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ADDENDUM #3

Fire Hazards Analysis Update For the Babar Detector Project

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Re: RPC Avalanche Chamber Gas Mixtures

Reference Documents:

[HAI 1996] Fire Hazards Analysis for the BaBar Detector Project, prepared for Stanford Linear Accelerator Center, Hughes Associates, Inc., December 19, 1996.

[HAI 2001] Addendum, Fire Hazards Analysis for the BaBar Detector Project, prepared for Stanford Linear Accelerator Center, Hughes Associates, Inc., December 19, 2001.

[HAI 2005] Addendum #2, Fire Hazards Analysis Update for the BaBar Detector Project, prepared for the Stanford Linear Accelerator Center, Hughes Associates, Inc., May 9, 2005.

[SLAC 2004] Messner, R. and JO'Neill, F., Internal Memorandum, Development of Procedure for Selecting Gas Mixtures for the BaBar Barrel IFR Upgrade, Stanford Linear Accelerator Center, March 22, 2004.

[SLAC 2006] Messner, R., Memorandum: Establishment of Region of Non-flammable Gas Mixtures for the RPC Avalanche Chamber, Stanford Linear Accelerator Center, March 27, 2006.

The BaBar Project is located in the PEP-II Research Hall at Interaction Region 2 (IR-2). IR-2 and all PEP-II facilities are located inside the SLAC Radiological Control Area. The objective of this Addendum to the BaBar Project Fire Hazards Analysis is to establish a region of non-flammable gas mixtures for the RPC avalanche chambers in order to provide experimental flexibility for operation of the RPC chambers. This effort included (1) review of the March 27, 2006 memorandum which details an approach to extend available gas mixture flammability data and (2) a review and correlation of available gas flammability data for both CERN and Bureau of Mines test data.

The reviewers at Hughes Associates, Inc. concur with the methodology of treating sulphur hexafluoride as Freon (R134a) as outlined in the March 27, 2006 memorandum. This is based on (1) sulphur hexafluoride having a higher specific heat than Freon (0.097 kJ/mol-K vs 0.087 kJ/mol-K), and (2) available CERN small scale flammability test data. The CERN test results indicate that the isobutane Tci value for isobutane and sulphur hexafluoride (19.43%) is significantly higher than isobutane and Freon (5.75%).

In the March 27, 2006 memorandum three curves (Options A, B, and C) are proposed for consideration in limiting the mixture of isobutane, Freon, and argon. The first curve (Option A) is based on CERN isobutane Tci values for isobutane and Freon (5.75%), and isobutane and argon. Based on a review of Tci values and the methodology used to determine these values, this curve has technical merit. However, use of this curve potentially provides an overly restrictive flammability limits.

The curves represented by Options B and C are based on the BaBar FHA, which relied on an assumption that Freon would behave as an inert substance. This is based on the unusually low isobutane Tci values for isobutane and Freon (5.75%), given the high specific heat of Freon (0.087 kJ/mol-K). However, after the FHA analysis was completed, CERN published results that indicate that Freon decomposes at high temperatures. Decomposition has been seen in some of the halon and halon alternative extinguishing agents, which have similar chemical compositions. Therefore, while the methodology presented in the memorandum of March 27 is technically sound, it is not recommended that the BaBar Project rely on Options B or C without verifying the assumption regarding the non-flammability of Freon.

The CERN tests, as the March 27, 2006 memo points out, measure the local ignition of a gas or gas mixture and do not consider flame propagation. The analytical techniques used to calculate flame propagation with inert gases have not been validated with decomposition products. Therefore, to provide a conservative estimate of the difference between the local ignition of a gas or gas mixture (CEN test method) and flame propagation (Bureau of Mines test method), a comparison of known lower flammable limit quantities (Bureau of Mines) to the Tci values (CEN method) was performed. These values are shown in Table 1. The ratios of these values vary between 1.14 and 1.32. This indicates that the CEN values can be increased by at least a factor of 1.14 and remain at or below those necessary for flame propagation (Bureau of Mines) for the gas mixtures of interest here.

Table 1 Comparison of Bureau of Mines Data to CEN Data

Gas	Bureau of Mines	CEN	Ratio
IsoButane	1.8	1.55	1.16

IsoButane/CO2	9.5	7.95	1.19
IsoButane/Nitrogen	5.4	4.1	1.32
Methane	5	4.4	1.14
Propane	2.1	1.8	1.17
Ethane	3	2.4	1.25
N-Butane	1.8	1.45	1.24
Hydrogen	4	3.5	1.14

This analysis is a reasonably conservative method for determining flame propagation values based on the CEN test results. The results indicate that the isobutane and Freon limit would be 6.5 percent, and the isobutane and argon would be 2.7 percent. The curve associated with these two values, Option D in Figure 1, approaches the values associated with Curve B of the March 27, 2006 memo, for isobutene and Freon based on the approach developed by Messner. In fact, Option D represents slightly greater flexibility, based on the analysis of available flammability data for gas mixtures of interest.

As an alternative to this analysis, the limits could be determined experimentally. Several of the halon and halon alternative agents decompose at elevated temperatures, but remain extinguishing agents. The high heat capacity and thermal decomposition of Freon will absorb much of the energy released from the isobutane and inhibit the propagation of flame more than the CERN data suggest. Unfortunately the exact amount of Freon needed to prevent flame propagation would need to be experimentally determined. In the absence of such an effort, it is recommended that the curve that represents Option D be used for determining non-flammable gas mixtures for use in the BaBar RPC avalanche chamber.

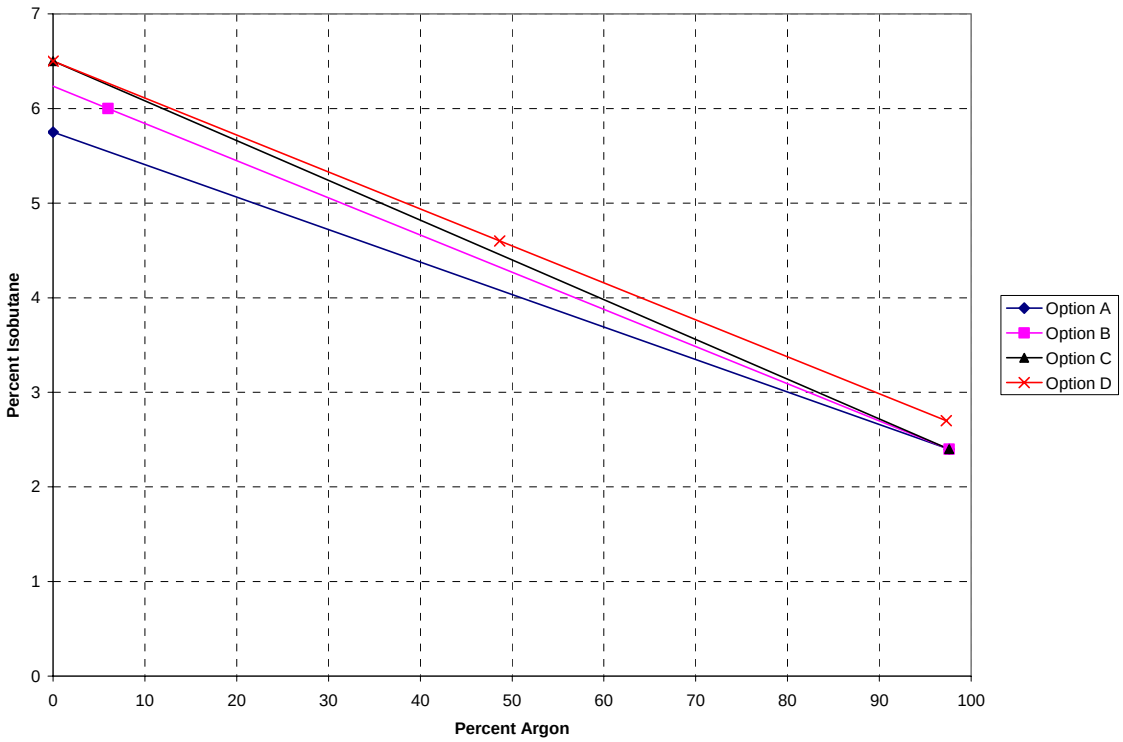

Figure 1 Plot of Isobutane-Freon-Argon Concentration