

WHEN YOU NEED TO BE SURE

SGS

Computing a Turbocharger Surge Margin

Version 1

August 2, 2022

Developed by SGS North America, Inc.

Version History

Version	Date	Revision Description
1	8/2/2022	Initial publication

Document Conventions

This document uses the following typographic and syntax conventions.

- Commands, command options, file names or any user-entered input appear in Courier type. Variables appear in Courier italic type.
Example: Select the `cmdapp-relVersion-buildVersion.zip` file....
- User interface elements, such as field names, button names, menus, menu commands, and items in clickable dropdown lists, appear in Arial bold type.

Example: **Type**: Click **Select Type** to display drop-down menu options.

- Cross-references are designated in Arial italics.

Example: Refer to *Figure 1*...

- Click intra-document cross-references and page references to display the stated destination.

Example: Refer to *Section 1 Overview* on page 1.

The clickable cross-references in the preceding example are *1*, *Overview*, and on page 1.

CyFlex Documentation

CyFlex manuals are available at <https://cyflex.com/>. View **Help & Docs** topics or use the **Search** facility to find topics of interest.

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1 Overview

CyFlex-based turbocharger test stands require real-time computation of the “surge margin”, a performance variable that indicates proximity of the current operating point to the turbo surge threshold in a given compressor map.

A compressor map is a text file of compressor mass flowrates, pressure ratios (outlet / inlet), and efficiencies all for various turbo speeds. It can be depicted graphically as contours of constant turbo speed on a grid of mass flowrate versus pressure ratio and optionally with islands of constant efficiency.

A CyFlex computation module samples pressures and temperatures at the compressor inlet and outlet, locates the operating point in the compressor map and computes the surge margin.

At the CyFlex test cell node, the `surge` application continuously computes the surge margin in a given compressor map.

Map files are maintained and available on a network server. Refer to *Section 3 Generic Map File* on page 3.

At startup, `surge` reads a new Turbo Specs file, refer to *Section 2 Turbo Specs File* on page 2. It specifies the map file, and also reads Real Variable labels for each turbocharger: Refer to *Section 3 Generic Map File* on page 3

- compressor map filename
- Real Variable labels:
 - surge margin (output)
 - compressor inlet pressure
 - compressor inlet temperature
 - compressor outlet pressure
 - compressor outlet temperature
 - compressor mass flowrate

If the compressor map filename matches one in the test cell `/data/turbo/`, then it is the Current Map File and `surge` reads it. If the filename is not current, `surge` copies and reads the file from the generic map files in comm node `/data/turbo/`.

The `surge` application requires these additional Real Variables and parameters located in CyFlex shared memory:

- barometer pressure
- compressor inlet diameter
- compressor outlet diameter

The surge margin output is a new Engine Performance Real Variable.

Refer to cyflex.com usage help for [surge](#) for command syntax.

Refer to *Appendix A. Surge Margin Computation* on page 4 for an outline of the surge margin computation algorithm.

2 Turbo Specs File

A new Turbo Specs file is created at the test cell node to specify the various labels and strings for computing the surge margin. After an initial version line, it is organized in blocks, one for each turbocharger and terminated with a \$ line. Refer to the following example.

```
version
  #turbocharger 1
  #output label:
  surge margin
  #input labels:
  compressor compressor compressor compressor compressor
  inlet         inlet         inlet         inlet         inlet
  pressure      temperature    pressure    temperature    flowrate
S

#turbocharger 2
...
S
```

3 Generic Map File

```
line 1: header
      first header line with datestamp

line 2: counts
  • number of turbo speeds           [%5d]
  • number of values for each turbo speed [%5d]

value blocks: multiple blocks of lines, one for each turbo speed
line 1: turbo speed                 [RPM/ $\sqrt{K}$ ]           [%10.0f]
line 2: compressor pressure ratios  [none]
[%8.3f]
line 3: mass flowrate               [(Kg/sec- $\sqrt{K}$ )/MPa]
[%8.1f]
line 4: efficiency values           [%]
[%8.3f]
```

surge then reads the /ram/version, sorts lines 2-4 in the value blocks by increasing mass flowrate and writes the final version to /data/turbo/.

Appendix A. Surge Margin Computation

The following is the surge margin computation algorithm.

```

compute:
  reference:
    Turbocharger class notes

  Inputs:
    Turbocharger #

get current values:
  barometer pressure           [in Hg]
  compressor inlet pressure    [in H2O]
  compressor inlet temperature [BF]
  compressor outlet pressure   [in Hg]
  compressor outlet temperature [BF]
  mass flowrate                [lbm/min]

compute absolute pressures:

  absolute inlet pressure = barometer pressure +
    compressor inlet pressure

  absolute outlet pressure = barometer pressure +
    compressor outlet pressure

compute dynamic pressures:

  constant = 8 * gas constant / pi * * 2

  dynamic inlet pressure = constant * mass flowrate * * 2 *
    compressor inlet temperature /
    (absolute inlet pressure *
    Compressor inlet diameter * * 4)

compute total pressures:

  total inlet pressure:
    absolute inlet pressure + dynamic inlet pressure

  total outlet pressure =
    total outlet pressure / total inlet pressure
corporate mass flowrate = mass flowrate [kg/sec] *
  sqrt (compressor inlet temperature [deg k]) /
  (total inlet pressure [MPa])

Compute surge mass flowrate:

```



```
For each speed
  If total pressure ratio in
    I'th map pressure ratio segment
  Map pressure ratio 1 =
    Map pressure ratio (I)
  Map pressure ratio 0 =
    Map pressure ratio (I-1)
  Map mass flowrate 1=
    Map mass flowrate (I)
  Map mass flowrate 0=
    Map mass flowrate (I-1)
  Break
```

```
Surge mass flowrate = map mass flowrate 1 +
  (total pressure ratio - map pressure ratio 0) *
  (map mass flowrate 1 - map mass flowrate 0) /
  (map pressure ratio 1 - map pressure ratio 0)
```

```
Surge margin =
  100 * (corporate mass flowrate - surge mass flowrate) /
  Surge mass flowrate
```