2 Description of a Physical Process with a Full Set of Dimensionless Numbers

2.1 The Relevance List for a Problem

All the essential ("relevant") physical quantities (variables, parameters) which describe a physical or technological interrelation must be known before this process can be described with a full set of dimensionless numbers. This demands a thorough and critical appraisal of the process being examined.

Langhaar [A 6] points out that this first step of naming the process parameters may often require a "philosophical insight" into natural phenomena. Bridgman [A 5] goes further still; when discussing the example of the period of oscillation of a pendulum, see page 8, he remarked that, when clearly defining the physical interdependence, it is sometimes necessary to carry out preliminary tests "by someone at some time soiling his hands with direct contact".

The application of dimensional analysis is indeed heavily dependent on the available knowledge. Pawlowski 5) outlines the following five steps (cf. also Fig. 2):

1. The physics of the basic phenomenon is unknown.  
   → Dimensional analysis cannot be applied.
2. Enough is known about the physics of the basic phenomenon to compile a first, tentative relevance list.  
   → The resultant \( \Pi \) set is unreliable.
3. All the relevant physical variables describing the problem are known.  
   → The application of dimensional analysis is unproblematic.
4. The problem can be expressed in terms of a mathematical equation.  
   → A closer insight into the \( \Pi \) relationship is feasible and may facilitate a reduction of the set of dimensionless numbers.
5. A mathematical solution of the problem exists.  
   → The application of dimensional analysis is superfluous.

It must, of course, be said that approaching a problem from the point of view of dimensional analysis remains useful even if all the variables rele-
vant to the problem are not yet known (case 2 above): The timely application of dimensional analysis may often lead to the discovery of forgotten variables or the exclusion of fakes (see example of pendulum, page 8).

<table>
<thead>
<tr>
<th>Knowledge available</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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</thead>
<tbody>
<tr>
<td>Basic physics of the process</td>
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<td>Relevance list</td>
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<td>Mathematical formulation</td>
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<td>Mathematical solution</td>
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Fig. 2: Ease of application of dimensional analysis depending on the degree of knowledge available on a particular problem. (*Pawlowski* 5) 

The relevant physical variables comprise a single *target quantity* (the only dependent variable; this can also be a target function (e.g. residence time distribution) or even a target field (e.g., a temperature field) and a series of parameters which influence it. These parameters can be divided into three categories:

1. *geometric* variables
2. *material* parameters (*physical properties*)
3. *process-related* variables

5) Personal communication by J. Pawlowski, 1984