# Determination of Flame Acceleration Conditions within RCFC Ducts

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## 1. Introduction

Reactor Containment Fan Coolers (RCFC) are used to remove heat from the reactor building atmosphere in the event of a Severe Accident (SA). Particularly, they can be operated as part of a mitigating strategy to "Reduce Fission Product Releases" following Severe Accident Management Guidelines (SAMG) and can be used in conjunction with containment spray pumps.

While the use of RCFCs is advantageous in that it reduces the off-site release of fission products through containment depressurization, an unintended outcome is flame acceleration that can occur in ducts in association with hydrogen combustion.

This paper focuses on inducing safety conditions to prevent flame acceleration in a hydrogen-air mixture during the use of RCFCs in an effort to reduce the release of fission products in a SAMG.

## 2. Analysis Methodology

### *2.1. σ-criterion for flame acceleration*

The possibility of the occurrence of Flame Acceleration (FA) can be evaluated using the "sigma" value, as follows [1, 2]:

If σ/ σ*<1: no FA occurrence
If σ/ σ*>1: possibility of FA occurrence

The value σ denotes the expansion ratio, which is defined as the ratio of the densities of the reactants and products. The value σ* is sigma critical as a function of the Lewis number (Le) and the Zeldovich number (β) [1, 3, 4]. The sigma critical value can be calculated by linear interpolation of experimental data [3], as shown in Table 1. In addition, σ is estimated by interpolating the predicted sigma values found by experimental investigation [4], as shown Fig. 1.

Table 1. List of critical sigma (σ*) values as a function of temperature for hydrogen lean and rich oxygen mixtures

| Temperature ($^oF$) | Critical Sigma $[H_2] < 2[O_2]$ | Critical Sigma $[H_2] \geq 2[O_2]$ |
|---|---|---|
| 300 | 3.75 | 3.75 |
| 400 | 2.80 | 3.75 |
| 500 | 2.25 | 3.75 |
| 600 | 2.10 | 3.75 |

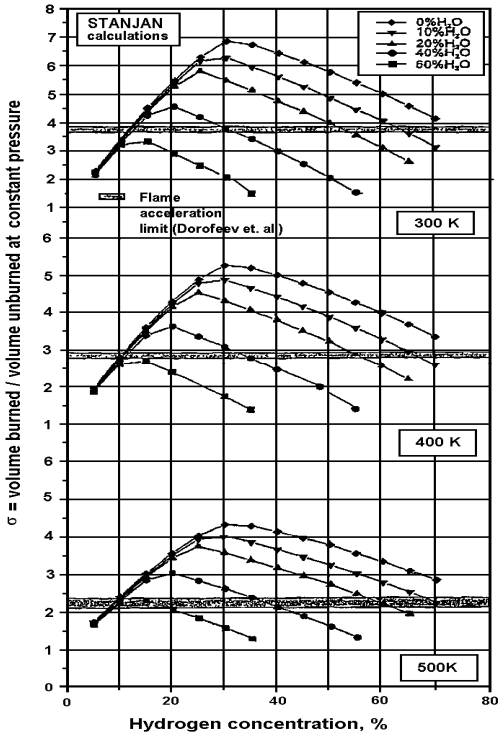


Fig. 1 Expansion ratio (σ) of an $H_2$-air-steam mixture

### *2.2. Assumption and data for RCFC*

In order to determine the criterion of FA occurrence from the σ-criterion value, the following assumptions are made:

◦ The atmosphere environment is assumed to be a homogeneous mixture of air, steam and hydrogen for which the ideal gas law applies.
◦ The containment atmosphere is assumed to be at 100% humidity when the RCFCs are activated.
◦ The volume, initial temperature, initial pressure of containment, and the cooling capacity of the RCFC are assumed to be within FSAR (Final Safety Analysis Report) specifications [5], as shown in Table 2 and Fig. 2.
◦ For conservative condition, certified vender data in Fig. 2 was utilized to calculate the condensation rate of steam in ducts.
◦ It is assumed that RCFCs contribute only to the condensation of steam in ducts without a reduction of the pressure and temperature.

Table 2. Plant-specific input data from FSAR

| Variable | YGN 3&4 | Unit |
|---|---|---|
| Initial containment temperature | 120 | $^{o}$F |
| Initial containment pressure | 15.7 | psia |
| Volume of containment | $2.727\times10^{6}$ | ft$^{3}$ |

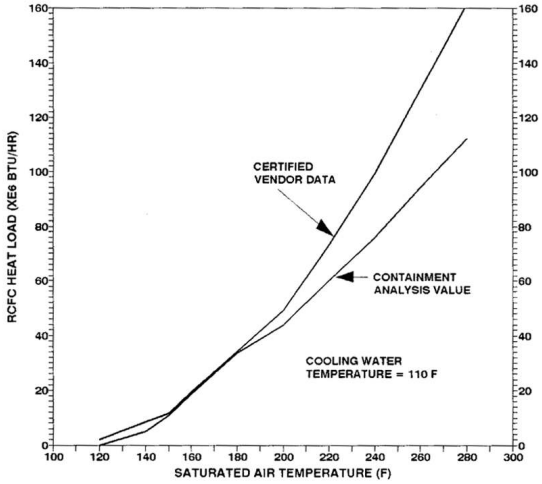


Fig. 2 RCFC performance in FSAR

### 3. Results of Analysis

According to the σ-criterion for FA, a graph was produced to discriminate the possibility of FA occurrence, as shown in Fig. 3, using containment pressure and hydrogen concentration, which are easily instrumented.

The area of FA occurrence within the ducts is larger than that in the containment atmosphere, as the hydrogen concentration is higher than that before cooling coils are used to condense the steam.

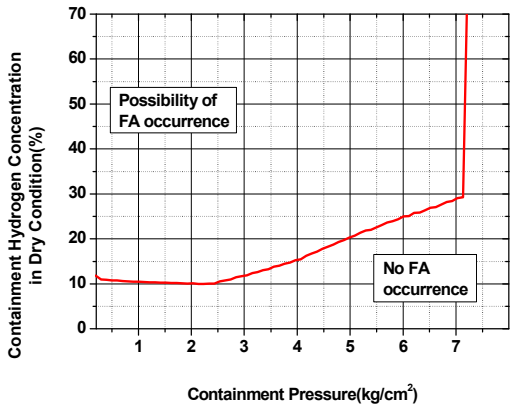


Fig. 3 The possibility of FA occurrence according to the hydrogen concentration and containment pressure

### 4. Conclusions

In this study, the discriminative conditions to prevent flame acceleration of burning hydrogen within ducts are suggested while using the RCFCs to reduce the release of fission products in a SAMG. According to the findings of this study, operators and the TSC can easily prevent the occurrence of FA using the values of the containment hydrogen concentration and the containment pressure. In addition, containment challenges due to FA can be intercepted by determining whether or not the RCFCs are activated.

### REFERENCES

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