

CHAPTER 60

Chemical and Color Quench Curves Over Extended Quench Ranges

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ABSTRACT

Chemical and color quench curves are presented for five nuclides over extended quench ranges. These curves may approximate the total domain of chemical/color quench because of the quenching agents used. The difference between chemical and color curves do not increase continuously as quench increases, rather they pass through a maximum. Study of that relationship suggested a heuristic approach for obtaining color efficiencies corrected from chemical quench curves.

INTRODUCTION

Chemical and color-quench curves used in liquid scintillation counting do not superimpose over the complete range of counting efficiencies for a given radionuclide. A study was conducted to define these curves for a few nuclides over extended quench ranges. An approach was taken to define the entire quench domain for a given nuclide. That information led to the capability of providing color quench correction automatically from conventionally prepared chemical quench curves.

The radionuclides studied were ^3H , ^{63}Ni , ^{125}I , ^{14}C , ^{35}S , ^{36}Cl , ^{32}Na and ^{32}P . Results reported here are for ^3H , ^{125}I , ^{14}C , ^{35}S , and ^{32}P .

QUENCHING AGENTS

A variety of chemical quenching agents was tried, but nitromethane and nitrobenzene provided representative results over extended quench ranges. Representative color quench agents used in the study included:

- erythrosine: di-sodium salt of 9(o-carboxyphenyl)-6-hydroxy-2,4,5,7-tetraiodo-3H-xanthene-3-one

FD&C red #3

- fluorescein: 3,4'-dehydroxyfluoran
- tartrazine: tri-sodium salt of 4,5-dihydro-5-oxo-1-(4-sulfophenyl)-4-[(4-sulfophenyl)azo]-1H-pyrazole-3-carboxylic acid
FD&C yellow #5
- methyl Red: 4'-dimethylaminoazobenzene-2-carboxylic acid
- ferrocene: dicyclopentadienyl iron
- allura Red AC: disodium salt of 6-hydroxy-5-[(2-methoxy-5-methyl-4-sulfophenyl)azo]-2-naphthalenesulfonic acid
FD&C red #40

Mixtures of some of the above dyes were used, but none was as useful as Alberta PAQ,¹ (Photon Absorbing Quencher) which consists of:

- 262.8 mg 4-phenylazo-1-naphthol
- 578 mg 1-(2'-methyl-4'-(2''methylphenylazo)-phenylazo)-2-naphthol
- 137.3 mg 4-phenylazoaniline
- 176.7 mg 4-phenylazo-1-naphthylamine in 100 mL toluene

The importance of PAQ for this study is explained below.

Some problems with precipitation occurred. For example, ³⁶Cl was in the form of 1NHCl and produced a precipitate with FD&C red #3. Apparently exchange of ³⁶Cl with iodide in the dye occurred before precipitation, or ³⁶Cl was carried by the precipitate into a 2 π counting condition, because the count rate of the sample decreased with time.

QUENCH CURVES

The general features of these quench curves are represented by Figures 1 to 5 for the nuclides ³H, ¹²⁵I, ¹⁴C, ³⁵S, and ³²P. Each plot presents chemical and color quench curves for the stated nuclide as measured by H#, the inflection point on the edge of the ³⁷Cs Compton spectrum. The upper curve is the chemical quench curve, the lower is the color curve.

These curves cover 600 H#'s, almost to 0% counting efficiency for each nuclide except ³²P, and are cubic polynomial fits to the original data. The color quench curve was generated using Alberta PAQ in standard 20 mL Pyrex vials. All other color quench curves generated in this study lie above the color curves shown here, whether composed of single or mixed dyes, whether the dyes were organic or inorganic soluble, whether mixtures of chemical and color quenching agents were used, and regardless of the chemical composition of the vial or volume of the sample up to 20 mL.

That the absorption spectrum¹ of the PAQ mixture absorbs essentially all photons between 375 and 525 nm was reconfirmed. Consequently each pair of chemical/color quench curves for each nuclide provides a reasonable approximation to the complete chemical/color quenching domain in liquid scintillation counting, if constrained in pathlength by the geometry of a standard 20 mL vial. This is supported by the fact that about 1690 μ mol of nitromethane

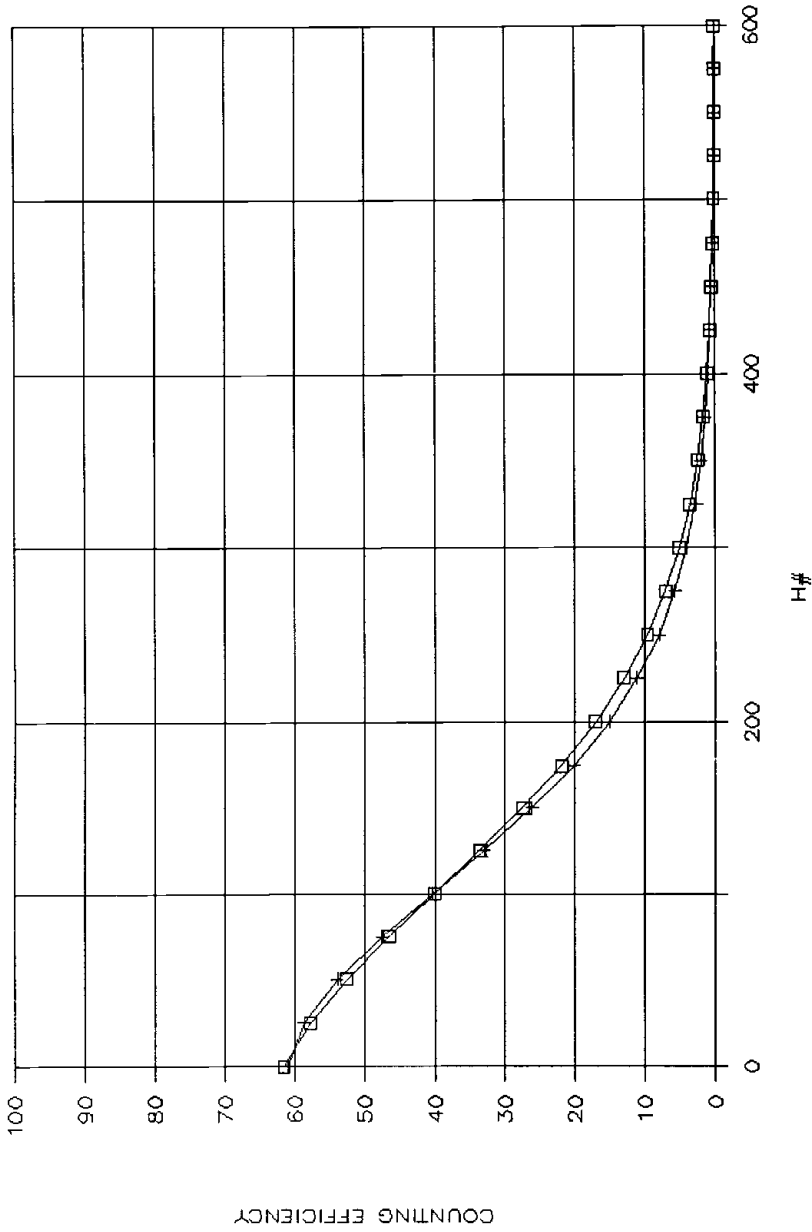


Figure 1. Chemical and color quench curves as a function of H# for ^3H .

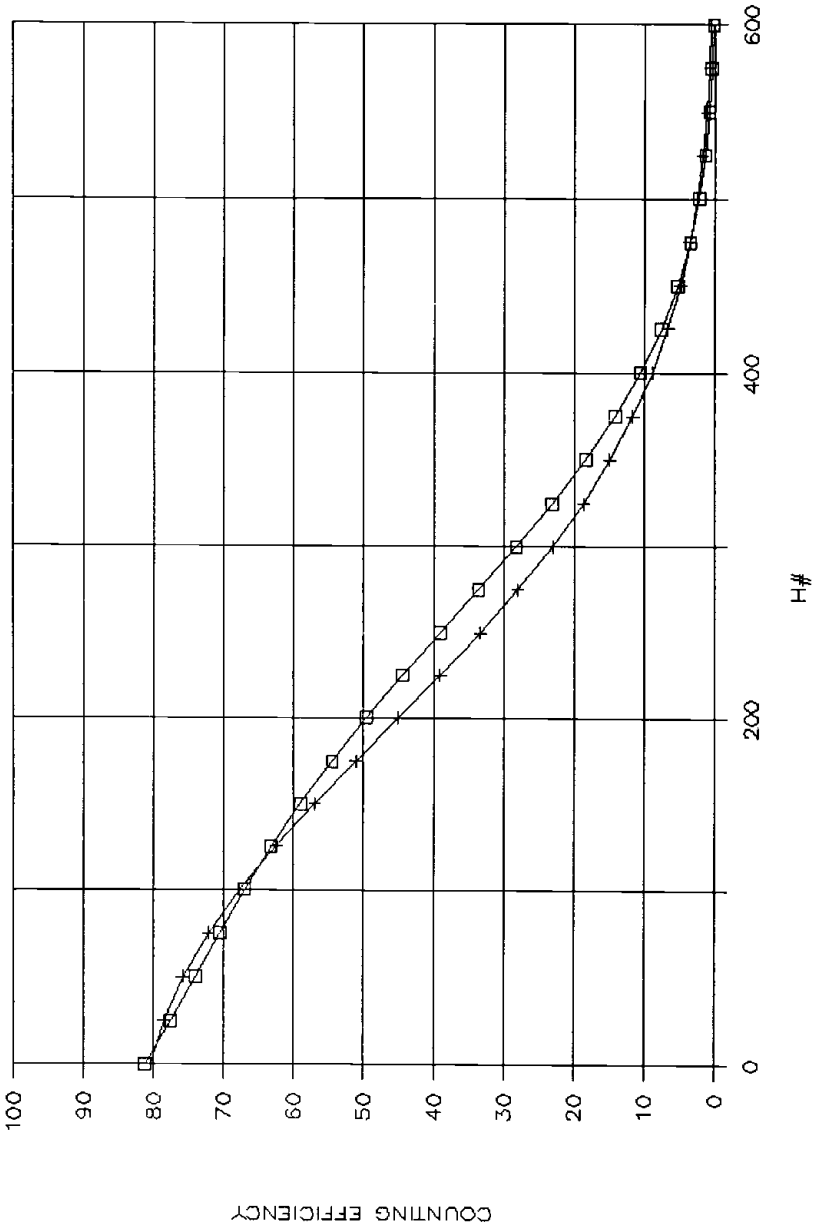


Figure 2. Chemical and color quench curves as a function of H# for ¹²⁵I.

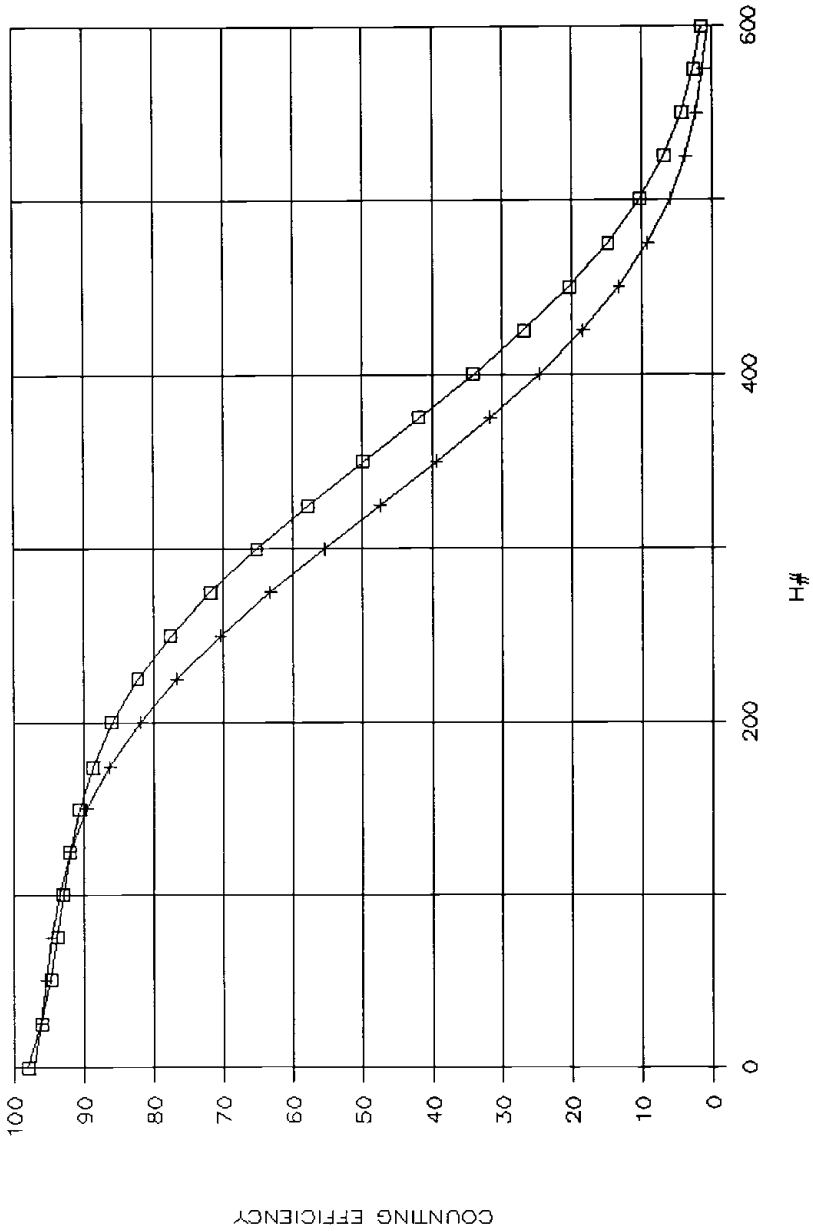


Figure 3. Chemical and color quench curves as a function of H# for ¹⁴C.

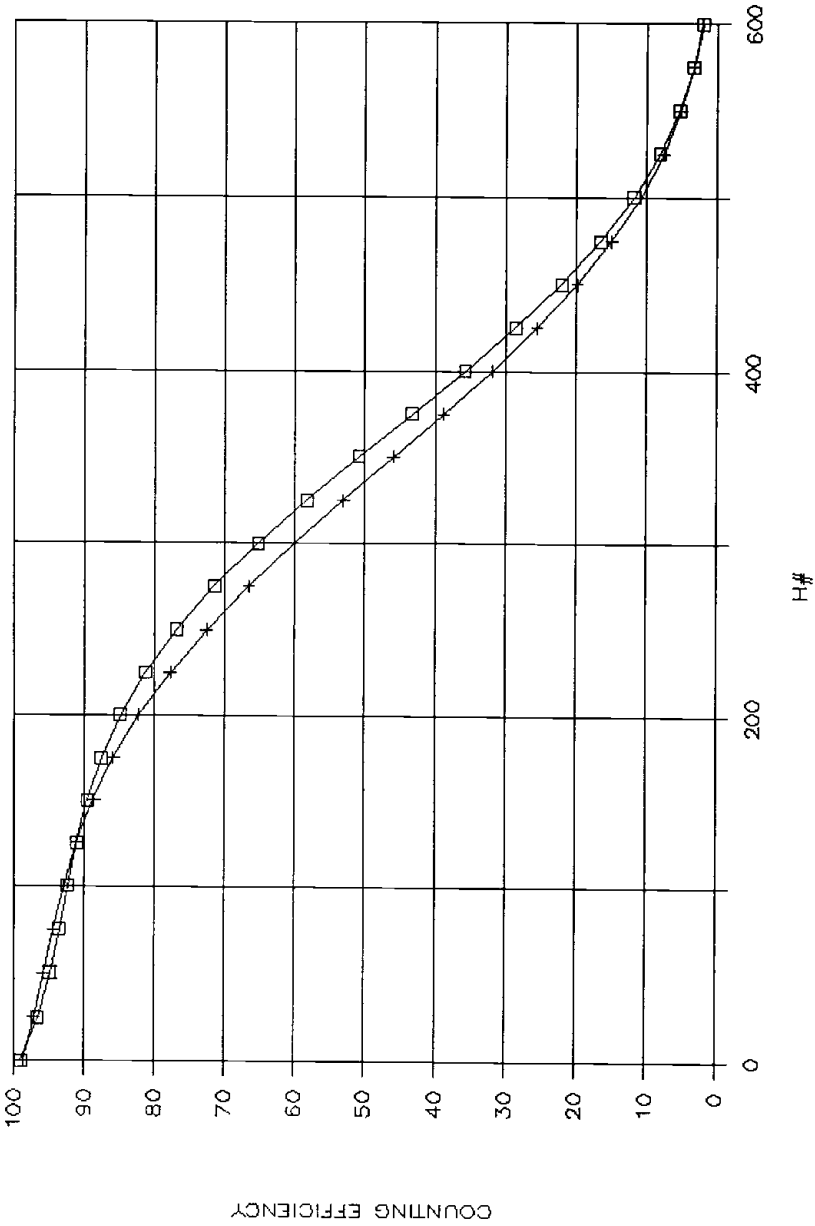


Figure 4. Chemical and color quench curves as a function of H# for ³⁵S.

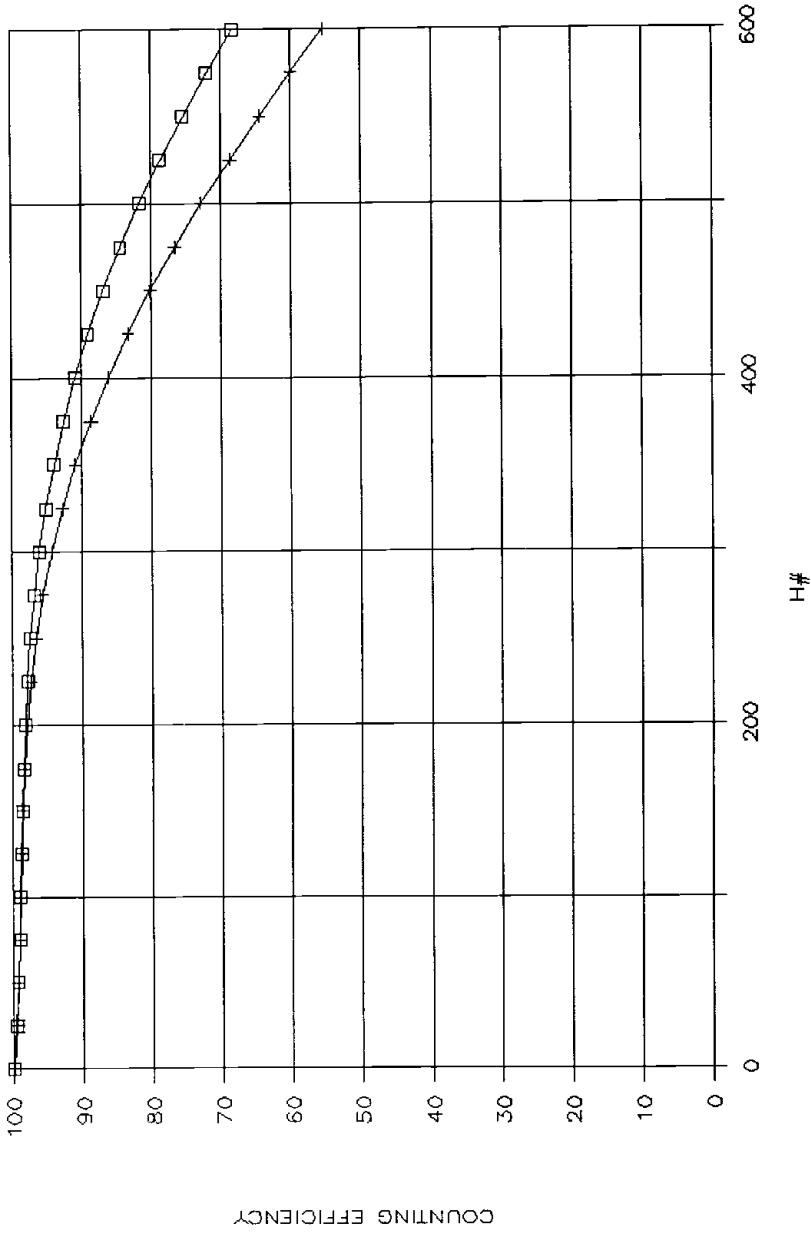


Figure 5. Chemical and color quench curves as a function of H# for ³²P.

Table 1. Chemical Quenched Unknowns vs Chemical Quench Curves

Nuclide	Minimum Error	Maximum Error	Mean Error
³ H	0.1	3.5	1.6
¹²⁵ I	0.4	4.8	1.4
¹⁴ C	0.3	1.9	1.0
³⁵ S	0.1	2.0	1.1
³² P	0.1	0.7	0.3

are required to produce the same counting efficiency as 1 μ mol of the Alberta mixture.

These plots show that the difference between chemical and color quench curves does not increase continuously with quench but passes through a maximum. Although the detailed shape of quench curves prepared from the same standards varies if different photomultiplier tubes are used, the difference between chemical and color curves is constant.

DPM RECOVERY

If means existed to determine whether color correction were required and to what extent, the actual correction could be obtained from the quench curve differences presented here. Such a proprietary color correction monitor has been developed.² It depends upon an appropriate calibration of the liquid scintillation counter in terms of a generalization of the Beer-Lambert law.

Chemical quench curve results for ³H, ¹²⁵I, ¹⁴C, ³⁵S, and ³²P obtained from the color correction monitor follow. Table 1 gives results in terms of %error in DPM recovery for chemical standards run against chemical quench curves for each of the five nuclides. This provides a measure of accuracy for each nuclide quench curve. Each sample set consisted of 12 samples in standard 20 mL vials and 12 samples in 7 mL vials. The least, largest, and mean errors are given for each data set.

Table 2 provides exactly the same information for colored samples run against previously prepared colored quench curves. Table 3 provides the same information for a set of 24 unknowns for each nuclide. For the unknowns, volumes varied from 2 to 16 mL, and quench varied from pure chemical to pure color; a variety of dyes were used. Table 4 illustrates the %error in DPM recovery for pure colored samples run against chemical quench curves.

Table 2. Color Quenched Unknowns vs Color Quench Curves

Nuclide	Minimum Error	Maximum Error	Mean Error
³ H	0.1	2.9	1.4
¹²⁵ I	0.7	2.5	1.6
¹⁴ C	0.4	4.5	1.8
³⁵ S	0.1	3.5	1.3
³² P	0.1	0.3	0.2

Table 3. Chemical/Color Unknowns vs Chemical Quench Curves via Color Correction Monitor

Nuclide	Minimum Error	Maximum Error	Mean Error
³ H	1.7	10.9	7.7
¹²⁵ I	0.3	5.0	3.6
¹⁴ C	0.1	2.1	1.2
³⁵ S	0.1	5.6	3.2
³² P	0.1	3.5	0.8

Table 4. % Error, DPM Recovery No Color Correction Applied

Nuclide	Mean Error			
	H# = 250	H# = 300	H# = 350	H# = 400
³ H	12.9	16.0	19.2	2.9
¹²⁵ I	12.2	16.0	18.8	18.4
¹⁴ C	9.9	14.9	23.0	29.4
³⁵ S	6.1	7.7	9.8	10.1
³² P	1.4	1.4	2.4	5.6

SUMMARY

A comparison of chemical and color quench curves for 5 nuclides over extended quench ranges shows that their differences pass through a maximum, and that this difference is independent from PMTs. Development of a color quench corrector combined with chemical quench curves and the fixed differences between chemical and color curves proved useful in providing efficiency correction for colored samples.

REFERENCES

1. Ediss, C., R.J. Flanagan, S.A. McQuarrie, and L.I. Wiebe. *Int. J. Appl. Radiat. Isot.* 33:296 (1982).
2. Dodson, C. To be published.

