AD-A127 423 FATIGUE CRACK PROPAGATION IN AN HSLA STEEL (MF-80) IN 1/1
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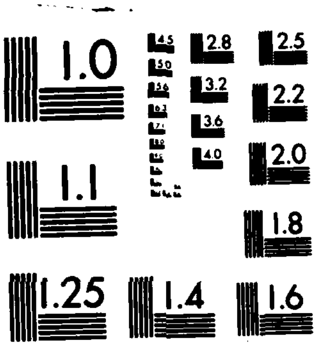
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Fatigue crack propagation was studied in MF-80 HSLA steel in ambient room air and in 3.5 percent NaCl salt water. Region-II fatigue crack growth rate (da/dN) data were obtained at two load ratios, R = 0.10 and R = 0.67. da/dN values were found to be affected by both load ratio and environment, with the greatest effect being caused by the combination of high load ratio and salt water environment. Overall, the results of this study suggest that MF-80 HSLA steel may have slightly less Region-II fatigue crack propagation resistance than other high-strength steels of comparable strength.

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CONTENTS

FATIGUE CRACK PROPAGATION IN AN HSLA STEEL (MF-80) IN AIR AND IN SALT WATER

S. J. Gill and T. W. Crooker

Mechanics of Materials Branch
Material Science and Technology Division
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INTRODUCTION

HSLA steels are currently under investigation as candidate materials for new naval ship structures. Essentially, HSLA steels are carbon-manganese steels with very small additions of vanadium and/or columbium for grain refinement and precipitation hardening. Potentially, HSLA steels offer the possibility of attaining high strength, high fracture toughness and good weldability without resorting to extensive use of scarce or expensive alloying elements.

The development of favorable strength and toughness is quite dependent on microstructural refinement [1,2]. However, recent studies have shown that microstructural refinement can be detrimental to fatigue crack propagation resistance in steels [3]. This investigation was undertaken to examine this aspect of the fatigue behavior of MF-80 HSLA steel base material.

MATERIALS AND EXPERIMENTAL PROCEDURES

The material used in this study was 6.4 mm thick MF-80 (TM) steel. The composition of this steel, as given by the producer, is shown in Table 1. In addition to the carbon, manganese and columbium, or vanadium, present in all HSLA steels, this steel contains more than a trace amount of silicon. The result is that the alloy shows good ductility despite its high strength [4]. MF-80 steel of this thickness is typically aluminum killed and hot rolled to a reduction of at least 50% at 900 to 925°C, cooled at rates between 8°C and 75°C per second and coiled at 650°C. The coils are then air cooled [4,5]. Mechanical properties of the plate are given in Table 2.

The microstructure of the steel is shown in Figure 1. Sections of the longitudinal, transverse and short transverse planes were examined and no significant differences due to orientation were found. The microstructure consisted of equiaxed ferrite. It was very fine grained, with a grain size corresponding roughly to ASTM grain size number 8 [6].

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Fatigue crack growth rate tests were conducted in ambient room air and in flowing 3.5 percent NaCl aqueous solution. Tests in air were conducted in accordance with ASTM E647-81 [7] and tests in salt water were conducted in accordance with a proposed Navy standard test method [8]. A schematic view of the test system is shown Figure 2.

Wedge-opening-loaded (WOL) specimens with planar dimensions corresponding to the 2T configuration were used. Width, (W) was 129.5 mm and thickness (B) was 6.4 mm. In each case, notches were machined in the T-L orientation, that is, parallel to the final rolling direction of the plate [9]. The test specimen is shown in Figure 3.

Replicate specimens were tested at load ratios (minimum load/maximum load) of R = 0.1 and 0.67 in both environments. The cyclic loading frequency for tests conducted in air was 5.0 Hz and for tests conducted in salt water the frequency was 0.5 Hz. For steels of the type studied in this investigation, evidence shows that crack growth rates in air are not affected by cyclic loading frequency [10]. However, for virtually all steels crack growth rates in salt water tend to increase with decreasing cyclic frequency [10,11]. Under freely corroding conditions, a salt water environment generally has little effect on crack growth rates at frequencies greater than 1 Hz. The frequency of 0.5 Hz used for the salt water tests in this investigation was chosen because it falls within the range of frequencies where environmental sensitivity is known to occur and it approximates cyclic loading rates known to occur in ship structures.

Crack length measurements were made by means of a crack-opening-displacement (COD) technique [12]. Crack length (a) versus cycles (N) data were reduced to a crack growth rate (da/dN) versus stress-intensity range (ΔK) format by means of a BASIC language computer program on a Tektronix 4051 computer per ASTM E647-81.

RESULTS AND DISCUSSION

Values of da/dN-versus-ΔK data for each specimen tested are plotted in Figures 4 and 5, and are tabulated in Appendix 1. Data generated in air are shown in Figure 4 and salt water data are shown in Figure 5. The da/dN-versus-ΔK data indicate that crack growth rates in MF-80 HSLA steel are sensitive to both load ratio and corrosion, with the greatest effects resulting from a combination of the two factors. This is illustrated by the fact that da/dN values in salt water at R = 0.67 are approximately five times greater than in air at R = 0.1. This is consistent with previous results obtained on HY-100 steel [13].

A straight line was fitted to the data from each specimen. The form of the equation used to describe these straight lines was the Paris power law [14],

$$\frac{da}{dN} = C\ (\Delta K)^n.$$

Calculated values of the constants C and n are given in Table 3 where they are compared to upper bounds found for two broad classes of steels [15].

Figure 6 shows a comparison between the air environment data for MF-80 HSLA steel and two other high-strength ship steels, HS and HY-100 [13]. For the most part, fatigue crack growth rates are faster in the HSLA steel, by factors ranging from approximately two to four. Typically, Region-II fatigue crack growth rates in steels tend to exhibit marked similarities with little variation from alloy to alloy [15]. Where significant differences do occur, most often it is in the near-threshold Region I, and there it can be modeled on the basis of yield strength and grain size considerations [3]. Based on these factors, the increased crack growth rates observed in the HSLA steel may be due to the finer microstructure which is characteristic of this material.

CONCLUSIONS

- Fatigue crack growth rates in MF-80 HSLA steel are affected by both load ratio and a salt water environment.
- The combination of a high load ratio (R = 0.67) and a salt water environment produces the fastest crack growth rates.
- Comparisons with two other high-strength ship steels, show that MF-80 HSLA steel exhibits less resistance to Region-II fatigue crack growth than HS or HY-100.

ACKNOWLEDGMENTS

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TABLE 1

Chemical Composition

Element	Weight percent
Carbon	0.07
Manganese	1.46
Phosphorus	0.009
Sulfur	0.012
Silicon	0.30
Vanadium	0.085
Columbium	0.10

TABLE 2

Mechanical Properties

Property	Values Obtained
0.2% Offset Tensile Yield Strength (MPa)	653
(ksi)	94.8
Ultimate Tensile Strength (MPa)	742
(ksi)	107.7
Hardness	R_B 90

TABLE 3

Calculated Values of Paris Power Law Constants C and n

Er onment	Steel	Load Ratio	ΔK Range $MPa\sqrt{m}$	C $\frac{m/cycle}{(MPa\sqrt{m})^n}$	n	Correlation Coefficient
Air	MF-80 HSLA	.1	14-90	5.06×10^{-11}	2.46	.981
		.67	12-43	2.42×10^{-11}	2.88	.992
	Martensitic	0 to 0.7	5-100	1.35×10^{-10}	2.25	-
	Ferritic-Pearlitic	0 to 0.7	15-60	6.91×10^{-12}	3.00	-
3.5% NaCl	MF-80 HSLA	.1	15-86	4.25×10^{-10}	2.05	.992
		.67	13-43	4.16×10^{-10}	2.25	.993

$$C\left(\frac{in./cycle}{(ksi\sqrt{in})^n}\right) = C\left(\frac{m./cycle}{(MPa\sqrt{m})^n}\right) \times \frac{39.37}{(.91)^n}$$

Figure 1 - Microstructure of MF-80 HSLA steel viewed in short transverse direction

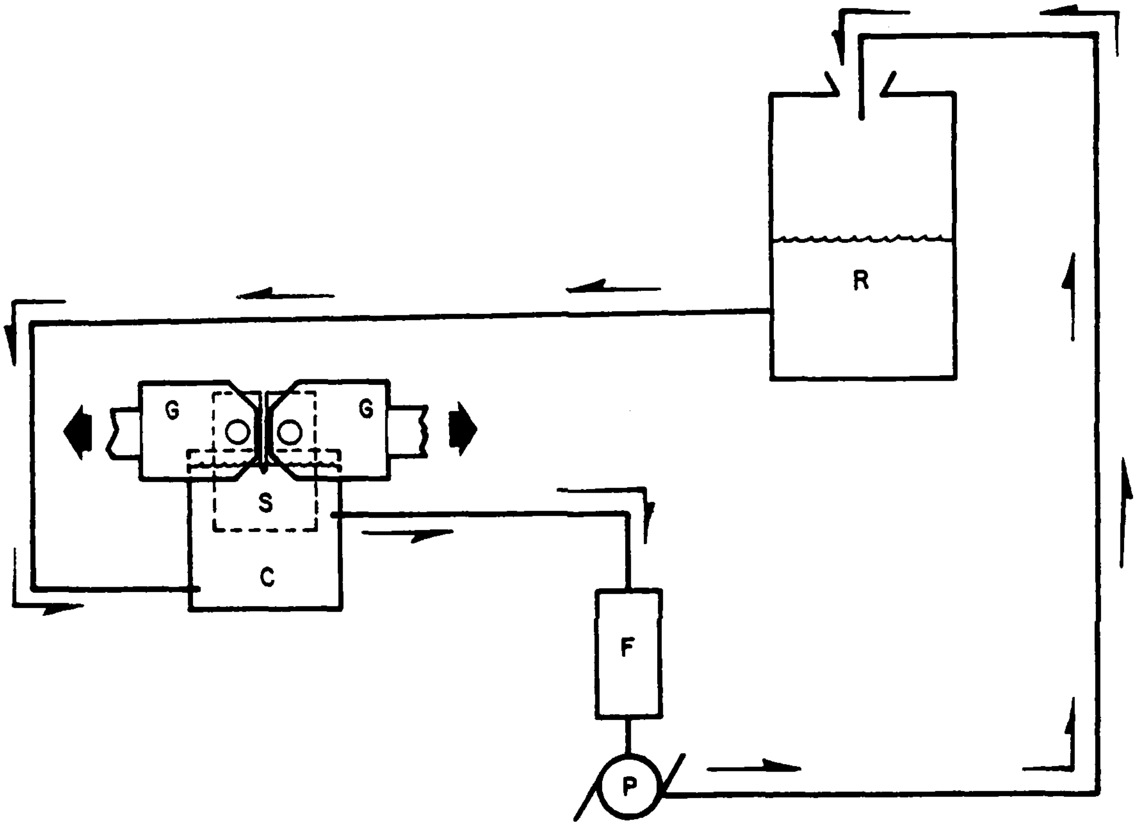
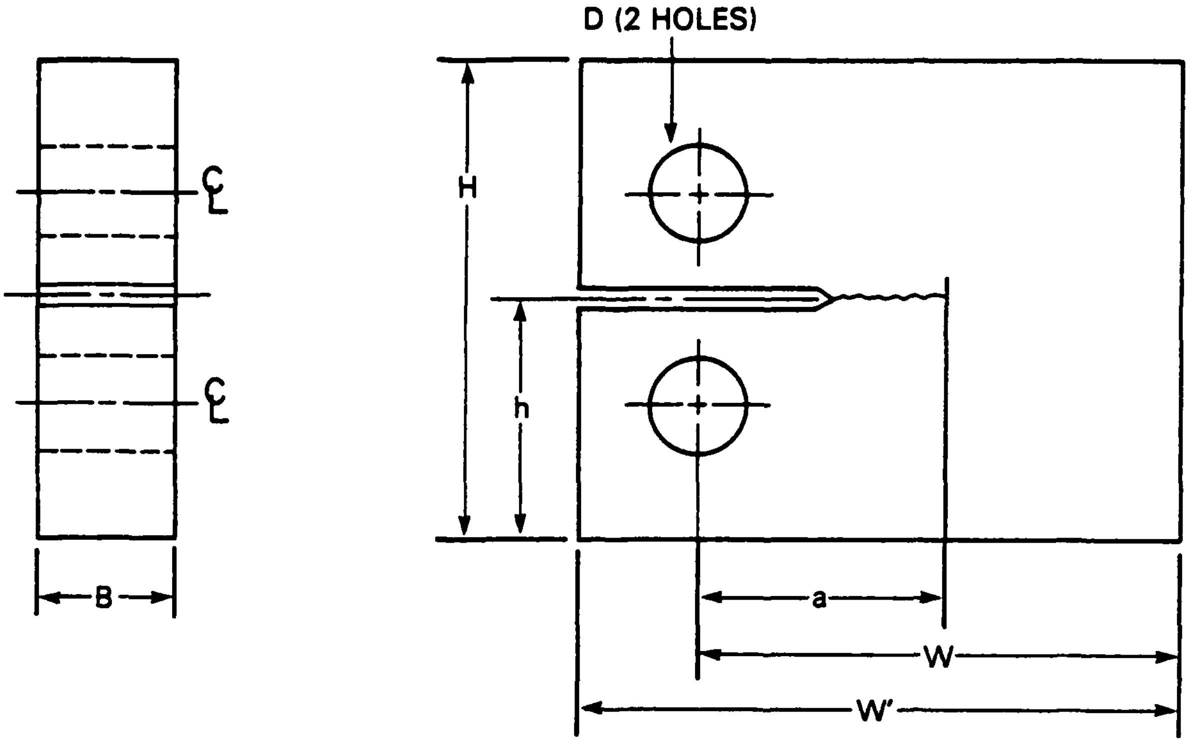


Figure 2 - Environmental circulation system showing the WOL test specimen (S), grips (G), environmental chamber (C), reservoir (R), pump (P), and filter (F).



	inches	mm.
W	5.10	129.54
W'	6.40	162.56
a	variable	variable
h	2.48	62.99
H	4.96	125.98
D	1.00	25.40
B	variable	variable

Figure 3 - 2T wedge-opening-loaded specimen

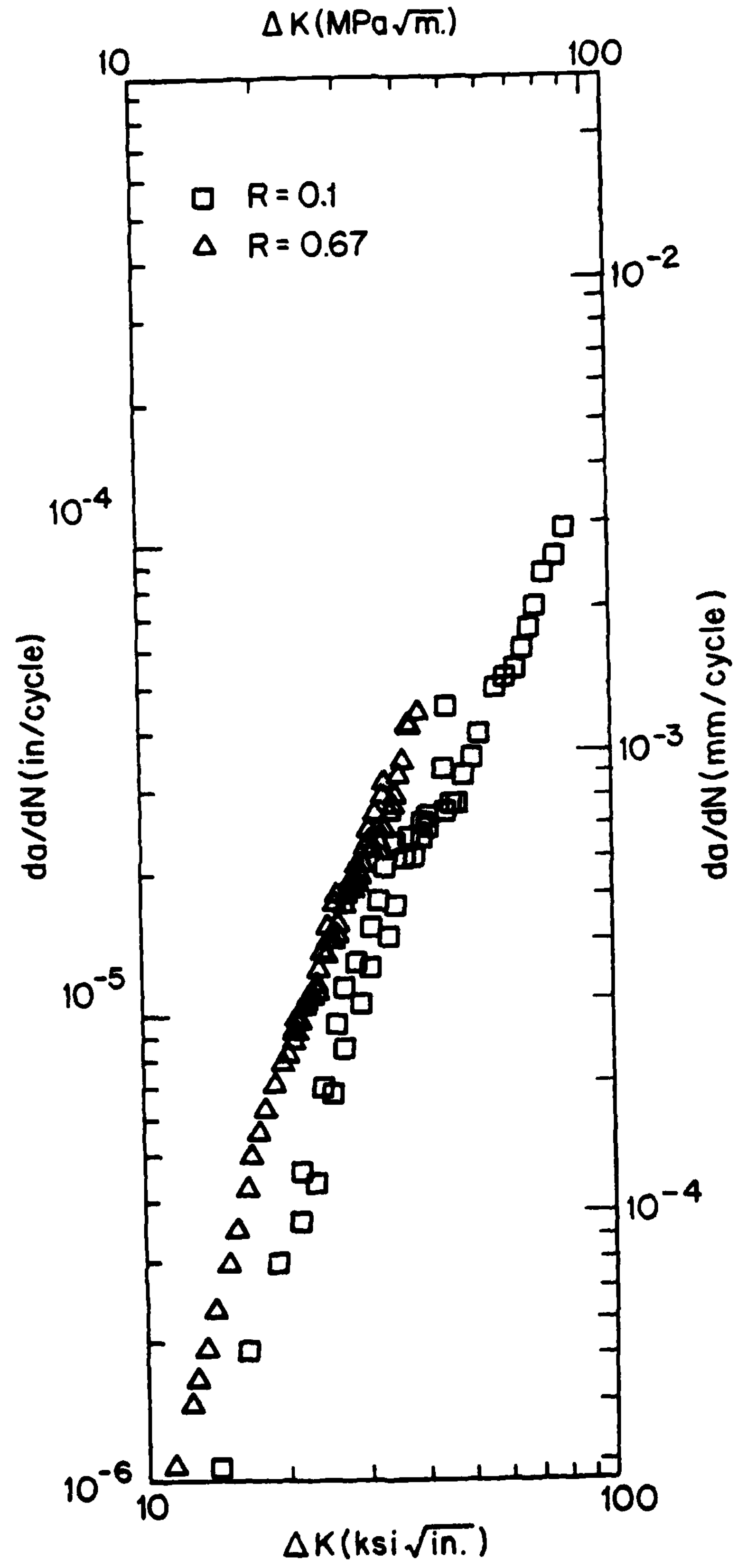


Figure 4 - Fatigue crack growth rate data for MF-80 HSLA steel in air

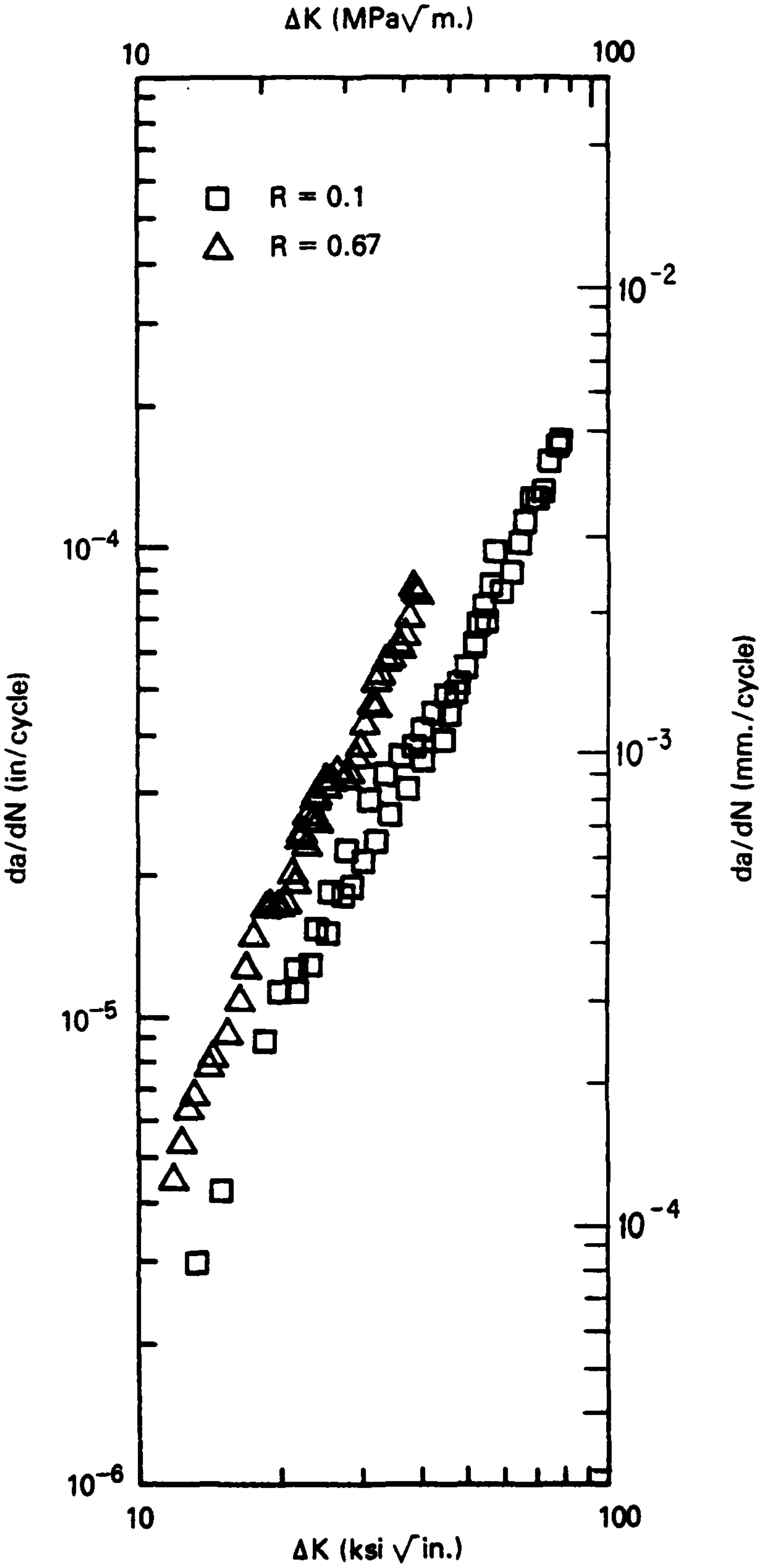


Figure 5 - Fatigue crack growth rate data for MF-80 HSLA steel in 3.5% NaCl

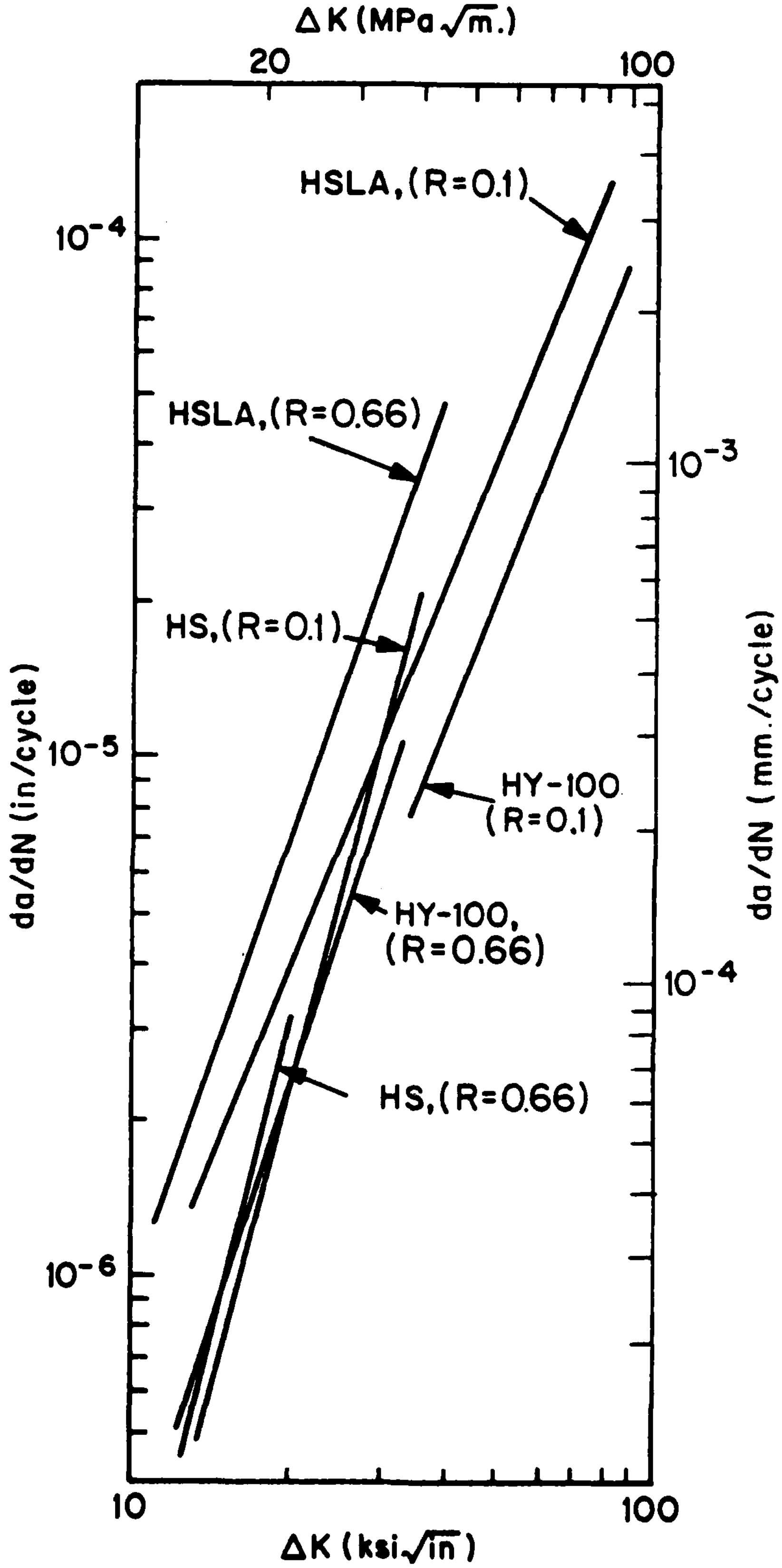


Figure 6 - Fatigue crack growth rate data for HSLA, HS and HY-100 steels in air

APPENDIX 1

Tabulated Fatigue Crack Growth Rate Data

```
HSLA-1
R= 0.1
TEMP. AMBIENT
FREQUENCY 5 HZ
ENVIRONMENT AIR

7 PT. POLYNOMIAL FIT

(1ST 3 PTS. FIT BY SECANT METHOD)

OBS.   CRACK LENGTH    CYCLES            DA/DN                      DELTA K
                                         PER CYCLE

          IN.      MM.                IN.           MM.        KSI√IN.   MPA√M.

 2      1.825    46.3     55000    3.608E-006    9.163E-005    21.07     23.15
 3      2.010    51.1     95000    4.332E-006    1.100E-004    22.80     25.04
 4      2.227    56.6    115000    6.789E-006    1.724E-004    25.06     27.52
 5      2.361    60.0    135000    8.358E-006    2.123E-004    26.67     29.28
 6      2.536    64.4    155000    1.053E-005    2.676E-004    29.07     31.92
 7      2.641    67.1    165000    1.256E-005    3.190E-004    30.74     33.75
 8      2.777    70.5    175000    1.460E-005    3.708E-004    33.22     36.47
 9      2.849    72.4    180000    1.694E-005    4.304E-004    34.70     38.10
10      2.938    74.6    185000    2.140E-005    5.436E-004    36.71     40.30
11      2.991    76.0    187500    2.157E-005    5.478E-004    38.02     41.75
12      3.049    77.4    190000    2.357E-005    5.986E-004    39.58     43.46
13      3.099    78.7    192000    2.508E-005    6.371E-004    41.02     45.04
14      3.203    81.4    196000    2.703E-005    6.864E-004    44.39     48.74
15      3.256    82.7    198000    2.807E-005    7.131E-004    46.28     50.82
16      3.281    83.3    199000    2.830E-005    7.188E-004    47.25     51.88
17      3.314    84.2    200000    3.219E-005    8.176E-004    48.54     53.29
18      3.370    85.6    202000    3.491E-005    8.868E-004    50.97     55.96
19      3.404    86.5    203000    3.935E-005    9.995E-004    52.50     57.64
20      3.492    88.7    205000    4.959E-005    1.260E-003    56.99     62.57
21      3.547    90.1    206000    5.196E-005    1.320E-003    60.08     65.97
22      3.602    91.5    207000    5.426E-005    1.378E-003    63.56     69.79
23      3.630    92.2    207500    6.017E-005    1.528E-003    65.45     71.86
24      3.658    92.9    208000    6.647E-005    1.688E-003    67.44     74.05
25      3.689    93.7    208500    7.361E-005    1.870E-003    69.74     76.58
26      3.730    94.7    209000    8.717E-005    2.214E-003    73.04     80.20
27      3.778    96.0    209500    9.362E-005    2.378E-003    77.30     84.88
28      3.826    97.2    210000    1.080E-004    2.742E-003    81.91     89.94
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HSLA-2
R= 0.666
TEMP. AMBIENT
FREQUENCY 5 HZ
ENVIRONMENT AIR

7 PT POLYNOMIAL FIT

(1ST 3 PTS. FIT BY SECANT METHOD)

OBS.	CRACK LENGTH		CYCLES	DA/DN PER CYCLE		DELTA K	
	IN.	MM.		IN.	MM.	KSI$\sqrt{IN.}$	MPA$\sqrt{M.}$
3	1.865	47.4	25000	8.815E-006	2.239E-004	21.05	23.12
4	1.955	49.7	30000	9.751E-006	2.477E-004	21.87	24.01
5	2.008	51.0	35000	1.054E-005	2.678E-004	22.37	24.56
6	2.062	52.4	40000	1.110E-005	2.819E-004	22.89	25.13
7	2.119	53.8	45000	1.170E-005	2.973E-004	23.46	25.75
8	2.180	55.4	50000	1.255E-005	3.187E-004	24.09	26.45
9	2.242	57.0	55000	1.351E-005	3.432E-004	24.78	27.21
10	2.313	58.8	60000	1.444E-005	3.668E-004	25.60	28.10
11	2.349	59.7	62500	1.493E-005	3.793E-004	26.03	28.58
12	2.380	60.4	64500	1.567E-005	3.980E-004	26.41	29.00
13	2.444	62.1	68500	1.731E-005	4.396E-004	27.25	29.92
14	2.478	62.9	70500	1.848E-005	4.693E-004	27.71	30.43
15	2.516	63.9	72500	1.905E-005	4.840E-004	28.25	31.02
16	2.547	64.7	74000	1.971E-005	5.006E-004	23.71	31.52
17	2.587	65.7	76000	2.068E-005	5.253E-004	29.31	32.18
18	2.627	66.7	78000	2.120E-005	5.385E-004	29.96	32.89
19	2.692	68.4	81000	2.253E-005	5.724E-004	31.05	34.09
20	2.714	68.9	82000	2.370E-005	6.019E-004	31.44	34.52
21	2.764	70.2	84000	2.468E-005	6.268E-004	32.35	35.53
22	2.790	70.9	85000	2.502E-005	6.356E-004	32.85	36.07
23	2.813	71.5	86000	2.539E-005	6.450E-004	33.32	36.59
24	2.840	72.1	87000	2.699E-005	6.856E-004	33.86	37.18
25	2.867	72.8	88000	2.814E-005	7.148E-004	34.44	37.82
26	2.894	73.5	89000	2.941E-005	7.470E-004	35.04	38.47
27	2.925	74.3	90000	3.227E-005	8.198E-004	35.75	39.25
28	2.958	75.1	91000	3.469E-005	8.812E-004	36.53	40.11
29	2.994	76.0	92000	4.188E-005	1.064E-003	37.40	41.07
30	3.016	76.6	92500	4.156E-005	1.056E-003	37.98	41.70
31	3.061	77.8	93500	4.435E-005	1.126E-003	39.20	43.04

HSLA-3
R= 0.1
TEMP. AMBIENT
FREQUENCY 0.5 HZ
ENVIRONMENT 3.5 % NACL

7 PT. POLYNOMIAL FIT

(1ST 3 PTS. FIT BY SECANT METHOD)

OBS.	CRACK LENGTH		CYCLES	DA/DN PER CYCLE		DELTA K	
	IN.	MM.		IN.	MM.	KSI $\sqrt{\text{IN.}}$	MPA $\sqrt{\text{M.}}$
2	1.902	48.3	20000	1.128E-005	2.864E-004	21.58	23.69
3	2.051	52.1	30000	1.281E-005	3.253E-004	22.98	25.23
4	2.252	57.2	40000	1.498E-005	3.804E-004	25.10	27.56
5	2.407	61.1	50000	1.794E-005	4.556E-004	27.00	29.64
6	2.497	63.4	55000	1.883E-005	4.783E-004	28.23	30.99
7	2.594	65.9	60000	2.136E-005	5.426E-004	29.69	32.59
8	2.700	68.6	65000	2.354E-005	5.977E-004	31.47	34.55
9	2.822	71.7	70000	2.696E-005	6.847E-004	33.80	37.11
10	2.965	75.3	75000	3.073E-005	7.806E-004	37.02	40.65
11	3.078	78.2	78700	3.518E-005	8.937E-004	40.02	43.94
12	3.207	81.4	82000	3.882E-005	9.860E-004	44.03	48.39
13	3.241	82.3	83000	4.382E-005	1.113E-003	45.29	49.73
14	3.286	83.5	84000	4.915E-005	1.248E-003	46.98	51.59
15	3.331	84.6	85000	5.538E-005	1.407E-003	48.81	53.59
16	3.391	86.1	86000	6.261E-005	1.590E-003	51.43	56.47
17	3.457	87.8	87000	6.961E-005	1.768E-003	54.60	59.96
18	3.530	89.7	88000	8.020E-005	2.037E-003	58.55	64.29
19	3.574	90.8	88500	8.818E-005	2.240E-003	61.20	67.20
20	3.619	91.9	89000	1.021E-004	2.594E-003	64.08	70.36
21	3.641	92.5	89250	1.135E-004	2.884E-003	65.58	72.00
22	3.672	93.3	89500	1.268E-004	3.219E-003	67.82	74.47
23	3.700	94.0	89700	1.270E-004	3.227E-003	69.98	76.83
24	3.725	94.6	89900	1.314E-004	3.338E-003	71.97	79.03
25	3.750	95.3	90100	1.522E-004	3.866E-003	74.08	81.34
26	3.782	96.1	90300	1.637E-004	4.158E-003	76.94	84.48
27	3.799	96.5	90400	1.688E-004	4.287E-003	78.54	86.23

```
HSLA-4
R= 0. 666
TEMP. AMBIENT
FREQUENCY 0. 5 HZ
ENVIRONMENT 3. 5 % NACL

7 PT. POLYNOMIAL FIT

(1ST 3 PTS. FIT BY SECANT METHOD)

OBS.   CRACK LENGTH    CYCLES          DA/DN                   DELTA K
                                       PER CYCLE

         IN.      MM.                 IN.           MM.         KSI√IN.  MPA√M.

  2     1. 910   48. 5    15000    2. 021E-005   5. 134E-004   21. 42    23. 52
  3     1. 985   50. 4    17000    2. 392E-005   6. 076E-004   22. 10    24. 27
  4     2. 055   52. 2    19000    2. 319E-005   5. 890E-004   22. 77    25. 00
  5     2. 150   54. 6    23000    2. 611E-005   6. 631E-004   23. 73    26. 06
  6     2. 201   55. 9    25000    2. 956E-005   7. 507E-004   24. 27    26. 65
  7     2. 262   57. 4    27000    3. 223E-005   8. 185E-004   24. 95    27. 39
  8     2. 298   58. 4    28000    3. 088E-005   7. 844E-004   25. 36    27. 85
  9     2. 330   59. 2    29000    3. 223E-005   8. 187E-004   25. 75    28. 27
 10     2. 395   60. 8    31000    3. 342E-005   8. 489E-004   26. 55    29. 16
 11     2. 459   62. 5    33000    3. 203E-005   8. 135E-004   27. 40    30. 08
 12     2. 491   63. 3    34000    3. 199E-005   8. 125E-004   27. 83    30. 56
 13     2. 523   64. 1    35000    3. 310E-005   8. 408E-004   28. 29    31. 06
 14     2. 593   65. 9    37000    3. 570E-005   9. 063E-004   29. 36    32. 23
 15     2. 625   66. 7    38000    3. 773E-005   9. 584E-004   29. 85    32. 78
 16     2. 661   67. 6    39000    4. 184E-005   1. 063E-003   30. 45    33. 44
 17     2. 707   68. 8    40000    4. 658E-005   1. 183E-003   31. 25    34. 31
 18     2. 731   69. 4    40500    4. 621E-005   1. 174E-003   31. 69    34. 79
 19     2. 753   69. 9    41000    5. 185E-005   1. 317E-003   32. 08    35. 23
 20     2. 782   70. 7    41500    5. 372E-005   1. 364E-003   32. 63    35. 83
 21     2. 839   72. 1    42500    5. 746E-005   1. 459E-003   33. 78    37. 09
 22     2. 869   72. 9    43000    5. 848E-005   1. 485E-003   34. 41    37. 78
 23     2. 928   74. 4    44000    6. 069E-005   1. 542E-003   35. 73    39. 23
 24     2. 960   75. 2    44500    6. 107E-005   1. 551E-003   36. 49    40. 07
 25     2. 987   75. 9    45000    6. 500E-005   1. 651E-003   37. 16    40. 80
 26     3. 005   76. 3    45250    7. 078E-005   1. 798E-003   37. 61    41. 30
 27     3. 037   77. 1    45700    8. 227E-005   2. 090E-003   38. 46    42. 23
 28     3. 054   77. 6    45900    8. 023E-005   2. 038E-003   38. 92    42. 74
 29     3. 070   78. 0    46100    7. 893E-005   2. 005E-003   39. 38    43. 23
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HSLA-5
R= 0.1
TEMP.  AMBIENT
FREQUENCY 5 HZ
ENVIRONMENT AIR

7 PT. POLYNOMIAL FIT

(1ST 3 PTS.  FIT BY SECANT METHOD)

OBS.   CRACK LENGTH    CYCLES              DA/DN                   DELTA K
                                           PER CYCLE

         IN.      MM.                 IN.            MM.        KSI\/IN.  MPA\/M.

 2      2.547    64.7    200000    8.760E-007    2.225E-005    12.88    14.14
 3      2.715    69.0    350000    1.074E-006    2.728E-005    14.11    15.50
 4      2.947    74.8    450000    1.919E-006    4.874E-005    16.27    17.86
 5      3.156    80.2    550000    2.947E-006    7.485E-005    18.85    20.70
 6      3.314    84.2    600000    4.602E-006    1.169E-004    21.38    23.48
 7      3.445    87.5    625000    7.007E-006    1.780E-004    24.01    26.36
 8      3.519    89.4    635000    9.536E-006    2.422E-004    25.76    28.28
 9      3.564    90.5    640000    1.137E-005    2.889E-004    26.93    29.56
10      3.620    92.0    645000    1.293E-005    3.284E-004    28.53    31.33
11      3.692    93.8    650000    1.529E-005    3.883E-004    30.81    33.83
12      3.721    94.5    652000    1.748E-005    4.441E-004    31.85    34.97
13      3.753    95.3    654000    2.051E-005    5.210E-004    33.04    36.28
14      3.796    96.4    656000    2.310E-005    5.866E-004    34.78    38.19
15      3.848    97.7    658000    2.395E-005    6.083E-004    37.08    40.71
16      3.899    99.0    660000    2.583E-005    6.561E-004    39.58    43.46
17      3.925    99.7    661000    2.649E-005    6.729E-004    40.94    44.95
18      3.980   101.1     663000    3.343E-005    8.490E-004    44.15    48.47
19      3.989   101.3     664000    4.480E-005    1.138E-003    44.74    49.12
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HSLA-6
R= 0.666
TEMP. AMBIENT
FREQUENCY 5 HZ
ENVIRONMENT AIR

7 PT. POLYNOMIAL FIT

(1ST 3 PTS. FIT BY SECANT METHOD)

OBS.	CRACK LENGTH		CYCLES	DA/DN PER CYCLE		DELTA K	
	IN.	MM.		IN.	MM.	KSI√IN.	MPA√M.
2	1.972	50.1	300000	9.118E-007	2.316E-005	11.03	12.11
3	2.072	52.6	400000	1.097E-006	2.787E-005	11.51	12.64
4	2.257	57.3	500000	1.475E-006	3.747E-005	12.49	13.72
5	2.331	59.2	550000	1.689E-006	4.290E-005	12.93	14.19
6	2.417	61.4	600000	1.952E-006	4.959E-005	13.46	14.78
7	2.514	63.8	650000	2.366E-006	6.010E-005	14.13	15.51
8	2.641	67.1	700000	2.963E-006	7.527E-005	15.11	16.59
9	2.717	69.0	725000	3.509E-006	8.912E-005	15.76	17.31
10	2.809	71.3	750000	4.305E-006	1.093E-004	16.64	18.27
11	2.851	72.4	760000	5.029E-006	1.277E-004	17.08	18.75
12	2.902	73.7	770000	5.653E-006	1.436E-004	17.62	19.35
13	2.959	75.2	780000	6.307E-006	1.602E-004	18.29	20.09
14	3.026	76.9	790000	7.144E-006	1.815E-004	19.15	21.03
15	3.082	78.3	797500	7.961E-006	2.022E-004	19.92	21.87
16	3.124	79.3	802500	8.340E-006	2.118E-004	20.53	22.54
17	3.165	80.4	807500	9.284E-006	2.358E-004	21.17	23.25
18	3.188	81.0	810000	9.840E-006	2.499E-004	21.56	23.67
19	3.240	82.3	815000	1.075E-005	2.730E-004	22.46	24.66
20	3.267	83.0	817500	1.103E-005	2.803E-004	22.95	25.20
21	3.295	83.7	820000	1.127E-005	2.863E-004	23.48	25.78
22	3.319	84.3	822000	1.263E-005	3.207E-004	23.95	26.30
23	3.342	84.9	824000	1.372E-005	3.484E-004	24.43	26.82
24	3.370	85.6	826000	1.548E-005	3.932E-004	25.02	27.47
25	3.403	86.4	828000	1.744E-005	4.430E-004	25.77	28.30
26	3.422	86.9	829000	1.809E-005	4.594E-004	26.22	28.79
27	3.462	87.9	831000	1.816E-005	4.613E-004	27.19	29.85
28	3.479	88.4	832000	1.873E-005	4.757E-004	27.62	30.33
29	3.498	88.8	833000	1.859E-005	4.722E-004	28.13	30.89
30	3.516	89.3	834000	1.918E-005	4.873E-004	28.62	31.43
31	3.534	89.8	835000	1.993E-005	5.062E-004	29.14	32.00
32	3.576	90.8	837000	2.298E-005	5.838E-004	30.39	33.37
33	3.599	91.4	838000	2.496E-005	6.339E-004	31.13	34.18
34	3.625	92.1	839000	2.713E-005	6.892E-004	31.96	35.09
35	3.654	92.8	840000	2.875E-005	7.302E-004	32.98	36.22
36	3.668	93.2	840500	3.139E-005	7.973E-004	33.48	36.76

HSLA
R= 0.1
TEMP. AMBIENT
FREQUENCY 0.5 HZ
ENVIRONMENT 3.5 % NACL

7 PT. POLYNOMIAL FIT

(1ST 3 PTS. FIT BY SECANT METHOD)

OBS.	CRACK LENGTH		CYCLES	DA/DN PER CYCLE		DELTA K	
	IN.	MM.		IN.	MM.	KSI$\sqrt{\text{IN.}}$	MPA$\sqrt{\text{M.}}$
2	2.352	59.7	395300	2.959E-006	7.517E-005	13.22	14.51
3	2.587	65.7	439100	4.222E-006	1.072E-004	14.87	16.32
4	2.956	75.1	469100	8.828E-006	2.242E-004	18.49	20.30
5	3.057	77.7	481400	1.127E-005	2.863E-004	19.82	21.76
6	3.158	80.2	490000	1.257E-005	3.193E-004	21.34	23.43
7	3.287	83.5	500000	1.532E-005	3.891E-004	23.63	25.94
8	3.365	85.5	505000	1.837E-005	4.666E-004	25.24	27.72
9	3.454	87.7	510000	2.259E-005	5.737E-004	27.35	30.03
10	3.570	90.7	515000	2.884E-005	7.325E-004	30.62	33.62
11	3.644	92.6	517500	3.277E-005	8.324E-004	33.07	36.31
12	3.713	94.3	519500	3.588E-005	9.114E-004	35.68	39.18
13	3.771	95.8	521000	3.755E-005	9.537E-004	38.14	41.88
14	3.806	96.7	522000	4.077E-005	1.036E-003	39.77	43.67
15	3.848	97.7	523000	4.426E-005	1.124E-003	41.85	45.95
16	3.894	98.9	524000	4.845E-005	1.231E-003	44.42	48.77
17	3.919	99.5	524500	4.870E-005	1.237E-003	45.88	50.37
18	3.943	100.2	525000	5.118E-005	1.300E-003	47.43	52.03
19	3.974	100.9	525575	5.561E-005	1.413E-003	49.49	54.34
20	3.997	101.5	526000	6.182E-005	1.570E-003	51.12	56.13
21	4.012	101.9	526250	6.871E-005	1.745E-003	52.25	57.38
22	4.029	102.3	526500	7 460E-005	1.895E-003	53.54	58.79
23	4.050	102.9	526750	8.314E-005	2.112E-003	55.24	60.65
24	4.069	103.3	527000	9.786E-005	2.486E-003	56.31	62.38

HSLA-8
R= 0.666
TEMP. AMBIENT
FREQUENCY 0.5 HZ
ENVIRONMENT 3.5 %NACL

7 PT. POLYNOMIAL FIT

OBS.	CRACK LENGTH		CYCLES	DA/DN PER CYCLE		DELTA K	
	IN.	MM.		IN.	MM.	KSI$\sqrt{IN.}$	MPA$\sqrt{M}$
4	2.131	54.1	155000	4.475E-006	1.137E-004	11.88	13.05
5	2.224	56.5	175000	5.364E-006	1.362E-004	12.38	13.59
6	2.305	58.6	190000	6.322E-006	1.606E-004	12.85	14.11
7	2.370	60.2	200000	6.776E-006	1.721E-004	13.24	14.54
8	2.519	64.0	220000	7.838E-006	1.991E-004	14.26	15.66
9	2.562	65.1	225000	8.177E-006	2.077E-004	14.53	16.01
10	2.689	68.3	240000	9.167E-006	2.329E-004	15.61	17.14
11	2.780	70.6	250000	1.082E-005	2.748E-004	16.46	18.07
12	2.833	72.0	255000	1.271E-005	3.230E-004	17.00	18.66
13	2.896	73.6	260000	1.490E-005	3.786E-004	17.63	19.41
14	2.974	75.5	265000	1.704E-005	4.327E-004	18.60	20.43
15	3.020	76.7	267500	1.721E-005	4.371E-004	19.19	21.07
16	3.093	78.6	271500	1.719E-005	4.366E-004	20.21	22.19
17	3.132	79.6	273500	1.751E-005	4.448E-004	20.80	22.84
18	3.182	80.8	276500	1.921E-005	4.880E-004	21.59	23.71
19	3.218	81.7	278500	2.464E-005	6.258E-004	22.20	24.38
20	3.241	82.3	279500	2.670E-005	6.782E-004	22.62	24.84
21	3.270	83.1	280500	2.680E-005	6.808E-004	23.15	25.42
22	3.302	83.9	281500	2.979E-005	7.567E-004	23.76	26.09
23	3.329	84.6	282500	3.076E-005	7.812E-004	24.32	26.71