

# Lawrence Berkeley National Laboratory

## Recent Work

### Title

MEASUREMENT OF THE ELECTRON-ASYMMETRY PARAMETER OF  $\bar{\nu}_n + e \rightarrow \nu + V$

### Permalink

<https://escholarship.org/uc/item/88m0140m>

### Authors

Gershwin, Lawrence K.  
Alston-Garnjost, Margaret  
Bangerter, Roger O.  
et al.

### Publication Date

1967-08-14

cy. 2

University of California  
Ernest O. Lawrence  
Radiation Laboratory

MEASUREMENT OF THE ELECTRON-ASYMMETRY  
PARAMETER OF  $\Sigma^- \rightarrow n + e^- + \bar{\nu}$

Lawrence K. Gershwin, Margaret Alston-Garnjost, Roger O. Bangerter,  
Angela Barbaro-Galtieri, Terry S. Mast, Joseph J. Murray,  
Frank T. Solmitz, M. Lynn Stevenson, Robert D. Tripp,  
Alain J. Verglas, and Bryan R. Webber

August 14, 1967

TWO-WEEK LOAN COPY

This is a Library Circulating Copy  
which may be borrowed for two weeks.  
For a personal retention copy, call  
Tech. Info. Division, Ext. 5545

UCRL-17740  
cy. 2

## **DISCLAIMER**

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

Presented at the International Conference  
on Elementary Particles, Heidelberg,  
Germany, September 20-27, 1967.

UCRL-17740  
Preprint

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory  
Berkeley, California

AEC Contract No. W-7405-eng-48

MEASUREMENT OF THE ELECTRON-ASYMMETRY  
PARAMETER OF  $\Sigma^- \rightarrow n + e^- + \bar{\nu}$

Lawrence K. Gershwin, Margaret Alston-Garnjost, Roger O. Bangerter,  
Angela Barbaro-Galtieri, Terry S. Mast, Joseph J. Murray,  
Frank T. Solmitz, M. Lynn Stevenson, Robert D. Tripp,  
Alain J. Verglas, and Bryan R. Webber

August 14, 1967

MEASUREMENT OF THE ELECTRON-ASYMMETRY  
PARAMETER OF  $\Sigma^- \rightarrow n + e^- + \bar{\nu}$

Lawrence K. Gershwin, Margaret Alston-Garnjost, Roger O. Bangerter,  
Angela Barbaro-Galtieri, Terry S. Mast, Joseph J. Murray,  
Frank T. Solmitz, M. Lynn Stevenson, Robert D. Tripp,  
Alain J. Verglas, and Bryan R. Webber

Lawrence Radiation Laboratory  
University of California  
Berkeley, California

August 14, 1967

We have examined the up-down asymmetry of electrons from the decay  $\Sigma^- \rightarrow n + e^- + \bar{\nu}$  using polarized  $\Sigma^-$ 's produced via the reaction  $K^- + p \rightarrow \Sigma^- + \pi^+$  at 400 MeV/c. This leads to a  $g_A/g_V$  which somewhat favors Willis' solution B,<sup>1</sup> unlike the recent<sup>2</sup>  $\Sigma^- \rightarrow \Lambda + e^- + \bar{\nu}$  rate which favors Willis' solution A.

I. SELECTION OF EVENTS

Although some leptonic decays were found in the scan, most of them were obtained from the measurement of all  $\Sigma^-$  events within the fiducial volume, about 50 000 of which passed the usual production and decay hypothesis. Most of these were measured on the Spiral Reader measuring machine. Those events that did not pass the usual hypothesis with confidence level greater than  $10^{-5}$  were fit to the hypotheses:

$$K^- + p \rightarrow \Sigma^- + \pi^+ \rightarrow \left\{ \begin{array}{l} e^- \\ \mu^- + \text{missing mass} \\ \pi^- \end{array} \right\}.$$

Events for which the missing mass for the electron hypothesis was greater than the neutron mass were investigated further. In addition, we subjected to missing-mass fits any events for which the confidence

level for the usual decay hypothesis was between  $10^{-5}$  and  $5 \times 10^{-2}$ , the measured momentum of the decay product was less than 170 MeV/c in the rest frame of the  $\Sigma^-$  (193 MeV/c for ordinary decay), and the measured momentum was pulled more than two standard deviations in order to fit the usual decay. One further source of events was those for which no fits were obtained, but for which the decay secondary had a laboratory momentum less than 130 MeV/c. Most of these events were the result of a poor measurement or a kink in the decay  $\pi^-$  which the measurer had not noticed. The remainder were considered leptonic- and radiative-decay candidates and were remeasured at least once on a Franckenstein measuring machine. After elimination of more candidates by these remeasurements and a careful examination for kinks in the tracks, 107 events remained.

The ionization of the decay tracks was examined on this sample; 69 events were considered  $\pi^-$  or  $\mu^-$  or unidentifiable by ionization, 2 were  $\mu^-$  where the  $\mu^-$  decayed to an  $e^-$ , and 36 were identified as electrons. Presumably there were a few  $e^-$  events among the 69 radiative-decay candidates where the particle is not identifiable by ionization. The momentum spectrum of electrons is seen in Fig. 1.

Of the electron events 32 had electron laboratory momentum less than 145 MeV/c and thus were visually identifiable as electrons by ionization. The other four had laboratory momenta from 156 to 175 MeV/c. For these, as well as for 10 others that subsequently were considered unidentifiable or nonminimum tracks, the gaps between bubbles were measured, and a gap length distribution was made. The distribution should follow an exponential behavior, after a correction

is made for small gaps because of finite bubble size. The mean gap length then is proportional to  $\beta^2$ , so if one measures another track on the frame (preferably associated with the event), one obtains

$$\frac{\text{mean gap length of candidate}}{\text{mean gap length of other track}} = \frac{\beta^2 \text{ of candidate}}{\beta^2 \text{ of other track}} .$$

In this way, obvious low-momentum electrons gave, on the average,  $\beta^2 \approx 1.0 \pm 0.2$ , and the four candidates had  $\beta^2 \approx 1.0$  with a statistical error such that a pion's  $\beta^2$  was at least 1.5 standard deviations away. The four events also all looked minimum-ionizing from examination by eye.

For the 36 electron events the momentum of the  $\Sigma^-$  at decay is greater than 80 MeV/c, the length of the  $\Sigma^-$  is greater than 1mm, and the dip angle of the electron is less than 70 deg. No electron candidates were eliminated because of these criteria.

## II. THEORY AND RESULTS

One can write the Hamiltonian for leptonic baryon decay as  $H = (G/\sqrt{2}) J_\lambda \ell^\lambda$ , where  $\ell^\lambda$  is the usual lepton current,  $\bar{u}_e \gamma^\lambda (1 + \gamma_5) u_\nu$ , and  $J_\lambda$  is the baryon current,  $V_\lambda + A_\lambda$ , with  $V_\lambda = g_V \gamma_\lambda$  and  $A_\lambda = g_A \gamma_\lambda \gamma_5$ . The baryon matrix element for  $\Sigma^- \rightarrow n + e^- + \bar{\nu}$  is then  $\langle n | \gamma_\lambda (g_V + g_A \gamma_5) | \Sigma^- \rangle$ . If we assume time reversal invariance,  $g_A$  and  $g_V$  are both real. For polarized baryons, this gives<sup>3</sup> a momentum spectrum for the electron

$$I(\hat{q}) = 1 + \alpha \langle \underline{\sigma}_\Sigma \rangle \cdot \hat{q} ,$$

where

$$\alpha = 2 \frac{g_A}{g_V} \left[ \frac{1 - g_A/g_V}{1 + 3 (g_A/g_V)^2} \right] .$$

Here,  $\hat{q}$  is the electron-momentum unit vector.<sup>4</sup>

The likelihood function for the momentum distribution of the electron is

$$\mathcal{L}(\alpha) = \prod_{i=1}^{36} (1 + \alpha \langle \underline{\sigma}_{\Sigma} \rangle_i \cdot \hat{q}_i).$$

The  $\Sigma^-$  polarization,  $\langle \underline{\sigma}_{\Sigma} \rangle$ , is computed for each event, using the partial-wave analysis of the  $\Sigma\pi$  system.<sup>5</sup> Our average polarization is 0.5 in magnitude.

The logarithm of  $\mathcal{L}$  is plotted in Fig. 2, yielding  $\alpha = 0.29 \pm 0.45$ . Positive  $\alpha$  means that electrons are emitted preferentially in the same direction as the  $\Sigma^-$  polarization, which is opposite to ordinary beta decay. Figure 3 is a plot of  $\alpha$  vs  $g_A/g_V$ . Our value of  $\alpha$  is near the maximal value,  $\alpha = 1/3$ , and thus by itself does not give a very good determination of a central value for  $g_A/g_V$ .

Cabibbo's theory assumes that  $A_\lambda$  and  $V_\lambda$  are members of  $SU_3$  octets of axial and vector currents.<sup>6</sup> Further,  $\Delta S = 0$  and  $\Delta S = 1$  leptonic-decay baryon currents are members of the same octets but have different strengths:

$$J_\lambda^i = \cos\theta_i J_\lambda^i(\Delta S = 0) + \sin\theta_i J_\lambda^i(\Delta S = 1)$$

with  $i = A, V$ .  $A_\lambda$  and  $V_\lambda$  each contribute D and F type  $SU_3$  couplings, because  $8 \otimes 8$  contains a symmetric and an antisymmetric octet. After computation of the  $SU_3$  coefficients, one obtains:

$\frac{\text{Decay}}{n \rightarrow p + e^- + \bar{\nu}}$	$\frac{g_A}{(D_A + F_A) \cos\theta_A}$	$\frac{g_V}{(D_V + F_V) \cos\theta_V}$
$\Sigma^- \rightarrow n + e^- + \bar{\nu}$	$(D_A - F_A) \sin\theta_A$	$(D_V - F_V) \sin\theta_V$



Here we include the neutron beta decay in order to compare the signs.

From conserved-vector-current (CVC) theory, we have

$F_V = 1$  and  $D_V = 0$ . Setting  $\theta_A = \theta_V$ , which nearly appears to hold experimentally,<sup>7</sup> one has  $(g_A/g_V)_{n \rightarrow p} = D_A + F_A$  and

$$(g_A/g_V)_{\Sigma^- \rightarrow n} = F_A - D_A.$$

Willis et al.<sup>1</sup> obtain two best-fit solutions to all leptonic baryon decays. These are shown in Table I along with the predicted value of  $g_A/g_V$ . More recently Brene et al.<sup>7</sup> and Carlson<sup>8</sup> have further investigated solution A. Their results as well as the two solutions of Willis are shown in Fig. 3, where a comparison is made with this experiment. Our likelihood function favors solution B over solution A by a probability ratio of 10.5, or solution B over Carlson's solution by a probability ratio of 16.0. On the other hand, recent evidence of Barash et al.<sup>2</sup> on the decay rate  $\Sigma^- \rightarrow \Lambda + e^- + \bar{\nu}$  strongly favors solution A, so that our limited sample of polarized  $\Sigma^-$  leptonic decays leads to a mild (less than two standard deviations) inconsistency with other baryon leptonic-decay results when they are related to each other through Cabibbo's theory.

We acknowledge the continuing support of Professor Luis W. Alvarez. We also wish to thank the 25-inch bubble chamber crew and our scanners and measurers for their help.

## FOOTNOTES AND REFERENCES

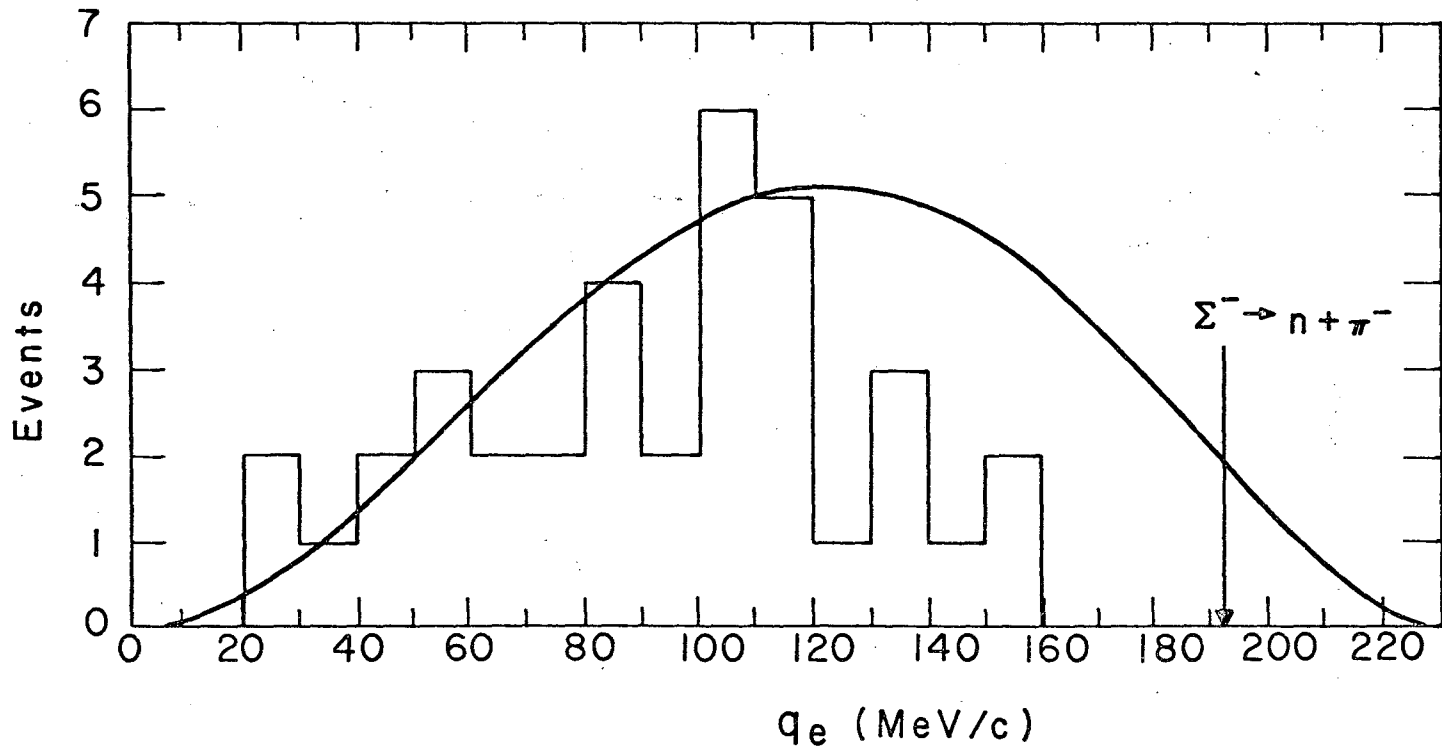
\*This work was done under the auspices of the U. S. Atomic Energy Commission.

1. W. Willis et al., Phys. Rev. Letters 13, 291 (1964).
2. N. Barash, T. B. Day, R. G. Glasser, B. Kehoe, R. Knop, B. Sechi-Zorn, and G. A. Snow, Phys. Rev. Letters 19, 181 (1967).
3. G. Källén, Elementary Particle Physics, (Addison-Wesley, Reading, Mass., 1964), p. 361. Källén uses the conventional beta-decay notation, with  $\gamma_\lambda(g_V - g_A\gamma_5)$ , so that our  $\alpha$  differs from his by the appropriate minus sign. Willis et al. use the notation  $G_A/G_V = 1.15$  for neutron decay in Table II, but tabulate something called  $A/V$  for  $\Sigma^- \rightarrow n + e^- + \bar{\nu}$  in Table III. This quantity  $A/V$  is actually  $-G_A/G_V$  in their notation and  $-g_A/g_V$  in ours. The notation  $A/V$  was apparently chosen following Cabibbo (see Table I of Ref. 6), the sign convention being established by  $A/V = -1.18$  for  $n \rightarrow p + e^- + \bar{\nu}$ . We are grateful to Prof. J. D. Jackson for pointing this out.
4. We neglect the  $\Sigma^- - n$  mass difference. If we do not neglect it, then  $\alpha$  is a more complicated function, with terms for the neutron energy and the electron momentum. These corrections turn out to be small and are thus neglected. There is very little change in our best answer for  $g_A/g_V$  if we use the more complicated expression for  $\alpha$ .
5. R. Bangerter, A. Barbaro-Galtieri, J. P. Berge, J. J. Murray, F. T. Solmitz, M. L. Stevenson, and R. D. Tripp, Phys. Rev.

- Letters 17, 495 (1966); M. Watson, M. Ferro-Luzzi, and R. D. Tripp, Phys. Rev. 131, 2248 (1963).
6. N. Cabibbo, Phys. Rev. Letters 10, 531 (1963).
  7. N. Brene, L. Veje, M. Roos, and C. Cronström, Phys. Rev. 149, 1288 (1966).
  8. C. Carlson, Phys. Rev. 152, 1433 (1966).

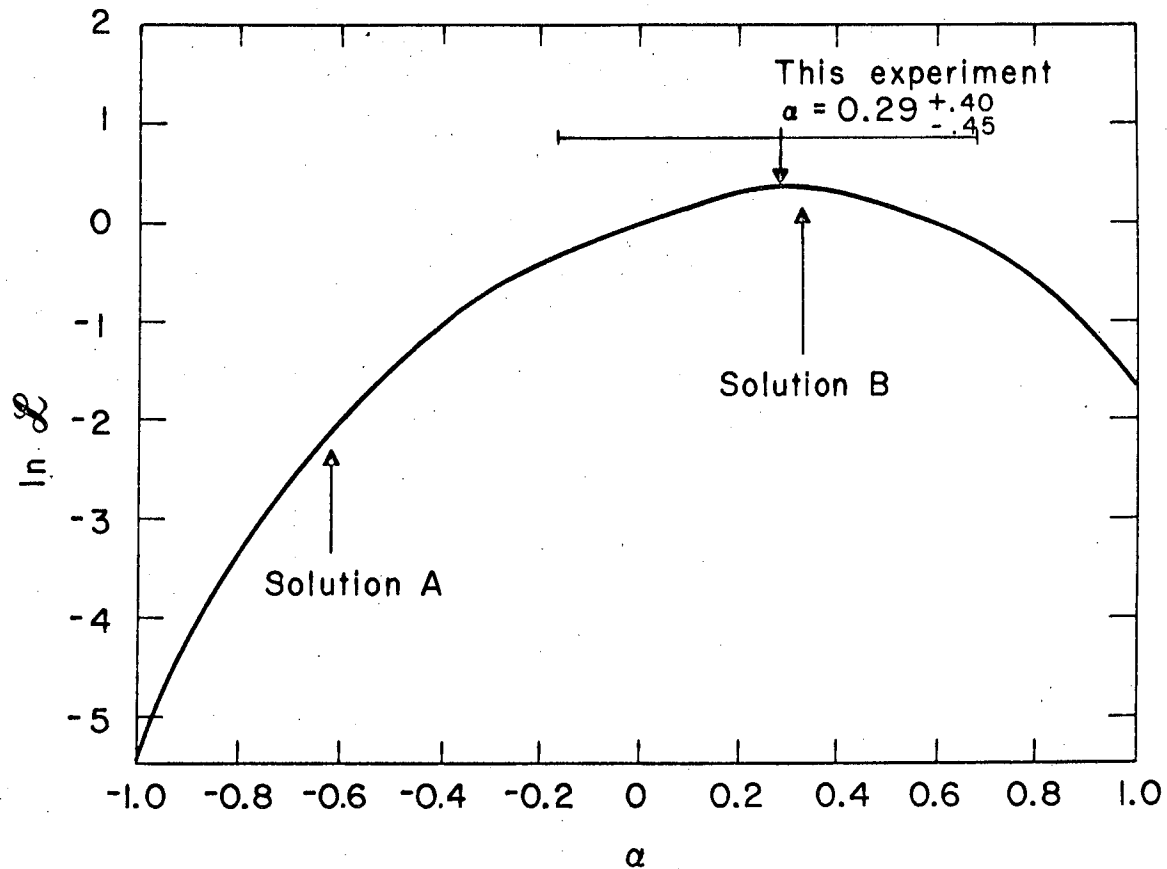
Table I. Best-fit solutions of Willis to all leptonic baryon decays,  
and predicted values of  $g_A/g_V$ .

Solution	$D_A$	$F_A$	$(g_A/g_V)_{n \rightarrow p}$	$(g_A/g_V)_{\Sigma^- \rightarrow n}$
A	0.742	0.436	1.178	-0.306
B	0.377	0.749	1.226	0.372



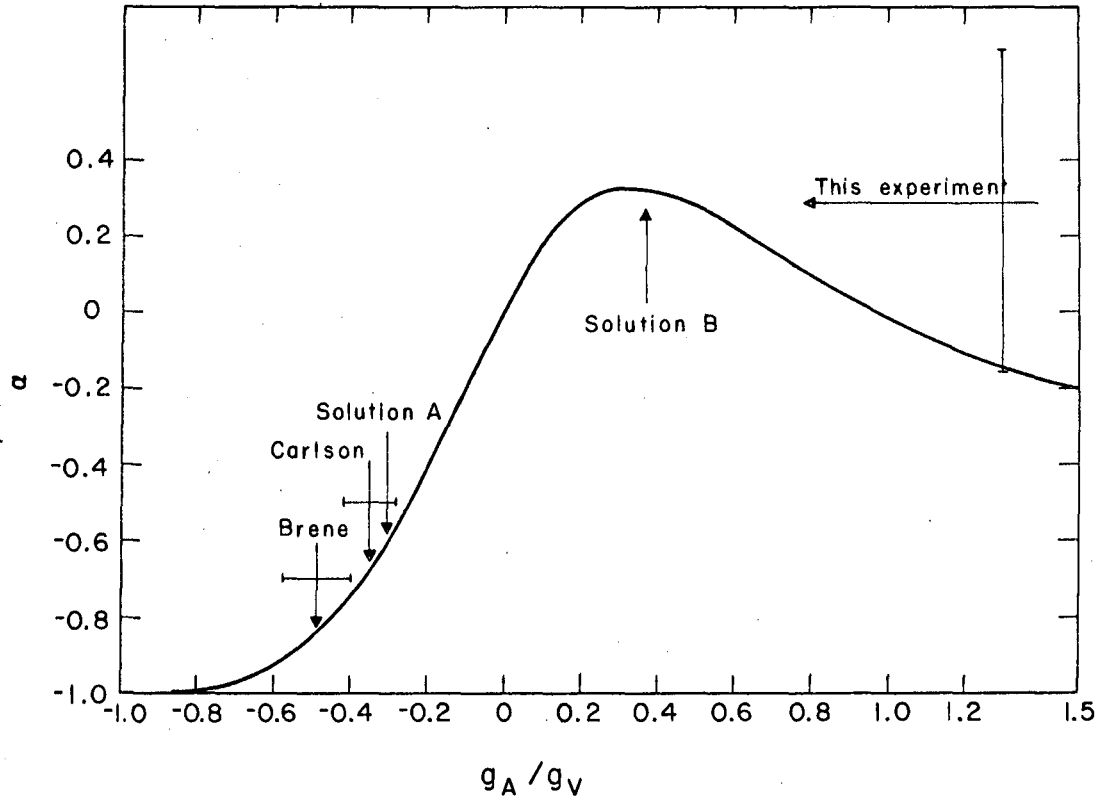
XBL 678-3874

Fig. 1. Momentum of electrons in the rest frame of the  $\Sigma^-$ . The smooth curve is the phase-space distribution on the basis of 50 000  $\Sigma^-$  decays and a branching ratio of 1:800.



XBL 678-3875

Fig. 2. Plot of  $\ln L$  vs  $\alpha$ .



XBL678-3876

Fig. 3. Plot of  $\alpha$  vs  $g_A/g_V$ . The predicted values of Willis, Brene, and Carlson are indicated.

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

- A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.



[The page contains extremely faint, illegible text, likely bleed-through from the reverse side of the document. The text is arranged in approximately 25 horizontal lines across the page.]

