in-active Safety Standard (Safety standard no longer included in the reaffirmation process acc. sec. 5.2 of the procedural statutes)

**SAFETY STANDARDS**

**of the**

**Nuclear Safety Standards Commission (KTA)**

# KTA 3102.2

# Reactor Core Design of High-Temperature Gas-Cooled Reactors

# Part 2: Heat Transfer in Spherical Fuel Elements

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**Comment:**

In these English translations of KTA-Safety Standards the words shall, should and may are used with the following meanings:

- **shall** indicates a mandatory requirement,
- **should** indicates a requirement[1] to which exceptions are allowed. However, the exceptions shall be substantiated during the licensing procedure,
- **may** indicates a permission and is, thus, neither a requirement (with or without exceptions) nor a recommendation: recommendations are worded as such, e.g., "it is recommended that ....".

The word combinations basically shall/shall basically are used in the case of mandatory requirements to which specific exceptions (and only those!) are permitted. These exceptions - other than in the case of should - are specified in the text of the safety standard.

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[1] Please note that in the case of IAEA NUSS standards and ANSI standards, the word “should” indicates a mere recommendation.

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**Nuclear Safety Standards Commission (KTA)**

**Federal Republic of Germany**

## Introduction

(1) The Safety Standard KTA 3102 "Reactor Core Design for High-Temperature Gas- Cooled Reactors" comprises the entire field of core design. Within the scope of the thermodynamic and flow-mechanical core design of high-temperature gas-cooled reactors, the following areas are dealt with:

Part 1: Calculation of the Material Properties of Helium

Part 2: Heat Transfer in Spherical Fuel Elements

Part 3: Loss of Pressure through Friction in Pebble Bed Cores

Part 4: Thermohydraulic Analytical Model for Stationary and Quasi- Stationary Conditions in Pebble Bed Cores

Part 5: Systematic and Statistical Errors in the Thermohydraulic Core Design of the Pebble Bed Reactors

(2) The reactor core of a high-temperature gas-cooled reactor, which is considered in Part 2, consists of a heaped bed of pebbles of identical diameter. The heat transfer coefficient is a pre-requisite for the calculation of the moderator and fuel temperatures. Thus it influences both the neutron-physical calculations of the reactivity of the core and the calculation of the fuel element behavior, e.g. fission product release and corrosion.

## 1 Scope

(1) This safety standard applies to the calculation of the heat transfer of peb bles to the gas which passes through a heaped bed of pebbles of identical diameter within the following scope:

| | |
|---|---|
| Reynolds number Re | $100 < Re < 10^5$ |
| Porosity of the bed c | 0.36 < e < 0.42 |
| Diameter ratio D/d | D/d > 20 |
| Height of bed H | H > 4 d |

(2) The restriction of the diameter ratio D/d does not apply if local values are used instead of the porosity values averaged over the cross section of the vessel and the Reynolds number Re.

## 2 Symbols Used

A vessel cross section

$A_K$ surface area of a pebble in the bed

d diameter of the pebbles forming the bed

D diameter of the vessel enclosing the bed

H height of the bed

m mass flow of the gas in the bed

Q heat transfer from the pebble to the gas

$T_G$ temperature of the gas

$T_K$ mean surface temperature of the pebble considered

$\alpha$ mean heat transfer coefficient

$\varepsilon$ porosity of the bed, i.e. the relation between the empty volume in the bed and the total volume of the bed

$\eta$ dynamic viscosity of the gas

$\lambda$ thermal conductivity of the gas

Nu Nusselt number

Pr Prandtl number

Re Reynolds number

## 3 Calculation Equations

The heat transfer Q from a pebble to the gas flow shall be calculated by means of the following equation:

$$\dot{Q} = \alpha\, A_K \left(T_K - T_G\right) \qquad (3\text{-}1)$$

For the calculation of the heat transfer coefficient,

$$\alpha = \frac{Nu\,\lambda}{d} \qquad (3\text{-}2)$$

shall be used, with the Nusselt number to be determined on the basis of the following relationship:

$$Nu = 1.27\,\frac{Pr^{1/3}}{\varepsilon^{1.18}}\,Re^{0.36} + 0.033\,\frac{Pr^{1/2}}{\varepsilon^{1.07}}\,Re^{0.86} \qquad (3\text{-}3)$$

The following equation shall be used for the Reynolds number:

$$Re = \frac{\left(\dot{m}/A\right)d}{\lambda} \qquad (3\text{-}4)$$

Figure 3-1 shows the value of the Nusselt number as a function of the Re number for a porosity 0.39 and Pr - 0.7. The dynamic viscosity q and the thermal conductivity A of the gas shall be determined as the arithmetic mean value of the surface temperature of the pebble and the gas temperature.

In the case of an unobstructed flow into the pebble bed, only one half of the value resulting from equation (3-3), which uses the value averaged over the pebble bed, shall be used for the pebble forming the first layer.

The uncertainty range of the Nusselt number in accordance with equation (3-3) is + 20% within the scope of application, with a confidence level of 95 %.

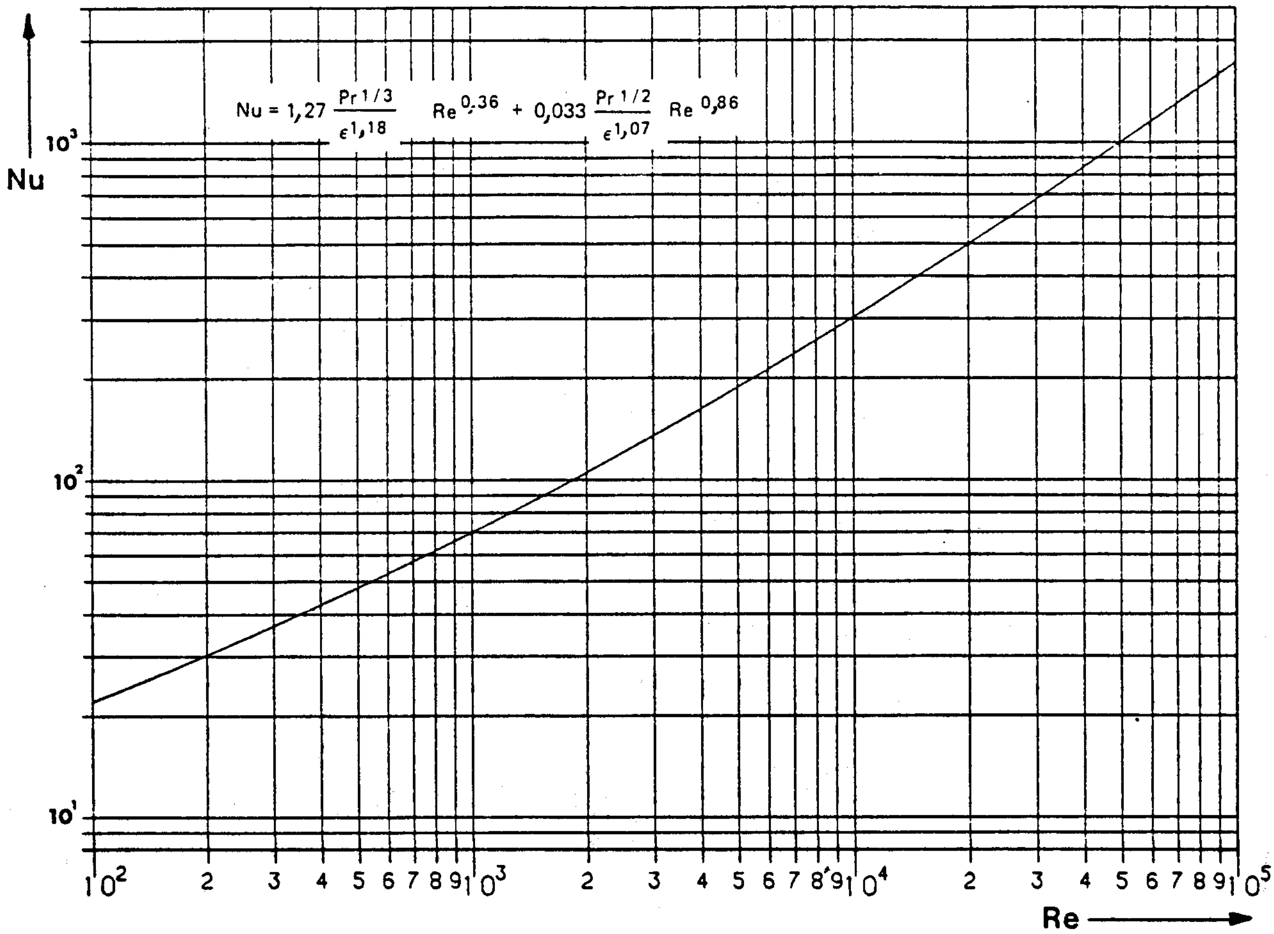


**Figure 3-1:** Nusselt number as a function of the Reynolds number for ε = 0.39 and Pr = 0.7