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Fourier cosine and sine transforms using lagged convolutions in double-precision (Subprograms DLAGF0/DLAGF1)

by

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This report contains listings of FORTRAN-77 computer subprograms that utilize new double-precision algorithms for fast and accurate evaluation of the Fourier cosine and sine integrals

$$\int_0^\infty f(g)\,\cos(bg)\,dg = C(b), \tag{1}$$

and

$$\int_0^\infty f(g)\,\sin(bg)\,dg = S(b), \tag{2}$$

where b>0 is the real transform argument, and f(g) is a continuous double-precision real function defined for all real g>0. In general, f(g) may be any continuous (and possibly oscillating) function that decreases to 0 as g tends to infinity, but it can have a multiple pole at g=0 as long as the integral converges. (See the restrictions on an oscillating function in the comment sections of Appendix 2 under parameter FUN.)

New double-precision cosine and sine digital filters were designed at a sampling of 0.1 in log-space (or equivalently 23.026 samples per decade in linear space) using the following known transform pairs

$$\int_0^\infty x^2 e^{-a^2x^2}\cos(bx)\,dx = \sqrt{\pi}\left(\frac{2a^2-b^2}{8a^5}\right)e^{-(b^2/4a^2)}, \tag{3}$$

and

$$\int_0^\infty x^3 e^{-a^2x^2}\sin(bx)\,dx = \sqrt{\pi}\left(\frac{6ba^2-b^3}{16a^7}\right)e^{-(b^2/4a^2)}, \tag{4}$$

where a>0, b>0. Background material for the cosine and sine

filter designs follow exactly the discussion given in Anderson (1982, p. 348-349) for Hankel transforms, and therefore will not be repeated here. (Note that design details are not necesary for a complete understanding of the algorithm's use in applications as discussed below and in Appendices 1 and 2.) Best expected relative and (or) absolute errors with these new filters are approximately less than 10^{-10} using double-precision arithmetic on a 32-bit computer with at least 16-digits of significance.

Equation (1) is implemented by subprogram DLAGF0, and equation (2) by subprogram DLAGF1, using a lagged convolution technique similar to that described in Anderson (1982) for Hankel transforms. The main purpose or use of DLAGF0 and DLAGF1 is for fast and accurate evaluation of continuous Fourier integrals needed in applications over large argument ranges, where the discrete Fourier transform may not be suitable--particularly because the latter requires a fixed interval in linear function space over the entire argument range. The lagged convolution method implemented in DLAGF0/DLAGF1 is designed to rapidly obtain a complete set of Fourier integrals with transform arguments spaced in log-space exactly at the same sampling interval as in the digital filters (in this case, at 23.026 samples per decade or 0.1 in log-space). For argument intervals different than the digital filter's, a subsequent interpolation (for instance using cubic splines) can be performed--generally without loss of accuracy--since smooth analytical-defined functions are involved.

Because of normal usage in applications, both subprograms have been designed for separate or individual calls. The complete description of the parameters for calling DLAGF0 and (or) DLAGF1 in a user's program are given in the comment sections of the attached listings. To illustrate the usage, two simple driver programs (TDLAGF0, TDLAGF1) are also provided. Results from the drivers are listed in Appendix 1, in which some simple known Fourier integral transform pairs are tested. The complete source codes for DLAGF0, DLAGF1, TDLAGF0, and TDLAGF1 are listed in Appendix 2.

REFERENCE

Anderson, W.L., 1982, Fast Hankel transforms using related and lagged convolutions: ACM Transactions on Mathematical Software, v. 8, no. 4, p. 344-368.

Appendix 1.--Test results from drivers TDLAGF0 and TDLAGF1.

The following definitions are used in the tables below:

NB = Number of desired lagged convolutions in [BMIN,BMAX], where NB $\geq$ DINT(10.D0*DLOG(BMAX/BMIN)) + 1.

ARG(I) = b = DEXP(-.1D0*(K-1))*BMAX, K=1,2,...,NB where the index I is defined as I=NB+1-K.

a = any fixed parameter (a>0) passed in COMMON/PASS/A

ABS.ERROR = |EXACT - FILTERED|

REL.ERROR = ABS.ERROR / EXACT

EXACT = known exact cosine/sine transform (see below)

FILTERED = result from DLAGF0 or DLAGF1

NF = number of f(g) function calls using TOL=.1D-12.

The test integrals listed in the comment sections of TDLAGF0 and TDLAGF1 in Appendix 2 are summarized here in mathematical form:

TDLAGF0:

1. $\int_0^\infty e^{-a^2x^2} \cos(bx)\,dx = \frac{\sqrt{\pi}}{2a} e^{-(b^2/4a^2)}$

2. $\int_0^\infty \frac{1}{a^2+x^2} \cos(bx)\,dx = \frac{\pi}{2a} e^{-ab}$

3. $\int_0^\infty e^{-ax} \cos(bx)\,dx = a/(a^2+b^2)$

TDLAGF1:

1. $\int_0^\infty x e^{-a^2x^2} \sin(bx)\,dx = \frac{b\sqrt{\pi}}{4a^3} e^{-(b^2/4a^2)}$

2. $\int_0^\infty \frac{x}{a^2+x^2} \sin(bx)\,dx = \frac{\pi}{2} e^{-ab}$

3. $\int_0^\infty e^{-ax} \sin(bx)\,dx = b/(a^2+b^2)$.

<TDLAGF0>: TEST RESULTS FOR DLAGF0 FILTER: TOL= 0.10000000D-12 BMAX= 0.20000000D+01 NB= 15

INTEGRAL	I	ARG(I)	a	EXACT	FILTERED	ABS.ERROR	REL.ERROR	NF
1	15	0.20000D+01	0.10000D+01	0.32602467D+00	0.32602466D+00	0.56590369D-08	0.17357695D-07	372
1	14	0.18097D+01	0.10000D+01	0.39081812D+00	0.39081812D+00	0.30560608D-08	0.78196497D-08	0
1	13	0.16375D+01	0.10000D+01	0.45334481D+00	0.45334481D+00	0.76498848D-08	0.16874319D-07	0
1	12	0.14816D+01	0.10000D+01	0.51191644D+00	0.51191645D+00	0.89452232D-08	0.17473991D-07	0
1	11	0.13406D+01	0.10000D+01	0.56546255D+00	0.56546256D+00	0.82012554D-08	0.14503622D-07	0
1	10	0.12131D+01	0.10000D+01	0.61344683D+00	0.61344684D+00	0.65036228D-08	0.10601771D-07	0
1	9	0.10976D+01	0.10000D+01	0.65574948D+00	0.65574949D+00	0.45845487D-08	0.69913112D-08	0
1	8	0.99317D+00	0.10000D+01	0.69254698D+00	0.69254698D+00	0.28446540D-08	0.41075249D-08	0
1	7	0.89866D+00	0.10000D+01	0.72420646D+00	0.72420647D+00	0.14521464D-08	0.20051553D-08	0
1	6	0.81314D+00	0.10000D+01	0.75120167D+00	0.75120167D+00	0.43401729D-09	0.57776402D-09	0
1	5	0.73576D+00	0.10000D+01	0.77405100D+00	0.77405100D+00	0.25090989D-09	0.32415163D-09	0
1	4	0.66574D+00	0.10000D+01	0.79327495D+00	0.79327495D+00	0.67065062D-09	0.84542014D-09	0
1	3	0.60239D+00	0.10000D+01	0.80936913D+00	0.80936913D+00	0.89386737D-09	0.11044001D-08	0
1	2	0.54506D+00	0.10000D+01	0.82278873D+00	0.82278873D+00	0.98098274D-09	0.11922656D-08	0
1	1	0.49319D+00	0.10000D+01	0.83394127D+00	0.83394127D+00	0.97897511D-09	0.11739137D-08	0
2	15	0.20000D+01	0.50000D+00	0.11557273D+01	0.11557274D+01	0.81571649D-09	0.70580357D-09	435
2	14	0.18097D+01	0.50000D+00	0.12711125D+01	0.12711125D+01	0.11072256D-08	0.87106816D-09	0
2	13	0.16375D+01	0.50000D+00	0.13854142D+01	0.13854142D+01	0.12812918D-08	0.92484387D-09	0
2	12	0.14816D+01	0.50000D+00	0.14976716D+01	0.14976716D+01	0.13486337D-08	0.90048691D-09	0
2	11	0.13406D+01	0.50000D+00	0.16070655D+01	0.16070655D+01	0.13263742D-08	0.82533925D-09	0
2	10	0.12131D+01	0.50000D+00	0.17129195D+01	0.17129195D+01	0.12344679D-08	0.72068060D-09	0
2	9	0.10976D+01	0.50000D+00	0.18146965D+01	0.18146965D+01	0.10930613D-08	0.60233836D-09	0
2	8	0.99317D+00	0.50000D+00	0.19119900D+01	0.19119900D+01	0.92067706D-09	0.48152818D-09	0
2	7	0.89866D+00	0.50000D+00	0.20045126D+01	0.20045126D+01	0.73320255D-09	0.36577598D-09	0
2	6	0.81314D+00	0.50000D+00	0.20920830D+01	0.20920830D+01	0.54342630D-09	0.25975370D-09	0
2	5	0.73576D+00	0.50000D+00	0.21746124D+01	0.21746124D+01	0.36103404D-09	0.16602225D-09	0
2	4	0.66574D+00	0.50000D+00	0.22520903D+01	0.22520903D+01	0.19282342D-09	0.85619757D-10	0
2	3	0.60239D+00	0.50000D+00	0.23245714D+01	0.23245714D+01	0.43116233D-10	0.18548036D-10	0
2	2	0.54506D+00	0.50000D+00	0.23921633D+01	0.23921633D+01	0.85799312D-10	0.35866829D-10	0
2	1	0.49319D+00	0.50000D+00	0.24550151D+01	0.24550151D+01	0.19320251D-09	0.78697075D-10	0
3	15	0.20000D+01	0.10000D+00	0.24937656D-01	0.24937656D-01	0.15010931D-11	0.60193833D-10	345
3	14	0.18097D+01	0.10000D+00	0.30442114D-01	0.30442114D-01	0.24270039D-11	0.79725210D-10	0
3	13	0.16375D+01	0.10000D+00	0.37157038D-01	0.37157038D-01	0.38689763D-11	0.10412499D-09	0
3	12	0.14816D+01	0.10000D+00	0.45346404D-01	0.45346404D-01	0.60277651D-11	0.13292708D-09	0
3	11	0.13406D+01	0.10000D+00	0.55330672D-01	0.55330672D-01	0.93112202D-11	0.16828316D-09	0
3	10	0.12131D+01	0.10000D+00	0.67498347D-01	0.67498347D-01	0.14159495D-10	0.20977543D-09	0
3	9	0.10976D+01	0.10000D+00	0.82319646D-01	0.82319646D-01	0.21240830D-10	0.25802869D-09	0
3	8	0.99317D+00	0.10000D+00	0.10036252D+00	0.10036252D+00	0.31322013D-10	0.31208873D-09	0
3	7	0.89866D+00	0.10000D+00	0.12231128D+00	0.12231128D+00	0.45462226D-10	0.37169283D-09	0
3	6	0.81314D+00	0.10000D+00	0.14898788D+00	0.14898788D+00	0.64839661D-10	0.43520092D-09	0
3	5	0.73576D+00	0.10000D+00	0.18137591D+00	0.18137591D+00	0.90559251D-10	0.49929040D-09	0
3	4	0.66574D+00	0.10000D+00	0.22064698D+00	0.22064698D+00	0.12340319D-09	0.55927883D-09	0
3	3	0.60239D+00	0.10000D+00	0.26818868D+00	0.26818868D+00	0.16280734D-09	0.60706267D-09	0
3	2	0.54506D+00	0.10000D+00	0.32563286D+00	0.32563286D+00	0.20560488D-09	0.63140089D-09	0
3	1	0.49319D+00	0.10000D+00	0.39488193D+00	0.39488193D+00	0.24363559D-09	0.61698338D-09	0

<TDLAGF1>: TEST RESULTS FOR DLAGF1 FILTER: TOL= 0.10000000D-12 BMAX= 0.20000000D+01 NB= 15

INTEGRAL	I	ARG(I)	a	EXACT	FILTERED	ABS.ERROR	REL.ERROR	NF
1	15	0.20000D+01	0.10000D+01	0.32602467D+00	0.32602468D+00	0.17724046D-07	0.54364125D-07	161
1	14	0.18097D+01	0.10000D+01	0.35362686U+00	0.35362689D+00	0.25722218D-07	0.72738303D-07	0
1	13	0.16375D+01	0.10000D+01	0.37116733D+00	0.37116736D+00	0.24080842D-07	0.64878666D-07	0
1	12	0.14816D+01	0.10000D+01	0.37923702D+00	0.37923704D+00	0.17902826D-07	0.47207483D-07	0
1	11	0.13406D+01	0.10000D+01	0.37904089D+00	0.37904090D+00	0.10858736D-07	0.28647929D-07	0
1	10	0.12131D+01	0.10000D+01	0.37207431D+00	0.37207432D+00	0.48890715D-08	0.13140040D-07	0
1	9	0.10976D+01	0.10000D+01	0.35988295D+00	0.35988295D+00	0.64377886D-09	0.17888563D-08	0
1	8	0.99317D+00	0.10000D+01	0.34390865D+00	0.34390865D+00	0.19386228D-08	0.56370282D-08	0
1	7	0.89866D+00	0.10000D+01	0.32540694D+00	0.32540694D+00	0.32222493D-08	0.99022143D-08	0
1	6	0.81314D+00	0.10000D+01	0.30541581D+00	0.30541580D+00	0.36157307D-08	0.11838715D-07	0
1	5	0.73576D+00	0.10000D+01	0.28475745D+00	0.28475744D+00	0.34736952D-08	0.12198786D-07	0
1	4	0.66574D+00	0.10000D+01	0.26405829D+00	0.26405829D+00	0.30515081D-08	0.11556191D-07	0
1	3	0.60239D+00	0.10000D+01	0.24377730D+00	0.24377729D+00	0.25228921D-08	0.10349168D-07	0
1	2	0.54506D+00	0.10000D+01	0.22423609D+00	0.22423609D+00	0.19871135D-08	0.88617024D-08	0
1	1	0.49319D+00	0.10000D+01	0.20564738D+00	0.20564738D+00	0.15011039D-08	0.72994065D-08	0
2	15	0.20000D+01	0.50000D+00	0.57786367D+00	0.57786368D+00	0.35188781D-09	0.60894606D-09	243
2	14	0.18097D+01	0.50000D+00	0.63555623D+00	0.63555623D+00	0.54538782D-09	0.85812678D-09	0
2	13	0.16375D+01	0.50000D+00	0.69270708D+00	0.69270708D+00	0.67312088D-09	0.97172513D-09	0
2	12	0.14816D+01	0.50000D+00	0.74883582D+00	0.74883582D+00	0.73837682D-09	0.98603298D-09	0
2	11	0.13406D+01	0.50000D+00	0.80353275D+00	0.80353275D+00	0.74907956D-09	0.93223278D-09	0
2	10	0.12131D+01	0.50000D+00	0.85645975D+00	0.85645975D+00	0.71566772D-09	0.83561162D-09	0
2	9	0.10976D+01	0.50000D+00	0.90734826D+00	0.90734826D+00	0.64932669D-09	0.71563116D-09	0
2	8	0.99317D+00	0.50000D+00	0.95599500D+00	0.95599500D+00	0.56085424D-09	0.58667068D-09	0
2	7	0.89866D+00	0.50000D+00	0.10022563D+01	0.10022563D+01	0.45981222D-09	0.45877709D-09	0
2	6	0.813140+00	0.50000D+00	0.10460415D+01	0.10460415D+01	0.35415051D-09	0.33856258D-09	0
2	5	0.73576D+00	0.50000D+00	0.10873062D+01	0.10873062D+01	0.25009578D-09	0.23001412D-09	0
2	4	0.66574D+00	0.50000D+00	0.11260451D+01	0.11260451D+01	0.15219656D-09	0.13516027D-09	0
2	3	0.60239D+00	0.50000D+00	0.11622857D+01	0.11622857D+01	0.63530348D-10	0.54659838D-10	0
2	2	0.54506D+00	0.50000D+00	0.11960816D+01	0.11960816D+01	0.14116763D-10	0.11802508D-10	0
2	1	0.49319D+00	0.50000D+00	0.12275076D+01	0.12275076D+01	0.79897783D-10	0.65089442D-10	0
3	15	0.20000D+01	0.10000D+00	0.49875312D+00	0.49875312D+00	0.41299117D-11	0.82804729D-11	240
3	14	0.18097D+01	0.10000D+00	0.55090327D+00	0.55090327D+00	0.53408944D-11	0.96947952D-11	0
3	13	0.16375D+01	0.10000D+00	0.60843219D+00	0.60843219D+00	0.69305534D-11	0.11390839D-10	0
3	12	0.14816D+01	0.10000D+00	0.67186884D+00	0.67186884D+00	0.87986840D-11	0.13095836D-10	0
3	11	0.13406D+01	0.10000D+00	0.74178517D+00	0.74178517D+00	0.11077042D-10	0.14932952D-10	0
3	10	0.121310+01	0.10000D+00	0.81879634D+00	0.81879634D+00	0.13564663D-10	0.16566590D-10	0
3	9	0.10976D+01	0.10000D+00	0.90355959D+00	0.90355959D+00	0.16181195D-10	0.17908277D-10	0
3	8	0.99317D+00	0.10000D+00	0.99677109D+00	0.99677109D+00	0.18386404D-10	0.18445964D-10	0
3	7	0.89866D+00	0.10000D+00	0.10991600D+01	0.10991600D+01	0.19331980D-10	0.17587958D-10	0
3	6	0.81314D+00	0.10000D+00	0.12114790D+01	0.12114790D+01	0.17601420D-10	0.14528869D-10	0
3	5	0.73576D+00	0.10000D+00	0.13344894D+01	0.13344894D+01	0.10555445D-10	0.79097261D-11	0
3	4	0.66574D+00	0.10000D+00	0.14689400D+01	0.14689400D+01	0.57439609D-11	0.39102760D-11	0
3	3	0.60239D+00	0.10000D+00	0.16155376D+01	0.16155376D+01	0.37427006D-10	0.23166905D-10	0
3	2	0.54506D+00	0.10000D+00	0.17749062D+01	0.17749062D+01	0.93440894D-10	0.52645541D-10	0
3	1	0.49319D+00	0.10000D+00	0.19475337D+01	0.19475337D+01	0.18556806D-09	0.95283619D-10	0

Appendix 2.--Source Listing

The attached subprograms are listed in the following order:


```
      SUBROUTINE DLAGF0(BMAX,NB,TOL,NTOL,FUN,                          00000010
     * DANS,ARG,NOFUN,IERR)                                            00000020
C=====================================================================00000030
      INTEGER NB,NTOL,NOFUN,IERR                                       00000040
      DOUBLE PRECISION BMAX,TOL,DANS(NB),ARG(NB)                       00000050
C=====================================================================00000060
C                                                                      00000070
C  PURPOSE                                                             00000080
C                                                                      00000090
C     THE PURPOSE OF SUBPROGRAM DLAGF0 IS TO PROVIDE IN DOUBLE PRECISION00000100
C    A GENERAL ALGORITHM FOR FAST FOURIER COSINE TRANSFORMS OF THE FORM:00000110
C    INTEGRAL FROM 0 TO INFINITY OF FUN(G)*DCOS(B*G)*DG, WHERE WE LAG B 00000120
C    IN [BMIN,BMAX]--USING IMPLIED VALUE OF BMIN=BMAX*DEXP(-.1*(NB-1)). 00000130
C                                                                      00000140
C     DLAGF0 USES A NEW DOUBLE-PRECISION COSINE DIGITAL FILTER FOR USE  00000150
C    IN LAGGED CONVOLUTION, WHERE THE ALGORITHM IS PATTERNED AFTER THE  00000160
C    DOUBLE-PRECISION HANKEL TRANSFORM ROUTINE DHANKL PUBLISHED IN THE  00000170
C    FOLLOWING REFERENCE:                                              00000180
C                                                                      00000190
C  ANDERSON, W.L., 1982, FAST HANKEL TRANSFORMS USING RELATED AND LAGGED00000200
C    CONVOLUTIONS: ACM TRANS. ON MATH. SOFTWARE, V.8, N.4, P.344-368.  00000210
C                                                                      00000220
C   DLAGF0 USES THE LAGGED CONVOLUTION METHOD IN THE ABOVE REFERENCE,   00000230
C  BUT USES INTERNAL WORK ARRAYS DWORK(787) AND KEY(787)--INSTEAD OF    00000240
C  PASSING DWORK IN THE CALLING SEQUENCE AS IN DHANKL.  THE MINIMUM     00000250
C  RELATIVE AND/OR ABSOLUTE ERRORS ARE ABOUT 10**-10 USING TOL<=10**-12.00000260
C  (SEE DESCRIPTION OF ALL PARAMETERS BELOW.)                          00000270
C=====================================================================00000280
C                                                                      00000290
C  AUTHOR                                                              00000300
C                                                                      00000310
C    ANDERSON, W.L., U.S. GEOLOGICAL SURVEY, DENVER, COLORADO.         00000320
C                                                                      00000330
C  MACHINE DEPENDENT REMARKS                                           00000340
C                                                                      00000350
```

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C       THIS SUBPROGRAM WAS IMPLEMENTED AND TESTED ON A 64-BIT DOUBLE-   00000360
C     WORD MACHINE WITH EXP-RANGE APPROXIMATELY 10**-38 TO 10**+38 AND   00000370
C     56-BIT MANTISSA (ABOUT 16-DECIMAL DIGITS).  ONLY DOUBLE-PRECISION  00000380
C     AND INTEGER OPERATIONS ARE USED.                                   00000390
C     FOR MACHINES WITH OTHER DOUBLE-WORD SIZES, CHANGES IN THE NUMBER OF00000400
C     DIGITS RETAINED IN SOME DATA STATEMENTS MAY BE REQUIRED.           00000410
C                                                                        00000420
C  DESCRIPTION OF PARAMETERS                                             00000430
C                                                                        00000440
C     INPUT                                                              00000450
C                                                                        00000460
C       BMAX - INITIAL COSINE TRANSFORM ARGUMENT B=BMAX>0.D0, AS         00000470
C              USED IN INTEGRAL FROM 0 TO INFINITY OF                    00000480
C              FUN(G)*DCOS(G*B)*DG, WHERE FUN(G) IS DEFINED BELOW.       00000490
C         NB - NUMBER OF LAGGED CONVOLUTIONS DESIRED (NB.GE.1).  USE     00000500
C              NB=1 IF B=BMIN=BMAX (I.E.,NO LAGGING DESIRED).  USE       00000510
C              NB>1 IF B IS LAGGED IN (BMIN,BMAX), WHERE                 00000520
C              BMIN=BMAX*DEXP(-.1D0*(NB-1)) DOES NOT UNDERFLOW THE DEXP  00000530
C              RANGE.  THE B-LAGGED SPACING IS .1D0 IN LOG-SPACE. FOR    00000540
C              CONVENIENCE IN SPLINE INTERPOLATION LATER, EACH B IN      00000550
C              (BMIN,BMAX) IS RETURNED IN ARRAY ARG(I),I=1,NB, WHERE     00000560
C              ARG(I+1)/ARG(I)=DEXP(.1D0) FOR ALL I.  IF BMAX>BMIN>0 IS  00000570
C              GIVEN, THEN AN EFFECTIVE VALUE OF NB IS DETERMINED AS     00000580
C              NB=DINT(10.*DLOG(BMAX/BMIN))+I, WHERE I>1 IS RECOMMENDED, 00000590
C              PARTICULARLY IF USING SUBSEQUENT SPLINE INTERPOLATION FOR  00000600
C              A DIFFERENT B-SPACING THAN USED IN THE DIGITAL FILTER. IF  00000610
C              SPLINE INTERPOLATION IS TO BE USED LATER, IT IS GENERALLY  00000620
C              BEST TO USE DLOG(ARG(I)) INSTEAD OF ARG(I) -VS- DANS(I),   00000630
C              FOR I=1,NB.                                               00000640
C        TOL - REQUESTED TRUNCATION TOLERANCE AT BOTH FILTER TAILS        00000650
C              FOR ADAPTIVE CONVOLUTION FOR ALL NB TRANSFORMS.  THE      00000660
C              TRUNCATION CRITERION IS ESTABLISHED DURING CONVOLUTION IN  00000670
C              A FIXED ABSCISSA RANGE (USING WEIGHTS 426-461) OF THE     00000680
C              COSINE FILTER AS THE MAXIMUM ABSOLUTE CONVOLVED PRODUCT   00000690
C              TIMES TOL.  THE CONVOLUTION SUMMATION IS TERMINATED       00000700
C              ON EITHER SIDE OF THE FIXED RANGE WHENEVER THE ABSOLUTE   00000710
C              PRODUCT .LE. THE TRUNCATION CRITERION.  IN GENERAL, A     00000720
C              DECREASING TOLERANCE WILL PRODUCE HIGHER ACCURACY SINCE   00000730
C              MORE FILTER WEIGHTS ARE USED (UNLESS EXPONENT UNDERFLOW   00000740
C              OCCURS IN THE TRANSFORM INPUT FUNCTION EVALUATION).       00000750
C              ONE MAY SET TOL=0.D0 TO OBTAIN MAXIMUM ACCURACY FOR ALL   00000760
C              NB DOUBLE-PRECISION COSINE TRANSFORMS IN DANS(NB).        00000770
C              HOWEVER, THE ACTUAL RELATIVE ERRORS CANNOT BE EXPECTED TO 00000780
C              BE SMALLER THAN ABOUT .1D-12 REGARDLESS OF THE TOLERANCE  00000790
C              VALUE USED, SINCE DOUBLE-PRECISION FILTER WEIGHTS AND A   00000800
C              DOUBLE-PRECISION FUNCTION ARE USED. IN ANY EVENT,         00000810
C              ONE SHOULD ALWAYS CHOOSE TOL<<DESIRED RELATIVE ERROR.     00000820
C           ** ACCURACY WARNING **  SOME HIGHLY OSCILLATORY FUNCTIONS    00000830
C              FUN(G) AND (OR) LIMITING CASES OF B NEAR MACHINE-ZERO     00000840
C              (OR INFINITY) SHOULD BE AVOIDED, OTHERWISE UNSATISFACTORY 00000850
C              RESULTS (E.G., RELATIVE & ABSOLUTE ERRORS>>TOL) MAY OCCUR.00000860
C       NTOL - NUMBER OF CONSECUTIVE TIMES THE TRUNCATION CRITERION (TOL)00000870
C              IS TO BE MET AT EITHER FILTER TAIL BEFORE FILTER           00000880
C              TRUNCATION OCCURS.  NTOL=1 SHOULD BE USED FOR INPUT       00000890
C              FUNCTIONS THAT DO NOT HAVE MANY ZEROS IN (0,INFINITY). FOR00000900
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C             OSCILLATORY FUNCTIONS WITH MANY ZEROS, NTOL>1 MAY BE USED 00000910
C             TO INSURE A PREMATURE CUTOFF DOES NOT OCCUR FOR TRUNCATION00000920
C             (SEE USE OF ITOL,NTOL,TOL IN THE CODE BELOW).             00000930
C      FUN  - NAME OF AN EXTERNAL DOUBLE PRECISION FUNCTION OF A REAL   00000940
C             ARGUMENT DEFINING THE GIVEN TRANSFORM INPUT FUNCTION. AN  00000950
C             EXTERNAL STATEMENT MUST APPEAR IN THE CALLING PROGRAM. THE00000960
C             DOUBLE PRECISION FUNCTION FUN(G) MUST BE CODED BY THE     00000970
C             USER AND MUST BE A CONTINUOUS REAL FUNCTION DEFINED FOR   00000980
C             ALL REAL G>0.0D0, WHERE FUN(G) GOES TO 0 AS G GOES TO     00000990
C             INFINITY IN THE LIMIT.  THE VALUE OF G MUST BE UNCHANGED  00001000
C             UPON RETURN FROM FUN. A MULTIPLE-POLE OF FUN(G) AT G=0.0D000001010
C             CAN EXIST, PROVIDED THE COSINE TRANSFORM CONVERGES (NOTE  00001020
C             FUN(0D0) IS NOT USED).  GENERALLY, FUN(G)                 00001030
C             IS DEFINED ANALYTICALLY FOR ALL G>0.D0.  HOWEVER,         00001040
C             DISCRETELY DEFINED FUNCTIONS MAY BE USED IF FUN(G)        00001050
C             RETURNS A SMOOTH INTERPOLATION VALUE (E.G., VIA CUBIC     00001060
C             SPLINES) WHICH SATISFIES THE CONTINUITY CONDITION FOR ALL 00001070
C             G>0, AND PROVIDED THE PROPER LIMITING VALUE OF FUN(G) IS  00001080
C             GIVEN AS G TENDS TO INFINITY.  PARAMETERS OTHER           00001090
C             THAN G NEEDED IN FUN(G) MAY BE INCLUDED BY USING LABELED  00001100
C             COMMON IN FUN AND IN THE USERS CALLING PROGRAM.  IF       00001110
C             FUN(G) IS AN OSCILLATING FUNCTION, THEN THE HIGHEST       00001120
C             FREQUENCY COMPONENT (IN LOG-SPACE) SHOULD NOT EXCEED THE  00001130
C             FILTER NYQUIST FREQUENCY, 1/(2*0.1D0).  IN GENERAL,       00001140
C             SUBPROGRAM DLAGF0 PERFORMS BEST WHEN USING SMOOTH, WELL-  00001150
C             BEHAVED FUNCTIONS FUN(G), THAT ARE CHARACTERIZED AS       00001160
C             MONOTONICALLY DECREASING FUNCTIONS WITH LIMIT 0 AS G      00001170
C             GOES TO INFINITY. (SEE THE ACCURACY WARNING UNDER TOL,    00001180
C             AND ERROR CONDITION (3).)                                 00001190
C                                                                       00001200
C  OUTPUT                                                               00001210
C                                                                       00001220
C      DANS - THE ARRAY DANS(NB) IS RETURNED GIVING THE NB DOUBLE-      00001230
C             PRECISION REAL COSINE TRANSFORMS, WITH CORRESPONDING      00001240
C             B ARGUMENTS GIVEN IN ARRAY ARG(NB).                       00001250
C       ARG - THE ARRAY ARG(NB) IS RETURNED GIVING THE RESULTING        00001260
C             B ARGUMENTS IN (BMIN,BMAX), WHERE ARG(I+1)/ARG(I)=EXP(.1),00001270
C             I=1,NB-1 (THIS ARRAY COULD BE ELIMINATED TO SAVE STORAGE  00001280
C             AND REGENERATED AFTER THE CALL DLAGF0, IF DESIRED).       00001290
C    NOFUN  - NUMBER OF DIRECT FUN EVALUATIONS USED FOR ALL NB          00001300
C             REAL COSINE TRANSFORMS.  NOFUN IS USUALLY NOT MORE        00001310
C             THAN THE NUMBER OF WEIGHTS NEEDED FOR A SINGLE DIRECT     00001320
C             CONVOLUTION FOR ANY NB. USUALLY, NOFUN<<787 FOR ANY NB.   00001330
C      IERR - ERROR RETURN CODE.  THE FOLLOWING CODES ARE POSSIBLE --   00001340
C             = 0, NO ERROR IN INPUT PARAMETERS. DANS,ARG COMPUTED.     00001350
C             = 1, IMPROPER INPUT PARAMETERS (I.E., NB<1,BMAX<=0, OR    00001360
C             BMAX*DEXP(-.1D0*(NB-1))<=0.D0).  DANS,ARG NOT COMPUTED.   00001370
C                                                                       00001380
C                                                                       00001390
C  ERROR CONDITIONS                                                     00001400
C                                                                       00001410
C    (1)  IMPROPER INPUT PARAMETERS GIVEN (SEE IERR=1 ABOVE).           00001420
C    (2)  UNDERFLOW CONDITIONS ARE POSSIBLE DURING CONVOLUTION, DUE TO  00001430
C         THE BEHAVIOR OF FUN, VALUE OF B IN (BMIN,BMAX), TOL, AND      00001440
C         NTOL.  EXPONENT AND (OR) ARITHMETIC UNDERFLOW TRAPS MUST RETURN00001450
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C          A VALUE OF 0.D0 FOR THE COMPUTER SYSTEM BEING USED.  NOTE THAT00001460
C          UNDERFLOW MAY ALSO OCCUR IN THE USERS EXTERNAL FUNCTION       00001470
C          FUN(G) FOR ANY VALUE OF G AS SET BY SUBPROGRAM DLAGF0.        00001480
C     (3)  UNDETECTED ERRORS ARE POSSIBLE IF FUN IS IMPROPERLY CODED, OR 00001490
C          DOES NOT YIELD DOUBLE-PRECISION ACCURACY, OR IS NOT           00001500
C          A CONTINUOUS DECREASING REAL FUNCTION FOR ALL G>0.D0.         00001510
C       .                                                                00001520
C  USAGE                                                                 00001530
C                                                                        00001540
C    SUBPROGRAM DLAGF0 IS CALLED AS FOLLOWS (USE NUMERICAL VALUES FOR    00001550
C    <EXPRESSION>, EXCLUDING < AND >, IN DECLARATIONS) --                00001560
C                                                                        00001570
C      DOUBLE PRECISION BMAX,TOL,DANS(<NB>),ARG(<NB>)                    00001580
C      EXTERNAL DFUN                                                     00001590
CC-----READ/LOAD INPUT PARAMETERS FOR DLAGF0 AS REQUIRED                 00001600
C      ...                                                               00001610
C      CALL DLAGF0(BMAX,NB,TOL,NTOL,DFUN,                                00001620
C     * DANS,ARG,NOFUN,IERR)                                            00001630
C      IF(IERR.EQ.1) STOP                                                00001640
C      ...                                                               00001650
C      END                                                               00001660
C      DOUBLE PRECISION FUNCTION DFUN(G)                                 00001670
C      DOUBLE PRECISION G                                                00001680
CC-----INSERT USER SUPPLIED CODE FOR EVALUATION OF DFUN(G),G>0.0D0       00001690
C      END                                                               00001700
C                                                                        00001710
C========================================================================00001720
      DOUBLE PRECISION ABSCIS,C,CMAX,DSUM,E,ER,FUN,G,Y,Y1,WT,DWORK       00001730
      DIMENSION KEY(787),WT(787),DWORK(787)                              00001740
C-----WE DEFINE C,CMAX FOR USE IN THE TRUNCATION CRITERION TESTS,        00001750
C     WHERE C IS ANY CONVOLUTION PRODUCT AND CMAX IS THE MAXIMUM         00001760
C     CONVOLVED PRODUCT IN THE FIXED ABSCISSA RANGE (SEE PARAMETER TOL).00001770
C-----ABSCIS=BASE CONSTANT FOR FILTER ABSCISSA GENERATION                00001780
      DATA ABSCIS/0.7866057737580476D0/                                  00001790
C-----E=DEXP(.1D0), ER=1.0D0/E (ALSO USED IN ABSCISSA GENERATION)        00001800
      DATA E/1.10517091807564762 D0/,ER/.904837418035959573 D0/          00001810
C////// DCOS FILTER WEIGHTS ///////                                     00001820
      DATA                                                               00001830
     *WT(  1)/ 7.214369775966785D-20/,WT(  2)/ 5.997984537445829D-20/,   00001840
     *WT(  3)/ 1.383536819510307D-20/,WT(  4)/ 6.127201193993877D-20/,   00001850
     *WT(  5)/ 2.735622069700930D-20/,WT(  6)/ 6.567948836420383D-20/,   00001860
     *WT(  7)/ 4.144963335850363D-20/,WT(  8)/ 7.316414067200350D-20/,   00001870
     *WT(  9)/ 5.682375914662966D-20/,WT( 10)/ 8.391977074915078D-20/,   00001880
     *WT( 11)/ 7.418756524583309D-20/,WT( 12)/ 9.829637687190485D-20/,   00001890
     *WT( 13)/ 9.430643800653847D-20/,WT( 14)/ 1.168146262188112D-19/,   00001900
     *WT( 15)/ 1.180370735968097D-19/,WT( 16)/ 1.401723019040171D-19/,   00001910
     *WT( 17)/ 1.463726071463266D-19/,WT( 18)/ 1.692722072070252D-19/,   00001920
     *WT( 19)/ 1.804796158499069D-19/,WT( 20)/ 2.052560499147526D-19/,   00001930
     *WT( 21)/ 2.217507732438609D-19/,WT( 22)/ 2.495469564846162D-19/,   00001940
     *WT( 23)/ 2.718603842873614D-19/,WT( 24)/ 3.039069705922034D-19/,   00001950
     *WT( 25)/ 3.328334008394297D-19/,WT( 26)/ 3.705052796297763D-19/,   00001960
     *WT( 27)/ 4.071277819975917D-19/,WT( 28)/ 4.520053409594589D-19/,   00001970
     *WT( 29)/ 4.977334107366132D-19/,WT( 30)/ 5.516707191291291D-19/,   00001980
     *WT( 31)/ 6.082931168675559D-19/,WT( 32)/ 6.734956703766505D-19/,   00001990
     *WT( 33)/ 7.432489554623685D-19/,WT( 34)/ 8.223651399147256D-19/,   00002000
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     *WT( 45)/ 2.469158736824458D-18/,WT( 46)/ 2.729043278909879D-18/,  00002070
     *WT( 47)/ 3.015882778812807D-18/,WT( 48)/ 3.333221019045560D-18/,  00002080
     *WT( 49)/ 3.683642665131121D-18/,WT( 50)/ 4.071174485366807D-18/,  00002090
     *WT( 51)/ 4.499238428427072D-18/,WT( 52)/ 4.972519918024098D-18/,  00002100
     *WT( 53)/ 5.495403162992602D-18/,WT( 54)/ 6.073431145514256D-18/,  00002110
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     *WT( 57)/ 8.198210388921290D-18/,WT( 58)/ 9.060466264497684D-18/,  00002130
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     *WT( 63)/ 1.493814249254853D-17/,WT( 64)/ 1.650922025025269D-17/,  00002160
     *WT( 65)/ 1.824549287949245D-17/,WT( 66)/ 2.016440324953847D-17/,  00002170
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     *WT( 69)/ 2.721908372832262D-17/,WT( 70)/ 3.008174877960754D-17/,  00002190
     *WT( 71)/ 3.324546598231868D-17/,WT( 72)/ 3.674192913569353D-17/,  00002200
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     *WT( 75)/ 4.959641037849226D-17/,WT( 76)/ 5.481251456381401D-17/   00002220
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     *WT(149)/ 8.113895860149252D-14/,WT(150)/ 8.967241736929777D-14/,  00002610
     *WT(151)/ 9.910334783010448D-14/,WT(152)/ 1.095261379057530D-13/   00002620
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     *WT(613)/-9.924966395649082D-11/,WT(614)/ 8.721036155589632D-11/,  00005060
     *WT(615)/-7.663146513121262D-11/,WT(616)/ 6.733582275589511D-11/,  00005070
     *WT(617)/-5.916777159927192D-11/,WT(618)/ 5.199053123157253D-11/,  00005080
     *WT(619)/-4.568391312831626D-11/,WT(620)/ 4.014230801823632D-11/,  00005090
     *WT(621)/-3.527291737272422D-11/,WT(622)/ 3.099419942203976D-11/,  00005100
     *WT(623)/-2.723450367478780D-11/,WT(624)/ 2.393087107406673D-11/,  00005110
     *WT(625)/-2.102797969829416D-11/,WT(626)/ 1.847721835214320D-11/,  00005120
     *WT(627)/-1.623587253411553D-11/,WT(628)/ 1.426640914879302D-11/,  00005130
     *WT(629)/-1.253584798559500D-11/,WT(630)/ 1.101520943914518D-11/,  00005140
     *WT(631)/-9.679029223044069D-12/,WT(632)/ 8.504931950483330D-12/,  00005150
     *WT(633)/-7.473256440847272D-12/,WT(634)/ 6.566726477759826D-12/,  00005160
     *WT(635)/-5.770161505244737D-12/,WT(636)/ 5.070222417415932D-12/,  00005170
     *WT(637)/-4.455188184705872D-12/,WT(638)/ 3.914759576021876D-12/,  00005180
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     *WT(643)/-2.050691376558676D-12/,WT(644)/ 1.801935938738539D-12/,  00005210
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     *WT(647)/-1.222521408656179D-12/,WT(648)/ 1.074225642782795D-12/,  00005240
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     *WT(651)/-7.288071777679118D-13/,WT(652)/ 6.404005307872462D-13/,  00005260
     *WT(653)/-5.627178934884672D-13/,WT(654)/ 4.944584091193514D-13/,  00005270
     *WT(655)/-4.344790190215893D-13/,WT(656)/ 3.817753212167385D-13/,  00005280
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     *WT(659)/-2.590150368003291D-13/,WT(660)/ 2.275956825191015D-13/,  00005300
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     *WT(665)/-1.192227758615040D-13/,WT(666)/ 1.047606709603187D-13/,  00005330
     *WT(667)/-9.205286574443716D-14/,WT(668)/ 8.088655803832021D-14/,  00005340
     *WT(669)/-7.107475925247343D-14/,WT(670)/ 6.245316311274798D-14/,  00005350
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     *WT(673)/-4.237127819154857D-14/,WT(674)/ 3.723150631847816D-14/,  00005370
     *WT(675)/-3.271520525003134D-14/,WT(676)/ 2.874674597896990D-14/,  00005380
     *WT(677)/-2.525967353907224D-14/,WT(678)/ 2.219559416454687D-14/,  00005390
     *WT(679)/-1.950319744058413D-14/,WT(680)/ 1.713739707017873D-14/,  00005400
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     *WT(707)/-5.219140562969427D-16/,WT(708)/ 4.586042081825544D-16/,  00005550
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     *WT(721)/-8.537792224005708D-17/,WT(722)/ 7.502130657839168D-17/   00005620
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     *WT(723)/-6.592098159645411D-17/,WT(724)/ 5.792455520756561D-17/,  00005640
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     *WT(729)/-3.034295811884372D-17/,WT(730)/ 2.666226003023219D-17/,  00005670
     *WT(731)/-2.342804241895063D-17/,WT(732)/ 2.058614577177349D-17/,  00005680
     *WT(733)/-1.808898029804633D-17/,WT(734)/ 1.589472900128195D-17/,  00005690
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     *WT(739)/-8.326228742065685D-18/,WT(740)/ 7.316230504610306D-18/,  00005720
     *WT(741)/-6.428748291129759D-18/,WT(742)/ 5.648920515191333D-18/,  00005730
     *WT(743)/-4.963688348418389D-18/,WT(744)/ 4.361577040171507D-18/,  00005740
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     *WT(747)/-2.959107033168789D-18/,WT(748)/ 2.600157864838119D-18/,  00005760
     *WT(749)/-2.284750381424515D-18/,WT(750)/ 2.007602836968745D-18/,  00005770
     *WT(751)/-1.764074178215185D-18/,WT(752)/ 1.550086326535024D-18/,  00005780
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     *WT(757)/-8.119907797435101D-19/,WT(758)/ 7.134936960083838D-19/,  00005810
     *WT(759)/-6.269446240781204D-19/,WT(760)/ 5.508942318228495D-19/   00005820
      DATA                                                              00005830
     *WT(761)/-4.840689957627215D-19/,WT(762)/ 4.253498749090647D-19/,  00005840
     *WT(763)/-3.737535715383304D-19/,WT(764)/ 3.284160650943604D-19/,  00005850
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     *WT(765)/-2.885781434802982D-19/,WT(766)/ 2.535726894517719D-19/,  00005860
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     *WT(769)/-1.720361053077579D-19/,WT(770)/ 1.511675741544441D-19/,  00005880
     *WT(771)/-1.328304627571508D-19/,WT(772)/ 1.167177017717951D-19/,  00005890
     *WT(773)/-1.025594703000911D-19/,WT(774)/ 9.011867747602604D-20/,  00005900
     *WT(775)/-7.918699208456320D-20/,WT(776)/ 6.958135363559505D-20/,  00005910
     *WT(777)/-6.114090626414241D-20/,WT(778)/ 5.372430364847189D-20/,  00005920
     *WT(779)/-4.720733874362162D-20/,WT(780)/ 4.148085614846149D-20/,  00005930
     *WT(781)/-3.644890635898519D-20/,WT(782)/ 3.202709755606534D-20/,  00005940
     *WT(783)/-2.814108611035396D-20/,WT(784)/ 2.472510802483146D-20/,  00005950
     *WT(785)/-2.172035832750181D-20/,WT(786)/ 1.907280017594962D-20/,  00005960
     *WT(787)/-7.276969157651721D-21/                                   00005970
C                                                                      00005980
      NOFUN=0                                                          00005990
C-----ERROR CHECKS                                                     00006000
      IF(NB.LT.1.OR.BMAX.LE.0.0D0) GO TO 9999                          00006010
      Y=BMAX*ER**(NB-1)                                                00006020
      IF(Y.LE.0.0D0) GO TO 9999                                        00006030
      IERR=0                                                           00006040
C-----INITIALIZE LAGGED CONVOLUTION LOOP                               00006050
      DO 10 I=1,787                                                    00006060
   10   KEY(I)=0                                                       00006070
      NB1=NB+1                                                         00006080
      LAG=-1                                                           00006090
C-----PRESET INITIAL FILTER ABSCISSA FOR STARTING BMAX, THE ARGUMENT   00006100
C     USED IN THE EXTERNAL FUNCTION FUN(G).  NOTE THE ABSCISSAS        00006110
C     ARE EQUALLY SPACED (E=DEXP(.1D0), ER=1.0D0/E) IN LOG-SPACE.      00006120
      Y1=ABSCIS/BMAX                                                   00006130
C-----LAGGED CONVOLUTION LOOP 1010                                     00006140
      DO 1010 ILAG=1,NB                                                00006150
        LAG=LAG+1                                                      00006160
        ISTORE=NB1-ILAG                                                00006170
        IF(LAG.GT.0) Y1=Y1*E                                           00006180
        ARG(ISTORE)=ABSCIS/Y1                                          00006190
C---------SPECIAL CASE FLAG NONE=1 IS SET IF FUN(G)=0 FOR ALL G IN     00006200
C         FILTER FIXED RANGE (USING WEIGHTS 426-461).                  00006210
          NONE=0                                                       00006220
          ITOL=NTOL                                                    00006230
          DSUM=0.0D0                                                   00006240
          CMAX=0.0D0                                                   00006250
          Y=Y1                                                         00006260
C---------BEGIN RIGHT SIDE CONVOLUTION AT WEIGHT 426 (M=RETURN LABEL)  00006270
          ASSIGN 20 TO M                                               00006280
          I=426                                                        00006290
          Y=Y*E                                                        00006300
C---------CALL PSEUDO SUBROUTINE AT 100 (RETURN TO 20 VIA M ASSIGNED)  00006310
          GO TO 100                                                    00006320
   20     CMAX=DMAX1(DABS(C),CMAX)                                     00006330
          I=I+1                                                        00006340
          Y=Y*E                                                        00006350
C---------CALL PSEUDO SUBROUTINE AT 100 (RETURN TO 20 VIA M ASSIGNED)  00006360
          IF(I.LE.461) GO TO 100                                       00006370
          IF(CMAX.EQ.0.0D0) NONE=1                                     00006380
C---------ESTABLISH TRUNCATION CRITERION                               00006390
          CMAX=TOL*CMAX                                                00006400
```

```
          ASSIGN 30 TO M                                                    00006410
C---------CALL PSEUDO SUBROUTINE AT 100 (RETURN TO 30 VIA M ASSIGNED)      00006420
          GO TO 100                                                         00006430
C---------CHECK FOR FILTER TRUNCATION AT RIGHT END                         00006440
   30     IF(DABS(C).LE.CMAX) GO TO 50                                      00006450
          ITOL=NTOL                                                         00006460
   40     I=I+1                                                             00006470
          Y=Y*E                                                             00006480
C---------CALL PSEUDO SUBROUTINE AT 100 (RETURN TO 30 VIA M ASSIGNED)      00006490
          IF(I.LE.787) GO TO 100                                            00006500
   50     ITOL=ITOL-1                                                       00006510
          IF(ITOL.GT.0.AND.I.LT.787) GO TO 40                               00006520
          ITOL=NTOL                                                         00006530
          Y=Y1                                                              00006540
C---------CONTINUE WITH LEFT SIDE CONVOLUTION AT WEIGHT 425                00006550
          ASSIGN 60 TO M                                                    00006560
          I=425                                                             00006570
C---------CALL PSEUDO SUBROUTINE AT 100 (RETURN TO 60 VIA M ASSIGNED)      00006580
          GO TO 100                                                         00006590
C---------CHECK FOR FILTER TRUNCATION AT LEFT END                           00006600
   60     IF(DABS(C).LE.CMAX.AND.NONE.EQ.0) GO TO 80                        00006610
          ITOL=NTOL                                                         00006620
   70     I=I-1                                                             00006630
          Y=Y*ER                                                            00006640
C---------CALL PSEUDO SUBROUTINE AT 100 (RETURN TO 60 VIA M ASSIGNED)      00006650
          IF(I.GT.0) GO TO 100                                              00006660
   80     ITOL=ITOL-1                                                       00006670
          IF(ITOL.GT.0.AND.I.GT.1) GO TO 70                                 00006680
C---------NORMALIZE DSUM BY ARG(ISTORE) TO ACCOUNT FOR INTEGRATION          00006690
C         RANGE CHANGE, AND STORE IN DANS(ISTORE)                           00006700
          DANS(ISTORE)=DSUM/ARG(ISTORE)                                     00006710
C---------SKIP OVER PSEUDO SUBROUTINE TO END OF DO 1010 LOOP                00006720
          GO TO 1010                                                        00006730
C                                                                           00006740
C===========================================================================00006750
C=====STORE/RETRIEVE PSEUDO SUBROUTINE FOR LAGGED CONVOLUTION.             00006760
C     THE INTERNAL (PSEUDO) SUBROUTINE ENTRY IS LABEL 100, AND RETURNS      00006770
C     TO THE LABEL ASSIGNED TO M.  THIS CALLING MECHANISM COULD OCCUR       00006780
C     A MAXIMUM OF 787*NB TIMES, WHERE PARAMETER NB>0                       00006790
C     CAN BE ARBITRARILY LARGE.  IF A MORE-STRUCTURED STANDARD FORTRAN      00006800
C     SUBROUTINE CALL WAS USED, THEN THE USUAL COMPILER LINKAGE             00006810
C     CONVENTION COULD GENERATE A MAXIMUM OF 787*NB MACHINE-                00006820
C     LANGUAGE INSTRUCTIONS FOR REGISTER SAVES/RESTORES AND OTHER           00006830
C     MEMORY REFERENCES.  FOR MOST COMPILERS, TIMING TESTS REVEAL THAT      00006840
C     THE PSEUDO-CALL METHOD USED HERE GENERATED FASTER MACHINE CODE        00006850
C     THAN WITH USING EXTERNAL SUBROUTINE CALLS.                            00006860
C=========PSEUDO-CALL ENTRY POINT AT 100 (RETURNS VIA GO TO M BELOW)       00006870
  100     LOOK=I+LAG                                                       00006880
          IQ=LOOK/788                                                       00006890
          IR=MOD(LOOK,788)                                                  00006900
          IF(IR.EQ.0) IR=1                                                  00006910
          IROLL=IQ*787                                                      00006920
          IF(KEY(IR).LE.IROLL) GO TO 150                                    00006930
C=========USE EXISTING SAVED FUNCTIONAL VALUES IN DWORK(IR)                 00006940
  110     C=DWORK(IR)*WT(I)                                                 00006950
```

```
          DSUM=DSUM+C                                                    00006960
C=========RETURN CONVOLUTION CONTROL VIA ASSIGNED M VALUE, AND WITH      00006970
C         THE LAST CONVOLUTION PRODUCT (C)                               00006980
          GO TO M,(20,30,60)                                             00006990
C=========COMPUTE EXTERNAL FUN DIRECTLY ONLY WHEN NECESSARY              00007000
  150     KEY(IR)=IROLL+IR                                               00007010
          G=Y                                                            00007020
          DWORK(IR)=FUN(G)                                               00007030
          NOFUN=NOFUN+1                                                  00007040
          GO TO 110                                                      00007050
C=========END OF PSEUDO SUBROUTINE (ENTRY 100, RETURN GO TO M ABOVE)     00007060
C=============================================================================00007070
C                                                                        00007080
C-----END LOOP 1010 (GET REMAINING LAGGED CONVOLUTIONS FOR NEXT ARG)     00007090
 1010 CONTINUE                                                           00007100
C-----EXIT WITH DANS(NB),ARG(NB) COMPLETED WITH MINIMAL FUN CALLS        00007110
      RETURN                                                             00007120
 9999 IERR=1                                                             00007130
      RETURN                                                             00007140
      END                                                                00007150
      SUBROUTINE DLAGF1(BMAX,NB,TOL,NTOL,FUN,                            00007160
     * DANS,ARG,NOFUN,IERR)                                             00007170
C=============================================================================00007180
      INTEGER NB,NTOL,NOFUN,IERR                                         00007190
      DOUBLE PRECISION BMAX,TOL,DANS(NB),ARG(NB)                         00007200
C=============================================================================00007210
C                                                                        00007220
C  PURPOSE                                                               00007230
C                                                                        00007240
C     THE PURPOSE OF SUBPROGRAM DLAGF1 IS TO PROVIDE IN DOUBLE PRECISION00007250
C    A GENERAL ALGORITHM FOR FAST FOURIER SINE TRANSFORMS OF THE FORM:   00007260
C    INTEGRAL FROM 0 TO INFINITY OF FUN(G)*DSIN(B*G)*DG, WHERE WE LAG B  00007270
C    IN [BMIN,BMAX]--USING IMPLIED VALUE OF BMIN=BMAX*DEXP(-.1*(NB-1)).  00007280
C                                                                        00007290
C     DLAGF1 USES A NEW DOUBLE-PRECISION SINE DIGITAL FILTER FOR USE     00007300
C    IN LAGGED CONVOLUTION, WHERE THE ALGORITHM IS PATTERNED AFTER THE   00007310
C    DOUBLE-PRECISION HANKEL TRANSFORM ROUTINE DHANKL PUBLISHED IN THE   00007320
C    FOLLOWING REFERENCE:                                                00007330
C                                                                        00007340
C  ANDERSON, W.L., 1982, FAST HANKEL TRANSFORMS USING RELATED AND LAGGED00007350
C    CONVOLUTIONS: ACM TRANS. ON MATH. SOFTWARE, V.8, N.4, P.344-368.    00007360
C                                                                        00007370
C   DLAGF1 USES THE LAGGED CONVOLUTION METHOD IN THE ABOVE REFERENCE,    00007380
C  BUT USES INTERNAL WORK ARRAYS DWORK(787) AND KEY(787)--INSTEAD OF     00007390
C  PASSING DWORK IN THE CALLING SEQUENCE AS IN DHANKL.  THE MINIMUM      00007400
C  RELATIVE AND/OR ABSOLUTE ERRORS ARE ABOUT 10**-10 USING TOL<=10**-12.00007410
C  (SEE DESCRIPTION OF ALL PARAMETERS BELOW.)                            00007420
C=============================================================================00007430
C                                                                        00007440
C  AUTHOR                                                                00007450
C                                                                        00007460
C    ANDERSON, W.L., U.S. GEOLOGICAL SURVEY, DENVER, COLORADO.           00007470
C                                                                        00007480
C  MACHINE DEPENDENT REMARKS                                             00007490
C                                                                        00007500
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C       THIS SUBPROGRAM WAS IMPLEMENTED AND TESTED ON A 64-BIT DOUBLE-   00007510
C     WORD MACHINE WITH EXP-RANGE APPROXIMATELY 10**-38 TO 10**+38 AND   00007520
C     56-BIT MANTISSA (ABOUT 16-DECIMAL DIGITS).  ONLY DOUBLE-PRECISION  00007530
C     AND INTEGER OPERATIONS ARE USED.                                   00007540
C     FOR MACHINES WITH OTHER DOUBLE-WORD SIZES, CHANGES IN THE NUMBER OF00007550
C     DIGITS RETAINED IN SOME DATA STATEMENTS MAY BE REQUIRED.           00007560
C                                                                        00007570
C  DESCRIPTION OF PARAMETERS                                             00007580
C                                                                        00007590
C     INPUT                                                              00007600
C                                                                        00007610
C       BMAX - INITIAL SINE TRANSFORM ARGUMENT B=BMAX>0.D0, AS           00007620
C              USED IN INTEGRAL FROM 0 TO INFINITY OF                    00007630
C              FUN(G)*DSIN(G*B)*DG, WHERE FUN(G) IS DEFINED BELOW.       00007640
C         NB - NUMBER OF LAGGED CONVOLUTIONS DESIRED (NB.GE.1).  USE     00007650
C              NB=1 IF B=BMIN=BMAX (I.E.,NO LAGGING DESIRED).  USE       00007660
C              NB>1 IF B IS LAGGED IN (BMIN,BMAX), WHERE                 00007670
C              BMIN=BMAX*DEXP(-.1D0*(NB-1)) DOES NOT UNDERFLOW THE DEXP  00007680
C              RANGE.  THE B-LAGGED SPACING IS .1D0 IN LOG-SPACE. FOR    00007690
C              CONVENIENCE IN SPLINE INTERPOLATION LATER, EACH B IN      00007700
C              (BMIN,BMAX) IS RETURNED IN ARRAY ARG(I),I=1,NB, WHERE     00007710
C              ARG(I+1)/ARG(I)=DEXP(.1D0) FOR ALL I.  IF BMAX>BMIN>0 IS  00007720
C              GIVEN, THEN AN EFFECTIVE VALUE OF NB IS DETERMINED AS     00007730
C              NB=DINT(10.*DLOG(BMAX/BMIN))+I, WHERE I>1 IS RECOMMENDED, 00007740
C              PARTICULARLY IF USING SUBSEQUENT SPLINE INTERPOLATION FOR 00007750
C              A DIFFERENT B-SPACING THAN USED IN THE DIGITAL FILTER. IF 00007760
C              SPLINE INTERPOLATION IS TO BE USED LATER, IT IS GENERALLY 00007770
C              BEST TO USE DLOG(ARG(I)) INSTEAD OF ARG(I) -VS- DANS(I),  00007780
C              FOR I=1,NB.                                               00007790
C        TOL - REQUESTED TRUNCATION TOLERANCE AT BOTH FILTER TAILS       00007800
C              FOR ADAPTIVE CONVOLUTION FOR ALL NB TRANSFORMS.  THE      00007810
C              TRUNCATION CRITERION IS ESTABLISHED DURING CONVOLUTION IN 00007820
C              A FIXED ABSCISSA RANGE (USING WEIGHTS 426-463) OF THE     00007830
C              SINE FILTER AS THE MAXIMUM ABSOLUTE CONVOLVED PRODUCT     00007840
C              TIMES TOL.  THE CONVOLUTION SUMMATION IS TERMINATED       00007850
C              ON EITHER SIDE OF THE FIXED RANGE WHENEVER THE ABSOLUTE   00007860
C              PRODUCT .LE. THE TRUNCATION CRITERION.  IN GENERAL, A     00007870
C              DECREASING TOLERANCE WILL PRODUCE HIGHER ACCURACY SINCE   00007880
C              MORE FILTER WEIGHTS ARE USED (UNLESS EXPONENT UNDERFLOW   00007890
C              OCCURS IN THE TRANSFORM INPUT FUNCTION EVALUATION).       00007900
C              ONE MAY SET TOL=0.D0 TO OBTAIN MAXIMUM ACCURACY FOR ALL   00007910
C              NB DOUBLE-PRECISION SINE TRANSFORMS IN DANS(NB).          00007920
C              HOWEVER, THE ACTUAL RELATIVE ERRORS CANNOT BE EXPECTED TO 00007930
C              BE SMALLER THAN ABOUT .1D-12 REGARDLESS OF THE TOLERANCE  00007940
C              VALUE USED, SINCE DOUBLE-PRECISION FILTER WEIGHTS AND A   00007950
C              DOUBLE-PRECISION FUNCTION ARE USED. IN ANY EVENT,         00007960
C              ONE SHOULD ALWAYS CHOOSE TOL<<DESIRED RELATIVE ERROR.     00007970
C           ** ACCURACY WARNING **  SOME HIGHLY OSCILLATORY FUNCTIONS    00007980
C              FUN(G) AND (OR) LIMITING CASES OF B NEAR MACHINE-ZERO     00007990
C              (OR INFINITY) SHOULD BE AVOIDED, OTHERWISE UNSATISFACTORY 00008000
C              RESULTS (E.G., RELATIVE & ABSOLUTE ERRORS>>TOL) MAY OCCUR.00008010
C       NTOL - NUMBER OF CONSECUTIVE TIMES THE TRUNCATION CRITERION (TOL)00008020
C              IS TO BE MET AT EITHER FILTER TAIL BEFORE FILTER           00008030
C              TRUNCATION OCCURS.  NTOL=1 SHOULD BE USED FOR INPUT       00008040
C              FUNCTIONS THAT DO NOT HAVE MANY ZEROS IN (0,INFINITY). FOR00008050
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C             OSCILLATORY FUNCTIONS WITH MANY ZEROS, NTOL>1 MAY BE USED 00008060
C             TO INSURE A PREMATURE CUTOFF DOES NOT OCCUR FOR TRUNCATION00008070
C             (SEE USE OF ITOL,NTOL,TOL IN THE CODE BELOW).             00008080
C      FUN  - NAME OF AN EXTERNAL DOUBLE PRECISION FUNCTION OF A REAL   00008090
C             ARGUMENT DEFINING THE GIVEN TRANSFORM INPUT FUNCTION. AN  00008100
C             EXTERNAL STATEMENT MUST APPEAR IN THE CALLING PROGRAM. THE00008110
C             DOUBLE PRECISION FUNCTION FUN(G) MUST BE CODED BY THE     00008120
C             USER AND MUST BE A CONTINUOUS REAL FUNCTION DEFINED FOR   00008130
C             ALL REAL G>0.0D0, WHERE FUN(G) GOES TO 0 AS G GOES TO     00008140
C             INFINITY IN THE LIMIT.  THE VALUE OF G MUST BE UNCHANGED  00008150
C             UPON RETURN FROM FUN. A MULTIPLE-POLE OF FUN(G) AT G=0.0D000008160
C             CAN EXIST, PROVIDED THE SINE TRANSFORM CONVERGES (NOTE    00008170
C             FUN(0D0) IS NOT USED).  GENERALLY, FUN(G)                 00008180
C             IS DEFINED ANALYTICALLY FOR ALL G>0.D0.  HOWEVER,         00008190
C             DISCRETELY DEFINED FUNCTIONS MAY BE USED IF FUN(G)        00008200
C             RETURNS A SMOOTH INTERPOLATION VALUE (E.G., VIA CUBIC     00008210
C             SPLINES) WHICH SATISFIES THE CONTINUITY CONDITION FOR ALL 00008220
C             G>0, AND PROVIDED THE PROPER LIMITING VALUE OF FUN(G) IS  00008230
C             GIVEN AS G TENDS TO INFINITY.  PARAMETERS OTHER           00008240
C             THAN G NEEDED IN FUN(G) MAY BE INCLUDED BY USING LABELED  00008250
C             COMMON IN FUN AND IN THE USERS CALLING PROGRAM.  IF       00008260
C             FUN(G) IS AN OSCILLATING FUNCTION, THEN THE HIGHEST       00008270
C             FREQUENCY COMPONENT (IN LOG-SPACE) SHOULD NOT EXCEED THE  00008280
C             FILTER NYQUIST FREQUENCY, 1/(2*0.1D0).  IN GENERAL,       00008290
C             SUBPROGRAM DLAGF1 PERFORMS BEST WHEN USING SMOOTH, WELL-  00008300
C             BEHAVED FUNCTIONS FUN(G), THAT ARE CHARACTERIZED AS       00008310
C             MONOTONICALLY DECREASING FUNCTIONS WITH LIMIT 0 AS G      00008320
C             GOES TO INFINITY. (SEE THE ACCURACY WARNING UNDER TOL,    00008330
C             AND ERROR CONDITION (3).)                                 00008340
C                                                                       00008350
C  OUTPUT                                                               00008360
C                                                                       00008370
C      DANS - THE ARRAY DANS(NB) IS RETURNED GIVING THE NB DOUBLE-      00008380
C             PRECISION REAL SINE TRANSFORMS, WITH CORRESPONDING        00008390
C             B ARGUMENTS GIVEN IN ARRAY ARG(NB).                       00008400
C       ARG - THE ARRAY ARG(NB) IS RETURNED GIVING THE RESULTING        00008410
C             B ARGUMENTS IN (BMIN,BMAX), WHERE ARG(I+1)/ARG(I)=EXP(.1),00008420
C             I=1,NB-1 (THIS ARRAY COULD BE ELIMINATED TO SAVE STORAGE  00008430
C             AND REGENERATED AFTER THE CALL DLAGF1, IF DESIRED).       00008440
C    NOFUN  - NUMBER OF DIRECT FUN EVALUATIONS USED FOR ALL NB          00008450
C             REAL SINE TRANSFORMS.  NOFUN IS USUALLY NOT MORE          00008460
C             THAN THE NUMBER OF WEIGHTS NEEDED FOR A SINGLE DIRECT     00008470
C             CONVOLUTION FOR ANY NB. USUALLY, NOFUN<<787 FOR ANY NB.   00008480
C      IERR - ERROR RETURN CODE.  THE FOLLOWING CODES ARE POSSIBLE --   00008490
C             = 0, NO ERROR IN INPUT PARAMETERS. DANS,ARG COMPUTED.     00008500
C             = 1, IMPROPER INPUT PARAMETERS (I.E., NB<1,BMAX<=0, OR    00008510
C             BMAX*DEXP(-.1D0*(NB-1))<=0.D0).  DANS,ARG NOT COMPUTED.   00008520
C                                                                       00008530
C                                                                       00008540
C  ERROR CONDITIONS                                                     00008550
C                                                                       00008560
C    (1)  IMPROPER INPUT PARAMETERS GIVEN (SEE IERR=1 ABOVE).           00008570
C    (2)  UNDERFLOW CONDITIONS ARE POSSIBLE DURING CONVOLUTION, DUE TO  00008580
C         THE BEHAVIOR OF FUN, VALUE OF B IN (BMIN,BMAX), TOL, AND      00008590
C         NTOL. EXPONENT AND (OR) ARITHMETIC UNDERFLOW TRAPS MUST RETURN00008600
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C          A VALUE OF 0.D0 FOR THE COMPUTER SYSTEM BEING USED.  NOTE THAT00008610
C          UNDERFLOW MAY ALSO OCCUR IN THE USERS EXTERNAL FUNCTION       00008620
C          FUN(G) FOR ANY VALUE OF G AS SET BY SUBPROGRAM DLAGF1.        00008630
C     (3)  UNDETECTED ERRORS ARE POSSIBLE IF FUN IS IMPROPERLY CODED, OR 00008640
C          DOES NOT YIELD DOUBLE-PRECISION ACCURACY, OR IS NOT           00008650
C          A CONTINUOUS DECREASING REAL FUNCTION FOR ALL G>0.D0.         00008660
C                                                                        00008670
C  USAGE                                                                 00008680
C                                                                        00008690
C    SUBPROGRAM DLAGF1 IS CALLED AS FOLLOWS (USE NUMERICAL VALUES FOR    00008700
C    <EXPRESSION>, EXCLUDING < AND >, IN DECLARATIONS) --                00008710
C                                                                        00008720
C      DOUBLE PRECISION BMAX,TOL,DANS(<NB>),ARG(<NB>)                    00008730
C      EXTERNAL DFUN                                                     00008740
CC-----READ/LOAD INPUT PARAMETERS FOR DLAGF1 AS REQUIRED                 00008750
C      ...                                                               00008760
C      CALL DLAGF1(BMAX,NB,TOL,NTOL,DFUN,                                00008770
C     * DANS,ARG,NOFUN,IERR)                                            00008780
C      IF(IERR.EQ.1) STOP                                                00008790
C      ...                                                               00008800
C      END                                                               00008810
C      DOUBLE PRECISION FUNCTION DFUN(G)                                 00008820
C      DOUBLE PRECISION G                                                00008830
CC-----INSERT USER SUPPLIED CODE FOR EVALUATION OF DFUN(G),G>0.0D0       00008840
C      END                                                               00008850
C                                                                        00008860
C========================================================================00008870
      DOUBLE PRECISION ABSCIS,C,CMAX,DSUM,E,ER,FUN,G,Y,Y1,WT,DWORK       00008880
      DIMENSION KEY(787),WT(787),DWORK(787)                             00008890
C-----WE DEFINE C,CMAX FOR USE IN THE TRUNCATION CRITERION TESTS,        00008900
C     WHERE C IS ANY CONVOLUTION PRODUCT AND CMAX IS THE MAXIMUM         00008910
C     CONVOLVED PRODUCT IN THE FIXED ABSCISSA RANGE (SEE PARAMETER TOL).00008920
C-----ABSCIS=BASE CONSTANT FOR FILTER ABSCISSA GENERATION                00008930
      DATA ABSCIS/0.7745022656977834D0/                                 00008940
C-----E=DEXP(.1D0), ER=1.0D0/E (ALSO USED IN ABSCISSA GENERATION)        00008950
      DATA E/1.10517091807564762 D0/,ER/.9048374180359573 D0/           00008960
C////// DSIN FILTER WEIGHTS ///////                                     00008970
      DATA                                                              00008980
     *WT(  1)/ 4.519086190454403D-29/,WT(  2)/-9.339715413211410D-29/,   00008990
     *WT(  3)/ 1.907086488243319D-28/,WT(  4)/-2.926740419085585D-28/,   00009000
     *WT(  5)/ 4.016341837702778D-28/,WT(  6)/-5.205269186311504D-28/,   00009010
     *WT(  7)/ 6.517833605193130D-28/,WT(  8)/-7.967548954470954D-28/,   00009020
     *WT(  9)/ 9.568276718198612D-28/,WT( 10)/-1.135805242625555D-27/,   00009030
     *WT( 11)/ 1.341437536522928D-27/,WT( 12)/-1.584604744296628D-27/,   00009040
     *WT( 13)/ 1.876875146781600D-27/,WT( 14)/-2.228200512918392D-27/,   00009050
     *WT( 15)/ 2.645681468388641D-27/,WT( 16)/-3.133421673989624D-27/,   00009060
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     *WT( 21)/ 6.719340442247252D-27/,WT( 22)/-7.710109799166923D-27/,   00009090
     *WT( 23)/ 8.824593601800077D-27/,WT( 24)/-1.008809737899913D-26/,   00009100
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     *WT( 27)/ 1.508632848921759D-26/,WT( 28)/-1.726724501006653D-26/,   00009120
     *WT( 29)/ 1.976529598469166D-26/,WT( 30)/-2.262087271971451D-26/,   00009130
     *WT( 31)/ 2.587877027540831D-26/,WT( 32)/-2.958891513809359D-26/,   00009140
     *WT( 33)/ 3.380756725224869D-26/,WT( 34)/-3.859914775323363D-26/,   00009150
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      DATA                                                              00009180
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     *WT( 45)/ 1.622403124908015D-25/,WT( 46)/-1.847622752118429D-25/,  00009220
     *WT( 47)/ 2.103817835334522D-25/,WT( 48)/-2.395181391816518D-25/,  00009230
     *WT( 49)/ 2.726499236157535D-25/,WT( 50)/-3.103251036607772D-25/,  00009240
     *WT( 51)/ 3.531729413199891D-25/,WT( 52)/-4.019163393605676D-25/,  00009250
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     *WT( 55)/ 5.924100002797128D-25/,WT( 56)/-6.742788104825517D-25/,  00009270
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     *WT( 67)/ 2.812864533285517D-24/,WT( 68)/-3.202964869374407D-24/,  00009330
     *WT( 69)/ 3.647071555907292D-24/,WT( 70)/-4.152674762505081D-24/,  00009340
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      DATA                                                              00010180
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     *WT(645)/ 2.373325310854237D-19/,WT(646)/-1.886978121843854D-19/   00012370
      DATA                                                              00012380
     *WT(647)/ 1.500294299097576D-19/,WT(648)/-1.192850600158091D-19/,  00012390
     *WT(649)/ 9.484089595818352D-20/,WT(650)/-7.540588530116191D-20/,  00012400
     *WT(651)/ 5.995354099387067D-20/,WT(652)/-4.766772603294524D-20/,  00012410
     *WT(653)/ 3.789954805412417D-20/,WT(654)/-3.013308718206562D-20/,  00012420
     *WT(655)/ 2.395814700817093D-20/,WT(656)/-1.904858950112549D-20/,  00012430
     *WT(657)/ 1.514510957672512D-20/,WT(658)/-1.204153954009819D-20/,  00012440
     *WT(659)/ 9.573960050057665D-21/,WT(660)/-7.612042487983742D-21/,  00012450
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     *WT(661)/ 6.052165469011701D-21/,WT(662)/-4.811941935554926D-21/,  00012460
     *WT(663)/ 3.825867772694447D-21/,WT(664)/-3.041862118819870D-21/,  00012470
     *WT(665)/ 2.418516642409082D-21/,WT(666)/-1.922908502426471D-21/,  00012480
     *WT(667)/ 1.528861481986123D-21/,WT(668)/-1.215563454903229D-21/,  00012490
     *WT(669)/ 9.664671642003589D-22/,WT(670)/-7.684162553978440D-22/,  00012500
     *WT(671)/ 6.109504047471497D-22/,WT(672)/-4.857528416823409D-22/,  00012510
     *WT(673)/ 3.862110855330143D-22/,WT(674)/-3.070676966569801D-22/,  00012520
     *WT(675)/ 2.441425971113178D-22/,WT(676)/-1.941122955877971D-22/,  00012530
     *WT(677)/ 1.543343556015419D-22/,WT(678)/-1.227078345565842D-22/,  00012540
     *WT(679)/ 9.756232141971099D-23/,WT(680)/-7.756971208813704D-23/,  00012550
     *WT(681)/ 6.167406266892664D-23/,WT(682)/-4.903581613923544D-23/,  00012560
     *WT(683)/ 3.898745781389350D-23/,WT(684)/-3.099825880130062D-23/   00012570
      DATA                                                              00012580
     *WT(685)/ 2.464624570708451D-23/,WT(686)/-1.959591536406367D-23/,  00012590
     *WT(687)/ 1.558051651712082D-23/,WT(688)/-1.238796173479821D-23/,  00012600
     *WT(689)/ 9.849625195167609D-24/,WT(690)/-7.831435654861331D-24/,  00012610
     *WT(691)/ 6.226795451209084D-24/,WT(692)/-4.950951685405124D-24/,  00012620
     *WT(693)/ 3.936520905478440D-24/,WT(694)/-3.129929802298849D-24/,  00012630
     *WT(695)/ 2.488584770157100D-24/,WT(696)/-1.978622297628744D-24/,  00012640
     *WT(697)/ 1.573121213803113D-24/,WT(698)/-1.250680505229501D-24/,  00012650
     *WT(699)/ 9.942866354722078D-25/,WT(700)/-7.904119407074957D-25/,  00012660
     *WT(701)/ 6.282983380266727D-25/,WT(702)/-4.993888550242444D-25/,  00012670
     *WT(703)/ 3.968764501205991D-25/,WT(704)/-3.153465565806142D-25/,  00012680
     *WT(705)/ 2.504952335417932D-25/,WT(706)/-1.989067071293495D-25/,  00012690
     *WT(707)/ 1.578744037087885D-25/,WT(708)/-1.252528942885154D-25/,  00012700
     *WT(709)/ 9.933547263601893D-26/,WT(710)/-7.875756004541075D-26/,  00012710
     *WT(711)/ 6.242484682723995D-26/,WT(712)/-4.946074258240189D-26/,  00012720
     *WT(713)/ 3.916606766138584D-26/,WT(714)/-3.098609190290296D-26/,  00012730
     *WT(715)/ 2.448266612392087D-26/,WT(716)/-1.931034281011451D-26/,  00012740
     *WT(717)/ 1.519618180226741D-26/,WT(718)/-1.192353131496834D-26/,  00012750
     *WT(719)/ 9.319757733847061D-27/,WT(720)/-7.247010142017766D-27/,  00012760
     *WT(721)/ 5.595281281317008D-27/,WT(722)/-4.277815801389812D-27/   00012770
      DATA                                                              00012780
     *WT(723)/ 3.228199604942252D-27/,WT(724)/-2.397244120563833D-27/,  00012790
     *WT(725)/ 1.748239591243191D-27/,WT(726)/-1.251355005015151D-27/,  00012800
     *WT(727)/ 8.794257877849950D-28/,WT(728)/-6.065291790558063D-28/,  00012810
     *WT(729)/ 4.090426687827314D-28/,WT(730)/-2.676669295980934D-28/,  00012820
     *WT(731)/ 1.687971022918484D-28/,WT(732)/-1.044337763175647D-28/,  00012830
     *WT(733)/ 7.050578391076381D-29/,WT(734)/-6.406578964496667D-29/,  00012840
     *WT(735)/ 8.047966445795522D-29/,WT(736)/-1.121534977637725D-28/,  00012850
     *WT(737)/ 1.496948518403447D-28/,WT(738)/-1.846610467538164D-28/,  00012860
     *WT(739)/ 2.120865254113486D-28/,WT(740)/-2.314246444782675D-28/,  00012870
     *WT(741)/ 2.456355516626332D-28/,WT(742)/-2.590895710468579D-28/,  00012880
     *WT(743)/ 2.753571339247125D-28/,WT(744)/-2.961734255384709D-28/,  00012890
     *WT(745)/ 3.222852751815456D-28/,WT(746)/-3.554096868418778D-28/,  00012900
     *WT(747)/ 3.994470369697907D-28/,WT(748)/-4.595315984451220D-28/,  00012910
     *WT(749)/ 5.391210400875100D-28/,WT(750)/-6.364075603215328D-28/,  00012920
     *WT(751)/ 7.416537866632483D-28/,WT(752)/-8.373375968928217D-28/,  00012930
     *WT(753)/ 9.020712825598172D-28/,WT(754)/-9.167392508097227D-28/,  00012940
     *WT(755)/ 8.694251225012477D-28/,WT(756)/-7.570921079500922D-28/,  00012950
     *WT(757)/ 5.849601896353324D-28/,WT(758)/-3.650523966203355D-28/,  00012960
     *WT(759)/ 1.141119602484722D-28/,WT(760)/ 1.491703156191346D-28/   00012970
      DATA                                                              00012980
     *WT(761)/-4.067578199248336D-28/,WT(762)/ 6.427512747502163D-28/,  00012990
     *WT(763)/-8.440676076304842D-28/,WT(764)/ 1.001129119104450D-27/,  00013000
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     *WT(765)/-1.108757116989416D-27/,WT(766)/ 1.166928305547677D-27/,  00013010
     *WT(767)/-1.180901419514423D-27/,WT(768)/ 1.160312647193067D-27/,  00013020
     *WT(769)/-1.116872557002111D-27/,WT(770)/ 1.060982755116985D-27/,  00013030
     *WT(771)/-9.988396142394386D-28/,WT(772)/ 9.317938546853034D-28/,  00013040
     *WT(773)/-8.581732798065989D-28/,WT(774)/ 7.758565868660186D-28/,  00013050
     *WT(775)/-6.839003286369139D-28/,WT(776)/ 5.828348637958973D-28/,  00013060
     *WT(777)/-4.740105434766476D-28/,WT(778)/ 3.587009166849001D-28/,  00013070
     *WT(779)/-2.377198496417097D-28/,WT(780)/ 1.119160774411077D-28/,  00013080
     *WT(781)/ 1.670017331897950D-29/,WT(782)/-1.438060858130858D-28/,  00013090
     *WT(783)/ 2.622750906188666D-28/,WT(784)/-3.630328238235802D-28/,  00013100
     *WT(785)/ 4.369496766662814D-28/,WT(786)/-4.761183982698324D-28/,  00013110
     *WT(787)/-3.708525899969828D-28/                                   00013120
C                                                                       00013130
      NOFUN=0                                                           00013140
C-----ERROR CHECKS                                                      00013150
      IF(NB.LT.1.OR.BMAX.LE.0.0D0) GO TO 9999                           00013160
      Y=BMAX*ER**(NB-1)                                                 00013170
      IF(Y.LE.0.0D0) GO TO 9999                                         00013180
      IERR=0                                                            00013190
C-----INITIALIZE LAGGED CONVOLUTION LOOP                                00013200
      DO 10 I=1,787                                                     00013210
   10   KEY(I)=0                                                        00013220
      NB1=NB+1                                                          00013230
      LAG=-1                                                            00013240
C-----PRESET INITIAL FILTER ABSCISSA FOR STARTING BMAX, THE ARGUMENT     00013250
C     USED IN THE EXTERNAL FUNCTION FUN(G).  NOTE THE ABSCISSAS         00013260
C     ARE EQUALLY SPACED (E=DEXP(.1D0), ER=1.0D0/E) IN LOG-SPACE.       00013270
      Y1=ABSCIS/BMAX                                                    00013280
C-----LAGGED CONVOLUTION LOOP 1010                                      00013290
      DO 1010 ILAG=1,NB                                                 00013300
        LAG=LAG+1                                                       00013310
        ISTORE=NB1-ILAG                                                 00013320
        IF(LAG.GT.0) Y1=Y1*E                                            00013330
        ARG(ISTORE)=ABSCIS/Y1                                           00013340
C---------SPECIAL CASE FLAG NONE=1 IS SET IF FUN(G)=0 FOR ALL G IN      00013350
C         FILTER FIXED RANGE (USING WEIGHTS 426-463).                   00013360
          NONE=0                                                        00013370
          ITOL=NTOL                                                     00013380
          DSUM=0.0D0                                                    00013390
          CMAX=0.0D0                                                    00013400
          Y=Y1                                                          00013410
C---------BEGIN RIGHT SIDE CONVOLUTION AT WEIGHT 426 (M=RETURN LABEL)   00013420
          ASSIGN 20 TO M                                                00013430
          I=426                                                         00013440
          Y=Y*E                                                         00013450
C---------CALL PSEUDO SUBROUTINE AT 100 (RETURN TO 20 VIA M ASSIGNED)   00013460
          GO TO 100                                                     00013470
   20     CMAX=DMAX1(DABS(C),CMAX)                                      00013480
          I=I+1                                                         00013490
          Y=Y*E                                                         00013500
C---------CALL PSEUDO SUBROUTINE AT 100 (RETURN TO 20 VIA M ASSIGNED)   00013510
          IF(I.LE.463) GO TO 100                                        00013520
          IF(CMAX.EQ.0.0D0) NONE=1                                      00013530
C---------ESTABLISH TRUNCATION CRITERION                                00013540
          CMAX=TOL*CMAX                                                 00013550
```

```
          ASSIGN 30 TO M                                                  00013560
C---------CALL PSEUDO SUBROUTINE AT 100 (RETURN TO 30 VIA M ASSIGNED)    00013570
          GO TO 100                                                       00013580
C---------CHECK FOR FILTER TRUNCATION AT RIGHT END                       00013590
   30     IF(DABS(C).LE.CMAX) GO TO 50                                    00013600
          ITOL=NTOL                                                       00013610
   40     I=I+1                                                           00013620
          Y=Y*E                                                           00013630
C---------CALL PSEUDO SUBROUTINE AT 100 (RETURN TO 30 VIA M ASSIGNED)    00013640
          IF(I.LE.787) GO TO 100                                          00013650
   50     ITOL=ITOL-1                                                     00013660
          IF(ITOL.GT.0.AND.I.LT.787) GO TO 40                             00013670
          ITOL=NTOL                                                       00013680
          Y=Y1                                                            00013690
C---------CONTINUE WITH LEFT SIDE CONVOLUTION AT WEIGHT 425              00013700
          ASSIGN 60 TO M                                                  00013710
          I=425                                                           00013720
C---------CALL PSEUDO SUBROUTINE AT 100 (RETURN TO 60 VIA M ASSIGNED)    00013730
          GO TO 100                                                       00013740
C---------CHECK FOR FILTER TRUNCATION AT LEFT END                         00013750
   60     IF(DABS(C).LE.CMAX.AND.NONE.EQ.0) GO TO 80                      00013760
          ITOL=NTOL                                                       00013770
   70     I=I-1                                                           00013780
          Y=Y*ER                                                          00013790
C---------CALL PSEUDO SUBROUTINE AT 100 (RETURN TO 60 VIA M ASSIGNED)    00013800
          IF(I.GT.0) GO TO 100                                            00013810
   80     ITOL=ITOL-1                                                     00013820
          IF(ITOL.GT.0.AND.I.GT.1) GO TO 70                               00013830
C---------NORMALIZE DSUM BY ARG(ISTORE) TO ACCOUNT FOR INTEGRATION        00013840
C         RANGE CHANGE, AND STORE IN DANS(ISTORE)                         00013850
          DANS(ISTORE)=DSUM/ARG(ISTORE)                                   00013860
C---------SKIP OVER PSEUDO SUBROUTINE TO END OF DO 1010 LOOP              00013870
          GO TO 1010                                                      00013880
C                                                                         00013890
C=========================================================================00013900
C=====STORE/RETRIEVE PSEUDO SUBROUTINE FOR LAGGED CONVOLUTION.           00013910
C     THE INTERNAL (PSEUDO) SUBROUTINE ENTRY IS LABEL 100, AND RETURNS    00013920
C     TO THE LABEL ASSIGNED TO M.  THIS CALLING MECHANISM COULD OCCUR     00013930
C     A MAXIMUM OF 787*NB TIMES, WHERE PARAMETER NB>0                     00013940
C     CAN BE ARBITRARILY LARGE.  IF A MORE-STRUCTURED STANDARD FORTRAN    00013950
C     SUBROUTINE CALL WAS USED, THEN THE USUAL COMPILER LINKAGE           00013960
C     CONVENTION COULD GENERATE A MAXIMUM OF 787*NB MACHINE-              00013970
C     LANGUAGE INSTRUCTIONS FOR REGISTER SAVES/RESTORES AND OTHER         00013980
C     MEMORY REFERENCES.  FOR MOST COMPILERS, TIMING TESTS REVEAL THAT    00013990
C     THE PSEUDO-CALL METHOD USED HERE GENERATED FASTER MACHINE CODE      00014000
C     THAN WITH USING EXTERNAL SUBROUTINE CALLS.                          00014010
C=========PSEUDO-CALL ENTRY POINT AT 100 (RETURNS VIA GO TO M BELOW)     00014020
  100     LOOK=I+LAG                                                      00014030
          IQ=LOOK/788                                                     00014040
          IR=MOD(LOOK,788)                                                00014050
          IF(IR.EQ.0) IR=1                                                00014060
          IROLL=IQ*787                                                    00014070
          IF(KEY(IR).LE.IROLL) GO TO 150                                  00014080
C=========USE EXISTING SAVED FUNCTIONAL VALUES IN DWORK(IR)               00014090
  110     C=DWORK(IR)*WT(I)                                               00014100
```

```
          DSUM=DSUM+C                                                    00014110
C=========RETURN CONVOLUTION CONTROL VIA ASSIGNED M VALUE, AND WITH      00014120
C         THE LAST CONVOLUTION PRODUCT (C)                               00014130
          GO TO M,(20,30,60)                                             00014140
C=========COMPUTE EXTERNAL FUN DIRECTLY ONLY WHEN NECESSARY              00014150
  150     KEY(IR)=IROLL+IR                                               00014160
          G=Y                                                            00014170
          DWORK(IR)=FUN(G)                                               00014180
          NOFUN=NOFUN+1                                                  00014190
          GO TO 110                                                      00014200
C=========END OF PSEUDO SUBROUTINE (ENTRY 100, RETURN GO TO M ABOVE)     00014210
C=============================================================================00014220
C                                                                        00014230
C-----END LOOP 1010 (GET REMAINING LAGGED CONVOLUTIONS FOR NEXT ARG)     00014240
 1010 CONTINUE                                                           00014250
C-----EXIT WITH DANS(NB),ARG(NB) COMPLETED WITH MINIMAL FUN CALLS        00014260
      RETURN                                                             00014270
 9999 IERR=1                                                             00014280
      RETURN                                                             00014290
      END                                                                00014300
C--<TDLAGF0>: DRIVER PROGRAM TO TEST SUBPROGRAM DLAGF0  [1/21/83]        00014310
C                                                                        00014320
C--BY W.L.ANDERSON, U.S.GEOLOGICAL SURVEY, DENVER, COLORADO.             00014330
C                                                                        00014340
C  REQUIRES ONLY A PRINTER FILE (UNIT 06).                               00014350
C                                                                        00014360
C  TEST DATA ARE PRESTORED IN DATA STATEMENTS FOR EVALUATING             00014370
C  FOURIER COSINE TRANSFORMS IN DOUBLE-PRECISION OF THE FORM:            00014380
C  INTEGRAL FROM 0 TO INFINITY OF FUN(G)*DCOS(G*B)*DG, B>0.0D0.          00014390
C  THE TEST INTEGRALS USED WITH KNOWN SOLUTIONS ARE:                     00014400
C                                                                        00014410
C  INTEGRAL  FUN(G)             KNOWN EXACT RESULT OF INTEGRAL           00014420
C  --------  --------------     ---------------------------------------  00014430
C     1      DEXP(-A*A*G*G)     SQPI*DEXP(-B*B/(4.*A*A))/(2.*A), WHERE   00014440
C                                SQPI="SQUARE ROOT OF PI"                00014450
C     2      1/(A*A+G*G)        (PI/2)*DEXP(-A*B)/A                      00014460
C     3      DEXP(-A*G)         A/(A*A+B*B)                              00014470
C                                                                        00014480
C--NOTE THAT USE OF DIFFERENT COMPUTERS AND WORD LENGTHS MAY PRODUCE     00014490
C  SLIGHTLY DIFFERENT ROUND-OFF AND POSSIBLY DIFFERENT NUMBER OF         00014500
C  DIRECT FUNCTION CALLS (NF) USED IN DLAGF0.  HOWEVER, THE FILTERED     00014510
C  RESULTS SHOULD AGREE REASONABLY WELL WITH EXACT RESULTS WITH           00014520
C  RESPECT TO THE TOLERANCE (TOL) USED IN THESE EXAMPLES.                00014530
C                                                                        00014540
C--THE USER SHOULD INSERT A CALL TO SUPPRESS EXPONENT UNDERFLOW MESSAGES 00014550
C  FOR THE MACHINE SYSTEM BEING USED (SEE NOTE(2) IN DLAGF0 COMMENTS).   00014560
C=============================================================================00014570
      IMPLICIT REAL*8 (A-H,O-Z)                                          00014580
      DIMENSION ARG(15),FILT(15),AJ(3)                                   00014590
      EXTERNAL C1,C2,C3                                                  00014600
      DATA BMAX,NB/2.D0,15/,TOL/0.1E-12/,AJ/1.D0,.5D0,.1D0/              00014610
     *  SQPI/1.772453850905516D0/,PI2/1.570796326794897D0/               00014620
      COMMON/PASS/A,AA                                                   00014630
        WRITE(6,60) TOL,BMAX,NB                                          00014640
   60   FORMAT('1<TDLAGF0>:    TEST RESULTS FOR DLAGF0 FILTER:',5X,      00014650
```

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     * 'TOL=',D16.8,'  BMAX=',D16.8,'  NB=',I4//                          00014660
     * ' INTEGRAL  I    ARG(I)',7X,'A  ',10X,'EXACT',11X,'FILTERED',      00014670
     * 8X,'ABS.ERROR',7X,'REL.ERROR',6X,'NF'/)                            00014680
C--GET INTEGRAL 1 LAGGED FOR ALL B USING GIVEN BMAX,NB                    00014690
      J=1                                                                 00014700
      A=AJ(1)                                                             00014710
      AA=A*A                                                              00014720
      CALL DLAGF0(BMAX,NB,TOL,1,C1,FILT,ARG,NF,IERR)                      00014730
      IF(IERR.NE.0) STOP 1                                                00014740
      DO 1 I=NB,1,-1                                                      00014750
        B=ARG(I)                                                          00014760
        BB=B*B                                                            00014770
        EXACT=SQPI*DEXP(-BB/(4.D0*AA))/(2.D0*A)                           00014780
        ABSERR=DABS(FILT(I)-EXACT)                                        00014790
          RELERR=ABSERR/(EXACT+1.7D-38)                                   00014800
          WRITE(6,66) J,I,B,A,EXACT,FILT(I),ABSERR,RELERR,NF              00014810
   66     FORMAT(5X,I1,I6,2D13.5,4D16.8,2X,I3)                            00014820
        NF=0                                                              00014830
    1 CONTINUE                                                            00014840
      WRITE(6,67)                                                         00014850
   67 FORMAT(' ')                                                         00014860
C--GET INTEGRAL 2 LAGGED FOR ALL B USING GIVEN BMAX,NB                    00014870
      J=2                                                                 00014880
      A=AJ(2)                                                             00014890
      AA=A*A                                                              00014900
      CALL DLAGF0(BMAX,NB,TOL,1,C2,FILT,ARG,NF,IERR)                      00014910
      IF(IERR.NE.0) STOP 2                                                00014920
      DO 2 I=NB,1,-1                                                      00014930
        B=ARG(I)                                                          00014940
        BB=B*B                                                            00014950
        EXACT=PI2*DEXP(-A*B)/A                                            00014960
        ABSERR=DABS(FILT(I)-EXACT)                                        00014970
          RELERR=ABSERR/(EXACT+1.7D-38)                                   00014980
          WRITE(6,66) J,I,B,A,EXACT,FILT(I),ABSERR,RELERR,NF              00014990
        NF=0                                                              00015000
    2 CONTINUE                                                            00015010
      WRITE(6,67)                                                         00015020
C--GET INTEGRAL 3 LAGGED FOR ALL B USING GIVEN BMAX,NB                    00015030
      J=3                                                                 00015040
      A=AJ(3)                                                             00015050
      AA=A*A                                                              00015060
      CALL DLAGF0(BMAX,NB,TOL,1,C3,FILT,ARG,NF,IERR)                      00015070
      IF(IERR.NE.0) STOP 3                                                00015080
      DO 3 I=NB,1,-1                                                      00015090
        B=ARG(I)                                                          00015100
        BB=B*B                                                            00015110
        EXACT=A/(A*A+B*B)                                                 00015120
        ABSERR=DABS(FILT(I)-EXACT)                                        00015130
          RELERR=ABSERR/(EXACT+1.7D-38)                                   00015140
          WRITE(6,66) J,I,B,A,EXACT,FILT(I),ABSERR,RELERR,NF              00015150
        NF=0                                                              00015160
    3 CONTINUE                                                            00015170
      WRITE(6,68)                                                         00015180
   68 FORMAT('1')                                                         00015190
      CALL EXIT                                                           00015200
```

```
      END                                                               00015210
      REAL*8 FUNCTION C1(X)                                             00015220
C--KERNEL FUNCTION FOR INTEGRAL 1.                                      00015230
      IMPLICIT REAL*8 (A-H,O-Z)                                         00015240
      COMMON/PASS/A,AA                                                  00015250
      C1=DEXP(-AA*X*X)                                                  00015260
        RETURN                                                          00015270
      END                                                               00015280
      REAL*8 FUNCTION C2(X)                                             00015290
C--KERNEL FUNCTION FOR INTEGRAL 2.                                      00015300
      IMPLICIT REAL*8 (A-H,O-Z)                                         00015310
      COMMON/PASS/A,AA                                                  00015320
      C2=1.D0/(AA+X*X)                                                  00015330
        RETURN                                                          00015340
      END                                                               00015350
      REAL*8 FUNCTION C3(X)                                             00015360
C--KERNEL FUNCTION FOR INTEGRAL 3.                                      00015370
      IMPLICIT REAL*8 (A-H,O-Z)                                         00015380
      COMMON/PASS/A,AA                                                  00015390
      C3=DEXP(-A*X)                                                     00015400
        RETURN                                                          00015410
      END                                                               00015420
C--<TDLAGF1>: DRIVER PROGRAM TO TEST SUBPROGRAM DLAGF1  [1/21/83]       00015430
C                                                                       00015440
C--BY W.L.ANDERSON, U.S.GEOLOGICAL SURVEY, DENVER, COLORADO.            00015450
C                                                                       00015460
C  REQUIRES ONLY A PRINTER FILE (UNIT 06).                              00015470
C                                                                       00015480
C  TEST DATA ARE PRESTORED IN DATA STATEMENTS FOR EVALUATING            00015490
C  FOURIER SINE TRANSFORMS IN DOUBLE-PRECISION OF THE FORM:             00015500
C  INTEGRAL FROM 0 TO INFINITY OF FUN(G)*DSIN(G*B)*DG, B>0.0D0.         00015510
C  THE TEST INTEGRALS USED WITH KNOWN SOLUTIONS ARE:                    00015520
C                                                                       00015530
C  INTEGRAL  FUN(G)            KNOWN EXACT RESULT OF INTEGRAL          00015540
C  --------  --------------    ---------------------------------------  00015550
C     1      G*DEXP(-A*A*G*G)  SQPI*B*DEXP(-B*B/(4.*A*A))/(4.*A**3),   00015560
C                               WHERE SQPI="SQUARE ROOT OF PI"          00015570
C     2      G/(A*A+G*G)       (PI/2)*DEXP(-A*B)                       00015580
C     3      DEXP(-A*G)        B/(A*A+B*B)                             00015590
C                                                                       00015600
C--NOTE THAT USE OF DIFFERENT COMPUTERS AND WORD LENGTHS MAY PRODUCE     00015610
C  SLIGHTLY DIFFERENT ROUND-OFF AND POSSIBLY DIFFERENT NUMBER OF        00015620
C  DIRECT FUNCTION CALLS (NF) USED IN DLAGF0.  HOWEVER, THE FILTERED    00015630
C  RESULTS SHOULD AGREE REASONABLY WELL WITH EXACT RESULTS WITH         00015640
C  RESPECT TO THE TOLERANCE (TOL) USED IN THESE EXAMPLES.               00015650
C                                                                       00015660
C--THE USER SHOULD INSERT A CALL TO SUPPRESS EXPONENT UNDERFLOW MESSAGES00015670
C  FOR THE MACHINE SYSTEM BEING USED (SEE NOTE(2) IN DLAGF1 COMMENTS).  00015680
C=======================================================================00015690
      IMPLICIT REAL*8 (A-H,O-Z)                                         00015700
      DIMENSION ARG(15),FILT(15),AJ(3)                                  00015710
      EXTERNAL C1,C2,C3                                                 00015720
      DATA BMAX,NB/2.D0,15/,TOL/0.1E-12/,AJ/1.D0,.5D0,.1D0/             00015730
     *  SQPI/1.772453850905516D0/,PI2/1.570796326794897D0/              00015740
      COMMON/PASS/A,AA                                                  00015750
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      WRITE(6,60) TOL,BMAX,NB                                          00015760
 60   FORMAT('1<TDLAGF1>:    TEST RESULTS FOR DLAGF1 FILTER:',5X,      00015770
     * 'TOL=',D16.8,'  BMAX=',D16.8,'  NB=',I4//                       00015780
     * ' INTEGRAL  I    ARG(I)',7X,'A  ',10X,'EXACT',11X,'FILTERED',   00015790
     * 8X,'ABS.ERROR',7X,'REL.ERROR',6X,'NF')                          00015800
C--GET INTEGRAL 1 LAGGED FOR ALL B USING GIVEN BMAX,NB                 00015810
      J=1                                                              00015820
      A=AJ(1)                                                          00015830
      AA=A*A                                                           00015840
      CALL DLAGF1(BMAX,NB,TOL,1,C1,FILT,ARG,NF,IERR)                   00015850
      IF(IERR.NE.0) STOP 1                                             00015860
      DO 1 I=NB,1,-1                                                   00015870
        B=ARG(I)                                                       00015880
        BB=B*B                                                         00015890
        EXACT=SQPI*B*DEXP(-BB/(4.D0*AA))/(4.D0*AA*A)                   00015900
        ABSERR=DABS(FILT(I)-EXACT)                                     00015910
          RELERR=ABSERR/(EXACT+1.7D-38)                                00015920
          WRITE(6,66) J,I,B,A,EXACT,FILT(I),ABSERR,RELERR,NF           00015930
 66       FORMAT(5X,I1,I6,2D13.5,4D16.8,2X,I3)                         00015940
        NF=0                                                           00015950
  1   CONTINUE                                                         00015960
      WRITE(6,67)                                                      00015970
 67   FORMAT(' ')                                                      00015980
C--GET INTEGRAL 2 LAGGED FOR ALL B USING GIVEN BMAX,NB                 00015990
      J=2                                                              00016000
      A=AJ(2)                                                          00016010
      AA=A*A                                                           00016020
      CALL DLAGF1(BMAX,NB,TOL,1,C2,FILT,ARG,NF,IERR)                   00016030
      IF(IERR.NE.0) STOP 2                                             00016040
      DO 2 I=NB,1,-1                                                   00016050
        B=ARG(I)                                                       00016060
        BB=B*B                                                         00016070
        EXACT=PI2*DEXP(-A*B)                                           00016080
        ABSERR=DABS(FILT(I)-EXACT)                                     00016090
          RELERR=ABSERR/(EXACT+1.7D-38)                                00016100
          WRITE(6,66) J,I,B,A,EXACT,FILT(I),ABSERR,RELERR,NF           00016110
        NF=0                                                           00016120
  2   CONTINUE                                                         00016130
      WRITE(6,67)                                                      00016140
C--GET INTEGRAL 3 LAGGED FOR ALL B USING GIVEN BMAX,NB                 00016150
      J=3                                                              00016160
      A=AJ(3)                                                          00016170
      AA=A*A                                                           00016180
      CALL DLAGF1(BMAX,NB,TOL,1,C3,FILT,ARG,NF,IERR)                   00016190
      IF(IERR.NE.0) STOP 3                                             00016200
      DO 3 I=NB,1,-1                                                   00016210
        B=ARG(I)                                                       00016220
        BB=B*B                                                         00016230
        EXACT=B/(A*A+B*B)                                              00016240
        ABSERR=DABS(FILT(I)-EXACT)                                     00016250
          RELERR=ABSERR/(EXACT+1.7D-38)                                00016260
          WRITE(6,66) J,I,B,A,EXACT,FILT(I),ABSERR,RELERR,NF           00016270
        NF=0                                                           00016280
  3   CONTINUE                                                         00016290
      WRITE(6,68)                                                      00016300
```

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   68 FORMAT('1')                                          00016310
      CALL EXIT                                            00016320
      END                                                  00016330
      REAL*8 FUNCTION C1(X)                                00016340
C--KERNEL FUNCTION FOR INTEGRAL 1.                         00016350
      IMPLICIT REAL*8 (A-H,O-Z)                            00016360
      COMMON/PASS/A,AA                                     00016370
      C1=X*DEXP(-AA*X*X)                                   00016380
        RETURN                                             00016390
      END                                                  00016400
      REAL*8 FUNCTION C2(X)                                00016410
C--KERNEL FUNCTION FOR INTEGRAL 2.                         00016420
      IMPLICIT REAL*8 (A-H,O-Z)                            00016430
      COMMON/PASS/A,AA                                     00016440
      C2=X/(AA+X*X)                                        00016450
        RETURN                                             00016460
      END                                                  00016470
      REAL*8 FUNCTION C3(X)                                00016480
C--KERNEL FUNCTION FOR INTEGRAL 3.                         00016490
      IMPLICIT REAL*8 (A-H,O-Z)                            00016500
      COMMON/PASS/A,AA                                     00016510
      C3=DEXP(-A*X)                                        00016520
        RETURN                                             00016530
      END                                                  00016540
$
```