SAFETY GUIDE 7

CONTROL OF COMBUSTIBLE GAS CONCENTRATIONS IN CONTAINMENT FOLLOWING A LOSS OF COOLANT ACCIDENT

A. Introduction

General Design Criterion 41 requires that systems to control hydrogen, oxygen, and other substances which may be released into the reactor containment be provided as necessary to control their concentrations following postulated accidents to assure that containment integrity is maintained. This guide describes an acceptable method of implementing this criterion.

B. Discussion

Following a loss of coolant accident, hydrogen gas may accumulate within the containment as a result of:

1. Metal-water reaction involving the zirconium fuel cladding and the reactor coolant.
2. Radiolytic decomposition of the post-accident emergency cooling solutions (oxygen will also evolve in this process).
3. Corrosion of metals by solutions used for emergency cooling or containment spray.

If a sufficient amount of hydrogen is generated, it may react with the oxygen present in the containment atmosphere or, in the case of inerted containments, with the oxygen generated following the accident. The reaction would take place at rates rapid enough to lead to high temperatures and significant overpressurization of the containment, which could result in a loss of integrity. Damage to systems and components essential to the continued control of the post loss of coolant accident conditions could also occur.

The extent of metal-water reaction and associated hydrogen production depends strongly on the course of events assumed for the accident and on the effectiveness of emergency cooling systems. The rate of production of gases from radiolysis of coolant solutions depends on (1) the amount and quality of radiation energy absorbed in the specific cooling solutions employed and (2) the net yield of gases generated from the solutions due to the absorbed radiation energy. Factors such as coolant flow rates and turbulence, chemical additives in the coolant, impurities, and coolant temperature can all exert an influence on the gas yields from radiolysis. The hydrogen production rate from corrosion of materials within the containment, such as aluminum, depends on the corrosion rate which in turn depends on such factors as the coolant chemistry, the coolant pH, the metal and coolant temperatures, and the surface area exposed to attack by the coolant. Accurate values of these parameters are difficult to establish with certainty for the conditions expected to prevail following a loss of coolant accident.

The regulatory staff has reviewed the available information concerning these parameters, including the results of calculations and experiments. Table 1 defines values and other assumptions which the staff believes to be reasonably conservative that may be used for purposes of evaluating the production of combustible gases following a loss of coolant accident.

If these assumptions are used to calculate the concentration of hydrogen (and oxygen) within the containment structures of reactor plants of current designs following a loss of coolant accident, the hydrogen concentration is calculated to reach the flammable limit within periods of less than a day after the accident for the smallest containments and up to more than a month for the largest ones. The hydrogen concentration could be maintained below its lower flammable limit by purging the containment atmosphere to the environs at a controlled rate after the loss of coolant accident; however, radioactive materials in the containment would also be released. If purging became necessary shortly after the accident, quantities of such material would be released.

In small containments the amount of metal-water reaction postulated in Table 1 would result in hydrogen concentrations above acceptable limits. The evolution rate of hydrogen from the metal-water reaction would be greater than that from either radiolysis or corrosion. Operation of small containments with inert (oxygen deficient) atmospheres would provide sufficient time for currently designed combustible gas control systems to reduce the concentration of hydrogen following a loss of coolant accident before the oxygen generated by radiolysis results in flammable mixtures in the containment.

It is therefore advisable to provide means for mixing, sampling and control of combustible gases resulting from the postulated metal-water reaction, radiolysis and corrosion following a loss of coolant accident which do not necessarily involve releases of radioactive materials to the environment. It is also advisable to provide the capability of purging the containment through filters to limit the potential release of radioactive iodine and other radioactive materials should the primary means of controlling combustible gas concentrations not perform properly. Since any system for combustible gas control is designed for the protection of the public in the event of an accident, it should meet the design and construction standards of engineered safety features. Care should be taken in its design to assure that the system itself does not introduce safety problems that may affect containment integrity; for example, if a flame recombiner is used, propagation of flame into the containment should be prevented.

C. Regulatory Position

1. All water-cooled power reactor facilities should have the capability for measuring the hydrogen concentration and for mixing the atmosphere in the containment following a loss of coolant accident, and for controlling combustible gas concentrations without reliance on purging of the containment atmosphere. The continuous presence of combustible gas control equipment at the site may not be necessary provided it is available on an appropriate time scale; however, appropriate design and procedural provisions should be made for its use.
2. Combustible gas control systems and the provisions for mixing, measuring, and sampling should meet the design, quality assurance, redundancy, energy source, and instrumentation requirements for an engineered safety feature and the system itself should not introduce safety problems that may affect containment integrity.
3. All water-cooled power reactors should also have the installed capability for a controlled purge of the containment atmosphere through appropriate fission product removal systems.
4. The parameter values listed in Table 1 should be used for the purpose of calculating hydrogen and oxygen gas concentrations in containments and evaluating designs provided to control and to purge combustible gases evolved in the course of loss of coolant accidents. These values may be changed on the basis of additional experimental evidence and analyses.
5. Materials within the containment that would yield hydrogen gas due to corrosion from the emergency cooling or containment spray solutions should be identified and their use should be limited as much as practical.

TABLE 1

1. Fraction of fission product radiation energy absorbed by the coolant[1]	(a) *Beta*
	(1) Betas from fission products in the fuel rods: 0
	(2) Betas from fission products intimately mixed with coolant: 1.0
	(b) *Gamma*
	(1) Gammas from fission products in the fuel rods, coolant in core region: 0.1[2]

TABLE 1—(cont.)

	(2) Gammas from fission products intimately mixed with coolant, all coolant: 1.0
2. $G(H_2)$[1]	0.5 molecules/100ev
3. $G(O_2)$[1]	0.25 molecules/100ev
4. Extent of metal-water reaction (percentage of fuel cladding that reacts with water)	5
5. Aluminum corrosion rate for aluminum exposed to alkaline solutions. (This value should be adjusted upward for higher temperatures early in the accident sequence)	200 mils/yr
6. Fission product distribution model	(a) 50% of the halogens and 1% of the solids present in the core are intimately mixed with the coolant water.

TABLE 1—(cont.)

	(b) All noble gases are released to the containment.
	(c) All other fission products remain in fuel rods.
7. (a) Hydrogen concentration limit (This limit should not be exceeded if more than 5 volume percent oxygen is present.)	4 volume percent
(b) Oxygen concentration limit (This limit should not be exceeded if more than 4 volume percent hydrogen is present.)	5 volume percent

[1] For water, borated water, and borated alkaline solutions; for other solutions, data should be presented.

[2] This fraction is thought to be conservative; further analysis may show that it should be revised.

SUPPLEMENT TO SAFETY GUIDE 7

CONTROL OF COMBUSTIBLE GAS CONCENTRATIONS IN CONTAINMENT FOLLOWING A LOSS OF COOLANT ACCIDENT

BACKFITTING CONSIDERATIONS

D. Introduction

Safety Guide 7 describes the regulatory position concerning the control of combustible gas concentrations in containments following a loss-of-coolant accident for present and future reactors. The purpose of this supplement is to provide guidance to applicants and licensees regarding the possible backfitting of combustible gas control systems to plants already licensed. This supplement does not represent a requirement for backfitting; such requirements will be formulated on an individual case basis pursuant to 10 CFR 50.109.

E. Regulatory Position

1. Plants for which a notice of hearing on application for construction permit was published between December 22, 1968, and November 5, 1970, should conform to the regulatory position in the safety guide prior to operation or as soon thereafter as practicable. It is recognized that for a few plants in this category the purge doses calculated using the assumptions in Section C of the safety guide may be negligible. Exceptions for such plants, if requested, will be considered on an individual case basis, taking into account the calculated radiological consequences of purging and the population distribution and density surrounding the plant.

2. Plants for which the notice of hearing on application for construction permit was published before December 22, 1968, should furnish information to the regulatory staff regarding the calculated dose from purging, using the assumptions in Section C of the safety guide. The need for backfitting these plants will be considered on an individual case basis.