; WHEEL UNDER DRAG BRAKING; OCTAHEDRAL SHEAR; STRESS

SYNOPSIS
EARLY FINITE ELEMENT ANALYSIS - (OBSOLETE)

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301447* DATE 00 73

AUTHOR
H. R. WETENKAMP

TITLE
THERMAL STRESSES DEVELOPED IN S PLATE, STRAIGHT PLATE, AND DEEP DISH WHEEELS

KEY WORDS
COMPREHENSIVE TESTING ON TRACK & DYNAMOMETER, TASK 6

STRESS ANALYSIS; SUBJECTING WHEELS TO BRAKING CYCLES; ELASTIC STRESS BY THERMAL LOAD; DESIGNS

SYNOPSIS
EFFECT OF WHEEL DESIGN ON ELASTIC THERMAL STRESS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER   301448*   DATE 00   73

AUTHOR
G. E. NOVAK, W. J. KUCERA, & B. J. ECK

TITLE
EFFECT ON RIM THICKNESS ON WHEEL STRESSES CAUSED BY SIMULATED SERVICE CONDITIONS (PAPER NO. 73-WA/RT-10)

KEY WORDS

STRESS ANALYSIS; WHEEL RIMS UNDER LOADS; OCTAHEDRAL STRESS MAPPING; COMPUTED & STRAIN GAGE VALUES

SYNOPSIS
EARLY FEA PAPER - (OBSOLETE)

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER   301449*   DATE 00   75

AUTHOR
H. R. WETENKAMP & R. M. KIPP

TITLE
HOT SPOT HEATING BY COMPOSITION SHOES (PAPER NO. 75-RT-2)

KEY WORDS
FAILURE MODEL, TASK 10

BRAKING; MEASURE HOT SPOTS ON WHEEL TREAD SURFACE; LOWER HOT SPOT LEVEL BY CUTTING SLOT ACROSS PAD

SYNOPSIS
FIRST PAPER ON HOT SPOT PHENOMENON

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301450* DATE 00 75

AUTHOR
G. E. NOVAK, L. P. GREENFIELD, & D. H. STONE

TITLE
SIMULATED OPERATING STRESSES IN 28-IN. DIAMETER WHEELS

KEY WORDS
COMPREHENSIVE TRACK AND DYNAMOMETER TESTING, TASK 6

STRESS ANALYSIS; WHEEL DESIGNS; SIMULATE VERTICAL, LATERAL, BRAKE SHOE FORCES; OCTAHEDRAL MAPPING

SYNOPSIS
EARLY FEA PAPER CONTRASTING STRAIGHT AND CURVED PLATE DESIGNS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301451* DATE 00 75

AUTHOR
G. E. NOVAK & B. J. ECK

TITLE
CYCLIC DISTORTIONS AND STRESSES IN 36-IN. WHEELS UNDER COMBINED SERVICE LOADS

KEY WORDS

STRESS ANALYSIS; TERMPERATURE IN WHEELS DUE TO TREAD BRAKING, CYCLIC LOAD COMBINATIONS, DISTORTION

SYNOPSIS
EARLY FEA PAPER - (OBSOLETE BUT USEFUL)

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER   301452*   DATE 00   76

AUTHOR
G. E. NOVAK, G. E. DAHLMAN, B. J. ECK, W. KUCERA

TITLE
THERMAL PATTERNS IN 36 INCH FREIGHT CAR WHEEL DURING SERVICE TESTS

KEY WORDS
PRELIMINARY TRACK TEST, TASK 5

STRESS ANALYSIS, SERVICE TESTS OF BRAKE SHOE FORCE, INSTRUMENTED WHEELS, HEAT-FLOW CHARACTERISTICS

SYNOPSIS
CORRELATION OF WHEEL THERMAL PATTERNS FROM FIELD TEST AND FINITE DIFFERENCE CALCULATION

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER   301453*   DATE 00   77

AUTHOR
G. E. NOVAK & D. H. STONE

TITLE
A COMPARISON OF THE STRESS LEVELS IN ONE-AND-TWO WEAR 36 IN. DIAMETER WHEELS UNDER SIMULATED SERVICE LOADS

KEY WORDS
FAILURE MODEL, TASK 10

STRESS ANALYSIS; STRESS LEVEL & WEAR IN SERVICE; RIM THICKNESS & STRESS LEVEL; SHATTER & CRACKS

SYNOPSIS
EARLY ATTEMPT TO CALCULATE STRESS DIFFERENCES IN ONE - AND TWO WEAR WHEELS BY ELASTIC FINITE ELEMENT ANALYSIS (OBSOLETE)

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301454* DATE 00 78

AUTHOR
T. M. RUSIN, D. G. KLEESCHULTE, J. M. COUGHLIN

TITLE
APPLICATION OF THE FINITE ELEMENT METHOD IN THE DEVELOPMENT OF IMPROVED RAILROAD CAR WHEEL DESIGNS

KEY WORDS
FINITE ELEMENT ANALYSIS, TASK 10,

THERMAL & MECHANICAL LOADS ON WHEEL DESIGNS; CALCULATED STRESSES, DYNAMOMETER

SYNOPSIS
FINITE ELEMENT ANALYSIS OF DIFFERENT WHEEL DESIGNS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301455* DATE 00 83

AUTHOR
E. J. PIPLING & P. B. CROSLEY

TITLE
THERMAL CRACKING OF RAILCAR WHEELS

KEY WORDS
MATERIAL PROPERTIES, TASK 3

FAILURE ANALYSIS; RADIAL CRACKS AFTER BRAKING; CONTROLLING CRACKS, CRACK ARREST; FRACTURE TOUGHNESS

SYNOPSIS

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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301456* DATE 00 JUL 72

AUTHOR
M. H. LARSON, M. H. HUNTRESS & M. HALEY

TITLE
DISTRIBUTION OF HEAT BETWEEN WHEEL AND BRAKE SHOE

KEY WORDS
BRAKE SHOE HEATING, TASK 7

HEATING UNDER BRAKING PRODUCES THERMAL CRACKS, RESIDUAL STRESS; WHEEL FAILURE; SAFETY

SYNOPSIS
EVALUATION OF HEAT DISTRIBUTION BETWEEN WHEEL AND SHOE

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301457* DATE 00 JUL 72

AUTHOR
M. B. ECK & M. G. NOVAK

TITLE
WHEEL STRESSES RESULTING FROM SIMULATED SERVICE DRAG BRAKING AND ASYMMETRICAL RAIL LOADING

KEY WORDS
FINITE ELEMENT ANLAYSIS, TASK 10

STRESS ANALYSIS; FINITE ELEMENT ANALYSIS; THERMAL STRESS UNDER BRAKING; DRAG BRAKING;

SYNOPSIS
OBSOLETE ELASTIC FINITE ELEMENT ANALYSIS PAPER

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301458* DATE 00 JUL 72

AUTHOR
M. K. MITURA

TITLE
INFLUENCE OF CHEMICAL COMPOSITION AND STRUCTURE ON THE MECHANICAL PROPERTIES OF SOLID WHEELS

KEY WORDS
MATERIAL PROPERTIES, TASK 3

WHEELS; HEAT-TREATMENT TECHNOLOGY; CHEMICAL COMPOSITION STRENGTH, YIELD LIMIT

SYNOPSIS
EFFECT OF ALLOYING ELEMENTS ON MECHANICAL PROPERTIES OF WHEEL STEELS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301460* DATE 00 JUL 72

AUTHOR
M. J. LEE & M. J. MURRAY

TITLE
EXPERIMENTAL WORKS ON SEGMENTS OF IMPROVED STEELS FOR WHEELS AND TYPES

KEY WORDS
MATERIAL PROPERTIES, TASK 3; DYNAMOMETER TESTING, TASK 4;

WHEEL TESTING MACHINE; THERMAL CRACKING OF TYRE STEEL; TENSILE, IMPACT, ABRASIVE WEAR TESTS

SYNOPSIS
LABORATORY TESTING OF VARIOUS STEEL SEGMENTS INTO THE TREAD OF TEST WHEEL. THERMAL CRACKING BEHAVIOR INVESTIGATED

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301463* DATE 00 JUL 72

AUTHOR
M. HIROOKA, M. KASAI, M. NISHIMURA, M. TOKIMASA

TITLE
RESIDUAL STRESSES IN THE RIM OF A RAILROAD SOLID WHEEL DUE TO ON-TREAD DRAG BRAKING AND THEIR EFFECT ON WHEEL FAILURE

KEY WORDS
FAILURE MODEL, TASK 10

JAPANESE EXPERIENCE; RIM STRESSES; MEASURING RESIDUAL STRESS; PLATE PROFILE EFFECTS

SYNOPSIS
EXCELLENT UNIFICATION OF RESIDUAL STRESS STATE AS AFFECTED BY WHEEL DESIGN

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301465* DATE 00 JUL 72

AUTHOR
M. P. FOX, & M. G. HEWITT

TITLE
WHEEL AND TYRE DEVELOPMENT ON BRITISH RAILWAYS

KEY WORDS
FAILURE MODEL, TASK 10

WHEELS; TYRED WHEELS (PASSENGER), MONOBLOC WHEELS (FREIGHT) AT BRITISH RAIL TREAD DEFECTS, SPALLING, SHELLING, FRACUTRE TOUGHNESS, THERMAL CRACKING;

SYNOPSIS
A REFERENCE PAPER FOR WHEEL DEFECTS ENCOUNTERED IN BRITISH RAIL PRACTICE INCLUDING SHELLNG

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                         FILE PRINTED BY FILE NUMBER

FILE NUMBER   301466*                           DATE  00     66

                                   AUTHOR


                                    TITLE
                 A STUDY OF THE STRESSES AFFECTING THE AXLES OF DRIVER WHEEL
                 SETS CAUSED BY VIBRATIONAL PHENOMENA

                                 KEY WORDS

--------------------------------------------------------------------------------
   SHELL WEAR; TORSIONAL OSCILLATION OF AXLES; WHEEL DEFORMATION; WHEEL/RAIL
   FORCE ANALYSIS


                                  SYNOPSIS
NOT DIRECTLY RELATED TO THE PROGRAM; REFERENCE PAPER ON TORSIONAL OSCILLATION
OF AXLES



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                         FILE PRINTED BY FILE NUMBER

FILE NUMBER   301495*                           DATE  00 NOV 79

                                   AUTHOR
                 ROLAND KARLSSON

                                    TITLE
                 CONTACT FORCES BETWEEN WHEEL AND RAIL IN DYNAMIC STUDIES OF
                 THE ORTHOPLANE TRAIN, PARTS I AND II

                                 KEY WORDS

--------------------------------------------------------------------------------
   SWEEDISH TECHNOLOGY; LOCAL CONTACT FORCES IN SURFACE; TANGENTAIL FORCES


                                  SYNOPSIS
APPLICABLE TO WHEEL SHELLING PHENOMENON



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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301504*                          DATE  00     81

                              AUTHOR
           ROLLAB, SOLLENTUNA

                               TITLE
           WHEEL SYSTEMS FOR TRAMWAYS AND UNDERGROUND VEHICLES

                             KEY WORDS

   WHEELS; SWEDISH TECHNOLOGY; WHEEL DRIVE ELECTRIC OR HYDRAULIC BOGGIE FRAME-
--------------------------------------------------------------------------------
   WORK, SENSORS, LOW UNSPRUNG MASS; DIAGRAMS


                              SYNOPSIS
NOT DIRECTLY APPLICABLE TO PROGRAM



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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301514*                          DATE  09 DEC 82

                              AUTHOR
           J. M. STEELE & T. LAM

                               TITLE
           IMPROVING THE ACCURACY OF FATIGUE ANALYSIS

                             KEY WORDS
   FAILURE MODEL, TASK 10

--------------------------------------------------------------------------------
   FATIGUE ANALYSIS; LIFE PREDICTION; CRACK INITIATION; LOCAL STRESSES &
   STRAINS; LOAD CYCLES; MEAN STRESS

                              SYNOPSIS
SHORT SUMMARY OF STRAIN-LIFE FATIGUE CRITERION



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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301536* DATE 00 APR 76

AUTHOR

P. W. MARSHALL

TITLE

PROBLEMS IN LONG-LIFE FATIGUE ASSESSMENT FOR FIXED OFFSHORE STRUCTURES

KEY WORDS

FAILURE MODEL, TASK 10

FATIGUE ANALYSIS; BURDEN OF RISK DESIGN CRITERIA VS. ENVIRONMENTAL/SAFETY WELDED TUBULAR HOT SPOT STRESS, HIGH CYCLE CORROSION, FRACTURE/SURFACE CRACKS

SYNOPSIS

APPLICATION OF STRAIN LIFE FATIGUE - NON RAILROAD

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301540* DATE 00 JAN 80

AUTHOR

M. R. HALEY, H. R. LARSON & D. G. KLEESCHULTE

TITLE

SYSTEMS APPROACH TO FAILURE RESISTANT CAST STEEL RAILROAD CARWHEEL DESIGN

KEY WORDS

FAILURE MODEL, TASK 10, CRACK INITIATION TESTING, TASK 8

WHEELS; WHEEL METALLURGY; CONTROL OF FRACTURE TOUGHNESS; DESIGN GEOMETRY; THERMAL/MECHANICAL STRESSES; DYNAMOMETER

SYNOPSIS

A FINITE ELEMENT ANALYSIS - FRACTURE MECHANICS APPROACH TO PREDICT WHEEL FAILURE WITH DYNAMOMETER VERIFICATION

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301541* DATE 00 JUN 79

AUTHOR

D. A. HILLS & D. W. ASHELBY

TITLE

A FRACTURE MECHANICS APPROACH TO ROLLING CONTACT FATIGUE

KEY WORDS

FRACTURE ANALYSIS; SUBSURFACE CRACKS & LINEAR ELASTIC FRACTURE MECHANICS;

SYNOPSIS

USEFUL PAPER FOR ANALYSIS OF SHELLING

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301542* DATE 00 69

AUTHOR

P. GAUTHIER

TITLE

"THE BEHAVIOR OF WHEEL SETS ON S.N.C.F. MOTIVE POWER UNITS
(THE EFFECTS OF CERTAIN TYPES OF STRESS)

KEY WORDS

FRETTING STRESSES, STRESSES DUE TO CYCLIC LOADS, FAILURE MODEL, TASK 10

WHEEL WEAR; FRENCH TECH., SOLID SURFACE TREATED WHEELS, RESIDUAL STRESS; COMPRESSIVE STRESSES IN RIM

SYNOPSIS

EFFECT OF MECHANICAL LOADS AND RESIDUAL STRESS - FRENCH EXPERIENCE

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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301543*                          DATE  00 DEC 76

                              AUTHOR
            P. J. STEVENS

                               TITLE
            AN X-RAY APPARATUS FOR THE MEASUREMENT OF RESIDUAL STRESSES
            IN RAILWAY WHEELS

                             KEY WORDS
  NDE TASK 14
-------------------------------------------------------------------------
  STRESS ANALYSIS; RESIDUAL STRESS IN WHEELS; X-RAY METHOD WITH FILM TECHNI-
  QUE; AUSTRAILIAN TECHNOLOGY; PROBLEMS


                              SYNOPSIS
APPLICATION OF X-RAY DIFFRACTION TO WHEELS FOR RESIDUAL STRESS DETERMINATION



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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301544*                          DATE  00     00

                              AUTHOR
            J. ELKINS & H. WEINSTOCK

                               TITLE
            THE EFFECT OF TWO POINT CONTACT ON THE CURVING BEHAVIOR OF
            RAILROAD VEHICLES

                             KEY WORDS

-------------------------------------------------------------------------
  CURVED TRACK; PREDICTION OF WHEEL/RAIL FORCES; VALIDATION OF TWO POINT
  CONTACT ANALYSIS; LARGER FORCES, HIGHER WEAR


                              SYNOPSIS
BACKGROUND MATERIAL FOR SHELLING PROBLEM



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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301545*                           DATE  00     82

                              AUTHOR
          TOKOY KEIKI CO., LTD.

                               TITLE
          HOW NDT GROUP IN TOKYO KEIKI IS WORKING WITH JAPAN NATIONAL
          RAILWAY & TOKYU CAR CORPORATION

                             KEY WORDS
  NDE, TASK 14
--------------------------------------------------------------------------------
  JAPANESE TECHNOLOGY; SAFE OPERATION THRU NON-DESTRUCTIVE TESTING; RAILS,
  AXLES, WHEELS AND DAILY MAINTENANCE


                              SYNOPSIS
NDE INSPECTION METHODS FOR WHEELS



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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301551*                           DATE  00     00

                              AUTHOR
          W. Y. LU

                               TITLE
          RESIDUAL STRESS EVALUATION BY ULTRASONICS IN AN ELASTIC-
          PLASTIC

                             KEY WORDS
  NDE TASK 14
--------------------------------------------------------------------------------
  ULTRASONICS, RESIDUAL STRESS EVALUATION


                              SYNOPSIS
USE OF ULTASONIC BIREFRINGENCE FOR RESIDUAL STRESS DETERMINATION IN ALUMINUM
ALLOY


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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301552*                         DATE  00     78

                              AUTHOR
          A. T. HOPPER, S. G SAMPATH, R. B. STONESIFER

                               TITLE
          THE ELASTIC FINITE ELEMENT ANALYSIS OF A CH-36 RAILCAR
          WHEEL UNDER MECHANICAL AND THERMAL LOADS

                             KEY WORDS

------------------------------------------------------------------------------
  FINITE ELEMENT ANALYSIS; WHEEL STRESS; SPECTRAL LOADING, PLASTICITY,
  THERMAL LOADS, RESIDUAL STRESS

                              SYNOPSIS
ELASTIC FINITE ELEMENT PROGRAM (OBSOLETE BUT USEFUL REFERENCE)



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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301553*                         DATE  00     00

                              AUTHOR
          J. L. VAN SWAAIJ

                               TITLE
          THERMAL DAMAGE TO RAILWAY WHEELS

                             KEY WORDS
  FAILURE MODEL, TASK 10; MATERIAL PROPERTIES, TASK 2
------------------------------------------------------------------------------
  SURVEY OF WHEEL DEFECTS; HEAT DURING BRAKING; MECHANISMS OF DEFECTS;
  CHARACTER OF THE DAMAGE

                              SYNOPSIS
THE CLASSIC PAPER ON WHEEL THERMAL CRACKING



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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301554* DATE 00 00

AUTHOR
T. H. COLEMAN & D. J. NAYLOR

TITLE
A METALLURGICAL STUDY OF THE FACTORS AFFECTING THERMAL FATIGUE CRACKING IN RAILWAY WHEEL AND TYRE STEELS

KEY WORDS
MATERIAL PROPERTIES, TASK 3

HEATING & QUENCHING OF WHEEL RIM; NUCLEATION & GROWTH OF THERMAL FATIGUE CRACKS IN STEELS

SYNOPSIS
EFFECT OF DEFORMATION AND ALLOY CONTENT ON THERMAL CRACKING SENSITIVITY OF WHEEL STEELS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301555* DATE 00 00

AUTHOR
G. G. HEWITT & C. MUSIOL

TITLE
THE SEARCH FOR IMPROVED WHEEL MATERIALS

KEY WORDS
FAILURE MODEL - TASK 10

TREAD DAMAGE FROM BRAKE; LOCAL FATIGUE ENVIRONMENT, HOT SPOT; IMPROVED MATERIAL, STRAIN,

SYNOPSIS
ANALYSIS OF DAMAGE DUE TO HOT SPOTTING

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301558* DATE 00 78

AUTHOR
Y. MASUKO & S. SUZUKI

TITLE
DEVELOPMENT OF WHEEL SET MANUFACTURING TECHNIQUE

KEY WORDS

WHEELS; JAPANESE TECH; WHEEL MANUFACTURE; JNR WHEEL; TOUGHNESS, WEAR RESISTANCE, ECONOMY, QUALTIY

SYNOPSIS
PAPER ON WROUGHT WHEEL MANUFACTURING; A GENERAL BACKGROUND PAPER

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301559* DATE 00 JAN 75

AUTHOR
H. I. ANDREWS

TITLE
THE 'CREEP' OF LOCOMOTIVE DRIVING WHEELS

KEY WORDS

CREEP; ADDITIONAL ROTATION DUE TO ELASTICITY OF TYRE & RAIL; EXPRESSION TO CALCULATE CREEPAGE

SYNOPSIS
NOT DIRECTLY RELATED TO THE PROGRAM

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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301556* DATE 00 JUL 80

AUTHOR

H. P. TAYAL

TITLE

MEASURING WHEEL FOR MEASUREMENT OF TRANSVERSE FORCES
EXCHANGED BETWEEN RAIL AND WHEEL

KEY WORDS

PRELIMINARY TRACK TESTS - TASK 5

MEASUREMENT; MEASURING WHEEL; VERTICAL AND LATERAL FORCES; SIX STRAIN GAUGE LOCATIONS

SYNOPSIS

INSTRUMENTATION METHODS FOR MEASURING TRANSVERSE FORCES

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301557* DATE 00 73

AUTHOR

E. KILB

TITLE

WHEEL LOAD & WHEEL DIAMETER FROM THE POINT OF VIEW OF STRESS
ON THE MATERIAL IN THEORY AND IN PRACTICE

KEY WORDS

WHEEL WEAR; CONTACT STRESSES; SMALL HIGH-SPEED WHEELS; FATIGUE STRENGTH; CONTACT AREA DURING WEARING PROCESS

SYNOPSIS

A GENERIC BACKGROUND PAPER FOR SHELLING PROBLEM

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301560* DATE 00 APR 79

AUTHOR

TITLE
PROCESSING SIGNALS FROM HIGH SPEED RAILWAY WHEELS

KEY WORDS
PRELIMINARY TRACK TESTS, TASK 5

MEASUREMENT; MEASURE WHEEL/RAIL FORCE; BRITISH RAIL MICROCOMPUTER SYSTEM;

SYNOPSIS
INSTRUMENTATION METHODLOGY

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301561* DATE 00 FEB 79

AUTHOR
B. KOPEC

TITLE
EFFECT OF INTERLAMELLAR SPACING OF PEARLITE ON THE ATTENUATION OF ULTRASOUND

KEY WORDS
NDE, TASK 14

METALLURGY; RAILWAY WHEEL STEEL (PEARLITIC); GRAIN SIZE; SCATTERING LOSSES PROPORTIONAL TO SPACING; WHEEL WEAR

SYNOPSIS
EXPLANATION OF THE MAJOR DIFFICULTY OF APPLYING ULTRASONIC BR

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301562* DATE 00 NOV 76

AUTHOR
R. J. MCDONALD & R. I. MAIR

TITLE
WROUGHT STEEL RAILWAY WHEELS - A BASIS FOR DEVELOPMENT

KEY WORDS
MATERIAL PROPERTIES, TASK 3

WHEELS; ABRASION RESISTANCE; RESIDUAL STRESSES; THERMAL CRACKING;
AUSTRALIAN TECHNOLOGY

SYNOPSIS
A FIRST ORDER APPROACH TO EXTENDING WHEEL LIFE BY INCREASING WEAR FRACTURE
RESISTANCE AND ROLLING CONTACT DEFECTS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301563* DATE 00 00

AUTHOR
J. J. KALKER

TITLE
SURVEY OF WHEEL-RAIL ROLLING CONTACT THEORY

KEY WORDS

FRICTIONAL ROLLING CONTACT THEORY; HISTORICAL SURVEY; HERTZ THEORY;
CREEPAGE & SPIN; LINEAR/NON-LINEAR

SYNOPSIS
IMPORTANT PAPER FOR SHELLING ANALYSIS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301566* DATE 00 NOV 75

AUTHOR
A. RESILLON & A. LELUAN

TITLE
EFFECT OF THE DEVELOPMENT OF RESIDUAL STRESSES IN SOLID WHEELS ON WEAR

KEY WORDS

WHEEL WEAR; RESIDUAL STRESSES; THERMAL FACTOR IN WEAR; FATIGUE CRACKS FORMED, DEGRADATION HISTORY

SYNOPSIS
BACKGROUND MATERIAL FOR REFERENCE; NOT DIRECTLY APPLICABLE TO PROGRAM

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER 301567* DATE 00 74

AUTHOR
V. K. GARG, SU. C. ANAND, & P. G. HODGE

TITLE
ELASTIC-PLASTIC ANALYSIS OF A WHEEL ROOLING ON A RIGID TRACK

KEY WORDS

FINITE ELEMENT ANALYSIS; MODEL FOR ROLLING WHEEL; MINIMUM STRESS-RATE; STEADY STATE REACHED; SHAKE-DOWN DEMONSTRATED

SYNOPSIS
NON-HERTZIAN ANALYSIS OF ROLLING CONTACT

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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301564*                         DATE  00 JUN 75

                                 AUTHOR
            E. PAHL

                                  TITLE
            CAUSES OF THE GROOVE FORMATION ON THE TREADS OF WHEELS WITH
            BRAKE BLOCK AND THEIR PREVENTION

                               KEY WORDS

---------------------------------------------------------------------------
  WHEEL WEAR; MELTING/REMOVAL OF FUSED WHEEL STEEL BY HEAT;


                                SYNOPSIS
PAPER DEALS WITH REDUCING BRAKE SHOE METAL PICKUP ON WHEEL TREAD



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                    FILE PRINTED BY FILE NUMBER

FILE NUMBER   301565*                         DATE  00 JAN 75

                                 AUTHOR
            W. BROHL & P. BRINKMANN

                                  TITLE
            STRESSES IN THE TREADS OF RAILWAY WHEELS

                               KEY WORDS

---------------------------------------------------------------------------
  WHEEL WEAR;  FRICTION, THERMAL STRESS, TENSILE STRESS WEAR;


                                SYNOPSIS
USEFUL FOR SHELLING ANALYSIS



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FILE PRINTED BY FILE NUMBER

FILE NUMBER 301569* DATE 00 JUL 81

AUTHOR

K. MITURA, P. MATUSEK & R. FAJA

TITLE

INTENSIVE BRAKING AS THE CAUSE OF THERMAL DAMAGING OF RAILWAY WHEELS

KEY WORDS

WHEEL WEAR; EFFECT OF BRAKE BLOCKS WHEN BRAKING TREAD OF WHEEL; WHEEL LOCKING; PETRIFICATION; PEARLITIC CEMENTITE;

SYNOPSIS

USEFUL METALLURGICAL DESCRIPTION OF METALLURGICAL CHANGES DUE TO BRAKING;
A GENERAL PURPOSE BACKGROUND PAPER

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER B98.9* DATE 00 OCT 73

AUTHOR

MEMBER ADMIN. OF THE OFC. OF RESEARCH & EXP. (ORE)

TITLE

GENERAL PROBLEMS CONNECTED WITH WHEELS AND THEIR ASSEMBLY;
SOLID CAST-STEEL WHEELS OF DIFFERENT DIAMETER AND SHAPE

KEY WORDS

TTC TRACK TESTS, TASKS 5 & 6

WHEELS; BRAKED WHEEL HAULING RUNS; WHEEL TESTING MACHINE RESULTS; WHEELS OF DIFFERING DIAMETERS TESTED AND COMPARED; VEHICLES/COMPONENTS

SYNOPSIS

TRACK TESTING RESULTS WITH WHEELSETS APPLIED WITH LIMITED INSTRUMENTATION;
MEASUREMENT OF PERMANENT WHEEL RIM DEFORMATIONS; COMPARISON OF THE RESULTS
WITH THOSE OF TESTS CONDUCTED ON WHEEL TESTING MACHINE

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER C300795* DATE 00 DEC 69

AUTHOR
R. P. HUBBARD

TITLE
CRACK GROWTH UNDER CYCLIC COMPRESSION

KEY WORDS

CRACK PROPAGATION; FATIGUE CRACK GROWTH UNDER COMPRESSIVE LOADING; FRACTURE MECHANICS MODEL STRESS INTENSITY

SYNOPSIS
LABORATORY INVESTIGATION OF FATIGUE CRACK GROWTH RATE UNDER CYCLIC COMPRESSION

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER C53.4* DATE 00 OCT 66

AUTHOR
MEMBER ADMIN. OF THE OFC. OF RESEARCH (ORE)

TITLE
BEHAVIOR OF THE METAL OF THE RAIL UNDER THE REPEATED ACTION
OF THE WHEEL; RESIDUAL LONGITUDINAL STRESSES IN THE RAIL

KEY WORDS
DETAILED RESIDUAL STRESSES, TASK 11

WHEEL RAIL DYNAMICS; DETERMINE RESIDUAL STRESSES IN RAIL; HEAT EFFECTS; TRIMMING, COLD ROLLING, FATIGUE IN SERVICE

SYNOPSIS
BACKGROUND PAPER FOR RESIDUAL STRESS ANALYSIS (WITH SPECIAL REFERENCE TO RAILS)

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER C53.6* DATE 00 OCT 70

AUTHOR
OFC. FOR RESEARCH & EXPERIMENTS (ORE)

TITLE
BEHAVIOR OF THE MEAL OF RAIL AND WHEEL IN THE CONTACT ZONE
"RESIDUAL STRESSES IN THE RAIL (CONT.) WORK HARDENED ZONE

KEY WORDS
RESIDUAL STRESSES, TASK 11;

RESIDUAL STRESS; WORK-HARDENING CHANGES' HYDROSTACK PRESSURE ZONE; FATIGUE CRACKS; RAIL CORRUGATIONS,

SYNOPSIS
STUDY OF RESIDUAL STRESS IN RAIL. REFERENCE MATERIAL FOR COMPREHENSIVE RESIDUAL STRESS ANALYSIS IN WHEELS.

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER C53.9* DATE 00 OCT 73

AUTHOR
MEMBER ADMIN. OF THE OFC. OF RESEARCH & EXP. (ORE)

TITLE
BEHAVIOR OF THE METAL OF RAILS AND WHEELS IN THE CONTACT
ZONE, QUEST. C53

KEY WORDS
FAILURE MODEL TASK 10; RESIDUAL STRESSES, TASK 11

STRESS ANALYSIS, RESIDUAL RAIL STRESSES FROM PASSAGE WHEELS; FATIGUE PLASTIC DEFORMATION

SYNOPSIS
RESIDAUL STRESS ANALYSIS OF RAIL; FATIGUE DAMAGE AS A FUNCTION OF LOAD CONDITIONS

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                        FILE PRINTED BY FILE NUMBER

FILE NUMBER   FRA 48/40*                          DATE  00 JUN 78

                                  AUTHOR
                  B. PAUL, &  J. HASHEM

                                   TITLE
                  USERS' MANUAL FOR PROGRAM CONFORM (CONFORMAL CONTACT STRESS
                  PROBLEMS)

                               KEY WORDS

-------------------------------------------------------------------------------
   RAIL WHEEL INTERACTION, CONTACT STRESS, CONFORMAL CONTACT, ELASTICITY,
   NON HERTZIAN CONTACT, COMPUTER PROGRAM

                                SYNOPSIS




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                        FILE PRINTED BY FILE NUMBER

FILE NUMBER   FRA 75/11*                          DATE  00 MAY 74

                                  AUTHOR


                                   TITLE
                  INSTRUMENTATION FOR MEASUREMENT OF FORCES ON WHEELS OF RAIL
                  VEHICLES

                               KEY WORDS
   PRELIMINARY TRACK TESTING, TASK 5;

-------------------------------------------------------------------------------
   INSTRUMENTED WHEEL; WHEEL STRESSES; WHEEL FORCES; FORCE MEASUREMENT,
   SLIP RINGS

                                SYNOPSIS
REFERENCE MATERIAL FOR THE FABRICATION AND CALIBRATION OF INSTRUMENTED WHEELSETS
CAPABLE OF MEASURING WHEEL/RAIL FORCES


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FILE PRINTED BY FILE NUMBER

FILE NUMBER FRA 75/12* DATE 00 SEP 74

AUTHOR
C. S. CARTER & R. G. CATON

TITLE
FRACTURE RESISTANCE OF RAILROAD WHEELS

KEY WORDS
FAILURE MODEL, TASK 10

WHEEL WEAR; RAILROAD WHEELS; CARBON STEELS; FRACTURE MECHANICS; FRACTURE TOUGHNESS; FAILURE ANALYSIS

SYNOPSIS
THE MATERIAL PROPERTIES EVATLUATED IN THIS REPORT WILL BE USED IN THE W.F.M. PROGRAM. AN EXCELLENT REFERENCE MATERIAL FOR METALLURGICAL TEST PROCEDURES AND FAILURE ANALYSIS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER FRA 75/12* DATE 00 SEP 74

AUTHOR
C. S. CARTER & R. S. CATON

TITLE
FRACTURE RESISTANCE OF RAILROAD WHEELS

KEY WORDS
MATERIAL PROPERTIES, TASK 3

RAILROAD WHEELS; CARBON STEELS; FRACTURE MECHANICS; FRACTURE TOUGHNESS; FAILURE ANALYSIS

SYNOPSIS
THE MATERIAL PROPERTIES EVATLUATED IN THIS REPORT WILL BE USED IN THE W.F.M. PROGRAM. AN EXCELLENT REFERENCE MATERIAL FOR METALLURGICAL TEST PROCEDURES AND FAILURE ANALYSIS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER FRA 76/271* DATE 00 JUL 76

AUTHOR
C. SCIAMMARELLA, M. PRESS, S. KUMAR, ET. AL.

TITLE
STUDY OF FRICTION AND CREEP BETWEEN STEEL WHEELS AND RAIL

KEY WORDS

TRACK/TRAIN DYNAMICS, FRICTION; CREEP; ADHESION; TRACTION; CONTACT ZONE

SYNOPSIS
USEFUL IN SHELLING ANALYSIS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER FRA 76/272* DATE 00 JUL 76

AUTHOR
K. C. KARAMCHANDANI, ET. AL.

TITLE
FRICTION-CREEP AND WEAR STUDIES FOR STEEL WHEEL AND RAIL

KEY WORDS

CREEP; FRICTION; WEAR; ADHESION; RAILROAD ENGINE; WHEEL/RAIL FORCES,
INTERACTION; METALLURGY

SYNOPSIS
USEFUL IN SHELLING ANALYSIS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER. FRA 76/290* DATE 00 OCT 76

AUTHOR
K. NAGY & R. D. FINISH

TITLE
FEASIBILITY OF FLAW DETECTION IN RAILROAD WHEELS USING ACOUSTIC SIGNATURES

KEY WORDS
NDE TECHNIQUES, TASK 14

FLAW DETECTION; DEFECT DETECTION IN RAILROAD WHEELS; ACOUSTIC SIGNATURE; INSTRUMENTATION

SYNOPSIS
NDE TECHNIQUE FOR NDE OF CRACKED WHEELS. PROBABILITY OF SUCCESS IS QUESTIONABLE

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER FRA 77/11* DATE 00 FEB 77

AUTHOR
R. R. KING, J. R. BARTON, & W. D. PERRY

TITLE
STRESS MEASUREMENTS IN RAILROAD WHEELS VIA THE BARKHAUSEN EFFECT

KEY WORDS
NDE TECHNIQUES, TASK 14

NONDESTRUCTIVE TESTING; RESIDUAL STRESS; BARKHAUSEN EFFECT; RAILROAD WHEELS

SYNOPSIS
THE FIRST ATTEMPT TO APPLY BARKHAUSEN TECHNIQUES TO RAILROAD WHEELS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER FRA 77/17* DATE 00 MAR 77

AUTHOR
G. F. CARPENTER

TITLE
THE CAUSE OF THERMAL FATIGUE CRACKING IN METROLINER WHEELS

KEY WORDS
DYNAMOMETER TESTING, TASKS 4, 6, AND 8; FAILURE MODEL, TASK 10;

FATIGUE ANALYSIS; WHEEL WEAR, RESIDUAL THERMAL STRESSES; THERMAL CRACKING; MACROSTRUCTURE, MICROSTRUCTURE

SYNOPSIS
DYNAMOMETER STUDY OF THERMAL CRACK INITIATION. (THIS DYNAMOMETER IS THE ONE NOW AT AAR)

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER FRA 77/50* DATE 00 NOV 77

AUTHOR
C. S. CARTER, R. G. CATON, J. L. GUTHERIE

TITLE
FRACTURE RESISTANCE AND FATIGUE CRACK GROWTH CHARACTERISTICS OF RAILROAD WHEELS AND AXLES

KEY WORDS
MATERIAL PROPERTIES, TASK 3

WHEEL WEAR; FRACTURE TOUGHNESS; FATIGUE CRACK GROWTH RATES; CARBON STEELS; RAILROAD AXLES; SUBCRITICAL FLAWS DETECTED

SYNOPSIS
MECHANICAL PROPERTIES FOR TOUGHNESS AND CRACK GROWTH HEREIN WILL BE USED IN PROGRAM. THE DEFINITIVE SOURCE OF WHEEL FRACTURE TOUGHNESS DATA

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER FRA 78/27* DATE 00 SEP 77

AUTHOR

B. PAUL & J. HASHEMI

TITLE

USER'S MANUAL FOR PROGRAM COUNTACT (COUNTerformal contACT STRESS PROBLEMS)

KEY WORDS

RAIL WHEEL INTERACTION; CONTACT STRESS; COUNTER-FORMAL CONTACT; ELASTICITY; NON-HERTZIAN CONTACT; COMPUTER PROGRAMS

SYNOPSIS

NON-HERTZIAN ELASTIC CONTACT STRESS SOLUTION CALCULATED CONTACT PATCH WITH A MORE ACCURATE REPRESENTATION OF SHAPE AND AREA THAN THE HERTZIAN CALCULATIONS YIELD; A GENERAL PURPOSE BACKGROUND PAPER

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER R-158* DATE 00 MAY 74

AUTHOR

D. H. STONE

TITLE

RESIDUAL STRESSES IN THE PLATE FILLETS OF TWENTY-EIGHT-INCH DIAMETER WROUGHT STEEL WHEELS

KEY WORDS

DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

WHEELS; B-28 WHEEL AND PLATE CRACKING; BULK RESIDUAL STRESS EVALUATION FATIGUE

SYNOPSIS

USE OF AISI METHOD TO DETERMINE BULK RESIDUAL STRESS

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER R-167* DATE 00 FEB 75

AUTHOR

D. H. STONE

TITLE

EXPERIMENTAL STRESS ANALYSIS OF LATERAL LOADS ON RAILWAY WHEELS

KEY WORDS

WHEEL WEAR, HUB-PLATE FILLETS OF RAILWAY WHEELS, THICKNESS AT RIM-PLATE DEPRESSION,

SYNOPSIS

OBSOLETE EXPERIMENTAL STRESS ANALYSIS; GENERAL PURPOSE BACKGROUND PAPER

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER R-268* DATE 00 FEB 77

AUTHOR

A. HOPPER, T. JOHNS, S. SAMPATH, R. STONESIFER

TITLE

WHEEL RESEARCH, VOLUME 1, ELASTIC STRESS ANALYSIS, ELASTIC FINITE-ELEMENT STRESS ANALYSIS OF RAIL CAR WHEELS

KEY WORDS

ELASTIC FINITE ELEMENT PROGRAM, TASK 10

WHEELS; FINITE ELEMENT ANALYSIS; ELASTIC STRESS ANALYSIS; HEAT TRANSFER ANALYSIS; CONTACT STRESS ANALYSIS

SYNOPSIS

ELASTIC FINITE ELEMENT PROGRAM

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER R-373* DATE 00 MAY 79

AUTHOR
Y. J. PARK

TITLE
CYCLIC BEHAVIOR OF CLASS B WHEEL STEEL

KEY WORDS
MATERIAL PROPERTIES, TASK 3; FAILURE MODEL, TASK 10

WHEELS; CLASS B WHEEL; LOW-CYCLE, FATIGUE, CYCLIC SOFTENING; STRESS, STRAIN, FATIGUE LIFE

SYNOPSIS
ROOM TEMPERATURE DATA WILL BE USED IN TASK 3

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER R-374* DATE 00 JUN 79

AUTHOR
M. K. KONG & D. H. STONE

TITLE
ANALYSIS OF TWO FAILED WHEELS SUBMITTED BY THE NATIONAL RAILROAD PASSENGER CORPORATION (AMTRAK)

KEY WORDS
FAILURE MODEL, TASK 10

WHEEL WEAR; FAILURE ANALYSIS; CLEAVAGE FRACTURE AND SPLIT; MARTENSITE FORMATION; HYDROGEN FLAKES

SYNOPSIS
FAILURE ANALYSIS METHODOLOGY

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER R-388* DATE 00 AUG 79

AUTHOR
T. J. THOMAS & V. K. GARG

TITLE
THERMAL FATIGUE ANALYSIS OF A RAIL CAR WHEEL UNDER DRAG BRAKING

KEY WORDS
FAILURE MODEL, TASK 10

WHEEL WEAR; FATIGUE LIFE; THERMAL STRESSES; DRAG BRAKING; FINITE-ELEMNT METHOD; PLASTICITY;

SYNOPSIS
AN EARLY FATIGUE ANALYSIS MODEL

****

FILE PRINTED BY FILE NUMBER

FILE NUMBER R-393* DATE 00 AUG 79

AUTHOR
Y. J. PARK

TITLE
CYCLIC BEHAVIOR OF CLASS A WHEEL STEEL

KEY WORDS
MATERIAL PROPERTIES, TASK 3

WHEEL WEAR; CLASS A WHEEL STEEL; STRESS, STRAIN, LOW-CYCLE FATIGUE; FATIGUE LIFE OF WHEELS;

SYNOPSIS
GRADE OF STEEL NOT APPLICABLE TO PROGRAM; USEFUL REFERENCE PAPER ON CYCLIC PROPERTIES

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                         FILE PRINTED BY FILE NUMBER

FILE NUMBER   R-411*                         DATE  00 FEB 80

                                   AUTHOR
             A. J. OPINSKY

                                    TITLE
             SEPTA WHEEL RESIDUAL STRESS INVESTIGATION


                                  KEY WORDS
  DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

------------------------------------------------------------------------------
  WHEEL WEAR; RESIDUAL STRESS; BACK RIM-PLATE FILLET; FRONT HUB-PLATE FILLET;
  RAILROAD WHEEL WEAR


                                   SYNOPSIS
AN EXPERIMENTAL ANALYSIS USING AISI TECHNIQUE




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                         FILE PRINTED BY FILE NUMBER

FILE NUMBER   R-467*                         DATE  00 FEB 81

                                   AUTHOR
             T. J. THOMAS, V. K. GARG, & D. H. STONE

                                    TITLE
             FATIGUE ANALYSIS OF RAILROAD FREIGHT CAR WHEELS UNDER THER-
             MAL LOADING CONDITIONS

                                  KEY WORDS
  FAILURE MODEL, TASK 10

------------------------------------------------------------------------------
  WHEEL WEAR; WHEEL LOADS (MECHNAICAL & THERMAL); WHEEL STRESSES AND TEMPERA-
  TURES; FINITE ELEMENT ANALYSIS;

                                   SYNOPSIS
AN EARLY FATIGUE ANALYSIS MODEL




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FILE PRINTED BY FILE NUMBER

FILE NUMBER R-503* DATE 00 NOV 81

AUTHOR

A. J. OPINSKY

TITLE

RAILROAD WHEEL BACK RIM FACE FAILURES. I. EXPEREINCE OF TWO RAILROADS OVER THE PERIOD 1973-1981

KEY WORDS

FAILURE MODEL, TASK 10

WHEEL WEAR; WHEEL FAILURES; WHEEL BACK RIM FACE FAILURES; RETARDER-INDUCED FAILURES

SYNOPSIS

INITIAL STUDY OF BACK-RIM THERMAL CRACKS

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APPENDIX 3.3

ANNOTATED BIBLIOGRAPHY
(Sorted by Subject)

FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER 100379* DATE 00 78

AUTHOR

ROBERT MARION KIPP, PH. D.

TITLE

INVESTIGATIONS OF CRACK GROWTH IN RAILROAD CAR WHEELS CAUSED BY THERMALLY INDUCED RESIDUAL STRESS CHG. & CYC. MEC. LOAD

KEY WORDS

FINITE ELEMENT SIMULATIONS, TASK 10, 33" CURVED PLATE, CLASS U, STRESS ANALYSIS, LABORATORY SIMUALTIONS, TASK 8, CRACK PROPAGATION.

WHEEL STRESS; THERMAL STRESS; CRACK PROPAGATION, WHEEL WEAR LOADING, METALLURGY

SYNOPSIS

A PSEUDO-ELASTIC FINITE ELEMENT SIMULATION OF DRAG BRAKING CYCLES PREDICTS DEVELOPMENT OF RESIDUAL STRESS AND CRACK STRESS INTENSITY, BUT NOT SEVERE ENOUGH TO PREDICT THE DEGREE OF CRACK GROWTH IN DYNAMOMETER TESTS OR ESPECIALLY IN SERVICE. POSSIBLE INTERACTION OF HOT THERMAL STRESSES AND RAIL LOAD STRESSES CITED AS CAUSE FOR DISCREPANCY

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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER 100542/61* DATE 00 SEP 82

AUTHOR

A. J. OPINSKY

TITLE

SECOND INTL. HEAVY HAUL CONF. "RAILROAD WHEEL BACK RIM FACE FAILURES: DATA AND ANALYSIS"

KEY WORDS

FAILURE MODEL, TASK 10

BACK RIM FACE FAILURE (BRFF), CRACK INITIATION & PROPOGATION, PROPOGATION RATE, STRESS INTENSITY FACTOR, SHAPE FACTOR, FAILURE INITIATED AT RIM STAMPING (RS)

SYNOPSIS

A CASE STUDY OF FAILURE REPORTS FROM TWO RAILROADS; FRACTURE MECHANICS APPROACH FOR THE FAILURE EVALUATION

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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   200545*                          DATE  00      78

                                  AUTHOR
                P  STANLEY, APPLIED SCIENCE PUBLISHERS LTD

                                   TITLE
                NON-LINEAR PROBLEMS IN STRESS ANALYSIS


                               KEY WORDS
  MATERIAL PROPERTIES, TASK 3, FINITE ELEMENT SIMULATIONS
 ------------------------------------------------------------------------------
  STRESS ANALYSIS, CRACK-TIP DEFORMATION; PLASTICITY CYCLING; CREEP COLLAPSE;
  BIAXIAL PLASTIC FLOW; THERMAL RATCHETING


                                SYNOPSIS
SOME OF THE PAPERS CONTAINED IN THIS BOOK TREAT MATERIAL AND STRESS ANALYSIS
NON-LINEARITIES ASSOCIATED WITH ELEVATED TEMPERATURE CREEP AND CYCLIC PLASTICITY
THAT MAY HAVE GENERAL APPLICABILITY TO THE ANALYSIS OF STRESS CHANGES AND
CRACKING OF WHEELS

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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   200222*                          DATE  00      00

                                  AUTHOR
                HIROSHI TADA, PAUL C. PARIS & GEORGE R. IRWIN

                                   TITLE
                STRESS ANALYSIS OF CRACKS HANDBOOK


                               KEY WORDS
  CRACK PROPOGATION, TASK 8,

 ------------------------------------------------------------------------------
  STRESS ANALYSIS ON CRACK PROBLEMS; FRACTURE MECHANICS CORRELATION PARAMETER
  COMPLIANCE CALIBRATION ANALYSIS; FUNCTION ANALYSIS, PLASTICITY ANALYSIS;
  MATERIALS SCIENCE

                                SYNOPSIS
COMPREHENISVE SOURCE OF FORMULAS AND STRESS ANALYSIS INFORMTAION ON CRACK PROPO-
GATION THROUGH FRACTURE MECHANICS CORRELATION PARAMETERS AND CURRENT FRACTURE
CRITERIA.  CLOSED FORM AND NUMERICAL SOLUTIONS.


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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   200256/1-4*                          DATE  00 OCT 78

                                   AUTHOR
                L. BRAZZODURO, P. BROZZO, R. DEMARTINI,

                                    TITLE
                6TH INTL WHEELSET CONG. "FINAL RESULTS OF THE RESEARCH WORK
                ON A NEW SOLID WHEEL APT TO MOST SEVERE OPER. COND.

                                  KEY WORDS
  MATERIAL PROPERTIES, TASK 3, UIC-R/2 AND R/6 STEEL

-----------------------------------------------------------------------------
  (ITALIAN PRACTICE) THERMAL CRACKING TESTS, DRAG & STOP BRAKING TESTS



                                  SYNOPSIS
THERMAL CRACKING TESTS, DRAG AND STOP BRAKING TESTS (UIC-R/6 & 5 CR WHEELS)
WERE PERFORMED TO INVESTIGATE RESISTANCE TO REPEATED THERMAL LOADING.



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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   200766*                              DATE  00 NOV 80

                                   AUTHOR
                I. KALEV, (NASA CONTRACTOR REPORT)

                                    TITLE
                A COMPUTER PROGRAM FOR CYCLIC PLASTICITY AND STRUCTURAL
                FATIGUE ANALYSIS

                                  KEY WORDS
  FINITE ELEMENT SIMULATION, TASK 10

-----------------------------------------------------------------------------
  CYCLIC PLASTICITY, CRACK INITIATION, CRACK GROWTH, CUMULATIVE DAMAGE
  CRITERIA, FATIGUE ANALYSIS, CYCLIC LOADS, ELASTOPLASTICITY, METAL FATIGUE,
  STRUCTURAL ANALYSIS

                                  SYNOPSIS
COMPUTER PROGRAM FOR SMALL STRUCTURAL COMPONENTS, CYCLIC PLASTICITY RESPONSE,
PREDICTION OF LIFE TO CRACK INITIATION & CRACK GROWTH RATE



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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   [illegible]                      DATE  00 DEC 81

                                AUTHOR
           M  R  JOHNSON & R. R  ROBINSON

                                 TITLE
           IMPROVED SAFETY OF RAILROAD CAR WHEELS

                              KEY WORDS

-------------------------------------------------------------------------------
  WHEEL FAILURES, THERMAL CRACKS, SAFETY


                               SYNOPSIS
A GENERIC BACKGROUND PAPER (REPORT) ON FACTORS WHICH LEAD TO RAILROD WHEEL
FAILURES



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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   201050*                          DATE  00 JUL 69

                                AUTHOR
           T. SUGIYAMA , K. NISHIOKA, (ET. AL.)

                                 TITLE
           THIRD INTERNATIONAL WHEELSET CONFERENCE

                              KEY WORDS

-------------------------------------------------------------------------------
  WHEEL/RAIL: TESTING, RESILIENCY, CAST STEEL; THERMAL CRACKING; RESIDUAL
  STRESS, METALLURGY


                               SYNOPSIS
GENERAL BACKGROUND REFERENCE



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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER 300226* DATE 00 SEP 78

AUTHOR
H. ICHINOSE, J. TAKEHARA, N. IWASAKI, M. UEDA

TITLE
"AN INVESTIGATION ON CONTACT FATIGUE AND WEAR RESISTANCE
BEHAVIOUR IN RAIL STEELS

KEY WORDS

FATIGUE ANALYSIS; LOAD AND SLIP INFLUENCES; MICRO-OBSERVATIONS OF CRACK;
RUBBING/DEFORMATION OF CRACK SURFACE; PLASTIC FLOW

SYNOPSIS
A BACKGROUND PAPER FOR CONTACT FATIGUE AND SHELLING PROBLEM;
JAPANESE TECHNOLOGY

****

FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER 300598* DATE 00 00

AUTHOR
R. J. COOKE, C. J. BEEVERS

TITLE
SLOW FATIGUE CRACK PROPAGATION IN PEARLITIC STEELS

KEY WORDS
FAILURE MODEL, TASK 10

PEARLITIC STEELS, LOAD RATIO, CRACK GROWTH, CRACK CLOSURE

SYNOPSIS
GENERAL REFERENCE PAPER DESCRIBING FACTORS WHICH CONTROL SLOW FATIGUE CRACK
PROPAGATION IN PEARLITIC STEELS

****

FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER 300591* DATE 00 [illegible] 00

AUTHOR
D. E. MOCHA, J. W. JONES, D. M. CORBLY

TITLE
ON THE VARIATION OF FATIGUE - CRACK-OPENING LOAD WITH MEASUREMENT LOCATION

KEY WORDS
FATIGUE-CRACK-OPENING, CRACK-TIP-OPENING LOAD

SYNOPSIS
LABORATORY INVESTIGATION OF DISPLACEMENT-LOAD BEHAVIOR FOR A FATIGUE CRACKED SPECIMAN

****

FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER 300824* DATE 00 JUL 74

AUTHOR
D. CANNON & R. ALLEN

TITLE
THE APPLICATION OF FRACTURE MECHANICS TO RAILWAY FAILURES

KEY WORDS
FAILURE MODEL, TASK 10

FRACTURE, PRE-EXISTING DEFECT, FATIGUE CRACKS. TO QUANTIFY FRACTURE PROCESS INVOLVING CRACK PROPOGATION TO CATASTROPHIC FAILURE

SYNOPSIS
APPLICATION OF FRACTURE MECHANICS TO RAILWAY FAILURES IN AXLES, WHEELS, RAILS, TRUCK COMPONENTS ETC.

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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   300834*                              DATE  00     76

                              AUTHOR
           K. FUJITA, A. YOSHIDA, & T. YAMAMOTO

                               TITLE
           ROLLING CONTACT FATIGUE IN ANNELAED 0.45% CARBON STEEL
           ROLLERS

                             KEY WORDS
  FAILURE MODEL, TASK 10

-----------------------------------------------------------------------------------
  CRACK PROPAGATION, STEEL; MICROSTRUCTURE AT SURFACE AND SUBSURFACE OF
  ROLLERS


                              SYNOPSIS
JAPANESE PAPER; ROLLING CONTACT FATIGUE ANALYSIS IN SMALL SIZE 0.45% CARBON
STEEL ROLLERS



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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   301000*                              DATE  00     70

                              AUTHOR
           T. KUNIKAKE, S. NISHIMURA, & H. TAGASHIRA

                               TITLE
           "THE METALLOGRAPHIC OBSERVATION OF THE TREAD OF WHEELS SUB-
           JECTED TO VARIOUS SERVICE CONDITIONS" (IRON & STEEL INST.)

                             KEY WORDS
  METALLOGRAPHIC ANALYSIS, TASK 3, CRACK INITIATION, TASK 8, NDE, TASK 14

-----------------------------------------------------------------------------------
  WHEELS; METALLURGY; TREAD REGION HARDENING; ON-TREAD BRAKE; HEAT-CHECKS,
  SPALLING, FLAKY SURFACE; SHELLING

                              SYNOPSIS
AN ANALYSIS AND ATLAS OF METALLURGICAL STRUCTURE CHANGES DUE TO BRAKE HEATING



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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   301147*                              DATE  00 APR 81

                                AUTHOR
                 I. Y. ELGINDY & C. A. SCIAMMARELA

                                 TITLE
                 ANALYSIS OF CYCLIC THERMAL AND RESIDUAL STRESSES IN CH36
                 WHEELS UNDER SERIES OF SEVERE DRAG BRAKING

                              KEY WORDS
   FINITE ELEMENT ANALYSIS SIMULATION, TASK 10, CH36 WHEEL, CLASS U, CRACK
   PROPAGATION
---------------------------------------------------------------------------------

   STRESS ANALYSIS; ELASTO-PLASTIC BEHAVIOR OF MATERIAL; THERMAL & RESIDUAL
   STRESS HISTORIES, DRAG BRAKING CYCLES; RESTART

                               SYNOPSIS
FINITE ELEMENT ANALYSIS DEMONSTRATION (WITH TEMPERATURE DEPENDENT PLASTIC
PROPERTIES) THAT REPETITION OF SEVERE DRAG BRAKE CYCLES CAN PRODUCE AN INCRE-
MENTAL INCREASE IN RESIDUAL STRESS TO LEVELS THAT WOULD CAUSE ACCELERATED CRACK
PROPAGATION DUE TO THERMAL FATIGUE

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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   301353*                              DATE  00     79

                                AUTHOR
                 CAMPBELL LAIRD

                                 TITLE
                 "MECHANISMS AND THEORIES OF FATIGUE"


                              KEY WORDS
   COMPREHENSIVE FAILURE MODEL, TASK 10

---------------------------------------------------------------------------------
   FATIGUE ANALYSIS, CYCLIC DEFORMATION & MONOTONIC; DISLOCATION, CRACK
   INITIATION; PLASTIC RUPTURE


                               SYNOPSIS
  GENERIC BACKGROUND MATERIAL FOR PHENOMENON AND MECHANISMS OF FATIGUE



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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER 301379* DATE 00 JUN 77

AUTHOR

FRANK A. MCCLINTOCK

TITLE

"PLASTIC FLOW AROUND A CRACK UNDER FRICTION AND COMBINED STRESS"

KEY WORDS

FAILURE MODEL, TASK 10

FRACTURE ANALYSIS; PLASTICITY AT CRACK TIP IN RAIL HEAD; SLIDING, LOCKING, SQUEEZING, UNLOADING

SYNOPSIS

A CORRECTION FOR CRACK GROWTH IN CONTACT STRESS AFFECTED ZONE

****

FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER 301400* DATE 00 SEP 78

AUTHOR

L. G. KEMENY,

TITLE

"THE COMPUTERIZED MONITORING OF RAILWAY WHEELS IN MOTION
(HEAVY HAUL RAILWAYS CONF. PROCEEDINGS)

KEY WORDS

NDE, TASK 14

FLAW DETECTION; WHEEL FAILURES BY THERMAL STRESS & CRACKS; AUTOMATED MONITOR IN MOTION & DERAILING

SYNOPSIS

RELEIGH WAVE METHOD FOR DETECTING CRACKS AND RESIDUAL STRESS. ACTUAL SYSTEM MAY NOT BE IN PLACE.

****

FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER 301403* DATE 00 SEP 82

AUTHOR

A. J. OPINSKY

TITLE

"RAILROAD WHEEL BACK RIM FACE FAILURES; DATA & ANALYSIS
(2ND INTL. HEAVY HAUL CONF. PRE-CONF. PROCEED.)

KEY WORDS

FAILURE MODEL, TASK 10, STRAIGHT PLATE DESIGN, CLASS B & C,

CRACK PROPAGATION & CATASTROPIC FAILURE

SYNOPSIS

A COMPARISON OF PERFORMANCE OF WHEEL DESIGN AND REAR RIM FACE FAILURES

* * *

FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER 301406* DATE 00 SEP 82

AUTHOR

T. DEVINE & R. ALBER

TITLE

WHEEL FLANGE WEAR TEST RESULTS IN HEAVY HAUL SERVICE

KEY WORDS

WHEEL WEAR; CARBON CONTENT REDUCED/THERMAL CRACKS; HARDNESS & FLANGE WEAR;
LUBRICATION, CURVES, SPEED

SYNOPSIS

GENERAL BACKGROUND MATERIAL, NOT DIRECTLY APPLICABLE TO THE PROGRAM

* * *

FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER 301455* DATE 00 83

AUTHOR
E. J. PIPLING & P. B. CROSLEY

TITLE
THERMAL CRACKING OF RAILCAR WHEELS

KEY WORDS
MATERIAL PROPERTIES, TASK 3

FAILURE ANALYSIS; RADIAL CRACKS AFTER BRAKING; CONTROLLING CRACKS,
CRACK ARREST; FRACTURE TOUGHNESS

SYNOPSIS

****

FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER 301456* DATE 00 JUL 72

AUTHOR
M. H. LARSON, M. H. HUNTRESS & M. HALEY

TITLE
DISTRIBUTION OF HEAT BETWEEN WHEEL AND BRAKE SHOE

KEY WORDS
BRAKE SHOE HEATING, TASK 7

HEATING UNDER BRAKING PRODUCES THERMAL CRACKS, RESIDUAL STRESS; WHEEL
FAILURE; SAFETY

SYNOPSIS
EVALUATION OF HEAT DISTRIBUTION BETWEEN WHEEL AND SHOE

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FILE PRINT SELECTED BY KEY WORD CRACK

 FILE NUMBER   301460*                        DATE  00 JUL 72

                                  AUTHOR
                 M. J  LEE & M  J. MURRAY

                                   TITLE
                 EXPERIMENTAL WORKS ON SEGMENTS OF IMPROVED STEELS FOR WHEELS
                 AND TYPES

                                KEY WORDS
  MATERIAL PROPERTIES, TASK 3; DYNAMOMETER TESTING, TASK 4;
--------------------------------------------------------------------------------
  WHEEL TESTING MACHINE; THERMAL CRACKING OF TYRE STEEL; TENSILE, IMPACT,
  ABRASIVE WEAR TESTS

                                 SYNOPSIS
LABORATORY TESTING OF VARIOUS STEEL SEGMENTS INTO THE TREAD OF TEST WHEEL.
THERMAL CRACKING BEHAVIOR INVESTIGATED



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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   301514*                         DATE  09 DEC 82

                                  AUTHOR
                 J. M. STEELE & T. LAM

                                   TITLE
                 IMPROVING THE ACCURACY OF FATIGUE ANALYSIS

                                KEY WORDS
  FAILURE MODEL, TASK 10
--------------------------------------------------------------------------------
  FATIGUE ANALYSIS; LIFE PREDICTION; CRACK INITIATION; LOCAL STRESSES &
  STRAINS; LOAD CYCLES; MEAN STRESS

                                 SYNOPSIS
SHORT SUMMARY OF STRAIN-LIFE FATIGUE CRITERION



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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   301540*                           DATE  00 JAN 80

                                  AUTHOR
                 M. R. HALEY, H. R. LARSON & D. G. KLEESCHULTE

                                   TITLE
                 SYSTEMS APPROACH TO FAILURE RESISTANT CAST STEEL RAILROAD
                 CARWHEEL DESIGN

                                 KEY WORDS
   FAILURE MODEL, TASK 10, CRACK INITIATION TESTING, TASK 8

-------------------------------------------------------------------------------
   WHEELS; WHEEL METALLURGY; CONTROL OF FRACTURE TOUGHNESS; DESIGN GEOMETRY;
   THERMAL/MECHANICAL STRESSES; DYNAMOMETER


                                  SYNOPSIS
A FINITE ELEMENT ANALYSIS - FRACTURE MECHANICS APPROACH TO PREDICT WHEEL
FAILURE WITH DYNAMOMETER VERIFICATION



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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   301541*                           DATE  00 JUN 79

                                  AUTHOR
                 D. A. HILLS & D. W. ASHELBY

                                   TITLE
                 A FRACTURE MECHANICS APPROACH TO ROLLING CONTACT FATIGUE


                                 KEY WORDS

-------------------------------------------------------------------------------
   FRACTURE ANALYSIS; SUBSURFACE CRACKS & LINEAR ELASTIC FRACTURE MECHANICS;


                                  SYNOPSIS
USEFUL PAPER FOR ANALYSIS OF SHELLING



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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   301562*                           DATE  00 NOV 76

                                  AUTHOR
              R  J. MCDONALD & R. I  MAIR

                                   TITLE
              WROUGHT STEEL RAILWAY WHEELS - A BASIS FOR DEVELOPMENT


                                KEY WORDS
  MATERIAL PROPERTIES, TASK 3
--------------------------------------------------------------------------
  WHEELS; ABRASION RESISTANCE; RESIDUAL STRESSES; THERMAL CRACKING;
  AUSTRALIAN TECHNOLOGY


                                 SYNOPSIS
A FIRST ORDER APPROACH TO EXTENDING WHEEL LIFE BY INCREASING WEAR FRACTURE
RESISTANCE AND ROLLING CONTACT DEFECTS



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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   301566*                           DATE  00 NOV 75

                                  AUTHOR
              A. RESILLON & A. LELUAN

                                   TITLE
              EFFECT OF THE DEVELOPMENT OF RESIDUAL STRESSES IN SOLID
              WHEELS ON WEAR

                                KEY WORDS

--------------------------------------------------------------------------
  WHEEL WEAR; RESIDUAL STRESSES; THERMAL FACTOR IN WEAR; FATIGUE CRACKS
  FORMED, DEGRADATION HISTORY


                                 SYNOPSIS
BACKGROUND MATERIAL FOR REFERENCE; NOT DIRECTLY APPLICABLE TO PROGRAM



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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   C300795*                              DATE  00 DEC 69

                                     AUTHOR
                R. P. HUBBARD

                                      TITLE
                CRACK GROWTH UNDER CYCLIC COMPRESSION


                                    KEY WORDS


-------------------------------------------------------------------------------
  CRACK PROPAGATION; FATIGUE CRACK GROWTH UNDER COMPRESSIVE LOADING; FRACTURE
  MECHANICS MODEL STRESS INTENSITY


                                     SYNOPSIS
LABORATORY INVESTIGATION OF FATIGUE CRACK GROWTH RATE UNDER CYCLIC COMPRESSION




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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER   FRA 77/17*                            DATE  00 MAR 77

                                     AUTHOR
                G. F. CARPENTER

                                      TITLE
                THE CAUSE OF THERMAL FATIGUE CRACKING IN METROLINER WHEELS


                                    KEY WORDS
  DYNAMOMETER TESTING, TASKS 4, 6, AND 8; FAILURE MODEL, TASK 10;

-------------------------------------------------------------------------------
  FATIGUE ANALYSIS; WHEEL WEAR, RESIDUAL THERMAL STRESSES; THERMAL CRACKING;
  MACROSTRUCTURE, MICROSTRUCTURE


                                     SYNOPSIS
DYNAMOMETER STUDY OF THERMAL CRACK INITIATION. (THIS DYNAMOMETER IS THE ONE NOW
AT AAR)



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FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER FRA 77/50* DATE 00 NOV 77

AUTHOR

C. S. CARTER, R. G. CATON, J. L. GUTHERIE

TITLE

FRACTURE RESISTANCE AND FATIGUE CRACK GROWTH CHARACTERISTICS OF RAILROAD WHEELS AND AXLES

KEY WORDS

MATERIAL PROPERTIES, TASK 3

WHEEL WEAR; FRACTURE TOUGHNESS; FATIGUE CRACK GROWTH RATES; CARBON STEELS; RAILROAD AXLES; SUBCRITICAL FLAWS DETECTED

SYNOPSIS

MECHANICAL PROPERTIES FOR TOUGHNESS AND CRACK GROWTH HEREIN WILL BE USED IN PROGRAM. THE DEFINITIVE SOURCE OF WHEEL FRACTURE TOUGHNESS DATA

****

FILE PRINT SELECTED BY KEY WORD CRACK

FILE NUMBER R-158* DATE 00 MAY 74

AUTHOR

D. H. STONE

TITLE

RESIDUAL STRESSES IN THE PLATE FILLETS OF TWENTY-EIGHT-INCH DIAMETER WROUGHT STEEL WHEELS

KEY WORDS

DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

WHEELS; B-28 WHEEL AND PLATE CRACKING; BULK RESIDUAL STRESS EVALUATION FATIGUE

SYNOPSIS

USE OF AISI METHOD TO DETERMINE BULK RESIDUAL STRESS

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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   100542/60*                          DATE  00 SEP 82

                                  AUTHOR
            V. ARONOV & M. RONS

                                   TITLE
            SECOND INTL. HEAVY HAUL CONF. "THE WEAR MECHANISM OF THE
            RAILROAD WHEEL STEEL IN THE FREE ROLLING & BRAKING COND."

                                KEY WORDS
  FATIGUE MODEL, TASK 10

-----------------------------------------------------------------------------
  WEAR MECHANISMS, MICROSLIP, CONTACT AREA, ADHESION AREA, FRICTION
  COEFFICIENT, TRANSITION FROM ONE WEAR MECHANISM TO ANOTHER


                                  SYNOPSIS
EXPERIMENTAL INVESTIGATION OF WHEEL STEELS ON A SMALL SCALE WEAR RIG; A
REFERENCE PAPER FOR SHELLING & WEAR MECHANISMS



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   201047*                             DATE  00 OCT 75

                                  AUTHOR
            S. TANAKA & K. HATSUNO, (ET. AL.)

                                   TITLE
            FIFTH INTERNATIONAL WHEELSET CONGRESS, VOL. 2

                                KEY WORDS

-----------------------------------------------------------------------------
  WHEEL/RAIL; AXLES, LOAD FATIGUE; BEARINGS & SPEED; HEAT REFINING;
  INSEPCTION & MAINTENANCE; ECONOMICS

                                  SYNOPSIS
GENERAL BACKGROUND REFERENCE



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   300226*   DATE 00 SEP 78

AUTHOR

H. ICHINOSE, J. TAKEHARA, N. IWASAKI, M. UEDA

TITLE

"AN INVESTIGATION ON CONTACT FATIGUE AND WEAR RESISTANCE BEHAVIOUR IN RAIL STEELS

KEY WORDS

FATIGUE ANALYSIS; LOAD AND SLIP INFLUENCES; MICRO-OBSERVATIONS OF CRACK; RUBBING/DEFORMATION OF CRACK SURFACE; PLASTIC FLOW

SYNOPSIS

A BACKGROUND PAPER FOR CONTACT FATIGUE AND SHELLING PROBLEM; JAPANESE TECHNOLOGY

****

FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   300436*   DATE 00   80

AUTHOR

T. J. THOMAS, V. GARG, D. STONE

TITLE

THERMAL FATIGUE ANALYSIS OF A RAILCAR WHEEL UNDER DRAG BRAKING

KEY WORDS

FINITE ELEMENT ANALYSIS, TASK 10, CH36 WHEELS

FATIGUE ANALYSIS, STRESSES FROM TEMPERATURE; DRAG BRAKING AND CYCLIC THERMAL LOADING; FINITE ELEMNT ANALYSIS

SYNOPSIS

CYCLIC THERMAL LOADING ON THE FATIGUE LIFE OF CH36 WHEEL WAS INVESTIGATED BY FINITE ELEMENT METHOD. CREEP PLAST PROGRAM WAS USED TO ESTIMATE THE STRESS & STRAIN DEVELOPED IN THE WHEEL

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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   300691*                              DATE  00      00

                                  AUTHOR
                D. E. MOCHA, J. W. JONES, D. M. CORBLY

                                   TITLE
                ON THE VARIATION OF FATIGUE - CRACK-OPENING LOAD WITH
                MEASUREMENT LOCATION

                                 KEY WORDS
   FATIGUE-CRACK-OPENING, CRACK-TIP-OPENING LOAD
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                                 SYNOPSIS
LABORATORY INVESTIGATION OF DISPLACEMENT-LOAD BEHAVIOR FOR A FATIGUE CRACKED
SPECIMAN



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   300824*                              DATE  00 JUL 74

                                  AUTHOR
                D. CANNON & R. ALLEN

                                   TITLE
                THE APPLICATION OF FRACTURE MECHANICS TO RAILWAY FAILURES


                                 KEY WORDS
   FAILURE MODEL, TASK 10
--------------------------------------------------------------------------------
   FRACTURE, PRE-EXISTING DEFECT, FATIGUE CRACKS, TO QUANTIFY FRACTURE PROCESS
   INVOLVING CRACK PROPOGATION TO CATASTROPHIC FAILURE


                                 SYNOPSIS
APPLICATION OF FRACTURE MECHANICS TO RAILWAY FAILURES IN AXLES, WHEELS, RAILS,
TRUCK COMPONENTS ETC.



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   300875*                          DATE  00 NOV 80

                                 AUTHOR
           Y. J. PARK & D  H. STONE

                                  TITLE
           CYCLIC BEHAVIOR OF CLASS U WHEEL STEEL


                               KEY WORDS
  MATERIAL PROPERTIES, TASK 3

------------------------------------------------------------------------
  WHEEL METALLURGY; MATERIAL PROPERTIES UNDER CYCLIC LOADING; FATIGUE TESTS;
  SOFTENING; FATIGUE; LIFE


                                SYNOPSIS
PROPERTIES OF CLASS U STEELS AT ROOM TEMPERATURE REPORTED IN THIS PAPER WILL BE
USED IN THE PROGRAM



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   301020*                          DATE  00 MAY 67

                                 AUTHOR
           J. BRUNER, G. BENJAMIN & D. BENCH

                                  TITLE
           ANALYSIS OF RESIDUAL, THERMAL AND LOADING STRESSES IN A B33
           WHEEL AND THEIR RELATIONSHIP TO FATIGUE DAMAGE

                               KEY WORDS
  FAILURE MODEL, TASK 10

------------------------------------------------------------------------
  STRESS ANALYSIS; SIMULATED LOADING CONDITIONS; STRESS PATTERN AND FATIGUE
  TESTS COMPARED; RIM HEATING


                                SYNOPSIS
A PRELIMINARY INVESTIGATION OF LOADING & THERMAL STRESSES IN A B-33 WHEEL



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER 301045* DATE 00 JUN 81

AUTHOR

A. IBRAHIM & S. GIBRAIEL

TITLE

EVALUATION OF DYNAMIC LOAD COMBINATION FATIGUE DAMAGE

KEY WORDS

COMPREHENSIVE FAILURE MODEL, TASK 10

FATIGUE ANALYSIS; FATIGUE DAMAGING CYCLES;

SYNOPSIS

A GENERIC BACKGROUND PAPER FOR FATIGUE ANALYSIS

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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER 301261* DATE 00 79

AUTHOR

K. IIJIMA, T. KIGAWA, T. YOSHIMURA, K. KUROYANAGI

TITLE

"ROLLING CONTACT FATIGUE FAILURE OF BEARING STEELS, WHEEL STREELS AND CARBURIZED GEAR STEELS" (QTRLY REPORTS)

KEY WORDS

FATIGUE ANALYSIS; FATIGUE BEHAVIOR OF BEARING STEELS; HEAT TREATMENT; ROLLING CONTACT FATIGUE STRENGTH;

SYNOPSIS

PERTINENT TO WHEEL SHELLING FAILURE

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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   301353*                          DATE  00      79

                                   AUTHOR
               CAMPBELL LAIRD

                                    TITLE
               "MECHANISMS AND THEORIES OF FATIGUE"

                                 KEY WORDS
  COMPREHENSIVE FAILURE MODEL, TASK 10

----------------------------------------------------------------------------
  FATIGUE ANALYSIS; CYCLIC DEFORMATION & MONOTONIC; DISLOCATION, CRACK
  INITIATION; PLASTIC RUPTURE

                                  SYNOPSIS
A GENERIC BACKGROUND MATERIAL FOR PHENOMENON AND MECHANISMS OF FATIGUE



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   301438*                          DATE  00      00

                                   AUTHOR
               W. S. LOVELACE,

                                    TITLE
               STUDY OF RIM STRESSES RESULTING FROM STATIC LOADS ON
               DIFFERENT 36-IN. RR WHEEL DESIGNS (PAP. NO. 71-RR-4)

                                 KEY WORDS

----------------------------------------------------------------------------
  WHEEL WEAR; STRESS IN RIM SECTIONS; WHEEL RIM AND FATIGUE FAILURES; STATIC
  LOADS UP TO 75,000 LB.

                                  SYNOPSIS
EARLIER EXPERIMENTAL STRESS ANALYSIS



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER 301514* DATE 09 DEC 82

AUTHOR
J. M. STEELE & T. LAM

TITLE
IMPROVING THE ACCURACY OF FATIGUE ANALYSIS

KEY WORDS
FAILURE MODEL, TASK 10

FATIGUE ANALYSIS; LIFE PREDICTION; CRACK INITIATION; LOCAL STRESSES & STRAINS; LOAD CYCLES; MEAN STRESS

SYNOPSIS
SHORT SUMMARY OF STRAIN-LIFE FATIGUE CRITERION

****

FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER 301536* DATE 00 APR 76

AUTHOR
P. W. MARSHALL

TITLE
PROBLEMS IN LONG-LIFE FATIGUE ASSESSMENT FOR FIXED OFFSHORE STRUCTURES

KEY WORDS
FAILURE MODEL, TASK 10

FATIGUE ANALYSIS; BURDEN OF RISK DESIGN CRITERIA VS. ENVIRONMENTAL/SAFETY WELDED TUBULAR HOT SPOT STRESS, HIGH CYCLE CORROSION, FRACTURE/SURFACE CRACKS

SYNOPSIS
APPLICATION OF STRAIN LIFE FATIGUE - NON RAILROAD

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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   301554*                           DATE  00     00

                                  AUTHOR
               T. H. COLEMAN & D. J. NAYLOR

                                   TITLE
               A METALLURGICAL STUDY OF THE FACTORS AFFECTING THERMAL
               FATIGUE CRACKING IN RAILWAY WHEEL AND TYRE STEELS

                                 KEY WORDS
   MATERIAL PROPERTIES, TASK 3
--------------------------------------------------------------------------------
   HEATING & QUENCHING OF WHEEL RIM; NUCLEATION & GROWTH OF THERMAL FATIGUE
   CRACKS IN STEELS


                                 SYNOPSIS
EFFECT OF DEFORMATION AND ALLOY CONTENT ON THERMAL CRACKING SENSITIVITY OF
WHEEL STEELS



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   301555*                           DATE  00     00

                                  AUTHOR
               G. G. HEWITT & C. MUSIOL

                                   TITLE
               THE SEARCH FOR IMPROVED WHEEL MATERIALS


                                 KEY WORDS
   FAILURE MODEL - TASK 10
--------------------------------------------------------------------------------
   TREAD DAMAGE FROM BRAKE; LOCAL FATIGUE ENVIRONMENT, HOT SPOT; IMPROVED
   MATERIAL, STRAIN,


                                 SYNOPSIS
ANALYSIS OF DAMAGE DUE TO HOT SPOTTING



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   301557*                               DATE  00      73

                                    AUTHOR
                 E. KILB

                                     TITLE
                 WHEEL LOAD & WHEEL DIAMETER FROM THE POINT OF VIEW OF STRESS
                 ON THE MATERIAL IN THEORY AND IN PRACTICE

                                  KEY WORDS

--------------------------------------------------------------------------------
   WHEEL WEAR; CONTACT STRESSES; SMALL HIGH-SPEED WHEELS; FATIGUE STRENGTH;
   CONTACT AREA DURING WEARING PROCESS


                                   SYNOPSIS
A GENERIC BACKGROUND PAPER FOR SHELLING PROBLEM




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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   301566*                               DATE  00 NOV 75

                                    AUTHOR
                 A. RESILLON & A. LELUAN

                                     TITLE
                 EFFECT OF THE DEVELOPMENT OF RESIDUAL STRESSES IN SOLID
                 WHEELS ON WEAR

                                  KEY WORDS

--------------------------------------------------------------------------------
   WHEEL WEAR; RESIDUAL STRESSES; THERMAL FACTOR IN WEAR; FATIGUE CRACKS
   FORMED, DEGRADATION HISTORY


                                   SYNOPSIS
BACKGROUND MATERIAL FOR REFERENCE; NOT DIRECTLY APPLICABLE TO PROGRAM



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   C300795*                          DATE  00 DEC 69

                                    AUTHOR
                 R. P. HUBBARD

                                     TITLE
                 CRACK GROWTH UNDER CYCLIC COMPRESSION


                                  KEY WORDS


---------------------------------------------------------------------------------
   CRACK PROPAGATION; FATIGUE CRACK GROWTH UNDER COMPRESSIVE LOADING; FRACTURE
   MECHANICS MODEL STRESS INTENSITY


                                   SYNOPSIS
LABORATORY INVESTIGATION OF FATIGUE CRACK GROWTH RATE UNDER CYCLIC COMPRESSION




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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   C53.6*                            DATE  00 OCT 70

                                    AUTHOR
                 OFC. FOR RESEARCH & EXPERIMENTS (ORE)

                                     TITLE
                 BEHAVIOR OF THE MEAL OF RAIL AND WHEEL IN THE CONTACT ZONE
                 "RESIDUAL STRESSES IN THE RAIL (CONT.) WORK HARDENED ZONE

                                  KEY WORDS
   RESIDUAL STRESSES, TASK 11;

---------------------------------------------------------------------------------
   RESIDUAL STRESS; WORK-HARDENING CHANGES' HYDROSTACK PRESSURE ZONE; FATIGUE
   CRACKS; RAIL CORRUGATIONS,


                                   SYNOPSIS
STUDY OF RESIDUAL STRESS IN RAIL.  REFERENCE MATERIAL FOR COMPREHENSIVE RESIDUAL
STRESS ANALYSIS IN WHEELS.



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER C53.9* DATE 00 OCT 73

AUTHOR

MEMBER ADMIN. OF THE OFC. OF RESEARCH & EXP. (ORE)

TITLE

BEHAVIOR OF THE METAL OF RAILS AND WHEELS IN THE CONTACT ZONE, QUEST. C53

KEY WORDS

FAILURE MODEL TASK 10; RESIDUAL STRESSES, TASK 11

STRESS ANALYSIS, RESIDUAL RAIL STRESSES FROM PASSAGE WHEELS; FATIGUE PLASTIC DEFORMATION

SYNOPSIS

RESIDAUL STRESS ANALYSIS OF RAIL; FATIGUE DAMAGE AS A FUNCTION OF LOAD CONDITIONS

****

FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER FRA 77/17* DATE 00 MAR 77

AUTHOR

G. F. CARPENTER

TITLE

THE CAUSE OF THERMAL FATIGUE CRACKING IN METROLINER WHEELS

KEY WORDS

DYNAMOMETER TESTING, TASKS 4, 6, AND 8; FAILURE MODEL, TASK 10;

FATIGUE ANALYSIS; WHEEL WEAR, RESIDUAL THERMAL STRESSES; THERMAL CRACKING; MACROSTRUCTURE, MICROSTRUCTURE

SYNOPSIS

DYNAMOMETER STUDY OF THERMAL CRACK INITIATION. (THIS DYNAMOMETER IS THE ONE NOW AT AAR)

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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER    FRA 77/50*                        DATE   00 NOV 77

                                  AUTHOR
                C. S. CARTER, R. G. CATON, J. L. GUTHERIE

                                   TITLE
                FRACTURE RESISTANCE AND FATIGUE CRACK GROWTH CHARACTERISTICS
                OF RAILROAD WHEELS AND AXLES

                                 KEY WORDS
  MATERIAL PROPERTIES, TASK 3
-------------------------------------------------------------------------------
  WHEEL WEAR; FRACTURE TOUGHNESS; FATIGUE CRACK GROWTH RATES; CARBON STEELS;
  RAILROAD AXLES; SUBCRITICAL FLAWS DETECTED


                                 SYNOPSIS
MECHANICAL PROPERTIES FOR TOUGHNESS AND CRACK GROWTH HEREIN WILL BE USED IN
PROGRAM.  THE DEFINITIVE SOURCE OF WHEEL FRACTURE TOUGHNESS DATA



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER    R-373*                            DATE   00 MAY 79

                                  AUTHOR
                Y. J. PARK

                                   TITLE
                CYCLIC BEHAVIOR OF CLASS B WHEEL STEEL

                                 KEY WORDS
  MATERIAL PROPERTIES, TASK 3;  FAILURE MODEL, TASK 10
-------------------------------------------------------------------------------
  WHEELS; CLASS B WHEEL; LOW-CYCLE, FATIGUE, CYCLIC SOFTENING; STRESS,
  STRAIN, FATIGUE LIFE

                                 SYNOPSIS
ROOM TEMPERATURE DATA WILL BE USED IN TASK 3



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   R-388*                           DATE  00 AUG 79

                                 AUTHOR
           T. J. THOMAS & V. K. GARG

                                  TITLE
           THERMAL FATIGUE ANALYSIS OF A RAIL CAR WHEEL UNDER DRAG
           BRAKING

                               KEY WORDS
  FAILURE MODEL, TASK 10

------------------------------------------------------------------------------
  WHEEL WEAR; FATIGUE LIFE; THERMAL STRESSES; DRAG BRAKING; FINITE-ELEMNT
  METHOD; PLASTICITY;


                                SYNOPSIS
AN EARLY FATIGUE ANALYSIS MODEL



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FILE PRINT SELECTED BY KEY WORD FATIGUE

FILE NUMBER   R-393*                           DATE  00 AUG 79

                                 AUTHOR
           Y. J. PARK

                                  TITLE
           CYCLIC BEHAVIOR OF CLASS A WHEEL STEEL

                               KEY WORDS
  MATERIAL PROPERTIES, TASK 3

------------------------------------------------------------------------------
  WHEEL WEAR; CLASS A WHEEL STEEL; STRESS, STRAIN, LOW-CYCLE FATIGUE;
  FATIGUE LIFE OF WHEELS;

                                SYNOPSIS
GRADE OF STEEL NOT APPLICABLE TO PROGRAM; USEFUL REFERENCE PAPER ON CYCLIC
PROPERTIES



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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER 100542/71* DATE 00 SEP 82

AUTHOR

D. G. BLAINE

TITLE

SENCOND INTL. HEAVY HAUL CONF. "EFFECT OF BRAKE EQUIPMENT UPON CAPABILITY AND ROLLING STOCK FOR HEAVY HAUL ROUTES"

KEY WORDS

TTC TRACK TESTS, TASKS 5, 6, 7, & 8

BRAKE EQUIPMENT BRAKING RATIO, BRAKE PIPE, STOPPING AND GRADE HANDLING ABILITY, TRAIN LENGTH, TRAIN SPACING

SYNOPSIS

EXCELLENT REFERENCE MATERIAL FOR TRAIN OPERTAION, AAR & UIC BRAKES, GRADE BRAKING, ENERGY ABSORPTION & DISSIPATION

****

FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER 200190* DATE 18 NOV 69

AUTHOR

G. R. WEAVER, P. A. ARCHIBALD, E. B. BRENNEMAN

TITLE

INVESTIGATION OF THE THERMAL CAPACITY OF RAILROAD WHEELS USING COBRA BRAKE SHOES

KEY WORDS

LABORATORY SIMULATION (FULL SCALE DYNAMOMETER BRAKING WITH COBRA BRAKE SHOES & CAST METAL BRAKE SHOES) RESIDUAL STRESS, TASKS 6 & 7,

---

36 INCH CR WHEELS, TREAD CRACKS, EMERGENCY STOP TESTS

SYNOPSIS

OBJECTIVE EVALUATION OF 36 INCH CR WHEELS BRAKED WITH COBRA SHOES AND CAST METAL SHOES, WHEEL TREAD CONDITONS, MACROSTRUCTURE OF RIM, RESIDUAL STRESS PATTERNS

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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   200256/1-4*                         DATE   00 OCT 78

                                   AUTHOR
                 L. BRAZZODURO, P. BROZZO, R. DEMARTINI,

                                    TITLE
                 6TH INTL WHEELSET CONG. "FINAL RESULTS OF THE RESEARCH WORK
                 ON A NEW SOLID WHEEL APT TO MOST SEVERE OPER. COND.

                                  KEY WORDS
  MATERIAL PROPERTIES, TASK 3, UIC-R/2 AND R/6 STEEL

--------------------------------------------------------------------------------
  (ITALIAN PRACTICE) THERMAL CRACKING TESTS, DRAG & STOP BRAKING TESTS



                                  SYNOPSIS
THERMAL CRACKING TESTS, DRAG AND STOP BRAKING TESTS (UIC-R/6 & 5 CR WHEELS)
WERE PERFORMED TO INVESTIGATE RESISTANCE TO REPEATED THERMAL LOADING.



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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   200256/3-5*                         DATE   00 OCT 78

                                   AUTHOR
                 D. G. BLAINE, F. J. GREJDA, & J. C. KAHR

                                    TITLE
                 SIXTH INTL WHEELSET CONG. "OPERATION ENVIRONMENT FOR NORTH
                 AMERICAN FREIGHT TRAIN WHEELS DURING SPEED & SLACK CON. BRAK

                                  KEY WORDS
  SERVICE EVALUATION, TRAIN BRAKE APPLICATION PRACTICES IN U. S. TASKS 5 & 6,

--------------------------------------------------------------------------------
  TRAIN BRAKE APPLICATIONS, NET BRAKING RATIOS, COMPOSITION BRAKE SHOES,
  TRAIN SLACK, ACCELERATION, BHP/CAR WHEELS


                                  SYNOPSIS
DISCUSSION OF BRAKE APPLICATION PRACTICE IN U. S.; SUGGESTIONS FOR OPTIMIZING
TRACTIVE EFFORT, FUEL SAVINGS AND BRAKE SHOE WEAR



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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER 201098* DATE 00 JUN 50

AUTHOR
H. R. WETENKAMP, O. M. SIDEBOTTOM, H. J. SCHRADER

TITLE
THE EFFECT OF BRAKE SHOE ACTION ON THERMAL CRACKING AND ON FAILURE OF WROUGHT STEEL RAILWAY CAR WHEELS

KEY WORDS
BRAKE DYNAMOMETER TESTING, TASKS 4, 6, & 8

LABORATORY TESTS, STOP BRAKING, DRAG BRAKING, WROUGHT STEEL WHEELS, THERMAL CRACKS, RESIDUAL STRESSES, FRACTURE, CARBON CONTENT, HEAT TREATMENT, WHEEL DESIGN

SYNOPSIS
WROUGHT STEEL WHEELS SUBJECTED TO A SERIES OF LABORATORY TESTS SUCH AS STOP BRAKING & DRAG BRAKING; STUDY OF EFFECT OF CARBON CONTENT, HEAT TREATMENT, WHEEL DESIGN

****

FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER 300436* DATE 00 80

AUTHOR
T. J. THOMAS, V. GARG, D. STONE

TITLE
THERMAL FATIGUE ANALYSIS OF A RAILCAR WHEEL UNDER DRAG BRAKING

KEY WORDS
FINITE ELEMENT ANALYSIS, TASK 10, CH36 WHEELS

FATIGUE ANALYSIS; STRESSES FROM TEMPERATURE; DRAG BRAKING AND CYCLIC THERMAL LOADING; FINITE ELEMNT ANALYSIS

SYNOPSIS
CYCLIC THERMAL LOADING ON THE FATIGUE LIFE OF CH36 WHEEL WAS INVESTIGATED BY FINITE ELEMENT METHOD. CREEP PLAST PROGRAM WAS USED TO ESTIMATE THE STRESS & STRAIN DEVELOPED IN THE WHEEL

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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   300773*                          DATE  00 JUL 79

                                AUTHOR
              H. A  TANVIR

                                 TITLE
              TEMPERATURE RISE DUE TO SLIP BETWEEN WHEEL AND RAIL - AN
              ANALYTICAL SOLUTION FOR HERTZIAN CONTACT

                               KEY WORDS
  WHEEL RAIL ADHESION; BRAKING PERFORMANCE, SLIPPING GENERATES HEAT,
  TEMPERATURE RISE INCREASE WHEEL AND RAIL WEAR
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                               SYNOPSIS
APPLICABLE TO WHEEL SHELLING




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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   301001*                          DATE  00 FEB 77

                                AUTHOR
              M. R. JOHNSON, R. E. WELCH, & K. S. YEUNG

                                 TITLE
              "ANALYSIS OF THERMAL STRESSES & RESIDUAL STRESS CHANGES IN
              RR WHEELS CAUSED BY SEVERE DRAG BRAKING (JOR. ENG. FOR IND)

                               KEY WORDS
  FINITE ELEMENT ANALYSIS AND SIMULATION, TASK 10

--------------------------------------------------------------------------------
  STRESS ANALYSIS; THERMAL STRESSES; DRAG BRAKING; HEATING FROM TREAD BRAKE;
  THERMAL CRACK GROWTH


                               SYNOPSIS
FINITE ELEMENT DEMONSTRATION OF THE FORMATION OF RESIDUAL STRESSES DUE TO BRAKE
HEATING.  THE STANDARD BY WHICH ELASTIC-PLASTIC F. E. ANALYSIS ARE JUDGED



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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   301404*                              DATE  00 SEP 82

                                    AUTHOR
            V. ARONOV & M. PONS

                                     TITLE
            THE WEAR MECHANISM OF THE RAILROAD WHEEL STEEL IN THE FREE
            ROLLING AND BRAKING CONDITIONS

                                   KEY WORDS

------------------------------------------------------------------------------
  WHEEL WEAR; WHEEL STEEL IN FREE ROLLING & BRAKING; WEAR PARTICLE FORMATION
  SEM ANALYSIS


                                    SYNOPSIS
A BACKGROUND PAPER FOR SHELLING PHENOMENON AND FATIGUE FAILURE; NOT DIRECLY
APPLICABLE TO THE PROGRAM



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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   301437*                              DATE  00    60

                                    AUTHOR
            J. M. WANDRISCO & F. J. DEWEZ

                                     TITLE
            STUDY OF THE DEFECTS THAT ORIGINATE & DEVELOP IN THE TREADS
            OF RR WHEELS DURING SERVICE (PAP. NO. 60-RR-1)

                                   KEY WORDS
  MATERIAL PROPERTIES; TASK 3
------------------------------------------------------------------------------
  FAILURE ANALYSIS; WHEEL TREAD DEFECT FORMATION; SERVICE DEFECTS; BRAKING
  DEFECTS; ROLLING LOADS


                                    SYNOPSIS
EFFECTS OF CARBON CONTENT AND HEAT ON WHEEL THERMAL CRACK FORMATION



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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   301440*                          DATE  00     67

                                 AUTHOR
            J. P. BRUNER, R. D. JONES, S. LEVEY & J. WANDRISCO

                                  TITLE
            EFFECT OF DESIGN VARIATION ON SERVICE STRESSES IN RAILROAD
            WHEELS (PAPER NO. 67-WA/RR-6)

                                KEY WORDS

--------------------------------------------------------------------------------
  WHEEL WEAR; SERVICE BRAKING & LOADING SIMULATED; BRAKING, LOADING STRESSES;
  FATIGUE


                                 SYNOPSIS
OBSOLETE EARLY COMPUTER BASED STRESS ANALYSIS



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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   301445*                          DATE  00     72

                                 AUTHOR
            G. M. CABBLE

                                  TITLE
            EFFECT OF WHEEL DIAMETER ON TREAD TEMPERATURE IN GRADE
            OPERATION (PAPER NO. 72-WA/RT-10)

                                KEY WORDS
  DYNAMOMETER TESTING, TASK 8
--------------------------------------------------------------------------------
  TEMPERATURE CONTROL; WHEEL SIZE AND TREAD TEMPERATURE; BRAKING ON GRADES;
  EQUIPMENT & PROCEDURES


                                 SYNOPSIS
DYNAMOMETER STUDY OF WHEEL TEMPERATURE.  USEFUL BUT OLD INSTRUMENTATION
TECHNIQUES



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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   301446*                               DATE  00     72

                                     AUTHOR
                  G. E. NOVAK & B. J. ECK

                                      TITLE
                  ASYMMETRICAL WHEEL STRESSES  CAUSED BY SIMULATED THERMAL AND
                  MECHANICAL SERVICE LOADS (PAPER NO. 72-WA/RT-13)

                                   KEY WORDS
  FINITE ELEMENT ANALYSIS, TASK 10
-----------------------------------------------------------------------------
  STRESS ANALYSIS; WHEEL UNDER DRAG BRAKING; OCTAHEDRAL SHEAR; STRESS


                                    SYNOPSIS
EARLY FINITE ELEMENT ANALYSIS - (OBSOLETE)



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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   301447*                               DATE  00     73

                                     AUTHOR
                  H. R. WETENKAMP

                                      TITLE
                  THERMAL STRESSES DEVELOPED IN S PLATE, STRAIGHT PLATE, AND
                  DEEP DISH WHEEELS

                                   KEY WORDS
  COMPREHENSIVE TESTING ON TRACK & DYNAMOMETER, TASK 6
-----------------------------------------------------------------------------
  STRESS ANALYSIS; SUBJECTING WHEELS TO BRAKING CYCLES; ELASTIC STRESS BY
  THERMAL LOAD; DESIGNS

                                    SYNOPSIS
EFFECT OF WHEEL DESIGN ON ELASTIC THERMAL STRESS



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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   301449*                            DATE  00     75

                                    AUTHOR
                 H. R. WETENKAMP & R. M. KIPP

                                     TITLE
                 HOT SPOT HEATING BY COMPOSITION SHOES (PAPER NO. 75-RT-2)


                                  KEY WORDS
   FAILURE MODEL, TASK 10

--------------------------------------------------------------------------------
   BRAKING; MEASURE HOT SPOTS ON WHEEL TREAD SURFACE; LOWER HOT SPOT LEVEL BY
   CUTTING SLOT ACROSS PAD


                                   SYNOPSIS
FIRST PAPER ON  HOT SPOT PHENOMENON




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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   301455*                            DATE  00     83

                                    AUTHOR
                 E. J. PIPLING & P. B. CROSLEY

                                     TITLE
                 THERMAL CRACKING OF RAILCAR WHEELS


                                  KEY WORDS
   MATERIAL PROPERTIES, TASK 3

--------------------------------------------------------------------------------
   FAILURE ANALYSIS; RADIAL CRACKS AFTER BRAKING; CONTROLLING CRACKS,
   CRACK ARREST; FRACTURE TOUGHNESS


                                   SYNOPSIS




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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   301456*                           DATE  00 JUL 72

                                 AUTHOR
            M. H. LARSON, M. H. HUNTRESS & M. HALEY

                                  TITLE
            DISTRIBUTION OF HEAT BETWEEN WHEEL AND BRAKE SHOE


                               KEY WORDS
  BRAKE SHOE HEATING, TASK 7
-------------------------------------------------------------------------------
  HEATING UNDER BRAKING PRODUCES THERMAL CRACKS, RESIDUAL STRESS; WHEEL
  FAILURE; SAFETY


                                SYNOPSIS
EVALUATION OF HEAT DISTRIBUTION BETWEEN WHEEL AND SHOE




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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   301457*                           DATE  00 JUL 72

                                 AUTHOR
            M. B. ECK & M. G. NOVAK

                                  TITLE
            WHEEL STRESSES RESULTING FROM SIMULATED SERVICE DRAG BRAKING
            AND ASYMMETRICAL RAIL LOADING

                               KEY WORDS
  FINITE ELEMENT ANLAYSIS, TASK 10
-------------------------------------------------------------------------------
  STRESS ANALYSIS; FINITE ELEMENT ANALYSIS; THERMAL STRESS UNDER BRAKING;
  DRAG BRAKING;


                                SYNOPSIS
OBSOLETE ELASTIC FINITE ELEMENT ANALYSIS PAPER




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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   301553*                            DATE  00     00

                                         AUTHOR
                  J. L. VAN SWAAIJ

                                          TITLE
                  THERMAL DAMAGE TO RAILWAY WHEELS


                                       KEY WORDS
   FAILURE MODEL, TASK 10; MATERIAL PROPERTIES, TASK 2

 -------------------------------------------------------------------------------
   SURVEY OF WHEEL DEFECTS; HEAT DURING BRAKING; MECHANISMS OF DEFECTS;
   CHARACTER OF THE DAMAGE


                                        SYNOPSIS
THE CLASSIC PAPER ON WHEEL THERMAL CRACKING




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FILE PRINT SELECTED BY KEY WORD BRAKING

FILE NUMBER   301569*                            DATE  00 JUL 81

                                         AUTHOR
                  K. MITURA, P. MATUSEK & R. FAJA

                                          TITLE
                  INTENSIVE BRAKING AS THE CAUSE OF THERMAL DAMAGING OF RAIL-
                  WAY WHEELS

                                       KEY WORDS

 -------------------------------------------------------------------------------
   WHEEL WEAR; EFFECT OF BRAKE BLOCKS WHEN BRAKING TREAD OF WHEEL; WHEEL LOCK-
   ING; PETRIFICATION; PEARLITIC CEMENTITE;


                                        SYNOPSIS
USEFUL METALLURGICAL DESCRIPTION OF METALLURGICAL CHANGES DUE TO BRAKING;
A GENERAL PURPOSE BACKGROUND PAPER



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FILE NUMBER   R-388*                              DATE  00 AUG 79

                               AUTHOR
           T. J. THOMAS & V. K. GARG

                                TITLE
           THERMAL FATIGUE ANALYSIS OF A RAIL CAR WHEEL UNDER DRAG
           BRAKING

                             KEY WORDS
  FAILURE MODEL, TASK 10

-----------------------------------------------------------------------------
  WHEEL WEAR; FATIGUE LIFE; THERMAL STRESSES; DRAG BRAKING; FINITE-ELEMNT
  METHOD; PLASTICITY;


                              SYNOPSIS
AN EARLY FATIGUE ANALYSIS MODEL




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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 100379* DATE 00 78

AUTHOR
ROBERT MARION KIPP, PH. D.

TITLE
INVESTIGATIONS OF CRACK GROWTH IN RAILROAD CAR WHEELS CAUSED
BY THERMALLY INDUCED RESIDUAL STRESS CHG. & CYC. MEC. LOAD

KEY WORDS
FINITE ELEMENT SIMULATIONS, TASK 10, 33" CURVED PLATE, CLASS U, STRESS
ANALYSIS, LABORATORY SIMUALTIONS, TASK 8, CRACK PROPAGATION.

WHEEL STRESS; THERMAL STRESS; CRACK PROPAGATION, WHEEL WEAR LOADING,
METALLURGY

SYNOPSIS
A PSEUDO-ELASTIC FINITE ELEMENT SIMULATION OF DRAG BRAKING CYCLES PREDICTS DEVELOPMENT OF RESIDUAL STRESS AND CRACK STRESS INTENSITY, BUT NOT SEVERE ENOUGH TO PREDICT THE DEGREE OF CRACK GROWTH IN DYNAMOMETER TESTS OR ESPECIALLY IN SERVICE. POSSIBLE INTERACTION OF HOT THERMAL STRESSES AND RAIL LOAD STRESSES CITED AS CAUSE FOR DISCREPANCY

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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 100545* DATE 00 78

AUTHOR
P. STANLEY, APPLIED SCIENCE PUBLISHERS LTD

TITLE
NON-LINEAR PROBLEMS IN STRESS ANALYSIS

KEY WORDS
MATERIAL PROPERTIES, TASK 3, FINITE ELEMENT SIMULATIONS

STRESS ANALYSIS; CRACK-TIP DEFORMATION; PLASTICITY CYCLING; CREEP COLLAPSE;
BIAXIAL PLASTIC FLOW; THERMAL RATCHETING

SYNOPSIS
SOME OF THE PAPERS CONTAINED IN THIS BOOK TREAT MATERIAL AND STRESS ANALYSIS NON-LINEARITIES ASSOCIATED WITH ELEVATED TEMPERATURE CREEP AND CYCLIC PLASTICITY THAT MAY HAVE GENERAL APPLICABILITY TO THE ANALYSIS OF STRESS CHANGES AND CRACKING OF WHEELS

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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   200028*                            DATE  00 NOV 66

                                    AUTHOR
                 IGOR L. PAUL & RANGANATH NAYAK

                                     TITLE
                 STRESS AND STRAIN IN ROLLING BODIES IN CONTACT

                                  KEY WORDS
   TREAD CONTACT STRESS; TASK 10
--------------------------------------------------------------------------------
   STRESS & STRAIN AT CONTACT REGION OF ROLLING SHEEL; WHEEL WITH NORMAL, LAT-
   ERAL & TANGENTIAL LOADS

                                   SYNOPSIS
COMPUTER SOLUTION OF TWO SPHERES OF SIMILAR MATEIRAL ROLLING ON EACH OTHER.
RESULTS NEED TO BE EXTENDED TO THE CASE OF WHEEL ROLLING ON RAIL



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   200190*                            DATE  18 NOV 69

                                    AUTHOR
                 G. R. WEAVER, P. A. ARCHIBALD, E. B. BRENNEMAN

                                     TITLE
                 INVESTIGATION OF THE THERMAL CAPACITY OF RAILROAD WHEELS
                 USING COBRA BRAKE SHOES

                                  KEY WORDS
   LABORATORY SIMULATION (FULL SCALE DYNAMOMETER BRAKING WITH COBRA BRAKE
   SHOES & CAST METAL BRAKE SHOES) RESIDUAL STRESS, TASKS 6 & 7.
--------------------------------------------------------------------------------

   36 INCH CR WHEELS, TREAD CRACKS, EMERGENCY STOP TESTS

                                   SYNOPSIS
OBJECTIVE EVALUATION OF 36 INCH CR WHEELS BRAKED WITH COBRA SHOES AND CAST METAL
 SHOES, WHEEL TREAD CONDITONS, MACROSTRUCTURE OF RIM, RESIDUAL STRESS PATTERNS


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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 200222* DATE 00 00

AUTHOR
HIROSHI TADA, PAUL C. PARIS & GEORGE R. IRWIN

TITLE
STRESS ANALYSIS OF CRACKS HANDBOOK

KEY WORDS
CRACK PROPOGATION, TASK 8,

STRESS ANALYSIS ON CRACK PROBLEMS; FRACTURE MECHANICS CORRELATION PARAMETER
COMPLIANCE CALIBRATION ANALYSIS; FUNCTION ANALYSIS, PLASTICITY ANALYSIS;
MATERIALS SCIENCE

SYNOPSIS
COMPREHENISVE SOURCE OF FORMULAS AND STRESS ANALYSIS INFORMTAION ON CRACK PROPOGATION THROUGH FRACTURE MECHANICS CORRELATION PARAMETERS AND CURRENT FRACTURE CRITERIA. CLOSED FORM AND NUMERICAL SOLUTIONS.

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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 200256/1-2* DATE 00 OCT 78

AUTHOR
A. S. BABB, D. S. HODDINOTT, D. J. NAYLOR

TITLE
SIXTH INTL. WHEELSET CONGRESS,"WHEELSET RESEARCH & DEVELOPMENT IN THE BRITISH STEEL CORPORATION"

KEY WORDS
FINITE ELEMENT ANALYSIS, RESIDUAL STRESSES, MATERIAL PROPERTIES, TASKS 10, 6 & 3

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36 IN. WROUGHT WHEELS, WHEEL DESIGNS, MECHANICAL STRUCTURAL LOADS,
METALURGICAL STUDIES, THERMAL CRACKING BEHAVIOR

SYNOPSIS
FINITE ELEMENT ANALYSIS OF TWO 36 INCH WHEELS SHOWS LOWER STRESSES IN DOUBLE CURVED PLATE WHEELS THAN IN STRAIGHT PLATE WHEELS. RESIDUAL STRESS DETERMINATION OF SERVICE WHEELS. THERMAL CRACKING BEHAVIOR OF WHEEL STEELS IN LABORATORY.

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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 201109* DATE 00 DEC 76

AUTHOR

S. C. ANAND

TITLE

SHAKEDOWN LOADS IN ROLLING DISKS, CYLINDERS AND SPHERES

KEY WORDS

WHEEL SHELLING

STRESS ANALYSIS; FINITE ELEMENTS; PLASTIC STRESS-STRAIN RELATIONS;
SUBSTRUCTURING UNLOADING CRITERIA; ELASTIC-PLASTIC

SYNOPSIS

USEFUL PAPER FOR WHEEL SHELLING

****

FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 300074* DATE 09 SEP 72

AUTHOR

N. A. BERG & R. H. ALBER

TITLE

TREAD BRAKING VERSUS THE WHEEL

KEY WORDS

WHEEL TREAD PROBLEMS. SHELLING PHENOMENA, WHEEL STRESSES, SPALLING, THERMAL
LOAD DAMAGE TO WHEELS, BRAKING

SYNOPSIS

EXCELLENT PRIMER ON WHEEL THERMAL FAILURE

****

FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 300167* DATE 00 64

AUTHOR

E. OLLERTON, PAPER 10, PROC. INSTN. MECH. ENGRS.

TITLE

"STRESSES IN THE CONTACT ZONE"

KEY WORDS

CONTACT-STRESS PROBLEMS; ADHESION IN RAIL-WHEEL CONTACT; FROZEN-STRESS PHOTOELASTIC TESTS, SURFACE SHEAR STRESS FROM TANGENTIAL FORCES, CREEP OF ROLLING BODIES, BENDING STRESSES IN RAILS,

SYNOPSIS

APPLICABLE TO SHELLING FAILURES

****

FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 300308* DATE 00 MAR 78

AUTHOR

M. JAMES & J. COHEN

TITLE

PARS - A PORTABLE X-RAY ANALYZER FOR RESIDUAL STRESSES

KEY WORDS

NDE, TASK 14

X-RAY DEVICE FOR MEASURING RESIDUAL STRESSES; PORTABLE MEASURNG INSTRUMENT; RESIDUAL STRESS ANALYSIS; POSITION SENSITIVE DETECTOR

SYNOPSIS

A PRIMER ON RESIDUAL STRESS DETERMINATION BY X-RAY ANALYSIS

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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 300436* DATE 00 80

AUTHOR

T. J. THOMAS, V. GARG, D. STONE

TITLE

THERMAL FATIGUE ANALYSIS OF A RAILCAR WHEEL UNDER DRAG BRAKING

KEY WORDS

FINITE ELEMENT ANALYSIS, TASK 10, CH36 WHEELS

FATIGUE ANALYSIS; STRESSES FROM TEMPERATURE; DRAG BRAKING AND CYCLIC THERMAL LOADING; FINITE ELEMNT ANALYSIS

SYNOPSIS

CYCLIC THERMAL LOADING ON THE FATIGUE LIFE OF CH36 WHEEL WAS INVESTIGATED BY FINITE ELEMENT METHOD. CREEP PLAST PROGRAM WAS USED TO ESTIMATE THE STRESS & STRAIN DEVELOPED IN THE WHEEL

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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 300843* DATE 00 77

AUTHOR

C. FREDERICK, D. CANNON, S. NEWTON

TITLE

DYNAMIC RAIL STRESSES DUE TO WHEEL FLAT IMPACT

KEY WORDS

WHEELFLATS CAUSE RAIL FRACTURE; WHEELFLAT IMPACT STRESSES; RAIL DEFECTS AND FINAL FRACTURE; IMPACT FORCE

SYNOPSIS

APPLICABLE TO SHELLING PROBLEM

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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   300868*                              DATE  00 NOV 80

                                      AUTHOR
                 S. KUMAR & B. RAJKUMAR

                                       TITLE
                 LABORATORY INVESTIGATION OF WHEEL RAIL CONTACT STRESSES FOR
                 U. S. FREIGHT CARS

                                     KEY WORDS

-----------------------------------------------------------------------------
   STRESS ANALYSIS; WHEEL RAIL DYNAMICS; CONTACT STRESS AND TRACK DEGRADATION
   SIMULATION FACILITY; FREIGHT CAR STRESS LEVELS;


                                      SYNOPSIS
APPLICABLE TO SHELLING PROBLEM




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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301001*                              DATE  00 FEB 77

                                      AUTHOR
                 M. R. JOHNSON, R. E. WELCH, & K. S. YEUNG

                                       TITLE
                 "ANALYSIS OF THERMAL STRESSES & RESIDUAL STRESS CHANGES IN
                 RR WHEELS CAUSED BY SEVERE DRAG BRAKING (JOR. ENG. FOR IND)

                                     KEY WORDS
   FINITE ELEMENT ANALYSIS AND SIMULATION, TASK 10

-----------------------------------------------------------------------------
   STRESS ANALYSIS; THERMAL STRESSES; DRAG BRAKING; HEATING FROM TREAD BRAKE;
   THERMAL CRACK GROWTH


                                      SYNOPSIS
FINITE ELEMENT DEMONSTRATION OF THE FORMATION OF RESIDUAL STRESSES DUE TO BRAKE
HEATING.  THE STANDARD BY WHICH ELASTIC-PLASTIC F. E. ANALYSIS ARE JUDGED


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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301003*                           DATE  00 MAY 67

                                  AUTHOR
                JOSEF MATHAR

                                   TITLE
                "DETERMINATION OF INITIAL STRESSES BY MEASURING THE DEFORMA-
                TION AROUND DRILLED HOLES"

                                 KEY WORDS

-----------------------------------------------------------------------------
  RESIDUAL STRESS ANALYSIS; DISTURB AREA OF STRESS EQUILIBRIUM AROUND DRILLED
  HOLE DETERMINES INHERENT STRESSES IN CASTING


                                  SYNOPSIS
AN EXCELLENT BACKGROUND PAPER FOR THE BASIS OF HOLE DRILLING TECHNIQUE FOR
RESIDUAL STRESS DETERMINATION



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301006*                           DATE  00 MAY 76

                                  AUTHOR
                S. NISHIMURA & K. TOKIMASA

                                   TITLE
                "STUDY OF THE RESIDUAL STRESSES IN RAILROAD SOLID WHEELS AND
                 THEIR EFFECT ON WHEEL FRACTURE (BUL. OF THE JSME) VOL. 19

                                 KEY WORDS
  FAILURE MODEL, TASK 10
-----------------------------------------------------------------------------
  WHEEL STRESS; WHEEL TESTING MACHINE; WHEEL FRACTURE ANALYZED BY LINEAR
  FRACTURE MECHANICS; RESIDUAL TENSILE STRESS IN RIM


                                  SYNOPSIS
A DEFINITIVE WORK ON COMBINING RESIDUAL STRESS STATE AND FRACTURE MECHANICS
DATA TO PREDICT WHEEL FAILURE



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301016*                              DATE  00 JUL 76

                                 AUTHOR
             E.  BEANEY

                                  TITLE
             ACCURATE MEASUREMENT OF RESIDUAL STRESS ON ANY STEEL USING
             THE CENTRE HOLE METHOD

                              KEY WORDS
   DETAILED RESIDUAL STRESS ANALYSIS,  TASK 11

--------------------------------------------------------------------------------
   RESIDUAL STRESS ANALYSIS;  AIR-ABRASIVE TECHNIQUE FOR FORMNG HOLE;


                                SYNOPSIS
AN EXCELLENT PAPER ON RESIDUAL STRESS MEASUREMENT BY HOLE DRILLING WITH AIR
ABRASIVE UNIT



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301017*                              DATE  00 DEC 66

                                 AUTHOR
             N.  RENDLER & I.  VIGNESS

                                  TITLE
             HOLE-DRILLING STRAIN-GAGE METHOD OF MEASURING RESIDUAL
             STRESSES

                              KEY WORDS
   DETAILED RESIDUAL STRESS ANALYSIS,  TASK 11

--------------------------------------------------------------------------------
   RESIDUAL STRESS ANALYSIS;  STRAIN RELAXATION AROUND A DRILLED HOLE


                                SYNOPSIS
A BACKGROUND PAPER FOR THE DETERMINATION OF RESIDUAL STESSES BY HOLE DRILLING-
STRAIN GAGING METHOD



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 301018* DATE 00 MAY 78

AUTHOR
J. SANDIFER & G. BOWIE

TITLE
RESIDUAL STRESS BY BLIND-HOLE METHOD WITH OFF-CENTER HOLE

KEY WORDS
DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

STRESS ANALYSIS; BLIND-HOLE DRILLING; STRAIN-GAGE-ROSETTE GEOMETRIES;
HAND-DRILLED-HOLE CENTER

SYNOPSIS
APPLICATION OF HOLE DRILLING TECHNIQUE FOR THE DETERMINATION OF RESIDUAL STRESSES IN RESTRICTED AREAS

****

FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 301019* DATE 00 00

AUTHOR
A. BUSH & F. KROMER

TITLE
SIMPLIFICATION OF THE HOLE-DRILLING METHOD OF RESIDUAL
STRESS MEASUREMENT

KEY WORDS
DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

RESIDUAL STRESS ANALYSIS; HOLE DRILLING METHOD; ABRASIVE JET MACHINING

SYNOPSIS
AN EXCELLENT PAPER ON THE DETERMINATION OF RESIDUAL STRESSES BY HOLE DRILLING-STRAIN GAGING METHOD USING ABRASIVE JET MACHINING PROCESS

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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301020*                                 DATE  00 MAY 67

                                  AUTHOR
                 J. BRUNER, G. BENJAMIN & D. BENCH

                                   TITLE
                 ANALYSIS OF RESIDUAL, THERMAL AND LOADING STRESSES IN A B33
                 WHEEL AND THEIR RELATIONSHIP TO FATIGUE DAMAGE

                                 KEY WORDS
   FAILURE MODEL, TASK 10

-----------------------------------------------------------------------------------
   STRESS ANALYSIS; SIMULATED LOADING CONDITIONS; STRESS PATTERN AND FATIGUE
   TESTS COMPARED; RIM HEATING


                                  SYNOPSIS
A PRELIMINARY INVESTIGATION OF LOADING & THERMAL STRESSES IN A B-33 WHEEL



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301022*                                 DATE  00      00

                                  AUTHOR
                 W. SOETE & R. VANCROMBRUGGE

                                   TITLE
                 AN INDUSTRIAL METHOD FOR THE DETERMINATION OF RESIDUAL
                 STRESSES

                                 KEY WORDS
   DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

-----------------------------------------------------------------------------------
   STRESS ANALYSIS; ELASTIC RECOVERY OF STRESSES; DIAL EXTENSOMETER; TENSILE
   AND COMPRESSIVE STRESSES


                                  SYNOPSIS
BACKGROUND PAPER FOR THE DEVELOPMENT OF RESIDUAL STRESS DETERMINATION BY
HOLE DRILLING - STRAIN GAGING METHOD


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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 301023* DATE 00 00

AUTHOR
K. MILBRADT

TITLE
RING-METHOD DETERMINATION OF RESIDUAL STRESSES

KEY WORDS
DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

RESIDUAL STRESS ANALYSIS; X-RAY DIFFRACTION; CHANGE IN STRESS DISTRIBUTION DUE TO A DRILLED HOLE

SYNOPSIS
BACKGROUND MATERIAL FOR THE DEVELOPMENT OF RESIDUAL STRESS DETERMINATION BY HOLE-DRILLING - STRAIN GAGING METHOD

****

FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 301098* DATE 00 79

AUTHOR
C. H. HO & O. TUNCEL

TITLE
INVESTIGATION OF THE INFLUENE OF VARIOUS PARAMETERS ON RESIDUAL-STRESS CALIBRATION

KEY WORDS
DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

RESIDUAL STRESS ANALYSIS; CALIBRATION TESTS OF RESIDUAL STRESS; HOLE DRILLING-STRAIN GAGE METHOD;

SYNOPSIS
A BACKGROUND PAPER FOR THE DETERMINATION OF RESIDUAL STRESS BY HOLE DRILLING - STRAIN GAUGE METHOD

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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301321*                               DATE  00     82

                                   AUTHOR
                M. R. JOHNSON & R. R. ROBINSON A. J. OPINSKY

                                   TITLE
                RESIDUAL STRESS CALCULATINS ON 33 INCH (838 mm) DIAMETER ONE
                WEAR FREIGHT CAR WHEELS UNDER SIM. UNREL. HAND BRAKE COND.

                                 KEY WORDS
  FAILURE MODEL, TASK 10

---------------------------------------------------------------------------
  WHEEL WEAR; TENSILE STRESSES IN RIM OF WHEEL; THERMAL LOAD FROM TREAD
  BRAKING; CRACKS ON RIM


                                  SYNOPSIS
AN ATTEMPT TO DETERMINE MAGNITUDE OF RESIDUAL STRESS CHANGE IN "LOW STRESS" AND
"HIGH STRESS" WHEELS WITH THE SAME THERMAL INPUTS



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301334*                               DATE  00     70

                                   AUTHOR
                K. NISHIOKA & Y. MORITA

                                   TITLE
                "THE STRENGTH OF RAILROAD WHEELS (2ND REPT. THE EFFECT OF
                WHEEL CONTOURS ON THERMAL STRESSES IN WHEELS) JSME

                                 KEY WORDS
  COMPREHENSIVE FAILURE MODEL, TASK 10, F.E.A. OF DIFFERENT WHEEL DESIGNS

---------------------------------------------------------------------------
  WHEEL WEAR; TREAD BRAKE; THERMAL STRESSES IN DIFFERENT WHEEL DESIGNS;
  CRACKS AT TREAD; RIGIDITY OF FLANGE


                                  SYNOPSIS
FINITE ELEMENT ANALYSIS OF DIFFERENT WHEEL DESIGNS



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301346*                           DATE  00     59

                                    AUTHOR
                 M. S. RIEGEL

                                      TITLE
                 STRESSES IN WROUGHT-STEEL WHEEL RIMS AND THEIR RELATION TO
                 WHEEL LIFE

                                    KEY WORDS
   FINITE ELEMENT ANALYSIS, TASK 10

------------------------------------------------------------------------------------
   WHEEL WEAR; RESIDUAL STRESSES OF NEW WHEELS; SIMULATED SERVICE STRESSES;
   WHEEL FAILURES; CONTROL


                                    SYNOPSIS
A PRELIMINARY ANALYSIS OF RELATING WHEEL RIM STRESSES & WHEEL LIFE




********************************************************************************


FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301400*                           DATE  00 SEP 78

                                    AUTHOR
                 L. Q. KEMENY,

                                      TITLE
                 "THE COMPUTERIZED MONITORING OF RAILWAY WHEELS IN MOTION
                 (HEAVY HAUL RAILWAYS CONF. PROCEEDINGS)

                                    KEY WORDS
   NDE, TASK 14

------------------------------------------------------------------------------------
   FLAW DETECTION; WHEEL FAILURES BY THERMAL STRESS & CRACKS; AUTOMATED MONI-
   TOR IN MOTION & DERAILING


                                    SYNOPSIS
RELEIGH   WAVE METHOD FOR DETECTING CRACKS AND RESIDUAL STRESS.  ACTUAL SYSTEM
MAY NOT BE IN PLACE.



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 301434* DATE 00 82

AUTHOR

S. KUMAR Y. ADENWALA, B. RAJKUMAR

TITLE

EXPERIMENTAL INVESTIGATION OF CONTACT STRESSES BETWEEN A U. S. LOCOMOTIVE WHEEL AND RAIL

KEY WORDS

CONTACT STRESS ANALYSIS; PLASTICITY AND WEAR; WHEEL/RAIL SIMULATION; LABORATORY & FIELD RESULTS COMPARED

SYNOPSIS

BACKGROUND MATERIAL FOR SHELLING PROBLEM

****

FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 301438* DATE 00 00

AUTHOR

W. S. LOVELACE,

TITLE

STUDY OF RIM STRESSES RESULTING FROM STATIC LOADS ON DIFFERENT 36-IN. RR WHEEL DESIGNS (PAP. NO. 71-RR-4)

KEY WORDS

WHEEL WEAR; STRESS IN RIM SECTIONS; WHEEL RIM AND FATIGUE FAILURES; STATIC LOADS UP TO 75,000 LB.

SYNOPSIS

EARLIER EXPERIMENTAL STRESS ANALYSIS

****

FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 301439* DATE 00 69

AUTHOR

G. E. NOVAK & B J. ECK

TITLE

A THREE DIMENSIONAL FINITE DIFFERENCE SOLUTION FOR THE THERMAL STRESSES IN RAILCAR WHEELS (PAP. NO. 69-RR-4)

KEY WORDS

WHEEL WEAR; THERMAL STRESS DISTRIBUTION FROM BRAKE; SHEAR STRESSES; THERMAL HISTORY OF WHEEL; FATIGUE

SYNOPSIS

EARLY FINITE ELEMENT ANALYSIS OF WHEELS (ELASTIC)

****

FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 301440* DATE 00 67

AUTHOR

J. P. BRUNER, R. D. JONES, S. LEVEY & J. WANDRISCO

TITLE

EFFECT OF DESIGN VARIATION ON SERVICE STRESSES IN RAILROAD WHEELS (PAPER NO. 67-WA/RR-6)

KEY WORDS

WHEEL WEAR; SERVICE BRAKING & LOADING SIMULATED; BRAKING, LOADING STRESSES; FATIGUE

SYNOPSIS

OBSOLETE EARLY COMPUTER BASED STRESS ANALYSIS

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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301441*                              DATE  00     00

                                 AUTHOR
            M. S. RIEGEL, S. LEVY & J. A. SLITER

                                  TITLE
            A COMPUTER PROGRAM FOR DETERMING THE EFFECT OF DESIGN VARIA-
            TION ON SERVICE STRESSES IN RR WHEELS (PAP. NO. 65-WA/RR-1)

                               KEY WORDS

------------------------------------------------------------------------------
  WHEEL WEAR; WHEEL SHAPE & DIMENSIONS; HEAT STRESS BY BRAKE SHOE FRICTION;
  LATERAL, TRACTIONAL FORCES

                                SYNOPSIS
OBSOLETE STRESS ANALYSIS



*****************************************************************************


FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301446*                              DATE  00     72

                                 AUTHOR
            G. E. NOVAK & B. J. ECK

                                  TITLE
            ASYMMETRICAL WHEEL STRESSES  CAUSED BY SIMULATED THERMAL AND
            MECHANICAL SERVICE LOADS (PAPER NO. 72-WA/RT-13)

                               KEY WORDS
  FINITE ELEMENT ANALYSIS, TASK 10

------------------------------------------------------------------------------
  STRESS ANALYSIS; WHEEL UNDER DRAG BRAKING; OCTAHEDRAL SHEAR; STRESS


                                SYNOPSIS
EARLY FINITE ELEMENT ANALYSIS - (OBSOLETE)



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 301447* DATE 00 73

AUTHOR
H. R. WETENKAMP

TITLE
THERMAL STRESSES DEVELOPED IN S PLATE, STRAIGHT PLATE, AND DEEP DISH WHEEELS

KEY WORDS
COMPREHENSIVE TESTING ON TRACK & DYNAMOMETER, TASK 6

STRESS ANALYSIS; SUBJECTING WHEELS TO BRAKING CYCLES; ELASTIC STRESS BY THERMAL LOAD; DESIGNS

SYNOPSIS
EFFECT OF WHEEL DESIGN ON ELASTIC THERMAL STRESS

****

FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 301448* DATE 00 73

AUTHOR
G. E. NOVAK, W. J. KUCERA, & B. J. ECK

TITLE
EFFECT ON RIM THICKNESS ON WHEEL STRESSES CAUSED BY SIMULATED SERVICE CONDITIONS (PAPER NO. 73-WA/RT-10)

KEY WORDS

STRESS ANALYSIS; WHEEL RIMS UNDER LOADS; OCTAHEDRAL STRESS MAPPING; COMPUTED & STRAIN GAGE VALUES

SYNOPSIS
EARLY FEA PAPER - (OBSOLETE)

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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301450*                         DATE  00     75

                                   AUTHOR
               G. E. NOVAK, L. P. GREENFIELD, & D. H. STONE

                                   TITLE
               SIMULATED OPERATING STRESSES IN 28-IN. DIAMETER WHEELS


                                 KEY WORDS
  COMPREHENSIVE TRACK AND DYNAMOMETER TESTING, TASK 6

------------------------------------------------------------------------------
  STRESS ANALYSIS; WHEEL DESIGNS; SIMULATE VERTICAL, LATERAL, BRAKE SHOE
  FORCES; OCTAHEDRAL MAPPING

                                  SYNOPSIS
EARLY FEA PAPER CONTRASTING STRAIGHT AND CURVED PLATE DESIGNS



*****************************************************************************


FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301452*                         DATE  00     76

                                   AUTHOR
               G. E. NOVAK, G. E. DAHLMAN, B. J. ECK, W. KUCERA

                                   TITLE
               THERMAL PATTERNS IN 36 INCH FREIGHT CAR WHEEL DURING
               SERVICE TESTS

                                 KEY WORDS
  PRELIMINARY TRACK TEST, TASK 5

------------------------------------------------------------------------------
  STRESS ANALYSIS, SERVICE TESTS OF BRAKE SHOE FORCE, INSTRUMENTED WHEELS,
  HEAT-FLOW CHARACTERISTICS

                                  SYNOPSIS
CORRELATION OF WHEEL THERMAL PATTERNS FROM FIELD TEST AND FINITE DIFFERENCE
CALCULATION


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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301453*                              DATE  00     77

                                   AUTHOR
                 G. E. NOVAK & D. H. STONE

                                    TITLE
                 A COMPARISON OF THE STRESS LEVELS IN ONE-AND-TWO WEAR 36 IN.
                 DIAMETER WHEELS UNDER SIMULATED SERVICE LOADS

                                 KEY WORDS
  FAILURE MODEL, TASK 10

------------------------------------------------------------------------------
  STRESS ANALYSIS; STRESS LEVEL & WEAR IN SERVICE; RIM THICKNESS & STRESS
  LEVEL; SHATTER & CRACKS


                                  SYNOPSIS
EARLY ATTEMPT TO CALCULATE STRESS DIFFERENCES IN ONE - AND TWO WEAR WHEELS BY
ELASTIC FINITE ELEMENT ANALYSIS (OBSOLETE)



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301454*                              DATE  00     78

                                   AUTHOR
                 T. M. RUSIN, D. G. KLEESCHULTE, J. M. COUGHLIN

                                    TITLE
                 APPLICATION OF THE FINITE ELEMENT METHOD IN THE DEVELOPMENT
                 OF IMPROVED RAILROAD CAR WHEEL DESIGNS

                                 KEY WORDS
  FINITE ELEMENT ANALYSIS, TASK 10,

------------------------------------------------------------------------------
  THERMAL & MECHANICAL LOADS ON WHEEL DESIGNS; CALCULATED STRESSES,
  DYNAMOMETER


                                  SYNOPSIS
FINITE ELEMENT ANALYSIS OF DIFFERENT WHEEL DESIGNS



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 301456* DATE 00 JUL 72

AUTHOR

M. H. LARSON, M. H. HUNTRESS & M. HALEY

TITLE

DISTRIBUTION OF HEAT BETWEEN WHEEL AND BRAKE SHOE

KEY WORDS

BRAKE SHOE HEATING, TASK 7

HEATING UNDER BRAKING PRODUCES THERMAL CRACKS, RESIDUAL STRESS; WHEEL FAILURE; SAFETY

SYNOPSIS

EVALUATION OF HEAT DISTRIBUTION BETWEEN WHEEL AND SHOE

****

FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 301457* DATE 00 JUL 72

AUTHOR

M. B. ECK & M. G. NOVAK

TITLE

WHEEL STRESSES RESULTING FROM SIMULATED SERVICE DRAG BRAKING
AND ASYMMETRICAL RAIL LOADING

KEY WORDS

FINITE ELEMENT ANLAYSIS, TASK 10

STRESS ANALYSIS; FINITE ELEMENT ANALYSIS; THERMAL STRESS UNDER BRAKING; DRAG BRAKING;

SYNOPSIS

OBSOLETE ELASTIC FINITE ELEMENT ANALYSIS PAPER

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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301463*                         DATE  00 JUL 72

                              AUTHOR
           M. HIROOKA, M. KASAI, M. NISHIMURA, M. TOKIMASA

                               TITLE
           RESIDUAL STRESSES IN THE RIM OF A RAILROAD SOLID WHEEL DUE
           TO ON-TREAD DRAG BRAKING AND THEIR EFFECT ON WHEEL FAILURE

                            KEY WORDS
  FAILURE MODEL, TASK 10
-------------------------------------------------------------------------
  JAPANESE EXPERIENCE; RIM STRESSES; MEASURING RESIDUAL STRESS; PLATE
  PROFILE EFFECTS


                             SYNOPSIS
EXCELLENT UNIFICATION OF RESIDUAL STRESS STATE AS AFFECTED BY WHEEL DESIGN




************************************************************************


FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301514*                         DATE  09 DEC 82

                              AUTHOR
           J. M. STEELE & T. LAM

                               TITLE
           IMPROVING THE ACCURACY OF FATIGUE ANALYSIS

                            KEY WORDS
  FAILURE MODEL, TASK 10
-------------------------------------------------------------------------
  FATIGUE ANALYSIS; LIFE PREDICTION; CRACK INITIATION; LOCAL STRESSES &
  STRAINS; LOAD CYCLES; MEAN STRESS

                             SYNOPSIS
SHORT SUMMARY OF STRAIN-LIFE FATIGUE CRITERION




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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301542*                             DATE  00     69

                                    AUTHOR
               P. GAUTHIER

                                     TITLE
               "THE BEHAVIOR OF WHEEL SETS ON S.N.C.F. MOTIVE POWER UNITS
               (THE EFFECTS OF CERTAIN TYPES OF STRESS)

                                  KEY WORDS
  FRETTING STRESSES, STRESSES DUE TO CYCLIC LOADS, FAILURE MODEL, TASK 10

----------------------------------------------------------------------------
  WHEEL WEAR; FRENCH TECH., SOLID SURFACE TREATED WHEELS, RESIDUAL STRESS;
  COMPRESSIVE STRESSES IN RIM


                                   SYNOPSIS
EFFECT OF MECHANICAL LOADS AND RESIDUAL STRESS - FRENCH EXPERIENCE




***************************************************************************


FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301543*                             DATE  00 DEC 76

                                    AUTHOR
               P. J. STEVENS

                                     TITLE
               AN X-RAY APPARATUS FOR THE MEASUREMENT OF RESIDUAL STRESSES
               IN RAILWAY WHEELS

                                  KEY WORDS
  NDE TASK 14

----------------------------------------------------------------------------
  STRESS ANALYSIS; RESIDUAL STRESS IN WHEELS; X-RAY METHOD WITH FILM TECHNI-
  QUE; AUSTRAILIAN TECHNOLOGY; PROBLEMS


                                   SYNOPSIS
APPLICATION OF X-RAY DIFFRACTION TO WHEELS FOR RESIDUAL STRESS DETERMINATION




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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301551*                             DATE  00     00

                                    AUTHOR
                 W. Y. LU

                                     TITLE
                 RESIDUAL STRESS EVALUATION BY ULTRASONICS IN AN ELASTIC-
                 PLASTIC

                                  KEY WORDS
   NDE TASK 14

--------------------------------------------------------------------------------
   ULTRASONICS, RESIDUAL STRESS EVALUATION



                                   SYNOPSIS
USE OF ULTASONIC BIREFRINGENCE FOR RESIDUAL STRESS DETERMINATION IN ALUMINUM
ALLOY



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301552*                             DATE  00     78

                                    AUTHOR
                 A. T. HOPPER, S. G SAMPATH, R. B. STONESIFER

                                     TITLE
                 THE ELASTIC FINITE ELEMENT ANALYSIS OF A CH-36 RAILCAR
                 WHEEL UNDER MECHANICAL AND THERMAL LOADS

                                  KEY WORDS

--------------------------------------------------------------------------------
   FINITE ELEMENT ANALYSIS; WHEEL STRESS; SPECTRAL LOADING, PLASTICITY,
   THERMAL LOADS, RESIDUAL STRESS


                                   SYNOPSIS
ELASTIC FINITE ELEMENT PROGRAM (OBSOLETE BUT USEFUL REFERENCE)



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 301557* DATE 00 73

AUTHOR

E. KILB

TITLE

WHEEL LOAD & WHEEL DIAMETER FROM THE POINT OF VIEW OF STRESS ON THE MATERIAL IN THEORY AND IN PRACTICE

KEY WORDS

WHEEL WEAR; CONTACT STRESSES; SMALL HIGH-SPEED WHEELS; FATIGUE STRENGTH; CONTACT AREA DURING WEARING PROCESS

SYNOPSIS

A GENERIC BACKGROUND PAPER FOR SHELLING PROBLEM

****

FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER 301562* DATE 00 NOV 76

AUTHOR

R. J. MCDONALD & R. I. MAIR

TITLE

WROUGHT STEEL RAILWAY WHEELS - A BASIS FOR DEVELOPMENT

KEY WORDS

MATERIAL PROPERTIES, TASK 3

WHEELS; ABRASION RESISTANCE; RESIDUAL STRESSES; THERMAL CRACKING; AUSTRALIAN TECHNOLOGY

SYNOPSIS

A FIRST ORDER APPROACH TO EXTENDING WHEEL LIFE BY INCREASING WEAR FRACTURE RESISTANCE AND ROLLING CONTACT DEFECTS

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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301565*                             DATE  00 JAN 75

                                   AUTHOR
                 W. BROHL & P. BRINKMANN

                                    TITLE
                 STRESSES IN THE TREADS OF RAILWAY WHEELS


                                 KEY WORDS

--------------------------------------------------------------------------------
   WHEEL WEAR;  FRICTION, THERMAL STRESS, TENSILE STRESS WEAR;



                                  SYNOPSIS
USEFUL FOR SHELLING ANALYSIS




*******************************************************************************


FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301566*                             DATE  00 NOV 75

                                   AUTHOR
                 A. RESILLON & A. LELUAN

                                    TITLE
                 EFFECT OF THE DEVELOPMENT OF RESIDUAL STRESSES IN SOLID
                 WHEELS ON WEAR

                                 KEY WORDS

--------------------------------------------------------------------------------
   WHEEL WEAR; RESIDUAL STRESSES; THERMAL FACTOR IN WEAR; FATIGUE CRACKS
   FORMED, DEGRADATION HISTORY


                                  SYNOPSIS
BACKGROUND MATERIAL FOR REFERENCE; NOT DIRECTLY APPLICABLE TO PROGRAM



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   301567*                             DATE  00      74

                                 AUTHOR
                V. K. GARG, SU. C. ANAND, & P. G. HODGE

                                  TITLE
                ELASTIC-PLASTIC ANALYSIS OF A WHEEL ROOLING ON A RIGID
                TRACK

                               KEY WORDS

-------------------------------------------------------------------------------
   FINITE ELEMENT ANALYSIS; MODEL FOR ROLLING WHEEL; MINIMUM STRESS-RATE;
   STEADY STATE REACHED; SHAKE-DOWN DEMONSTRATED


                                SYNOPSIS
NON-HERTZIAN ANALYSIS OF ROLLING CONTACT



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   C53.4*                              DATE  00 OCT 66

                                 AUTHOR
                MEMBER ADMIN. OF THE OFC. OF RESEARCH (ORE)

                                  TITLE
                BEHAVIOR OF THE METAL OF THE RAIL UNDER THE REPEATED ACTION
                OF THE WHEEL; RESIDUAL LONGITUDINAL STRESSES IN THE RAIL

                               KEY WORDS
   DETAILED RESIDUAL STRESSES, TASK 11
-------------------------------------------------------------------------------
   WHEEL RAIL DYNAMICS; DETERMINE RESIDUAL STRESSES IN RAIL; HEAT EFFECTS;
   TRIMMING, COLD ROLLING, FATIGUE IN SERVICE


                                SYNOPSIS
BACKGROUND PAPER FOR RESIDUAL STRESS ANALYSIS (WITH SPECIAL REFERENCE TO RAILS)



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   C53.6*                              DATE  00 OCT 70

                                     AUTHOR
                OFC. FOR RESEARCH & EXPERIMENTS (ORE)

                                      TITLE
                BEHAVIOR OF THE MEAL OF RAIL AND WHEEL IN THE CONTACT ZONE
                "RESIDUAL STRESSES IN THE RAIL (CONT.) WORK HARDENED ZONE

                                   KEY WORDS
   RESIDUAL STRESSES, TASK 11;

--------------------------------------------------------------------------------
   RESIDUAL STRESS; WORK-HARDENING CHANGES' HYDROSTACK PRESSURE ZONE; FATIGUE
   CRACKS; RAIL CORRUGATIONS,


                                    SYNOPSIS
STUDY OF RESIDUAL STRESS IN RAIL.  REFERENCE MATERIAL FOR COMPREHENSIVE RESIDUAL
STRESS ANALYSIS IN WHEELS.



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   C53.9*                              DATE  00 OCT 73

                                     AUTHOR
                MEMBER ADMIN. OF THE OFC. OF RESEARCH & EXP. (ORE)

                                      TITLE
                BEHAVIOR OF THE METAL OF RAILS AND WHEELS IN THE CONTACT
                ZONE, QUEST. C53

                                   KEY WORDS
   FAILURE MODEL TASK 10; RESIDUAL STRESSES, TASK 11

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   STRESS ANALYSIS, RESIDUAL RAIL STRESSES FROM PASSAGE WHEELS: FATIGUE
   PLASTIC DEFORMATION


                                    SYNOPSIS
RESIDAUL STRESS ANALYSIS OF RAIL: FATIGUE DAMAGE AS A FUNCTION OF LOAD
CONDITIONS



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   FRA 48/40*                            DATE  00 JUN 78

                                 AUTHOR
                B. PAUL, &  J. HASHEM

                                  TITLE
                USERS' MANUAL FOR PROGRAM CONFORM (CONFORMAL CONTACT STRESS
                PROBLEMS)

                               KEY WORDS

--------------------------------------------------------------------------------
  RAIL WHEEL INTERACTION, CONTACT STRESS, CONFORMAL CONTACT, ELASTICITY,
  NON HERTZIAN CONTACT, COMPUTER PROGRAM


                                SYNOPSIS




*******************************************************************************


FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   FRA 75/11*                            DATE  00 MAY 74

                                 AUTHOR


                                  TITLE
                INSTRUMENTATION FOR MEASUREMENT OF FORCES ON WHEELS OF RAIL
                VEHICLES

                               KEY WORDS
  PRELIMINARY TRACK TESTING, TASK 5;

--------------------------------------------------------------------------------
  INSTRUMENTED WHEEL; WHEEL STRESSES; WHEEL FORCES; FORCE MEASUREMENT,
  SLIP RINGS


                                SYNOPSIS
REFERENCE MATERIAL FOR THE FABRICATION AND CALIBRATION OF INSTRUMENTED WHEELSETS
CAPABLE OF MEASURING WHEEL/RAIL FORCES


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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   FRA 77/11*                          DATE  00 FEB 77

                                    AUTHOR
                R. R.  KING, J. R. BARTON, & W. D. PERRY

                                     TITLE
                STRESS MEASUREMENTS IN RAILROAD WHEELS VIA THE BARKHAUSEN
                EFFECT

                                  KEY WORDS
  NDE TECHNIQUES, TASK 14

------------------------------------------------------------------------------
  NONDESTRUCTIVE TESTING; RESIDUAL STRESS; BARKHAUSEN EFFECT; RAILROAD WHEELS


                                   SYNOPSIS
THE FIRST ATTEMPT TO APPLY BARKHAUSEN TECHNIQUES TO RAILROAD WHEELS



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   FRA 77/17*                          DATE  00 MAR 77

                                    AUTHOR
                G. F. CARPENTER

                                     TITLE
                THE CAUSE OF THERMAL FATIGUE CRACKING IN METROLINER WHEELS


                                  KEY WORDS
  DYNAMOMETER TESTING, TASKS 4, 6, AND 8; FAILURE MODEL, TASK 10;

------------------------------------------------------------------------------
  FATIGUE ANALYSIS; WHEEL WEAR, RESIDUAL THERMAL STRESSES; THERMAL CRACKING;
  MACROSTRUCTURE, MICROSTRUCTURE


                                   SYNOPSIS
DYNAMOMETER STUDY OF THERMAL CRACK INITIATION. (THIS DYNAMOMETER IS THE ONE NOW
AT AAR)


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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER FRA 78/27* DATE 00 SEP 77

AUTHOR

B. PAUL & J. HASHEMI

TITLE

USER'S MANUAL FOR PROGRAM COUNTACT (COUNTerformal contACT STRESS PROBLEMS)

KEY WORDS

RAIL WHEEL INTERACTION; CONTACT STRESS; COUNTER-FORMAL CONTACT; ELASTICITY; NON-HERTZIAN CONTACT; COMPUTER PROGRAMS

SYNOPSIS

NON-HERTZIAN ELASTIC CONTACT STRESS SOLUTION CALCULATED CONTACT PATCH WITH A MORE ACCURATE REPRESENTATION OF SHAPE AND AREA THAN THE HERTZIAN CALCULATIONS YIELD; A GENERAL PURPOSE BACKGROUND PAPER

****

FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER R-158* DATE 00 MAY 74

AUTHOR

D. H. STONE

TITLE

RESIDUAL STRESSES IN THE PLATE FILLETS OF TWENTY-EIGHT-INCH DIAMETER WROUGHT STEEL WHEELS

KEY WORDS

DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

WHEELS; B-28 WHEEL AND PLATE CRACKING; BULK RESIDUAL STRESS EVALUATION FATIGUE

SYNOPSIS

USE OF AISI METHOD TO DETERMINE BULK RESIDUAL STRESS

****

FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER R-268* DATE 00 FEB 77

AUTHOR

A. HOPPER, T. JOHNS, S. SAMPATH, R. STONESIFER

TITLE

WHEEL RESEARCH, VOLUME 1, ELASTIC STRESS ANALYSIS, ELASTIC FINITE-ELEMENT STRESS ANALYSIS OF RAIL CAR WHEELS

KEY WORDS

ELASTIC FINITE ELEMENT PROGRAM, TASK 10

WHEELS; FINITE ELEMENT ANALYSIS; ELASTIC STRESS ANALYSIS; HEAT TRANSFER ANALYSIS; CONTACT STRESS ANALYSIS

SYNOPSIS

ELASTIC FINITE ELEMENT PROGRAM

* * *

FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER R-373* DATE 00 MAY 79

AUTHOR

Y. J. PARK

TITLE

CYCLIC BEHAVIOR OF CLASS B WHEEL STEEL

KEY WORDS

MATERIAL PROPERTIES, TASK 3; FAILURE MODEL, TASK 10

WHEELS; CLASS B WHEEL; LOW-CYCLE, FATIGUE, CYCLIC SOFTENING; STRESS, STRAIN, FATIGUE LIFE

SYNOPSIS

ROOM TEMPERATURE DATA WILL BE USED IN TASK 3

* * *

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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   R-388*                              DATE  00 AUG 79

                                    AUTHOR
                 T. J. THOMAS & V. K. GARG

                                     TITLE
                 THERMAL FATIGUE ANALYSIS OF A RAIL CAR WHEEL UNDER DRAG
                 BRAKING

                                  KEY WORDS
   FAILURE MODEL, TASK 10

--------------------------------------------------------------------------------
   WHEEL WEAR; FATIGUE LIFE; THERMAL STRESSES; DRAG BRAKING; FINITE-ELEMNT
   METHOD; PLASTICITY;


                                   SYNOPSIS
AN EARLY FATIGUE ANALYSIS MODEL



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   R-393*                              DATE  00 AUG 79

                                    AUTHOR
                 Y. J. PARK

                                     TITLE
                 CYCLIC BEHAVIOR OF CLASS A WHEEL STEEL

                                  KEY WORDS
   MATERIAL PROPERTIES, TASK 3

--------------------------------------------------------------------------------
   WHEEL WEAR; CLASS A WHEEL STEEL; STRESS, STRAIN, LOW-CYCLE FATIGUE;
   FATIGUE LIFE OF WHEELS;

                                   SYNOPSIS
GRADE OF STEEL NOT APPLICABLE TO PROGRAM; USEFUL REFERENCE PAPER ON CYCLIC
PROPERTIES



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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   R-411*                                DATE  00 FEB 80

                              AUTHOR
            A. J. OPINSKY

                               TITLE
            SEPTA WHEEL RESIDUAL STRESS INVESTIGATION


                             KEY WORDS
   DETAILED RESIDUAL STRESS ANALYSIS, TASK 11

--------------------------------------------------------------------------------
   WHEEL WEAR; RESIDUAL STRESS; BACK RIM-PLATE FILLET; FRONT HUB-PLATE FILLET;
   RAILROAD WHEEL WEAR


                              SYNOPSIS
AN EXPERIMENTAL ANALYSIS USING AISI TECHNIQUE




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FILE PRINT SELECTED BY KEY WORD STRESS

FILE NUMBER   R-467*                                DATE  00 FEB 81

                              AUTHOR
            T. J. THOMAS, V. K. GARG, & D. H. STONE

                               TITLE
            FATIGUE ANALYSIS OF RAILROAD FREIGHT CAR WHEELS UNDER THER-
            MAL LOADING CONDITIONS

                             KEY WORDS
   FAILURE MODEL, TASK 10

--------------------------------------------------------------------------------
   WHEEL WEAR; WHEEL LOADS (MECHNAICAL & THERMAL); WHEEL STRESSES AND TEMPERA-
   TURES; FINITE ELEMENT ANALYSIS;


                              SYNOPSIS
AN EARLY FATIGUE ANALYSIS MODEL




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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER   200256/1-4*                      DATE  00 OCT 78

                               AUTHOR
                L. BRAZZODURO, P. BROZZO, R. DEMARTINI,

                                 TITLE
                6TH INTL WHEELSET CONG. "FINAL RESULTS OF THE RESEARCH WORK
                ON A NEW SOLID WHEEL APT TO MOST SEVERE OPER. COND.

                              KEY WORDS
  MATERIAL PROPERTIES, TASK 3, UIC-R/2 AND R/6 STEEL

------------------------------------------------------------------------------
  (ITALIAN PRACTICE) THERMAL CRACKING TESTS, DRAG & STOP BRAKING TESTS


                               SYNOPSIS
THERMAL CRACKING TESTS, DRAG AND STOP BRAKING TESTS (UIC-R/6 & 5 CR WHEELS)
WERE PERFORMED TO INVESTIGATE RESISTANCE TO REPEATED THERMAL LOADING.


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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER   200784*                          DATE  00 DEC 81

                               AUTHOR
                M. R. JOHNSON & R. R. ROBINSON

                                 TITLE
                IMPROVED SAFETY OF RAILROAD CAR WHEELS


                              KEY WORDS

------------------------------------------------------------------------------
  WHEEL FAILURES, THERMAL CRACKS, SAFETY


                               SYNOPSIS
A GENERIC BACKGROUND PAPER (REPORT) ON FACTORS WHICH LEAD TO RAILROD WHEEL
FAILURES


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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER 201050* DATE 00 JUL 69

AUTHOR
T. SUGIYAMA , K. NISHIOKA, (ET. AL.)

TITLE
THIRD INTERNATIONAL WHEELSET CONFERENCE

KEY WORDS

WHEEL/RAIL; TESTING; RESILIENCY; CAST STEEL; THERMAL CRACKING; RESIDUAL STRESS; METALLURGY

SYNOPSIS
GENERAL BACKGROUND REFERENCE

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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER 201098* DATE 00 JUN 50

AUTHOR
H. R. WETENKAMP, O. M. SIDEBOTTOM, H. J. SCHRADER

TITLE
THE EFFECT OF BRAKE SHOE ACTION ON THERMAL CRACKING AND ON FAILURE OF WROUGHT STEEL RAILWAY CAR WHEELS

KEY WORDS
BRAKE DYNAMOMETER TESTING, TASKS 4, 6, & 8

LABORATORY TESTS, STOP BRAKING, DRAG BRAKING, WROUGHT STEEL WHEELS, THERMAL CRACKS, RESIDUAL STRESSES, FRACTURE, CARBON CONTENT, HEAT TREATMENT, WHEEL DESIGN

SYNOPSIS
WROUGHT STEEL WHEELS SUBJECTED TO A SERIES OF LABORATORY TESTS SUCH AS STOP BRAKING & DRAG BRAKING; STUDY OF EFFECT OF CARBON CONTENT, HEAT TREATMENT, WHEEL DESIGN

****

FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER 300074* DATE 09 SEP 72

AUTHOR
N. A. BERG & R. H. ALBER

TITLE
TREAD BRAKING VERSUS THE WHEEL

KEY WORDS

WHEEL TREAD PROBLEMS, SHELLING PHENOMENA, WHEEL STRESSES, SPALLING, THERMAL LOAD DAMAGE TO WHEELS, BRAKING

SYNOPSIS
EXCELLENT PRIMER ON WHEEL THERMAL FAILURE

****

FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER 301001* DATE 00 FEB 77

AUTHOR
M. R. JOHNSON, R. E. WELCH, & K. S. YEUNG

TITLE
"ANALYSIS OF THERMAL STRESSES & RESIDUAL STRESS CHANGES IN
RR WHEELS CAUSED BY SEVERE DRAG BRAKING (JOR. ENG. FOR IND)

KEY WORDS
FINITE ELEMENT ANALYSIS AND SIMULATION, TASK 10

STRESS ANALYSIS; THERMAL STRESSES; DRAG BRAKING; HEATING FROM TREAD BRAKE; THERMAL CRACK GROWTH

SYNOPSIS
FINITE ELEMENT DEMONSTRATION OF THE FORMATION OF RESIDUAL STRESSES DUE TO BRAKE HEATING. THE STANDARD BY WHICH ELASTIC-PLASTIC F. E. ANALYSIS ARE JUDGED

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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER   301321*                                DATE  00      82

                                      AUTHOR
                M. R. JOHNSON & R. R. ROBINSON A. J. OPINSKY

                                       TITLE
                RESIDUAL STRESS CALCULATINS ON 33 INCH (838 mm) DIAMETER ONE
                WEAR FREIGHT CAR WHEELS UNDER SIM. UNREL. HAND BRAKE COND.

                                     KEY WORDS
  FAILURE MODEL, TASK 10

----------------------------------------------------------------------------
  WHEEL WEAR; TENSILE STRESSES IN RIM OF WHEEL; THERMAL LOAD FROM TREAD
  BRAKING; CRACKS ON RIM


                                      SYNOPSIS
AN ATTEMPT TO DETERMINE MAGNITUDE OF RESIDUAL STRESS CHANGE IN "LOW STRESS" AND
"HIGH STRESS" WHEELS WITH THE SAME THERMAL INPUTS



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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER   301334*                                DATE  00      70

                                      AUTHOR
                K. NISHIOKA & Y. MORITA

                                       TITLE
                "THE STRENGTH OF RAILROAD WHEELS (2ND REPT. THE EFFECT OF
                WHEEL CONTOURS ON THERMAL STRESSES IN WHEELS) JSME

                                     KEY WORDS
  COMPREHENSIVE FAILURE MODEL, TASK 10, F.E.A. OF DIFFERENT WHEEL DESIGNS

----------------------------------------------------------------------------
  WHEEL WEAR; TREAD BRAKE; THERMAL STRESSES IN DIFFERENT WHEEL DESIGNS;
  CRACKS AT TREAD; RIGIDITY OF FLANGE


                                      SYNOPSIS
FINITE ELEMENT ANALYSIS OF DIFFERENT WHEEL DESIGNS



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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER   301400*                              DATE  00 SEP 78

                                 AUTHOR
               L. G.  KEMENY,

                                   TITLE
                "THE COMPUTERIZED MONITORING OF RAILWAY WHEELS IN MOTION
                (HEAVY HAUL RAILWAYS CONF. PROCEEDINGS)

                                 KEY WORDS
  NDE, TASK 14

-------------------------------------------------------------------------------
  FLAW DETECTION; WHEEL FAILURES BY THERMAL STRESS & CRACKS; AUTOMATED MONI-
  TOR IN MOTION & DERAILING


                                  SYNOPSIS
RELEIGH   WAVE METHOD FOR DETECTING CRACKS AND RESIDUAL STRESS.   ACTUAL SYSTEM
MAY NOT BE IN PLACE.


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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER   301406*                              DATE  00 SEP 82

                                 AUTHOR
                T.  DEVINE & R.  ALBER

                                   TITLE
                WHEEL FLANGE WEAR TEST RESULTS IN HEAVY HAUL SERVICE


                                 KEY WORDS


-------------------------------------------------------------------------------
  WHEEL WEAR; CARBON CONTENT REDUCED/THERMAL CRACKS; HARDNESS & FLANGE WEAR;
  LUBRICATION, CURVES, SPEED


                                  SYNOPSIS
GENERAL BACKGROUND MATERIAL; NOT DIRECTLY APPLICABLE TO THE PROGRAM



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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER 301439* DATE 00 69

AUTHOR

G. E. NOVAK & B. J. ECK

TITLE

A THREE DIMENSIONAL FINITE DIFFERENCE SOLUTION FOR THE THERMAL STRESSES IN RAILCAR WHEELS (PAP. NO. 69-RR-4)

KEY WORDS

WHEEL WEAR; THERMAL STRESS DISTRIBUTION FROM BRAKE; SHEAR STRESSES; THERMAL HISTORY OF WHEEL; FATIGUE

SYNOPSIS

EARLY FINITE ELEMENT ANALYSIS OF WHEELS (ELASTIC)

FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER 301454* DATE 00 78

AUTHOR

T. M. RUSIN, D. G. KLEESCHULTE, J. M. COUGHLIN

TITLE

APPLICATION OF THE FINITE ELEMENT METHOD IN THE DEVELOPMENT OF IMPROVED RAILROAD CAR WHEEL DESIGNS

KEY WORDS

FINITE ELEMENT ANALYSIS, TASK 10,

THERMAL & MECHANICAL LOADS ON WHEEL DESIGNS; CALCULATED STRESSES, DYNAMOMETER

SYNOPSIS

FINITE ELEMENT ANALYSIS OF DIFFERENT WHEEL DESIGNS

FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER 301456* DATE 00 JUL 72

AUTHOR

M. H. LARSON, M. H. HUNTRESS & M. HALEY

TITLE

DISTRIBUTION OF HEAT BETWEEN WHEEL AND BRAKE SHOE

KEY WORDS

BRAKE SHOE HEATING, TASK 7

HEATING UNDER BRAKING PRODUCES THERMAL CRACKS, RESIDUAL STRESS; WHEEL FAILURE; SAFETY

SYNOPSIS

EVALUATION OF HEAT DISTRIBUTION BETWEEN WHEEL AND SHOE

****

FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER 301457* DATE 00 JUL 72

AUTHOR

M. B. ECK & M. G. NOVAK

TITLE

WHEEL STRESSES RESULTING FROM SIMULATED SERVICE DRAG BRAKING
AND ASYMMETRICAL RAIL LOADING

KEY WORDS

FINITE ELEMENT ANLAYSIS, TASK 10

STRESS ANALYSIS; FINITE ELEMENT ANALYSIS; THERMAL STRESS UNDER BRAKING; DRAG BRAKING;

SYNOPSIS

OBSOLETE ELASTIC FINITE ELEMENT ANALYSIS PAPER

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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER   301460*                           DATE  00 JUL 72

                                    AUTHOR
                 M. J. LEE & M. J. MURRAY

                                     TITLE
                 EXPERIMENTAL WORKS ON SEGMENTS OF IMPROVED STEELS FOR WHEELS
                 AND TYPES

                                  KEY WORDS
   MATERIAL PROPERTIES, TASK 3; DYNAMOMETER TESTING, TASK 4;

--------------------------------------------------------------------------------
   WHEEL TESTING MACHINE; THERMAL CRACKING OF TYRE STEEL; TENSILE, IMPACT,
   ABRASIVE WEAR TESTS


                                   SYNOPSIS
LABORATORY TESTING OF VARIOUS STEEL SEGMENTS INTO THE TREAD OF TEST WHEEL.
THERMAL CRACKING BEHAVIOR INVESTIGATED



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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER   301554*                           DATE  00     00

                                    AUTHOR
                 T. H. COLEMAN & D. J. NAYLOR

                                     TITLE
                 A METALLURGICAL STUDY OF THE FACTORS AFFECTING THERMAL
                 FATIGUE CRACKING IN RAILWAY WHEEL AND TYRE STEELS

                                  KEY WORDS
   MATERIAL PROPERTIES, TASK 3

--------------------------------------------------------------------------------
   HEATING & QUENCHING OF WHEEL RIM; NUCLEATION & GROWTH OF THERMAL FATIGUE
   CRACKS IN STEELS


                                   SYNOPSIS
EFFECT OF DEFORMATION AND ALLOY CONTENT ON THERMAL CRACKING SENSITIVITY OF
WHEEL STEELS



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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER   301562*                          DATE  00 NOV 76

                                 AUTHOR
             R  J. MCDONALD & R  I. MAIR

                                  TITLE
             WROUGHT STEEL RAILWAY WHEELS - A BASIS FOR DEVELOPMENT

                                KEY WORDS
  MATERIAL PROPERTIES, TASK 3
------------------------------------------------------------------------------
  WHEELS; ABRASION RESISTANCE; RESIDUAL STRESSES; THERMAL CRACKING;
  AUSTRALIAN TECHNOLOGY

                                 SYNOPSIS
A FIRST ORDER APPROACH TO EXTENDING WHEEL LIFE BY INCREASING WEAR FRACTURE
RESISTANCE AND ROLLING CONTACT DEFECTS



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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER   301565*                          DATE  00 JAN 75

                                 AUTHOR
             W. BROHL & P. BRINKMANN

                                  TITLE
             STRESSES IN THE TREADS OF RAILWAY WHEELS

                                KEY WORDS

------------------------------------------------------------------------------
  WHEEL WEAR;  FRICTION, THERMAL STRESS, TENSILE STRESS WEAR;


                                 SYNOPSIS
USEFUL FOR SHELLING ANALYSIS



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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER   301566*                          DATE  00 NOV 75

                                  AUTHOR
                A. RESILLON & A. LELUAN

                                   TITLE
                EFFECT OF THE DEVELOPMENT OF RESIDUAL STRESSES IN SOLID
                WHEELS ON WEAR

                                KEY WORDS


--------------------------------------------------------------------------------
  WHEEL WEAR; RESIDUAL STRESSES; THERMAL FACTOR IN WEAR; FATIGUE CRACKS
  FORMED, DEGRADATION HISTORY


                                 SYNOPSIS
BACKGROUND MATERIAL FOR REFERENCE; NOT DIRECTLY APPLICABLE TO PROGRAM




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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER   FRA 77/17*                       DATE  00 MAR 77

                                  AUTHOR
                G. F. CARPENTER

                                   TITLE
                THE CAUSE OF THERMAL FATIGUE CRACKING IN METROLINER WHEELS

                                KEY WORDS
  DYNAMOMETER TESTING, TASKS 4, 6, AND 8; FAILURE MODEL, TASK 10;

--------------------------------------------------------------------------------
  FATIGUE ANALYSIS; WHEEL WEAR, RESIDUAL THERMAL STRESSES; THERMAL CRACKING;
  MACROSTRUCTURE, MICROSTRUCTURE

                                 SYNOPSIS
DYNAMOMETER STUDY OF THERMAL CRACK INITIATION. (THIS DYNAMOMETER IS THE ONE NOW
AT AAR)


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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER   R-388*                             DATE  00 AUG 79

                                  AUTHOR
            T. J. THOMAS & V. K. GARG

                                   TITLE
            THERMAL FATIGUE ANALYSIS OF A RAIL CAR WHEEL UNDER DRAG
            BRAKING

                                 KEY WORDS
  FAILURE MODEL, TASK 10
-----------------------------------------------------------------------------------
  WHEEL WEAR; FATIGUE LIFE; THERMAL STRESSES; DRAG BRAKING; FINITE-ELEMNT
  METHOD; PLASTICITY;


                                  SYNOPSIS
AN EARLY FATIGUE ANALYSIS MODEL



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FILE PRINT SELECTED BY KEY WORD THERMAL

FILE NUMBER   R-467*                             DATE  00 FEB 81

                                  AUTHOR
            T. J. THOMAS, V. K. GARG, & D. H. STONE

                                   TITLE
            FATIGUE ANALYSIS OF RAILROAD FREIGHT CAR WHEELS UNDER THER-
            MAL LOADING CONDITIONS

                                 KEY WORDS
  FAILURE MODEL, TASK 10
-----------------------------------------------------------------------------------
  WHEEL WEAR; WHEEL LOADS (MECHNAICAL & THERMAL); WHEEL STRESSES AND TEMPERA-
  TURES; FINITE ELEMENT ANALYSIS;


                                  SYNOPSIS
AN EARLY FATIGUE ANALYSIS MODEL



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APPENDIX 4.1

ELEVATED TEMPERATURE FATIGUE BEHAVIOR OF CLASS B, C, AND U WHEEL STEELS

APPENDIX 4.1

ELEVATED TEMPERATURE FATIGUE BEHAVIOR OF CLASS B, C, AND U WHEEL STEELS

ELEVATED TEMPERATURE FATIGUE BEHAVIOR OF CLASS B, C and U WHEEL STEELS

M. C. Fec, Senior Research Engineer and D. Utrata, Research Engineer
Association of American Railroads
Chicago, Illinois

ABSTRACT

Material properties of railroad wheel steels are very critical when using finite element analysis to determine wheel material performance. In the past, high temperature cyclic properties of ordinary wheel steels have been estimated in the calculations of fatigue lives. Furthermore, fatigue life properties of railroad wheel steels have never been determined. A program investigating high temperature fatigue properties of these materials has been completed at the Association of American Railroads. A high temperature testing facility was developed to monitor these tests and determine these properties. Through low cycle fatigue testing, more accurate predictions of fatigue lives of wheel steels can be made. Three different grades of wheel steels, B, C and U were used for analysis. These steels were tested at room temperature, 200, 400 and 600°C.

It was generally observed that cyclic performance deteriorated with increasing temperature. The heat-treated Classes B and C materials performed better than the unheat-treated Class U material. The differences in carbon level had a noticeable effect in fatigue performance.

INTRODUCTION

The development of fatigue cracks are the primary cause of most wheel failures in service. The majority of these cracks are a result of thermal damage arising from frictional heating developed during brake applications. To improve the service performance of wheels, selection of material with better resistance to fatigue failure at all temperatures that encompass wheel use is of considerable importance.

One way of evaluating the material properties and predicting service performance is full-scale tests. While this type of approach has its own merits, it also has serious drawbacks; the tests are usually complicated, time consuming and expensive.

Another way of predicting service performance is through the use of finite element techniques. This type of analysis can provide stress conditions that develop in the wheel from cyclic thermal and mechanical loading experienced during service. Therefore, the properties used in the finite element analysis need to be derived from cyclic testing.

A convenient way of studying the fatigue behavior of wheel steels is through the use of small-scale laboratory tests. These tests, reported in this study were performed under fixed strain limits and isothermal conditions at room and elevated temperatures.

A number of papers reporting the cyclic behavior and properties of Classes B, C and U wheel steels at room temperature have been issued [1], [2] and [3] and the results are summarized in this report as well as new findings at the elevated temperatures.

EXPERIMENTAL PROCEDURES

Material and Specimens

Specimens were taken from the rim section of Class B, C and U wheels. The chemical composition of these steel are listed in Table 1.

The microstructure of these steels range from a relatively coarse pearlite for the unheat-treated Class U material to a finer pearlite for the rim quenched Class B and C materials. Specimens were cut from the rim such that their longitudinal direction was parallel to the tangential direction of the rim surface. The specimen dimensions are

TABLE 1

Chemical Composition of
Class B, C and U Wheels
(wt %)

Element	B Wheel	C Wheel	U Wheel
Carbon	0.63%	0.68%	0.70%
Manganese	0.72	0.81	0.90
Phosphorus	0.018	0.022	0.012
Sulfur	0.025	0.033	0.035
Silicon	0.29	0.28	0.25

shown in Figure 1. The room temperature tests, which had been previously performed, utilized specimens with a 0.50 in. (1.27 cm.) gage length sections whereas the elevated temperature tests required a 1.00 in. (2.54 cm.) gage length section as dictated by the extensometer.

Test Procedure

An automated materials test system was used for performing these tests and consisted of a 22-kip (100 kN) closed-loop servo-hydraulic test frame interfaced with a minicomputer. A strain controlled constant amplitude program was implemented to run and monitor the tests. The parameters, strain amplitude and temperature were held constant throughout the test. Heating was provided by a 3-zone furnace. Strain measurements were made using a high temperature extensometer utilizing quartz rods. This test setup is shown in Figure 2.

Tests were performed at 200, 400, and 600°C. Typically, 12 tests were run for each material at each temperature.

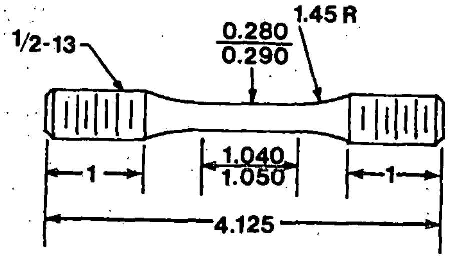

Figure 1. Low Cycle Fatigue Test Specimen.
Dimensions in inches
one inch = 25.4 mm

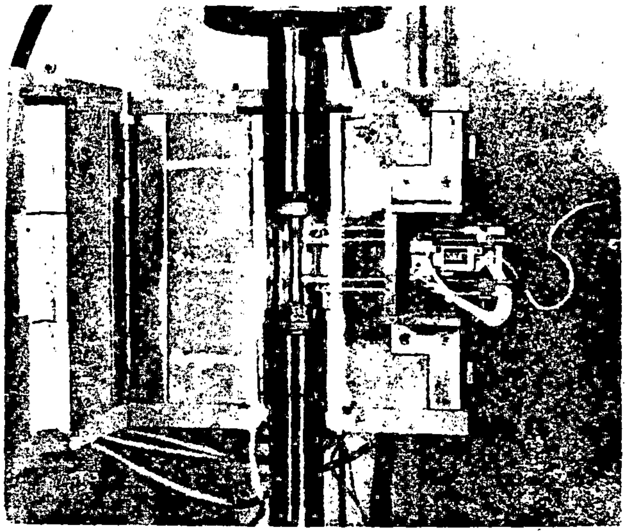

Figure 2. High Temperature Test Set-up.

RESULTS

The cyclic fatigue properties derived from these tests are listed in Table 2.

Table 2

Fatigue Properties for
Classes B, C and U Wheel Steel

Wheel Steel	Temp. °C	σ_f' (ksi)	b	ϵ_f'	c	K' (ksi)	n'
B	25	224	-0.106	0.631	-0.606	243	0.175
B	200	303	-0.156	0.257	-0.595	433	0.263
B	400	196	-0.114	2.590	-0.879	174	0.130
B	600	76	-0.093	0.918	-0.739	77	0.125
C	25	260	-0.111	1.850	-0.721	237	0.154
C	200	222	-0.092	0.147	-0.468	324	0.196
C	400	187	-0.096	8.700	-0.982	152	0.098
C	600	68	-0.075	1.921	-0.828	64	0.091
U	25	180	-0.101	0.528	-0.587	201	0.172
U	200	159	-0.102	0.147	-0.448	246	0.228
U	400	166	-0.118	1.685	-0.771	153	0.153
U	600	81	-0.104	0.762	-0.698	84	0.148

σ_f' -- Fatigue strength coefficient
b -- Fatigue strength exponent
ϵ_f' -- Fatigue ductility coefficient
c -- Fatigue ductility exponent
K' -- Cyclic strength coefficient
n' -- Cyclic strain hardening exponent

(1 ksi = 6.8948 MPa)

The cyclic stress-strain relationship can be expressed by an equation of the following form:

$$\sigma/2 = K' \, (e_p/2)^{n'} \qquad (1)$$

The strain-life and stress-life curves are described by the equations:

$$e/2 = (\sigma_f'/E)(2N_f)^b + e_f'(2N_f)^c \qquad (2)$$

$$\sigma/2 = \sigma_f' \, (2N_f)^b \qquad (3)$$

The tests were run under strain control, therefore the strain amplitude was constant throughout the test. These curves, shown in Figures 3, 4 and 5, exhibit the effect of temperature on fatigue lives.

The stress amplitude changes during the test due to cyclic softening or hardening. The material however, cyclically stabilized after only a few percent of the fatigue life. The value for the stress amplitude was chosen at the half life. These curves are shown in Figures 6, 7 and 8 and also exhibit the effect of temperature on the fatigue lives.

Failure of a test was arbitrarily chosen at a decrease in the tensile stress of 75%.

A comparison between the three wheel materials was made at all the temperatures tested and can be seen in Figures 9 through 16.

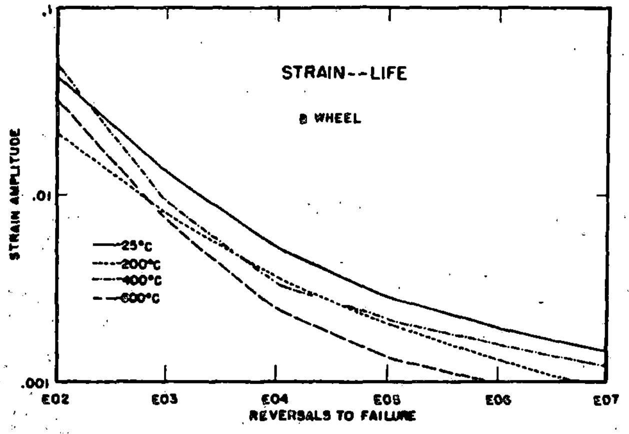

Figure 3. Strain Amplitude-life Curves for B Wheel Material.

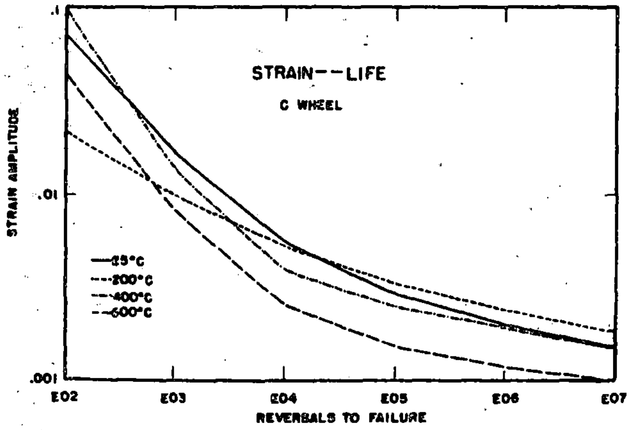

Figure 4. Strain Amplitude-life Curves for C Wheel Material.

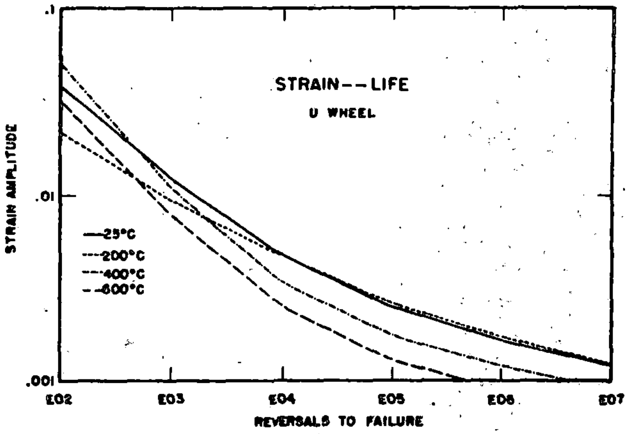

Figure 5. Strain Amplitude-life Curves for U Wheel Material.

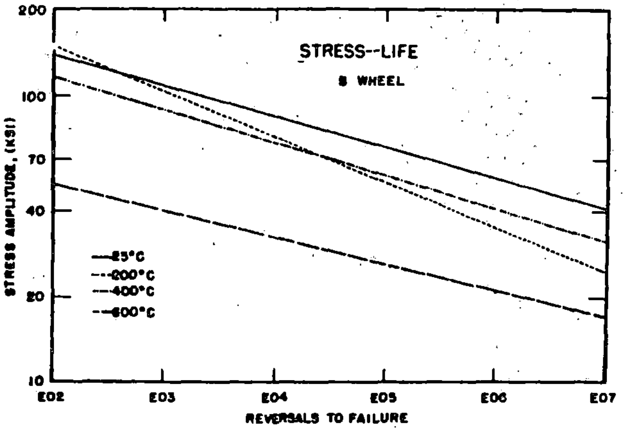

Figure 6. Stress Amplitude-life Curves for B Wheel Material.

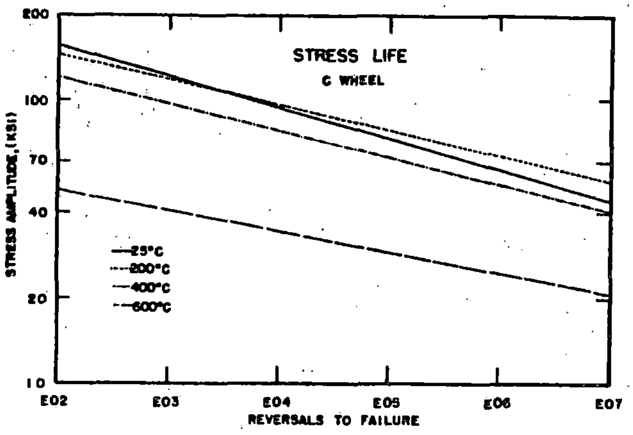

Figure 7. Stress Amplitude-life Curves for C Wheel Material.

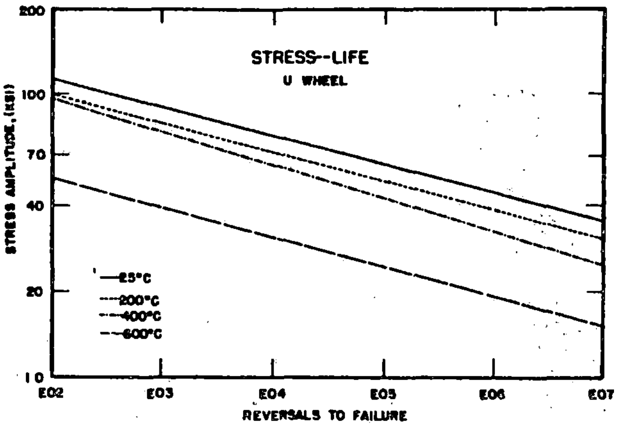

Figure 8. Stress Amplitude-life Curves for U Wheel Material.

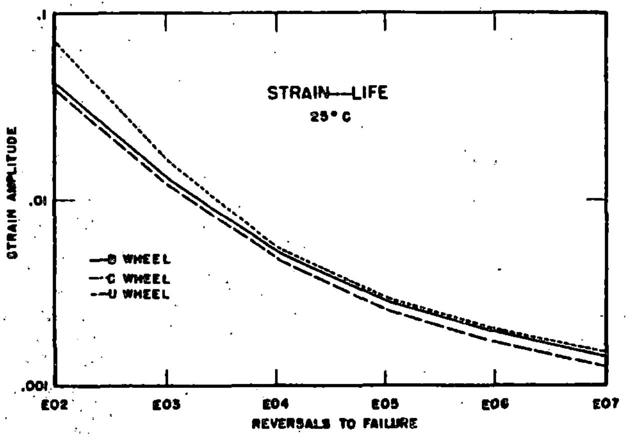

Figure 9. Strain Amplitude-life Curves for B, C and U Wheel Materials at 25°C.

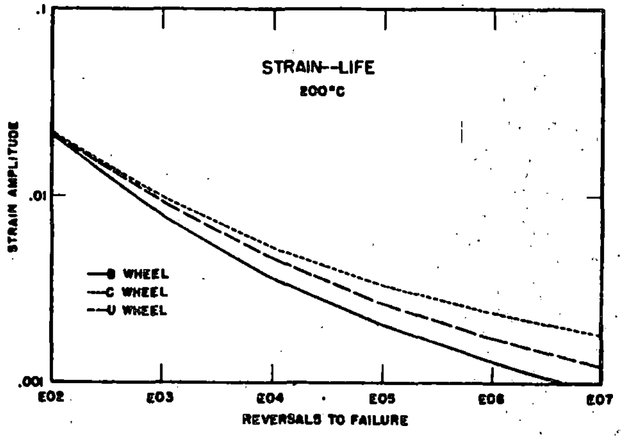

Figure 10. Strain Amplitude-life Curves for B, C and U Wheel Materials at 200°C.

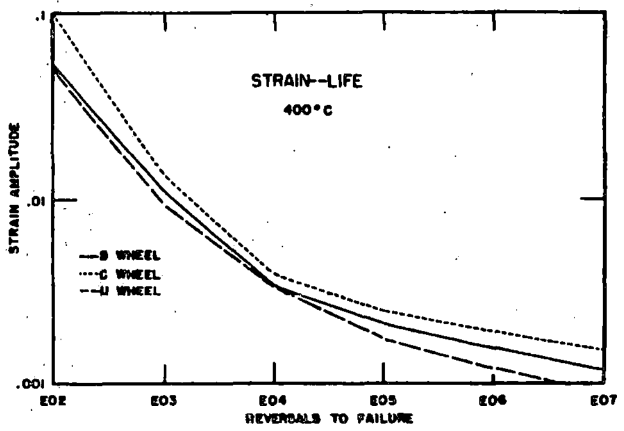

Figure 11. Strain Amplitude-life Curves for B, C and U Wheel Materials at 400°C.

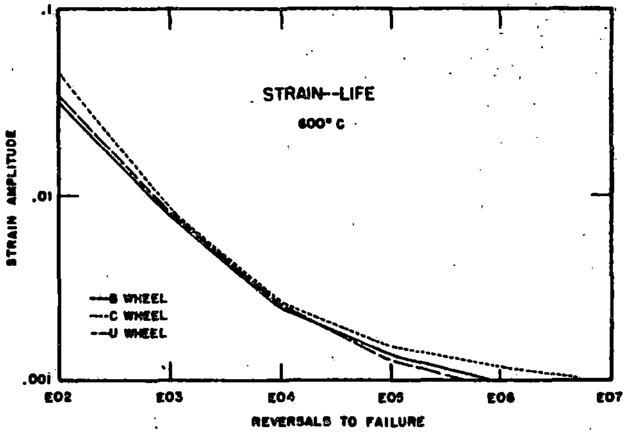

Figure 12. Strain Amplitude-life Curves for B, C and U Wheel Materials at 600°C.

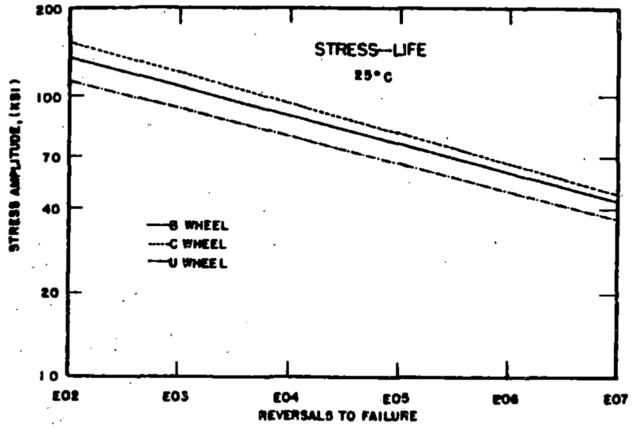

Figure 13. Stress Amplitude-life Curves for B, C and U Wheel Materials at 25°C.

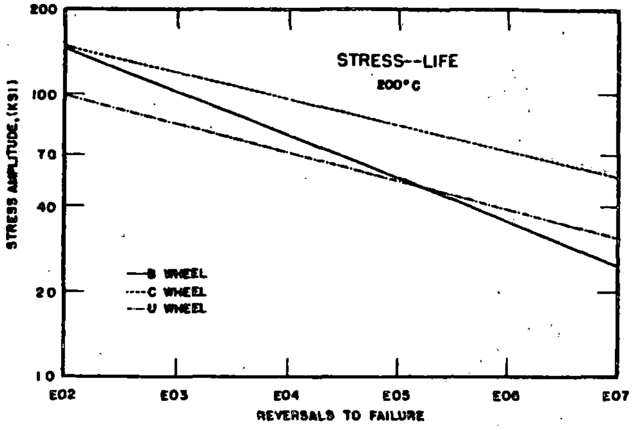

Figure 14. Stress Amplitude-life Curves for B, C and U Wheel Materials at 200°C.

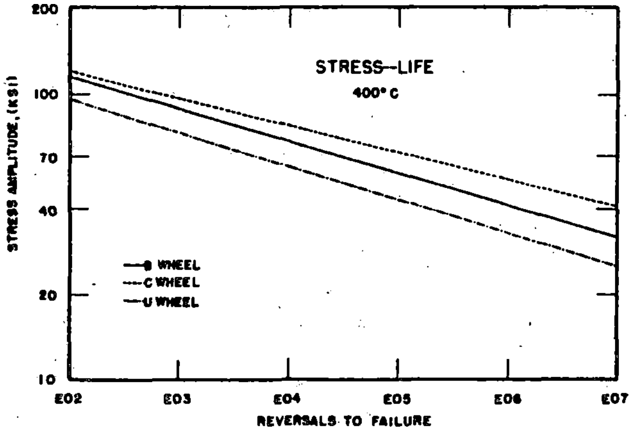

Figure 15. Stress Amplitude-life Curves for B, C and U Wheel Materials at 400°C.

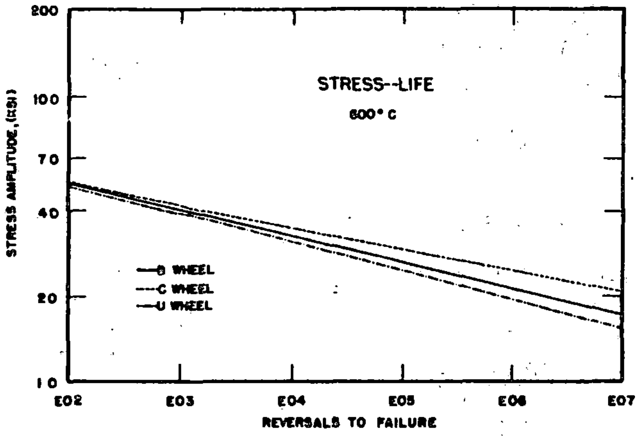

Figure 16. Stress Amplitude-life Curves for B, C and U Wheel Materials at 600°C.

The cyclic properties given in Table 2 are graphically represented in Figures 17 through 22 to show their variation with temperature.

DISCUSSION

As the temperature is increased, strain- and stress-life curves generally show reduced reversals to failure for a given strain or stress range. This is evident in Figures 3 through 8. However, in the low cycle region of the strain-life curves (<1000 reversals), life is independent of temperature. This is not evident on the stress-life curves because of the dramatic decrease in strength of the material beyond 400°C.

For a given cycle, cyclic plasticity increases with temperature and as the ratio of plastic strain to total strain increases, so does the damage per cycle. Even at a constant plastic strain range, the fatigue properties are reduced with an increase in temperature because there is a transition from transgranular to intergranular cracking [4]. This is promoted by creep and oxidation.

The cyclic performance of the materials at a particular temperature is shown in Figures 9 through 16. A general observation is that in the low cycle region, the life is independent of material. This is evident in the strain-life curves, but not so much in the stress-life curves. At longer lives, material performance is more pronounced. It can be seen that the C wheel material has a higher resistance to fatigue than the other two wheel materials. With the exception of the curves at 200°C, it can also be seen that for a given strain or stress range, the B wheel material has a higher resistance to fatigue than the U wheel material.

The variation of the cyclic properties with temperature is shown in Figures 17 through 22. With the exception of Figure 18,

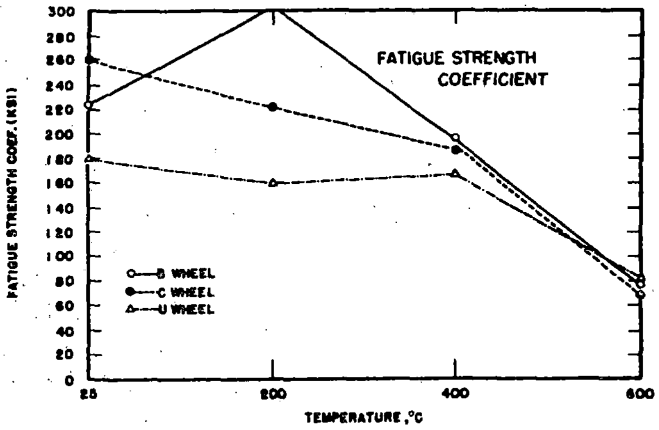

Figure 17. Variation with Temperature of Fatigue Strength Coefficient for B, C and U Wheel Materials.

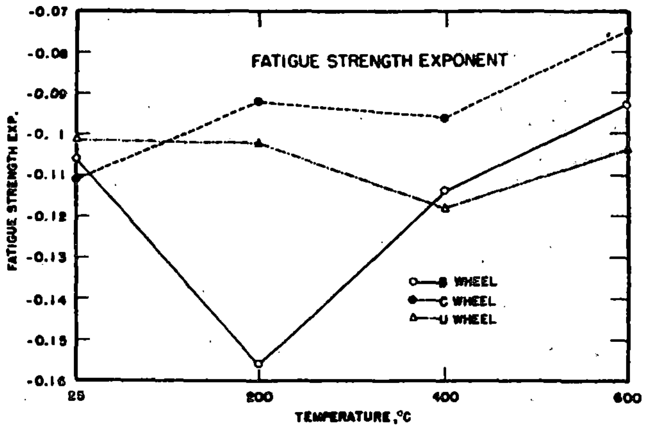

Figure 18. Variation with Temperature of Fatigue Strength Exponent for B, C and U Wheel Materials.

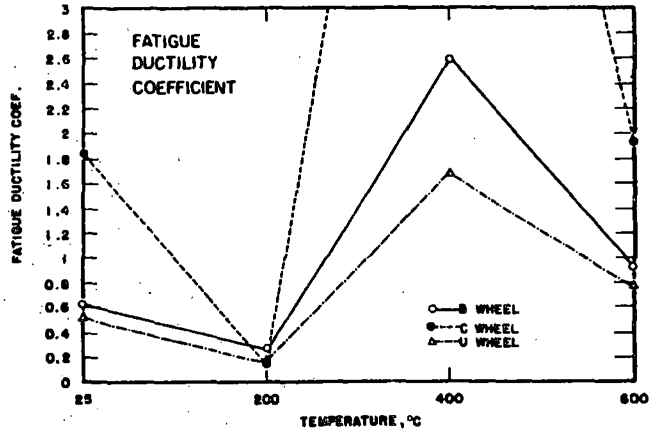

Figure 19. Variation with Temperature of Fatigue Ductility Coefficient for B, C and U Wheel Materials.

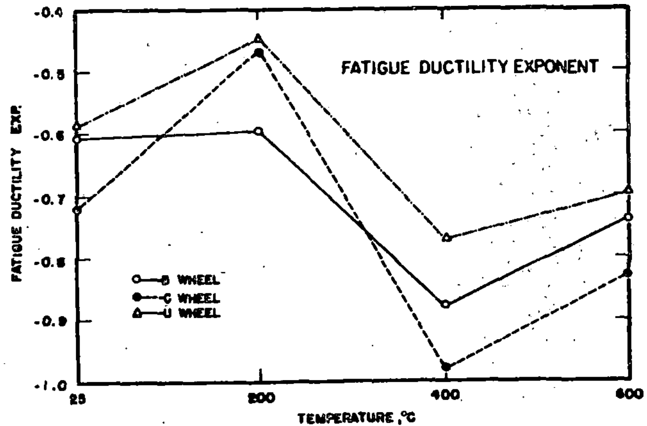

Figure 20. Variation with Temperature of Fatigue Ductility Exponent for B, C and U Wheel Materials.

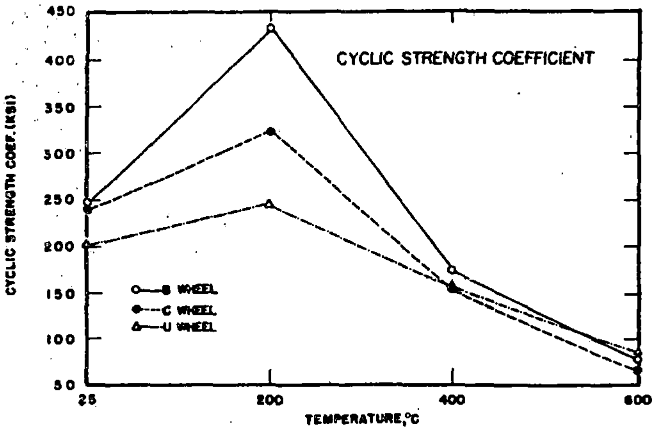

Figure 21. Variation with Temperature of Cyclic Strength Coefficient for B, C and U Wheel Materials.

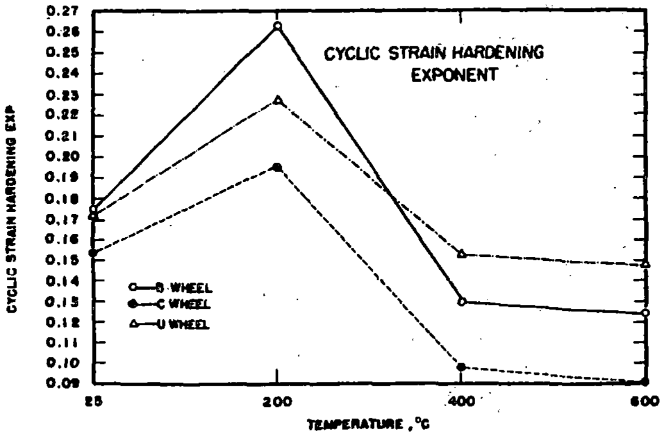

Figure 22. Variation with Temperature of Cyclic Strain Hardening Exponent for B, C and U Wheel Materials.

the trends of the cyclic properties with temperature are evident.

To help understand some of these observations, three factors must be kept in mind:

1. carbon diffusion rate;
2. dislocation density and movement and;
3. recovery.

At test temperatures approaching 200°C, the carbon diffusion rate increases without any significant decrease in material strength. Beyond this temperature the material strength decreases at an accelerated rate. It is the interaction between interstitial carbon atoms and dislocations that control the strengthening process. This can also be referred to as strain aging. As the test temperature exceeds about 540°C, the recovery temperature, strain aging is no longer a factor. This is due to the accelerated thermal recovery. However, creep and hot working are major factors at these temperatures.

CONCLUSIONS

1. Cyclic fatigue lives at all temperatures tested converged at strains exceeding one percent.
2. At strains less than one percent, lives are considerably reduced as the test temperature is increased.
3. Differences in material performance is more pronounced at longer lives (low strain amplitudes) than at shorter lives (high strain amplitudes).
4. The heat treated wheel materials (C and B) exhibit a higher resistance to fatigue than the unheat-treated U wheel material.
5. The higher carbon C material shows better resistance to fatigue than the lower carbon B material.

ACKNOWLEDGMENTS

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APPENDIX 4.2

CRACK ARREST TESTING OF CLASS U AND CLASS C RAILROAD WHEEL STEELS

CRACK ARREST TESTING OF CLASS U AND CLASS C RAILROAD WHEEL STEELS

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ABSTRACT

The crack arrest fracture toughness (K_{Ia}) properties of two classes of railroad wheel steels were examined. Results indicate that the heat-treated Class C steel had a slightly higher K_a value than the untreated Class U steel at room temperature. At higher temperatures, this difference increased because the Class C steel exhibited an increase in crack arrest toughness with higher test temperatures, while the Class U steel K_{Ia} value remained essentially constant.

A calculation for critical flaw size tolerance, based on K_{Ia} values, suggested that Class C wheels could tolerate larger flaws than Class U wheels prior to catastrophic failure.

Attempts at correlation to actual wheel failure data suggested that further refinement to theory was necessary to adequately predict the behavior of thermal crack propagation. A possible modification employing crack initiation toughness in conjunction with crack arrest toughness is discussed.

INTRODUCTION

The railroad wheel is subjected to stresses arising from both mechanical and thermal loads. Mechanical loads include both vertical and lateral forces seen by the wheel under normal service conditions, and thermal loads are encountered due to the frictional heating created during brake applications. As the wheel is heated during braking, the rim of the wheel undergoes thermal expansion. Cooler underlying material nearer the center of the wheel restricts this expansion. This condition results in tensile stresses in the inner portion of the rim, and compressive stresses in the surface region while the rim is hot. The elevated temperatures which arise in the wheel during braking can significantly reduce the yield strength of the metal, thereby promoting permanent deformation in the outer regions of the rim. When the wheel cools to ambient temperatures, the residual stress state consists of tensile stresses in the outer regions of the rim, with a stress gradient extending radially inward, achieving compressive stresses in the inner portions of the rim. The combination of cooler temperatures and tensile residual stresses can then result in thermal cracking.

The calculation of such stress gradients has been documented for various braking conditions and wheel designs [1,2,3,4]. Although specific gradient values may differ, the general existence of tensile residual stresses in the circumferential direction of the wheel rim has been shown to be a result of such thermally-induced loading. Further, actual service investigations and dynamometer trials have suggested that the initiation of thermal cracks is an unavoidable condition [5].

Ripling and Crosley [6] have suggested that the growth of such thermal cracks in the rim of railroad wheels is governed by the crack arrest fracture toughness, K_{Ia}, rather than the crack initiation fracture toughness, K_{Ic}. They have stated that the crack driving force, K, will cause cracks to propagate until $K_{Ia} > K$, at which point crack growth will be arrested.

The following study was undertaken to determine the crack arrest fracture toughness behavior, as a function of temperature, for both untreated and rim heat-treated railroad wheels.

CRACK ARREST TOUGHNESS TESTING

Material Composition and Properties

Two wheel steels were studied in this investigation. The compositions of both the untreated Class U steel and the rim heat-treated Class C steel are shown in Table 1. It should be noted that the compositions of the two steels were chosen to be roughly identical in order to avoid effects introduced by differences such as carbon content. Both steels were virtually fully pearlitic, with the difference between the two being a much finer interlamellar spacing in the Class C steel than the Class U steel.

The tensile properties of the two steels were also determined over the range of test temperatures investigated. These properties are listed in Table 2. The values shown were averaged from two test results at each test temperature.

Specimen Design and Orientation

The specimen design used for the crack arrest tests is shown in Figure 1. Not shown in this figure are the removable knife edges which were attached to the specimens by four machine screws. This specimen design allowed two adjacent specimen blanks to be machined from one portion of wheel rim. The orientation of the specimens relative to the wheel configuration is shown in Figure 2. Although the crack propagation direction of these specimens is not the true radial direction of thermal crack extension, the crack plane is oriented similar to that of thermal rim cracks, and the proximity to the tread surface made this the most favorable specimen orientation. The specimens were tested in the as-machined condition, without the introduction of a brittle weld at the notch tip.

Crack Arrest Test Procedure

The procedure used in this study for the crack arrest tests was documented by Crosley and Ripling [7]. Simply stated, the test specimens were wedge-loaded in an appropriate test fixture until rapid crack extension occurred. The test configuration for the crack arrest testing is shown schematically in Figure 3. The load applied to the wedge and the notch opening displacement were autographically recorded during the test, and specimen temperature was determined with a thermocouple spot-welded directly to the specimens. Crack jumps were quite pronounced for all specimens tested, both on the test record of load-displacement and by audible detection. Specimens were heat-tinted following the test at approximately 450°C for 1-2 hours. The specimens were then submerged in liquid nitrogen, broken open to reveal the crack presence, and appropriate measurements were made for data reduction.

For a test result to be considered a valid measure of crack arrest fracture toughness, three requirements must be fulfilled. First, the unbroken ligament in the specimen must exceed 10% of the original specimen width. Second, the unbroken ligament must exceed the value:

$$(4/\pi)[K_f/(\sigma_{ys}+\sigma_o)]^2,$$

where: K_f is the conditional stress intensity at arrest,
σ_{ys} is the 0.2% offset yield strength at temperature,
and σ_o is a strain rate correction factor = 30ksi (205 MPa).

These requirements must be fulfilled to justify using linear elastic fracture mechanics for data reduction. Finally, the specimen thickness, B, must be greater than or equal to the value:

$$1.25[K_f/(\sigma_{ys}+\sigma_o)]^2$$

This requirement must be met to ensure the condition of plane strain.

Test Results

The test results for the Class U wheel steel are shown in Figure 4. The results are shown with a linear regression plotted for the valid data points, along with a standard deviation band. This line indicates a slight decrease in crack arrest fracture toughness as temperature increases, although the lower value at 75°C probably weighs the linear analysis too heavily. Therefore, an apparently more reasonable estimate of the Class U steel behavior is that the untreated steel is fairly insensitive to test temperature.

The equation of the line shown on the graph is:

$$K(\text{ksi-in}^{1/2}) = -0.062\ T(^\circ C) + 43.53 \quad (1)$$

On virtually all specimen fracture surfaces, the crack front did not proceed in a completely uniform fashion. That is, islands of apparently uncracked material were discovered within the perimeter of the crack front. The extent of this irregularity in the crack front progression varied between specimens, but no correlation was found to exist between a greater severity of this behavior with an increased inability to meet the validity requirements. The reason for the clustering of points not meeting the validity requirements at two particular test temperatures (50°C, 100°C) is not known at this time. Specimens which did not meet validity requirements typically failed the second and third requirements, meaning that they did not satisfy linear elastic fracture mechanics limitations and/or did not meet the requirements of a plane strain condition.

The Class U steel experienced greater than a 17% reduction in yield strength over the range of test temperatures, with the ramification being an increasingly difficult ability for this specimen geometry to conform to validity requirements as test temperature increased. The use of thicker specimens in repeat tests should, therefore, provide a higher frequency of valid data points.

Figure 5 shows the crack arrest fracture toughness behavior of the Class C wheel steel. The data is plotted in a similar manner to the Class U data, with a linear regression and standard deviation band shown on the plot. Fewer invalid data points were encountered, and the linear analysis appears to be fairly evenly representative of the scatter in data. The plot shows a tendency for increasing crack arrest fracture toughness with test temperature for this pearlitic quenched and tempered steel.

The equation of the linear regression describing this behavior is:

$$K(\text{ksi-in}^{1/2}) = 0.158\ T(^{\circ}\text{C}) + 56.26 \quad (2)$$

The appearance of unbroken islands of material on the specimen fracture surfaces was also discovered in this steel after testing, but as a whole, no conclusive correlation between this phenomenon and the ability to meet validity requirements was found to exist. The only instance when the appearance of the crack front correlated directly with an ability to meet validity requirements was for the Class C specimens tested at 100°C. Of the six specimens tested, three were determined to give invalid results. These three specimens also exhibited a much more pronounced tendency to leave unbroken regions of material within the boundary of the crack front. This suggests that a refinement in the data reporting technique might result in a more accurate definition of K_a values which conform to validity requirements. For example, data collection which utilized area measurements of crack surfaces instead of lengths might provide a different interpretation of some of the data points presented in this paper. Such measurements are planned for a future reevaluation of the data, but have not been performed to date.

The appearance of the fracture surface on a specimen from each class of steel is shown in Figure 6. Both steels exhibited cleavage type failure over the entire fracture surface. The general appearance of the Class C specimen fracture surfaces differed from those taken from the Class U wheel due to the refinement of the microstructure achieved in the heat treating process. Specifically, the Class U specimens appeared to be notably shinier than the Class C specimens, because the cleavage facets on the fracture surfaces were significantly larger. The tendency to leave unbroken islands of material or to produce uneven crack fronts, however, was not limited to either steel. Both specimens shown are from valid tests performed at 25°C.

A general observation regarding the occurrence of unbroken regions of material is that adjacent to these areas, the crack deviates from continuing in one plane. This difference in "plateau" height was quite pronounced in some instances, but this behavior was not accompanied by a change in fracture morphology when going from one side of the plateau to the other.

The general fracture surface appearance of specimens from the Class U and Class C steels are shown in Figures 7 and 8, respectively. These figures show the fractographic appearance in regions of both early crack growth and approximate crack arrest, as viewed on the scanning electron microscope (SEM). No distinct demarcation was found to reveal the exact presence of the arrested crack front on either specimen. The effect of a grain size difference is again visible on these specimens, with the finer-grained Class C steel exhibiting more facets on the fracture surface. It should be noted, however, that for each class of steel, a pronounced change in fracture morphology before and after crack arrest was not evident. A more critical review of crack morphology is planned for these specimens, but data is currently not available for inclusion in this paper.

Flaw Tolerance Analysis

The stress intensity factor, K, may be thought of as the crack driving force. The most general definition of K is:

$$K = Y\sigma\sqrt{\pi a} \qquad (3)$$

where Y = a shape factor dependent on the dimensions of both the structure containing the flaw and the shape of the crack,
σ = stress, and
a = crack depth.

For the scope of this paper, the shape factor, Y, was chosen to be equal to unity.

The stress intensity values at which a crack will arrest, K_{Ia}, may then be used to calculate the critical flaw size, below which the crack should not propagate. Figure 9 shows the calculated critical flaw size for Class C and Class U steels at 25°C over a range of stress values. The data used for calculating critical flaw size employed the crack arrest toughness values for these two steels at room temperature. These calculations are not directly applicable to real-life situations over the entire stress range for both steels. At lower stress values, the graph shows that the Class C steel would theoretically tolerate a flaw size of over two inches in size. This is probably not accurate, as a flaw of this size in the rim of a railroad wheel would be very likely to continue growing into the plate of the wheel. Flaws of this size are considered to be equivalent to full wheel failure, and therefore to predict tolerance of a crack of this magnitude would not be realistic.

The Class U steel data for the higher stresses shown is also somewhat tentative, as this data approaches the yield strength of the material. The stress at which the in-service extension of existing flaws actually occurs is not accurately known, but it is reasonable to assume that a wheel having a flaw and being subjected to stresses approaching the yield strength will undergo significant damage. Therefore, characterizing the flaw tolerance of Class U steel at these stresses is probably non-conservative at best.

The graph does show, however, that based on crack arrest toughness, the heat-treated Class C steel could tolerate a larger flaw in the wheel structure at a given stress level than the untreated Class U steel.

If the K_{Ia} values at higher temperatures is used, the curves relating flaw size to stress would shift accordingly. That is, the Class C steel was shown to have a higher K_{Ia} value at higher temperatures. This would mean a larger flaw size could be tolerated at similar stress levels, if the steel was at higher temperatures. Another observation this suggests is that Class C wheels would be better off running at slightly elevated temperatures than would Class U wheels, since the data would indicate that larger flaws could be tolerated.

Because of the shallow slope in the relationship between K_{Ia} values and temperature, the flaw size tolerated by the Class U steel would change by a much smaller increment. In fact, if the downward trend in crack arrest toughness value is actually overly affected by the one particularly low value reported and should instead be horizontal, the critical flaw size tolerated at any stress level would appear to be independent of temperature.

DISCUSSION

The crack arrest toughness value has been suggested to be the controlling parameter governing the propagation of thermal cracks in railroad wheels. This property was determined for two classes of steel used in wheels, namely, an untreated Class U wheel steel and a quenched and tempered Class C wheel steel.

Using only those data points which conformed to the validity requirements associated with this test procedure, the Class U steel exhibited essentially no dependence of crack arrest fracture toughness for the test temperatures studied, while the K_{Ia} values determined for the Class C steel increased with an increase in test temperature. The reason for this contrast in behavior is possibly related to microstructural effects. The Class U steel had a much coarser pearlitic structure than the heat-treated Class C steel. This suggests that the finer interlamellar structure present in the heat-treated steel offered a more resistant path to crack propagation, resulting in an increase in the crack arrest fracture toughness value.

A simple analysis to calculate the critical flaw size which could be tolerated by the two steels for crack arrest was performed. The Class C steel was shown to tolerate larger flaws than the Class U steel at a given stress level. Further, the Class C steel, exhibiting a temperature dependency for K_{Ia} values, could tolerate larger flaw sizes at higher temperatures; or more accurately, arrest the growth of larger flaws. This behavior is not expected of the Class U steel over the temperature range studied, based on the data in this report. Since the data for the Class U steel becomes so scattered at increasing temperatures and also exhibits an increase in the amount of invalid data points, a refinement in the test procedure employing thicker specimens might lessen the frequency of invalid tests, and possibly reveal an increase in crack arrest fracture toughness only evident at higher temperatures than those studied here. That is, the difference in behavior may reflect a change in transition temperatures between the steels studied.

Both classes of steel exhibited the occurrence of unbroken islands of material within the boundary of the crack front. This behavior is not readily explained, and in general, does not correlate with the ability of test data to conform to validity requirements for plane-strain fracture or behavior consistent with linear elastic fracture mechanics. The effect of underlying microstructure in relation to this phenomenon remains to be investigated. The use of thicker specimens in an attempt to obtain a higher frequency of valid data points might also yield more insight into this behavior.

The correlation of crack arrest to documented wheel failures is warranted at this point.

Opinsky has analyzed data for wheel failure incidents [8]. The vast majority of wheel failures were characterized by the appearance of thermal crack growth, initiating at various points on the rim surface, which had progressed to some critical crack size and caused full failure of the wheel. This crack growth was typically characterized by an average crack size of about 3/4", and experienced unstable crack growth at stresses estimated to be on the order of 30 ksi. This data shows good correlation with the critical flaw size predicted in Figure 9 for Class U steel, suggesting that the stress intensity for critical flaw tolerance, based on crack arrest toughness, was fairly representative of actual experience. It should be noted, though, that the crack arrest toughness value for Class U steel used in this study is quite close to the crack initiation toughness reported for the same steel [7]. The calculated critical flaw sizes for Class C wheels, however, were larger than those actually measured on failed Class C wheels.

Two areas of discrepancy are noted which question the applicability of solely using crack arrest properties in an analysis of the thermal cracking problem. First, the mode of cracking for the virtually all real failures (both wheel classes) was apparent fatigue crack propagation up to some critical size, and not an arrested cleavage crack which saw subsequent unstable growth. If crack arrest toughness were truly the parameter which controls the behavior of thermal cracks in wheels, one would expect to find a larger population of cleavage cracks which exhibited temporarily arrested behavior along their crack paths. This suggests, at least, that the stress intensity at a growing crack in a railroad wheel rim is subject to additional factors, possibly dynamic in nature, which preclude the arrest of the crack in most cases. Second, the crack sizes present in Class C wheels prior to catastrophic failure were found to be closer to crack sizes in Class U wheels than predicted by the critical flaw calculation based on K_a values. Opinsky's data suggests, though, that there is a tendency for the failure of Class C wheels to occur at higher stresses for a given flaw size as compared to Class U wheels.

From Carter and Caton's work [1], the crack initiation toughnesses for both classes of wheels was determined to be quite similar, being dependent on carbon content and not heat treatment. Keeping this in mind and reviewing the actual wheel failure data, it seems likely that a combination of both crack toughness and arrest properties is actually governing the behavior of thermal cracks in wheels. Specifically, the ratio of K_{Ic} to K_a for both steels is not a constant term, but instead is a larger value for Class U wheel steel.

A physical interpretation of this might be that a greater number of cracks could initiate and grow to critical size in Class U wheels than in Class C wheels for similar stresses. Then, if crack arrest is only partially effective in retarding crack growth in actual wheels, the greater crack arrest toughness in Class C wheels could conceivably be the mechanical property which allows the Class C wheels to withstand more dynamic aspects of stress loadings.

The idea of viewing crack arrest in railroad wheels as only a partially effective mechanism for modeling crack growth might also suggest that crack patterns assumed to be strictly fatigue in nature actually include some points of crack arrest and re-initiation. Since crack arrest in laboratory specimens was difficult, if not impossible, to identify through fracture mode changes, it seems reasonable to assume that a small crack jump and arrest in the life of a wheel rim crack may be quite undetectable in service failures undergoing visual inspection, particularly if fatigue processes before and after such a jump/arrest continue to rub the fracture surfaces together.

CONCLUSIONS

The results of this study indicate that the crack arrest fracture toughness of heat-treated Class C wheel steel is somewhat higher than untreated Class U steel at room temperature, and that this difference increases with temperature.

A dependency of K_{Ia} values on test temperature was noted for Class C steel, while Class U steel appeared fairly insensitive to temperature. This difference appears to be related to the effect of interlamellar pearlite spacing on crack propagation in the steel.

Based solely on the K_{Ia} data, it may also be concluded that rim heat-treated wheels could arrest larger thermal cracks, prior to unstable propagation, than untreated wheels. The critical flaw size tolerated would increase with temperature for the Class C wheels. This behavior would not appear in Class U wheels below 100°C.

A comparison of actual wheel failure data revealing critical flaw size prior to full failure showed fairly good agreement for Class U data, but suggested that predictions for critical flaw size tolerance for the Class C wheels based on K_a values were too large.

Considering that Class U wheels appear to fail more frequently than Class C wheels, and coupled with the fact that in all wheel classes, pronounced crack arrest is seemingly rare, it is suggested that crack arrest data be modified with some correction factor to more accurately reflect actual service lives. This factor could be based on the ratio of crack initiation fracture toughness to crack arrest fracture toughness.

ACKNOWLEDGEMENTS

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Table 1.
Chemical Composition of Class U and C Wheel Steels (wt. %)

Element	Class U	Class C
Carbon	0.70%	0.72%
Manganese	0.78	0.78
Phosphorus	0.011	0.029
Sulfur	0.032	0.036
Silicon	0.27	0.27
Nickel	0.04	0.02
Chromium	0.05	0.06
Molybdenum	0.01	0.01
Copper	0.04	0.01

Table 2.
Tensile Properties of Class U and C Wheel Steels

	Temperature (deg C)					
	-25	0	25	50	75	100
Class U Steel						
Yield Strength (ksi)	67.14	58.77	59.32	57.92	55.77	55.22
Ultimate Tensile Strength (ksi)	139.3	127.2	125.5	120.9	117.0	114.6
Reduction in Area (%)	13.6	9.9	12.3	13.6	17.8	16.4
Class C Steel						
Yield Strength (ksi)	107.5	105.5	109.7	105.4	108.2	106.2
Ultimate Tensile Strength (ksi)	173.9	168.1	170.8	163.3	166.0	164.7
Reduction in Area (%)	17.0	22.7	28.3	22.3	24.3	23.3

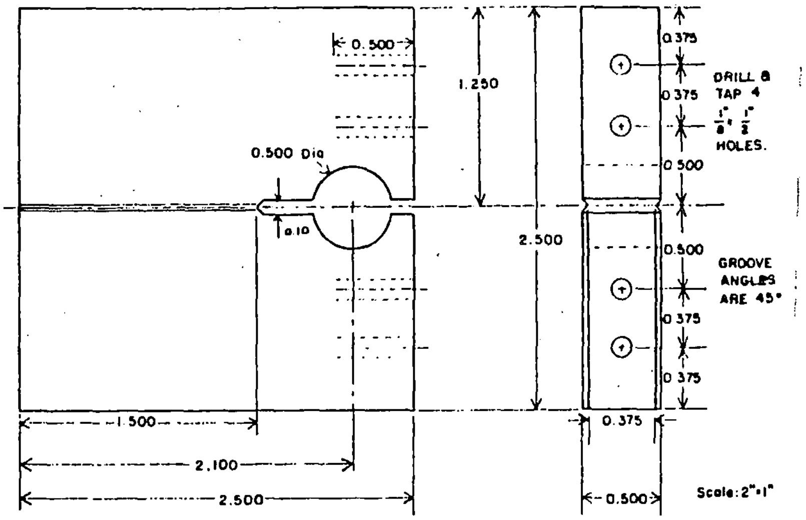

Figure 1. Specimen Used for Crack Arrest Tests.

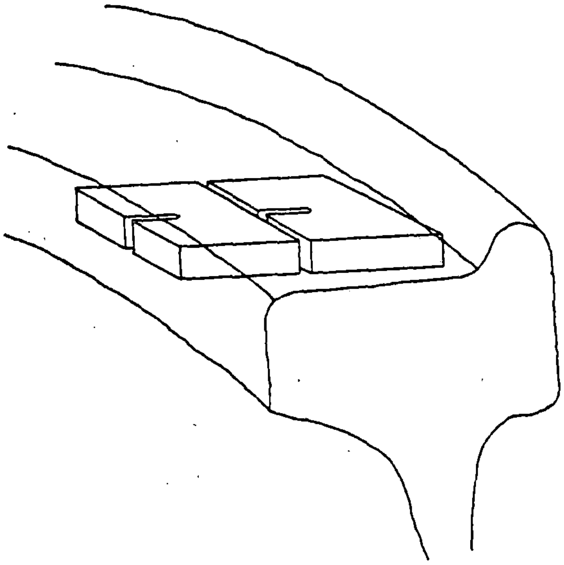

Figure 2. Orientation of Crack Arrest Specimens in Wheel Rim.

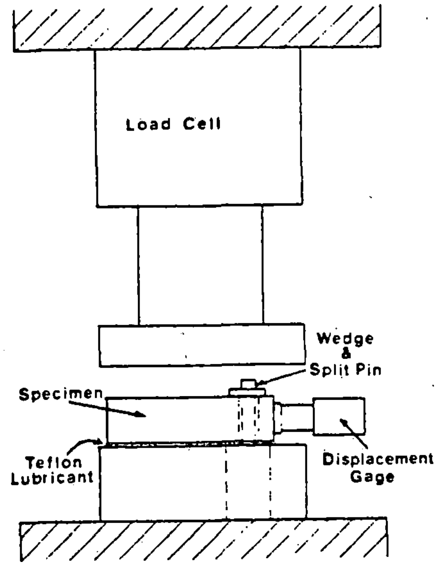

Figure 3. Schematic of Crack Arrest Test.

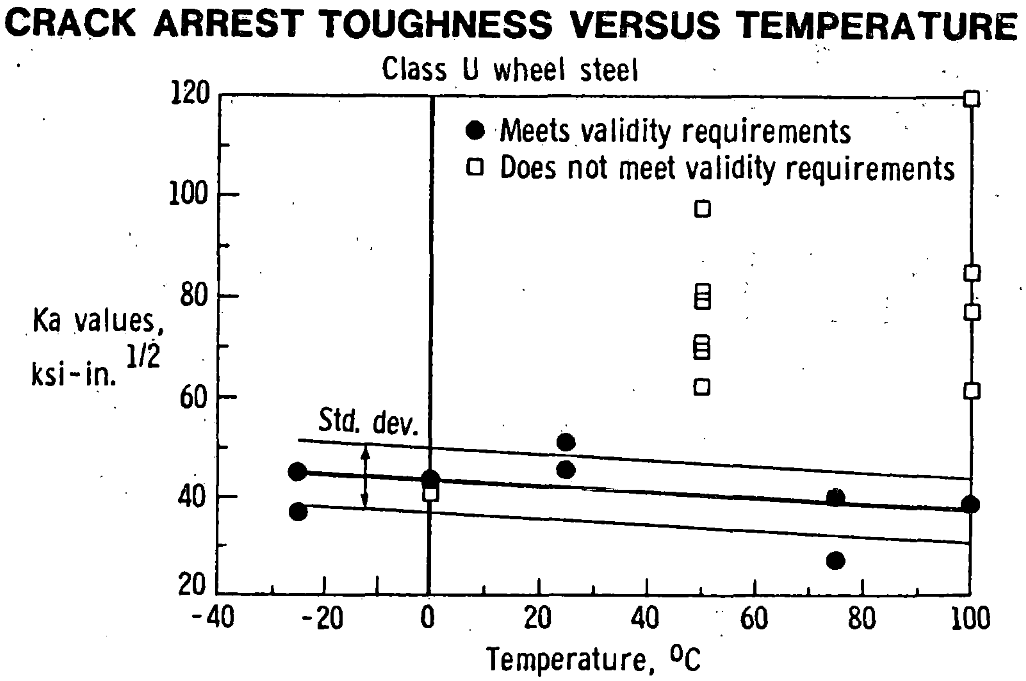

Figure 4. Crack Arrest Fracture Toughness Versus Temperature for Class U Steel.

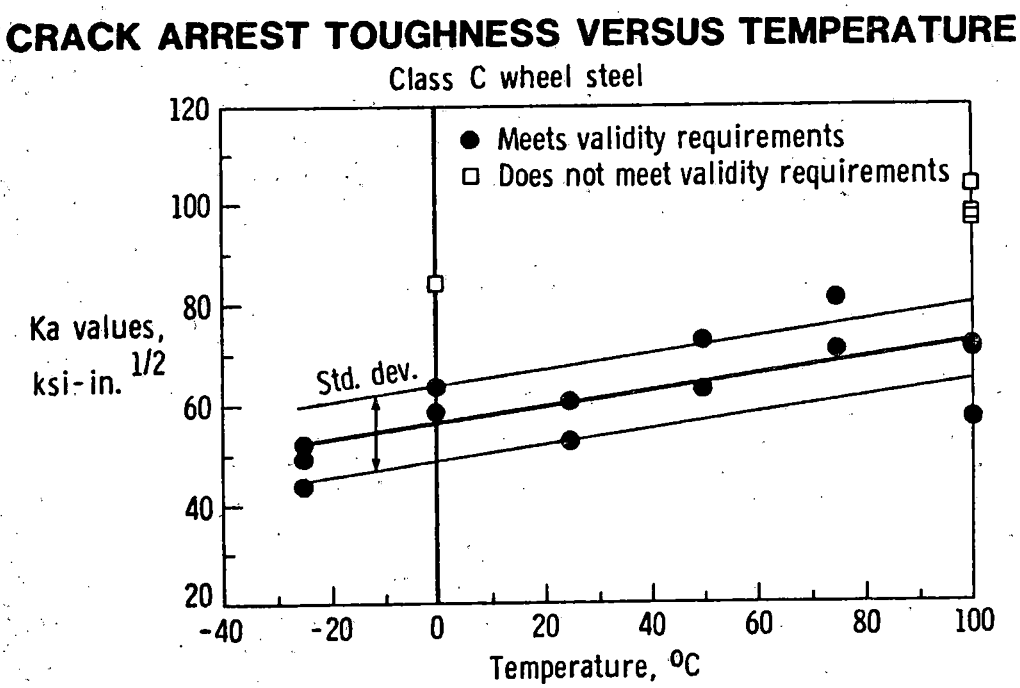

Figure 5. Crack Arrest Fracture Toughness Versus Temperature for Class C Steel.

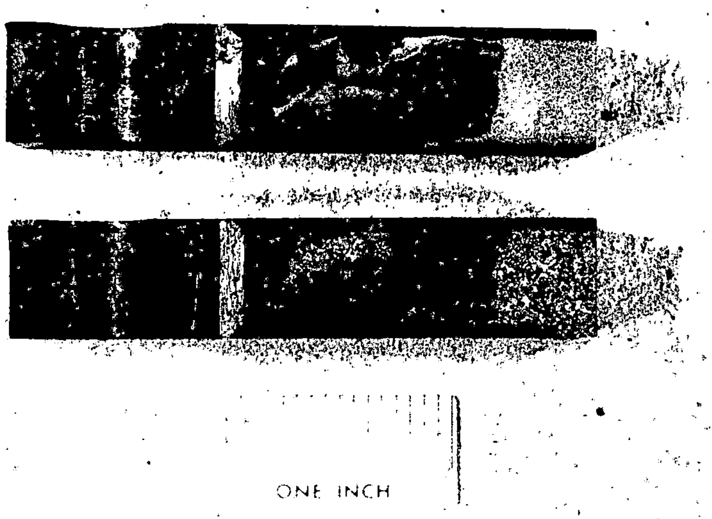

Figure 6. General Fracture Appearance of Crack Arrest Specimens, from Class C (top) and Class U.

Figure 7. Fracture Surface of Class U Crack Arrest Specimen, Before (left) and After Crack Arrested; Mag. 500X.

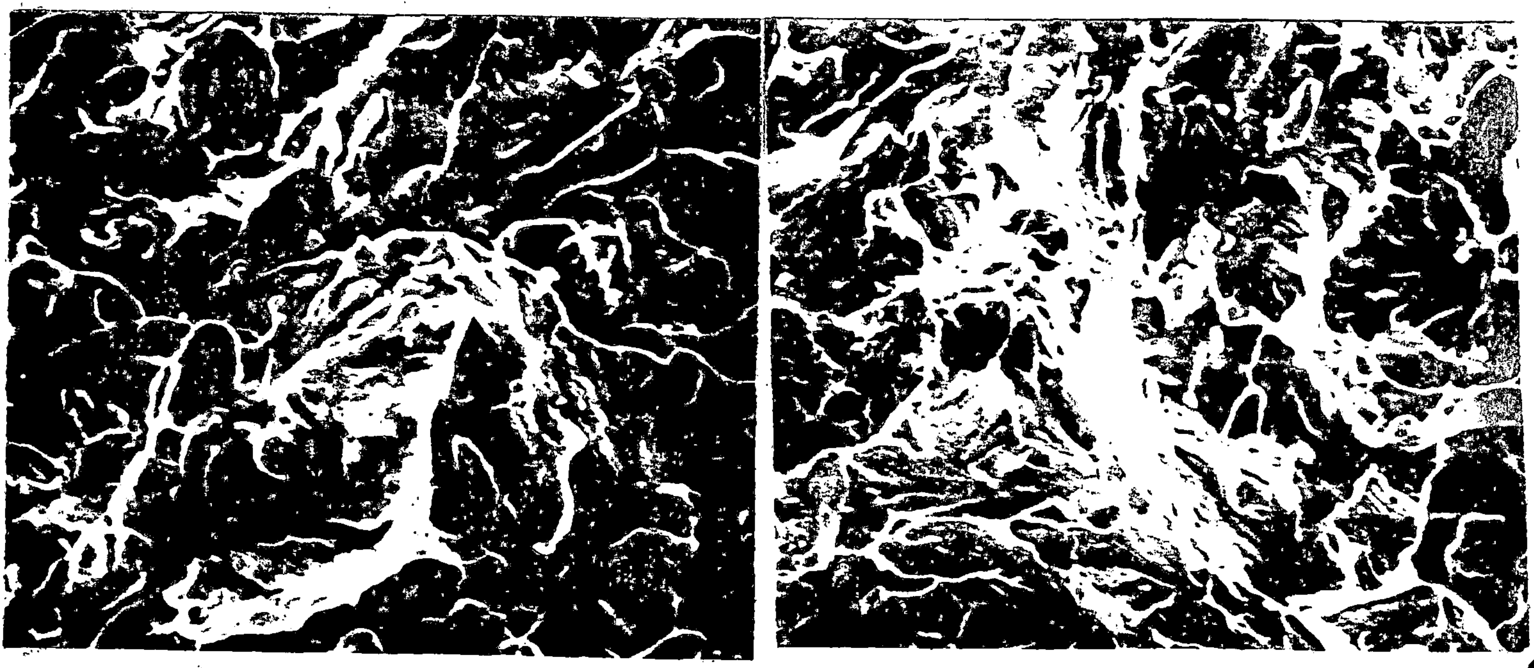

Figure 8. Fracture Surface of Class C Crack Arrest Specimen, Before (left) and After Crack Arrested; Mag. 500X.

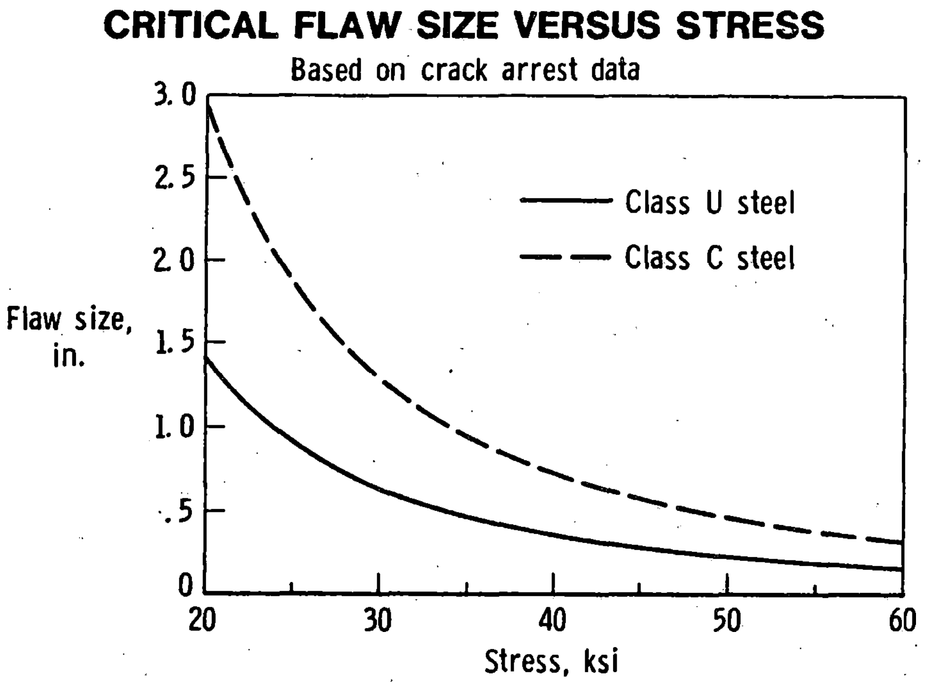

Figure 9. Critical Flaw Size Vs. Stress For Wheel Steels, Based on Crack Arrest Data.

APPENDIX 4.3

MASTER DATA BASE OF SAW-CUT WHEELS

APPENDIX 4.3

MASTER DATA BASE OF SAW-CUT WHEELS
(GREATER THAN 4-INCHES DISCOLORATION BOTH SIDES)

.	FROM	DESIGN 1=Low Str 2=High *	DISCOLORATION			CLOSED	MAX. OPEN.	MIXED			CLASS	H-T	FLANGE HEIGHT	FLANGE THICK.	RIM THICK.	RR ID	REF.
			FRT	BACK	CODE 89			C.O.1	C.O.2	MIN							
1	SRy	1	4.50		Y		0.009	0.70	3.4	0.0027	CJ-33	U	0.75			1	AD HOC
2	SRy	1	5.00		Y		0.018	0.60	2.6	0.0018	CJ-33	U				2	AD HOC
3	SRy	1	3.00		N		0.006	0.30	3.6	0.0038	CJ-33	U				3	AD HOC
4	SRy	2	3.75		N		0.999				J-33	U				4	AD HOC
5	SRy	1	4.00		Y		0.001	0.30	5.0	0.0022	CJ-33	U				5	AD HOC
6	SRy	1	0.00		N	1					CJ-33	C				6	AD HOC
7	SRy	1	0.00		N		0.024	0.40	2.2	0.0007	CH-36	U				7	AD HOC
8	SRy	1	4.00		Y		0.010	0.30	3.1	0.0016	CJ-33	U				8	AD HOC
9	SRy	1	4.50		N	1					CJ-33	C				9	AD HOC
10	SRy	2	0.00		N	1					H-36	C				10	AD HOC
11	SRy	1	0.00		N	1					CJ-33	C				11	AD HOC
12	SRy	1	0.00		N		0.008	0.50	3.2	0.0020	CJ-33	U				12	AD HOC
13	SRy	1	0.00		N	1					CJ-33	U				13	AD HOC
14	SRy	1	5.00		Y		0.003	0.50	5.4	0.0040	CJ-33	U				14	AD HOC
15	SRy	1	5.00		Y		0.006	0.50	3.2	0.0014	CJ-33	U				15	AD HOC
16	SRy	1	4.00		Y	1					CJ-33	C				16	AD HOC
17	SRy	2	3.00		N	1					H-36	C				17	AD HOC
18	SRy	1	4.00		Y		0.005	0.40	3.8	0.0027	CJ-33	U				18	AD HOC
19	SRy	1	0.00		N		0.022	0.30	2.7	0.0009	CH-36	U				19	AD HOC
20	SRy	2	3.50		N		0.016	0.70	2.2	0.0010	CH-36	U				20	AD HOC
21	SRy	1	0.00		N		0.015	0.30	2.5	0.0012	CJ-33	U				21	AD HOC
22	SRy	1	5.00		Y	1					CJ-36	C				22	AD HOC
23	SRy	2	3.50		N		0.002	0.50	4.1	0.0023	J-33	U				23	AD HOC
24	SRy	1	0.00		N		0.035				CH-36	U				24	AD HOC
25	SRy	1	3.50		N		0.011	0.30	3.0	0.0018	CJ-33	U				25	AD HOC
26	SRy	2	3.50		N		0.031				CH-36	U				26	AD HOC
27	SRy	2	4.50		Y		0.015	1.20	3.0	0.0013	H-36	U				27	AD HOC
28	SRy	1	0.00		N		0.007	0.00	3.6	0.0027	CJ-33	U				28	AD HOC
29	SRy	2	3.00		N		0.040				J-33	U				29	AD HOC
30	SRy	1	4.50		Y		0.014	1.20	2.9	0.0014	CJ-33	U				30	AD HOC
31	SRy	1	4.00		Y		0.018	0.30	2.9	0.0014	CH-36	U				31	AD HOC
32	SRy	2	3.00		N	1					J-36	C				32	AD HOC
33	SRy	1	4.50		Y		0.001	0.50	6.2	0.0047	CH-33	U				33	AD HOC
34	SRy	1	4.50		Y		0.008	0.40	3.1	0.0018	CJ-33	U				34	AD HOC
35	SRy	2	3.50		N		0.031				CH-36	U				35	AD HOC
36	SRy	2	5.00		Y		0.999				H-36	U				36	AD HOC
37	SRy	1	3.00		N		0.007	0.50	3.5	0.0020	CJ-33	U				37	AD HOC
38	SRy	2	5.50		Y		0.999				H-36	U				38	AD HOC
39	SRy	1	3.50		N		0.017	0.60	3.0	0.0014	CJ-36	U				39	AD HOC
40	SRy	1	4.63		Y		0.050				CJ-33	U				40	AD HOC
41	SRy	2	4.30		Y		0.033				CH-36	U				41	AD HOC
42	SRy	1	3.63		N		0.001	0.20	5.3	0.0050	CJ-33	U				42	AD HOC
43	SRy	1	3.00		N	1					CJ-33	U				43	AD HOC
44	SRy	2	2.75		N	1					J-36	C				44	AD HOC
45	SRy	1	5.50		Y		0.043				CJ-33	U				45	AD HOC

46 SRy	1	0.00		N		0.005	0.50	4.0	0.0005	CJ-33	U				46 AD HOC
47 SRy	1	4.00		Y		0.033	0.50	2.0	0.0007	CH-36	U	1.3		1.6	47 AD HOC
48 SRy	2	0.00		N	1					J-36	C	1.25		2	48 AD HOC
49 SRy	2	3.00		N		0.013	1.00	3.2	0.0014	H-36	U	1.2		1.9	49 AD HOC
50 SRy	1	5.00		Y	1					CJ-33	C	1.25		1.2	50 AD HOC
51 SRy	1	3.00		N		0.011	0.60	2.3	0.0012	CJ-?	U	1.2		1.2	51 AD HOC
52 SRy	2	0.00		N		0.022	1.20	1.9	0.0003	CH-36	U	1.2		1.4	52 AD HOC
53 SRy	2	3.50		N	1					J-33	U	1.4		1.3	53 AD HOC
54															
55 UP	1	1.68		N		0.051				CM-33	U	1.2	1.08	1.9	1 AD HOC
56 UP	1	1.88		N		0.014	0.00	1.5	0.0020	CJ-33	U				2 AD HOC
57 UP	1	5.25		Y		0.013				CC-38	B				3 AD HOC
58 UP	1	3.63		N		0.018	0.00	3.0	0.0060	CJ-33	U				4 AD HOC
59 UP	1	4.08		Y	1					CC-38	B				5 AD HOC
60 UP	1	3.25		N		0.034	0.00	2.5	0.0040	CJ-33	U				6 AD HOC
61 UP	1	3.19		N		0.011	0.00	2.0	0.0030	CJ-33	U				7 AD HOC
62 UP	1	4.08		Y		0.044				CM-33	U				8 AD HOC
63 UP	1	4.63		Y	1					CJ-33	U				9 AD HOC
64 UP	2	4.50		Y		0.038				H-36	U				10 AD HOC
65 UP	2	4.92		Y		0.045	0.00	1.5	0.0010	H-36	U				11 AD HOC
66 UP	2	4.32		Y		0.092				H-36	C				12 AD HOC
67 UP	2	5.13		Y		0.999				J-36	U				13 AD HOC
68 UP	1	5.19		Y		0.999				CH-36	U				14 AD HOC
69 UP	2	4.94		Y		0.033				H-36	U				15 AD HOC
70 UP	1	4.56		Y		0.037				CH-36	U				16 AD HOC
71 UP	1	4.44		Y		0.020	0.50	2.0	0.0050	CJ-33	U				17 AD HOC
72 UP	1	4.44		Y		0.026	0.50	1.5	0.0020	CJ-33	U				18 AD HOC
73 UP	1	0.00		N		0.030	1.00	1.5		CJ-36	U				19 AD HOC
74 UP	1	0.00		N		0.007		3.0		CJ-36	U				20 AD HOC
75 UP	1	0.00		N		0.005	1.00	3.5	0.0020	CM-33	U				21 AD HOC
76 UP	1	0.00		N	1					CE-28	U				22 AD HOC
77 UP	1	0.00		N		0.007	1.50	3.7	0.0020	CM-33	U				23 AD HOC
78 UP	2	2.63		N	1					B-38	C				24 AD HOC
79 UP	1	0.00		N		0.009				CJ-36	U				25 AD HOC
80 UP	1	0.00		N		0.023	0.00	2.0	0.0030	CJ-36	U				26 AD HOC
81 UP	1	0.00		N	1					CE-28	B				27 AD HOC
82 UP	2	3.13		Y		0.047				CC-38	C				28 AD HOC
83 UP	1	3.50		N	1					CC-38	C				29 AD HOC
84 UP	1	3.75		N	1					C-38	B				30 AD HOC
85 UP	2	3.50		N		0.028				C-38	B				31 AD HOC
86 UP	2	2.50		N	1					C-38	B				32 AD HOC
87 UP	2	2.88		N	1					J-36	B				33 AD HOC
88 UP	2	0.00		N	1					H-36	U				34 AD HOC
89 UP	2	0.00		N	1					H-36	U				35 AD HOC
90 UP	2	3.19		N		0.007	1.50	3.7	0.0015	H-36	U				36 AD HOC
91 UP	2	4.00		Y	1					J-36	B				37 AD HOC
92 UP	2	4.44		Y	1					CJ-36	U				38 AD HOC
93 UP	1	4.00		Y		0.042	0.00	2.2	0.0020	CJ-33	U				39 AD HOC
94 UP	1	4.68		Y		0.026	1.00	2.4	0.0040	CC-38	B				40 AD HOC
95 UP	1	0.00		N	1					CC-38	B				41 AD HOC
96 UP	1	4.63		Y	1					CC-38	B				42 AD HOC
97 UP	1	5.25		Y	1					CC-38	B				43 AD HOC
98 SRy	2	0.00	0	N	1					J-33	C				34 O H EXP
99 SRy	2	0.00		N		0.017	0.90	2.3	0.0005	J-33	C				35 O H EXP
100 SRy	2	0.00		N	1					J-33	C				36 O H EXP
101 SRy	2	0.00		N	1					J-33	C				37 O H EXP

102	SRy	1	0.00	0	N	1					J-33	C				38 0 H EX
103	SRy	1	0.00		N	1					J-33	C				39 0 H E
104	SRy	1	0.00		N	1					J-33	C				40 0 H EX
105	SRy	1			N		0.011	0.95	2.8	0.0008	J-33	C				41 0 H EX
106	SRy	1	0.00		N	1					J-33	C				42 0 H EX
107	SRy	1	0.00	0	N	1					J-33	C				43 0 H EX
108	SRy	1	0.00		N	1					J-33	C				44 0 H EX
109	SRy	1	0.00		N	1					J-33	C				45 0 H EX
110	SRy	1	0.00		N	1					J-33	C				46 0 H EX
111	SRy	1	0.00	0	N		0.008	0.75	2.0	0.0002	CJ-33	U				47 0 H EX
112	SRy	1	0.00		N		0.007	0.75	2.5	0.0007	CJ-33	U				48 0 H EX
113	SRy	1	0.00	0	N	1					CJ-33	C				49 0 H EX
114	SRy	1	0.00		N	1					CJ-33	C				50 0 H EX
115	SRy	1	0.00		N	1					CJ-33	C				51 0 H EX
116	SRy	1	0.00		N		0.005	0.60	3.3	0.0011	CJ-33	U				52 0 H EX
117	SRy	1	0.00		N		0.008	0.50	3.6	0.0014	CJ-33	U				53 0 H EX
118	SRy	1	0.00	0	N	1					CJ-33	C				54 0 H EX
119	SRy	1	4.00		Y	1					CJ-33	C				55 0 H EX
120	SRy	1	0.00		N	1					CJ-33	C				56 0 H EX
121	ATSF	2	4.75		Y		0.046				H-36	U	1.25	1.25	1.63	1 AD HOC
122	ATSF	2	4.25		Y	1					H-36	U	1.25	1.25	1.63	2 AD HOC
123	ATSF	2	4.25		Y	1					CH-36	U	1.25	1.31	1.38	3 AD HOC
124	ATSF	2	3.00		N	1					CH-36	U	1.38	1.38	1.19	4 AD HOC
125	ATSF	2	0.00		N		0.009				H-36	U	1.31	1.25	1.56	5 AD HOC
126	ATSF	2	0.00		N		0.006				H-36	U	1.25	1.13	1.56	7 AD HOC
127	ATSF	2	0.00		N	1					H-36	U	1.31	1.25	1.25	8 AD HOC
128	ATSF	2	2.00		N		0.032				CH-36	U	1.44	1.25	1.25	9 AD HOC
129	ATSF	2	5.00		Y		0.017				CH-36	U	1.25	1.38	1.31	10 AD HOC
130	ATSF	2	4.00		Y		0.030				H-36	U	1.38	1.25	1.31	15 AD HOC
131	ATSF	2	5.00		Y		0.030				H-36	U	1.31	1.19	1.31	16 AD HOC
132	ATSF	2	3.25		N		0.040				H-36	U	1.25	1.13	1.63	17 AD HOC
133	ATSF	2	4.00		Y		0.013				H-36	C	1.31	1.19	1.56	18 AD HOC
134	ATSF	2	4.50		Y		0.040				CH-36	U	1.38	1.31	1.25	19 AD HOC
135	ATSF	2	3.00		N		0.005	0.50	3.3	0.0014	CH-36	U	1.25	1.19	1.31	20 AD HOC
136	ATSF	2	4.00		Y		0.030				CH-36	U	1.25	1.31	1.38	21 AD HOC
137	ATSF	2	3.50		N		0.002	1.00	2.8	0.0011	H-36	U	1.25	1.25	1.5	22 AD HOC
138	ATSF	2	4.75		N	1					H-36	U	1.38	1.25	1.44	23 AD HOC
139	ATSF	2	3.50		N		0.025				CH-36	U	1.25	1.25	1.31	24 AD HOC
140	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.31	1.25	1.15	1 BN BAR
141	ATSF	1	5.00	5.00	Y		0.006	0.50	3.7	0.0020	CJ-36	C	1.19	1.25	1.63	2 BN BAR
142	ATSF	1	5.00	5.00	Y		0.024	0.75	3.7	0.0010	CJ-36	C	1.13	1.38	1.63	3 BN BAR
143	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.13	1.38	1.63	4 BN BAR
144	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.19	1.44	1.63	5 BN BAR
145	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.25	1.38	1.56	6 BN BAR
146	ATSF	1	4.50	4.50	Y		0.027	0.50	2.3	0.0010	CJ-36	C	1.06	1.50	1.69	7 BN BAR
147	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.19	1.58	1.19	8 BN BAR
148	ATSF	1	4.00	5.00	Y	1					CJ-36	C	1.25	1.13	1.63	9 BN BAR
149	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.25	1.31	1.69	10 BN BAR
150	ATSF	1	4.00	4.50	Y	1					CJ-36	C	1.06	1.50	1.69	11 BN BAR
151	ATSF	1	4.00	5.00	Y	1					CJ-36	C	1.06	1.44	1.75	12 BN BAR
152	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.06	1.44	1.31	13 BN BAR
153	ATSF	1	4.00	4.50	Y		0.025	0.65	2.9	0.0030	CJ-36	C	1.75	1.31	1.56	14 BN BAR
154	ATSF	1	4.00	4.00	Y		0.009	0.00	3.8	0.0024	CJ-36	C	1.06	1.44	1.69	15 BN BAR
155	ATSF	1	4.00	3.00	N		0.005	0.00	5.5	0.0028	CJ-36	C	1.13	1.44	1.69	16 BN BAR
156	ATSF	1	3.50	5.00	N		0.004	0.70	6.5	0.0038	CJ-36	C	1.31	1.38	1.5	17 BN BAR
157	ATSF	1	3.00	3.00	N	1					CJ-36	C	1.25	1.31	1.56	18 BN BAR

8	ATSF	1	5.00	4.00	Y	1					CJ-36	C	1.19	1.38	1.63	19 BN BARK
9	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.13	1.38	1.63	20 BN BARK
0	ATSF	1	4.50	4.50	Y	1					CJ-36	C	1.19	1.44	1.56	21 BN BARK
1	ATSF	1	4.50	5.00	Y	1					CJ-36	C	1.00	1.31	1.44	22 BN BARK
2	ATSF	1	6.00	4.50	Y		0.043				CJ-36	C	1.19	1.25	1.19	23 BN BARK
3	ATSF	1	5.00	4.00	Y	1					CJ-36	C	1.06	1.31	1.31	24 BN BARK
4	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.19	1.38	1.44	25 BN BARK
5	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.19	1.38	1.56	26 BN BARK
6	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.31	1.38	1.56	27 BN BARK
7	ATSF	1	4.00	4.00	Y		0.020	0.00	2.5	0.0015	CJ-36	C	1.13	1.50	1.63	28 BN BARK
8	ATSF	1	3.00	4.00	Y	1					CJ-36	C	1.56	1.50	1.56	29 BN BARK
9	ATSF	1	4.00	4.00	Y		0.045	0.50	1.6	0.0007	CJ-36	C	1.13	1.44	1.69	30 BN BARK
0	ATSF	1	5.00	5.00	Y		0.030	0.50	1.4	0.0004	CJ-36	C	1.06	1.31	1	31 BN BARK
1	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.06	1.19	1.13	32 BN BARK
2	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.13	1.31	1.63	33 BN BARK
3	ATSF	1	4.00	5.00	Y	1					CJ-36	C	1.06	1.44	1.75	34 BN BARK
4	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.13	1.31	1.63	35 BN BARK
5	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.19	1.31	1.63	36 BN BARK
6	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.19	1.38	1.56	37 BN BARK
7	ATSF	1	4.00	4.00	Y		0.022	0.00	3.0	0.0030	CJ-36	C	1.25	1.44	1.56	38 BN BARK
8	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.13	1.38	1.69	39 BN BARK
9	ATSF	1	5.00	4.00	Y	1					CJ-36	C	1.19	1.19	1.25	40 BN BARK
0	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.19	1.38	1.56	41 BN BARK
1	ATSF	1	4.00	4.50	Y		0.020				CJ-36	C	1.19	1.25	1.63	42 BN BARK
2	ATSF	1	4.00	4.50	Y		0.011	0.40	4.7	0.0027	CJ-36	C	1.13	1.44	1.63	43 BN BARK
3	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.19	1.31	1.63	44 BN BARK
4	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.13	1.38	1.69	45 BN BARK
5	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.13	1.25	1.63	46 BN BARK
6	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.19	1.19	1.63	47 BN BARK
7	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.06	1.50	1.69	48 BN BARK
8	ATSF	1	4.00	4.00	Y	1					CJ-36	C	1.06	1.38	1.69	49 BN BARK
9	ATSF	1	4.00	4.00	Y	1					CJ-36	U	1.13	1.38	1.69	50 BN BARK
0	AAR	1	4.50	3.50	N	1					CH-36	U				1 FRA 6
1	AAR	1	4.50	8.50	Y	1					CH-36	U				2 FRA 6
2	AAR	1	5.50	4.50	Y	1					CH-36	B				3 FRA 6
3	AAR	1	4.50	3.50	N	1					CH-36	B				4 FRA 6
4	AAR	1	2.50	2.50	N	1					CH-36	U				5 FRA 6
5	AAR	1	3.50	2.50	N		0.002	1.25	4.3	0.0020	CH-36	U				6 FRA 6
6	AAR	1	4.50	3.50	N		0.028	1.00	2.0	0.0005	CH-36	U				7 FRA 6
7	AAR	1	3.50	4.00	N		0.016	0.00	2.9	0.0020	CH-36	U				8 FRA 6
8	AAR	1	3.00	2.50	N		0.022	0.75	2.5	0.0012	CH-36	U				9 FRA 6
9	AAR	1	2.50	1.50	N		0.013	0.70	3.1	0.0025	CH-36	U				10 FRA 6
0	AAR	1	4.00	3.00	N		0.013	0.75	2.4	0.0013	CH-36	U				11 FRA 6
1	AAR	1	4.50	4.50	Y		0.029				CH-36	U				12 FRA 6
2	AAR	1	3.00	2.00	N		0.018	0.80	2.8	0.0015	CH-36	U				13 FRA 6
03	AAR	1	6.00	5.50	Y		0.021	0.00	2.8	0.0015	CH-36	U				14 FRA 6
4	AAR	1	4.50	3.50	N		0.017	1.00	2.7	0.0012	CH-36	U				15 FRA 6
5	AAR	1	4.50	4.50	Y		0.014	0.50	2.7	0.0012	CH-36	U				16 FRA 6
6	AAR	1	4.50	4.50	Y		0.031				CH-36	U				17 FRA 6
07	AAR	1	4.50	4.00	Y		0.012	0.50	3.1	0.0020	CH-36	U				18 FRA 6
8	AAR	1	4.50	3.50	N		0.001	0.50	5.0	0.0030	CH-36	U				19 FRA 6
09	AAR	1	4.50	4.00	Y		0.002	0.50	5.0	0.0035	CH-36	U				20 FRA 6
10	AAR	1	4.50	3.50	N		0.024	1.20	1.9	0.0002	CH-36	U				21 FRA 6
11	AAR	1	4.50	5.00	Y		0.022	0.80	2.5	0.0010	CH-36	U				22 FRA 6
12	AAR	1	2.50	1.50	N		0.008	0.80	3.3	0.0025	CH-36	U				23 FRA 6
13	AAR	1	3.50	3.50	N		0.015	1.20	2.9	0.0015	CH-36	U				24 FRA 6

214	AAR	1	3.50	3.00	N		0.023	1.10	1.5	0.0001	CH-36	U	25 FRA 6
215	AAR	1	4.00	3.00	N		0.028				CH-36	U	26 FRA 6
216	AAR	1	3.50	3.00	N		0.025	1.20	2.1	0.0005	CH-36	U	27 FRA 6
217	AAR	1	4.00	5.00	Y		0.041				CH-36	U	28 FRA 6
218	AAR	1	4.50	4.50	Y		0.053				CH-36	U	29 FRA 6
219	AAR	1	4.50	4.00	Y		0.049				CH-36	U	30 FRA 6
220	AAR	1	4.50	4.00	Y		0.041				CH-36	U	31 FRA 6
221	AAR	1	4.50	3.50	N		0.047				CH-36	U	32 FRA 6
222	AAR	1	4.50	3.00	N		0.032				CH-36	U	33 FRA 6
223	AAR	1	5.00	4.00	Y		0.037				CH-36	U	34 FRA 6
224	AAR	1	4.50	3.50	N		0.021				CH-36	U	35 FRA 6
225	AAR	1	4.50	3.50	N		0.027	1.70	4.5	0.0012	CH-36	U	36 FRA 6
226	AAR	1	4.50	3.50	N		0.049				CH-36	U	37 FRA 6
227	AAR	1	4.00	3.50	N		0.024	1.30	1.7	0.0001	CH-36	U	38 FRA 6
228	AAR	1	2.50	2.50	N		0.018	1.30	2.4	0.0007	CH-36	U	39 FRA 6
229	AAR	1	2.50	4.00	N		0.022	1.00	2.5	0.0012	CH-36	U	40 FRA 6
230	AAR	1	4.50	4.00	Y		0.999				CH-36	U	41 FRA 6
231	AAR	1	4.50	4.50	Y		0.037	1.20	1.6	0.0001	CH-36	U	42 FRA 6
232	AAR	1	3.00	3.50	N	1					CH-36	U	43 FRA 6
233	AAR	1	3.00	2.50	N		0.019	1.40	2.5	0.0007	CH-36	U	44 FRA 6
234	AAR	1	4.50	4.50	Y		0.027	1.00	2.0	0.0006	CH-36	U	45 FRA 6
235	AAR***	1	4.50	4.50	Y		0.038				CH-36	U	46 FRA 6
236	AAR	1	4.50	3.50	N		0.017	0.50	2.7	0.0020	CH-36	U	47 FRA 6
237	AAR	1	4.50	4.00	Y		0.028	0.80	2.1	0.0010	CH-36	U	48 FRA 6
238	AAR	1	4.50	3.50	N		0.006	0.70	3.4	0.0020	CH-36	U	49 FRA 6
239	AAR	1	3.50	3.50	N	1					CH-36	U	50 FRA 6
240	AAR	1	4.50	4.50	Y		0.048				CH-36	U	51 FRA 6
241	AAR	1	3.50	4.50	N		0.027	1.40	2.4	0.0008	CH-36	U	52 FRA 6
242	AAR***	1	4.50	4.50	Y		0.115				CH-36	U	53 FRA 6
243	AAR***	1	4.50	4.50	Y		0.039				CH-36	U	54 FRA 6
244	AAR	1	4.00	3.50	N		0.033	0.70	2.0	0.0006	CH-36	U	55 FRA 6
245	AAR	1	4.00	2.50	N		0.033	0.90	1.7	0.0005	CH-36	U	56 FRA 6
246	AAR	1	2.50	3.50	N		0.017	0.90	2.8	0.0028	CH-36	U	58 FRA 6
247	AAR	1	4.00	3.50	N		0.037				CH-36	U	59 FRA 6
248	AAR	1	4.00	4.50	Y		0.040				CH-36	U	60 FRA 6
249	AAR	2	0.00		N		0.011	1.10	2.5	0.0010	CJ-36	B	61 FRA 6
250	AAR	2	0.00		N	1					CJ-36	B	62 FRA 6
251	AAR	2	0.00		N	1					J-36	U	63 FRA 6
252	AAR	2	0.00		N	1					J-36	U	64 FRA 6
253	AAR	2	0.00		N	1						U	65 FRA 6
254	AAR	2	0.00		N	1						U	66 FRA 6
255	AAR	2	0.00		N		0.022	0.80	2.5	0.0020	J-36	U	67 FRA 6
256	AAR	2	0.00		N		0.019	1.20	2.3	0.0007	J-36	U	68 FRA 6
57	AAR	2	0.00		N	1							69 FRA 6
258	AAR	2	0.00		N	1						U	70 FRA 6
59	AAR	2	0.00		N		0.013	0.00	2.7	0.0015	H-36	U	71 FRA 6
260	AAR	2	0.00		N		0.018	1.30	2.5	0.0012	H-36	U	72 FRA 6
61	AAR	2	0.00		N	1					J-36	U	73 FRA 6
62	AAR	2	0.00		N		0.008	0.60	3.2	0.0025	J-36	U	74 FRA 6
63	AAR---		0.00		N	1						C	75 FRA 6
64	AAR---		0.00		N	1						B	76 FRA 6
65	AAR	2	0.00		N	1					J-36	C	77 FRA 6
66	AAR	2	0.00		N	1					J-36	C	78 FRA 6
67	AAR	1	0.00		N	1					CJ-36	B	79 FRA 6
68	AAR	1	0.00		N	1					CJ-36	B	80 FRA 6
69	AAR	1	0.00		N	1					CJ-33	B	81 FRA 6

270	AAR	1	0.00	N		0.080				CJ-33	B	82	FRA	6
271	AAR	1	0.00	N	1					CE-28	B	84	FRA	6
272	AAR	2	0.00	N		0.009	0.60	2.3	0.0010	CM-33	B	85	FRA	6
273	AAR	2	0.00	N		0.999				CM-33	B	86	FRA	6
274	AAR	2	0.00	N	1					R-33	U	87	FRA	6
275	AAR	1	0.00	N		0.050				R-33	U	88	FRA	6
276	AAR	2	0.00	N	1					J-36	B	89	FRA	6
277	AAR	2	0.00	N	1					J-36	B	90	FRA	6
278	AAR	1	0.00	N		0.013	1.10	3.0	0.0015	CJ-33	U	91	FRA	6
279	AAR	1	0.00	N		0.037				CJ-33	U	92	FRA	6
280	AAR	2	0.00	N		0.007	0.00	4.5	0.0055	J-33	C	93	FRA	6
281	AAR	2	0.00	N		0.047				J-33	C	94	FRA	6
282	AAR	2	0.00	N		0.025	1.10	1.9	0.0003	CH-36	C	95	FRA	6
283	AAR	2	0.00	N		0.999				CH-36	C	96	FRA	6
284	AAR	2	0.00	N	1					H-36	C	97	FRA	6
285	AAR	2	0.00	N	1					H-36	C	98	FRA	6
286	AAR	2	0.00	N		0.012	1.00	2.4	0.0007	CM-33	C	99	FRA	6
287	AAR	2	0.00	N		0.009	0.80	2.4	0.0020	CM-33	C	100	FRA	6
288	AAR	2	0.00	N	1					CJ-33	B	101	FRA	6
289	AAR	2	0.00	N	1					CJ-33	B	102	FRA	6
290	AAR	2	0.00	N	1					J-33	U	103	FRA	6
291	AAR	2	0.00	N	1					J-33	U	104	FRA	6
292	AAR	1	0.00	N	1					CM-33	U	105	FRA	6
293	AAR	1	0.00	N	1	0.005				CM-33	U	106	FRA	6
294	AAR	2	0.00	N	1					J-36	U	107	FRA	6
295	AAR	2	0.00	N	1					J-36	U	108	FRA	6
296	AAR	2	0.00	N	1					H-36	U	109	FRA	6
297	AAR	2	0.00	N	1					H-36	U	110	FRA	6
298	AAR	2	0.00	N	1					H-36	U	111	FRA	6
299	AAR	2	0.00	N	1					H-36	U	112	FRA	6
300	AAR	1	0.00	N	1					CJ-33	U	113	FRA	6
301	AAR	1	0.00	N	1					CJ-33	U	114	FRA	6
302	AAR	1	0.00	N	1					CJ-33	U	115	FRA	6
303	AAR	1	0.00	N	1					CJ-33	U	116	FRA	6
304	AAR	1	0.00	N	1					CJ-33	U	117	FRA	6
305	AAR	1	0.00	N	1					CJ-33	U	118	FRA	6
306	AAR	1	0.00	N	1					CJ-33	U	119	FRA	6
307	AAR	1	0.00	N	1					CJ-33	U	120	FRA	6
308	AAR	1	0.00	N	1					CJ-33	U	121	FRA	6
309	AAR	1	0.00	N	1					CJ-33	U	122	FRA	6
310	AAR	1	0.00	N	1					CJ-33	U	123	FRA	6
311	AAR	1	0.00	N	1					CJ-33	U	124	FRA	6
312	AAR	1	0.00	N	1	0.034				CJ-33	U	125	FRA	6
313	AAR	1	0.00	N		0.002	0.80	3.1	0.0040	CJ-33	U	126	FRA	6
314	AAR	1	0.00	N		0.015	1.00	2.3	0.0006	CJ-33	U	127	FRA	6
315	AAR	1	0.00	N	1					CJ-33	U	128	FRA	6
316	AAR	1	0.00	N	1					CJ-33	U	129	FRA	6
317	AAR	1	0.00	N	1					CJ-33	U	130	FRA	6
318	AAR	1	0.00	N		0.010	0.80	2.8	0.0015	CJ-33	U	131	FRA	6
319	AAR	1	0.00	N		0.007	0.50	3.4	0.0030	CJ-33	U	132	FRA	6
320	AAR	1	0.00	N		0.006	1.00	3.3	0.0020	CJ-33	U	133	FRA	6
321	AAR	1	0.00	N		0.012	1.10	2.6	0.0008	CJ-33	U	134	FRA	6
322	AAR	1	0.00	N	1					CJ-33	U	135	FRA	6
323	AAR	1	0.00	N	1					CJ-33	U	136	FRA	6
324	AAR	1	0.00	N	1					CJ-33	U	137	FRA	6
325	AAR	1	0.00	N	1					CJ-33	U	138	FRA	6

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AAR      1   0.00       N            0.008   0.60   3.2  0.0027 CJ-33      U                     139 FRA 6
AAR      1   0.00       N            0.001   0.80   5.5  0.0032 CJ-33      U                     140 FRA 6
AAR      1   0.00       N     1                                 CJ-33      U                     141 FRA 6
AAR      1   0.00       N            0.007   0.80   3.2  0.0022 CJ-33      U                     142 FRA 6
AAR      1   0.00       N     1                                 CM-33      U                     143 FRA 6
AAR      1   0.00       N     1                                 CM-33      U                     144 FRA 6
AAR      1   0.00       N     1                                                                  145 FRA 6
AAR      1   0.00       N     1                                                                  146 FRA 6
AAR      1   0.00       N     1                                 CM-33      U                     147 FRA 6
AAR      1   0.00       N     1                                 CM-33      U                     148 FRA 6
AAR      1   0.00       N     1                                 CJ-33      C                     149 FRA 6   NEW
AAR      2   0.00       N     1                                 H-36       C                     150 FRA 6   NEW
AAR      1   0.00       N     1                                 H-36       U                     151 FRA 6   NEW
AAR      2   0.00       N     1                                 J-33       U                     152 FRA 6   NEW
AAR      1   0.00       N     1                                 J-33       U                     153 FRA 6   NEW
AAR      2   0.00       N     1                                 J-33       U                     154 FRA 6   NEW
AAR      2   0.00       N     1                                 J-33       C                     155 FRA 6   NEW
AAR      1   0.00       N            0.011   0.00   2.5  0.0008 CJ-33      U                     156 FRA 6   NEW
AAR      2   0.00       N     1                                 J-33       U                     157 FRA 6   NEW
AAR      2   0.00       N            0.001   1.00   5.0  0.0025 H-36       U                     158 FRA 6
AAR      2   0.00       N            0.005   1.00   3.0  0.0020 H-36       U                     159 FRA 6
AAR      2   0.00       N     1                                 H-36       U                     160 FRA 6
AAR      2   0.00       N     1                                 H-36       U                     161 FRA 6
AAR      1   0.00       N
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APPENDIX 5.1

TABULATIONS OF BRAKE DYNAMOMETER DATA

Heat Transfer Study

Wheel No. 95409(5)

Date	(kips) VL	Position* TC5	Position* TC10	Temperature (°F) Start TC5	Start TC10	End TC5	End TC10	Change TC5	Change TC10	TC10-TC5	Max. Wheel Tread Temp (°F)	Rail Temperature (°F) Dynamic Top	Static Top	Static Side	Static Web
12-3	27	16	16	95	105	153	180	58	75	+17	NOT	DETERMINED			
12-3	27	16	16	105	90	130	145	25	55	+30	–	"	"		
12-4+	27	16	16	83	85	135	150	52	65	+13	–	"	"		
12-5	27	NOT Determined										"	"		
12-5	27			"								"	"		
12-5	27			"								"	"		
12-5	27			"								"	"		
12-6	27			"								"	"		
12-6	27			"								"	"		
12-6	27			"								"	"		
12-6	27			"								"	"		
2-4	5	13.5	13.5	70	70	102	102	32	32	0	440	–	"		
2-4	5	13.5	13.5	80	85	115	125	35	40	+5	520	–	"		
2-5	27	13.5	13.5	80	95	160	162	80	67	-13	480	–	"		
2-5	27	13.5	13.5	105	108	175	175	70	67	-3	430	168	"		
2-6	5	13.5	12	85	75	105	105	20	30	40	565	107	"		
2-6	27	13.5	12	80	78	175	155	95	67	-18	–	155	"		
2-7	5	13.5	11	75	80	115	125	40	45	+5	530	106	"		
2-7	27	13.5	11	50	50	165	190	115	140	+25	500	–	"		
2-14	5	13.5	11	75	85	115	138	40	53	+13	490	105	"		
2-14	17	13.5	11	80	82	155	173	75	91	+16	500	140	128	123	85
2-14	17	13.5	11	97	100	170	192	73	92	+19	500	154	147	140	105
2-14	17	13.5	11	95	98	165	190	70	92	+22	500	148			
#2-15	27	13.5	11	80	80	–	–	–	–	–	–	Start	68	68	68
#2-15	5	13.5	11	–	–	–	–	–	–	–	–	Fin.	76	74	72
												Start	74	74	72
												Fin.	72	72	72

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* Inches from contact (TC5 Lead, TC10 Trail)
# No Brake
+ This test at 30 mph – all others at 20 mph.

Note: Brake force for all tests – 1500 lb.

Speed 20 MPH
Time 45 Min.

			Temperature (F)					
Date	Strain		Tread		Rim		Plate	
	Eo	Ef	To	Tf	To	Tf	To	Tf
6- 7-85	0000	+2520	75	520	75	-	75	180
"	-0088	+2420	65	520	65	-	65	180
"	-0021	+2481	80	530	80	-	80	175
6-10-85	+0047	+2566	80	550	80	-	50	185
"	+0016	+2553	80	560	80	-	80	190
"	+0164	+2566	100	570	-	-	80	195
6-11-85	0000	+2562	80	540	-	-	80	195
"	+0064	+2489	85	550	-	-	85	200
"	+0150	+2520	100	550	-	-	85	180
"	-0041	+2560	80	545	-	-	80	190
"	-0012	+2553	95	560	-	-	85	200
"	-0039	+2522	95	565	-	-	80	210
6-12-85	0066	+2660	75	570	-	-	75	195
"	-0108	+2426	80	550	-	-	80	190
"	-0040	+2336	95	555	-	-	95	190
6-13-85	-0097	-2276	75	540	-	-	75	160
"	-0065	+2486	80	550	-	-	80	185
"	+0036	+2559	85	590	-	-	85	180
"	-0083	+2278	80	500	-	-	80	190
"	-0013	+2374	85	560	-	-	85	190
"	-0033	+2462	90	530	-	-	85	190
6-14-85	-0087	+2624	70	570	-	-	70	195
"	-0134	+2854	85	630	-	-	85	200
"	-0293	+3020	80	770	-	-	80	200
"	-0303	+3242	85	845	-	-	85	220
Max.	+164	+3242	100	845			95	220
Min.	-303	+2276	65	500			65	160
Avg.	-41	+2556	83	573	76		81	191

Wheel 6

VL 27,000	Wheel 95526
LL -	Tape 162
BSF 3,000	BS Cobra
105PS1	CJ-33U

Torque		Rev.	
Max.	Min.		
		9080.4	
		9301.0	
		9179.5	
		9428.4	
		9074.9	
		9121.3	
		9362.4	
		10230.9	47.43 min.
		9253.6	
		9457.0	
		11662.1	52.62 min.
		11760.8	53.44 Min.
		9925.6	47.13 min.
		9569.4	
		9398.9	
		9125.8	
		9323.1	
		9489.6	New Shoe
		10964.6	53.5 min.
		9448.7	
		9174.6	
		9602.7	
		9377.2	
		9209.9	Fire
		9773.3	"

FRA DRAG TESTS

Speed 40 MPH
Time 45 Min.

Date	Strain		Temperature (F)					
			Tread		Rim		Plate	
	Eo	Ef	To	Tf	To	Tf	To	Tf
4- 1-85	0000	+2163	70	525	-	-	70	150
"	+0151	+2305	80	550	-	-	80	155
4- 2-85	+0176	+2473	70	570	70	470	70	165
"	-0077	+2471	60	595	60	470	90	185
4- 3-85	+0282	+2564	80	580	80	535	80	190
"	+0112	+2569	80	595	80	520	80	190
"	+0035	+2568	80	610	80	505	80	200
"	+0151	+2536	80	610	80	500	80	205
4- 4-85	+0243	+2315	75	580	75	460	75	180
"	+0141	+2619	80	595	80	515	80	200
"	+0201	+2360	80	600	80	460	80	190
"	+0060	+2703	95	615	60	515	90	200
4- 8-85	+0206	+2013	75	545	75	420	75	160
"	+0055	+2160	70	580	70	440	70	180
4- 9-85	+0184	+2484	75	620	75	485	75	175
"	+0033	+2480	75	630	75	510	75	195
"	-0036	+2485	70	620	70	510	70	200
"	-0002	+2004	50	560	50	420	50	170
4-10-85	+0186	+2069	80	575	80	460	80	175
"	+0120	+2574	80	665	80	510	80	200
4-22-85	-	-	80	700	80	490	80	165
"	0000	+2290	90	680	80	500	85	200
"	-0055	+2270	95	660	95	500	95	200
"	-0028	+1620	110	580	100	380	100	150
Max.	+282	+2574	95	700	50	535	95	205
Min.	-77	+2013	50	525	95	420	50	150
Avg.	+99	+2385	74	579	79	485	78	184

- Wheel 7

VL 27,000	Wheel 95403
LL -	Tape 160
BSF 1,500	BS Cobra
	CJ-33U

Torque		Rev.	
Max.	Min.		
		18318.0	
		17555.7	
		18328.1	
		18207.6	
		18202.5	
		17610.9	
		17839.3	
		17703.1	
		17419.7	
		17727.4	
		17793.8	
		17793.7	
		17353.7	New Shoe
		17892.5	
		17088.8	
		17352.3	
		18324.2	
		17450.4	
		17365.4	
		17462.3	
Shoe on fire at end		18147.6	Metal pick made groove in wheel
		18034.3	
(34 min.)		13736.5	
(14.94 min.)		6042.0	
		16702.5	

FRA DRAG TESTS - W

Speed 20 MPH
Time 45 Min.

			Temperature (F)					
Date	Strain		Tread		Rim		Plate	
	Eo	Ef	To	Tf	To	Tf	To	Tf
3- 7-85	0000	+2180	70	530	70	455	70	155
"	-0085	+2234	50	560	50	490	-	-
3-12-85	+0117	+2190	80	560	80	450	-	-
3-13-85	+0106	+2400	80	580	80	470	-	-
3-13-85	-0048	+2254	80	575	80	455	-	-
3-13-85	+0084	+2210	85	570	85	470	-	-
3-14-85	+0143	+2222	80	570	80	445	-	-
3-15-85	-	-	80	545	80	440	-	-
"	-	-	70	570	70	450	-	-
"	-	-	100	570	100	435	-	-
3-19-85	+0115	+2264	75	565	75	450	75	185
"	+0097	+2188	80	560	80	450	80	190
3-20-85	+0130	+2440	80	590	80	470	80	195
"	+0115	+2320	90	560	80	450	80	190
"	-0035	+2288	80	560	70	430	70	190
3-21-85	-	-	80	560	80	450	80	190
"	+0071	+2280	80	570	80	435	80	180
"	-0008	+2215	60	550	60	430	60	185
3-22-85	-0041	+2304	75	555	75	430	75	175
"	+0016	+2270	80	560	80	435	80	185
"	+0118	+2180	75	570	75	430	75	185
"	+0006	+2238	70	570	70	435	70	190
3-25-85	+0113	+2290	70	560	70	440	70	180
"	-0043	+2286	70	585	70	425	70	180
"	+0018	+2189	75	570	55	435	60	185
Max.	+143	+2440	100	590	100	490	100	195
Min.	-43	+2180	60	530	55	430	60	155
Avg.	+47	+2259	76	565	76	446	82	184

heel 9

VL 27,000
LL -
BSF 1,500

Wheel 94783
Tape 160
BS Cobra
CJ-33C

Torque		Rev.
Max.	Min.	
1500	1000	9721.4
1550	1250	9661.0
1600	1500	9844.7
1500	1250	9908.5
1600	1350	9827.2
1650	1300	9648.6
1300	1050	9901.5
1400	1200	9808.9
1400	1300	10061.0
1500	1300	10080.5
1300	1100	9982.5
1250	1000	10023.1
1400	1050	9665.2
-	-	10060.8
-	-	10136.5
1200	1000	10016.6
1000	900	10115.6
1000	900	9910.2
1100	950	9937.1
1000	700	10221.8
1000	1000	10008.6
1100	950	10178.6
1250	900	10140.1
1050	900	10172.0
1300	850	10064.1

FRA DRAG TESTS - Wheel 10

Speed 20 MPH
Time 45 Min.

VL 28,000 Wheel 94787
LL - Tape 162
BSF 3,000 BS Cobra
105PS1 CJ-33C

			Temperature (F)									
Date	Strain		Tread		Rim		Plate		Torque		Rev.	
	Eo	Ef	To	Tf	To	Tf	To	Tf	Max.	Min.		
7- 2-85	-0000	+2291	80	600	80	520	80	155			9707.7	New shoe
"	+0051	+2275	95	560	95	550	95	190			9703.0	
"	+0086	+2374	85	580	85	530	85	200			9546.4	
"	-0037	+2381	85	600	85	530	85	190			9765.0	
"	-0031	+2236	90	595	90	530	90	190			9754.2	
7- 3-85	+0123	+2592	80	595	80	520	80	205			9783.4	
"	+0051	+2524	90	580	95	555	95	180			9384.6	
"	-0062	+2463	90	575	90	535	90	185			9670.7	
"	-0044	-	85	550	85	-	85	-			2592.2	
"	+0076	+2498	80	595	80	575	80	170			9847.2	
"	-0087	+2410	85	590	85	560	85	190			9651.7	New shoe
7- 8-85	+0100	+2610	80	605	80	580	80	185			9571.1	
"	-0024	+2128	80	570	80	540	80	195			10212.0	
"	+0043	+2410	80	580	80	550	80	170			9698.3	
"	-0016	-	85	645	85	-	85	-			9628.8	
"	-	-	75	650	-	-	-	-			9856.4	
7- 9-85	-	-	90	650	-	-	-	-			9768.1	
"	-	-	80	650	-	-	-	-			10039.5	
"	-	-	90	660	-	-	-	-			10160.3	
"	-	-	90	690	-	-	-	-			9719.8	
"	-	-	80	730	-	-	-	-			9800.0	
7-15-85	-	-	80	770	-	-	-	-			9600.4	
"	-	-	80	795	-	-	-	-			9599.0	
"	-	-	95	600	-	-	-	-			9837.8	
"	-	-	85	550	-	-	-	-			9773.6	
Max.	+123	+2592	95	795	95	580	95	205				
Min.	-87	+2128	75	550	80	520	80	155				
Avg.	+30	+2399	85	623	85	543	85	185				

FRA DRAG TESTS - Wheel 11

Speed 20 MPH	VL 27,000	Wheel 94777
Time 45 Min.	LL -	Tape 162
	BSF 1,500	BS Cobra
	53PSI	CJ-33C

Date	Strain		Temperature (F)						Torque		Rev.	
			Tread		Rim		Plate					
	Eo	Ef	To	Tf	To	Tf	To	Tf	Max.	Min.		
6-18-85	0000	+1575	75	370	75	425	75				18020.9	New Shoe
"	-0129	+1704	90	530	80	450	75	160			18052.6	
6-19-85	0095	+1752	75	560	75	470	75	170			17932.2	
"	-0096	+1774	85	590	85	445	70	160			18046.6	
"	-0010	+1786	90	610	85	460	80	170			18115.8	
6-20-85	-0094	+1739	80	570	80	465	80	170			18187.7	
"	-0022	+1708	85	560	85	450	85	165			18031.8	
"	-0112	+1664	85	550	80	430	80	160			18199.3	
"	=0116	+1694	75	560	75	450	75	160			17901.7	
"	-0081	+1636	75	545	75	440	75	160			18055.7	
"	-0071	+1325	90	500	85	410	85	160			20880.7	51.59 min.
6-21-85	-0038	+0934	80	480	80	285	80	110	Shoe Gone		7384.9	17.88 min.
"	-0079	+1268	80	440	80	410	80	155	New Shoe		19383.9	48.38 min.
"	-0110	+1275	85	450	85	400	85	150			18148.2	
"	-0090	+1438	85	465	85	415	85	155			17954.2	
"	-0015	+1382	90	490	90	425	85	170			24122.9	58.15 min.
"	-0000	+1442	100	500	85	420	85	160			18990.6	47.30 min.
6-24-85	-0024	+1587	70	500	70	440	70	155			18128.7	
"	-0036	+1378	85	510	85	430	85	160			18540.9	46.86 min.
"	-0063	+1438	90	525	90	460	90	175			18634.1	45.78 min.
6-25-85	-0057	+1597	75	510	75	420	75	165			18064.5	
"	-0088	+1595	80	530	80	450	80	150			17970.4	
"	-0048	+1607	85	560	85	440	85	160			18343.1	
"	-0081	+1574	100	590	85	450	85	180			18656.5	46.45 min.
"	-0096	+1630	80	590	80	440	80	158			18337.0	
Max.	0	+1786	100	610	85	470	85	180				
Min.	-129	+1215	75	370	75	400	75	150				
Avg.	-66	+1381	84	525	81	437	80	162				

FRA DRAG TESTS -

Speed 20 MPH
Time 45 Min.

Date	Strain		Temperature (F)					
			Tread		Rim		Plate	
	Eo	Ef	To	Tf	To	Tf	To	Tf
4-29-85	0000	+2360	70	545	70	420	70	170
"	+0073	+2342	100	580	100	435	100	185
"	+0123	+2496	75	600	75	440	75	185
"	+0181	+2485	100	620	100	440	75	190
"	+0161	+2475	110	640	90	440	70	190
"	+0173	+2547	115	670	110	440	80	190
4-30-85	+0180	+2805	70	680	70	480	70	198
"	+0150	+2873	100	700	95	495	80	205
"	+0210	+3046	110	750	100	480	80	208
"	+0086	+3222	90	750	80	490	70	210
"	+0135	+3181	100	790	80	495	70	210
"	+0034	+2936	80	760	70	470	70	205
5- 1-85	+0170	+3125	75	615	75	490	75	210
"	+0126	+3030	110	610	110	470	75	200
"	+0185	+3118	110	620	105	465	70	200
"	+0134	+3121	100	580	80	500	80	205
"	+0076	+2886	100	580	80	505	65	210
"	+0091	+3055	100	590	90	480	65	205
5- 2-85	-	-	70	560	70	430	70	190
"	-	-	70	555	70	455	70	185
"	-	-	120	590	110	500	70	200
"	-	-	75	560	65	455	65	180
"	-	-	100	560	80	480	65	195
"	-	-	100	560	80	450	70	185
5- 3-85	-	-	75	-	75	470	75	190
Max.	+210	+3222	120	790	110	505	100	210
Min.	0	+2342	70	545	65	420	65	170
Avg.	127	+2839	93	628	85	467	73	196

Wheel 15

VL 27,000 Wheel 43878
LL - Tape 162
BSF 1,500 BS Cobra
J-33U

Torque		Rev.	
Max.	Min.		
-	-	9367.4	
1000	900	9067.1	
-	-	9425.1	
1300	1100	9333.6	
1350	1200	9128.2	
-	-	9438.0	
-	-	9599.9	
1350	1100	9659.4	
-	-	9210.0	
1200	1000	9535.2	
-	-	9485.7	
-	-	9495.3	
-	-	10055.1	48 min.
1500	1300	9389.5	
-	-	9465.2	
-	-	9372.0	
-	-	10208.3	48 min.
-	-	9762.3	
1600	1200	9202.9	
-	-	9241.9	
-	-	9396.6	
-	-	9369.8	
1500	1250	10301.4	
-	-	-	
-	1000	9537.8	46.2 min.

FRA DRAG TESTS - Wheel 16

Speed 20 MPH
Time 45 Min.

VL 27,000 Wheel 47382
LL - Tape 162
BSF 3,000 BS Cobra
105PSl J-33U

			Temperature (F)									
Date	Strain		Tread		Rim		Plate		Torque		Rev.	
	Eo	Ef	To	Tf	To	Tf	To	Tf	Max.	Min.		
5-20-85	0000	+2520	75	195	75	510	75	530			9418.4	
5-21-85	+0405	+3016	75	210	75	565	75	520			9224.0	
"	+0154	+2950	60	145	70	520	75	650			9695.2	47 Min.
"	+0340	+3442	80	220	100	590	110	680			9571.3	
"	+0186	+3187	80	220	80	545	80	720			9077.9	
"	+0024	+3153	80	190	80	560	80	785			9007.4	
"	-0084	+3068	50	220	50	600	75	750			9586.2	
5-22-85	-	-	75	165	75	555	75	675			9281.4	
"	-0383	+2251	65	165	90	530	90	610			9057.1	New Cobra
"	-0437	+1902	70	130	75	490	90	490			9188.3	
"	-0395	+2120	80	170	80	520	90	575			9434.6	
"	-0423	+2357	55	160	55	515	75	660			9519.0	
"	-0470	+2411	50	150	75	540	75	640			9570.5	
5-23-85	-0460	+2114	75	185	75	505	75	560			9462.1	
"	-0438	+2385	60	190	60	515	70	585			9307.8	
"	-0395	+2583	50	200	70	520	70	610			9144.9	
"	-0453	-	75	230	75	610	75	700			9459.9	
"	-0500	+2581	55	185	55	560	80	750			9291.0	
"	-0467	+2240	70	200	70	480	70	530			9607.7	
5-24-85	-0416	+2934	75	220	75	585	75	700			9550.9	
"	-0327	+2623	70	200	85	560	85	600			9440.9	
"	-0455	+2246	80	200	75	505	75	560			9416.2	
"	-0393	+1954	80	180	80	470	80	520			9138.5	
"	-0417	+2112	75	150	75	460	75	540			9606.2	
"	-0385	+2109	75	180	75	480	90	555			9299.6	
Max.	+405	+3442	80	220	100	610	110	785				
Min.	-599	+1892	69	145	50	460	70	490				
Avg.	-258	+2533	70	186	77	532	79	620				

FRA DRAG TESTS - Wheel 18

Speed 40 MPH
Time 45 Min.

VL 27,000 Wheel 042283
LL - Tape 162
BSF 750 BS Cobra
27 PSI J-33U

			Temperature (F)									
Date	Strain		Tread		Rim		Plate		Torque		Rev.	
	Eo	Ef	To	Tf	To	Tf	To	Tf	Max.	Min.		
5-29-85	0000	+2071	75	405	75	385	75	150			17902.4	
"	+0010	+2206	75	430	75	410	75	145			18023.1	
"	-0054	+2243	80	465	80	400	75	145			18451.0	
5-30-85	-0025	+2409	75	480	75	420	75	150			17976.0	
"	-	-	80	500	80	425	70	150			17758.1	
"	-0046	+2342	80	550	80	410	70	150			18275.1	
"	-0134	+2305	80	540	80	415	80	150			18322.6	
"	+0056	+2258	80	550	80	400	80	160			18547.0	
"	-0094	+2345	75	500	75	405	75	140			18387.7	Forward R
5-31-85	-0004	+2525	75	535	75	440	75	150			18071.5	
"	-0048	+2548	80	555	80	445	80	155			20261.8	50.9 min.
"	-0050	+2641	75	580	75	460	75	150			17789.0	
"	-0212	+2562	75	550	75	460	75	150			18205.7	
"	-0032	+2656	80	595	80	500	80	170			20315.7	51.47 min.
"	-0056	+2475	85	555	85	480	85	155			17875.8	
6- 3-85	-0188	+2662	75	550	75	515	75	155			17736.3	
"	-0176	+2760	90	560	85	480	75	150			18041.5	
"	-0222	+2442	80	535	75	425	75	140			18107.2	
"	-0339	+2345	75	530	75	440	75	150			17899.8	
"	-0286	+2335	80	530	80	395	80	145			18124.0	
"	-0261	+2269	80	525	80	400	80	155			18633.4	46.6 min.
6- 4-85	-0204	+2363	75	525	75	430	75	150			18174.2	
"	-0164	+2312	80	540	80	430	80	155			18434.2	
"	-0141	+2240	80	530	80	395	80	150			18115.0	
"	-0344	+2246	85	530	80	385	80	150			18246.1	
"	-0162	+2432	100	560	80	410	80	150			18215.7	
Max.	+056	+2760	100	595	80	515	85	170				
Min.	-344	+2071	75	405	75	385	75	145				
Avg.	-127	+2400	80	527	78	446	77	151				

FRA DRAG TESTS - Wheel 17

Speed 40 MPH
Time 45 Min.

VL 27,000 Wheel 043888
LL - Tape 162
BSF 1,500 BS Cobra
J-33U

			Temperature (F)									
Date	Strain		Tread		Rim		Plate		Torque		Rev.	
	Eo	Ef	To	Tf	To	Tf	To	Tf	Max.	Min.		
5-13-85	0000	+3605	75	600	75	480	75	170			10718.4	30 min.
"	+0440	+3600	110	725	110	510	85	205			18225.5	
"	+0032	+2745	90	490	80	390	70	190			18055.2	
5-14-85	+0190	2680	75	620	75	410	75	150			18073.6	
"	+0142	+3100	90	580	90	420	90	150			17683.3	
"	+0197	3050	90	600	90	430	90	180			17972.9	
"	-0072	2850	90	600	90	410	90	170			18142.9	
5-15-85	+0153	+3020	80	560	80	520	80	165			17480.3	
"	-0202	+2705	75	560	75	455	75	175			17808.4	
"	+0076	+2643	115	565	-	-	110	155			17537.2	
"	+0002	+2218	60	450	50	410	50	140			17812.5	New Cobra
"	+0067	+2184	110	490	110	415	90	170			18064.0	
"	-0199	+2366	75	500	50	440	80	175			18160.0	
5-16-85	+0019	+2570	75	520	75	470	75	140			17656.8	
"	-0108	+2562	100	510	95	470	95	175			17952.9	
"	-0160	+2728	95	560	90	475	100	183			18243.8	
"	-0140	+2845	90	550	80	495	80	175			18079.5	
"	+0002	+3146	90	670	80	545	70	190			18031.3	
"	-0060	+2816	80	610	70	500	60	180			17800.1	
5-17-85	-0067	+2900	75	620	75	515	75	167			17681.1	
"	-0083	+2845	100	610	100	495	80	190			18052.9	
"	-0205	+2872	75	580	75	510	75	200			17639.0	
"	-0137	+3095	100	610	75	510	80	180			17780.5	
"	-0115	+2562	80	550	80	465	80	185			18204.3	
"	-0138	+2702	90	600	90	490	90	170			18284.6	
Max.	+440	+3605	115	725	110	545	110	205				
Min.	-205	+2184	60	450	50	390	50	140				
Avg.	-15	+2816	87	573	83	467	82	174				

APPENDIX 5.2

ADAPTATION OF SOLUTION FOR MOVING HEAT SOURCE ON A HALF SPACE

Adaptation of Solution for Moving Heat Source on a Half Space

by
G.J. Moyar

Some insight into the problem of estimating the rate of heat transfer at the wheel/rail interface (based on surface temperature measurements behind the moving contact) may be gained from the classical closed form solutions of Rosenthal (Transaction ASME, vol 68, 1946, pp. 849-866).

The fundamental quasi-stationary 3-D solution for the temperature T in a half space bounded by the x-y plane and traversed by a point heat source of strength q moving with a constant velocity v along the x-axis is:

$$T-T_0 = \frac{q}{2\pi kR} e^{-DVS} e^{-DvR} \qquad (1)$$

where:

To is the reference temperature far from the heat source
k is the thermal conductivity
D is 0.5(c*w/k)
w is the density
c is the specific heat
s is the distance of the point considered from the point source (-behind, +ahead)
R = $\sqrt{s^2+y^2+z^2}$

For the unique situation of surface temperatures (z=0) and points along the x-axis (y=0) and behind the point source (s<0) this solution reduces to a very simple expression:

$$T-T_0 = \frac{q}{2\pi k|s|} \qquad (2)$$

Remarkably, this equation does not depend on speed v nor the thermal diffusivity (.5/D). This special case situation was also recognized by Rosenthal in his application of theory to the arc welding of thick plates. He notes that "the same expression is obtained if the point source instead of being in motion remains stationary, except that in this case |s| represents not only the distance behind the source, but the distance from the source measured in any direction."

APPENDIX 5.3

ADAPTATION OF SOLUTION FOR MOVING HEAT SOURCE ON THE EDGE OF A SEMI-INFINITE PLATE

Adaptation of Solution for Moving Heat Source on the Edge of a Semi-infinite Plate

by
G.J. Moyar

In order to further explore the problem of estimating the rate of heat transfer based on the closed form solutions of Rosenthal (Trans. ASME, vol. 68, 1946, pp. 849-866), the two dimensional solution for a moving heat source on the edge of a large plate will be obtained for comparison to the previous (11/7/84) 3D solution of a point source moving on a half space.

For this 2D case:

$$T - T_0 = \frac{q}{\pi g k} e^{-Dvs} K_0(Dvr) \qquad (1)$$

where:

Ko is the modified Bessel function of the second kind and zero order
To is the reference temperature far from the heat source
D is 0.5*(c*w/k)
k is the thermal conductivity
w is the density
c is the specific heat
s is the distance of the point considered from the point source (-behind, +ahead) along the X-axis
q is the heat transfer rate
r $= \sqrt{s^2 + y^2}$
v is the velocity of the source along the X-axis

As Rosenthal observes, when the dimensionless argument of the particular Bessel function becomes very large:

$$K_0(Dvr) \rightarrow \sqrt{\frac{\pi}{2Dvr}}\, e^{-Dvr}$$

For the relatively high velocities of interest in the wheel/rail situation this condition exists except very near the heat transfer point. Therefore Equation (1) may be approximated by:

$$T - T_0 = \frac{q/g}{\sqrt{\pi c w k v r}}\, e^{-Dvs}\, e^{-Dvr} \qquad (2)$$

At the surface (Y=0) and at points behind the heat source (s<0) Equation (2) simplifies to:

$$T - T_0 = \frac{q/g}{\sqrt{\pi c w k v |s|}} \qquad (3)$$

This may be numerically evaluated for the following case of interest:

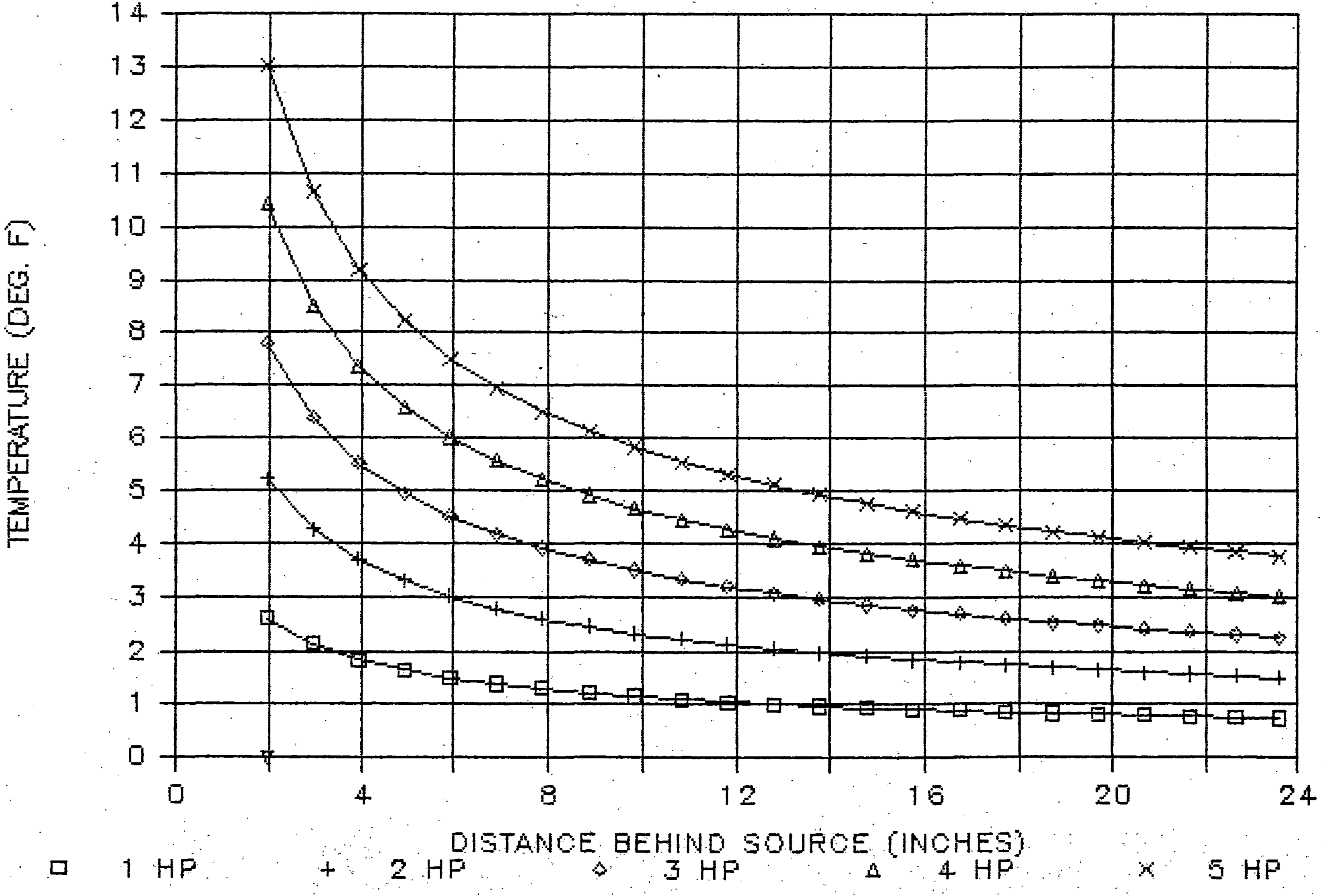
c = 0.1072 BTU/LB*DegF
w = 489 LB/FT©3
k = 27.5 BTU/HR*FT*DegF
q = 2544.5 BTU/HR*HP * H
H is heating rate in horsepower
v = 184,800 FT/HR (35 MPH)
g = 1/12 FT (1 inch thick plate)
s expressed in inches

$$T - T_0 = 3.65615 \frac{H}{\sqrt{|s|}} \qquad (4)$$

This expression for surface temperature rise behind a 1 inch line heat source moving at 35 MPH is plotted on the attached figure for values of source strength ranging from 1 to 5 HP.

TEMP. RISE (DEG. F) BEHIND HEAT SOURCE

MOVING 35MPH ON EDGE OF 1"THK. PLATE



APPENDIX 5.4

ESTIMATE OF WHEEL/RAIL HEAT TRANSFER RATE BASED ON LEADING AND TRAILING SURFACE TEMPERATURES

APPENDIX 5.4

ESTIMATE OF WHEEL/RAIL HEAT TRANSFER RATE BASED ON LEDING AND TRAILING SURFACE TEMPERATURES

The theoretical solution for the surface temperature difference from leading (inlet) to trailing (outlet) position relative to a heat input source, idealized as a line source across the width of contact may be obtained from Appendix 5.3.

The geometrical arrangement and constants assumed are given in Figure 5.4.1.

This expression may be solved for the strength of the heat source or heat transfer rate in horsepower:

$$HP = \frac{H \times ({}^{T}O - {}^{T}I) \cdot \sqrt{MPH} \cdot \sqrt{X}}{21.63}$$

If we assume the following typical values:

H = 0.625 inches

X = 16 miles

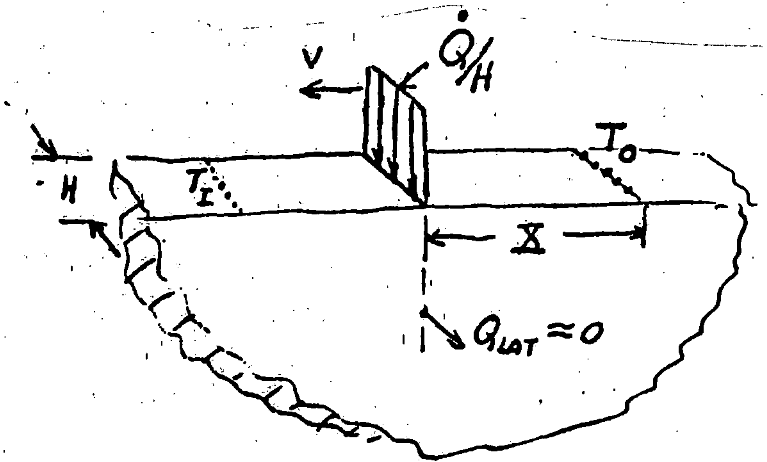
$T_O - T_I = 15°F$

The estimated heat transfer rate would be:

$$HP = \frac{0.625\ (15)\ \sqrt{20}\ \sqrt{16}}{21.63} = 7.75$$

MOVING LINE SOURCE ON SEMI-INFINITE PLATE

Rosenthal (1946)



$$T_0 - T_I = \frac{\dot{Q}/H}{\sqrt{\pi c \rho k V X}}$$

$c = 0.1072 \left[BTU/LB \cdot {}^\circ F\right]$

$\rho = 489 \left[\frac{LB}{FT^3}\right]$

$k = 27.5 \left[\frac{BTU}{HR \cdot FT \cdot {}^\circ F}\right]$

$\dot{Q} = 2544.5 \cdot HP \left[\frac{BTU}{HR}\right]$

$$\therefore \boxed{T_0 - T_I = \frac{21.63\ HP/H}{\sqrt{MPH \cdot X}}}$$

HIGH ESTIMATE OF TEMP.

X AND H IN INCHES

FIGURE 5.4.1. GEOMETRY AND CONSTANTS ASSIGNED IN ANALYSIS OF MOVING LINE SOURCE ON SEMI-INFINITE PLATE.

APPENDIX 5.6

STEPS INVOLVED IN DETERMINING ACTUAL STRAINS

STEPS INVOLVED IN DETERMINING ACTUAL STRAINS

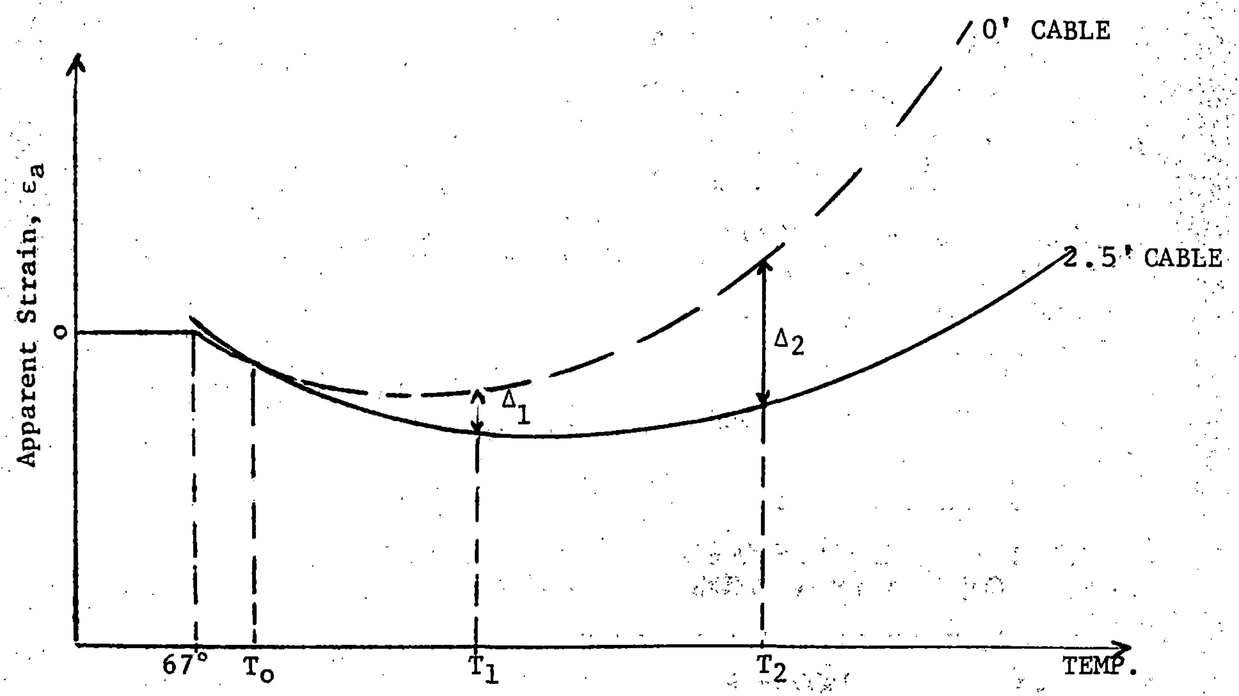
1. RAW STRAIN ANALYSIS, ε_r

A. COMPLETE TIME HISTORIES OF THE RAW STRAINS (ε_r) AND TEMPERATURES (T) ARE TABULATED FOR ALL GAGES.

B. SPSS PROGRAM IS THEN USED TO REDUCE THE DATA INTO THE PLOTS OF RAW STRAIN VS TEMPERATURE (ε_r VS T).

2. CALIBRATION TO COMPENSATE FOR CABLE LENGTH AND MISMATCH OF THE STRAIN GAGE AND WHEEL MATERIAL

2.5' CABLE WAS USED DURING TEMPERATURE CYCLING WHEREAS 0' CABLE WAS USED DURING TESTING. TEMPERATURE CYCLING CURVE (2.5' CABLE) TO COMPENSATE FOR MISMATCH OF MATERIALS IS MODIFIED TO REPRESENT APPARENT STRAIN CURVE (0' CABLE).



CALIBRATION CURVE

[✓ CURVED]/STRAIGHT PLATE B1C0 VS THB1

TEMPERATURE (°F)	STRAIN CORRECTION (με)
67	0
128	-97
196	-185
264	-273
332	-323
400	-350
468	-365
536	-366
604	-349
672	-322
726	-282

THE POINTS ARE TAKEN FROM THE PLOT.

THE POINTS ARE BEST FITTED BY A 6-DEGREE POLYNOMIAL WITH COEFFICIENTS.

	T	T^2	T^3	T^4	T^5	T^6
C_0	C_1	C_2	C_3	C_4	C_5	C_6
96.247	-1.305	-0.2878 *10-2	0.1238* 10-4	-0.7636 *10-8	-0.1064 *10-10	0.1105 *10-13

STATISTICS

TOTAL VARIATION	EXPLAINED VARIATION	UNEXPLAINED VARIATION	R^2
146296	146214	82	0.9994397

THE CALIBRATION CURVE FOR 0' CABLE LENGTH IS CONSTRUCTED AS FOLLOWS:

A. PLOT THE DIFFERENCES IN APPARENT STRAINS, FOR 2.5' AND 0' CABLES, 0, Δ_1, AND Δ_2 AT TEMPERATURES T_0, T_1, AND T_2 FROM THE DATA PROVIDED BY MANUFACTURER (SEE FIGURE ON THE LAST PAGE).

B. FIT THE DOTTED CURVE TO PASS THROUGH THESE POINTS.

C. READJUST THE SCALE SUCH THAT THE APPARENT STRAIN IS ZERO AT AMBIENT TEMPERATURE T=67°F.

D. FIND ANALYTICAL EXPRESSION FOR THE CURVE BY FITTING A 6-DEGREE POLYNOMIAL SUCH AS:

$$\varepsilon_a=C_0+C_1T+C_2T^2+C_3T^3+C_4T^4+C_5T^5+C_6T^6 \qquad (1)$$

THE COEFFICIENTS C_0------C_6 ARE DETERMINED AND RECORDED TO DEFINE 0' CABLE CALIBRATION CURVE (CORRECTION I) FOR ALL STRAIN GAGES.

E. CURVE FITTING WAS EXCELLENT WITH CORRELATION COEFFICIENT (R^2) AVERAGING 0.9999.

F. CORRECTION (I) TAKES CARE OF DIFFERENCE IN CABLE LENGTH AS WELL AS MISMATCH OF STRAIN GAGE AND WHEEL MATERIALS.

3. ADJUSTED STRAIN AFTER CORRECTION (I)

A. THE CORRECTION (I) IS APPLIED TO RAW STRAIN (ε_r) TO FIND

$$\varepsilon_I=\varepsilon_r-\varepsilon_a \qquad (2)$$

WHERE:

TEMPERATURE HISTORY OF ε_r IS KNOWN AND ε_a AT CORRESPONDING TEMPERATURE CAN BE DETERMINED BY eqn (1)

B. THE STRAINS (ε_I) ARE INITIALIZED SO THAT THEY ARE ZERO AT AMBIENT TEMPERATURE T=67°F.

4. ACTUAL STRAIN AFTER GAGE FACTOR COMPENSATION (CORRECTION II)

A. THE FORMULA FOR GAGE FACTOR COMPENSATION IS:

$$GFC=GFN\{1-0.000185(T-67)\}\frac{RA}{RA+RTCM+RL} \qquad (3)$$

$$GF=\frac{GFC}{GFN}=\frac{RA+RTCM+RL}{RA\{1-0.000185(T-67)\}} \qquad (4)$$

WHERE VALUES OF RA, RTCM, AND RL ARE PROVIDED BY MANUFACTURER FOR EACH STRAIN GAGE.

B. THE ACTUAL STRAIN IS:

$$\varepsilon_{act}=GF*\varepsilon_I \qquad (5)$$

GF IS CALCULATED USING eqn(4) FOR A GIVEN GAGE AT GIVEN TEMPERATURE (T).

C. SPSS IS USED TO MAKE X-Y PLOT OF ε_{act} VS T.

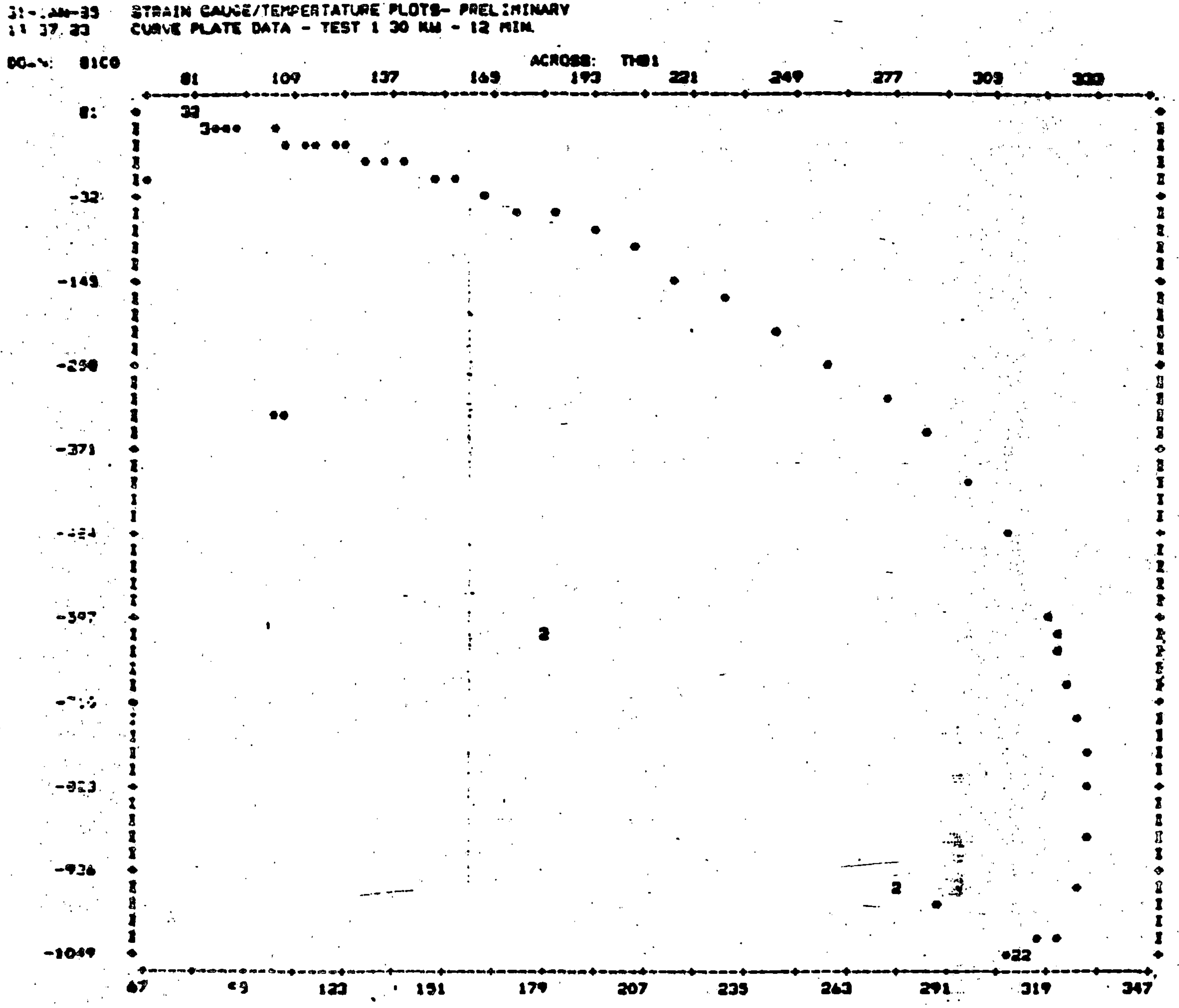
CURVED PLATE - TEST 1 -

TEMP.	RAW STRAIN	CALIB. STRAIN
67.00	214.00	214.55
104.10	-129.90	-71.06
105.70	-141.80	-81.50
178.80	-503.70	-335.98
180.10	-503.20	-333.71
277.20	-891.00	-610.56
277.90	-898.00	-616.93
287.20	-632.80	-632.80
308.70	-990.00	-683.71
309.80	-988.00	-680.90

ACTUAL STRAIN CALCULATIONS - B1C0

ADJUSTED STRAIN	GAGE FACTOR	ACTUAL STRAIN AFTER GFC.
0.00	1.11	0.00
-285.61	1.12	-320.60
-296.05	1.12	-332.41
-548.26	1.14	-626.70
-548.26	1.14	-624.27
-825.11	1.16	-957.06
-831.48	1.16	-964.57
-847.35	1.16	-984.74
-898.27	1.17	-1048.26
-895.46	1.17	-1045.21

ε_{act} VS TEMPERATURE - TEST 1 - CURVED PLATE - B1C0


31-JAN-85 STRAIN GAUGE/TEMPERTATURE PLOTS- PRELIMINARY
11 37 23 CURVE PLATE DATA - TEST 1 30 KW - 12 MIN

APPENDIX 5.5

ANALYSIS OF BRAKE DYNAMOMETER UNIT HEAT TRANSFER DATA

appendix 9...

NATIONAL 42-381 50 SHEETS 5 SQUARE
42-382 100 SHEETS 5 SQUARE
42-389 200 SHEETS 5 SQUARE

ANALYSIS OF BRAKE DYNAMOMETER UNIT HEAT TRANSFER DATA

FROM

NOMINAL 50 BHP*** 40 MPH RUN
(FULL* VERTICAL LOAD)
ON 4/26/85 AT AAR TECH. CTR.

MEASUREMENTS

TEMPERATURE MEASUREMENTS MADE BEFORE, DURING (1/8" FROM SURFACE), AND AFTER TESTS BY G. MOYAR USING EXERGEN CORP MICROSCANNER D-SERIES DIGITAL INFRARED THERMOMETER ON RAIL WHEEL SURFACE (PRE-SPRAYED WITH FLAT BLACK WHERE SHINY METAL EXPOSED).

WHEEL + RAIL TEMPERATURES ALSO RECORDED BY HUGHES AIRCRAFT CO. "PROBEYE" THERMAL VIDEO SERIES 4000 SYSTEM (ART FISHMAN, SALES REP).

RESULTS

A MINIMUM HEAT TRANSFER RATE INTO THE RAIL WHEEL EQUIVALENT TO ~~7.4~~ 7.3 HP IS ESTIMATED, IGNORING CONVECTION HEAT LOSES. WHEEL COOL DOWN DATA (VIDEO) AT SPEED, FOLLOWING BRAKE REMOVAL AND VERTICAL LOAD REDUCTION** TO MINIMUM, ARE AVAILABLE TO ALLOW ESTIMATES OF CONVECTION LOSSES.

G. Moyar
4/30/85

* 27,000 lbs

** 4,535 lbs

*** 1625 x .3 =

CHRONOLOGY OF EVENTS + TEMPERATURES
AAR BDU 4/26/85
(BASED ON NOTES FROM RECORD BOOK OF Morgan)

42-381 50 SHEETS 5 SQUARE
42-382 100 SHEETS 5 SQUARE
42-389 200 SHEETS 5 SQUARE
NATIONAL

TIME (AM)

9:01 AMBIENT TEMP 75°F

9:35:30 START BRAKE APPLICATION

9:54 T1 = 160°F
T3 = 146

10:04 CHANGE THERMAL VIDEO TO SOUTH (INLET) SIDE OF WHEEL
~~10:15~~ ? CHANGE THERMAL VIDEO TO PIT

10:19 T1 = 205
T2 = 192
T3 = 185
T5 = 94
T6 = 88

10:21 T1 = 204
T2 = 200
T3 = 184
T5 = 93
T6 = 89

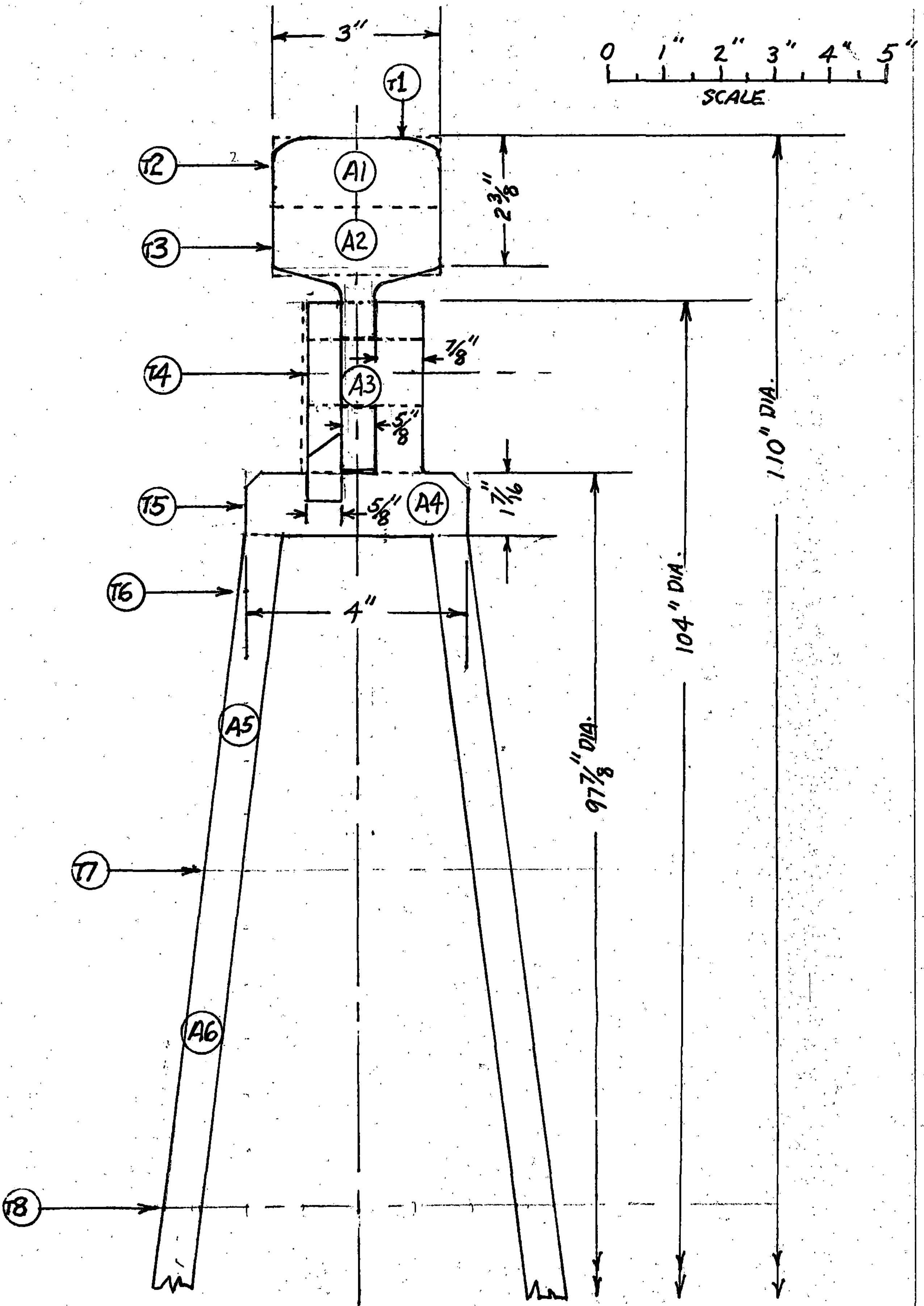
10:21:30 BRAKE OFF - SLOW RAIL TO FEW RPM - REDUCE VERTICAL LOAD TO MINIMUM AFTER BRIEF STOP FOR TEMP MEASUREMENTS:
T1 = 199
T2 = 192
T3 = 184
T5 = 94
T6 = 90
T7 = 81
T8 = 76

10:24 INCREASE RAIL WHEEL TO 40 MPH
→ 10:25:30
10:34 T1 = 148°F

10:44 T1 = 122°F (BY THERMAL VIDEO) ✓
10:52:20 STOP
10:53 STOP RAIL WHEEL

T1 = 114°F
T2 = 114
T3 = 113
T4 = 98

T5 = 93
T6 = 90
T7 = 85
T8 = 81



AAR BRAKE DYNAMOMETER UNIT

Moyer
4/30/85

42-381 50 SHEETS 5 SQUARE
42-382 100 SHEETS 5 SQUARE
42-389 200 SHEETS 5 SQUARE
NATIONAL

'17' 4/30/85

ΔT_i

AREA #	AREA (IN²)	DIA (IN)	TEMP. BASIS
A1	3×1.25 = 3.75	108.75	(T1+T2)/2
A2	3×1.25 = 3.75	107.50	T3
A3	2.25 × 3.125 = 7.03	100.88	(T3+T5)/2
A4	1.43 × 4.00 = 1.72	96.44	T5
A5	0.625 × 6.00 = 3.75	89.00	(T6 + T7)/2
A6	0.625 × 6.00 = 3.75	77.00	(T7+ T8)/2

RING VOLUME X STEEL DENSITY X SPECIFIC HT X AVG TEMP INCREASE

$$\pi \cdot D_i \cdot A_i \times \rho \times C \times \underbrace{\left(T_i - T_{initial}\right)}_{T_i'}$$

RING 1

$\pi \times 108.75 \times 3.75 \times 0.283 \times 0.1072 \times \Delta T_1 = 38.868\,\Delta T_1$

RING 2

$\pi \times$ ~~107.50~~ 106.25 $\times 3.75 \times 0.283 \times 0.1072 \times \Delta T_2 =$ ~~38.421~~ 37.974 ΔT_2

RING 3

$\pi \times 100.88 \times 7.03 \times 0.283 \times 0.1072 \times \Delta T_3 = 67.591\,\Delta T_3$

RING 4

$\pi \times 96.44 \times 1.72 \times 0.283 \times 0.1072 \times \Delta T_4 = 15.809\,\Delta T_4$

2 X RING 5

$2 \times \pi \times 89.00 \times 3.75 \times 0.283 \times 0.1072 \times \Delta T_5 = 63.618\,\Delta T_5$

2 X RING 6

$2 \times \pi \times 77.00 \times 3.75 \times 0.283 \times 0.1072 \times \Delta T_6 = 55.041\,\Delta T_6$

Σ RINGS $= \frac{38.868}{2}(T1' + T2') +$ ~~38.421~~ 37.974 $\cdot T3' + \frac{67.592}{2}(T3' + T5')$

$+ 15.809 \cdot T5' + \frac{63.618}{2}(T6' + T7') + \frac{55.041}{2}(T7' + T8')$

$= 19.434\,T1' + 19.434\,T2' +$ ~~72.217~~ 71.770 $T3' + 49.605\,T5'$

$+ 31.809\,T6' + 59.330\,T7' + 27.521\,T8'$

FOR $T1' = 199 - 75 = 124$ $T5' = 94 - 75 = 19$ $T8 = 76 - 75 = 1$

$T2' = 192 - 75 = 117$ $T6' = 90 - 75 = 15$

$T3' = 184 - 75 = 109$ $T7' = 81 - 75 = 6$

Σ RING HEAT $= 2409.816 + 2273.776 +$ ~~7871.653~~ 7822.977 $+ 942.495 + 477.135$

$+ 355.98 + 27.521 =$ ~~14,358.376~~ 14,309.7 BTU $\equiv \Delta I$

INCREASE IN INTERNAL ENERGY OR HEAT OF RAIL WHEEL (ΔI) EQUALS HEAT TRANSFER INTO RAIL WHEEL AT WHEEL CONTACT (ΔQ) DURING BRAKING (IGNORE CONVECTION LOSSES);

ALSO $\Delta Q = 2544.5 \left[\frac{BTU}{HR \cdot HP}\right] \times HP \times \Delta time\ (HR)$

THEREFORE THE HEAT TRANSFER RATE IN TERMS OF HP IS

$$HP = \frac{\Delta I\,[BTU]}{2544.5 \times \Delta t\,[HR]}$$

$\Delta t = 46$ MIN OR 0.766 HRS

$$HP = \frac{\overset{14{,}309.7}{\cancel{14{,}358.376}}\ BTU}{2544.5 \times 0.766} = \overset{7.342}{\cancel{7.367}}\ HP$$

NOTE: NOMINAL INPUT BRAKE HP WAS 50

∴ HEAT TRANSFER ≈ 14.7%

E J Moyer
4/30/85

APPENDIX 5.7

PRELIMINARY RDU HEAT TRANSFER ANALYSIS

APPENDIX 5.7

PRELIMINARY RDU HEAT TRANSFER ANALYSIS

(Memo to Dan Stone)

The attached notes represent the preliminary analysis of the first heat transfer test conducted by Britto Rajkumar and I at the TTC during the RDU tests on 4/11/85. Data from additional tests are available and more information is forthcoming on the actual BHP history of the wheel running on the subject roller. Your comments, suggesting and corrections are requested now prior to our completion of all data reduction and analysis.

The result, a wheel/roller heat transfer rate about 15.9% of the input BHP, appears to be generally consistent with our earlier estimates based on the BDU tests by George Carpenter.

The many plots of temperature history following the end of the RDU test are not really essential to the purpose of this analysis. Nevertheless, they do provide some insight into the transient heat flow pattern into the stationary roller during cool down of the loaded wheel as well as some indication of our temperature measurement variability.

I should also note that Britto and I found the Exergen Digital Infared Thermometer to be easy to use. He also got some wheel data up to about 550°F and found it convenient to get a quick measurement of wheel front face rim temperature for comparison of the relative severity of braking at the several wheel locations.

Jerry Moyar

ANALYSIS OF RDU ROLLER HEAT TRANSFER DATA

FROM

NOMINAL 50 BHP - WEST RUN

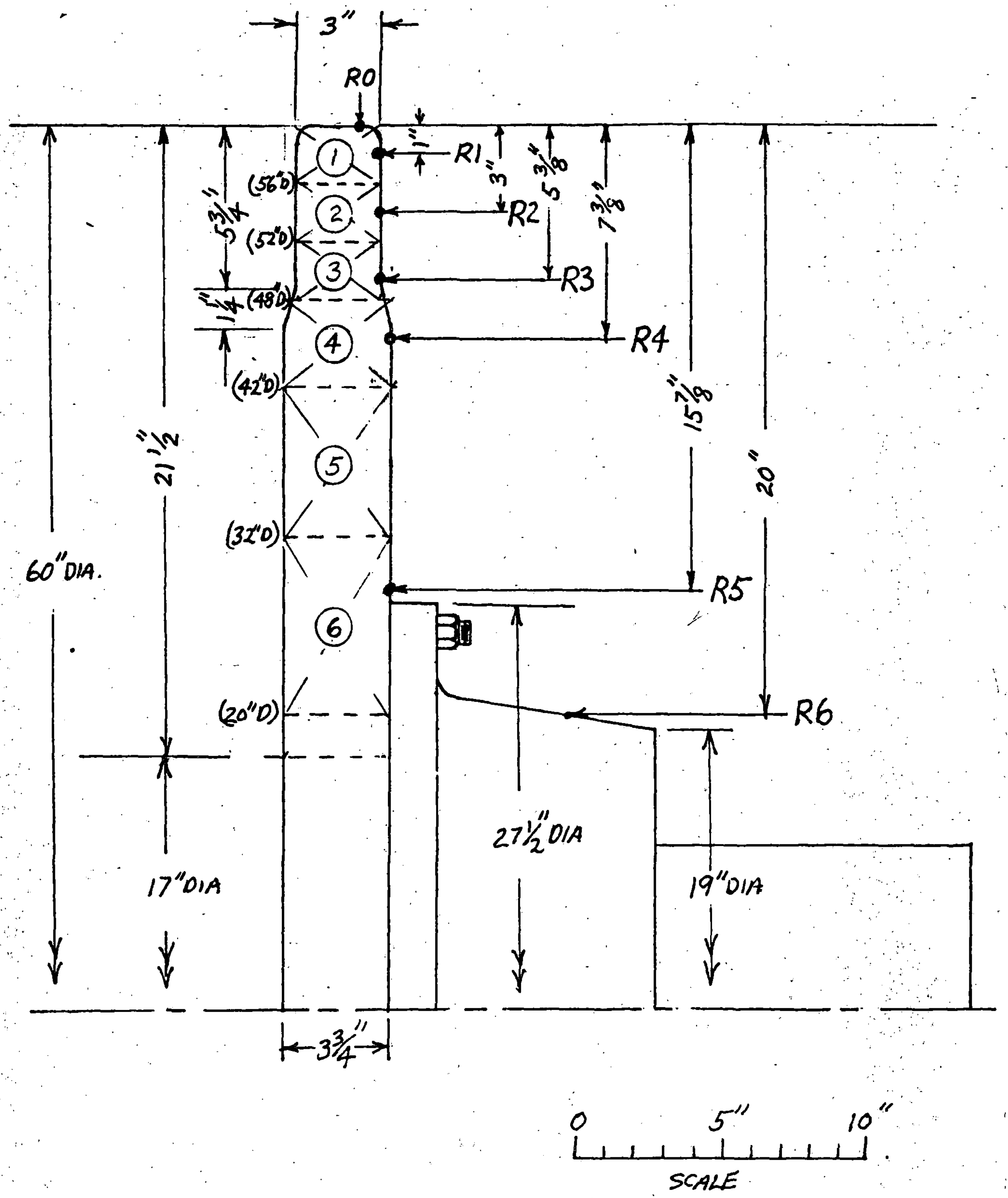
ON 4/11/85 AT TTC

MEASUREMENTS

Temperature measurements made before and after braking test by G. Moyar and B. Rajkumar using Exergen Corp. Microscanner D-Series Digital Infared Thermometer on roller surface (pre-sprayed with flat black paint).

RESULTS

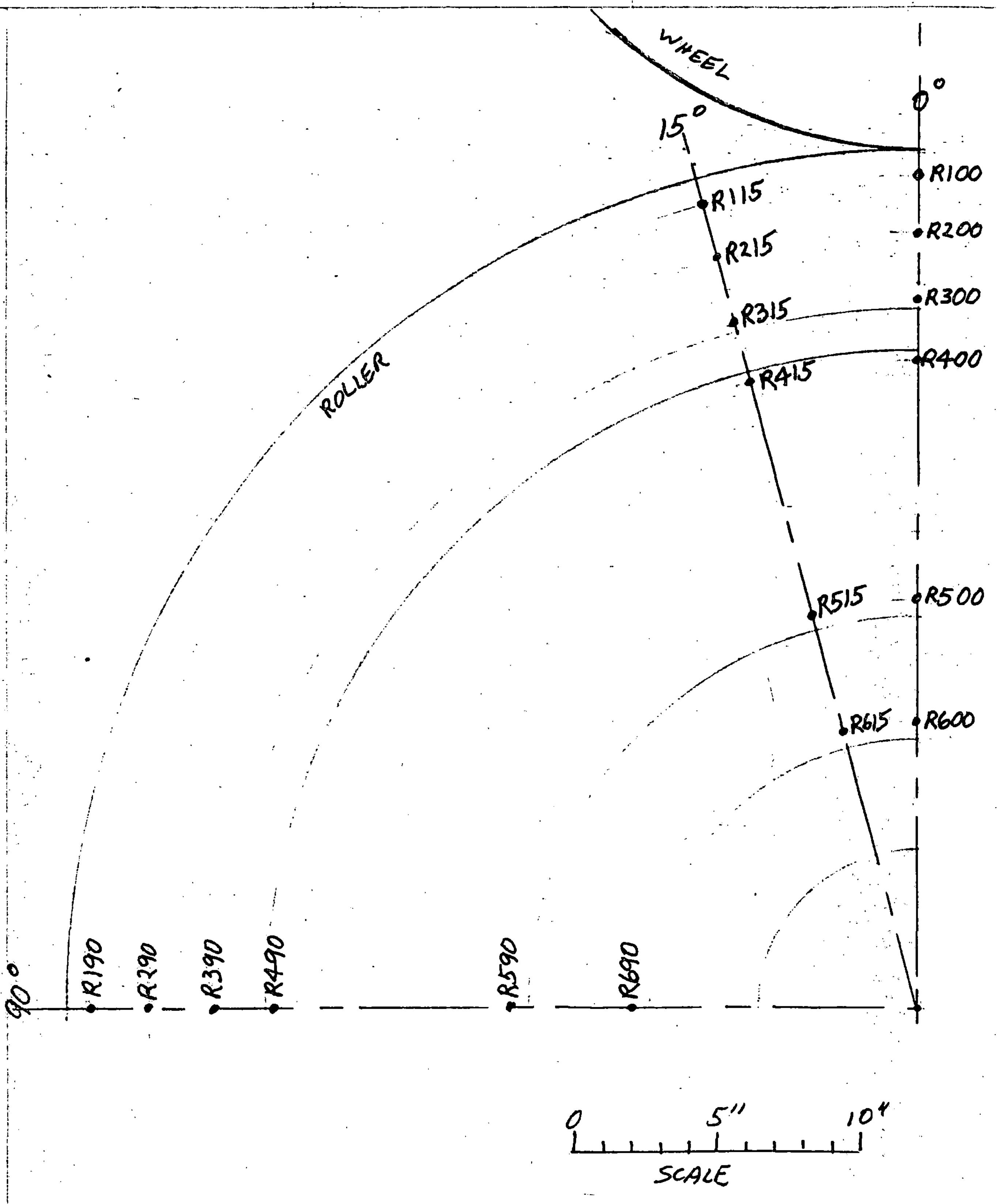
A minimum heat transfer rate into the roller equivalent to 7.9 HP is estimated, based on the overall increase in internal energy (heat) of the roller disk during the 1 hour test.



RDU ROLLER GEOMETRY + RADIAL TEMPERATURE MEASUREMENT POSITIONS (SECTION)

4/24/85

42 381 50 SHEETS 5 SQUARE
42 382 100 SHEETS 5 SQUARE
42 389 200 SHEETS 5 SQUARE



ROLLER TEMPERATURE MEASUREMENT POSITIONS
(ELEVATION)

4/24/85

	H			Ri
RING #	THICKNESS (")	O.D. (")	I.D. (")	AVG. TEMP BASIS
①	3.00	60	56	$\Delta R1$
②	3.00	56	52	$\Delta R2$
③	3.00	52	48	$\Delta R3$
④	3.75	48	42	$\Delta R4$
⑤	3.75	42	32	$\Delta(R4+R5)/2$
⑥	3.75	32	20	$\Delta R5$

CHANGE IN
RING HEAT CONTENT (BTU):

RING VOLUME × STEEL DENSITY × SPECIFIC HEAT × AVG. TEMP. INCREASE

$$\frac{\pi}{4}\cdot H\cdot(OD^2-ID^2)\times\rho\times C\times(Ri-\text{INITIAL TEMP})$$

RING#1 $\pi/4\times3\times(60^2-56^2)\times0.283\times0.1072\times\Delta R1 = 33.167\,\Delta R1$

RING#2 $\pi/4\times3\times(56^2-52^2)\times0.283\times0.1072\times\Delta R2 = 30.880\,\Delta R2$

RING#3 $\pi/4\times3\times(52^2-48^2)\times0.283\times0.1072\times\Delta R3 = 28.593\,\Delta R3$

RING#4 $\pi/4\times3.75\times(48^2-42^2)\times0.283\times0.1072\times\Delta R4 = 48.250\,\Delta R4$

RING#5 $\pi/4\times3.75\times(42^2-32^2)\times0.283\times0.1072\times\frac{(\Delta R4+\Delta R5)}{2}$

$= 33.060\,\Delta R4 + 33.060\,\Delta R5$

RING#6 $\pi/4\times3.75\times(32^2-20^2)\times0.283\times0.1072\times\Delta R5 = 55.755\,\Delta R5$

$\sum$ RINGS $= 33.167\,\Delta R1 + 30.880\,\Delta R2 + 28.593\,\Delta R3 + 48.250\,\Delta R4$
$+ 33.060\,\Delta R4 + 33.060\,\Delta R5 + 55.755\,\Delta R5$

$$\boxed{\sum \text{RING(BTU)} = 33.167\,\Delta R1 + 30.880\,\Delta R2 + 28.593\,\Delta R3 + 81.310\,\Delta R4 + 88.815\,\Delta R5 \ \text{BTU} = \Delta I}$$

4/24/85

THE CHANGE OF ROLLER HEAT CONTENT OR INTERNAL ENERGY EQUALS THE HEAT TRANSFERED INTO ROLLER THROUGH WHEEL CONTACT DURING BRAKING TEST.

THIS HEAT TRANSFER MAY BE EXPRESSED IN TERMS OF AVG. HEATING RATE OR HORSEPOWER

$$\Delta Q = 2544.5\left[\frac{BTU}{HR \cdot HP}\right] \times HP \times \Delta time[HR]$$

$$\overset{set}{=} \Delta I$$

THEREFORE:

$$HP = \frac{\Delta I[BTU]}{2544.5 \times \Delta t[HR]}$$

42-381 50 SHEETS 5 SQUARE
42-382 100 SHEETS 5 SQUARE
42-389 200 SHEETS 5 SQUARE

EXTRAPOLATION OF ROLLER TEMPS MEASURED 90 TO 170 SEC. AFTER BRAKES RELEASED TO 0 SEC.

SEE ATTACHED PLOTS OF "RDU ROLLER COOL DOWN AT" – R100 THROUGH R590

NOTE: HEAT FLOW FROM STATIONARY COOLING WHEEL (STILL UNDER LOAD) INTO ROLLER CAUSES TRANSIENT NON-AXISYMMETRIC TEMP. DISTRIBUTION IN ROLLER WITH HIGHER TEMPS AT 0° + 15° THAN 90°. THEREFORE BASE ESTIMATE OF ROTATIONALLY SYMMETRIC TEMPERATURES AT TIME = 0 SEC MORE HEAVILY ON 90° CASE EXTRAPOLATION.

EXTRAPOLATED TEMPS

LOCATION	TEMP. (°F)	Δ TEMP FROM 75°F	
R190	240	165	= ΔR1
R290	212	137	= ΔR2
R390	173	98	= ΔR3
R490	152	77	= ΔR4
R590	92	17	= ΔR5

4/24/85

$$\therefore \Delta I = 33.167 \times 165 + 30.880 \times 137 + 28.593 \times 98 + 81.310 \times 77 + 88.815 \times 17$$

$$= 5472.555 + 4230.560 + 2802.114 + 6260.870 + 1509.855$$

$$= 20{,}275.954 \text{ BTU}$$

$$\therefore HP = \frac{20{,}275.954 \left[BTU\right]}{2544.5 \left[\frac{BTU}{HR \cdot HP}\right] \times 1 \left[HR\right]} = 7.969 \text{ HP}$$

THE NOMINAL BRAKE HORSEPOWER INPUT WAS ABOUT 50 (ACTUALLY DECREASED WITH TIME DURING THE 1 HR TEST AS SHOES HEATED UP - NO FORCED AIR COOLING IN THIS PARTICULAR TEST). THEREFORE THE HEAT TRANSFER RATE AT THE ROLLER IS AT LEAST $\frac{7.969}{50} \times 100 = \underline{15.94\%}$ OF THE BRAKE SHOE TO WHEEL HEAT INPUT RATE ASSUMING ALL BRAKING POWER GOES INTO WHEEL AND NO HEAT LOSS FROM ROLLER DUE TO CONVECTION. FULL 70 TON VERTICAL CAR LOADING WAS MAINTAINED ON WHEEL DURING TEST + COOL DOWN. NO WHEEL SLIP AT ROLLER.

4/24/85

42 381 50 SHEETS 5 SQUARE
42 382 100 SHEETS 5 SQUARE
42 389 200 SHEETS 5 SQUARE
NATIONAL

42-381 50 SHEETS 5 SQUARE
42-382 100 SHEETS 5 SQUARE
42-389 200 SHEETS 5 SQUARE

RDU1 HEAT TRANS. 4/11/85 50 BHP for 1 HR.

Position	OrigTemp	PstBrkSec	Temp.F	SEC.	Temp.F	SEC.	Temp.F	SEC.	Temp.F	SEC.	Temp.F	SEC.	Temp.F	SEC.	Temp.F
R100	75	90	252	240	260	360	257	480	255	600	249	900	232	1200	225
R200	75	94	214	244	208	364	206	484	211	604	207	904	195	1204	191
R300	75	98	171	248	170	368	175	488	173	608	175	908	168	1208	168
R400	75	102	149	252	149	372	152	492	153	612	154	912	150	1212	152
R500	75	106	92	256	91	376	94	496	94	616	95	916	91	1216	96
R600	75	110	76	260	73	380	75	500	74	620	74	920	67	1220	69
R115	75	120	249	270	234	390	224	510	214	630	208	930	190	1230	185
R215	75	124	207	274	207	394	203	514	198	634	193	934	179	1234	179
R315	75	128	168	278	174	398	175	518	173	638	171	938	164	1238	162
R415	75	132	148	282	151	402	153	522	153	642	154	942	150	1242	150
R515	75	136	91	286	92	406	95	526	94	646	96	946	94	1246	98
R615	75	140	73	290	74	410	75	530	74	650	74	950	70	1250	72
R090	75	150	242	300	228	420	219	540	208	660	203	960	184	1260	174
R190	75	154	239	304	227	424	218	544	207	664	202	964	184	1264	175
R290	75	158	209	308	207	428	203	548	194	668	192	968	176	1268	170
R390	75	162	172	312	173	432	173	552	172	672	171	972	161	1272	159
R490	75	166	147	316	152	436	152	556	153	676	153	976	150	1276	149
R590	75	170	89	320	92	440	94	560	95	680	97	980	97	1280	100
R690	75	174	71	324	72	444	74	564	73	684	74	984	72	1284	73

7.

BDM
4/24/85

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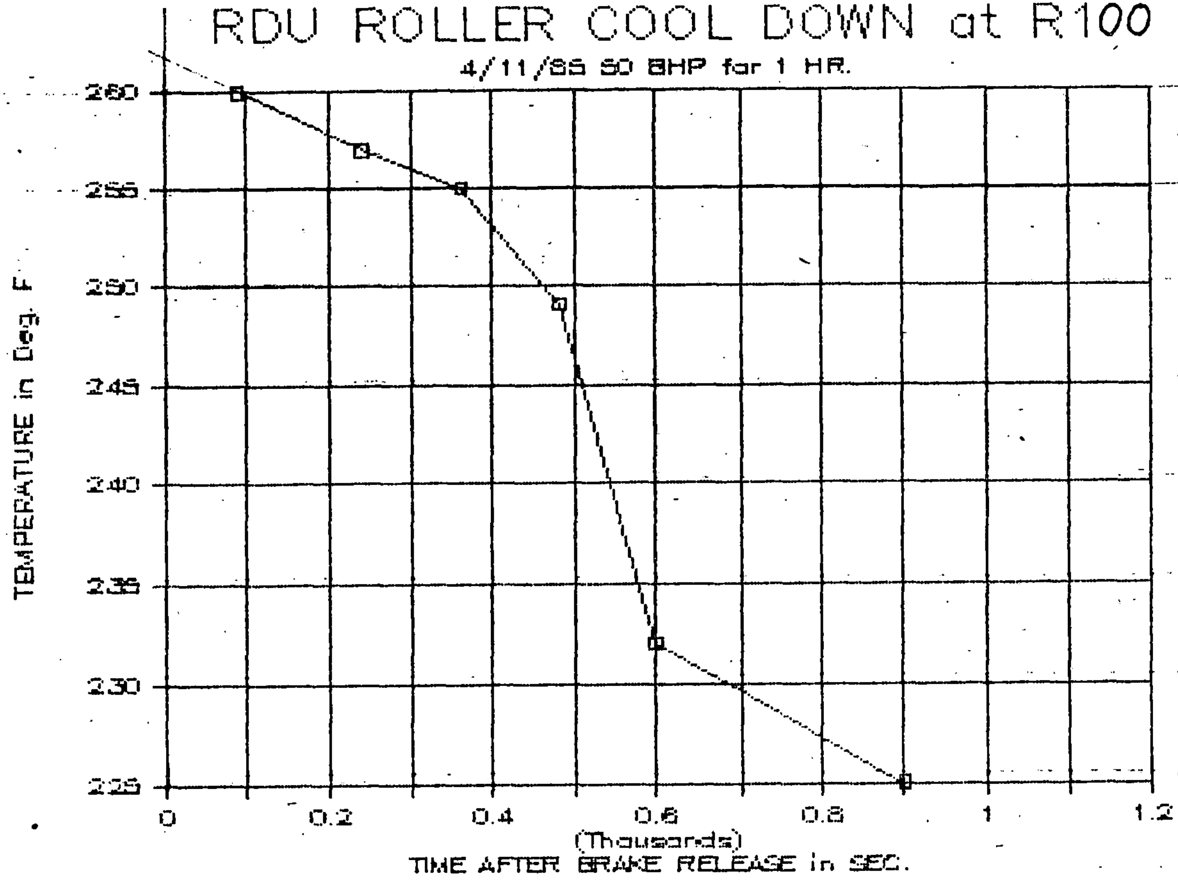
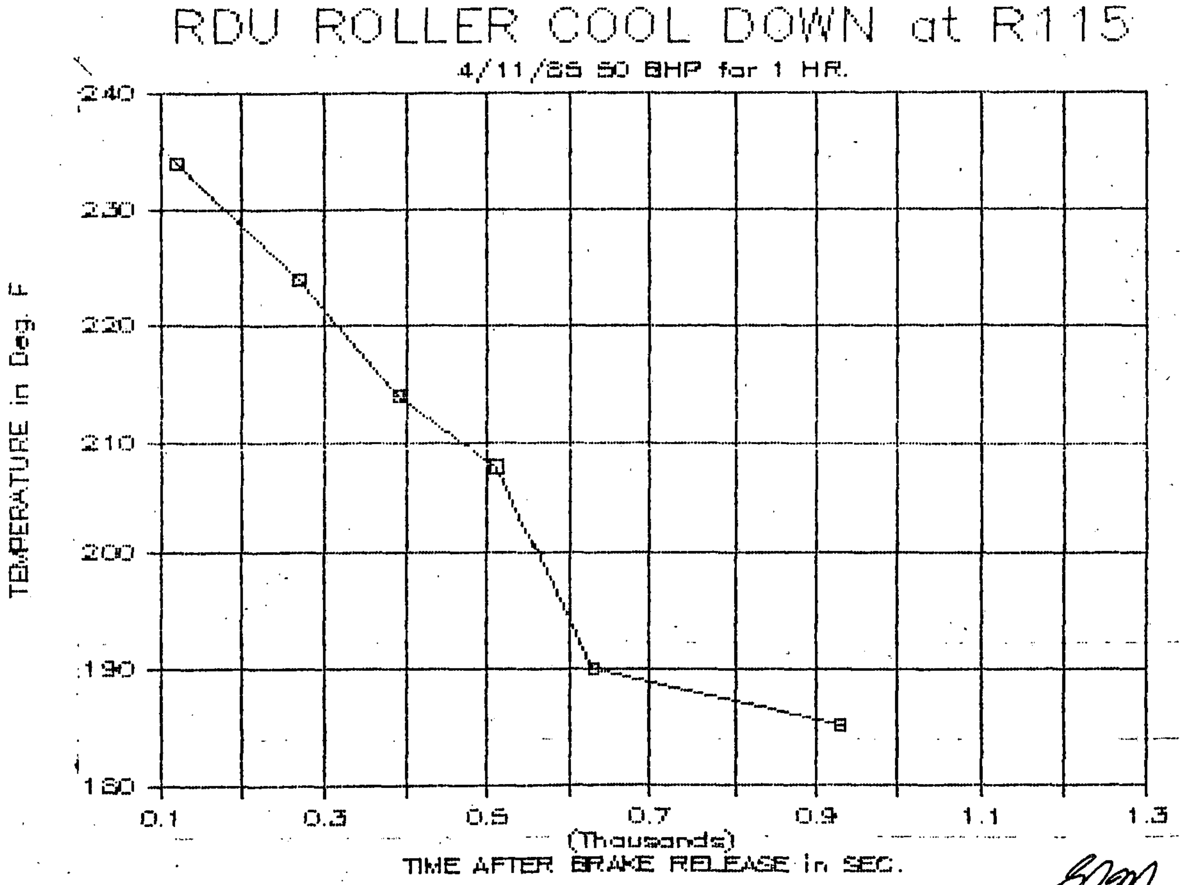

RDU ROLLER COOL DOWN at R100

4/11/85 50 BHP for 1 HR.


RDU ROLLER COOL DOWN at R115

4/11/85 50 BHP for 1 HR.

SJM
4/24/85

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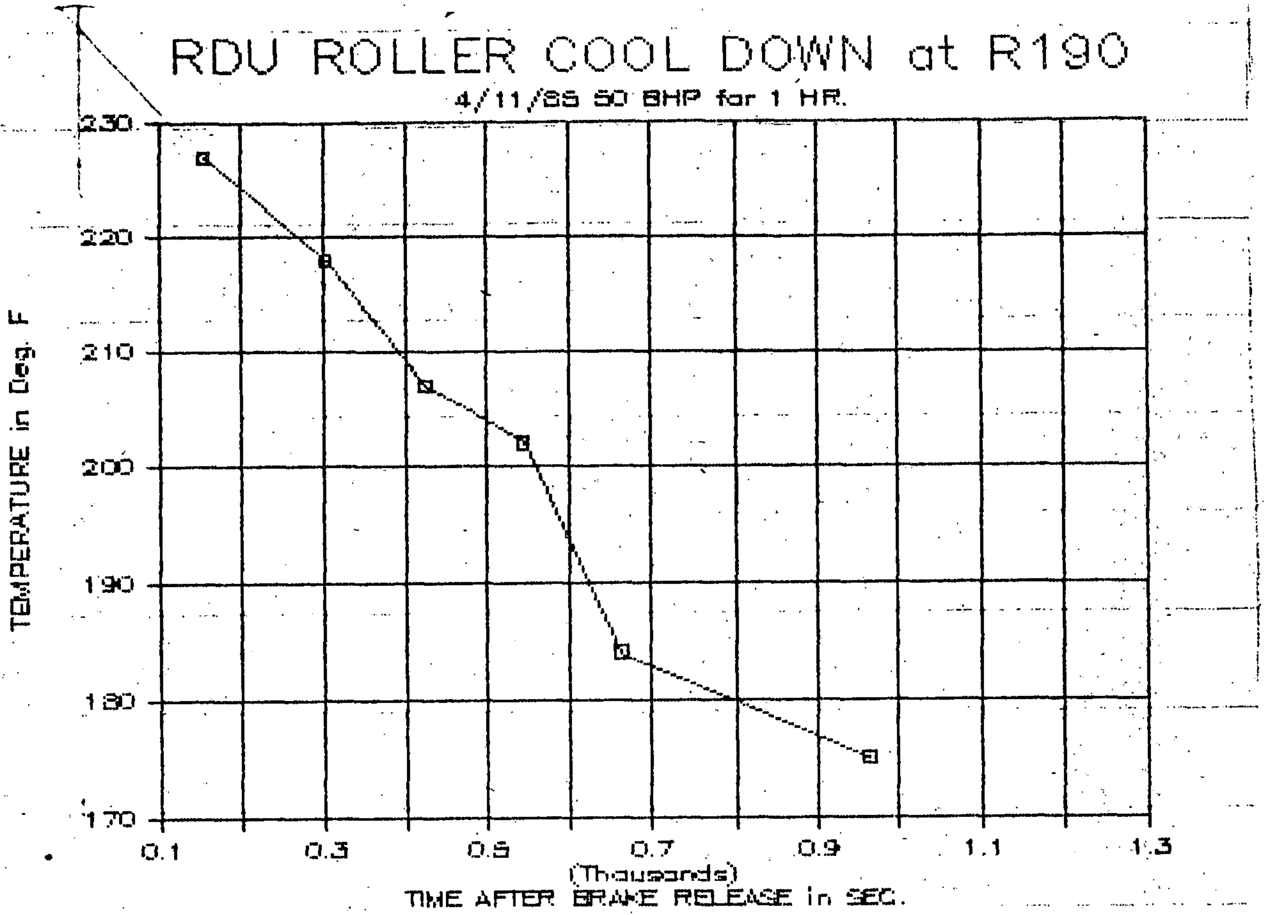
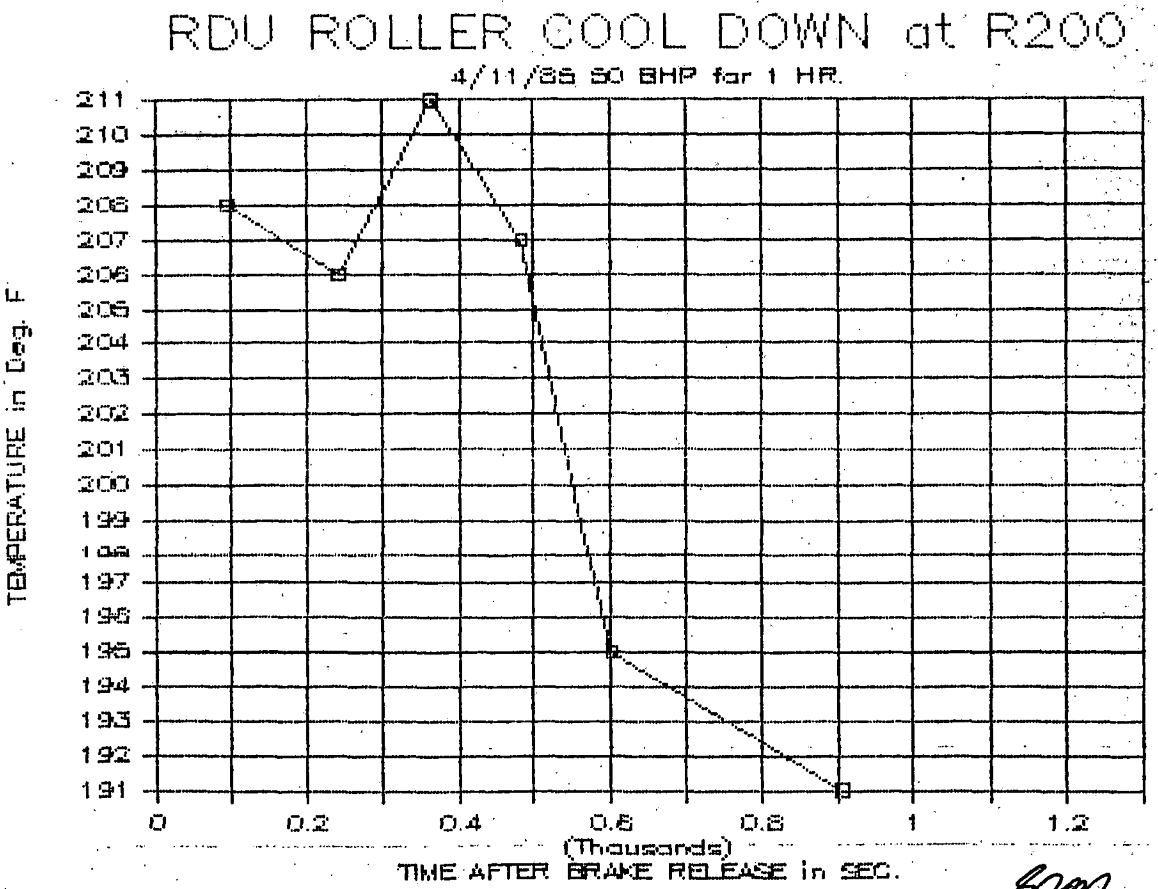

RDU ROLLER COOL DOWN at R190

4/11/85 50 BHP for 1 HR.


RDU ROLLER COOL DOWN at R200

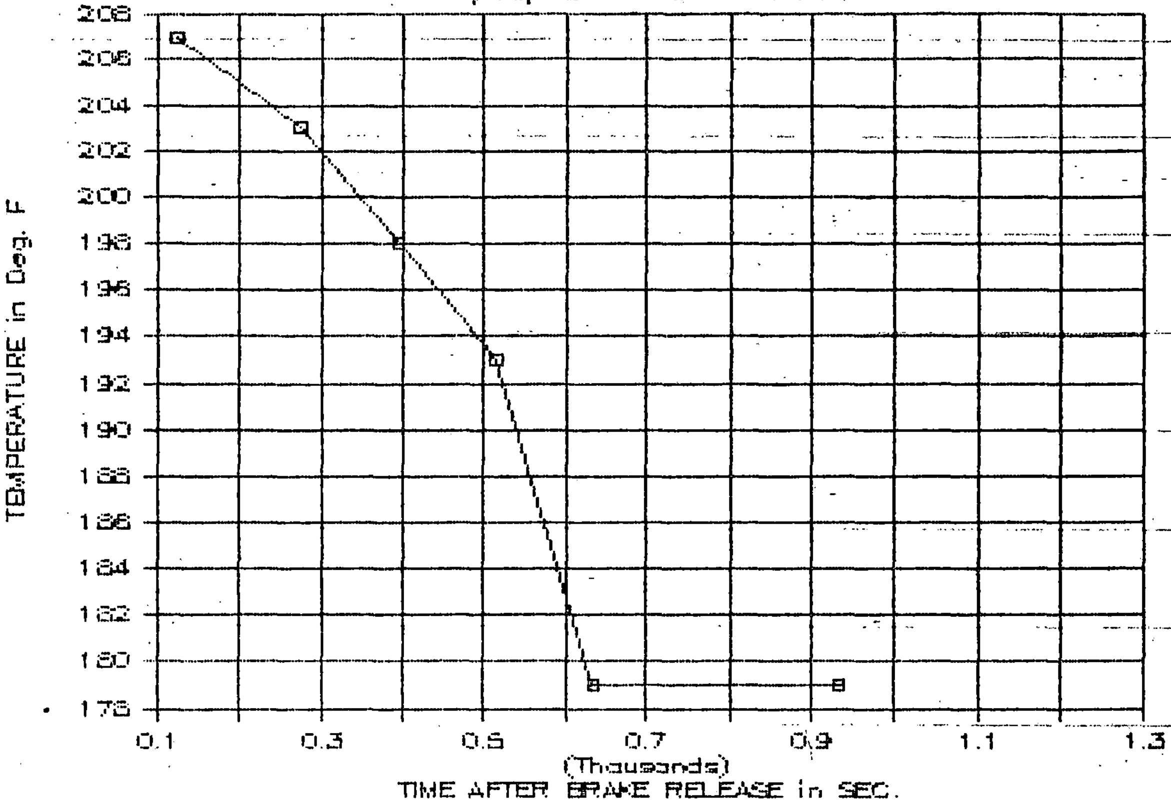
4/11/85 50 BHP for 1 HR.

4/24/85

42 381 50 SHEETS 5 SQUARE
42 382 100 SHEETS 5 SQUARE
42 389 200 SHEETS 5 SQUARE
NATIONAL

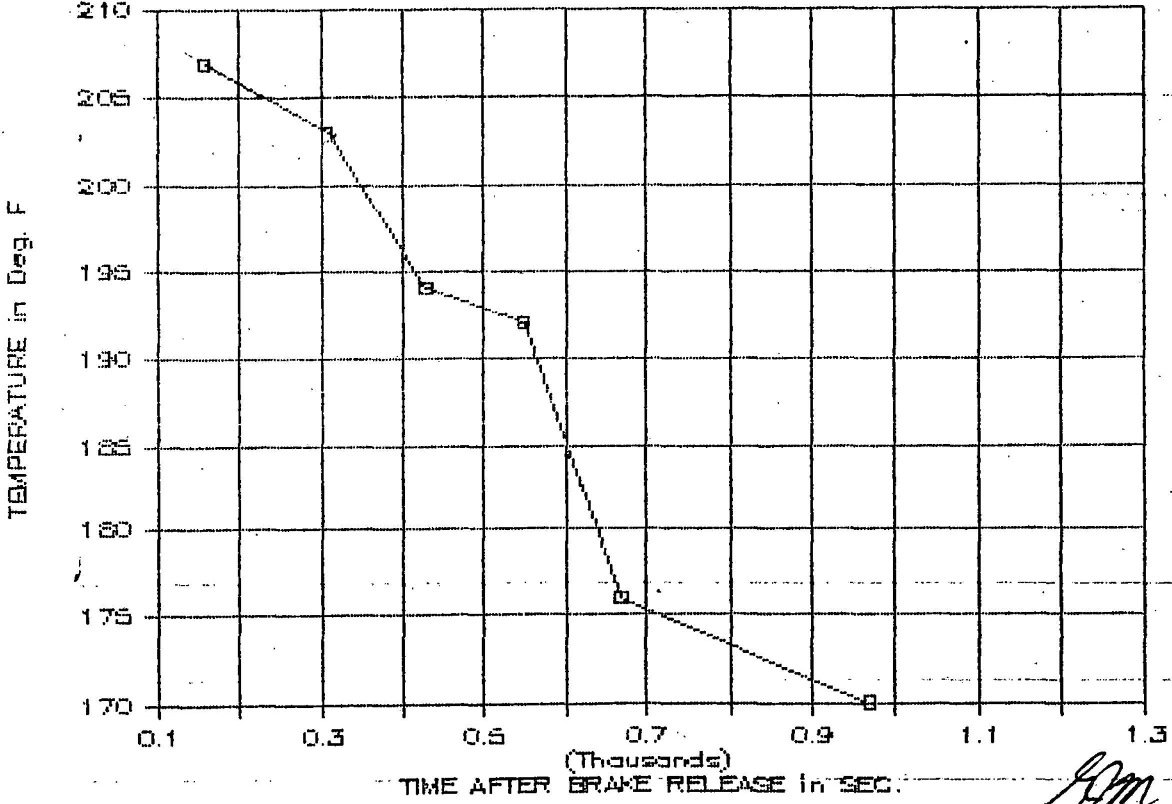
RDU ROLLER COOL DOWN at R215

4/11/85 50 BHP for 1 HR.

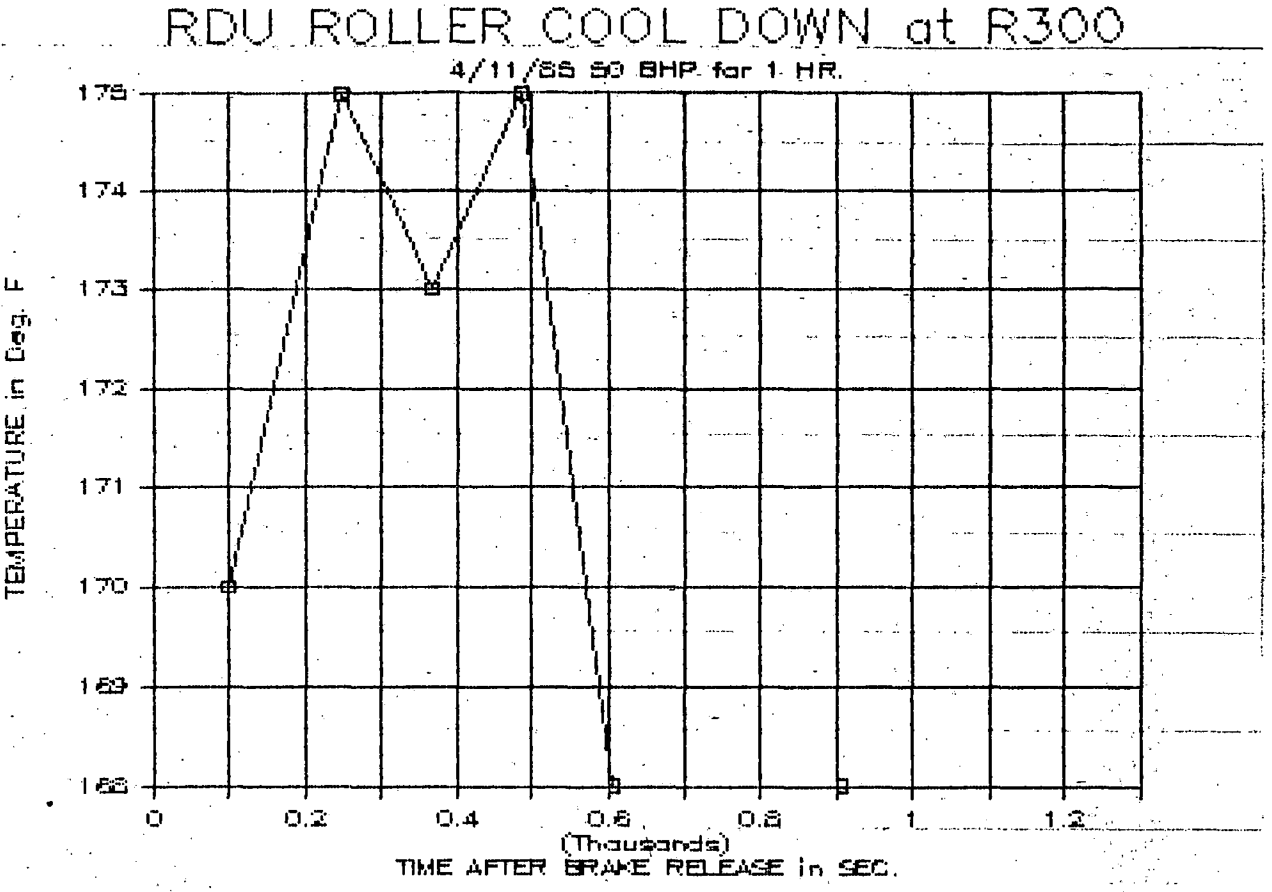


RDU ROLLER COOL DOWN at R290

4/11/85 50 BHP for 1 HR.

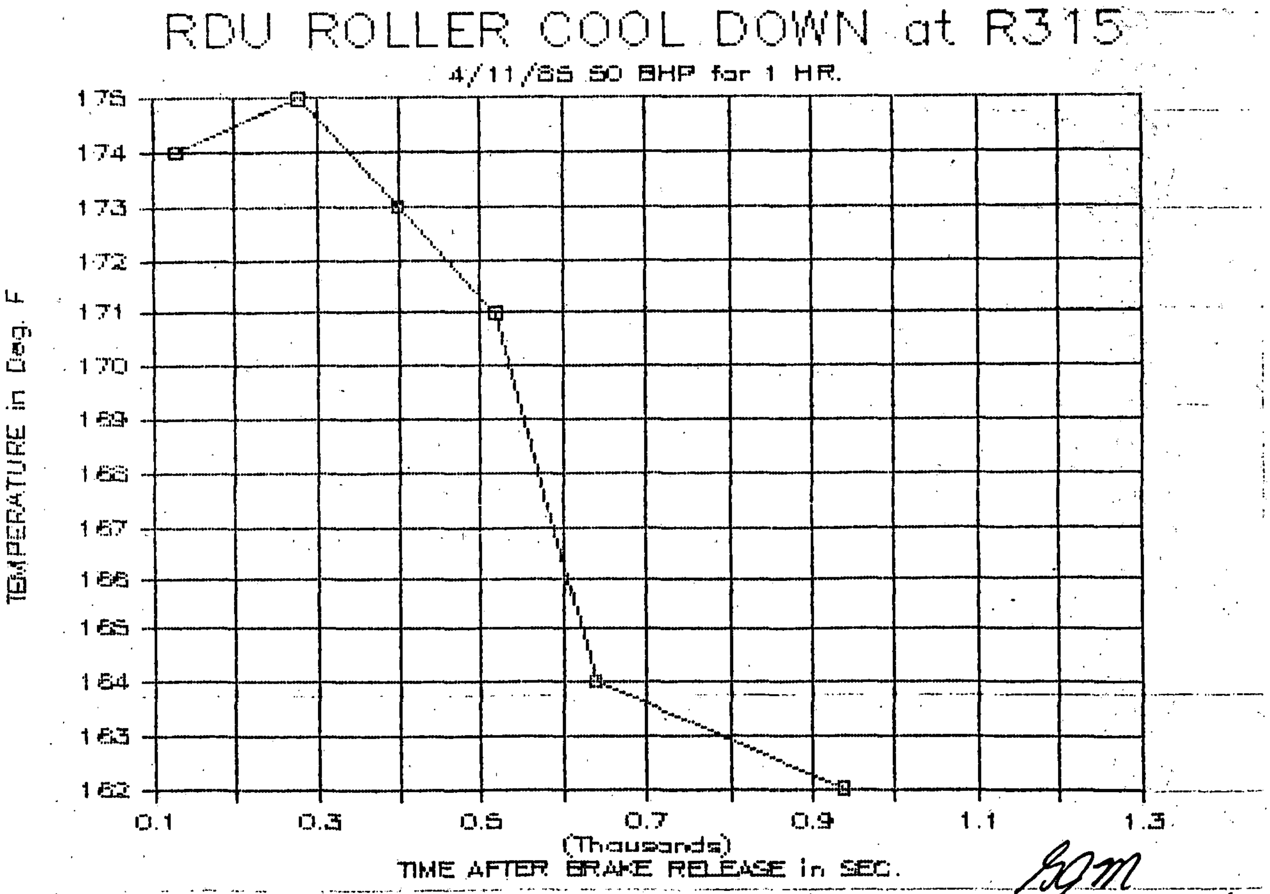


11



RDU ROLLER COOL DOWN at R300

4/11/85 50 BHP for 1 HR.

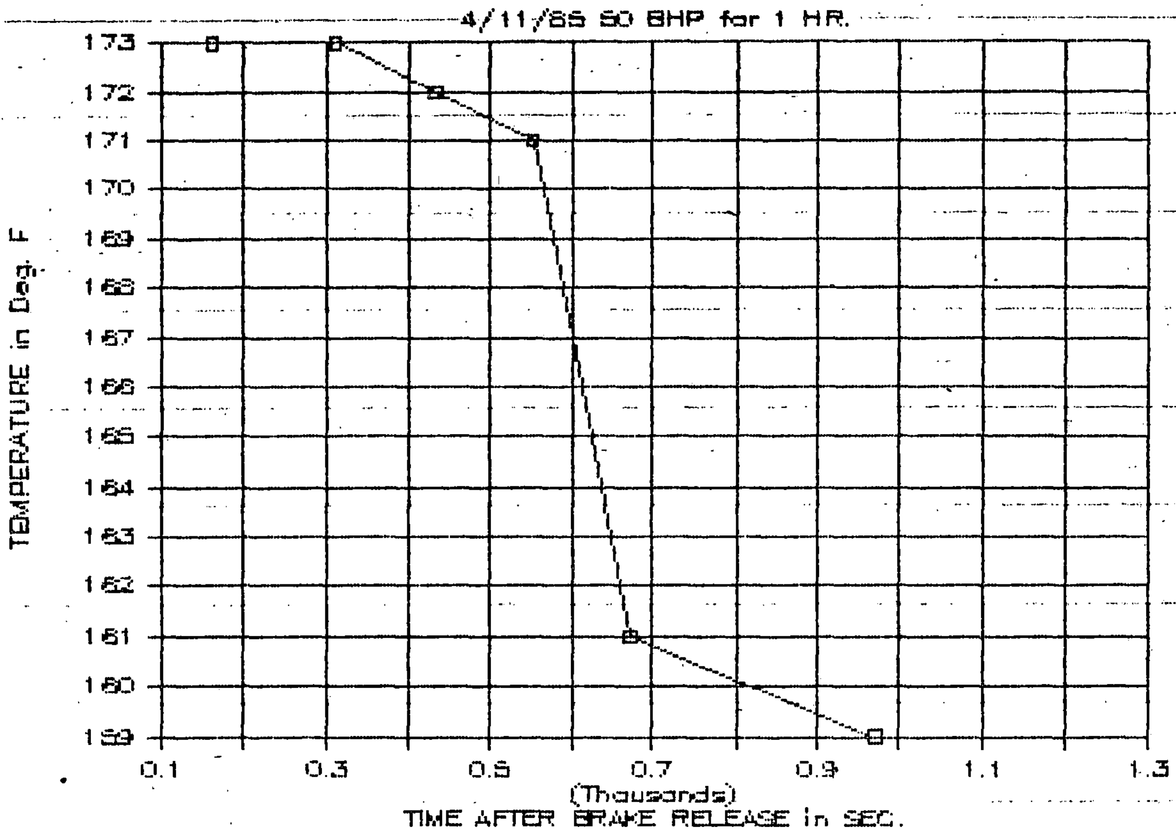


RDU ROLLER COOL DOWN at R315

4/11/85 50 BHP for 1 HR.

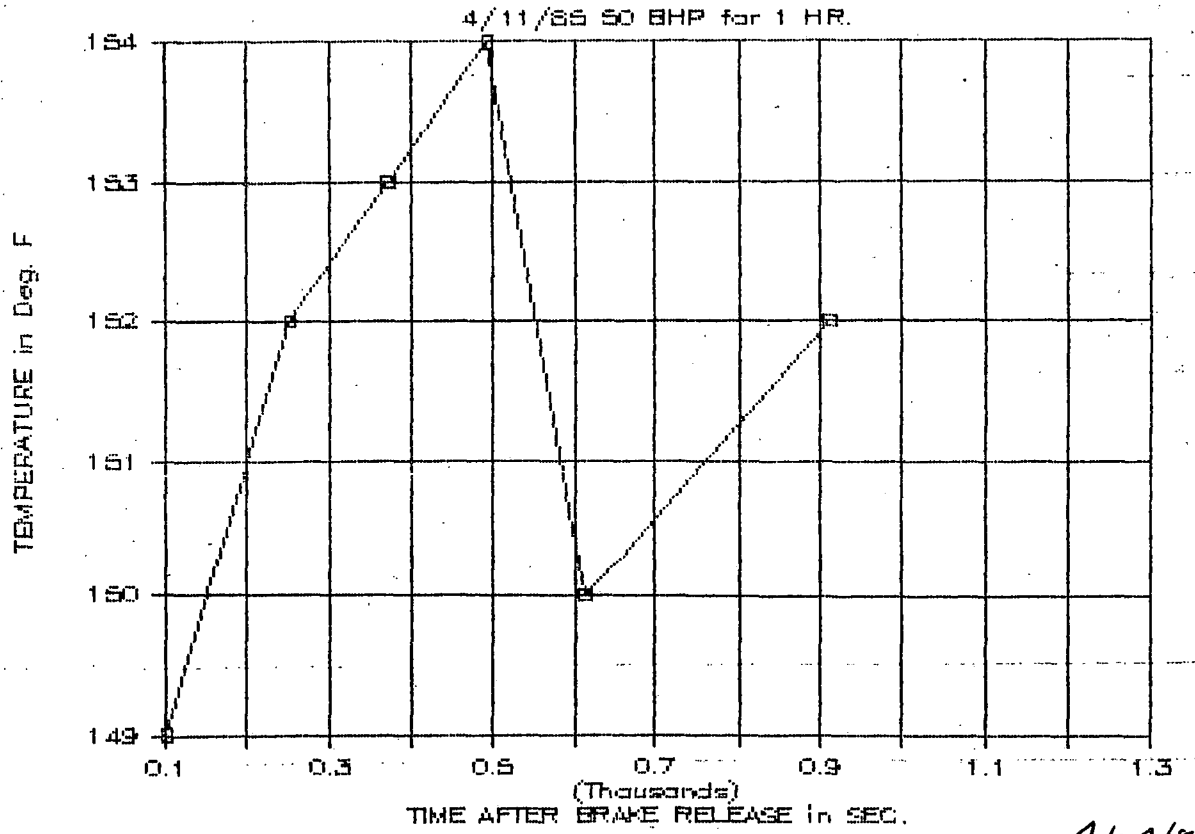
GJM
4/24/85

12



RDU ROLLER COOL DOWN at R390

4/11/85 50 BHP for 1 HR.



RDU ROLLER COOL DOWN at R400

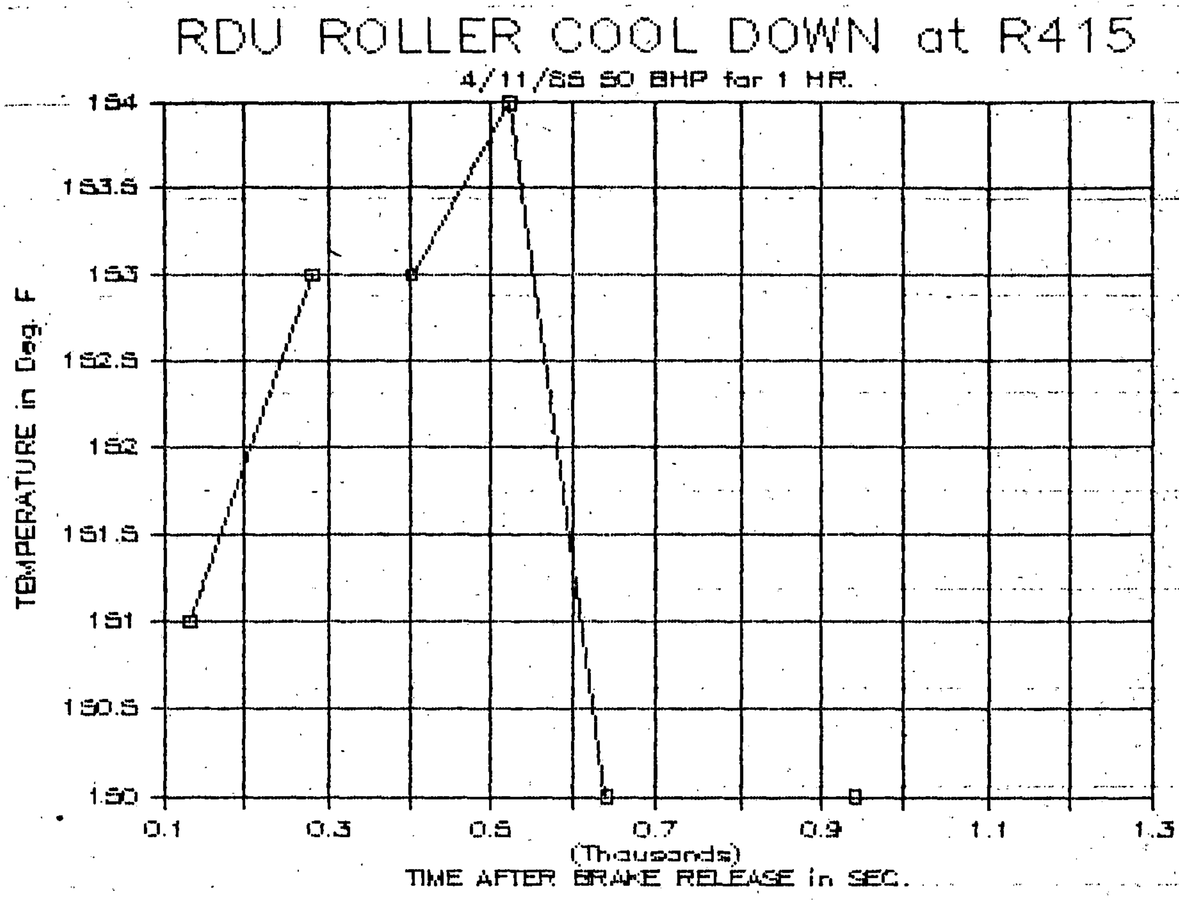
4/11/85 50 BHP for 1 HR.

4/24/85
SJM

42 381 50 SHEETS 5 SQUARE
42 382 100 SHEETS 5 SQUARE
42 389 200 SHEETS 5 SQUARE

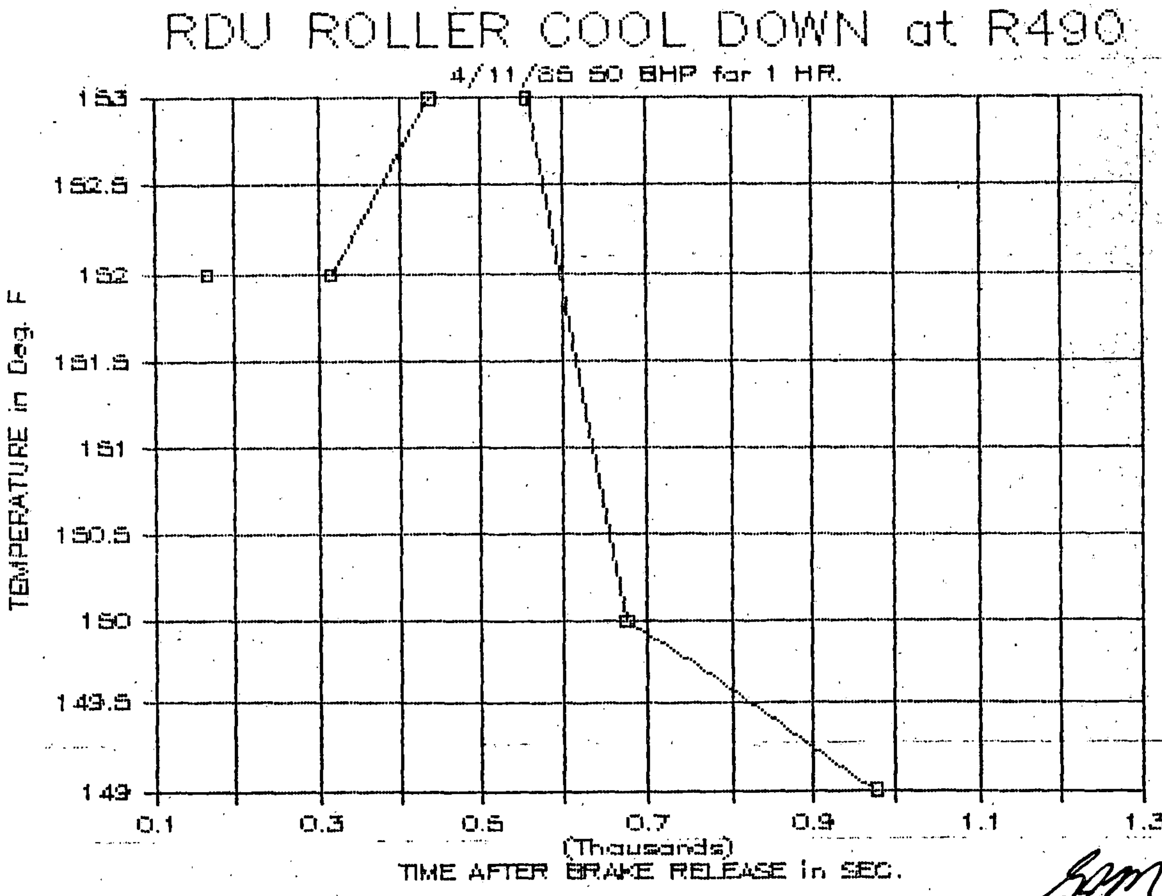
13

42 381 50 SHEETS 5 SQUARE
42 382 100 SHEETS 5 SQUARE
42 389 200 SHEETS 5 SQUARE
NATIONAL



RDU ROLLER COOL DOWN at R415

4/11/85 50 BHP for 1 HR.



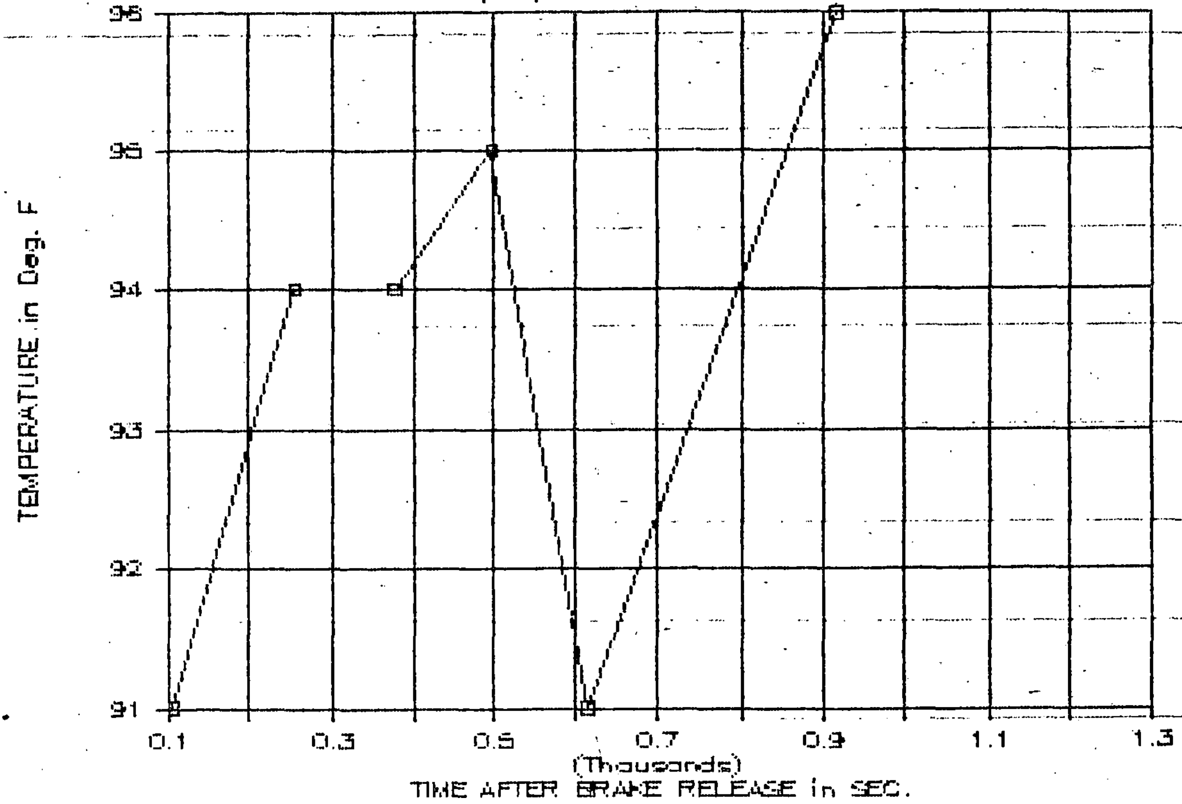
RDU ROLLER COOL DOWN at R490

4/11/85 50 BHP for 1 HR.

4/29/85

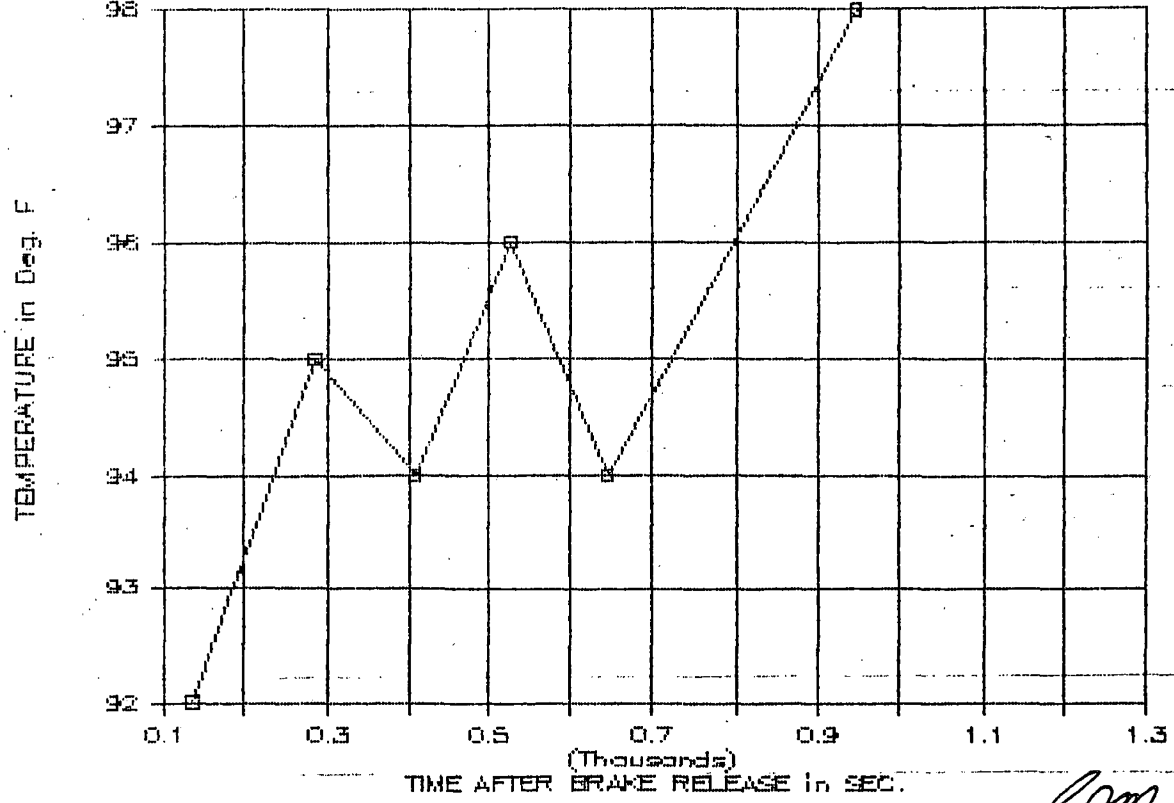
RDU ROLLER COOL DOWN at R500

4/11/85 50 BHP for 1 HR.

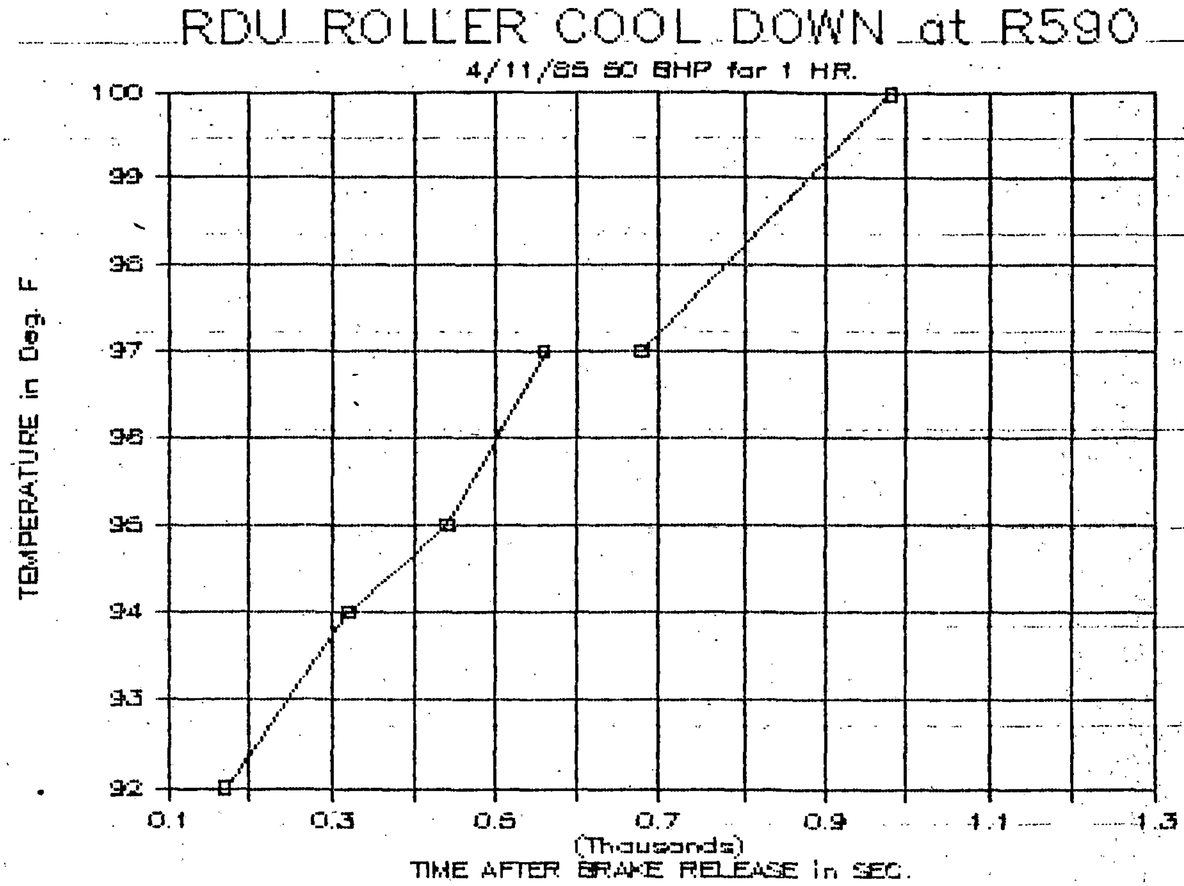


RDU ROLLER COOL DOWN at R515

4/11/85 50 BHP for 1 HR.



SGM
4/24/85



RDU ROLLER COOL DOWN at R590

4/11/85 50 BHP for 1 HR.

42-381 50 SHEETS 5 SQUARE
42-382 100 SHEETS 5 SQUARE
42-389 200 SHEETS 5 SQUARE
NATIONAL

Gerald J Moyer
4/24/85

APPENDIX 11.1

REVIEW OF LIFE PREDICTION METHODS FOR APPLICATIONS IN RAILROAD RIM FAILURE RESEARCH

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2051 Ogden Ave., Suite D
Downers Grove, IL 60515
(312) 964-9405

REVIEW OF LIFE PREDICTION METHODS FOR APPLICATIONS IN RAILROAD WHEEL RIM FAILURE RESEARCH

by

Gerald J. Moyar

DRAFT
of

3/25/85

Consultant report for D. H. Stone, Director of Metallurgy, Association of American Railroads Technical Center, Chicago, Ill. under FRA/AAR Wheel Failure Mechanisms of Railroad Cars Program Contract

ABSTRACT

This report presents an overview of current life prediction methods for potential application to the analysis of railroad wheel failures originating in the hot tread and rim region of the tread braked wheel. Six groups or classes of theories are reviewed:

1. Simple time independent fatigue approaches
2. Strain Range Partitioning (SRP)
3. Frequency Modified and Frequency Separation (FM)
4. Energy Based
5. Damage Rate
6. Continuum Damage

Several papers that report recent design applications of some of these methods to diesel and turbine engine components are also summarized. Recommendations for applications in railroad wheel research include: (1) additional cyclic flow behavior testing under thermomechanical fatigue simulation situations; (2) initial trials of the simple time independent elevated temperature fatigue methods (Universal Slopes with and without 10% life rule) in wheel life analysis; (3) further critical evaluation and wheel applications of the SRP (Manson et al.), FM (Coffin) and Damage or Crack rate (Sehitoglu) methods.

TABLE OF CONTENTS

5.0 REFERENCES

6.0 APPENDICES

6.1 Creep/Fatigue Survey from Sandor

6.2 Bibliography from NASA Lewis

6.3 References from Halford

NOMENCLATURE

Term		Eqn.No.
A	Basquin equation coefficient for unequal ramp rates.	4
B	low cycle fatigue constant from Coffin.	1
C	material constant to account for compression in Majumdar's Damage Rate theory.	10
C_0	fatigue material constant in Chrzanowski's theory.	18
C'	creep material constant in Chrzanowski's theory.	18
D	allowable damage index ($D<1.0$) in ASME Code Case N-47.	2
D_c	creep ductility from SRP relation.	
D_p	tensile plastic ductility from SRP relation.	
E	Young's Modulus.	15
F	low cycle fatigue constant in FM relation.	3
G	material constant in Majumdar's theory.	11
G'	material constant in Majumdar's interactive damage eqn.	12
H	Heaviside function.	18
K	factor in frequency exponent of Ostergren's theory.	6
K'	frequency exponent term in FM Coffin theory, Eqn.3.	
K_c	plastic strain rate exponent for cavity growth.	11
K_p	plastic strain rate exponent for crack growth.	10
K_1'	tension-going frequency exponent term.	4
N	number of cycles.	2
N_f	number of cycles to failure.	1
N_{pp}	cycles to failure under plastic tension and compression cycles (SRP).	
N_{pc}	cycles to failure under plastic tension-creep compression cycles (SRP).	
N_{cp}	cycles to failure under creep tension and plastic compression cycles (SRP).	
N_{cc}	cycles to failure under creep tension and compression cycles (SRP)	
S	material constant in Ostergren's theory.	6
S_0	flow stress from Sehitoglu's theory.	15
ΔS	stress range over which the crack remains open from Sehitoglu's theory.	15
T	material constant to account for tension in Majumdar's Damage Rate theory.	10
$\bar{T}$	ultimate tensile strength of previously cycled material in Wareing's theory.	13
W	specimen width in Wareing's theory.	14
a	crack length.	10
a_0	initial crack length.	13
a_f	crack length at fracture.	13
c	creep cavity size.	11
c_0	initial cavity size.	11
d	compression/tension frequency ratio exponent in modified FM Coffin relation Eqn.5.	
k	low cycle fatigue exponent.	1
m	plastic strain exponent in Majumdar's theory.	10
t	time at stress.	2
t_d	time to creep rupture at stress.	2

NOMENCLATURE (Continued)

w	half plate width in Sehitoglu's theory.	15
α	cyclic life exponent in Ostergren's theory.	6
β	cyclic life exponent in FM Coffin equation.	3
β'	tension-going frequency term in modified FM Coffin eqn.	4
γ	material creep exponent in Chrzanowski's damage theory.	18
γ_0	material fatigue exponent in Chrzanowski's damage theory.	18
$\Delta\delta_t$	range of crack tip opening displacement.	15
ν	frequency.	3
ν_c	compression-going frequency from modified FM Coffin relation.	5
ν_t	tension-going frequency from modified FM Coffin relation.	4
ϵ_p	plastic strain.	10
$\dot{\epsilon}_p$	plastic strain rate.	10
$\Delta\epsilon_p$	plastic strain range.	1
$\Delta\epsilon_{pp}$	inelastic strain range for plastic strain in tension and compression (SRP)	
$\Delta\epsilon_{pc}$	inelastic strain range for plastic strain in tension and creep strain in compression (SRP)	
$\Delta\epsilon_{cc}$	inelastic strain range for creep strain in tension and compression (SRP)	
$\Delta\epsilon_{cp}$	inelastic strain range for creep strain in tension and plastic strain in compression (SRP)	
σ	stress.	18
σ_T	peak tensile stress from Ostergren.	6
$\Delta\sigma_{sf}$	stress range for fracture from modified FM Coffin relation.	
τ_c	compression-going or compression hold time.	7
τ_t	tension-going or tension hold time.	7
τ_0	continuous cycle time in Ostergren theory.	7
ω	Kachanov's continuum damage parameter.	17

1.0 INTRODUCTION

Most current railroad wheel failures begin with cracks that originate in the rim regions that are subjected to periodic high temperature cycles due to tread braking. Thus any applicable life prediction method should be capable of treating, either directly or indirectly, the damage contribution of these thermal excursions.

1.1 Purpose of Review

One of the objectives of the FRA sponsored research program on Wheel Failure Mechanisms of Railroad Cars (1) is to develop and apply a suitable cumulative low-cycle fatigue method to predict the damage caused by various braking programs. The purpose of this review (2) is to survey the current state of the art in elevated temperature fatigue, creep-fatigue or thermomechanical fatigue, and select several candidate methods that appear to have greatest potential for wheel cumulative damage application.

1.2 Wheel Rim Application Issues

This review concentrates on theories applicable especially to the hot portion of rim where time dependent material behavior may be a factor. Further, allowance is made for the fact that the damaging strain cycles, whether at wheel revolution frequencies or slower brake cycle frequencies, occur under varying temperatures. Thus, thermomechanical fatigue (TMF) models are needed that are applicable to either tread hot spot analysis (3) or macrocrack initiation in the hot rim or flange (4). The hot rim is subjected to major residual stress reversing braking cycles and both simultaneous rail load or transient thermal strain subcycles and subsequent rail load and contact stress cycles. Although crack initiation is the main focus, damage rate or TMF crack propagation models are not excluded.

Many wheel stress analyses have been reported over the years, some treating the temperature dependent inelastic strain behavior. These have been reviewed as part of the literature search (5) included in the current FRA/AAR program . Nevertheless, the damage models employed (when used at all) have not been representative of the current state of the art in TMF. Therefore, a survey of that art is presented for candidate models for critical evaluation and use within the current wheel failure research program.

1.3 Existing Reviews

Within the last 20 years a proliferation of research and method development in elevated high temperature fatigue design has taken place. A great many technical, professional, national and even international commitees have been formed to direct, monitor and codify this research. These include:

- -- ASME Subcommittee 3 of the Metal Properties Council
- -- ASTM Committee E-9 on Thermal Fatigue of Materials and Components
- -- The Pressure Vessel Research Committee
- -- Welding Research Council
- -- Oak Ridge National Laboratory High-Temperature Structural Design Program
- -- Argonne National Laboratory Fracture and Low Cycle Fatigue Program
- -- NATO AGARD Structures and Materials Panel

Many special technical publications and symposia proceedings dealing with the topic are also available (6)(7)(8)(9). In addition, a number of papers (10)(11)(12)(13) have been published in recent years that specifically review and compare the various models. In view of this, the present review represents only a "gleaning" from these reviews, and only brief descriptions of some of the apparently dominant or currently popular models are given.

In addition to the dependence on existing review papers, such as the excellent one by Coffin (10), the author is indebted to suggestions and references received through personal communication from three of the leading researchers in the field, Dr. Gary Halford of NASA Cleveland, Prof. Bela Sandor of the University of Wisconsin, and Prof. Huseyin Sehitoglu of the University of Illinois. Appendices 1 through 3 contain copies of some reference lists and annotations received from Dr. Halford and Prof. Sandor. In some cases text has been copied freely from existing review papers. These instances are indicated by the use of brackets enclosing the copied text, followed immediately by a reference number that identifies the source.

2.0 REVIEW OF LEADING THEORIES

The leading theories, grouped according to six categories, will be briefly reviewed in the following six subsections.

2.1 Simple Life Prediction Methods

It should be recalled that the most fundamental low-cycle fatigue life prediction relationship

$$(N_f)^k \Delta \epsilon_p = B \qquad 1.$$

was developed, at least in part, from constrained thermal cycling tests performed by Coffin (14) on 304 Stainless Steel to temperatures as high as 500°C. As Coffin (15) has often pointed out: "Although the cyclic temperature alone could produce internal damage in some materials, that was not the case here." Therefore, applications of this observation were made in early elevated temperature fatigue life prediction methods.

2.1.1 Linear Damage Approach

Many of these early "time-independent" elevated temperature fatigue approaches, even those dealing with varying temperature during the cycle such as that of Taira (16), ignored inherent time dependency in the fatigue damage assessment and considered creep damage separately. This approach gave rise to the so called "Time and Cycle Fraction Method," "Linear Damage Approaches" or "Linear Life Fraction" rule adopted in ASME Boiler and Pressure Vessel Code Case N-47(17):

$$\sum \frac{N}{N_d} + \sum \frac{t}{t_d} \leq D \qquad 2.$$

2.1.2 Universal Slopes Method

[Although the inelastic strain range could not always be calculated accurately, the total strain range could be by using the concept of strain invariance along with an elastic stress-strain analysis. Thus, by expressing the low-cycle fatigue resistance of a material in terms of total strain range versus cycles to failure, practical predictions of life could be made. In 1964 Manson and Hirschberg (18) recognized the importance of this viewpoint and developed a procedure for representing low cycle fatigue curves in terms of the total strain range. Then these researchers proposed a procedure for estimating the total strain range versus cycles to failure curve from only a knowledge of a material's tensile test properties. Their method was called the Method of Universal Slopes since it assumed a constant slope of -0.60 for the inelastic line. Furthermore, the intercept of the elastic line was related directly to the (ultimate tensile strength) and the E (modulus of elasticity) of the material. The intercept of the inelastic lines was related to D (the ductility in a tensile test). The approach was an immediate success and is used widely during preliminary design. Numerous components of the Space Shuttle Main Engine (SSME) were designed on the basis of fatigue resistance estimated from the Method of Universal Slopes.

First attempts to apply the Method of Universal Slopes at high temperatures, using high-temperature tensile properties, resulted in overpredictions of life. The cyclic lives are invariably lower than expected because at high temperatures detrimental attack of the material grain boundaries occurred from oxidation and cyclic creep strain. Short-time tensile properties are unaffected by oxidation and cyclic creep strain and hence are not directly appropriate for use in estimating cyclic lifetimes in the same way as before. Modifications were in order.

As a first approximation to the effects of grain boundary attack on the fatigue process, it was recognized that the microcrack initiation process was being bypassed, leaving only the crack propagation portion of the total life. Since the propagation life could be as low as about 10 percent of the total life in low-cycle fatigue, it was reasoned that an estimate of the minimum high-temperature low-cycle fatigue behavior of a material could be taken as equal to 10 percent of the life calculated by the Method of Universal Slopes. This rule, referred to as the "10 Percent Rule," was proposed in 1967 by Manson and Halford (19) and applied to all of the high-temperature low-cycle fatigue data available at the time.] (20)

2.2 Strain Range Partitioning Methods

Because of the limitations of the Time and Cyclic Fraction Method, Manson et al. (21) proposed a method that was called "Strainrange Partitioning."

[The method was strain-based, and recognized the desirability of dividing (or partitioning) the inelastic strain into its creep and plastic strain components. The creep strain is thermally activated, diffusion controlled, and is the time-dependent component of inelastic strain, while the plastic strain is time-independent and is a result of crystallographic slip within metallic grains. The two basic types of inelastic strain can then be combined in the two directions of uniaxial loading -- tension and compression to four distinctly different combinations. The cycle types are shown in Figure 1 and are called the four basic cycles of Strainrange Partitioning (SRP). They are denoted as follows: PP (plastic strain in tension and compression), CP (creep in tension, plasticity in compression), PC (plasticity in tension and creep in compression), and finally, CC (creep in both tension and compression). Strain cyclic tests can be conducted in the laboratory that individually feature these four types of cycles. A series of such tests conducted to failure gives the results shown schematically in Figure 2.

Each SRP cycle type produces a unique curve of inelastic strain range versus cycles to failure on logarithmic coordinates. These curves are called the SRP life relations. As shown in Figure 2 the PP curve is usually the highest and the CP curve is usually the lowest with the PC and the CC curves being intermediate. It should be noted that these relations represent

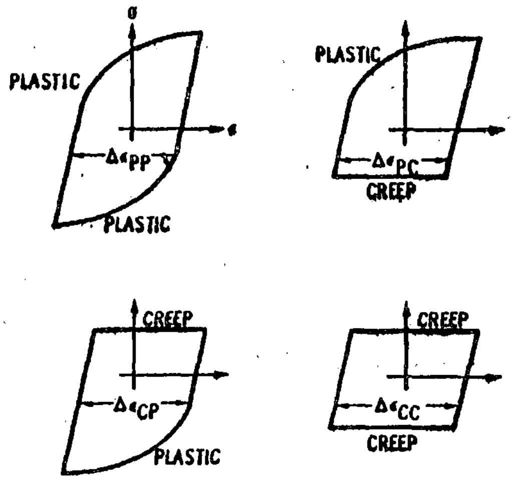

Figure 1 Four Basic Cycles of SRP.

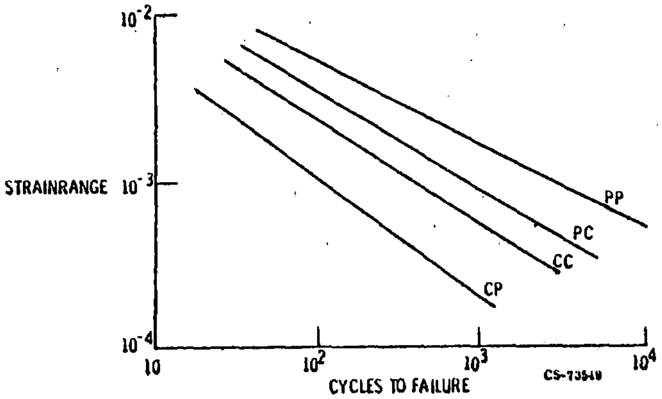

Figure 2 . Partitioned Strainrange - Life Relationships.

extremes in cyclic lives, and that any closed cycle is a combination of components of these types of cycles and thus will have a cyclic life that lies somewhere between these extremes.

Using the Strainrange Partitioning Method it is possible to characterize the creep-fatigue properties of high-temperature alloys. Because the SRP Method is generic, it is applicable to any material that undergoes high-temperature cyclic inelastic deformation, and it is applicable to any conceivable inelastic strain cycle.] (20)

It is claimed by Halford that the reason for the generality of the SRP Method is that it is based on a micromechanistic deformation model that is physically sound. [The SRP life relations may not be available for a particular material; therefore, a set of equations has been provided (22) for estimating the four SRP life relations from a knowledge only of a material's tensile plastic ductility D_p and creep ductility D_c . The constants in these equations were arrived at by correlating measured ductilities with SRP data for a large number of materials. There are two equations for the CP life relation. The first equation is to be used when the creep cracking is transcrystalline and the second is for when the cracking is intercrystalline. The life relations estimated by these equations,

$$\Delta \epsilon_{pp} = 0.50\ D_p (N_{pp})^{-0.60}$$
$$\Delta \epsilon_{pc} = 0.25\ D_p (N_{pc})^{-0.60}$$
$$\Delta \epsilon_{cc} = 0.25\ (D_c)^{0.60} (N_{cc})^{-0.60}$$
$$\Delta \epsilon_{cp} = 0.20\ (D_c)^{0.60} (N_{cp})^{-0.60} \quad \text{(TRANSCRYSTALLINE)}$$
$$\Delta \epsilon_{cp} = 0.10\ (D_c)^{0.60} (N_{cp})^{-0.60} \quad \text{(INTERCRYSTALLINE)}$$

are in agreement with measured life relations to within a factor of approximately three in cyclic lifetime. The greater the ductility, the greater the resistance to failure by cyclic inelastic deformation. These equations also help to predict whether the SRP life relations are sensitive to test temperature. For example, if the ductility of an alloy does not change appreciably with temperature, it would be predicted that the SRP life relations would be insensitive to test temperature. Such a set of circumstances would be a distinct advantage in the analysis of thermal fatigue cycling with temperatures varying throughout the cycle.

It should be pointed out that although the life relations may not be functions of temperature, the stress-strain relationships and the creep rate versus stress relationships are still highly sensitive to temperature.](20) [The method is assumed to have broader applicability than to isothermal conditions, based on tests performed at various temperatures in which the CC, CP, and PC baseline failure data show an insensitivity to temperature. The assumption is then made that the baseline data are temperature independent, such that thermomechanical loading conditions can be included in the predictive scheme. The method has been used for life prediction in a large number of cases. A comprenensive review of the method and its application to a wide variety of problems is available (23)(24)(25). A critical evaluation of this and other methods was presented a part of an Oak Ridge study on time-dependent fatigue (26).](10)

[Various modifications based on ductility normalization have been tried in an attempt to rationalize the SRP approach further. Priest and Ellison suggested a technique which took account of the length of the hold period and, subsequently, more detailed metallographic analysis led to a further refinement which took account of the observed damage processes. Rates of deformation were associated with the different damage mechanisms operative during the hold periods. Domains of dominant mechanisms were then defined, and these were used to 'sub-partition' the SRP creep strain components. Very good predictions resulted from application of the Damage Modified SRP approach.](11)

Some current research is focused on casting SRP in terms of total strain range rather than just inelastic strain range (27). The total strain range SRP approach should be of considerable practical value to designers who are faced with creep-fatigue problems for which the inelastic strain cannot be calculated with sufficient accuracy to make reliable life predictions by the conventional inelastic strain range SRP approach.

Simple procedures have also been developed and verified (28) for treating the difficult problem of nonlinear cumulative fatigue crack initiation damage under complex loading histories. The Double Linear Damage Rule (DLDR) is a concept arrived at through viewing the fatigue process as two sequential phases.] (20)

As usual with such design and evaluation approaches that have wide applicability, there are examples of both good and poor correlation with data. Naturally, the instances of poor correlation have given rise to the modifications. In any event, the Modified SRP Method(s) retain a dominant position in current elevated temperature fatigue design technology and serve as a bench mark for competitive theories.

2.3 Frequency Modified and Frequency Separation Methods

[In the Frequency Modified Strain-Life method, Coffin (29) takes account of environmental and other time dependent effects in fatigue at high temperature, by the introduction of a frequency term into the Manson-Coffin law, so that

$$(N_f \nu^{K'-1})^{\beta} \Delta\epsilon_p = F \qquad 3.$$

where K', β, and F are material constants. It was later assumed that damage only occurred during the tension-going part of the hysteresis loop, but this did not always yield reliable predicted lives; an approach to cater for severely unbalanced loop shapes was subsequently devised, termed frequency separation. Complex hysteresis loops containing hold periods are assumed to be approximated by continuous loops with constant, though different, tension- and compression-going strain rates. With reference to Basquin's Law, Coffin derived a lifetime equation of the form

$$N_f = \left(\frac{A}{\Delta\sigma_{sf}}\right)^{1/\beta} \left(\frac{\nu_t}{2}\right)^{K_1'/\beta'} \qquad 4.$$

where A, β' and K_1' are coefficients from the Basquin relation, $\Delta\sigma = A\, N_f^{-\beta'} \nu^{K_1'}$ and $\Delta\sigma_{sf}$ is the stress range for loops with unequal ramp rates.

This frequency separation technique uses coefficients obtained from balanced loops only. Coffin points out that this may not always be possible, and a similar equation which uses some hold period data also, viz:

$$N_f = \left(\frac{F}{\Delta\epsilon_p}\right)^{1/\beta} \left(\frac{\nu_t}{2}\right)^{1-K} \left(\frac{\nu_c}{\nu_t}\right)^{d} \qquad 5.$$

In Eqn.5, F, β and K are constants obtained from balanced loop data, and d is found from unbalanced loop data.] (11)

The rationale for these two frequency modifications has been summarized by Coffin as follows:

> "There is a large volume of evidence to support the position that low-cycle fatigue is largely a process of microcrack propagation. To a first approximation damage by crack growth can be assumed to occur only when the crack is opening, that is, when tensile stresses are acting in the region of the crack. Thus the conditions of temperature, frequency or strain rate, environment and strain which contribute to crack advance apply while the crack is opening, that is, during the tensile going part of the loop. Two procedures were developed to utilize this damage concept, based on the frequency-modified fatigue equations.

The first of these procedures is very simple, requiring only that the frequency term in Eqn.3 is replaced by that associated with damage, i.e. the so-called tension-going frequency. Actually, it is more straightforward to deal with time quantities rather than frequencies. Thus in Eqn.3, $\tau = 1/\nu = \tau_t + \tau_c$ where τ_t and τ_c are the tension and compression going times. Since the coefficients in Eqns.5-7 have been determined for balanced loop conditions, $\tau_t = \tau_c$. By definition $\tau_t = 1/\nu_t$, $\tau_c = 1/\nu_c$. Thus for balanced loop conditions $1/\nu = 2\nu_t$ or, Eqn.3, $\nu = \nu_t/2$. For any other loop the tension going time τ_t is found, such that $\nu = 1/(2\tau_t)$ and this is used in Eqn.3.

The second procedure is more involved than the first, and involves a readjustment of the plastic strain range to account for loop unbalance. For details the reader is directed to Ref.(29)." (10)

Coffin argues that the types of materials tests required to determine the constants in Eqn.4 or 5 are more conventional and easier to control than those required by the SRP Method.

2.4 Energy Based Approaches

Energy based approaches which consider the hysteresis loop have also been developed.

2.4.1 Ostergren's Theory

[A damage function which includes stress as well as strain range to describe failure under fatigue-creep conditions has been proposed by Ostergren (30). The basic assumption of the method is that the net tensile hysteresis energy is a measure of damage and can be approximated by the product $\sigma_T \Delta\epsilon_p$, where σ_T is the peak tensile stress. This energy term was then used in the following relationship in a similar manner to the frequency modified approach:

$$\sigma_T \Delta\epsilon_p N_f^{\alpha} \nu^{\alpha(K-1)} = S \qquad 6.$$

where S , α , K are material constants. For materials in which damage is independent of wave shape

$$\nu = \frac{1}{(\tau_0 + \tau_t + \tau_c)} \qquad 7.$$

but to take account of waveshape dependence

$$\nu = \frac{1}{\tau_0 + \tau_t - \tau_c} \quad for\ \tau_t > \tau_c \qquad 8.$$

or

$$\nu = \frac{1}{\tau_0} \quad for\ \tau_t < \tau_c \qquad 9.]\ (11)$$

As pointed out by Ostergren, although a variation on the frequency modified approach was selected in developing his theory, similar modifications could in principle be made to other predictive techniques like SRP.

2.4.2 Other Energy Approaches

Other examples of this general approach have been developed by Leis (31) and Radhakrishnan (32). Leis proposes a general damage parameter for fatigue and creep-fatigue applications based on the hypothesis that damage is dependent on the internal total octahedral strain energy. Radhakrishnan develops a damage interaction parameter that, together with the tensile energy expended in crack propagation, determine the time dependent fatigue life.

2.5 Damage Rate Approaches (Crack and Void Growth)

A number of life prediction methods, such as that of Radhakrishnan above, have focused on the crack growth or cavity development process. These are termed "damage rate approaches."

2.5.1 Method of Majumdar and Maiya

[The approach developed by Majumdar and Maiya (33)(34)(35) is once again a strain based approach, but unlike SRP, for example, it takes account of the rate at which the fatigue or creep damage is accumulated. In its simplest form, (33), the approach considers damage to be made up of microcracks. The growth of each microcrack is assumed to be governed by the equations

$$\frac{da}{dt} = a\left(\frac{T}{C}\right) |\epsilon_p|^m \, |\dot{\epsilon}_p|^{K_p} \qquad 10.$$

where T, C, m and K_p are material parameters which are approximately constant over a range of $\dot{\epsilon}_p$ and ϵ_p. T and C are included to account for differences that can occur in growth rates under tension or compression. Eqn.10 can be integrated to calculate the life for the appropriate waveshape.

An extension of the original approach was subsequently proposed (34), in which damage was considered to be made up of crack damage <u>and</u> cavity damage which accumulate independently. The rate of growth of cracks is still given by Eqn.10, but in addition cavity growth rates are assumed to be described by

$$\frac{1}{c}\frac{dc}{dt} = G |\epsilon_p|^m \, |\dot{\epsilon}_p|^{K_c} \qquad 11.$$

where c is the cavity size at time t and G is a material constant, with appropriate sign for tensile and compresive stress regimes. It should be noted that although the incremental cavity damage can be negative, the net calculated size cannot be; if c becomes less than c_0, it is assumed that the cavities anneal out instantly. Final failure is calculated as the reciprocal of the sum of the crack and cavity damages.

Recently (35) a final interactive damage equation has been proposed of the form

$$\frac{1}{a}\frac{da}{dt} = \left(\frac{T}{C}\right)\left(1 + G' \ln \frac{c}{c_0}\right) \epsilon_p^{m} \left(\dot{\epsilon}_p\right)^{K_p} \qquad 12.]\ (11)$$

2.5.2 Wareing's Crack Propagation Method

[Wareing (36) has proposed a model for a creep-fatigue interaction which assumes that all the specimen indurance is taken up in crack propagation. For pure fatigue situations, the model of Tomkins was used to describe specimen lifetime as follows:

$$N_f = \frac{\ln(a_f/a_0)}{\Delta\epsilon_p\left[\sec(\pi\sigma_T/2\bar{T}) - 1\right]} \qquad 13.$$

Eqn.13 was subsequently treated as an upper bound on endurance.

Wareing goes on to consider a lower bound case in which the plastic zone size becomes effectively infinite (i.e., it extends across the specimen width). For this case the endurance relationship becomes

$$\Delta\epsilon_p N_f \simeq \frac{a_f}{W} \qquad 14.$$

Under simultaneous cyclic-hold test conditions, the creep-damage formed during constant strain hold periods increases the plastic zone size associated with a surface fatigue crack, until it extends it across the specimen width. Eqn.14, therefore, describes the endurance under these conditions also.

For cycles containing varying periods of tensile relaxation, specimen lifetimes should be between the upper and lower bounds described by Eqns.13 and 14, respectively.] (11)

2.5.3 Method of Sehitoglu and Morrow

Another crack propagation model developed by Sehitoglu and Morrow (37) has been developed for TMF applications especially for steel wheels. It is based on the crack tip opening displacement parameter

$$\Delta\delta_t = \frac{8}{\pi}\,\frac{2S_0}{E}\,a \ln\left[\frac{2w}{\pi a}\sin^{-1}\left[\sin\frac{\pi a}{2w}\sec\frac{\pi}{2}\,\frac{\Delta S}{2S_0}\right]\right] \qquad 15.$$

A relationship of the following form is suggested for crack rates over the ΔS range of interest,

$$\frac{da}{dN} = 3.86\times10^{7}\left(\Delta\delta_t\right)^{3.68} \qquad 16.$$

The flow stress, So, used applies to the lower temperature in the cycle, and the crack propagation factor and exponent are also determined at lower temperature. Therefore, temperature dependent properties enter only into the determination of the tensile stress range, ΔS . This approach is being developed by Sehituglo, supported in part by AAR, to make life predictions for thermalmechanical histories, including the influence of damage due to thermal <u>subcycles</u> within a major thermal cycle.

Creep-fatigue interaction in crack propagation models is also treated in the 6th International Conference on Fracture by Sadananda (38) and Challenger (39) as well as by Taplin, et al., (40) who emphasize environmental effects and use of "fatigue maps."

2.6 Continuum Damage Approaches

A stress based approach has been developed, primarily by Russian authors, to predict macrocrack initiation based on constituitive equations that govern the evolution of damage. This approach has been reviewed by Priest and Ellison.

[The concept of a continuum damage parameter, ω , was first proposed by Kachanov (41). This abstract parameter was defined to be 0 for material in its virgin condition, and approaches unity at failure. The nonlinear nature of creep-fatigue interactions can then be described by expressing the rate of damage accumulation as a function of effective stress, e.g.

$$\frac{d\omega}{dt} = f\left(\frac{\sigma}{1-\omega}\right) \qquad 17.$$

Currently there are a number of approaches based on the damage parameter concept (42)(43). The method due to Chrzanowski (42) is typical of these approaches; in this case damage is only considered to occur for positive stress increments and under tensile stress conditions (as indicated by the Heaviside Function H). The complete damage law is then given by

$$\frac{d\omega}{dt} = \left[C_0\left(\frac{\sigma}{1-\omega}\right)^{\gamma_0}\frac{d\sigma}{dt}H(d\sigma) + C'\left(\frac{\sigma}{1-\omega}\right)^{\gamma}\right]H(\sigma) \qquad 18.$$

where the first and second terms define fatigue and creep damage respectively and C_0 , C' , γ_0 and γ are material constants. Note the ability of this equation to describe a nonlinear creep-fatigue interaction, due to the presence of the total damage term, ω , in each part of the equation. Eqn.18 may be integrated for a known stress-time history to give an equation for the predicted lifetime.] (11)

A critical evaluation of the method in comparison to SRP was made by Chaboche et al. (44). They acknowledge the adequacy of the SRP method over the intermediate range of frequency, but believe the "continuous" damage approach of Kachanov covers a larger range of test conditions.

3.0 RECENT DESIGN APPLICATIONS

There are several recent published examples of the application of TMF life prediction methods, primarily SRP, to practical elevated temperature designs that bear some similarities to the strain/temperature loading expected for the hot rim regions of a braked railroad wheel. They illustrate the problems and successes of predicting the overall cyclic stress-strain loops based on appropriate elevated temperature flow models used in advanced F.E.A., as well as the application of crack initiation theories. These applications to diesel engine and gas turbine components are briefly described in the following subsections.

3.1 Diesel Engine Components

The experiments and analyses of Saugerud (45)(46) relating to the life prediction of diesel engine cylinder liners and crowns illustrates a number of phenomena applicable to research on braked wheels. These are:

1. A dominant thermal load cycle (engine load level).
2. Superimposed higher frequency cycles (combustion cycles).
3. An initial compressive plastic strain caused by start-up.
4. The applicability of induction heating experiments with ring type specimens.
5. The separation of high cycle and low cycle fatigue damage.

The ADINA and ADINAT F.E.A. computer programs developed at M.I.T. were used to predict local stress-strain cycles for characteristic engine thermal cycles. The number of cycles to crack initiation could be predicted "qualitatively" correct according to Saugerud. Cyclic creep effects were not evaluated in this analysis, however. Some observations of crack propagation and application of fracture mechanics theory is also given. The Jaske overlay model (two layer idealization) for cyclic data was shown to be in good agreement with measured strains.

3.2 Turbine Combuster Liner

Another high temperature component with a similar thermomechanical loading -- a turbine combuster liner -- is analyzed by Moreno et al. (47) using the MARC general purpose F.E.A. program and SRP life prediction methods, as well as a Pratt & Whitney Combuster Life Prediction Method. For this analysis the component response in the critical area contains only the pp (tensile plasticity reversed by compressive plasticity) and pc (tensile plasticity reversed by compressive creep damage cycles.

[The results of the combustor liner nonlinear structural and life analyses can be summarized as follows:

(1) The nonlinear structural analysis indicated that the time-dependent plasticity model and the creep model did not

accurately predict the cyclic thermomechanical response at the louver failure location. Tests of a uniaxial strain controlled specimen run with the same mechanical strain-temperature history as computed at the failure location showed that the stress-strain response stabilized within the first few cycles. Analytical simulation of this experiment with the Hastelloy X creep-plasticity models exhibited continued cyclic hardening (increasing peak tensile stress and reduced inelastic strainrange) and ratcheting after many cycles. Use of one of the rate-dependent (unified) constitutive theories currently under development may be required to improve the prediction for the varying temperature loading conditions. Determination of correct thermomechanical response is critical for the life prediction of engine hot section components.

(2) The linear elastic structural analysis and the nonlinear inelastic analysis predicted total strainrange values that were within 8% of one another. In addition, the inelastically calculated total strainrange remained constant even though the stresses and strains ratcheted.

(3) Both the SRP and Pratt & Whitney Methods overpredicted the cracking life.

(4) The overpredictions in the combustor liner life based on the analyses in conjunction with isothermal, strain-controlled fatigue test data suggest that a thermomechanical fatigue cycle produces damage at a faster rate than a comparable isothermal cycle.] (47)

3.3 Turbine Blade

A comparable analysis of the cracking of a turbine blade tip of cast Rene 80 material was made by McKnight et al. (48) with somewhat greater success in life prediction. Both SRP and the Frequency Modified (FM) Life Relation Method were used. The ANSYS F.E.A. program was used with the ANSYS kinemateic hardening option and a time hardening exponential creep law. Only the pc inelastic strain component was considered to be present in this case.

[The results of the turbine blade nonlinear structural and life analyses can be summarized as follows:

1) The total strain range at the critical cracking site was calculated using both elastic and inelastic ANSYS analyses. The total strain range values were within less and 3% of each other, thus indicating the potential value of the simpler, much less expensive, elastic analysis.

2) Tests of a uniaxial strain controlled specimen following the same strain-temperature history as computed at the blade tip crack initiation location showed that the stress-strain response stabilized by the fourth cycle. Analytical simulation of this experiment demonstrated later stabilization of the stress-strain

response, higher peak stresses, and a smaller amount of stress relaxation than the test results indicated. These discrepancies between analysis and experiment suggest that the creep model and/or data did not accurately represent the material cyclic time-dependent behavior.

3) The three-dimensional structural analyses produced results in qualitative agreement with the limited experimental evidence. The maximum strain ranges were predicted for the blade tip region where actual cracking occurred.

4) Cyclic crack initiation life of the blade tip was calculated by the strainrange partitioning (SRP) and frequency modified (FM) approaches and compared to the observed life of 3000 cycles from factory engine testing. Predicted lives ranged from 1200 to 4420 cycles for SRP depending upon the magnitude of the expected inelastic strain range. Based upon a calculated total strain range of 0.31%, the FM method predicted a crack initiation life of 2700 cycles.] (48)

4.0 RECOMMENDATIONS FOR WHEEL RESEARCH

Based on the above "review of reviews" of the state of the art in thermomechanical fatigue, the following recommendations are made for further study of methods that may be useful for wheel failure research:

4.1 Define Cyclic Flow Behavior

An essential prerequisite for the application of TMF life prediction methods is a satisfactory modelling of cyclic flow behavior under variable temperature and strain cycles. Uniaxial experimental simulations, employed in several recent design evaluation studies such as those described above, are important aids in this task. As indicated in Stone's letter to Stevens (2) such tests are planned as part of the continuing materials testing task under the FRA sponsored Wheel Fracture Program.

4.2 Apply Simple Methods

Time independent fatigue assumptions should be tested over the temperature range of interest. Some dependence of cycles to failure on temperature for a given inelastic strain range is evident from fatigue properties for wheel steels over the range 25 C to 600 C reported by Fec and Utrata (49). The method of Universal Slopes with and without the 10% life rule should be used in an attempt to extrapolate lower temperature isothermal test data and test the limits of its applicability.

4.3 Apply and Evaluate Leading Theories

Following the above exploratory applications of simple life prediction methods, a more thorough critical and comparative study should be made of the leading macrocrack initiation theories with wide acceptance and design application experience. These are the SRP and FM Methods with their several modifications. For initial illustrative applications, estimates of the special properties required by these methods can be made using guidelines established by Halford and Coffin respectively. Although special tests may ultimately be required to establish either method for wheel steels, some mechanics applications to wheel tread and hot rim regions should be attempted before advanced materials testing for special TMF properties begins. Such analytical application attempts may reveal unappreciated weaknesses of these methods in the wheel rim application or, indeed, open possibilities for application of other crack initiation or even crack propagation or damage rate theories.

The leading crack propagation method adapted to wheel steels appears to be that of Sehitoglu. Its application to rim failure prediction depends on the determination of the nominal tensile stress range in the cycle at the critical location. This application should be possible on the basis of the uniaxial simulation of measured wheel strain/temperature cycles or adequate inelastic F.E.A. predictions of the stress cycle.

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ENCLOSURES
6.0 ~~APPENDICES~~

6.1 Creep/Fatigue Survey - Annotated Bibliography -
B. I. Sandor, 5/3/84

6.2 Bibliography - NASA Lewis Fatigue and Fracture Related
Publications, listing as of June 1984

6.3 References on Low-Cycle Thermal Fatigue received from
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CREEP/FATIGUE SURVEY

Annotated bibliography

B I SANDOR
3 May 1984

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p.1 possibility of "healing"
concept of equivalent micromechanistic damage
interaction of LCF and HCF
creep rates in tension vs. compression

p.2 10% rule for first approximations

p.4 list of major methods

p.5 permutations of loading lead to different micromechanistic effects

p.9 SRP most promising for the materials studied

p.10 Life depends on $\Delta\epsilon$, not $\Delta\sigma$ (for given metal)
all deformation in slip planes, for time-dep. and time-indep.

p.11 role of oxidation for some mat.
maverick mat.

p.13 interaction damage rule

p.15 healing

p.16 a few cycles of LCF extremely damaging with concurrent or subsequent HCF; Fig 33 ✓

p.17 $\dot{\epsilon}$ creep, tension vs. compr.

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p.4 for extrapolation into HCF creep-fatigue p.9 covered only isothermal conditions

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p.3 Fig 3. in-phase more damaging

p.12 important conclusions

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p.18 creep-fatigue interaction; ratcheting

p.19 Fig. 8 proposed ratcheting design limits

p.23 Fig.D1 master curve for damage accum.

p.26 "negative" frequency dependency Fig. D4 plastic poisson ratio cycle-dep.

p.79 Figs. time-temp. responses, measured and calculated.

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p.191 Fig. 4 stress relaxation

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p.179.1 major cracking during heating shock, not during cooling

p.179.3 Fig 179.4 calculated strain-temp. histories for heating and cooling shocks

p.179.11 Fit 179.18 calculated stable loop for temp. shocks

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p.182.2 life prediction, frequency method

p.182.6 SRP doubtful for A286
note environmental effect

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p.167.8 three distinct frequency regions

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p.163.4 equation for cyclically stable relaxation

p.163.3 Fig 163.2 large effect of tension hold time on life for 316 SS

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p.185.1 frequency method

p.185.6 Figs. creep-fatigue damage plots for copper and 304 SS

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p.222.5 Fig 222.9 estimated and experimental rupture behaviour for static and cyclic loadings

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p.125 Eq. 5b conversion from elastic to plastic

p.128 Fig 5 hysteresis loop with common hold period; conversion from elastic to plastic

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ENCLOSURE 6.3 OF APPENDIX 11.1

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APPENDIX 11.2

DESCRIPTION OF STRESS6 PROGRAM FOR CALCULATION OF WHEEL STRESSES DURING RDU TESTING

STRES6

STRES6.FOR is a program written to determine the circumferential, radial, and "effective" stresses and plastic strains in the wheels during RDU braking (heating) testing. The computations are based on biaxial state of stress including yield and plasticity.

The program accepts strain-gage coefficient data from a file MIF.DAT and raw strain, temperature, and horsepower data from the various run files such as WFM3132.DAT. It produces the following files:

TEMP.LIS - Description of each information channel
List of raw strain, adjustments, actual strain

TEMP.STR - For each time, a listing of actual strains, temperature, stresses, and effective stress.

RESULT6.DAT - Tabulation of:

- raw strain
- temperature
- strain-gage correction factors
- actual (total) strain
- brake horsepower
- plastic strains
- effective plastic strain

- effective elastic stress
- effective elastic stress after yield has occurred
- radial and tangential stresses
- net effective stress (real)
- total braking energy input

In the RDU test program strains and temperatures are measured at three locations, B1, B2, and B3 on the wheels. At B1, strain is measured only in the tangential (hoop) direction. At B2 and B3, strains are measured in both tangential and radial directions.

The information at B1 is treated as if it were a uni-axial stress situation. At each time that data is taken, a value of temperature dependent yield stress is calculated from:

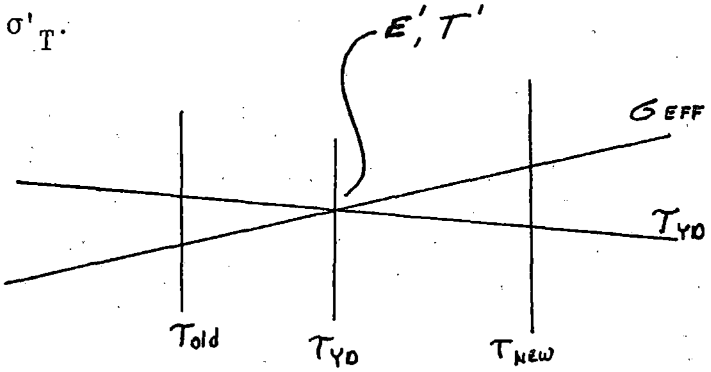
SIGYDN = 68. - .028 * TEMP (I)

From the actual tangential strain an "elastic" tangential stress is calculated from:

$$\sigma_T = E \cdot \varepsilon_T$$

If this value is less than the temperature dependent yield stress, then σ_t is the true tangential stress and there is no plastic strain.

When the comparison of the "elastic" tangential stress with the yield stress indicates that yielding has occurred the program determines the moment of yield by linear interpolation, finding the "crossover" point of the descending value of yield stress and the ascending value of "elastic" tangential stress. The tangential strain and tangential stress are evaluated at this point as ε'_T and σ'_T.



The subsequent change in plastic strain over the interval $T_{YD} - T_1$ is found by

$$\Delta\varepsilon_T^{PL} = \Delta\varepsilon_T^{TOT} - \Delta\varepsilon_T^{E} \quad \text{or}$$

$$\Delta\varepsilon_T^{P} = (\varepsilon_{T_1} - \varepsilon'_T) - \frac{(\sigma_{T_1} - \sigma'_T)}{E}$$

For subsequent intervals within the plastic regime the tangential stress is the yield stress at the "new" temperature and the change in plastic strain is found from

$$\Delta\varepsilon_T^{P} = (\varepsilon_{T_N} - \varepsilon_{T_{N-1}}) - \frac{(\sigma_{T_N} - \sigma_{T_{N-1}})}{E}$$

When the elastic regime is re-entered, the last value of accumulated plastic strain is retained and is subtracted from the actual strain to give an elastic strain, $\varepsilon_T^{E} = \varepsilon_T^{T} - \varepsilon_T^{PL}$ then:

$$\sigma_T = \varepsilon_T^{E} \cdot E$$

In the calculations dealing with B1 location, the following program symbols are used:

AC STRC (ICX NCHOUT)	actual tangential strain at time ICX
AC STRR (ICX NCHOUT	actual radial strain at time ICX = 0
EC STR	elastic stress
SIGYDN	yield stress at "new" time
SIGT (ICX NCHOUT)	tangential stress at time ICX
EFFSTR (ICX NCHOUT)	effective stress at time ICX (equal to tangential stress)
SIGR (ICX NCHOUT)	radial stress - 0
PL STNT (ICX NCHOUT)	plastic tangential strain at time ICX
PL STNR (ICX NCHOUT)	plastic radial strain at time ICX = 0
SLYD	slope of yield stress curve
SLSG	slope of tangential stress curve
FAC3	proportioning factor
SNPRT	ε_T
SIGPRT	σ_T
DPLSTN	$\Delta\varepsilon_T^{PL}$
SNTE	ε_T
SIGYDO	yield stress at "old" time

Locations B2 and B3 are treated as bi-axial stress fields. The yield criteria is given by:

$$\sigma_R{}^2 + \sigma_T{}^2 - \sigma_R\sigma_T = \sigma_Y{}^2 \text{ ----------(1)}$$

The plastic flow rule for small changes in strain gives:

$$\sigma_R^2 - \sigma_T^2 - C_1\sigma_R + C_1\sigma_T = 0 \text{ -----(2)}$$

where

$$C_1 = \frac{2K_2 + K_1}{1 - 2\gamma}, \qquad C_2 = \frac{2K_1 + K_2}{1 - 2\gamma}$$

$$K_1 = E\ (\varepsilon_R - \varepsilon_R') + \sigma_R' - \gamma\sigma_T'$$

$$K_2 = E\ (\varepsilon_T - \varepsilon_T') + \sigma_T' - \gamma\sigma_R'$$

When dealing with locations B2 and B3, the program directs the calculations to different loops, depending on which stress regime is encountered at the time. First, for each data point the temperature dependent yield stress is computed as for B1. It is SIGYDN. Then "elastic" stresses (ERSTR and ECSTR) are calculated from:

$$\sigma_R^E = \frac{E}{(1-\gamma^2)} \quad (\varepsilon_R + \gamma\varepsilon_T)$$

$$\sigma_T^E = \frac{E}{(1-\gamma^2)} \quad (\varepsilon_T + \gamma\varepsilon_R)$$

From these, an elastic effective stress [EFFSTR(ICS, NCHOUT)] is calculated from:

$$\sigma_E = \left| \sqrt{\sigma_T^2 + \sigma_R^2 - \sigma_T\sigma_R} \right|$$

This is compared with the yield stress. If the effective stress is less than the yield stress and yielding has not occurred in the run, then:

$$\sigma_R \text{ [SIGR (ICX, NCHOUT)]} = \sigma_R^E$$
$$\sigma_T \text{ [SIGT (ICS, NCHOUT)]} = \sigma_T^E$$

and the plastic strains [PLSTNT (ICS, NCHOUT) and PLSTNR (ICX, NCHOUT)] are both zero.

If it is in the elastic regime but yielding has previously occurred, the plastic strains will have been carried along from the last time in the plastic regime. From them, elastic strains are determined from:

$\varepsilon_T^E = \varepsilon_T^E - \varepsilon_T^{PL}$ SNTE = ACSTRC (I, J) - PLSTNT (I, J)

$\varepsilon_R^E = \varepsilon_R^T - \varepsilon_R^{PL}$ SNRE = ACSTRR (I, J) - PLSTNR (I, J)

then stresses are determined as on previous page.

At the first data time when yielding has occurred, "prime" values of σ_T', σ_R', ε_T', and ε_R' are determined as with B1 by interpolating the yield stress and effective stress curves. The coefficients K_1, K_2, C_1, and C_2 are calculated and equations (1.) and (2.) are solved simultaneously, first for σ_R. Since a fourth order equation is formed in the process, there will be four potential roots. The real root which is closest to the last calculated value of σ_R is selected and then a corresponding value of σ_T is found.* The plastic strains are then determined by:

---

*For large changes in strain, the procedure fails.

$$\varepsilon_T^P = \varepsilon_T^T - \frac{(\sigma_T - \gamma\sigma_R)}{E}$$

$$\varepsilon_R^P = \varepsilon_R^T - \frac{(\sigma_R - \gamma\sigma_T)}{E}$$

For subsequent points within the plastic regime the "prime" values are taken as the values at the last data time and the equations (1) and (2) are solved simultaneously for σ_T and σ_R as before.

Finally, for all situations a new effective stress, STREF (I, J) is calculated from:

$$\sigma_{EFF} = \left| \sqrt{\sigma_T{}^2 + \sigma_R{}^2 - \sigma_T\sigma_R} \right|$$

Where applicable, an effective plastic strain, EFPLSN (I, J) is calculated from:

$$\varepsilon_{EFF}^{PL} = \sqrt{\frac{2}{3}} \sqrt{(\varepsilon_T^{PL} - \varepsilon_R^{PL})^2 + (2\varepsilon_R^{PL} + \varepsilon_T^{PL})^2 + (-2\varepsilon_T^{PL} - \varepsilon_R^{PL})^2}$$

All values are then written to RESULT5.DAT which, when printed, presents the data in tabular form.

APPENDIX 11.3

SPECIAL NON-LINEAR CREEP/KINEMATIC STRAIN HARDENING MODEL FOR VARIABLE TEMPERATURE AND TOTAL STRAIN INPUT

The objective of this analysis is creation of a closed form solution for a uniaxial rheological material model subjected to an enforced total strain and temperature history. The model should include cyclic plasticity and non-linear creep characteristics that allow a reasonable simulation of steel response to thermomechanical cycles and will serve as an "exact" benchmark for independent finite element solutions which exercises the capability of the computer program's material "menu." The following analysis follows much of the thermomechanical analysis formulation of Sehitoglu (1982).

The expression for total strain rate enforced on the element is:

$$\dot{\epsilon} = \dot{\epsilon}_e + \dot{\epsilon}_p + \dot{\epsilon}_c + \dot{\epsilon}_t \tag{1}$$

where the elastic strain rate in general is:

$$\dot{\epsilon}_e = \dot{\sigma}/E - (\sigma/E^2)\,\frac{dE}{dT}\,\dot{T}$$

For simplicity the elastic modulus, E, is taken to be independent of temperature, T. The thermal strain rate is simply:

$$\dot{\epsilon}_t = \alpha\,\dot{T}$$

since the coefficient of thermal expression, α, is also assumed to be independent of T.

The plastic strain rate is based on the kinematic hardening rule

$$\dot{\epsilon}_p = \frac{1}{E_p}\left(\dot{\sigma} - \mathrm{sgn}\,(\sigma - \sigma^c)\,\frac{d\sigma_0}{dT}\cdot\dot{T}\right)$$

where E_p is the plastic modulus, σ_0 is the yield stress, and σ^c is the "back-stress" or current center of the elastic range.

The creep rate is taken as proportional to the square of the stress:

$$\dot{\epsilon}_c = \mathrm{sgn}\,(\sigma)\,\frac{\sigma^2}{C}$$

Equation (1) may now be rewritten in terms of stress as:

$$\dot{\sigma} = \left(1 + E/E_p\right)^{-1} E/C\left[C/E_p\ \mathrm{sgn}\,(\sigma - \sigma^c)\,\frac{d\sigma_0}{dT}\,\dot{T} - \mathrm{sgn}(\sigma)\sigma^2 + C(\dot{\epsilon} - \alpha\dot{T})\right] \qquad (2)$$

The first order differential equation may be integrated in closed form for certain selection of property dependence on T and loading conditions.

The plastic and creep property dependence on T is:

E_p = F/T where F is constant

σ_0 = Y - BT where Y and B are constants.

Therefore,

$$\frac{d\sigma_0}{dT} = -B$$

The creep coefficient is

$C = D/T$ where D is constant

The time region loading conditions selected are listed on the Table. With these particular temperature dependent properties and thermomechanical loading cycles, integration separated for stress may be completed in terms of functions. For example in time region after yield occurs Equation (2) may be rewritten as:

$$\dot{\sigma} = f(t) \cdot g(\sigma) \tag{3}$$

WHERE :

$$f(t) = E\left(\frac{T_0 + M/N\, t}{D}\right)\left[1 + \frac{E}{F}\left(T_0 + \frac{M}{N}t\right)\right]^{-1}$$

$$g(\sigma) = -\sigma^2 \operatorname{sgn}\sigma - \frac{DBM}{FN}\operatorname{sgn}(\sigma - \sigma^c) - DK$$

The integral solution of Equation (3) then has the following form:

$$\int \frac{dx}{ax^2+b}$$

The solution over all time regions will be made up of the several "regional" solutions within which the integrand function g (σ) differs somewhat and the integral limits are determined by changes from viscoelastic behavior to viscoplastic behavior (or vice versa) brought about by changes in direction of loading or yielding.

Such a solution has been illustrated for a particular numerical example using a personal computer and popular spreadsheet analysis software.

The thermomechanical properties were selected to approximate elevated temperature properties for Class U steel, within the limitations of the relatively simple forms of temperature and stress dependence. These are

$Y = 500\ \text{MPa}$ $\alpha = 3 \times 10^{-6}\ {}^{\circ}K^{-1}$

$B = 0.285\ \text{MPa}/{}^{\circ}K$

$E_p = 1.89 \times 10^{7}\ \text{MPa} \cdot {}^{\circ}K$

$D = 6 \times 10^{12}\ \text{MPa}^{2} \cdot {}^{\circ}K \cdot \text{Sec}$

$E = 208{,}670\ \text{MPa}$

The enforced strain and temperature loading history or cyclic parameters are

$K = 2.4 \times 10^{-8}\ \text{Sec}^{-1} \cdot {}^{\circ}K^{-1}$

$M = 500^{\circ}K$

$N = 500\ \text{SEC}$

$T_0 = 300^{\circ}K$

These example properties and loading conditions are illustrated in Figures 11.3.1 through 11.3.6.

The solution for stress history is presented graphically in Figure 11.3.7. The associated stress - total strain loops are illustrated in Figure 11.3.8 in terms of MPa units and in Figure 11.3.9 in terms of KSI stress units.

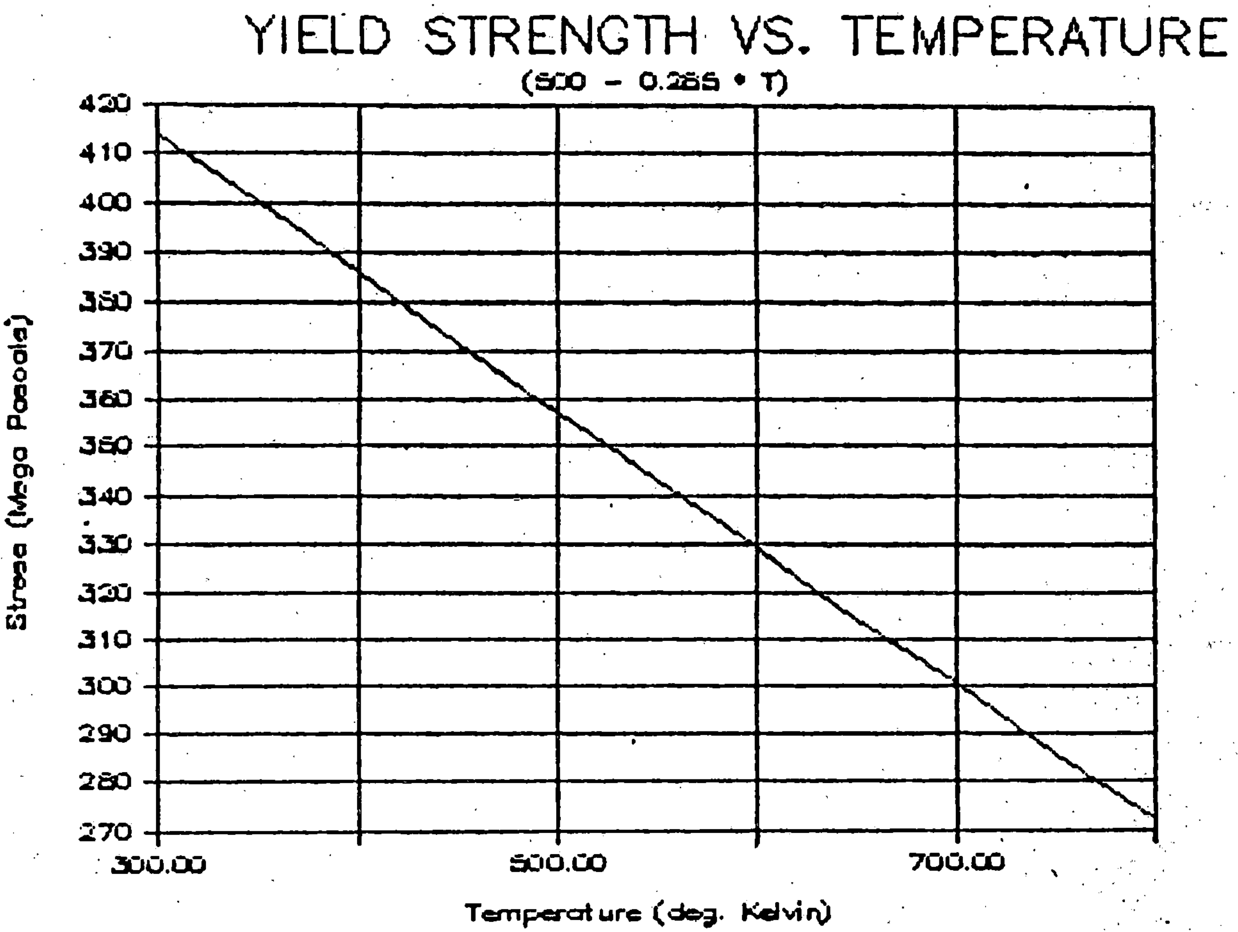


FIGURE 11.3.1. ASSUMED YIELD STRENGTH VS TEMPERATURE FOR NON-LINEAR MODEL.

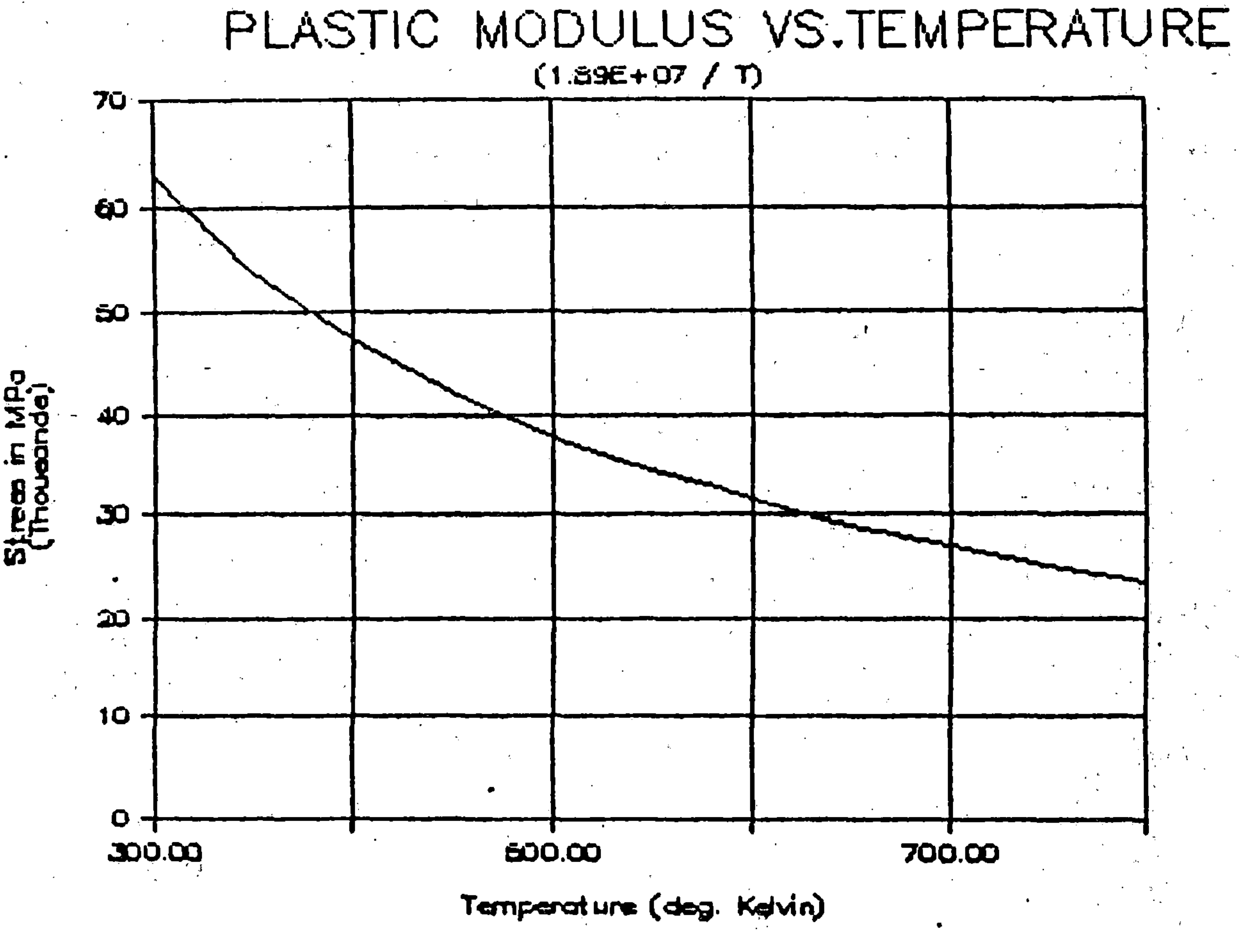


FIGURE 11.3.2. ASSUMED PLASTIC MODULUS AS A FUNCTION ON TEMPERATURE IN NON-LINEAR MODEL.

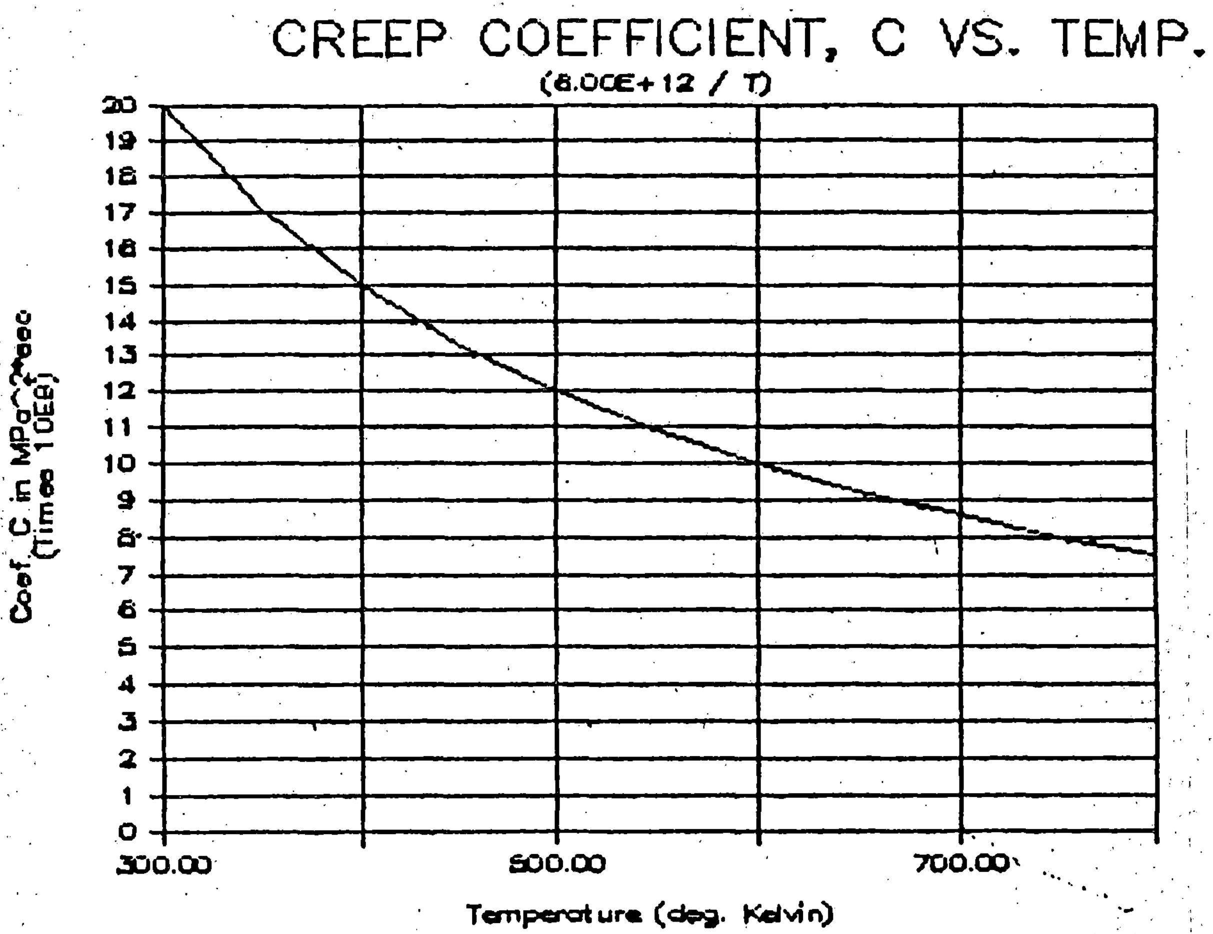


FIGURE 11.3.3. ASSUMED VARIATION OF CREEP COEFFICIENT WITH TEMPERATURE IN NON-LINEAR MODEL.

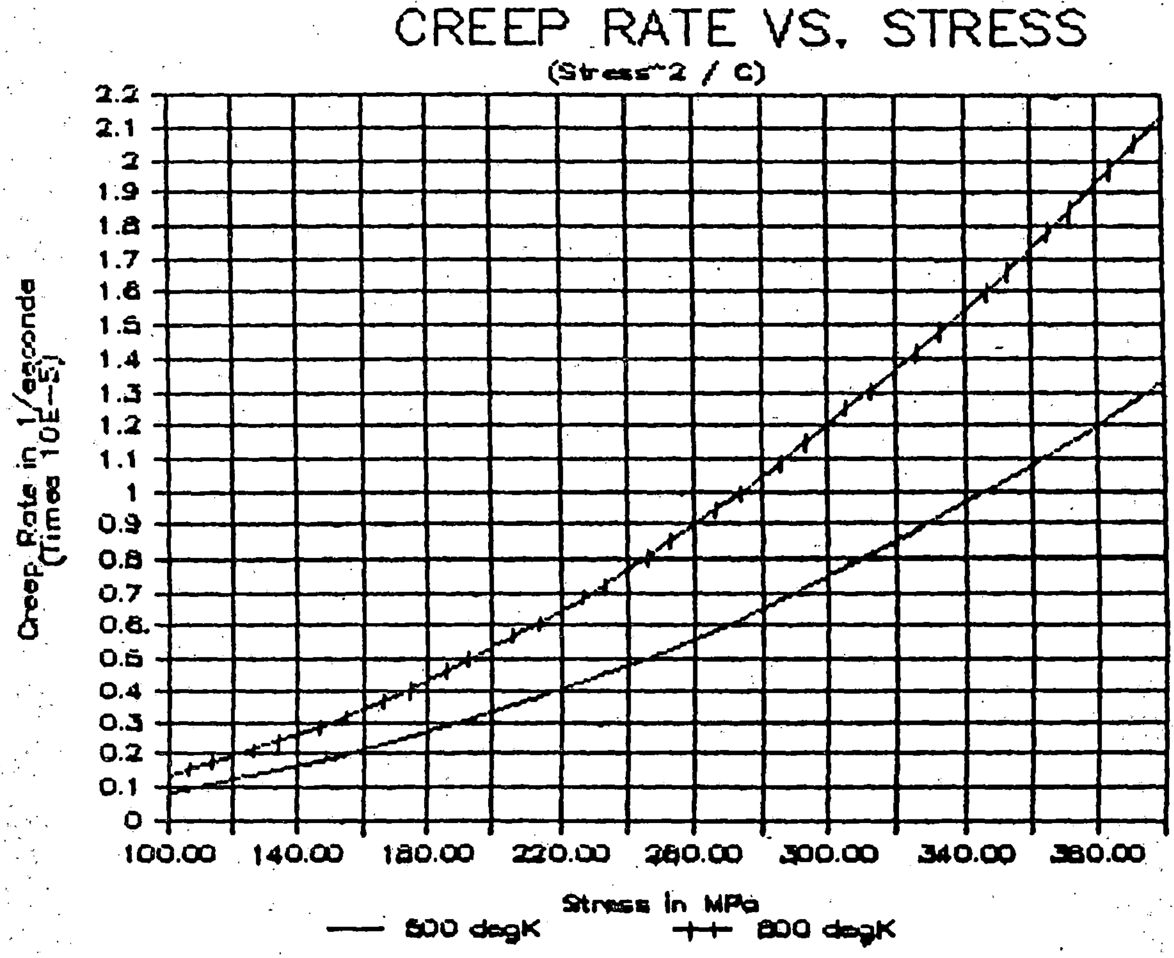


FIGURE 11.3.4. ASSUMED DEPENDENCE OF CREEP RATE ON STRESS FOR TWO TEMPERATURES IN NON-LINEAR MODEL.

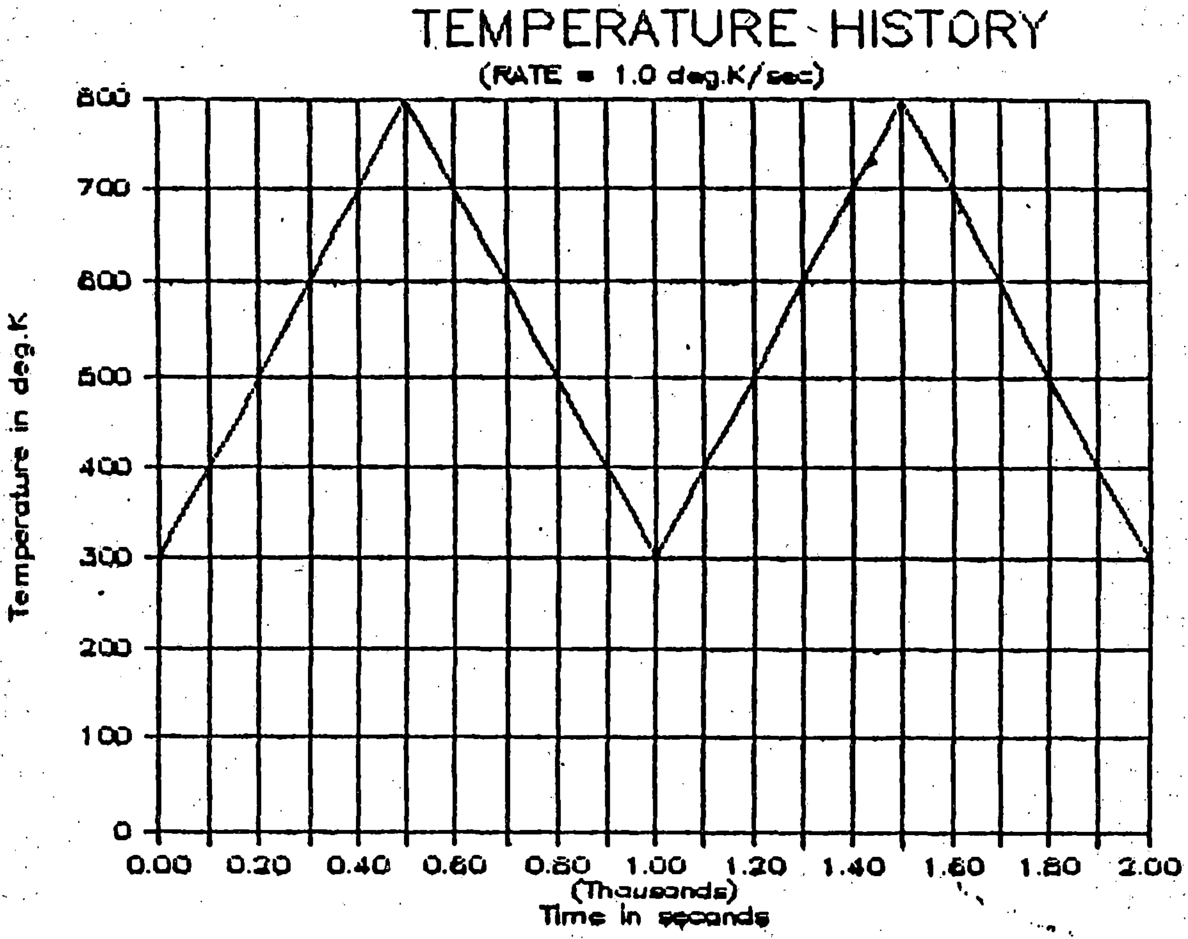


FIGURE 11.3.5. ENFORCED TEMPERATURE CYCLES FOR NON-LINEAR MODEL.

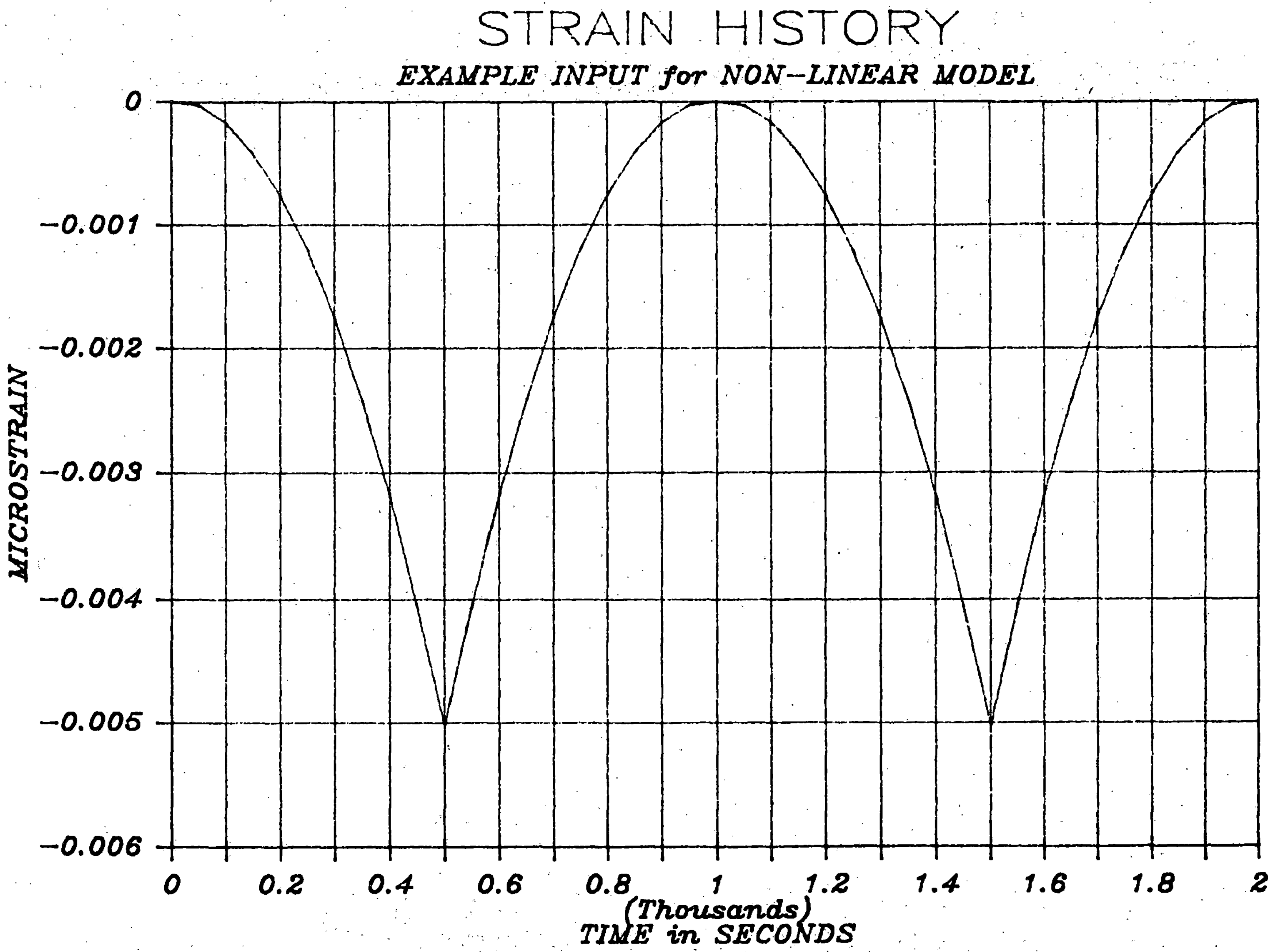


FIGURE 11.3.6. ENFORCED TOTAL STRAIN CYCLES FOR NON-LINEAR MODEL.

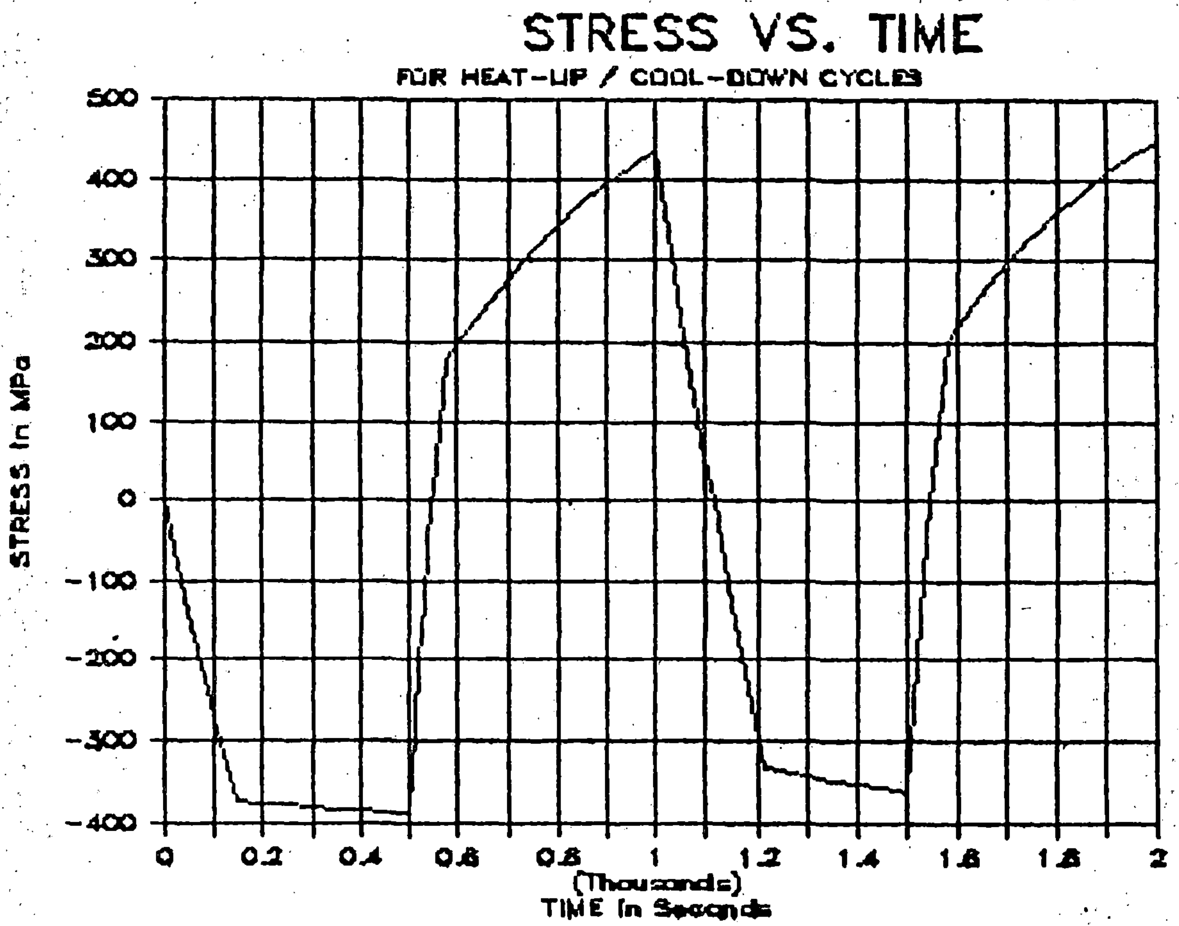


FIGURE 11.3.7. CALCULATED STRESS CYCLES FOR NON-LINEAR MODEL.

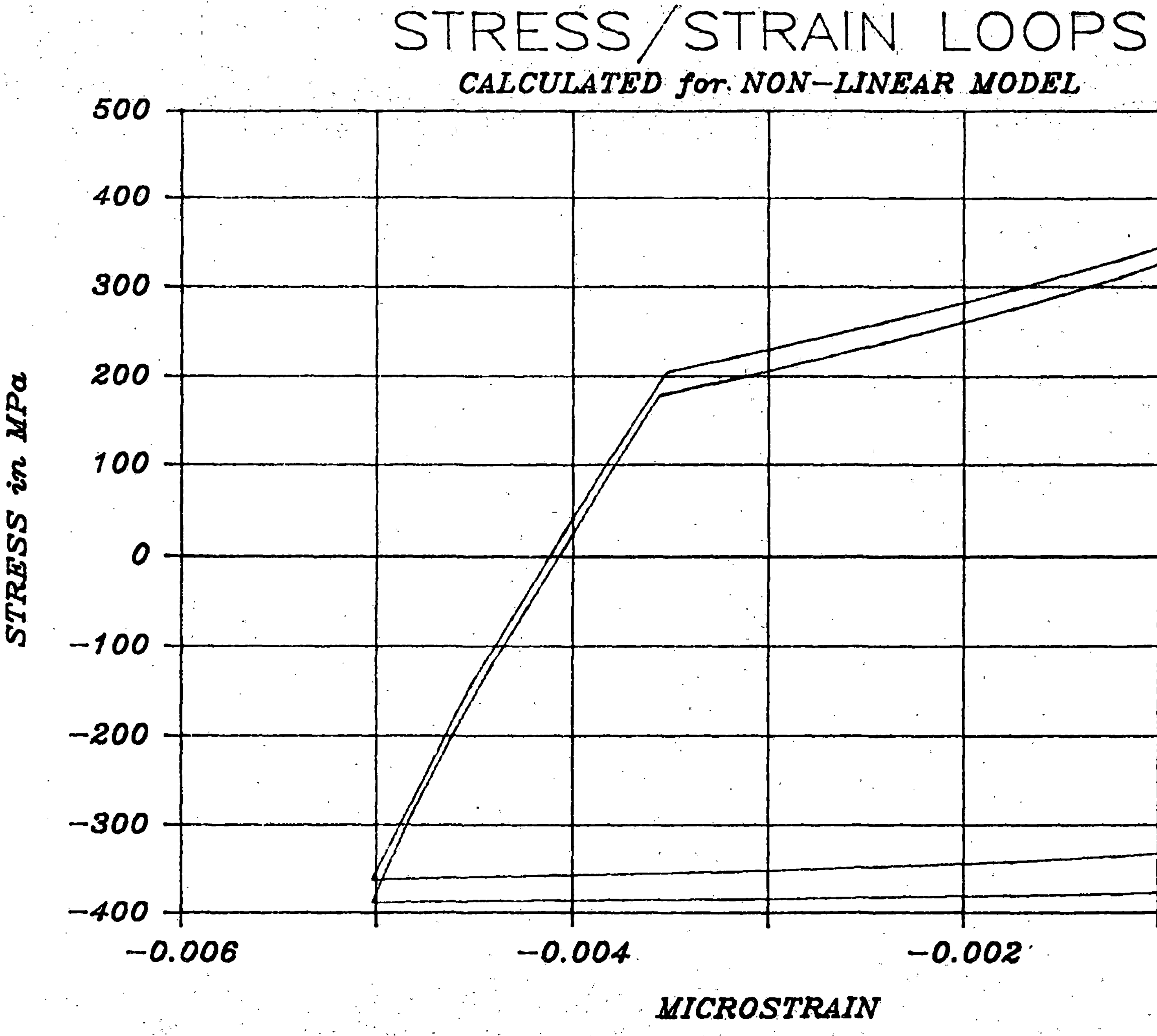


FIGURE 11.3.8. CALCULATED STRESS (MPa)/STRAIN LOOP FOR NON-LINEAR MODEL.

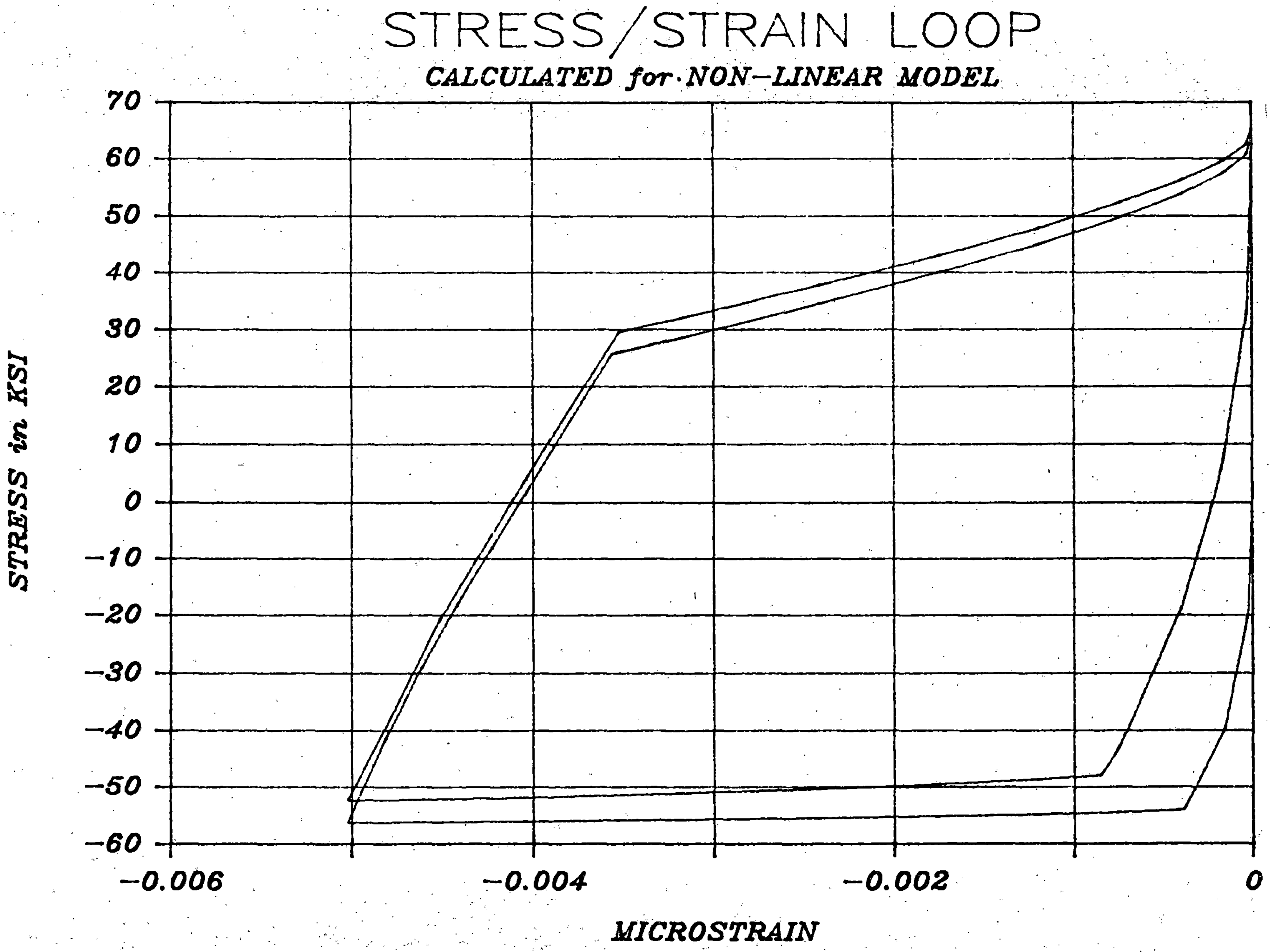


FIGURE 11.3.9. CALCULATED STRESS (KSI)/STRAIN LOOPS FOR NON-LINEAR MODEL.