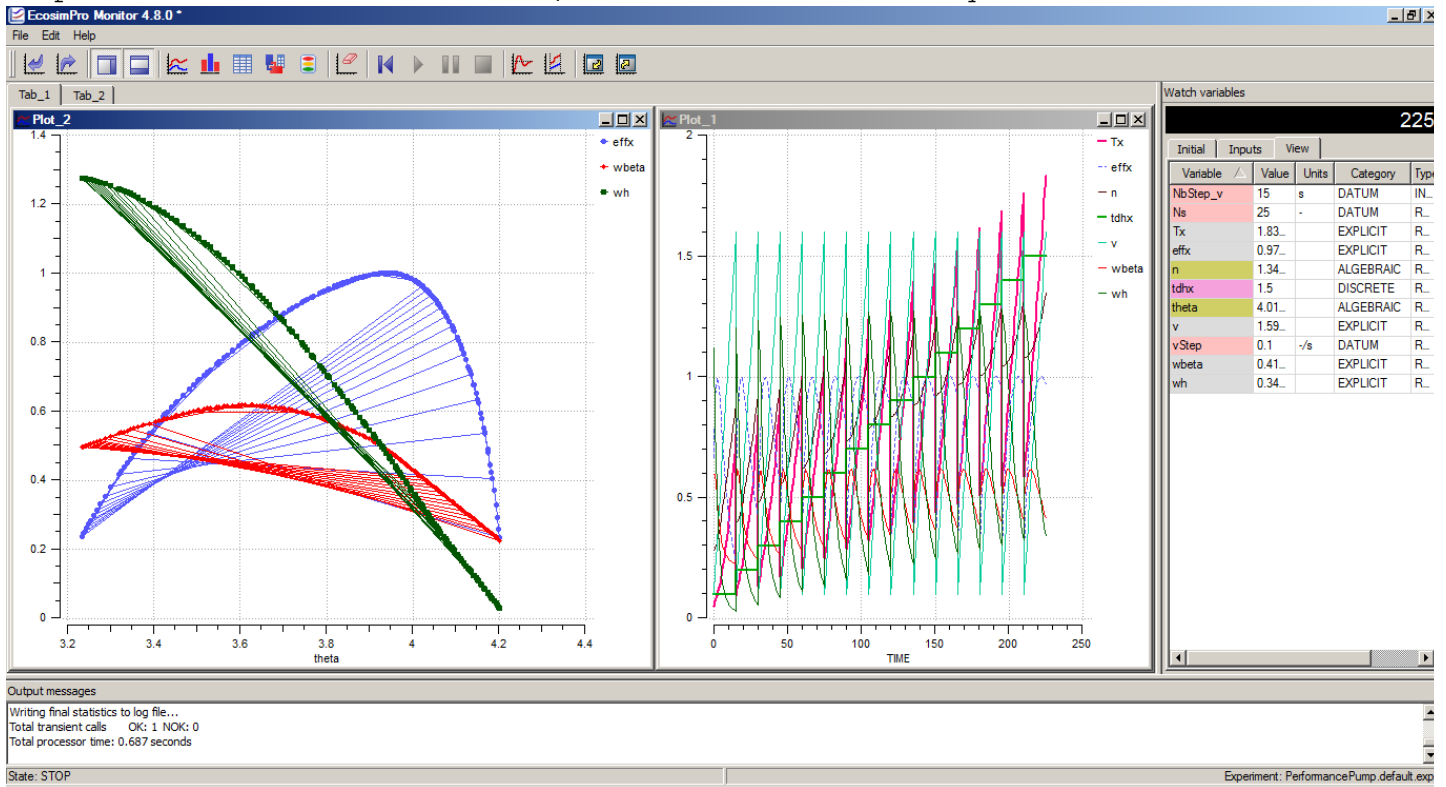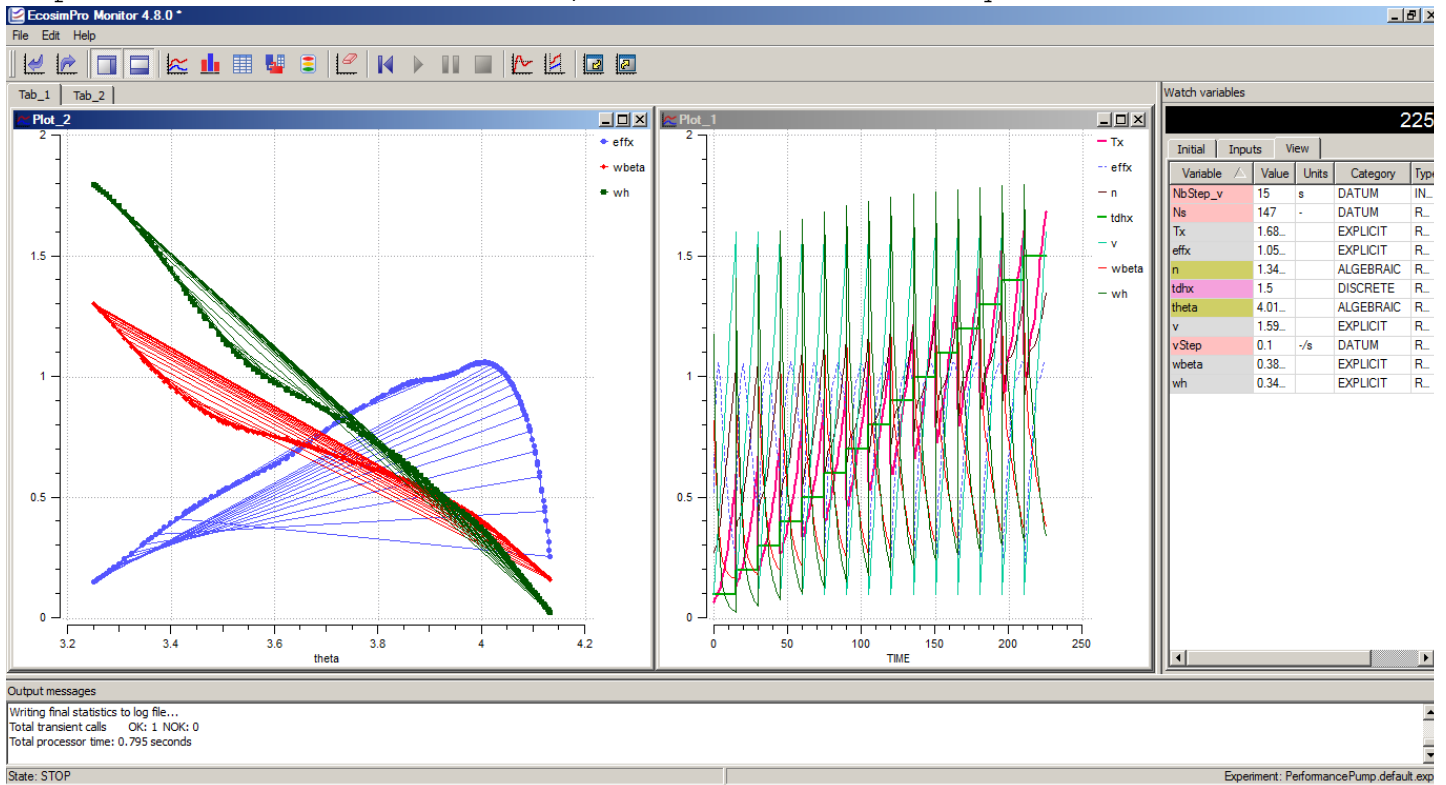FLUID TRANSIENTS IN SYSTEMS, Pumps

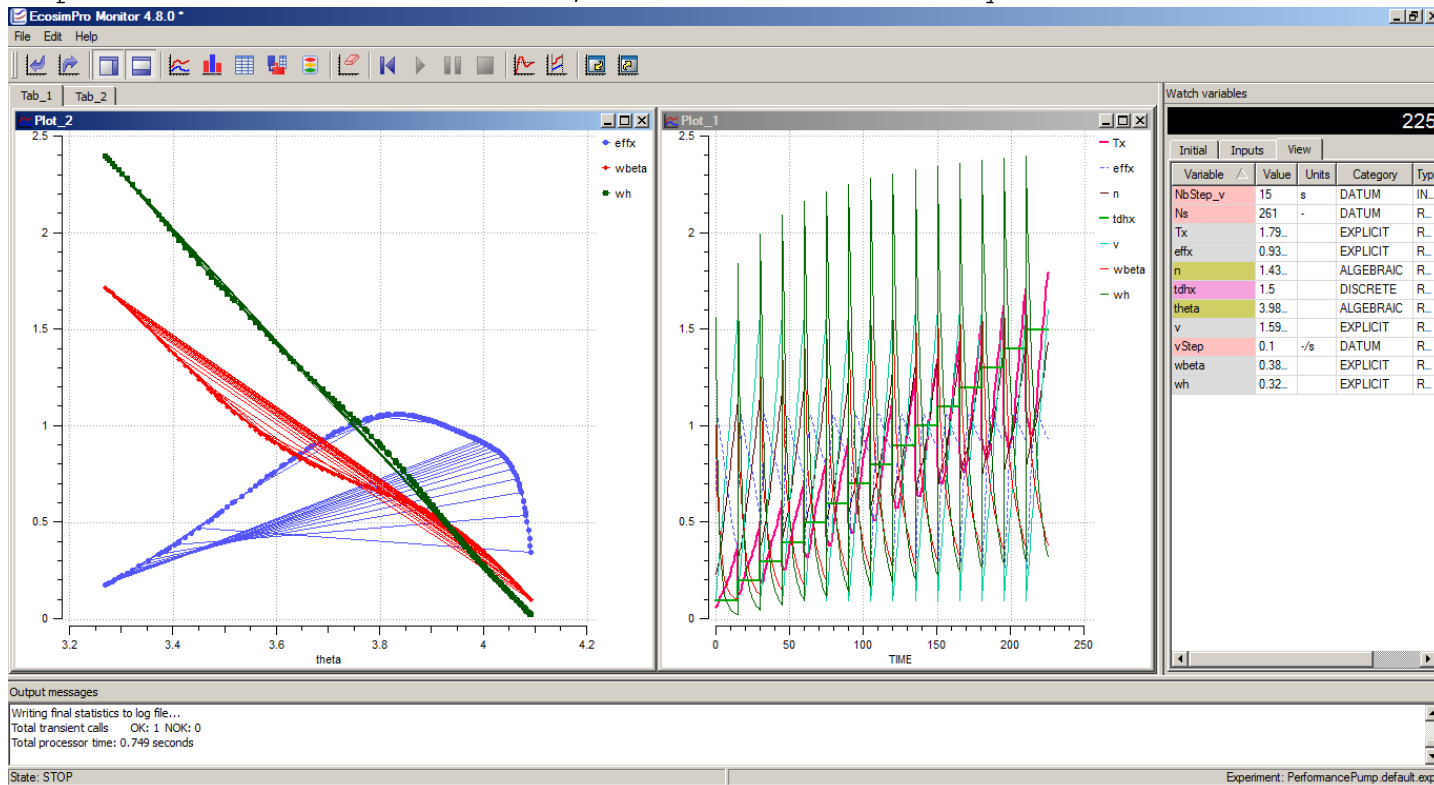Outputs of the tables for Ns=25 wh, wbeta and effx efficiency normalised

Outputs of the tables for Ns=147 wh, wbeta and effx efficiency normalised
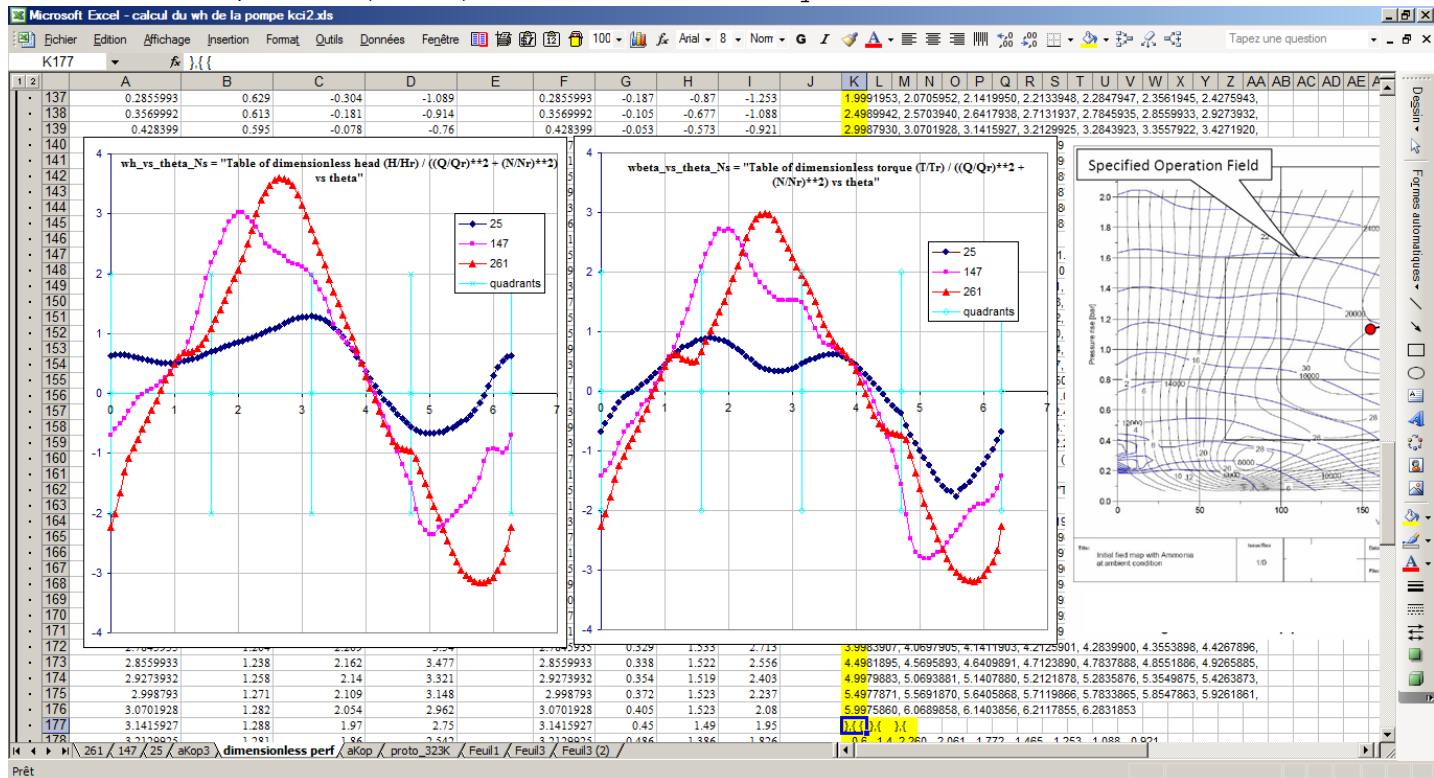
Outputs of the tables for Ns=261 wh, wbeta and effx efficiency normalised

Full curves wh, wbeta (theta) for 3 Ns for each quadrants

USE MATH
FUNCTION NO_TYPE FunctionTablePumps(INTEGER Type,REAL phi, OUT REAL psi, OUT REAL cplus, REAL Ns,REAL theta, OUT REAL wh, OUT REAL wbeta)
   Listings 5.15, June 07, Copyright 1992-2007 Support@KopooS.com, Release   26 juil 2011 21:32:24
   --torque = cplus*rho*sh_in.omega**2
   --dP=rho*sh_in.omega**2*psi
   ---- for Type=2 Calculation of wh, wbeta with v reduced flow; n reduced speed
   --torque = torque_r * (n**2+v**2) * wbeta

   -- tdh = tdh_r * (n**2+v**2) *wh
   --call with FunctionTablePumps(Type, phi, psi, cplus, Ns, theta, wh, wbeta)
   DECLS
   TABLE_1D psi_vs_phi = {{-0.0082,-0.000114651,-5.70322E-05,-3.76948E-05,-2.79266E-05,-2.19851E-05,
   -1.79555E-05,-1.50172E-05,-1.27594E-05,-1.09539E-05,-9.4633E-06,-8.2E-06,-7.10534E-06,-6.13844E-06,

```
  -5.26982E-06,-4.47754E-06,-3.74481E-06,-3.05844E-06,-2.40774E-
06,-1.7838E-06,-1.17898E-06,
  -5.86476E-07,3.80564E-13,5.86476E-07,1.17898E-06,1.7838E-
06,2.40774E-06,3.05844E-06,3.74482E-06,
  4.47754E-06,5.26982E-06,6.13844E-06,7.10534E-06,8.2E-
06,9.46331E-06,1.09539E-05,1.27594E-05,1.50172E-05,
  1.79555E-05,2.1985E-05,2.79266E-05,3.76948E-05,5.70322E-
05,0.000114651,0.0082},

{2352.802353,0.482346756,0.126407686,0.05884385,0.034611154,0.0
23163111,0.01688478,0.013012038,

0.010515494,0.00880452,0.007603255,0.0067728,0.006113551,0.005
623638,0.005236627,0.004961053,

0.00478711,0.00466308,0.004572103,0.004479606,0.004410733,0.00
4381097,0.0043792,0.004377679,

0.00437256,0.004362097,0.004328356,0.0042874,0.00423649,0.0041
5775,0.004045174,0.003888799,

0.003672893,0.0034,0.002917621,0.002272134,0.001454023,0.00016
2836,-0.002009624,-0.004677166,
  -0.010923074,-0.025734776,-0.071009889,-0.330026661,-
1890.40189}} "Dp coeff.: Psi+ = f(Phi+ (m^3)) (m^2)"
  TABLE_1D Cplus_vs_phi = {{-0.0082,-0.000114651,-5.70322E-05,-
3.76948E-05,-2.79266E-05,-2.19851E-05,
  -1.79555E-05,-1.50172E-05,-1.27594E-05,-1.09539E-05,-9.4633E-
06,-8.2E-06,-7.10534E-06,-6.13844E-06,
  -5.26982E-06,-4.47754E-06,-3.74481E-06,-3.05844E-06,-2.40774E-
06,-1.7838E-06,-1.17898E-06,
  -5.86476E-07,3.80564E-13,5.86476E-07,1.17898E-06,1.7838E-
06,2.40774E-06,3.05844E-06,3.74482E-06,
  4.47754E-06,5.26982E-06,6.13844E-06,7.10534E-06,8.2E-
06,9.46331E-06,1.09539E-05,1.27594E-05,1.50172E-05,
  1.79555E-05,2.1985E-05,2.79266E-05,3.76948E-05,5.70322E-
05,0.000114651,0.0082},
  {0.034600035,6.94007E-06,1.74982E-06,7.76381E-07,4.32891E-
07,2.74472E-07,1.8636E-07,1.3201E-07,
  9.6205E-08,7.18395E-08,5.43789E-08,4.16E-08,3.17951E-
08,2.54655E-08,2.09126E-08,1.78108E-08,
  1.60013E-08,1.49907E-08,1.46856E-08,1.48301E-08,1.51876E-
08,1.62829E-08,0.000000018,1.95394E-08,
  2.123E-08,2.31249E-08,2.51568E-08,2.74754E-08,2.97789E-
08,3.20386E-08,3.42514E-08,3.63258E-08,
  3.82381E-08,4E-08,4.02945E-08,4.00965E-08,3.94126E-
08,3.72693E-08,2.85102E-08,1.21187E-08,
  -2.67092E-08,-1.42528E-07,-4.89791E-07,-2.46793E-06,-
0.014880015}} "Torque coeff.: C+ = f(Phi+ (m^3)) (m^5)"
  CONST TABLE_2D wh_vs_theta_Ns = \
  { { 25, 147, 261 },
  { 0.0000000, 0.0713998, 0.1427997, 0.2141995, 0.2855993,
0.3569992, 0.4283990,
  0.4997988, 0.5711987, 0.6425985, 0.7139983, 0.7853982,
0.8567980, 0.9281978,
  0.9995977, 1.0709975, 1.1423973, 1.2137972, 1.2851970,
1.3565968, 1.4279967,
  1.4993965, 1.5707963, 1.6421962, 1.7135960, 1.7849958,
1.8563957, 1.9277955,
  1.9991953, 2.0705952, 2.1419950, 2.2133948, 2.2847947,
2.3561945, 2.4275943,
  2.4989942, 2.5703940, 2.6417938, 2.7131937, 2.7845935,
2.8559933, 2.9273932,
  2.9987930, 3.0701928, 3.1415927, 3.2129925, 3.2843923,
3.3557922, 3.4271920,
  3.4985918, 3.5699917, 3.6413915, 3.7127913, 3.7841912,
3.8555910, 3.9269908,
  3.9983907, 4.0697905, 4.1411903, 4.2125901, 4.2839900,
4.3553898, 4.4267896,
  4.4981895, 4.5695893, 4.6409891, 4.7123890, 4.7837888,
4.8551886, 4.9265885,
  4.9979883, 5.0693881, 5.1407880, 5.2121878, 5.2835876,
5.3549875, 5.4263873,
  5.4977871, 5.5691870, 5.6405868, 5.7119866, 5.7833865,
5.8547863, 5.9261861,
  5.9975860, 6.0689858, 6.1403856, 6.2117855, 6.2831853
  },
  { { 0.634, 0.643, 0.646, 0.640, 0.629, 0.613, 0.595,
  0.575, 0.552, 0.533, 0.516, 0.505, 0.504, 0.510,
  0.512, 0.522, 0.539, 0.559, 0.580, 0.601, 0.630,
  0.662, 0.692, 0.722, 0.753, 0.782, 0.808, 0.832,
  0.857, 0.879, 0.904, 0.930, 0.959, 0.996, 1.027,
  1.060, 1.090, 1.124, 1.165, 1.204, 1.238, 1.258,
  1.271, 1.282, 1.288, 1.281, 1.260, 1.225, 1.172,
  1.107, 1.031, 0.942, 0.842, 0.733, 0.617, 0.500,
  0.368, 0.240, 0.125, 0.011, -0.102, -0.168, -0.255,
  -0.342, -0.423, -0.494, -0.556, -0.620, -0.655, -0.670,
  -0.670, -0.660, -0.655, -0.640, -0.600, -0.570, -0.520,
  -0.470, -0.430, -0.360, -0.275, -0.160, -0.040, 0.130,
```

```
  0.295, 0.430, 0.550, 0.620, 0.634
  },
  { -0.690, -0.599, -0.512, -0.418, -0.304, -0.181, -0.078,
  -0.011, 0.032, 0.074, 0.130, 0.190, 0.265, 0.363,
  0.461, 0.553, 0.674, 0.848, 1.075, 1.337, 1.629,
  1.929, 2.180, 2.334, 2.518, 2.726, 2.863, 2.948,
  3.026, 3.015, 2.927, 2.873, 2.771, 2.640, 2.497,
  2.441, 2.378, 2.336, 2.288, 2.209, 2.162, 2.140,
  2.109, 2.054, 1.970, 1.860, 1.735, 1.571, 1.357,
  1.157, 1.016, 0.927, 0.846, 0.744, 0.640, 0.500,
  0.374, 0.191, 0.001, -0.190, -0.384, -0.585, -0.786,
  -0.972, -1.185, -1.372, -1.500, -1.940, -2.160, -2.290,
  -2.350, -2.350, -2.230, -2.200, -2.130, -2.050, -1.970,
  -1.895, -1.810, -1.730, -1.600, -1.420, -1.130, -0.950,
  -0.930, -0.950, -1.000, -0.920, -0.690
  },
  { -2.230, -2.000, -1.662, -1.314, -1.089, -0.914, -0.760,
  -0.601, -0.440, -0.284, -0.130, 0.055, 0.222, 0.357,
  0.493, 0.616, 0.675, 0.680, 0.691, 0.752, 0.825,
  0.930, 1.080, 1.236, 1.389, 1.548, 1.727, 1.919,
  2.066, 2.252, 2.490, 2.727, 3.002, 3.225, 3.355,
  3.475, 3.562, 3.604, 3.582, 3.540, 3.477, 3.321,
  3.148, 2.962, 2.750, 2.542, 2.354, 2.149, 1.909,
  1.702, 1.506, 1.310, 1.131, 0.947, 0.737, 0.500,
  0.279, 0.082, -0.112, -0.300, -0.505, -0.672, -0.797,
  -0.872, -0.920, -0.949, -0.960, -1.080, -1.300, -1.500,
  -1.700, -1.890, -2.080, -2.270, -2.470, -2.650, -2.810,
  -2.950, -3.040, -3.100, -3.150, -3.170, -3.170, -3.130,
  -3.070, -2.960, -2.820, -2.590, -2.230
  }
  }
  } "Table of dimensionless head (H/Hr) / ((Q/Qr)**2 + (N/Nr)**2) vs
theta"
  CONST TABLE_2D wbeta_vs_theta_Ns = \
  { { 25, 147, 261 },
  { 0.0000000, 0.0713998, 0.1427997, 0.2141995, 0.2855993,
0.3569992, 0.4283990,
  0.4997988, 0.5711987, 0.6425985, 0.7139983, 0.7853982,
0.8567980, 0.9281978,
  0.9995977, 1.0709975, 1.1423973, 1.2137972, 1.2851970,
1.3565968, 1.4279967,
  1.4993965, 1.5707963, 1.6421962, 1.7135960, 1.7849958,
1.8563957, 1.9277955,
  1.9991953, 2.0705952, 2.1419950, 2.2133948, 2.2847947,
2.3561945, 2.4275943,
  2.4989942, 2.5703940, 2.6417938, 2.7131937, 2.7845935,
2.8559933, 2.9273932,
  2.9987930, 3.0701928, 3.1415927, 3.2129925, 3.2843923,
3.3557922, 3.4271920,
  3.4985918, 3.5699917, 3.6413915, 3.7127913, 3.7841912,
3.8555910, 3.9269908,
  3.9983907, 4.0697905, 4.1411903, 4.2125901, 4.2839900,
4.3553898, 4.4267896,
  4.4981895, 4.5695893, 4.6409891, 4.7123890, 4.7837888,
4.8551886, 4.9265885,
  4.9979883, 5.0693881, 5.1407880, 5.2121878, 5.2835876,
5.3549875, 5.4263873,
  5.4977871, 5.5691870, 5.6405868, 5.7119866, 5.7833865,
5.8547863, 5.9261861,
  5.9975860, 6.0689858, 6.1403856, 6.2117855, 6.2831853
  },
  { { -0.684, -0.547, -0.414, -0.292, -0.187, -0.105, -0.053,
  -0.012, 0.042, 0.097, 0.156, 0.227, 0.300, 0.371,
  0.444, 0.522, 0.596, 0.672, 0.738, 0.763, 0.797,
  0.837, 0.865, 0.883, 0.886, 0.877, 0.859, 0.838,
  0.804, 0.758, 0.703, 0.645, 0.583, 0.520, 0.454,
  0.408, 0.370, 0.343, 0.331, 0.329, 0.338, 0.354,
  0.372, 0.405, 0.450, 0.486, 0.520, 0.552, 0.579,
  0.603, 0.616, 0.617, 0.606, 0.582, 0.546, 0.500,
  0.432, 0.360, 0.288, 0.214, 0.123, 0.037, -0.053,
  -0.161, -0.248, -0.314, -0.372, -0.580, -0.740, -0.880,
  -1.000, -1.120, -1.250, -1.370, -1.490, -1.590, -1.660,
  -1.690, -1.770, -1.650, -1.590, -1.520, -1.420, -1.320,
  -1.230, -1.100, -0.980, -0.820, -0.684
  },
  { -1.420, -1.328, -1.211, -1.056, -0.870, -0.677, -0.573,
  -0.518, -0.380, -0.232, -0.160, 0.000, 0.118, 0.308,
  0.442, 0.574, 0.739, 0.929, 1.147, 1.370, 1.599,
  1.839, 2.080, 2.300, 2.480, 2.630, 2.724, 2.687,
  2.715, 2.688, 2.555, 2.434, 2.288, 2.110, 1.948,
  1.825, 1.732, 1.644, 1.576, 1.533, 1.522, 1.519,
  1.523, 1.523, 1.490, 1.386, 1.223, 1.048, 0.909,
  0.814, 0.766, 0.734, 0.678, 0.624, 0.570, 0.500,
  0.407, 0.278, 0.146, 0.023, -0.175, -0.379, -0.585,
  -0.778, -1.008, -1.277, -1.560, -2.070, -2.480, -2.700,
  -2.770, -2.800, -2.800, -2.760, -2.710, -2.640, -2.540,
  -2.440, -2.340, -2.240, -2.120, -2.000, -1.940, -1.900,
  -1.900, -1.850, -1.750, -1.630, -1.420
  },
```

{
-2.260, -2.061, -1.772, -1.465, -1.253, -1.088, -0.921,
-0.789, -0.632, -0.457, -0.300, -0.075, 0.052, 0.234,
0.425, 0.558, 0.630, 0.621, 0.546, 0.525, 0.488,
0.512, 0.660, 0.850, 1.014, 1.162, 1.334, 1.512,
1.683, 1.886, 2.105, 2.325, 2.580, 2.770, 2.886,
2.959, 2.979, 2.962, 2.877, 2.713, 2.556, 2.403,
2.237, 2.080, 1.950, 1.826, 1.681, 1.503, 1.301,
1.115, 0.960, 0.840, 0.750, 0.677, 0.604, 0.500,
0.352, 0.161, -0.040, -0.225, -0.403, -0.545, -0.610,
-0.662, -0.699, -0.719, -0.730, -0.810, -1.070, -1.360,
-1.640, -1.880, -2.080, -2.270, -2.470, -2.650, -2.810,
-2.950, -3.040, -3.100, -3.150, -3.170, -3.200, -3.160,
-3.090, -2.990, -2.860, -2.660, -2.260
}
}

} "Table of dimensionless torque (T/Tr) / ((Q/Qr)**2 + (N/Nr)**2) vs theta"
 BODY
 IF Type==1 **THEN**
   -- Calculation of Psi+
   psi = linearInterp1D(psi_vs_phi,phi)
   -- Calculation of C+
   cplus = linearInterp1D(Cplus_vs_phi,phi)
   ELSE**IF** Type==2 **THEN**
   wh = splineInterp2D(wh_vs_theta_Ns, Ns, theta)
   wbeta = splineInterp2D(wbeta_vs_theta_Ns, Ns, theta)
 END IF
END FUNCTION

COMPONENT PerformancePump
 PORTS
 DATA
   REAL Ns=25 "Specific velocity 25 to 261 (-)"
   INTEGER Type=2 "2-Calculation of wh, wbeta with v reduced flow; n reduced speed (-)"
   REAL tdhStep=0.1 "increment on tdh for each loop (-)"
   REAL vStep=0.1 "increment on v for 1 second (-/s)"
   INTEGER NbStep_v=15 "total number of vStep for one value of tdh i.e. duration of one loop in s (s)"
 DECLS
   REAL phi, psi, cplus
   REAL wh, wbeta
   ALG REAL theta=4
   REAL v, n, Tx, effx, nn

   DISCR REAL tdhx=0
   DISCR REAL dvdt =0
   DISCR REAL t0=0
   INTEGER i=0
 TOPOLOGY
 INIT
 DISCRETE
   WHEN **TIME**==i*NbStep_v **THEN** *-- loop on tdh, discrete condition every whole period (s)*
       i=i+1
       tdhx=tdhx+tdhStep *-- increment tdh*
       dvdt=vStep *--slope = 1 step per second*
       t0=**TIME** *--to reset the local time: TIME-t0*
       n=0
       theta =4
       PRINT ("loop tdh done")
 END WHEN
 CONTINUOUS
   v= (**TIME**-t0)*dvdt + vStep *--loop on v, volume flow periodic*

   n**2+v**2= tdhx/wh *--tdhx=(n**2+v**2)*wh tdh normalised*
   n**2+v**2= Tx/wbeta *--Tx=(n**2+v**2)*wbeta T normalised*
   nn=abs(n)
   effx=tdhx*v/(nn*Tx) *--efficiency normalised (to be multiplied by the efficiency at rated condition)*
   theta=PI+atan2(v,nn)
   FunctionTablePumps(Type, phi, psi, cplus, Ns, theta, wh, wbeta)
   /*
   Table of performance in the 2D space Volume flow; Pressure rise, i.e. versus v and tdh
   for Type=2 Calculation of wh, wbeta with v reduced flow; n reduced speed
   tdhx reduced tdh = tdh/tdh_r ; Tx reduced torque = torque/torque_r
   torque = torque_r * (n**2+v**2) * wbeta
   tdh = tdh_r * (n**2+v**2) *wh
   eff=Pressure*volflow/(omega*T) normalised to 1: effx=tdhx*v/(n*Tx)
   */
END COMPONENT

EXPERIMENT exp1 ON PerformancePump.default
DECLS
INIT
-- initial values for algebraics
theta =4
BOUNDS
-- Set equations for boundaries: boundVar = f(TIME;...)
phi = 0
BODY
-- report results in file reportAll.rpt
REPORT_TABLE("reportAll.rpt", "*")
Ns=261 *--"Specific velocity 25 to 261 (-)" --261 --147 --25*
Type=2 *--"2-Calculation of wh, wbeta with v reduced flow; n reduced speed (-)"*

tdhStep=0.1 *-- "increment on tdh for each loop (-)"*
vStep=0.1 *--"increment on v for 1 second (-/s)"*
NbStep_v=15 *--"total number of vStep for one value of tdh i.e. duration of one loop in s (-)"*
-- integrate the model 15 seconds and obtain results every 0.1 seconds
TIME = 0
TSTOP = 225-1e-6
CINT = 1
ABS_ERROR=1E-6
REL_ERROR=ABS_ERROR
--REPORT_MODE=IS_STEP -- REPORT_MODE=IS_EVENT,IS_CINT,IS_STEP
INTEG()
END EXPERIMENT

FLUID TRANSIENTS IN SYSTEMS
Wylie and Streeter

    This disk contains programs referred to in the textbook,
FLUID TRANSIENTS IN SYTEMS, by E. B. Wylie and V. L Streeter,
Prentice Hall, Inc., 1993.

    The codes are presented for the educational benefit of the
users of the book. With the exception of GRAF.BAS the programs
are written in FORTRAN and are designed to run on an IBM-
compatible personal computer using a FORTRAN compiler. It is
assumed that the user has a fundamental knowledge and
understanding of FORTRAN programming in order to successfully use
the codes. It is necessary to generate an executable (.EXE) file
to actually run any of the programs included in the disk. This
means a compiler is needed to generate an .OBJ code, which then
has to be linked with FORTRAN.LIB to produce the .EXE file. All
source files are called xxx.FOR, data files are called xxx.DAT,
output files are called xxx.OUT, and data for graphing are stored
in xxx.GRF.

    The objective in producing these programs and in supplying
them in this disk is to facilitate understanding of the theory
provided in the book. Thus, the codes do not contain error
messages, nor are they particularly user friendly. Users are
encouraged to modify the programs to suit their needs.

                          DISCLAIMER

    The authors make no warranties as to the contents of the
software. Although every effort has been made to ensure that the
programs are accurate and reliable, no responsibility is assumed
for results generated through the use of these computer codes.
That is, no warranty, expressed or implied, is made as to the
accuracy of these programs. Neither the authors nor the
publishers can be held responsible for any damages suffered as a
result of the use of the computer codes.

    E. B. Wylie
    Department of Civil and Environmental Engineering
    The University of Michigan
    Ann Arbor, Michigan 48109-2125

    June, 1992
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