SpatialAnalyzer Geometry Fitting Test

The National Institute of Standard and Technology has created a touchstone dataset for many of the common geometry fitting operations. These data sets contain XYZ values and the corresponding geometric parameters for the least-squares best-fit geometry. The algorithms used by NIST are described in detail in the attached paper, "*Least-Squares Fitting Algorithms of the NIST Algorithm Testing System*" (Journal of Research of the NIST, Volume 103, Number 6, 1998).

New River Kinematics uses these data sets to verify the performance of the fitting algorithms used in the SpatialAnalyzer metrology platform. The results of the comparisons are listed below. All of the results presented here were created by fitting directly to the NIST data sets without a user-defined guess. This means that the guess algorithms of SpatialAnalyzer were able to properly discern the initial conditions necessary to avoid local minima.

Since the form of the geometric description used by SA differs slightly from that used by NIST, and neither is completely unique, it is necessary to compare the results after the fact to determine correspondence. A best-fit line, for example is specified by NIST using a point on the line. This point could be anywhere on the line. For this reason, we compare the SA point on the line to the line defined by NIST.

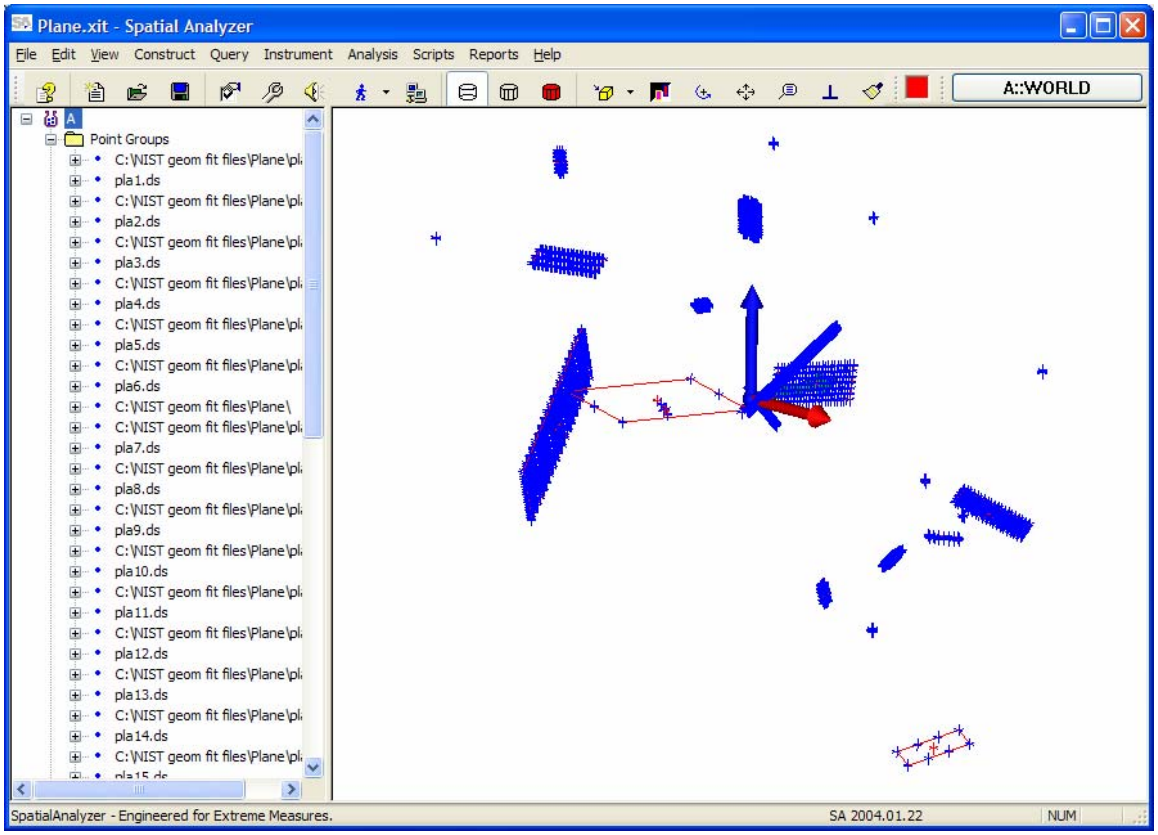
The NIST test data is provided in an attachment to this report along with the SpatialAnalyzer XIT files containing the imported data. The names in the results tables below match the filenames of the XYZ values provided by NIST. Pla27.ds, for example, contains the XYZ data used for Plane fit test #27.

SpatialAnalyzer matches the touchstone quite well. There are several cases (noted below the tables) where there are slightly higher than normal angular discrepancies. In these specific cases, the geometries are extremely short along their axis and therefore insensitive to slight angular differences. Open the XIT files to see the test geometries for more information.

If you wish to run these tests on SA or try these data sets on other software packages, simply import the points in the ".ds" files (remember they are mm.), run the fits, and compare to the touchstone results. The results are contained in the corresponding ".fit" files. The format of the files is described in "Readme2-NIST-L2-reference.doc", attached with the data. You will need to do some basic analysis to compare the results given the representation differences.

If you have any questions about these tests, geometry fitting, or SpatialAnalyzer in general, contact support@kinematics.com

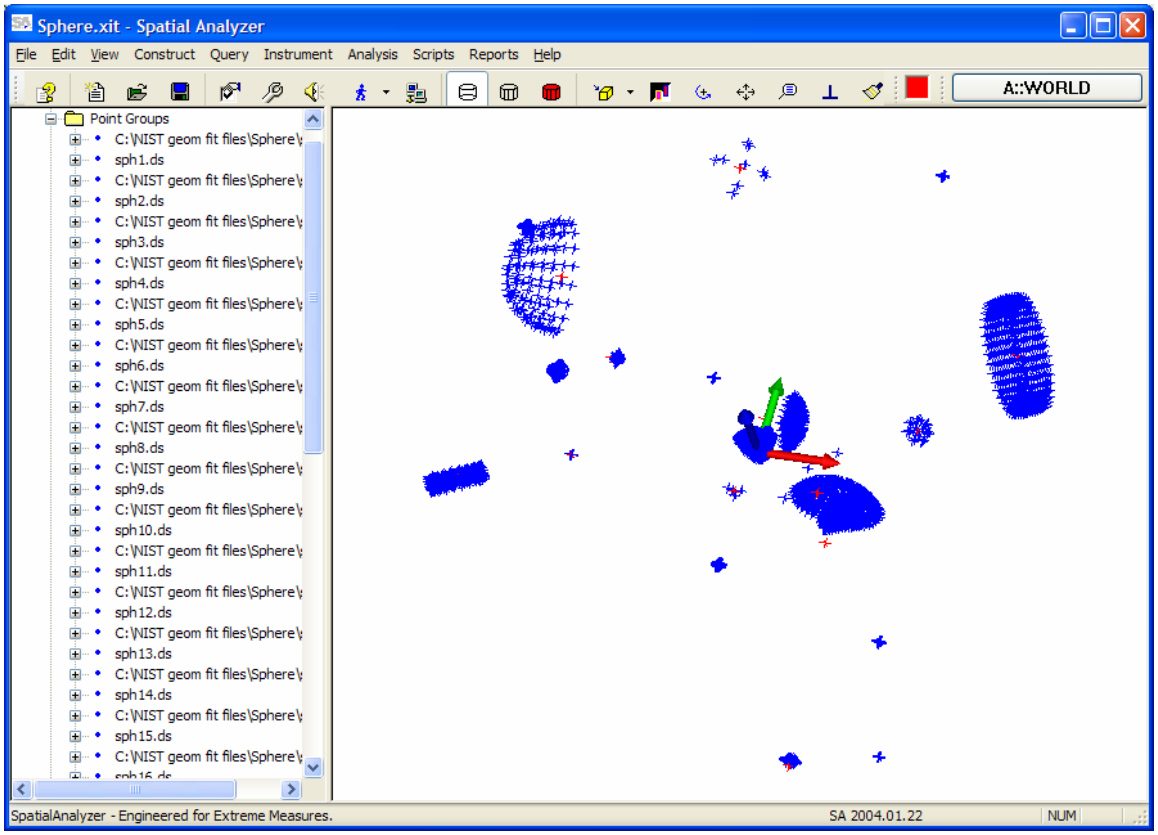
Plane:



-Set-	Pt to Plane Dist (mm)	Angle between Normals (deg)
pla1	0.000000000000	0.000000015671
pla10	0.000000000000	0.000000000002
pla11	0.000000000000	0.000000043730
pla12	0.000000000000	0.000000006553
pla13	0.000000000000	0.000000025687
pla14	0.000000000000	0.000000000016
pla15	0.000000000000	0.000000000013
pla16	0.000000000000	0.000000009262
pla17	0.000000000000	0.000000000015
pla18	0.000000000000	0.000000046193
pla19	0.000000000000	0.000000008146
pla2	0.000000000000	0.000000000033
pla20	0.000000000000	0.000000000165
pla21	0.000000000000	0.000000023609
pla22	0.000000000000	0.000000000013
pla23	0.000000000000	0.000000009110
pla24	0.000000000000	0.000000004563
pla25	0.000000000000	0.000000001152
pla26	0.000000000000	0.000000029094
pla27	0.000000000000	0.000000000386
pla28	0.000000000000	0.000000005371
pla29	0.000000000000	0.000000000031

pla3	0.000000000000	0.000000000439
pla30	0.000000000000	0.000000000000
pla4	0.000000000000	0.000000000000
pla5	0.000000000000	0.000000000048
pla6	0.000000000000	0.000000000240
pla7	0.000000000000	0.000000000000
pla8	0.000000000000	0.000000001769
pla9	0.000000000000	0.000000000112

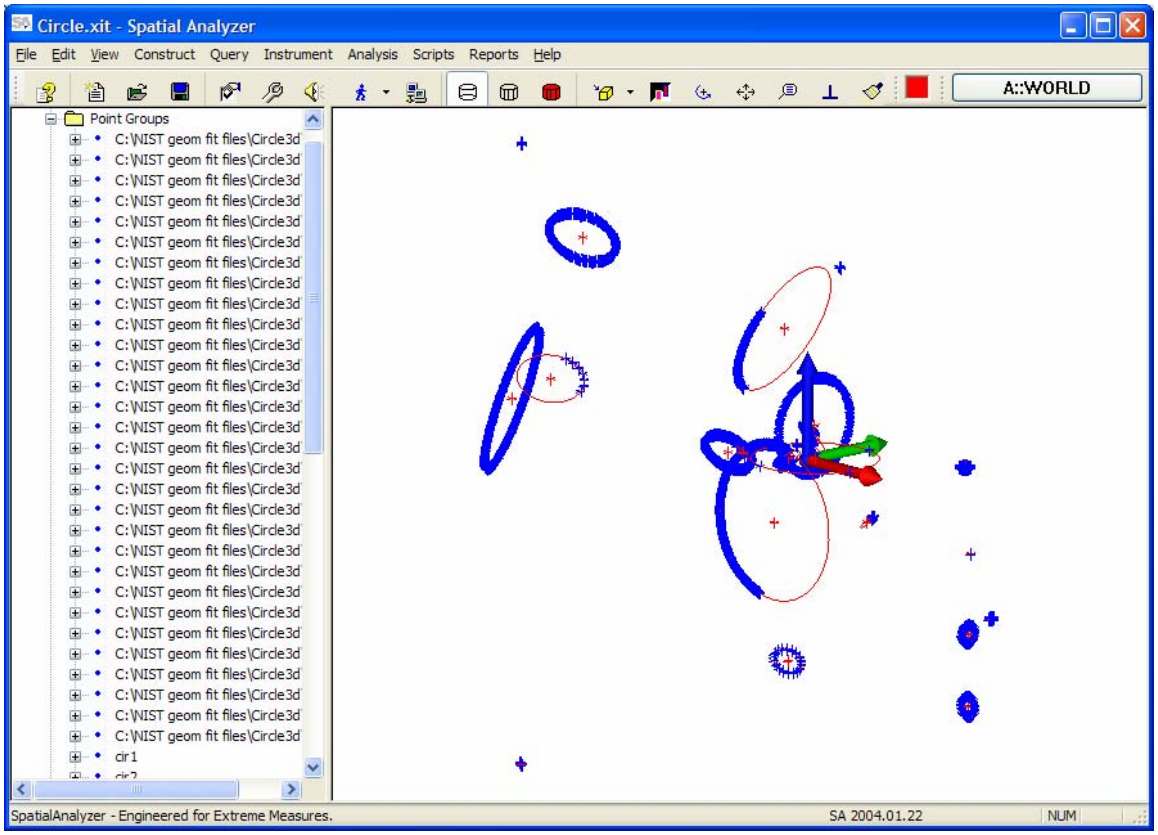
Sphere:



-Set-	Center to Center (mm)	Delta Diameter (mm)
sph1	0.000005034167	-0.000003319556
sph10	0.000000320061	-0.000000000021
sph11	0.000000001508	0.000000000000
sph12	0.000016626961	0.000012720193
sph13	0.000000268468	0.000000361786
sph14	0.000015697919	-0.000012378713
sph15	0.000001984292	0.000001707183
sph16	0.000000028260	0.000000041273
sph17	0.000001733788	0.000000921512
sph18	0.000007532418	-0.000003504083
sph19	0.000000039360	0.000000058265
sph2	0.000000044078	0.000000025474
sph20	0.000000145510	-0.000000016137
sph21	0.000001339831	0.000001191127
sph22	0.000000000008	0.000000000066
sph23	0.000000037269	0.000000033239
sph24	0.000000290357	0.000000191604
sph25	0.000001038469	0.000000710883
sph26	0.000000032678	0.000000025118
sph27	0.000000012819	-0.000000000031
sph28	0.000000327023	-0.000000536944
sph29	0.000000082085	-0.000000070655

sph3	0.000000294113	0.000000480868
sph30	0.000001895946	0.000000001367
sph4	0.000000328029	0.000000390468
sph5	0.000000840195	-0.000000861358
sph6	0.000000133973	-0.000000000028
sph7	0.000000008303	0.000000011774
sph8	0.000000041483	0.000000031211
sph9	0.000000000000	0.000000000000

Circle:



-Set-	Center to Center (mm)	Delta Diameter (mm)	Angle between Normals (deg)
cir1	0.000000137222	-0.000000000004	0.000019573345
cir10	0.000000123663	-0.000000000023	0.000000726004
cir11	0.000000000147	0.000000000000	0.000000000170
cir12	0.000000458219	0.000000000206	0.000126062332
cir13	0.000000025623	-0.000000000024	0.000005510357
cir14	0.000001705180	0.000000598347	0.000144540458
cir15	0.000188983035	-0.000012657891	0.000623653910
cir16	0.000000009639	0.000000000004	0.000000043281
cir17	0.000000132250	-0.000000001645	0.000096499904
cir18	0.000000122599	-0.000000000023	0.000165261039
cir19	0.000000219463	-0.000000000182	0.000000314515
cir2	0.000003835217	-0.000000234742	0.000063836980
cir20	0.000000960858	0.000000876422	0.000004416033
cir21	0.000604061448	0.000004451810	0.000237850395
cir22	0.000000000001	0.000000000003	0.000000000000
cir23	0.000000064653	0.000000000064	0.000000083888
cir24	0.000031967777	-0.000000369313	0.000027141271
cir25	0.000001256222	-0.000000012898	0.000050277599
cir26	0.000001664145	0.000000153415	0.000006037331
cir27	0.000000065667	0.000000000019	0.000000004032
cir28	0.000055845837	-0.000001928077	0.000107204555

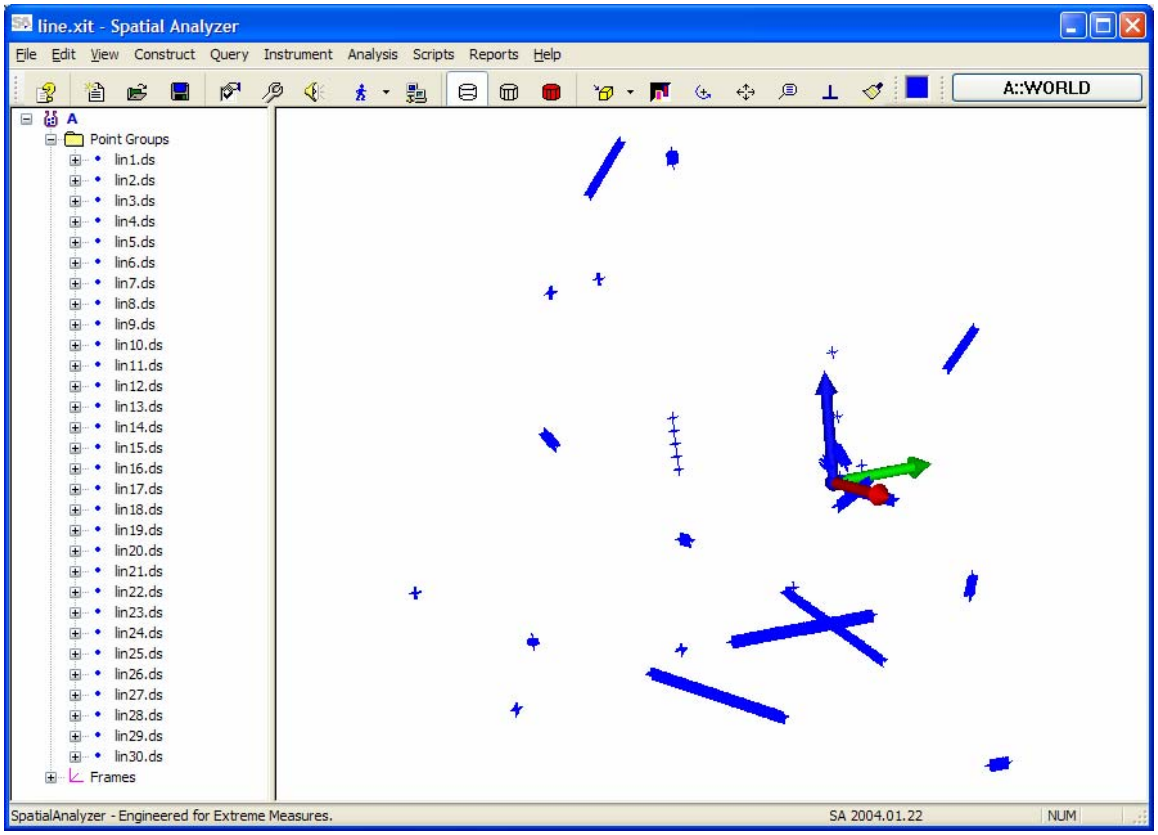
cir29	0.000000015456	-0.000000000004	0.000000131733
cir3	0.000084480035	0.000007421358	0.000042578226
cir30	0.000023555916	0.000000260612	0.000073866883
cir4	0.000001700217	-0.000000064070	0.000086532337
cir5	0.000005448298	-0.000004501581	0.000098014809
cir6	0.000000020904	-0.000000000023	0.000000078320
cir7	0.000000033814	0.000000007746	0.000002057536
cir8	0.000000010625	-0.000000005204	0.000000088771
cir9	0.000000000000	0.000000000000	0.000000000000

Note: NIST fitted with a 2-step process when creating the touchstone data:

> *A note on three-dimensional circles: There are two approaches to their least-squares fitting: 1) Fit the data to a least-squares plane, project the data onto that plane, then fit a circle to the projected points in a least-squares sense, or 2) perform a full-3d least-squares fit to the data, defining each residual distance as the shortest 3d distance from the data point to the curve. The fits here were done according to the first strategy, which is by far the most commonly used and in most measuring situations is the correct approach to use. We can also provide reference fits for the second method if needed.*
>
> *- Readme2-NIST-L2-reference.doc (readme for data sets)*

SpatialAnalyzer, however, performs a full, 3-D optimization on the entire circle data set. It matches number (2) in the above description.

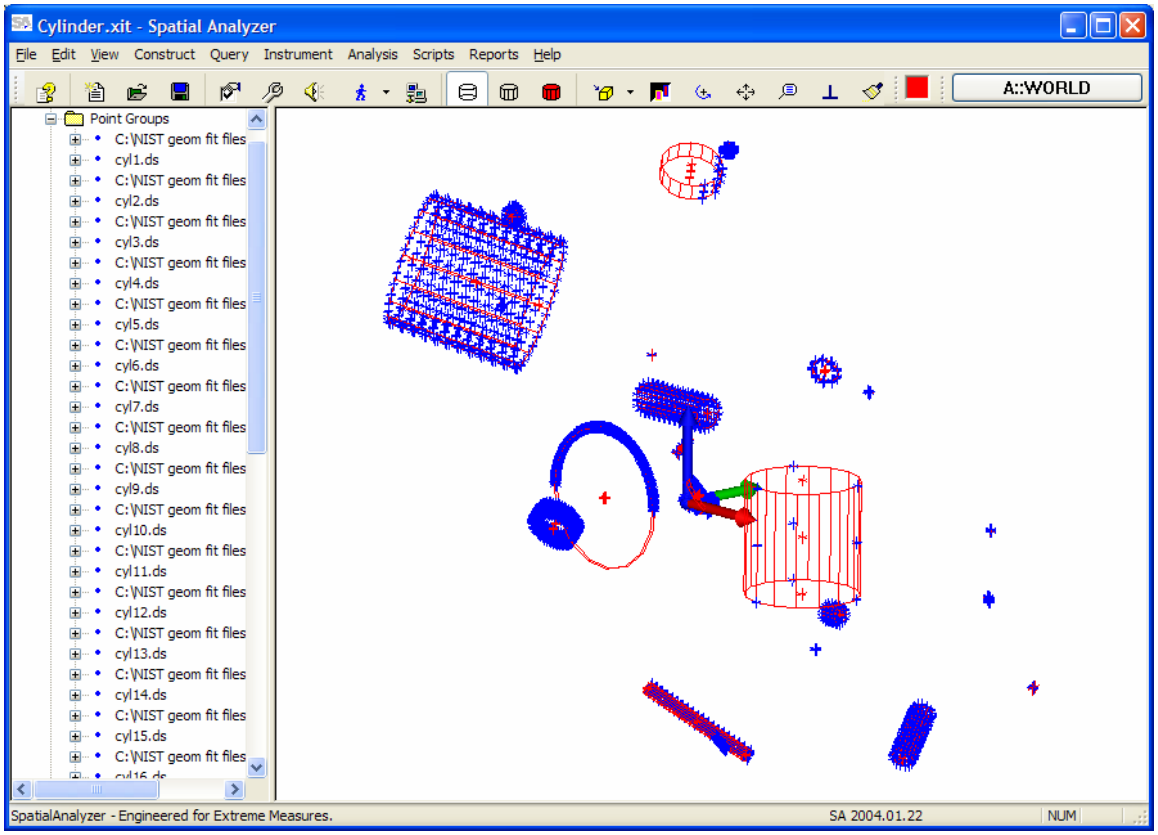
Line:



-Set-	Pt to Line Dist (mm)	Angle between Normals (deg)
lin1	0.00000000000000000	0.00026234516959000
lin10	0.00000000000000000	0.00000024368623000
lin11	0.00000000000000000	0.00000000230084000
lin12	0.00000000000000000	0.00005309733176000
lin13	0.00000000000000000	0.00000002254168000
lin14	0.00000002107342000	0.00244193133215000
lin15	0.00000000000000000	0.00009260238997000
lin16	0.00000000000000000	0.00000000033140000
lin17	0.00000000000000000	0.00231813459189000
lin18	0.00000000000000000	0.00021875747401000
lin19	0.00000000000000000	0.00000003260633000
lin2	0.00000000000000000	0.00000052191757000
lin20	0.00000000000000000	0.00003184984597000
lin21	0.00000000000000000	0.00004183841102000
lin22	0.00000000000000000	0.00000000000005000
lin23	0.00000000000000000	0.00000059338141000
lin24	0.00000134869915000	0.00000021299420000
lin25	0.00000000000000000	0.00001523913787000
lin26	0.00000000000000000	0.00000005244515000
lin27	0.00000000000000000	0.00000000006569000
lin28	0.00000000000000000	0.01959773725355000

lin29	0.00000000000000000	0.00000040430358000
lin3	0.00000000000000000	0.00025596171616000
lin30	0.00000000000000000	0.00007652593252000
lin4	0.00000000000000000	0.00022141555564000
lin5	0.00000000000000000	0.03847995527940000
lin6	0.00000000000000000	0.00000071985650000
lin7	0.00000002107342000	0.00000000097830000
lin8	0.00000008429370000	0.00000027287177000
lin9	0.00000000000000000	0.00000000000000000

Cylinder:



-Set-	Pt to Line Dist (mm)	Delta Diameter (mm)	Angle between Normals (deg)
cyl1	0.000000203277	-0.000000376748	0.000041083760
cyl10	0.000000022587	0.000000020605	0.000000049293
cyl11	0.000000968365	-0.000000786024	0.000075914699
cyl12	0.000000294770	-0.000000000029	0.000001178740
cyl13	0.000000054348	0.000000007926	0.000305828602
cyl14	0.000000006473	-0.000000000050	0.000000087233
cyl15	0.000000094209	0.000000000059	0.000088047799
cyl16	0.000002083374	-0.000003564950	0.000000675652
cyl17	0.000000004603	-0.000000000010	0.000000270604
cyl18	0.000056575010	0.000054492546	0.025393102900
cyl19	0.000011933034	-0.000020185273	0.000035719725
cyl2	0.000000004912	0.000000001003	0.000000120726
cyl20	0.000000003362	0.000000000001	0.000000000919
cyl21	0.000153775850	0.000046267480	0.013708054209
cyl22	0.000000031306	0.000000000019	0.000000001558
cyl23	0.000000085706	0.000000003717	0.000016371836
cyl24	0.000000155893	0.000000603526	0.048293864259
cyl25	0.000000001221	-0.000000001675	0.000020255601
cyl26	0.000000101239	-0.000000093735	0.000096946276
cyl27	0.000000000266	0.000000000147	0.000000010696
cyl28	0.000000187095	0.000001037677	0.000077445971

cyl29	0.000000008622	0.000000018883	0.000005906243
cyl3	0.000000001309	-0.000000018612	0.000077487237
cyl30	0.000000000000	-0.000000000002	0.000000000000
cyl4	0.000000000429	-0.000000002952	0.000000781284
cyl5	0.000001406761	-0.000004052050	0.000005913719
cyl6	0.000000186760	-0.000000473728	0.000021688901
cyl7	0.000000000023	-0.000000000143	0.000000000309
cyl8	0.000000054747	-0.000000056112	0.000007245684
cyl9	0.000000014338	-0.000000017128	0.000024103633

Note: Cyl 24 has a 0.048 deg difference. See the data set. This cylinder is 0.343 inches long. A 0.048 degree shift from the center to the end of the cylinder is 0.00014 inches.