PIPENET - Suter Curve for Turbo Pump

How to Estimate Suter Curve from Pump Performance Curve

1. Introduction

Typically, it is possible to obtain the performance curve for the pump in the positive quadrant without difficulty. In this quadrant both the flowrate and the head are positive. However, in order to model the behaviour of a pump in certain situations it is necessary to consider all four quadrants. In other words, both positive and negative values for the head and the flowrate need to be considered. However, this kind of data is often extremely difficult to obtain and even pump manufacturers do not generally have such data.

The classic text book called Fluid Transients by Wylie and Streeter outlines a technique based on the use of Suter Curves for modelling the behaviour of a pump in all four quadrants. It also gives the Suter Curves for a limited range of pumps. Nevertheless, unless pump data is available for all four quadrants, it is not possible to determine the Suter Curves for other pumps accurately.

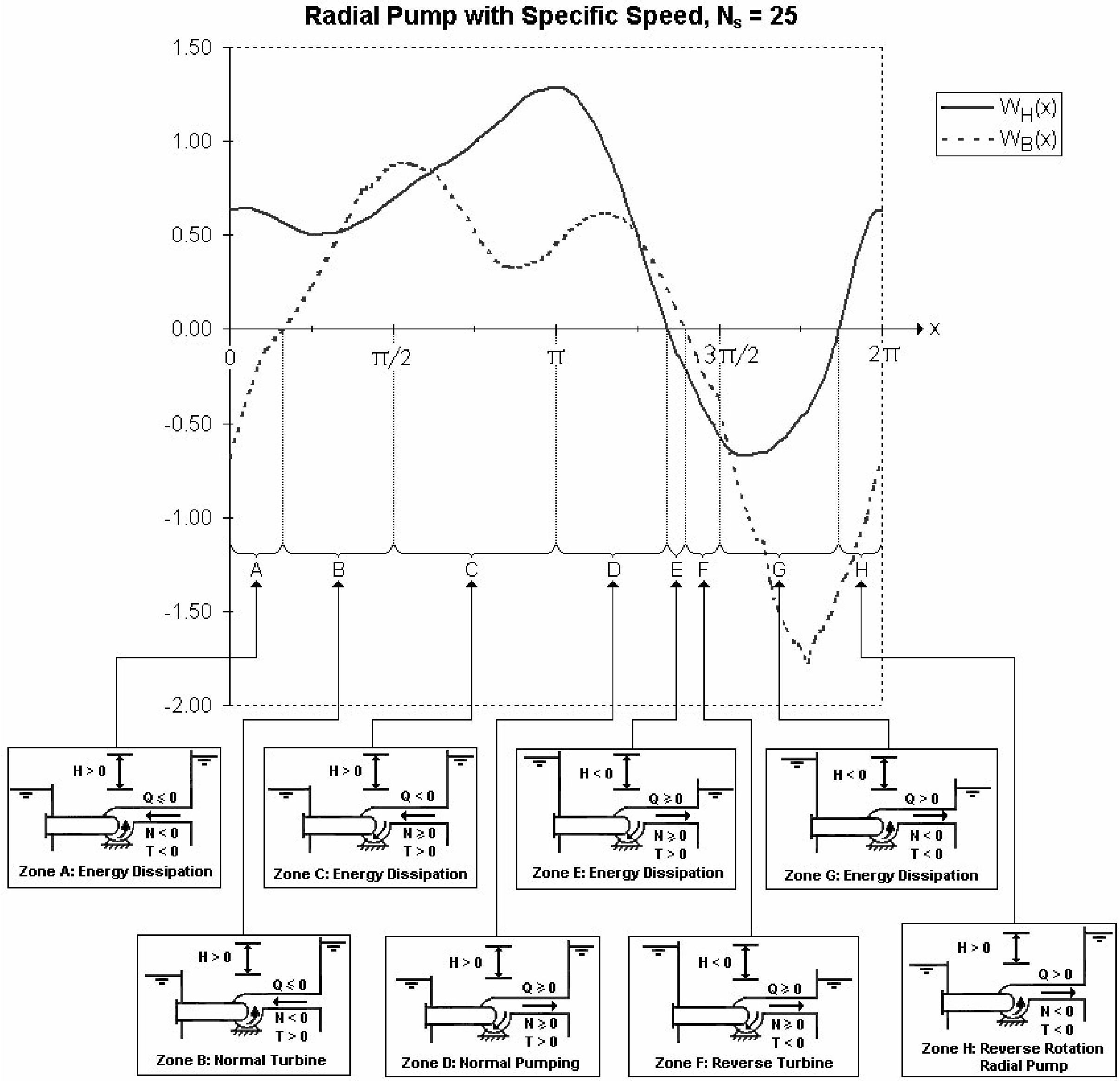
In this document we show how to use the PIPENET built-in Suter Curves and the known pump performance curve (in the positive quadrant) to achieve the following:

a. In the positive quadrant where the pump curve is known, the Suter Curve follows the pump curve
b. In the other three quadrants where the pump behaviour is not known we extrapolate the built-in curves

2. Background

During transient flow, a pump may experience a reversal in flow through the pump, or a change in its rotational speed, or both. Furthermore, it may also experience negative torque values and/or pressures during a transient event. Hence for accurate simulation of a Turbo pump, more performance data is needed and this should cover regions of abnormal operation. Suter curve graphically represents all operating status of turbo pump. A detailed description of the Suter Curve and the corresponding concepts and equations refers to the web site of Sunrise Systems Limited and the Transient Module Technical Manual, Chapter 1 – Modelling Aspects, page 16-19.

The figure shows typical Suter curves for a Radial Pump. A whole Suter curve should cover all four Quadrants, i.e. 0-2π phase angle. There are eight possible zones of pump operation: four occur during normal operation and four are abnormal zones. During a transient event, a pump may enter most, if not all, regions in the figure depending on the appropriate circumstances. However, not all manufactories can provide whole range Suter curves. In most cases only the information at the normal operating condition can be obtained, i.e. Zone D in the above figure. Now the key question is "Is it possible to deduce a whole range Suter curve reasonably in this case?" This document introduces a simple way to solve this problem.

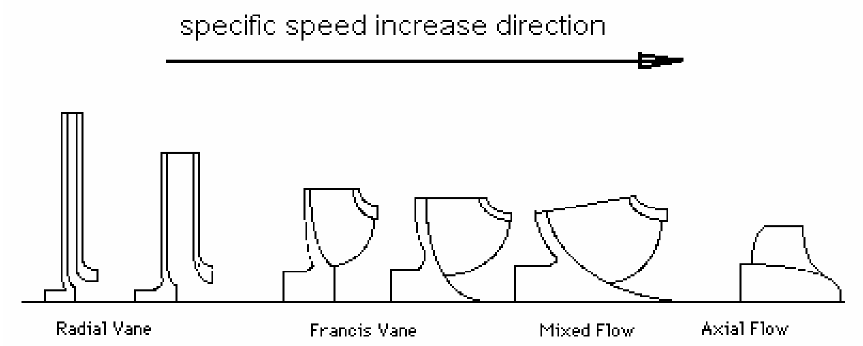


3. Methodology

It is well known that Pumps are traditionally divided into three types: radial pump, mixed pump and axial pump. The classification is tightly relative with specific speed (Ns), see the equation and the figure below:

$$Ns = \frac{N_R \sqrt{Q_R}}{H_R^{0.75}} \qquad (1)$$

Ns: specific speed
N_R: rated pump speed, rpm
Q_R: rated pump flowrate, m^3/s
H_R: rated pump piezometric head, m



Three built-in Suter curves represent three typical pumps: (1) Radial Pump @ Ns=25, (2) Mixed Pump @ Ns=147 and (3) Axial Pump @ Ns=261. Please notice their units when using the above equation to calculate specific speed. In order to supply the lack part of Suter curve for a certain pump, we must base on these three built-in Suter curves and make some assumptions.

- Assumption 1: a specific speed is only mapped to a pump type and the value shift from radial pump to axial pump is continual and uninterrupted.
- Assumption 2: a Suter curve is only match with a pump type and the shift from radial pump to axial pump is continual and uninterrupted.
- Assumption 3: any Suter curve between the two built-in Suter curves has a linear relationship with the specific speeds.

In the next section, we will show the method by an instance.

4. Example 1 – Deduce Suter Curve from a known P-Q curve

In this section we should how to derive the Suter Curve from the known performance curve in the positive quadrant. We also show that the Suter Curve derived in this manner follows the performance curve of the pump faithfully. The last table in this section compares the performance curve which we input and the results obtained from the corresponding Suter Curve.

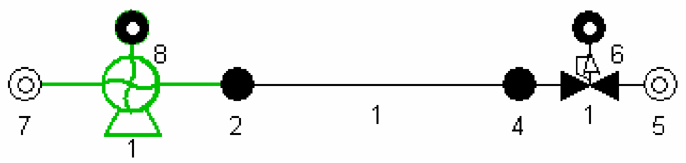
- The known parameters:
  $H_R = 47.5$ m
  $Q_R = 42840$ m^3/hr
  $N_R = 6.16667$ 1/s = 370 rpm
  $T_R = 164$ KN.m
  I = 11530 kg.m^2

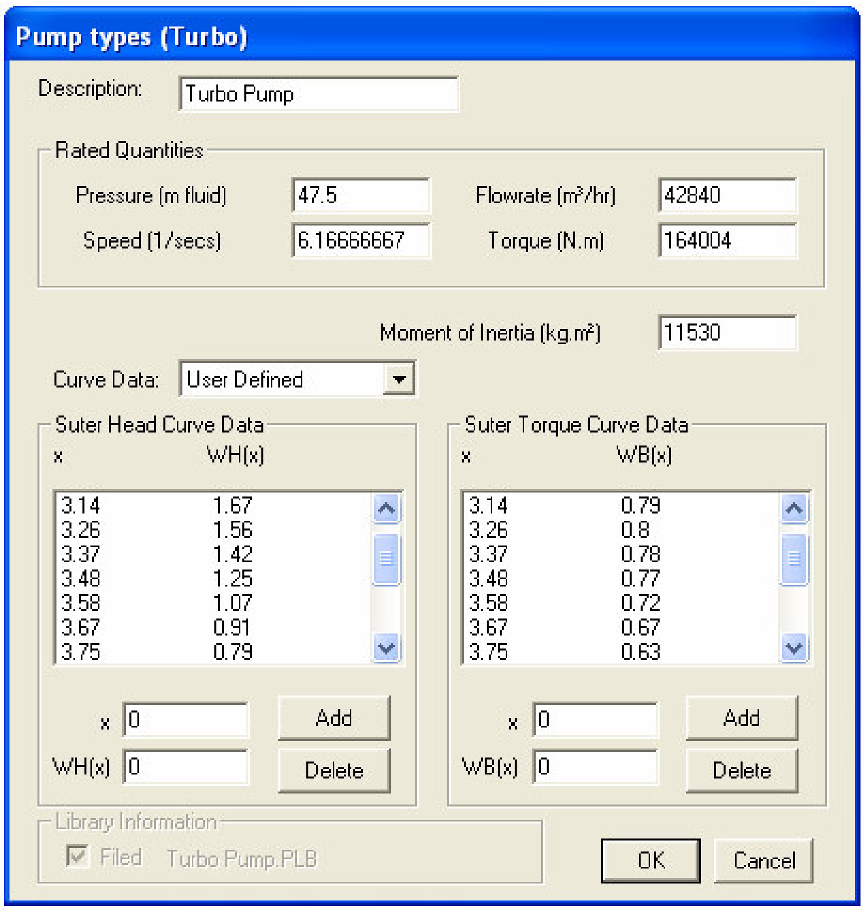
Turbo Pump Characteristic and Suter Curve

Q_R	Q	ν	H_R	H	h	N_R	α	η	P	T_R	T	β	$\alpha^2+\nu^2$	W_H	W_B	x
m^3/h			m			rpm		%	KW	KN.m						
42840	0.00	0.00	47.50	79.50	1.67	370	1.00	0.0%	5007	164.0	129.2	0.79	1.00	1.67	0.79	3.14
42840	5000	0.12	47.50	75.20	1.58	370	1.00	20.5%	5126	164.0	132.3	0.81	1.01	1.56	0.80	3.26
42840	10000	0.23	47.50	71.1	1.50	370	1.00	38.0%	5229	164.0	135.0	0.82	1.05	1.42	0.78	3.37
42840	15000	0.35	47.50	66.6	1.40	370	1.00	51.0%	5475	164.0	141.3	0.86	1.12	1.25	0.77	3.48
42840	20000	0.47	47.50	61.7	1.30	370	1.00	62.0%	5563	164.0	143.6	0.88	1.22	1.07	0.72	3.58
42840	25000	0.58	47.50	58.2	1.23	370	1.00	71.0%	5728	164.0	147.8	0.90	1.34	0.91	0.67	3.67
42840	30000	0.70	47.50	56	1.18	370	1.00	79.0%	5944	164.0	153.4	0.94	1.49	0.79	0.63	3.75
42840	35000	0.82	47.50	54.3	1.14	370	1.00	85.4%	6220	164.0	160.5	0.98	1.67	0.69	0.59	3.83
42840	40000	0.93	47.50	50.8	1.07	370	1.00	89.1%	6374	164.0	164.5	1.00	1.87	0.57	0.54	3.89
42840	42840	1.00	47.50	47.5	1.00	370	1.00	89.5%	6355	164.0	164.0	1.00	2.00	0.50	0.50	3.93
42840	45000	1.05	47.50	44.6	0.94	370	1.00	88.6%	6331	164.0	163.4	1.00	2.10	0.45	0.47	3.95
42840	50400	1.18	47.50	37	0.78	370	1.00	82.8%	6295	164.0	162.5	0.99	2.38	0.33	0.42	4.01

- Scenario:

The test-bed for checking that the Suter Curve follows the pump performance curve in the positive quadrant is described here. (This pump performance curve is normally provided by the pump manufacturer.)





- Results:

In this section we show that the results from the test-bed follow the actual pump curve which was used to generate the Suter Curve.

We change the flowrate specification at the node 5 to check the relationship of the flow rate and pressure lift of the turbo pump. We can see the input data roughly equal to the calculated results, see the table below.

Flow Rate	m^3/h	0.00	5000	10000	15000	20000	25000	30000	35000	40000	42840	45000	50400
Input Lift	m	79.5	75.2	71.1	66.6	61.7	58.2	56.0	54.3	50.8	47.5	44.6	37.0
Calculated Lift	m	79.26	75.21	71.06	66.79	62.07	57.97	55.71	54.99	50.26	48	44.65	37.85
Error	%	-0.3%	0.0%	-0.1%	0.3%	0.6%	-0.4%	-0.5%	1.3%	-1.1%	1.1%	0.1%	2.3%

5. Example 2 - Deduce unknown Suter Curve from the known part

In this section we show how to extrapolate the built-in Suter Curves to the cases where the Suter Curve is not known. It is important to emphasise that this technique of extrapolating known data to unknown data, and it should be regarded as an approximation.

- The known parameters:
  H_R = 47.5 m
  Q_R = 42840 m^3/hr
  N_R = 6.16667 1/s = 370 rpm
  T_R = 164 KN.m
  I = 11530 kg.m^2

The known part of Suter curve

X	3.14	3.26	3.37	3.48	3.58	3.67	3.75	3.83	3.89	3.93	3.95	4.01
Wh	1.67	1.56	1.42	1.25	1.07	0.91	0.79	0.69	0.57	0.50	0.45	0.33
W_B	0.79	0.80	0.78	0.77	0.74	0.67	0.63	0.59	0.54	0.50	0.47	0.42

- The pseudo specific speeds at the boundaries:
  The real specific speed can be calculated by Equation 1, see the table below. The calculated pump (Ns=70.54) is between radial pump (Ns=25) and mixed pump (Ns=147). Therefore, the deduced Suter curve will be based on the data for these two built-in Suter curves.

Name	Symbol	Value	Unit
Rated pump speed	N_R	370	rpm
Rated pump flowrate	Q_R	11.90	m^3/s
Rated pump piezometric head	H_R	47.5	m
Specific speed	N_S	70.54	

From the known Suter curve, we can interpolate to obtain the pseudo specific speeds at the boundaries (X=3.14 and X=4.01), see the table below:

Boundaries	X	3.14	4.01
Built-in radial pump	Wh	1.288	0.35
	W_B	0.45	0.42
	Ns	25	25
Built-in mixed pump	Wh	1.97	0.348
	W_B	1.49	0.389
	Ns	147	147
The calculated pump	Wh	1.67	0.33
	Ns (Wh)	93.33	70.54
	W_B	0.79	0.42
	Ns (W_B)	64.88	70.54

For example, the pseudo specific speed for the head curve (Wh) at the boundary of X=3.14 can be calculated by:

$$Ns = 25 + \frac{1.67 - 1.288}{1.97 - 1.288} \times (147 - 25) = 93.33$$

However, at the boundary of X=4.01, the two built-in head curve is too close to use interpolation simply. Otherwise, it may cause great error. See the calculation below:

$$Ns = 25 + \frac{0.33 - 0.35}{0.348 - 0.35} \times (147 - 25) = 1245$$

The obtained value is ridiculously big. Therefore, we recommend the actual specific speed (70.54) in this case.

Now, we have obtained four pseudo specific speeds at two Suter curves boundaries, i.e. head curve (Wh) and torque curve (W_B). Next step, we will deduce a whole Suter curve for the calculated pump.

- A whole Suter curve:

First, we assume the specific speeds at the unknown zone linearly shift between the two abovementioned boundaries, i.e. phase angle from X=4.01 to X=3.14+2π. Here, 2π means pump curve get into next circle. For instance, the pseudo specific speed for head curve at the phase angle of 0 can be calculated by:

$$Ns = 93.33 + \frac{(0 + 2\pi) - 4.01}{(3.14 + 2\pi) - 4.01} \times (70.54 - 93.33) = 83.76$$

For instance again, the pseudo specific speed for head curve at the phase angle of 1.5π can be calculated by:

$$Ns = 93.33 + \frac{1.5\pi - 4.01}{(3.14 + 2\pi) - 4.01} \times (70.54 - 93.33) = 90.37$$

After getting the pseudo specific speeds at whole range phase angle (except the known zone), we can deduce the unknown part of Suter curve by the interpolated method, the following table show the calculating process at the phase angles of 0 and 1.5π.

Boundaries	X	0	1.5π
Built-in radial pump	Ns	25	25
	Wh	0.634	-0.556
Built-in mixed pump	Ns	147	147
	Wh	-0.69	-1.5
The calculated pump	Ns	83.76	90.37
	Wh	-0.004	-1.062

In detail, for the head curve @ X=0,

$$Wh = 0.634 + (-0.69 - 0.634) \times \frac{83.76 - 25}{147 - 25} = -0.004$$

6. Program

In this section we show how our spreadsheet program can be used for extrapolating the built-in Suter Curve to represent the actul pump.

Although the abovementioned method is not difficult to understand, the actual calculation is very enormous. Of course, this simple and repeated work can be done easily by computer. Therefore, a small program was written in Excel. The whole range Suter curve can be obtained just by inputting the boundaries conditions, i.e. the phase angles and the pseudo specific speeds at the start and end points of the known zone. However, the input pseudo specific speeds must be between 25 and 261 because the unacceptable error may be caused by external interpolation. The table below exhibits the calculated results for the above example. All needed input data is coloured in red and all known part of Suter curve is marked as “-“ respectively.

7. Summary

The steps to approach Suter curve are:

(1). Obtain the relative information from the manufactory, which include P-Q curve, pump speed curve, efficiency curve (or power curve), rated flow rate, head, speed and the total moment of inertia of the pump.

(2). Calculate the known part of Suter curve.

(3). Deduce the specific speed of the pump.

(4). Interpolate the pseudo specific speed at the ends of the known Suter curve.

(5). Input the deduced data, i.e. the pseudo specific speed and the corresponding phase angle, into the Excel program to get entire range Suter curve.

	Built-in Standard Suter Curve				Deduced Suter Curve			
	Phase Angle	Head Curve (Wh)			Input Data		Output Data	
No.	X	Ns=25	Ns=147	Ns=261	Start Point		Ns	Wh
0	**0.0000**	0.634	-0.690	-2.230	X	3.140	79.827	**0.039**
1	**0.0714**	0.643	-0.599	-2.000	Wh	1.67	80.089	**0.082**
2	**0.1428**	0.646	-0.512	-1.662	Ns	91.3	80.350	**0.121**
3	**0.2142**	0.640	-0.418	-1.314	End Point		80.612	**0.158**
4	**0.2856**	0.629	-0.304	-1.089	X	4.010	80.874	**0.202**
5	**0.3570**	0.613	-0.181	-0.914	Wh	0.330	81.135	**0.248**
6	**0.4284**	0.595	-0.078	-0.760	Ns	71.500	81.397	**0.284**
7	**0.4998**	0.575	-0.011	-0.601			81.658	**0.303**
8	**0.5712**	0.552	0.032	-0.440			81.920	**0.309**
9	**0.6426**	0.533	0.074	-0.284			82.181	**0.318**
10	**0.7140**	0.516	0.130	-0.130			82.443	**0.334**
11	**0.7854**	0.505	0.190	0.055			82.704	**0.356**
12	**0.8568**	0.504	0.265	0.222			82.966	**0.390**
13	**0.9282**	0.510	0.363	0.357			83.228	**0.440**
14	**0.9996**	0.512	0.461	0.493			83.489	**0.488**
15	**1.0710**	0.522	0.553	0.616			83.751	**0.537**
16	**1.1424**	0.539	0.674	0.675			84.012	**0.604**
17	**1.2138**	0.559	0.848	0.680			84.274	**0.699**
18	**1.2852**	0.580	1.075	0.691			84.535	**0.822**
19	**1.3566**	0.601	1.337	0.752			84.797	**0.962**
20	**1.4280**	0.630	1.629	0.825			85.058	**1.122**
21	**1.4994**	0.662	1.929	0.930			85.320	**1.288**
22	**1.5708**	0.692	2.180	1.080			85.582	**1.431**
23	**1.6422**	0.722	2.334	1.236			85.843	**1.526**
24	**1.7136**	0.753	2.518	1.389			86.105	**1.637**
25	**1.7850**	0.782	2.726	1.548			86.366	**1.760**
26	**1.8564**	0.808	2.863	1.727			86.628	**1.846**
27	**1.9278**	0.832	2.948	1.919			86.889	**1.905**
28	**1.9992**	0.857	3.026	2.066			87.151	**1.962**
29	**2.0706**	0.879	3.015	2.252			87.412	**1.972**
30	**2.1420**	0.904	2.927	2.490			87.674	**1.943**
31	**2.2134**	0.930	2.873	2.727			87.936	**1.932**
32	**2.2848**	0.959	2.771	3.002			88.197	**1.898**
33	**2.3562**	0.996	2.640	3.225			88.459	**1.851**
34	**2.4276**	1.027	2.497	3.355			88.720	**1.795**
35	**2.4990**	1.060	2.441	3.475			88.982	**1.784**
36	**2.5704**	1.090	2.378	3.562			89.243	**1.768**
37	**2.6418**	1.124	2.336	3.604			89.505	**1.765**
38	**2.7132**	1.165	2.288	3.582			89.766	**1.761**
39	**2.7846**	1.204	2.209	3.510			90.028	**1.740**
40	**2.8560**	1.238	2.162	3.477			90.290	**1.732**
41	**2.9274**	1.258	2.140	3.321			90.551	**1.732**
42	**2.9988**	1.271	2.109	3.148			90.813	**1.723**
43	**3.0702**	1.282	2.054	2.962			91.074	**1.700**
44	**3.1416**	1.288	1.970	2.750			-	-
45	**3.2130**	1.281	1.860	2.542			-	-
46	**3.2844**	1.260	1.735	2.354			-	-
47	**3.3558**	1.225	1.571	2.149			-	-
48	**3.4272**	1.172	1.357	1.909			-	-
49	**3.4986**	1.107	1.157	1.702			-	-
50	**3.5700**	1.031	1.106	1.506			-	-
51	**3.6414**	0.942	0.927	1.310			-	-
52	**3.7128**	0.842	0.846	1.131			-	-
53	**3.7842**	0.733	0.744	0.947			-	-
54	**3.8556**	0.617	0.640	0.737			-	-
55	**3.9270**	0.500	0.500	0.500			-	-
56	**3.9984**	0.368	0.374	0.279			-	-
57	**4.0698**	0.240	0.191	0.082			71.719	**0.221**
58	**4.1412**	0.125	0.001	-0.112			71.981	**0.077**
59	**4.2126**	0.011	-0.190	-0.300			72.242	**-0.067**
60	**4.2840**	-0.102	-0.384	-0.505			72.504	**-0.212**
61	**4.3554**	-0.168	-0.585	-0.672			72.765	**-0.331**
62	**4.4268**	-0.255	-0.786	-0.797			73.027	**-0.464**
63	**4.4982**	-0.342	-0.972	-0.872			73.288	**-0.591**
64	**4.5696**	-0.423	-1.185	-0.920			73.550	**-0.726**
65	**4.6410**	-0.494	-1.372	-0.949			73.811	**-0.845**
66	**4.7124**	-0.556	-1.500	-0.960			74.073	**-0.936**
67	**4.7838**	-0.620	-1.940	-1.080			74.335	**-1.154**
68	**4.8552**	-0.655	-2.160	-1.300			74.596	**-1.267**
69	**4.9266**	-0.670	-2.290	-1.500			74.858	**-1.332**
70	**4.9980**	-0.670	-2.350	-1.700			75.119	**-1.360**
71	**5.0694**	-0.660	-2.350	-1.890			75.381	**-1.358**
72	**5.1408**	-0.655	-2.230	-2.080			75.642	**-1.309**
73	**5.2122**	-0.640	-2.200	-2.270			75.904	**-1.291**
74	**5.2836**	-0.600	-2.130	-2.470			76.166	**-1.242**
75	**5.3550**	-0.570	-2.050	-2.650			76.427	**-1.194**
76	**5.4264**	-0.520	-1.970	-2.810			76.689	**-1.134**
77	**5.4978**	-0.470	-1.895	-2.950			76.950	**-1.077**
78	**5.5692**	-0.430	-1.810	-3.040			77.212	**-1.021**
79	**5.6406**	-0.360	-1.730	-3.100			77.473	**-0.949**
80	**5.7120**	-0.275	-1.600	-3.150			77.735	**-0.848**
81	**5.7834**	-0.160	-1.420	-3.170			77.996	**-0.707**
82	**5.8548**	-0.040	-1.130	-3.170			78.258	**-0.516**
83	**5.9262**	0.130	-0.950	-3.130			78.520	**-0.344**
84	**5.9976**	0.295	-0.930	-3.070			78.781	**-0.245**
85	**6.0690**	0.430	-0.950	-2.960			79.043	**-0.181**
86	**6.1404**	0.550	-1.000	-2.820			79.304	**-0.140**
87	**6.2118**	0.620	-0.920	-2.590			79.566	**-0.069**
88	**6.2832**	0.634	-0.690	-2.230			79.827	**0.039**

	Built-in Suter Curve				Deduced Suter Curve			
	Phase Angle	Torque Curve (W_B)			Input Data		Output Data	
No.	X	Ns=25	Ns=147	Ns=261	Start Point		Ns	W_B
0	**0.0000**	-0.684	-1.420	-2.260	X	3.140	68.720	**-0.948**
1	**0.0714**	-0.547	-1.328	-2.061	W_B	0.79	68.633	**-0.826**
2	**0.1428**	-0.414	-1.211	-1.772	Ns	64.9	68.545	**-0.698**
3	**0.2142**	-0.292	-1.056	-1.465	End Point		68.458	**-0.564**
4	**0.2856**	-0.187	-0.870	-1.253	X	4.010	68.371	**-0.430**
5	**0.3570**	-0.105	-0.677	-1.088	W_B	0.420	68.283	**-0.308**
6	**0.4284**	-0.053	-0.573	-0.921	Ns	71.500	68.196	**-0.237**
7	**0.4998**	-0.012	-0.518	-0.789			68.109	**-0.191**
8	**0.5712**	0.042	-0.380	-0.632			68.021	**-0.107**
9	**0.6426**	0.097	-0.232	-0.457			67.934	**-0.019**
10	**0.7140**	0.156	-0.160	-0.300			67.847	**0.045**
11	**0.7854**	0.227	0.000	-0.075			67.760	**0.147**
12	**0.8568**	0.300	0.118	0.052			67.672	**0.236**
13	**0.9282**	0.371	0.308	0.234			67.585	**0.349**
14	**0.9996**	0.444	0.442	0.425			67.498	**0.443**
15	**1.0710**	0.522	0.574	0.558			67.410	**0.540**
16	**1.1424**	0.596	0.739	0.630			67.323	**0.646**
17	**1.2138**	0.672	0.929	0.621			67.236	**0.761**
18	**1.2852**	0.738	1.147	0.546			67.148	**0.879**
19	**1.3566**	0.763	1.370	0.525			67.061	**0.972**
20	**1.4280**	0.797	1.599	0.488			66.974	**1.073**
21	**1.4994**	0.837	1.839	0.512			66.886	**1.181**
22	**1.5708**	0.865	2.080	0.660			66.799	**1.281**
23	**1.6422**	0.883	2.300	0.850			66.712	**1.367**
24	**1.7136**	0.886	2.480	1.014			66.624	**1.430**
25	**1.7850**	0.877	2.630	1.162			66.537	**1.474**
26	**1.8564**	0.859	2.724	1.334			66.450	**1.493**
27	**1.9278**	0.838	2.687	1.512			66.362	**1.465**
28	**1.9992**	0.804	2.715	1.683			66.275	**1.451**
29	**2.0706**	0.758	2.688	1.886			66.188	**1.410**
30	**2.1420**	0.703	2.555	2.105			66.101	**1.327**
31	**2.2134**	0.645	2.434	2.325			66.013	**1.246**
32	**2.2848**	0.583	2.288	2.580			65.926	**1.155**
33	**2.3562**	0.520	2.110	2.770			65.839	**1.052**
34	**2.4276**	0.454	1.948	2.886			65.751	**0.953**
35	**2.4990**	0.408	1.825	2.959			65.664	**0.880**
36	**2.5704**	0.370	1.732	2.979			65.577	**0.823**
37	**2.6418**	0.343	1.644	2.962			65.489	**0.775**
38	**2.7132**	0.331	1.576	2.877			65.402	**0.743**
39	**2.7846**	0.329	1.533	2.713			65.315	**0.727**
40	**2.8560**	0.338	1.522	2.556			65.227	**0.728**
41	**2.9274**	0.354	1.519	2.403			65.140	**0.737**
42	**2.9988**	0.372	1.523	2.237			65.053	**0.750**
43	**3.0702**	0.405	1.523	2.080			64.965	**0.771**
44	**3.1416**	0.450	1.490	1.950			-	-
45	**3.2130**	0.486	1.386	1.826			-	-
46	**3.2844**	0.520	1.223	1.681			-	-
47	**3.3558**	0.552	1.048	1.503			-	-
48	**3.4272**	0.579	0.909	1.301			-	-
49	**3.4986**	0.603	0.814	1.115			-	-
50	**3.5700**	0.616	0.766	0.960			-	-
51	**3.6414**	0.617	0.734	0.840			-	-
52	**3.7128**	0.606	0.678	0.750			-	-
53	**3.7842**	0.582	0.624	0.677			-	-
54	**3.8556**	0.546	0.570	0.604			-	-
55	**3.9270**	0.500	0.500	0.500			-	-
56	**3.9984**	0.432	0.407	0.352			-	-
57	**4.0698**	0.360	0.278	0.161			71.427	**0.329**
58	**4.1412**	0.288	0.146	-0.040			71.340	**0.234**
59	**4.2126**	0.214	0.023	-0.225			71.252	**0.142**
60	**4.2840**	0.123	-0.175	-0.403			71.165	**0.010**
61	**4.3554**	0.037	-0.379	-0.545			71.078	**-0.120**
62	**4.4268**	-0.053	-0.585	-0.610			70.990	**-0.254**
63	**4.4982**	-0.161	-0.778	-0.662			70.903	**-0.393**
64	**4.5696**	-0.248	-1.008	-0.699			70.816	**-0.533**
65	**4.6410**	-0.314	-1.277	-0.719			70.728	**-0.675**
66	**4.7124**	-0.372	-1.560	-0.730			70.641	**-0.816**
67	**4.7838**	-0.580	-2.070	-0.810			70.554	**-1.136**
68	**4.8552**	-0.740	-2.480	-1.070			70.466	**-1.388**
69	**4.9266**	-0.880	-2.700	-1.360			70.379	**-1.557**
70	**4.9980**	-1.000	-2.770	-1.640			70.292	**-1.657**
71	**5.0694**	-1.120	-2.800	-1.880			70.204	**-1.742**
72	**5.1408**	-1.250	-2.800	-2.080			70.117	**-1.823**
73	**5.2122**	-1.370	-2.760	-2.270			70.030	**-1.883**
74	**5.2836**	-1.490	-2.710	-2.470			69.942	**-1.939**
75	**5.3550**	-1.590	-2.640	-2.650			69.855	**-1.976**
76	**5.4264**	-1.660	-2.540	-2.810			69.768	**-1.983**
77	**5.4978**	-1.690	-2.440	-2.950			69.681	**-1.965**
78	**5.5692**	-1.770	-2.340	-3.040			69.593	**-1.978**
79	**5.6406**	-1.650	-2.240	-3.100			69.506	**-1.865**
80	**5.7120**	-1.590	-2.120	-3.150			69.419	**-1.783**
81	**5.7834**	-1.520	-2.000	-3.170			69.331	**-1.694**
82	**5.8548**	-1.420	-1.940	-3.200			69.244	**-1.609**
83	**5.9262**	-1.320	-1.900	-3.160			69.157	**-1.530**
84	**5.9976**	-1.230	-1.900	-3.090			69.069	**-1.472**
85	**6.0690**	-1.100	-1.850	-2.990			68.982	**-1.370**
86	**6.1404**	-0.980	-1.750	-2.860			68.895	**-1.257**
87	**6.2118**	-0.820	-1.630	-2.660			68.807	**-1.111**
88	**6.2832**	-0.684	-1.420	-2.260			68.720	**-0.948**