

A Transient Data Extension to the GasLib

Dennis Gabriel*

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GasLib [1] provides a collection of realistic and artificial gas networks and corresponding load scenarios for the stationary case. In this document we describe an extension to this dataset containing transient scenarios.

This extension was developed within the collaborative research center TRR154 „Mathematical modeling, simulation and optimisation using the example of gas networks“. The goal was to provide a base set of data that can be used for computations and comparisons of different approaches. These datasets are available on the homepage of the research center (<https://www.trr154.fau.de/transient-data/>). The data is supplied in XML-format, as are the datasets of GasLib. In this document we explain the format and how the datasets have been constructed.

*Department of Mathematics, TU Darmstadt

1 Description of the XML Files

In this section we take a closer look at the developed XML format. So far, we constructed two different kinds of files which we will describe by means of an example; for more details on XML see also [3]. The goal was to create a generalized format for many different kinds of files with different purposes. The base structure should always be the same, but one or the other information is added while others are left out. This idea led to the XML format we describe in the following.

To validate the constructed XML files we also developed XSD (XML Schema Definition) files. They can also be found on the research center's website (see <https://www.trr154.fau.de/transient-data/>). These schemes specify the format of the XML files and the types of the data; more information on XSD can be found in [4].

For an exemplary description we consider the Gaslib-11 network from the GasLib homepage (<http://gaslib.zib.de/>, [1]). For more information about the GasLib gas network instances and more general information see also the report on the GasLib library [2]. For this network we supply the files `GasLib-11-sinus-InputData.bcd` and `GasLib-11-sinus_5000_60-initial.state`. The latter file contains a state for the Gaslib 11 network. More precisely, pressures and flows are given at the nodes and at the pipes, respectively. Furthermore, for pipes we also provide this data at spacial points according to a given space discretization. For compressor stations and control valves, the pressure is replaced by the pressure difference and for valves then open/closed status is specified. The first file only contains information about nodes and not about edges. Instead, all nodes have an additional child node that specifies the timepoint to which the data belongs.

1.1 The .state file

We continue by taking a closer look on the `.state` file because it is more general than the `.bcd` file. The top node `initialdata` of the file has three child nodes. These are `metadata`, `nodes` and `edges`. Figure 1 shows the node `metadata`. This node is characterized by a summary of important general information about the file and the setting of the dataset. Its child nodes are `network`, which gives the name of the network file to which the `.state` file belongs. Furthermore, `metadata` contains the author, the version and the date. This information makes it possible to identify the file unambiguously. Finally, a value and unit for the speed of sound is provided. This value can optionally be used for further calculations.

```
<metadata>
  <network>GasLib-11.net</network>
  <author>A05</author>
  <version>1.0</version>
  <date>2021-11-10</date>
  <speedOfSound value="340" unit="m_per_s"/>
</metadata>
```

Figure 1: An example for a `metadata` node in a `.state` file. It contains important general information on the file.

Going on, we consider the first sibling of the `metadata` node, that is the node `nodes`. This section is a list of nodes from the network. Every node is described by its id and type. The id states the name of the specific node. The type it is `boundaryNode` or `innode`. If one wants to identify whether a node is source or sink, one has to take a look at the sign of the flow. In every node, information about pressure and flow is stored. More precisely, each node has a child node `nodedata` that itself contains two child nodes: `massflow` and `pressure`. Both nodes have attributes that provide the value and unit of the massflow and the pressure respectively. Figure 2 shows an example.

```
<node id="entry01" type="boundaryNode">
  <nodedata>
    <massflow value="15.223430916557934" unit="kg_per_s"/>
    <pressure value="53.0" unit="bar"/>
  </nodedata>
</node>
```

Figure 2: An example of a node in the section `nodes`. It has the child node `nodedata`, which itself has the child nodes `massflow` and `pressure`.

The last child node of `initialdata` is `edges`. This node contains a list of edges similar to the section of `nodes`. Possible choices for child nodes are `pipes`, `valves` or `compressor stations`. The structure of this child node is similar to the structure of the nodes from the `nodes` section. The top node `edge` has the attributes `id` and `type`. Below that we have `edgedata`. This yields a major difference in comparison to the `nodes` section. If the edge type is `pipe`, `edgedata` has the child node `space` with attributes `value` and `unit`. It refers to a specific spatial point on the pipe according to a given (here equidistant) space discretization. Because of that, edges of type `pipe` have the same number of `edgedata` child nodes as the pipe has spatial points. Besides the information about the space, `edgedata` also contains child nodes `massflow` and `pressure` similar to `nodes`. Figure 3 shows an example for the described pipe structure.

The next possible choice for a type of an edge are the `valves`. An example can be found in figure 4.

In comparison to the pipes, the valves child node `valvedata` has no child node for space and thus we do not need several instances. Furthermore, we have no node for pressure, but instead a node `open`, which describes the status of the valve. If it is open, the value is 1, if it is closed, the value is 0.

The last possible choice are the compressor stations. Their structure is similar to the valves, but the pressure difference is provided instead of the status. It gives us the difference of pressure between the from and to node of the compressor station. An example is shown in Figure 5.

Note that there are actually more possible choices for edges, for example control valves, resistors or shortpipes. These are established in a similar structure as pipes, valves and compressor stations, but we will not give an example here.

```

<edge id="pipe08_N05_exit03" type="pipe">
  <edgedata>
    <space value="0.0" unit="m"/>
    <massflow value="22.677777777777777" unit="kg_per_s"/>
    <pressure value="46.12179630432075" unit="bar"/>
  </edgedata>
  <edgedata>
    <space value="5000.0" unit="m"/>
    <massflow value="22.677777777777777" unit="kg_per_s"/>
    <pressure value="45.89120822674979" unit="bar"/>
  </edgedata>
  ...
</edge>

```

Figure 3: An example of an edge of type `pipe` in the section `edges`. It has child nodes `edgedata` that themselves have child nodes `space`, `massflow` and `pressure`.

```

<edge id="V01_N01_N03" type="valve">
  <edgedata>
    <massflow value="0.0" unit="kg_per_s"/>
    <open value="0"/>
  </edgedata>
</edge>

```

Figure 4: An example of an edge of type `valve` in the section `edges`. It has a child node `edgedata` that itself has child nodes `massflow` and `open`. The latter describes the status of the valve.

```

<edge id="CS01_entry03_N01" type="compressorStation">
  <edgedata>
    <massflow value="53.27911316234031" unit="kg_per_s"/>
    <pressureDifference value="5.144230483504607" unit="bar"/>
  </edgedata>
</edge>

```

Figure 5: An example of an edge of type `compressorStation` in the section `edges`. It has a child node `edgedata` that itself has child nodes `massflow` and `pressureDifference`.

1.2 The `.bcd` file

The `.state` file provides an initial state for further work. For computations over time, we also need information about pressure and/or flow at certain timepoints. These specifications can be found in the `.bcd` (boundary conditions) file. For every node and every time point according to a given time discretization, values for flow and/or pressure are provided.

The structure of the `.bcd` file is similar to the structure of the `.state` file. The

top level node `boundarydata` has two child nodes. These are `metadata` and `nodes`. The first is almost the same as in the `.state` file with one addition. Here `metadata` is complemented by an additional node `timeInterval`, which specifies the start and end of the considered time interval together with the unit of the time. Figure 6 shows an example for the `metadata` node in `GasLib-11-sinus-InputData.bcd`.

```
<metadata>
  <network>GasLib-11.net</network>
  <author>A05</author>
  <version>1.0</version>
  <date>2021-11-09</date>
  <timeInterval start="0" end="86400" unit="s"/>
  <speedOfSound value="340" unit="m_per_s"/>
</metadata>
```

Figure 6: An example for a `metadata` node in a `.bcd` file. The difference to a `metadata` node in a `.state` file is the node `timeInterval` with start- and endtime and their unit (here in seconds).

The second child node of `boundarydata`, `nodes` is a list of nodes in the corresponding network. Again, the structure is similar to the `nodes` section in the `.state` file with one important difference, which is shown in Figure 7. Here the node `node` has more than one child node `nodedata`. More precisely, it has one child node for every timepoint according to a given (here equidistant) time discretization. All `nodedata` nodes contain a node `time` with two attributes to specify a certain timepoint. These are the value and a unit. The value is a time on the time interval given in `metadata` together with its unit. An example for this structure is given in Figure 7. Here the massflow is specified at all timepoints. Another possibility is to specify the pressure.

In general, the files we provide have the pressure specified at the entries and the massflow specified at the exits. Figure 8 shows an entry with information about the pressure. Here we can also see a special case of our format: In this case, the pressure is constant over all timepoints. Instead of adding a child node for all timepoints with identical pressure value, there are two timepoints provided, one for the start and one for the end.

Note that this case where the pressure is specified at the entries and the massflow is specified at the exits is only an example. Our format also supports other configurations where for example flow is given at entries and exits. One can also mix it up and specify the flow at some entries and some exits. More precisely, in this format we only know if a boundary node is an exit or entry by the sign of the flow. If the flow changes through time an exit might become an exit, but this is also supported by our format.

```

<node id="exit01" type="boundaryNode">
  <nodedata>
    <time value="0" unit="s"/>
    <massflow value="-28.34722222222222" unit="kg_per_s"/>
  </nodedata>
  <nodedata>
    <time value="60" unit="s"/>
    <massflow value="-28.359590992014123" unit="kg_per_s"/>
  </nodedata>
  <nodedata>
    <time value="120" unit="s"/>
    <massflow value="-28.37195952632247" unit="kg_per_s"/>
  </nodedata>
  ...
</node>

```

Figure 7: An example for a node from the `nodes` section in a `.bcd` file. The difference to such a node in a `.state` file is the node `time` with a value and its unit (here in seconds). The value describes a certain timepoint that is considered at this datapoint. In this case the massflow is specified at every timepoint.

```

<node id="entry02" type="boundaryNode">
  <nodedata>
    <time value="0" unit="s"/>
    <pressure value="51" unit="bar"/>
  </nodedata>
  <nodedata>
    <time value="86400" unit="s"/>
    <pressure value="51" unit="bar"/>
  </nodedata>
</node>

```

Figure 8: An example for a node from the `nodes` section in a `.bcd` file. The difference to such a node in a `.state` file is the node `time` with a value and its unit (here in seconds). The value describes a certain timepoint that is considered at this datapoint. In this case the pressure is specified at the start and end timepoint of the time interval.

References

- [1] M. Schmidt, D. Aßmann, R. Burlacu, J. Humpola, I. Joormann, N. Kanelakis, T. Koch, D. Oucherif, M. E. Pfetsch, L. Schewe, R. Schwarz, and M. Sirvent. GasLib – A Library of Gas Network Instances. *Data*, 2(4):article 40, 2017.
- [2] M. Schmidt, D. Aßmann, R. Burlacu, J. Humpola, I. Joormann, N. Kanelakis, T. Koch, D. Oucherif, M. E. Pfetsch, L. Schewe, R. Schwarz, and M. Sirvent. Gaslib—a library of gas network instances. Technical report, Optimization Online, 2017. http://www.optimization-online.org/DB_HTML/2015/11/5216.html.
- [3] Extensible Markup Language (XML). <https://www.w3.org/XML/>.
- [4] W3C XML Schema Definition Language (XSD). <https://www.w3.org/TR/xmlschema11-1/>.