Image Cover Sheet

CLASSIFICATION	SYSTEM NUMBER 510328
UNCLASSIFIED	

TITLE

DEVELOPMENT OF CAN/MIL HYW700QT STEEL

System Number:

Patron Number:

Requester:

Notes: Paper #23 contained in Parent Sysnum #510305

DSIS Use only:

Deliver to: DK

#510328 (23)

DEVELOPMENT OF CAN/MIL HYW700QT STEEL

by G.R. Labbé, R. René, J.F. Porter and C.E. Billard

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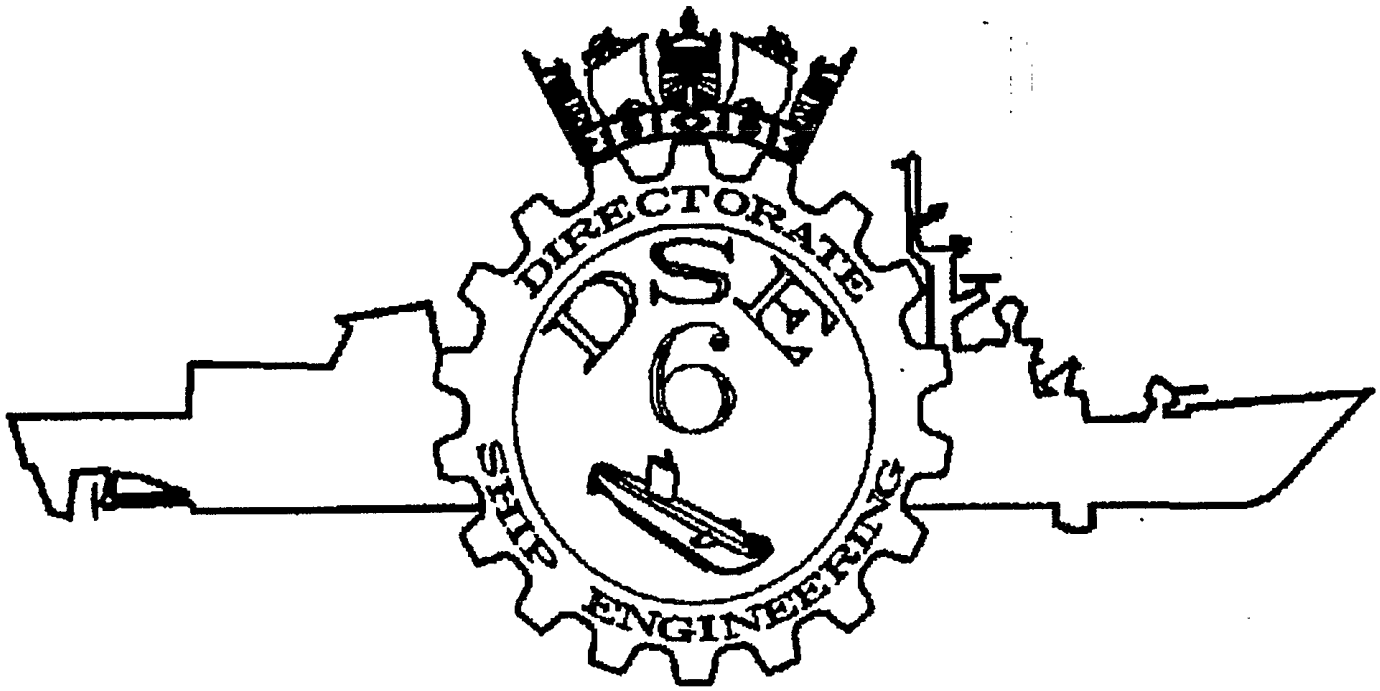
*** ABSTRACT ***

As directed by the Scientific Authority, and contracted out to M.I.L. Davie Inc., Lévis, Quebec, the goal of this project was to develop a Canadian technology for the production of an high strength weldable steel, primarily for pressure hull application, as well as, for surface fleet and/or offshore application using a lower thickness process. A history of the first phase of the project will be covered, including the establishment of a consortium to produce quenched and tempered rolled plates, the mechanical properties of the steel, and the characterization of the steel with regards to welding cycles. The initial phase of Explosion Bulge Test will be discussed. A way ahead for the next phases, including filler material and weld evaluation will also be discussed as conclusion.

The consortium which is composed of SLATER STEEL as slab producer, IPSCO Inc. as roller, and ALGOMA STEEL as heat treater was established by the prime contractor. Approximately 31 metric tons of heat treated steel plates were acquired for evaluation. Promising mechanical properties were found such as yield strength (> 118 ksi), charpy at -85°C (>37 ft-lb), and dynamic tear values at -40° (500 ft-lb). Also, nil ductility temperature was found below -100°C, which makes the steel ideal for low temperature applications. Explosion bulge tests performed in Dartmouth, Nova Scotia, with the Defence Research Establishment Atlantic (DREA) collaboration, demonstrated that the material can sustain high level of dynamic plastic deformation prior to rupture. Finally, over 1600 implants were welded and monitored for thermal fluctuations. The results were successfully collected and treated to draw the continuous cooling transformation diagrams and related abacuses.



Metallic Materials

Metallic Materials

DEVELOPMENT OF CANADIAN STEEL AND WELDING PROCEDURES AND SPECIFICATION FOR SUBMARINE PRESSURE HULLS

April 1993

Metallic Materials

CONTENT

PART 1	---------->	OPENING REMARKS
PART 2	---------->	DEVELOPMENT PROJECT
PART 3	---------->	CONCLUSION

Metallic Materials

REQUIREMENT

TO DEVELOP PROCEDURES FOR THE WELDING OF HIGH STRENGTH, WELDABLE, QUENCHED AND TEMPERED STEEL OF THE HY100 TYPE WHICH WILL BE USED PRIMARILY IN THE FABRICATION AND/OR REPAIR OF SUBMARINE PRESSURE HULLS.

Metallic Materials

SCOPE

1.- NEED FOR ADVANCED WELDING TECHNIQUES.

2.- IMPROVE ADEQUACY OF WELDING TECHNIQUES.

3.- REDUCE HIGH COSTS OF WELD REWORK.

4.- OPTIMIZE THE WELDING PROCEDURES.

5.- OPEN ACCESS TO STEEL AVAILABILITY WITHIN CANADIAN BOUNDARIES.

Metallic Materials

SCOPE (Cont'd)

6.- PROVIDE MEANS TO WRITE STANDARDS FOR STEEL FABRICATION AND SPECIFICATIONS FOR THE WELDING OF THAT STEEL.

7. ENSURE THE APPLICATION OF DEPARTMENTAL POLICY TO ENCOURAGE INDUSTRIAL PARTICIPATION IN DEVELOPMENT, DESIGN AND FABRICATION OF MILITARY PROJECTS.

Metallic Materials

MATRIX

SCIENTIFIC AUTHORITY ---------->	Mr. G.R. Labbé DSE 6
PROJECT DIRECTOR ---------->	Dr. J.L. Kennedy DRDM 8
PROCUREMENT MANAGER ----->	Mr. T.W. Patrick DSS/SPO
PROCUREMENT OFFICER -------->	CPO2 S.M. Decary DPSupM 2

Metallic Materials

CONTRACTOR

MIL DAVIE Inc.
22 George D. Davie
Lévis-Lauzon, Québec
G6V 6N7

(418) 837-5841

Metallic Materials

PHASING

PHASE	SERIES	ITEM
I	1000	Characterization of Canadian HYW700QT Steel
II	2000	Evaluation of Filler Materials
III	3000	Welding Procedures
IV	4000	Technical Specification Documentation

Metallic Materials

MILESTONES

PHASE	ESTIMATED DATES
I	21 May 93
II	15 Sep 93
III	29 Apr 94
IV	27 May 94

Metallic Materials

COST

DATA AS PER MAR 93 FORECAST

TOTAL ($000) -----> $5,341

FY	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	SUBYRS
BY	83	353	1,067	825	1,140	950	365	227	331

CRAD MEETING – HALIFAX, April 29, 1993

STRUCTURE OF THE CONFERENCE

PART 1: OPENING REMARKS AND CONTRACTUAL ASPECTS (DND)

SLIDE #	CONTENT	SUBJECT OF DISCUSSION	TIME
N/A	N/A		10 min.
Total: 3 OVERHEADS			

PART 2: STEEL DEVELOPMENT PROJECT:

2a: INTRODUCTION (MIL)

SLIDE #	CONTENT	SUBJECT OF DISCUSSION	TIME
1	PROJECT TITLE	BUDGET, SCHEDULE	10 min.
2	PHASES	DESCRIPTION OF EACH PHASE	
3	GANTT CHART	STATUS OF THE PROJECT:	
4	LIST OF SUBJECTS	CONFERENCE PLAN:	
Total: 4 SLIDES			

2b: HISTORICAL REVIEW OF STEEL ACQUISITION (METASOUDAGE)

SLIDE #	CONTENT	SUBJECT OF DISCUSSION	TIME
N/A	N/A		15 min.
Total: 12 SLIDES			

2c: PRELIMINARY MECHANICAL PROPERTIES (MIL)

SLIDE #	CONTENT	SUBJECT OF DISCUSSION	TIME
5	SUB-PHASE TITLE	INTRODUCTION TO MECHANICAL TESTS	5 min.
6	MECHANICAL PROPERTIES	TENSION, CHARPY, CTOD, DW, DT, HARDNESS, ETC MELT I AND II + ANTICIPATED MELT II RESULTS	
Total: 2 SLIDES			

2d: EXPLOSION BULGE TEST (DREA)

SLIDE #	CONTENT	SUBJECT OF DISCUSSION	TIME
N/A	N/A		15 min.
Total: 12 OVERHEADS			

2e: STEEL CHARACTERIZATION WITH REGARDS TO THERMAL CYCLES (MIL)

SLIDE #	CONTENT	SUBJECT OF DISCUSSION	TIME
7	SUB-PHASE TITLE	INTRODUCTION TO STEEL CHARACTERIZATION USING THE IMPLANT METHOD	15 min.
8	PLAN OF THIS PART	LIST OF COVERED SUBJECTS	
9	LIST OF AVAILABLE METHODS	DESCRIPTION OF THE METHODS AND METHOD SELECTION	
10	SCKETCH OF AN IMPLANT	PRINCIPLE OF THE METHOD	
11	PHOTO OF AN IMPLANT	DESCRIPTION OF THE PHOTO, HARDNESS MEASUREMENTS	
12	CRUDE DATA POINTS	DESCRIPTION OF THE DATA POINTS AND CURVE ASPECT	
13	COOLING PART OF THE CRUDE DATA CURVE AND LINEAR REGRESSION CURVE	DESCRIPTION OF THE DADA ANALYSIS METHOD AND FINDING OF Tr8-5 AND Tr7-3	
14	RESULTING DATA POINTS ON CCT DIAGRAMS	DESCRIPTION OF DATA POINTS, NUMBER OF TEST PERFORMED COOLING TIME CRITERION	
15	RESULTING CCT DIAGRAM WITH HARDNESS CURVE	DESCRIPTION OF CCT DIAGRAM	
16	ABACUS OF ENERGY vs Tr	DESCRIPTION OF COOLING TIME ABACUS	
17	CCT AND ABACUS	USES OF CURVES AND ABACUSES	
Total: 11 SLIDES			

2f: WAY AHEAD (MIL)

SLIDE #	CONTENT	SUBJECT OF DISCUSSION	TIME
18	LIST OF NEXT PHASES	DESCRIPTION OF PHASES TO COME	5 min.
Total: 1 SLIDE			

PART 3: QUESTION PERIOD (DND)

SLIDE #	CONTENT	SUBJECT OF DISCUSSION	TIME
1	PROJECT TITLE	QUESTIONS	10 min.
Total: 1 SLIDE			

TOTAL NUMBER OF SLIDES/OVERHEADS: 46 **TOTAL TIME: 1h25min.**

disk 20: d:\tableaux\CRADMEET.wk1

(29)

5 th CF/CRAD MEETING

DEVELOPMENT OF CAN/MIL HYW700QT STEEL

MIL DAVIE INC.

DEVELOPMENT OF CAN/MIL HYW700QT STEEL

Covered Subjects

- General Overview of the Project
- Historical Review of Steel Acquisition
- Mechanical Properties
- Steel Characterization - Implant Test
- Explosion Bulge Test Trials

MIL DAVIE INC.

DEVELOPMENT OF CAN/MIL HYW700QT STEEL

- General Overview of the Project
- Historical Review of Steel Acquisition
- Mechanical Properties
- Steel Characterization - Implant Test
- Explosion Bulge Test Trials

MIL DAVIE INC.

General Overview

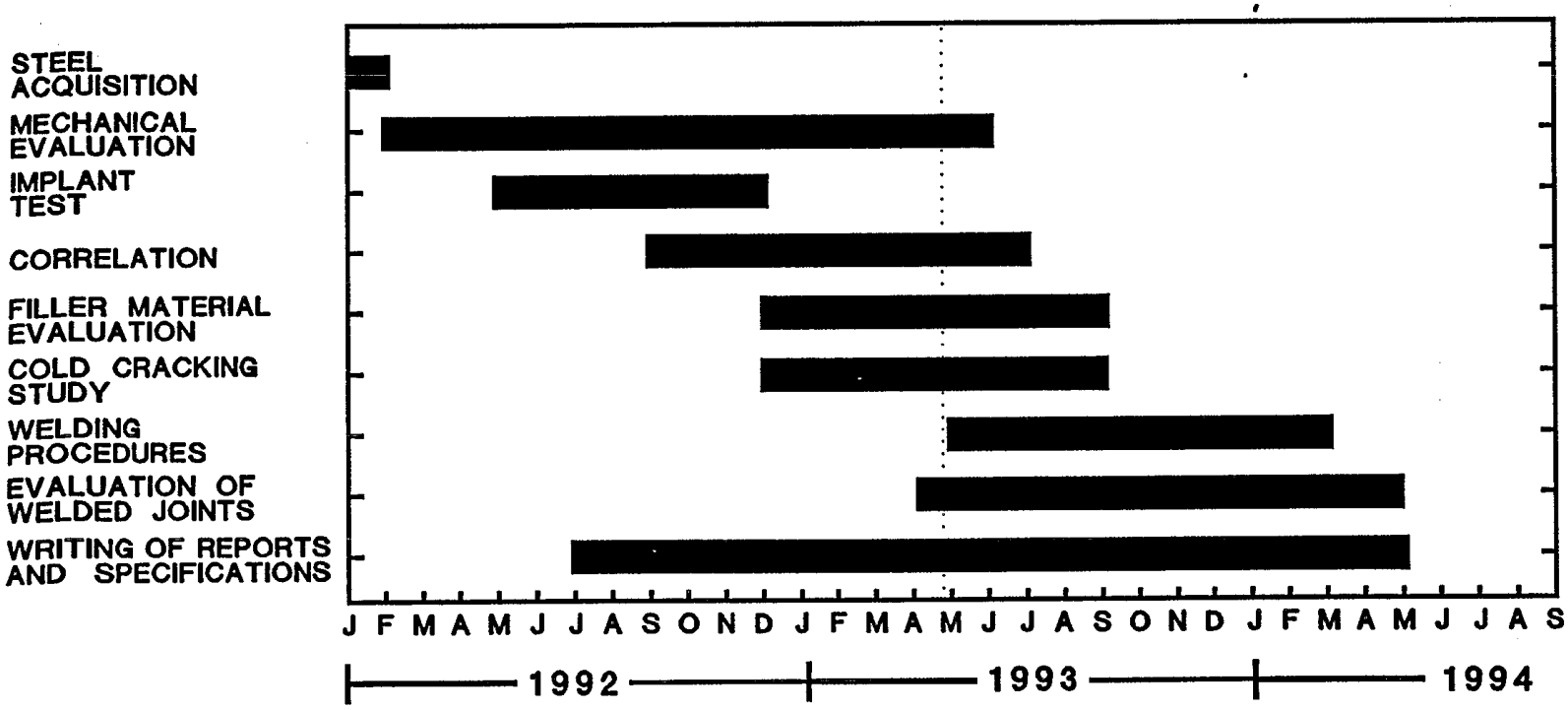
The four phases of the project

- Phase I : Steel Acquisition
- Phase II : Filler Material Evaluation
- Phase III: Development of Welding Procedures
- Phase IV: Writing of Reports and Specifications

MIL DAVIE INC.

DEVELOPMENT OF CAN/MIL HYW700QT STEEL

WORK PLANNING



MIL DAVIE INC.

DEVELOPMENT OF CAN/MIL HYW700QT STEEL

- ○ General Overview of the Project
- • Historical Review of Steel Acquisition
- ○ Mechanical Properties
- ○ Steel Characterization - Implant Test
- ○ Explosion Bulge Test Trials

MIL DAVIE INC.

DEVELOPMENT OF CAN/MIL HYW700QT STEEL

- ○ General Overview of the Project
- ○ Historical Review of Steel Acquisition
- • **Mechanical Properties**
- ○ Steel Characterization - Implant Test
- ○ Explosion Bulge Test Trials

MIL DAVIE INC.

HYW700QT STEEL
MECHANICAL PROPERTIES

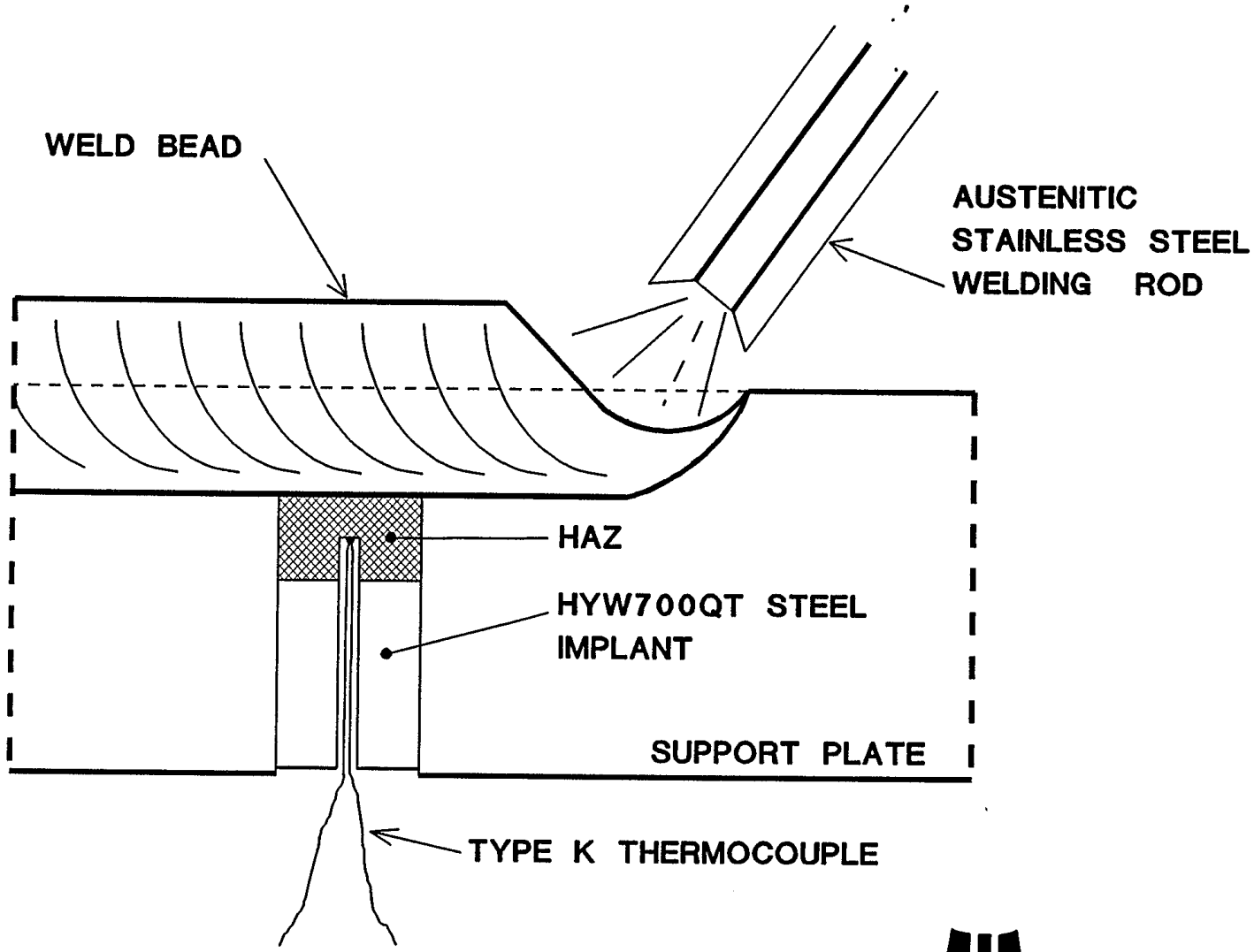
	HARDNESS	CVNT AT -85 °C	NDT	DTE AT -40 °C	TENSILE			
					YS	UTS	E	R
Melt I	26 HRc	37 ft-lb	-105°C	500 ft-lb	118 ksi	130 ksi	21%	68%
Melt II	28 HRc	45 ft-lb	-105°C	>500 ft-lb	120 ksi	135 ksi	20%	65%

MIL DAVIE INC.

DEVELOPMENT OF CAN/MIL HYW700QT STEEL

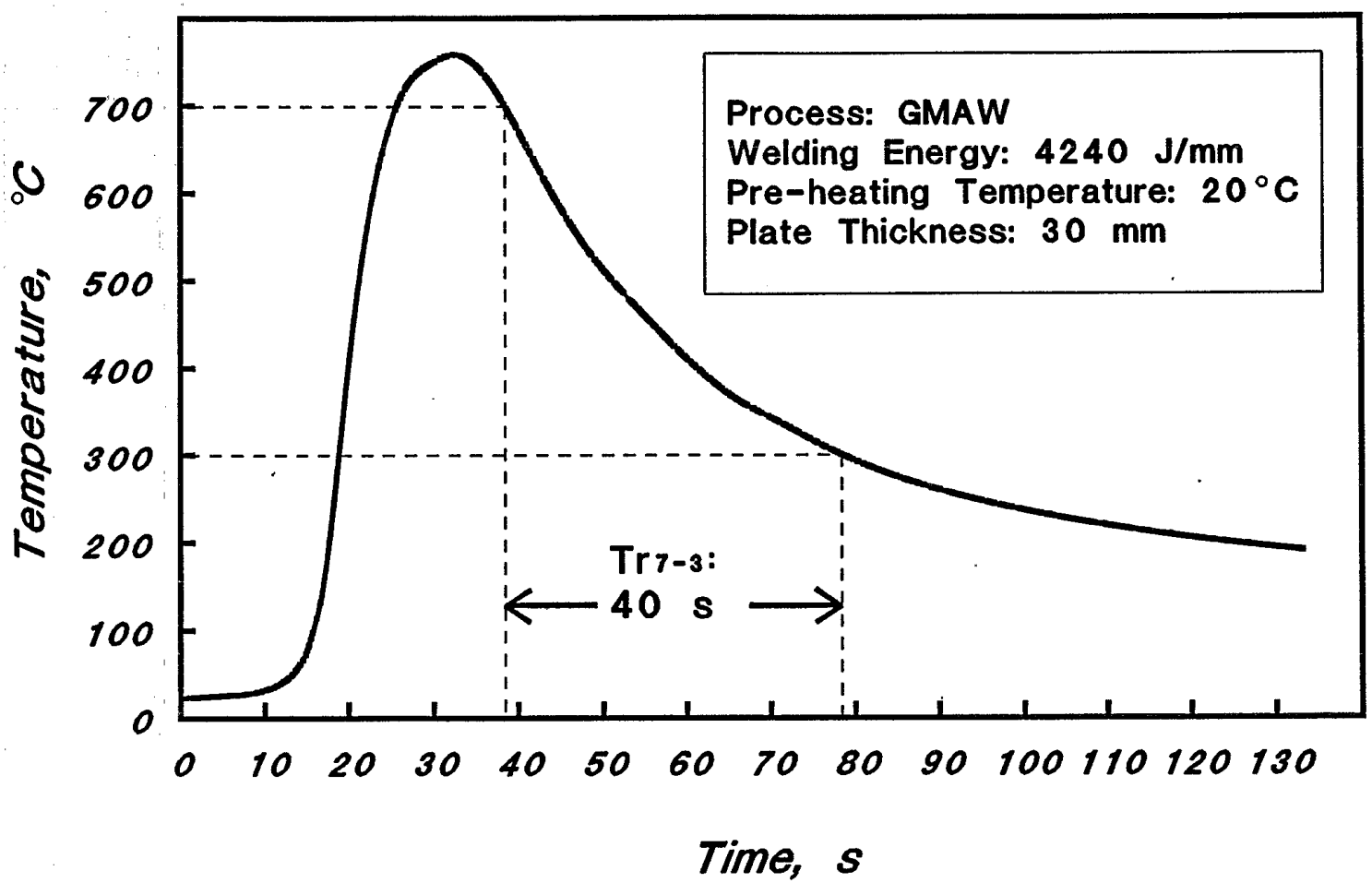
- ○ General Overview of the Project
- ○ Historical Review of Steel Acquisition
- ○ Mechanical Properties
- • **Steel Characterization - Implant Test**
- ○ Explosion Bulge Test Trials

MIL DAVIE INC.



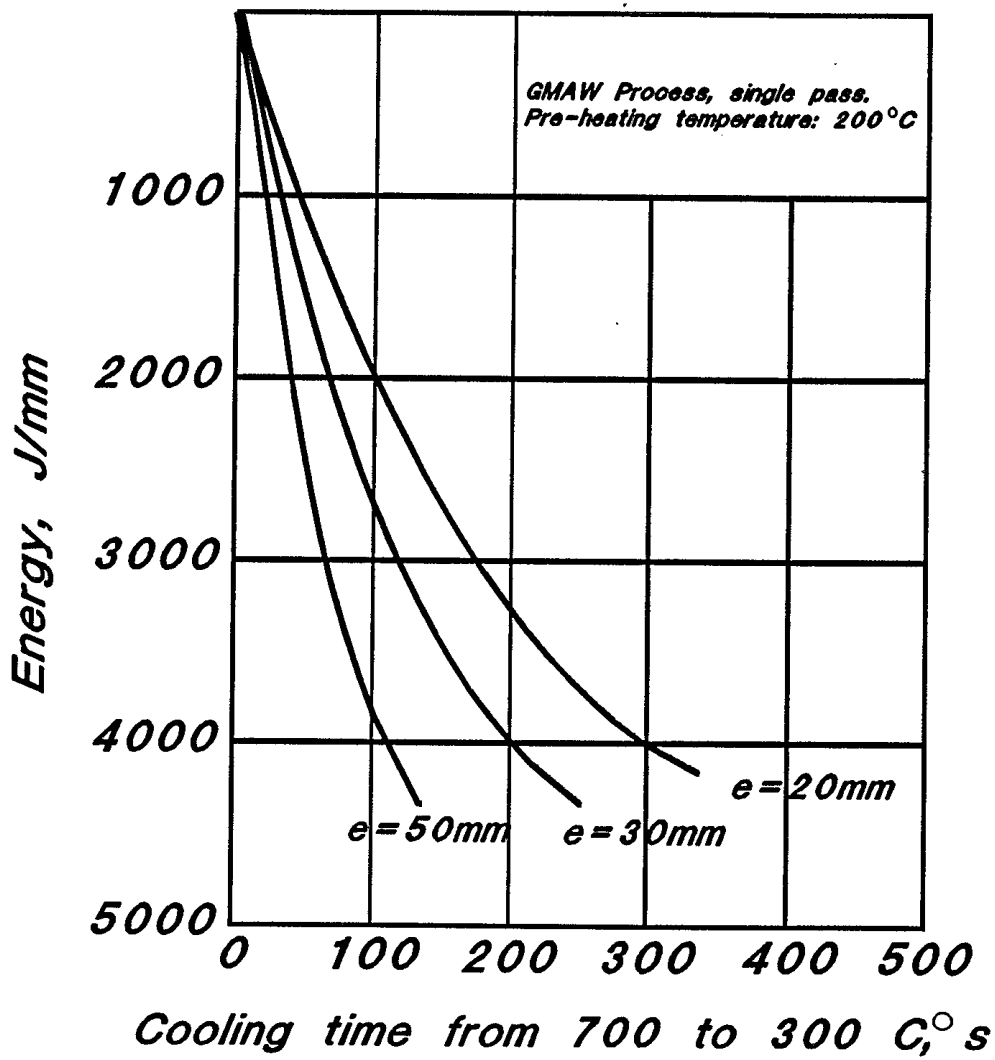
MIL DAVIE INC.

IMPLANT TEST DATA CURVE



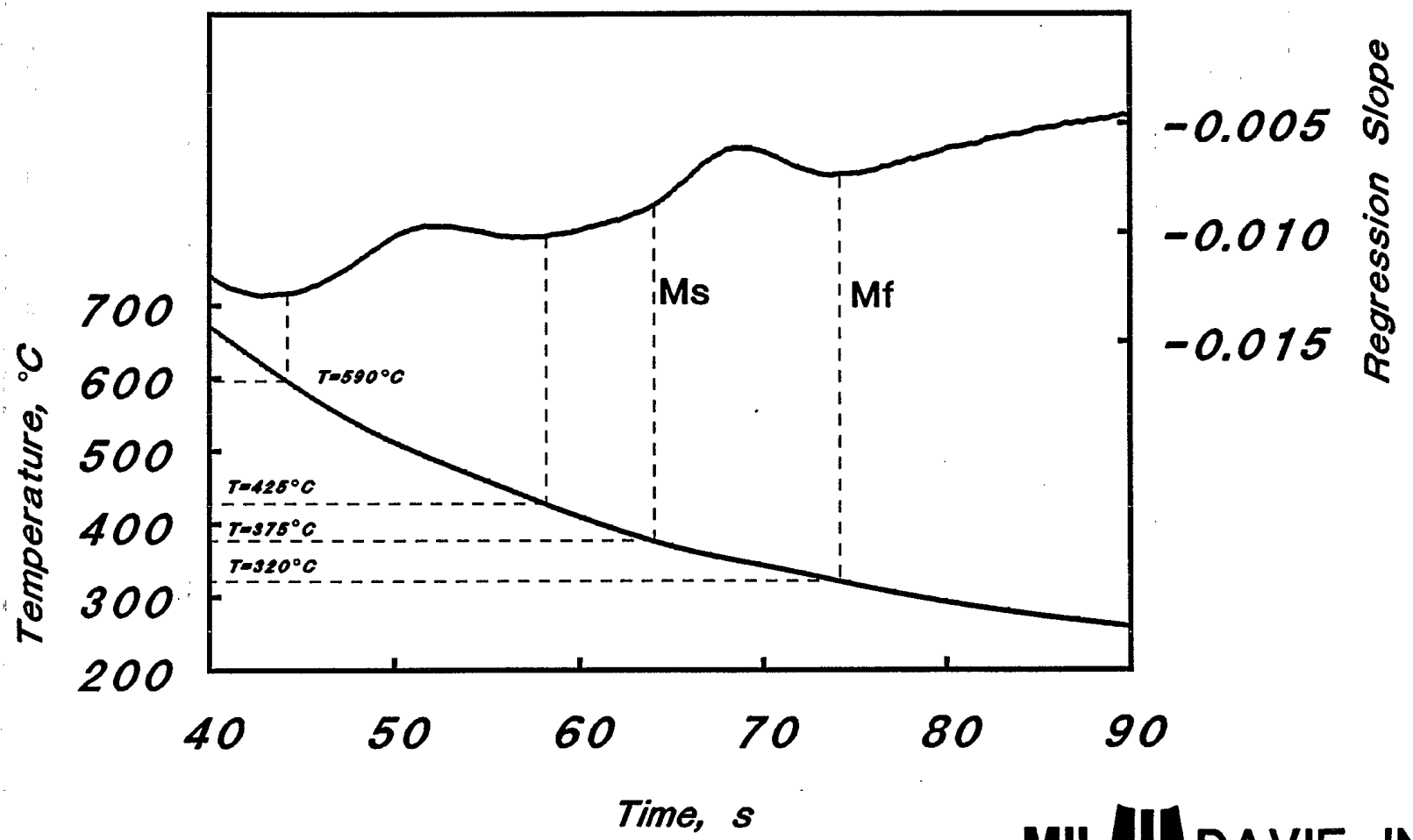
MIL DAVIE INC.

CAN/MIL HYW700QT STEEL



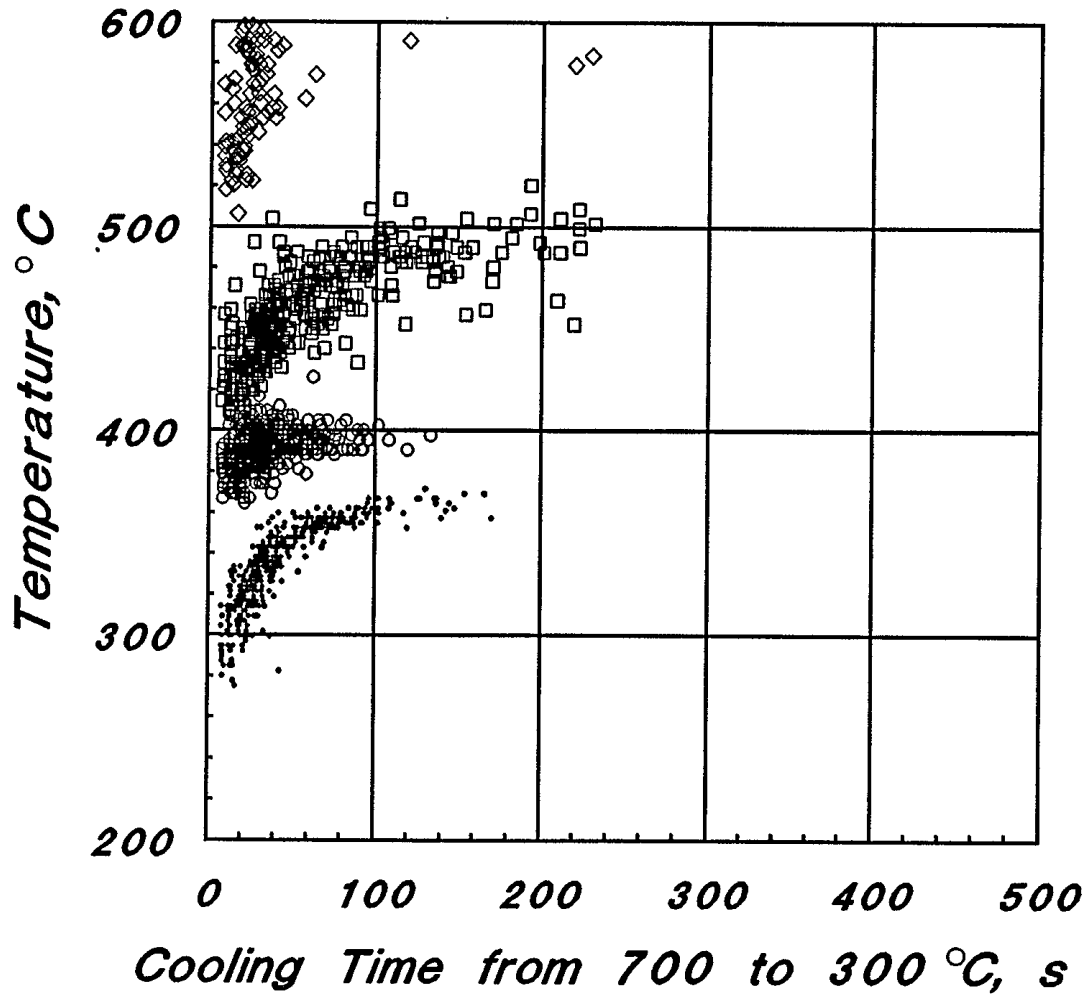
MIL DAVIE INC.

TRANSFORMATION TEMPERATURES

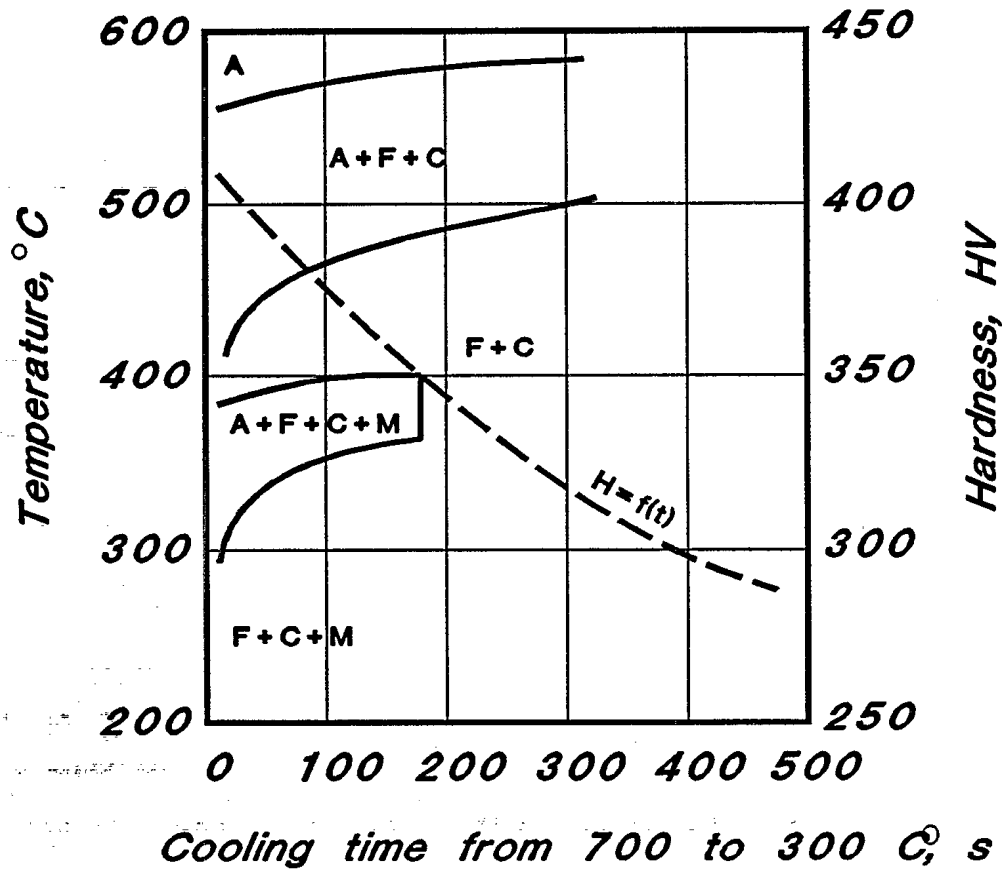


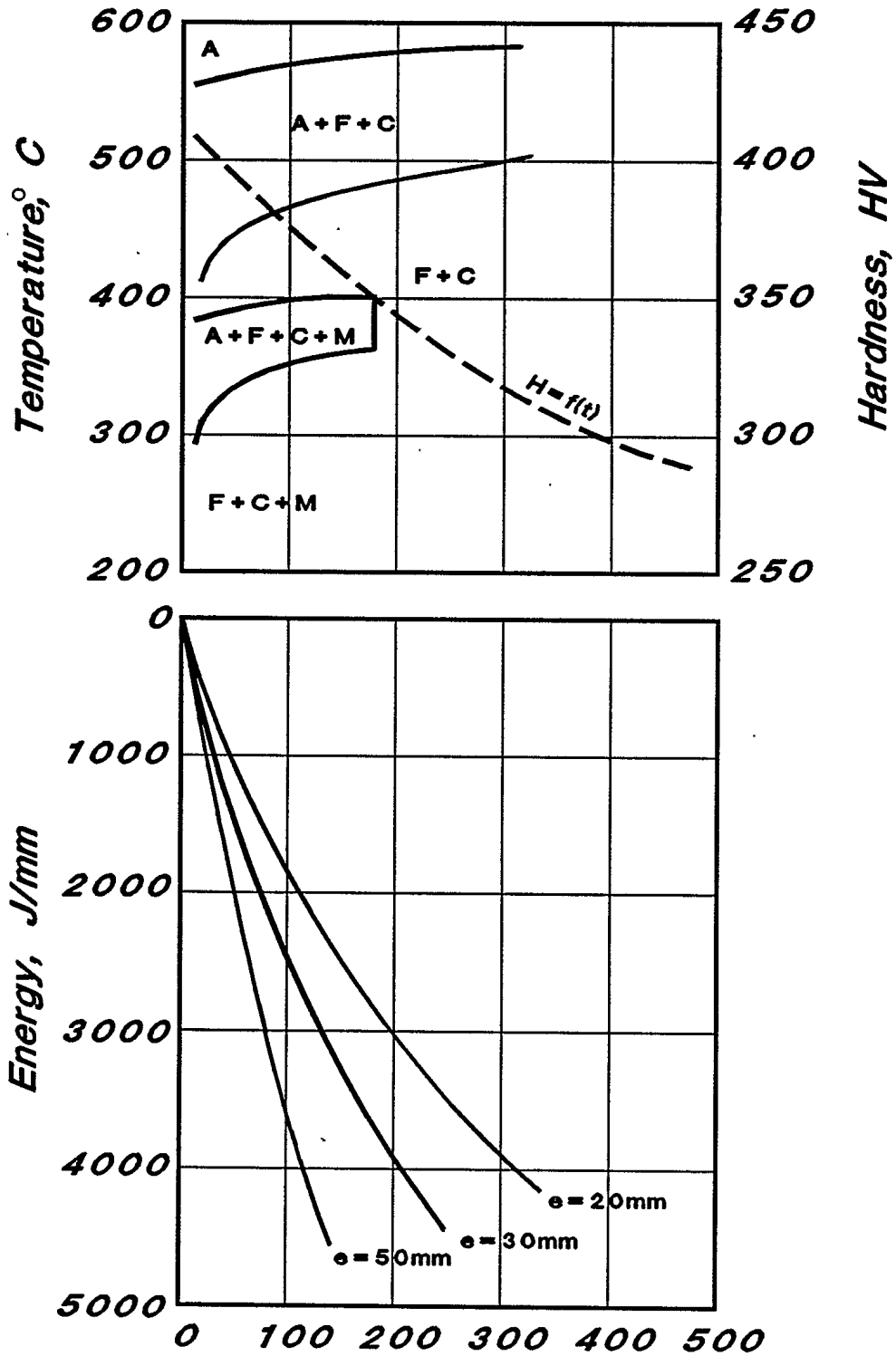
MIL DAVIE INC.

DATA POINTS


600
500
400
300
200
Temperature, °C
0
100
200
300
400
500
Cooling Time from 700 to 300 °C, s

CONTINUOUS COOLING TRANSFORMATION DIAGRAM FOR CAN/MIL HYW700QT STEEL





GMAW Process - Pre-heated at 200 °C

DEVELOPMENT OF CAN/MIL HYW700QT STEEL

- General Overview of the Project
- Historical Review of Steel Acquisition
- Mechanical Properties
- Steel Characterization - Implant Test
- **Explosion Bulge Test Trials**

MIL DAVIE INC.

DEVELOPMENT OF CANADIAN STEEL AND WELDING PROCEDURES AND SPECIFICATIONS

Contract Serial No W8477-7-PE01/01-SV

SSC File No 05SV.W8477-7-PE01

ONCE UPON A TIME . . .

DEPARTMENT OF NATIONAL DEFENCE

AND

MARINE INDUSTRIES LIMITED

HYW 700 QT

TO DEVELOP A

- Canadian Made
- High Strength
- High Toughness
- Structural Steel

TO BE USED FOR THE

- Fabrication
- Repair

of HMC Ships

MILESTONES

1984, December
*Request for Approval of Capital Project.

1986, November
* Request for Quotation.

1987, February
Submittal of the Proposal of the MIL Group.

1987, November
Signature of the Contract between DND/SSC and The MIL Group.

1988, June
Start of the Activities at MIL Tracy Plant, Tracy, Que.

1989, November
First melting.

1990, January
First rolling.

1990, October
Transfer of Welding R & D Laboratories to MIL Davie Inc Plant. in Lauzon, Que.

1991, April
Start of Testing Activities at MDI Plant.

Development
of
Canadian Steel and Welding
Procedures and Specidications

SSC File No. 05SV.W8477-7-PE01

SUMMARY

PHASE I CARACTERIZATION OF DEVELOPPED STEEL

- -Draft of steel specification
- -Steel Acquisition
  - *Melting
  - *Rolling
  - *Heat treating
- -Mechanical Properties Evaluation
- -Steel Response to Welding Thermal Cycles
- -Toughness Evaluation

PHASE II CARACTERIZATION OF FILLER MATERIALS

- -Humidity
- -Potential Diffusible Hydrogen
- -Storing and Handling Conditions
- -SMAW, GMAW, FCAW, SAW.

PHASE III CARACTERIZATION OF WELDED JOINTS

- -Susceptibility to Cold cracking
- -Welding Procedure Qualification
- -Weld Toughness Evaluation

PHASE IV SPECIFICATIONS & PROCEDURES

- -Developped Steel
- -Welding of Developped Steel

Development
of
Canadian Steel and Welding
Procedures and Specifications

SSC File No. 05sv.w8477-7-PE01

PARTICIPANTS

STEEL DRAFT SPECIFICATION by

The MIL GROUP
(MIL Davie Inc.)
Lauzon, Que.

STEEL MAKING by

SLATER STEEL
(Les Forges de Sorel)
Sorel, Que.

STEEL ROLLING by

IPSCO
Regina, Sask.

HEAT TREATING by

ALGOMA STEEL
Sault-Ste-Marie, Ont.

STEEL TESTING by

The MIL GROUP
(MIL Davie Inc.)
Lauzon, Que.

SUMMARY OF DRAFT SPECIFICATION FOR "CAN/MIL H Y W 7 0 0 Q T"

STEEL MAKING:

ELECTRIC ARC FURNACE; FULLY KILLED; VACUUM DEGASSED; FINE GRAIN PRACTICE.

DELIVERY CONDITION:

QUENCHED and TEMPERED.

TENSILE PROPERTIES:

Yield Strength:	700 - 800 MPa
Elongation (50mm):	18% min.
Reduction of Area:	45% min.

TOUGHNESS PROPERTIES:

Transverse CVN:	55 Joules
Explosion Bulge:	12% Red. of Thickness @ - 5°C

CHEMISTRY:

% C:	0.15 max.
% Mn:	0.50 max.
% Si:	0.25 max.
% Ni:	4.0 - 4.8
% Cr:	0.50 max.
% Mo:	0.40 max.
% V:	0.10 max
% S:	0.008 max.
% P:	0.015 max.

Development
of
Canadian Steel and Welding
Procedures and Specifications

CAN/MIL HYW 700 QT

TYPICAL RESULTS

CHEMISTRY

DRAFT SPECIFICATION REQUIREMENTS	MELT #1	MELT #2 LAB. A	MELT #2 LAB. B
% C : 0.15 max.	0.13	0.155	0.148
% Mn: 0.50 max.	0.36	0.29	0.27
% Si: 0.25 max	0.10	0.20	0.20
% Ni: 4.0 - 4.8	4.26	4.66	4.40
% Cr: 0.50 max.	0.39	0.41	0.40
% Mo: 0.40 max.	0.25	0.41	0.39
% V : 0.10 max	0.004	0.06	0.05
% Al: 0.015-0.050	0.018	0.016	0.025
% Cu: 0.25 max.	0.11	0.10	0.10
% Ti: 0.02 max.	0.001	0.000	0.002
% P : 0.015 max.	0.008	0.008	0.008
% S : 0.008 max.	0.004	0.010	0.008
% N_2: 0.015 max.	0.0070	0.0095	0.010

Development
of
Canadian Steel and Welding
Procedures and Specifications

SSC File No. 05SV.W8477-7-PE01

CAN/MIL HYW 700 QT
TYPICAL RESULTS
FOR MELT #1

HEAT TREATMENT:

*DOUBLE QUENCHING from 850°C,

*TEMPERING @ 600°C.

TENSILE PROPERTIES:

*YIELD STRENGTH:	763 MPa	747MPa
*TENSILE STRENGTH:	822 MPa	812MPa
*ELONGATION IN 50mm:	21.5%	22%
*REDUCTION OF AREA:	72.2%	69%

TOUGHNESS

*CVN @ -85°C	137J	104J