TECHNICAL SUPPORT DOCUMENT

REPORT TO THE AIR RESOURCES BOARD ON CARBON TETRACHLORIDE

PART C - PUBLIC COMMENTS AND RESPONSES

April 1987

PART C - PUBLIC COMMENTS AND RESPONSES TO THE DRAFT AND FINAL PART A AND PART B CARBON TETRACHLORIDE REPORT

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I. Chevron Environmental Health Center, Inc.

Chevron Environmental Health Center, Inc.
A Chevron Research Company Subsidiary
15299 San Pablo Avenue, Richmond, California
Mail Address: P.O. Box 4054, Richmond, CA 94804-0054

R. D. Cavalli
Manager
Product Evaluation and Community Health

September 18, 1986

Carbon Tetrachloride Risk Assessment

Mr. William V. Loscutoff
Chief, Toxic Pollutants Branch
Air Resources Board
P.O. Box 2815
Sacramento, California 95812

Dear Mr. Loscutoff:

The draft risk assessment on carbon tetrachloride prepared for the Air Resources Board by the Department of Health Services (DHS) raises a significant question not directly encountered to date in the air toxics program, namely, "what constitutes sufficient valid data upon which to base a quantitative risk assessment?". While the studies presented by the DHS may be sufficient to qualitatively characterize the carcinogenic potential of carbon tetrachloride, the serious limitations that exist in the data, which are recognized by the DHS, prevent their application in quantitative risk estimation. While a range of risk can be derived from these data, we believe the very low nonstatistical confidence in such values severely limits their utility for the risk manager. Risk assessment, even when it is based on adequate reliable data, is uncertain due to the many assumptions that must be made and which may not be applicable to all of the individuals in the potentially exposed human population. We urge the Board to use more traditional approaches in assessing the potential adverse effects from this compound rather than developing and applying these highly uncertain and potentially misleading quantitative risk estimates (our reasons are set forth below). Should this be unacceptable, we suggest that the Board acquire additional data to better define the dose-response nature of carbon tetrachloride's potential carcinogenicity as its first step in the risk management of this compound. Such data would enable the Board to more confidently predict the excess risk which might be incurred by a population living in the vicinity of a specific source, and more accurately assess the benefits and attendant costs of any control options that might be considered.

The DHS has properly pointed out the serious limitations in the data upon which it has based a quantitative risk assessment. The flaws include improper or inadequate controls, small exposure groups, inadequate or inconsistent dosing regimens, incomplete histopathological examinations, premature sacrifice of experimental animals, high noncancer mortality rates, and questionable relevance of the dose route (oral gavage) to the

human exposure situation under evaluation. In addition, there is considerable debate over the human relevance of rodent liver tumors. It is unclear why flaws similar to these, and of equal severity, led the DHS to exclude several studies from further consideration, but not all. Given the serious limitations of the studies selected, their use in quantitative risk assessment is inconsistent with the principles discussed in both the State and Federal cancer risk assessment guidelines.

Recent data presented by Condie, et al. (Fundamental & Appl. Tox. 7:199-206, 1986) raises additional concerns over the appropriateness of using the results of animal gavage studies which utilize an oil vehicle to predict the carcinogenic risk encountered by humans from the inhalation of ambient concentrations of carbon tetrachloride. The use of oil as a vehicle was found to significantly increase both the incidence and severity of carbon tetrachloride's hepatotoxicity over that encountered when the agent is administered in water. This effect may be due to alteration of either the distribution and metabolism of carbon tetrachloride, or the nutritional status of the animal by the oil vehicle. Thus, it appears that the use of an oil vehicle further limits the utility of the studies selected by DHS for quantitatively estimating the risks to humans from inhalation exposure.

Finally, it is not clear why the study by Kotin, et al. (1962), in which carbon tetrachloride administered by gavage to mice failed to produce tumors, was excluded from the DHS's discussion of the carcinogenicity studies performed in mice.

Thank you for your continued interest in the public's comments concerning the toxic air contaminants program. Questions concerning our comments should be directed to R. M. Wilkenfeld of my staff at (415) 231-6018.

Sincerely,

R. D. Cavalli
Manager, Product Evaluation
and Community Health

RMW:dcc-C/0986-123

STATE OF CALIFORNIA GEORGE DEUKMEJIAN, Governor

AIR RESOURCES BOARD
1102 Q STREET
P.O. BOX 2815
SACRAMENTO, CA 95812

January 23, 1987

Mr. R. D. Cavalli
Manager, Products Evaluation
and Community Health
Chevron Environmental Health Center, Inc.
P. O. Box 4054
Richmond, California 94804

Dear Mr. Cavalli:

Comments on the Draft Carbon Tetrachloride Report

Thank you for your comments on the Draft Carbon Tetrachloride Report. We referred your comments on "Part B - Health Effects of Carbon Tetrachloride" to the Department of Health Services (DHS). Their response to your comments are attached to this letter. Your comments and the DHS response will be included in Part C of the Final Draft Report on Carbon Tetrachloride.

We will have the Final Draft Report on Carbon Tetrachloride (Part A with the Overview, Part B, and the Part C) available for review within the next month. A copy of this report will be sent to you when it becomes available.

If you have any further questions on this matter, please contact Gary Murchison, Manager of the Compound Evaluation Section, at (916) 322-8521.

Sincerely,

William V. Loscutoff

William V. Loscutoff, Chief
Toxic Pollutants Branch
Stationary Source Division

Attachment

cc: Peter D. Venturini
Michael Lipsett, DHS

II. DOW Chemical U.S.A.

DOW CHEMICAL U.S.A.

WILLARD H. DOW CENTER
MIDLAND, MICHIGAN 48674

September 22, 1986

Mr. William V. Loscutoff, Chief
Toxic Pollutants Branch
Air Resources Board
P. O. Box 2815
Sacramento, California 95812

ATTENTION: CARBON TETRACHLORIDE

INTRODUCTION

In his letter of August 15, 1986, Peter Venturini, Chief of the Secondary Source Division of the California Air Resources Board (CARB), announced the availability of a two part draft report designed for the consideration of carbon tetrachloride as a toxic air contaminant in the State of California. Part A discusses the uses, emissions and exposure to ambient concentrations of carbon tetrachloride in California, while Part B discusses the effects of that compound on health and the risk from exposure to ambient concentrations.

As Part A states, the Dow Chemical Company manufactures carbon tetrachloride at Pittsburg, California. Dow, therefore, appreciates the opportunity to comment on this carbon tetrachloride draft report.

Mr. Venturini indicated, starting with carbon tetrachloride, CARB was initiating a new process for public review of such reports on alleged toxic air contaminants. The new process is intended to improve the ability of interested parties to have input into the process of identifying toxic air contaminants before the report is reviewed by the SRP. We applaud that intent. However, we are concerned that the rigid 30 day period from the time when draft reports are mailed to when written comments must be received may not always be long enough. This is important, because the initial comment period is the only opportunity for comments on Parts A & B in entirety. The later, even shorter, rigid 20 day comment period for the final draft will only allow comments on the report overview and revision made to the preliminary draft report. That is the last opportunity for any public comment.

These issues are very important to all sectors of the public...from industry to environmental groups. Thus we strongly urge slight extensions of these comment periods (perhaps by 2 weeks each) or some provision for case-by-case extension. The time period allowed for this initial carbon tetrachloride review is a good example of the possible need for additional review time. In mid-August, industry's environmental personnel were engaged in answering several Clean Air Act

Section 114 data requests as well as numerous other state requests associated with their air toxics programs. Then, almost simultaneous to Mr. Venturini's letter, we received for comment, the federal EPA overview and 12 inch thick, technical reports on their proposed hazardous organics national emissions standards for hazardous air pollutants (HON) project. Comments on that massive project were required by the September 17th National Air Pollution Control Techniques Advisory Committee (NAPTAC) meeting. Industry has been very hard pressed to physically examine its facilities and records for accuracy and currency of cited data and to assimilate its comments into response documents. An additional two weeks to review CARB's carbon tetrachloride drafts and to cross-check references to carbon tetrachloride in the federal EPA HON technical reports and the EPA/UNEP stratospheric ozone studies would have been greatly appreciated and would have led to a more thorough review.

TECHNICAL COMMENTS

As to uses of carbon tetrachloride in California, Dow Chemical restricts sales of this product and has not knowingly sold it into fumigant or pesticide production usage for more than ten years. Our California customers use it to manufacture chlorofluorocarbons (CFC's). We believe current control on emissions from carbon tetrachloride production and its further usage in fluorocarbon manufacture do thoroughly protect the health of people.

The draft report reviews possible exposure to carbon tetrachloride from drinking water, based on an examination of 2,500 California wells sampled. The California Department of Health Services indicated less than 2% of these wells, which included 753 large public water systems, have CCl_4 concentrations above the 0.5 ug/liter. DOHS concluded California results to be consistent with federal EPA findings where EPA estimated over 86% of the U.S. population is exposed to levels below 0.5mg/liter and 12.5% is exposed to 0.5 to 5 ug/liter. Recent EPA proposals to set the Maximum Contaminant Level (MCL) for carbon tetrachloride at 5ppb or 5 ug/liter will lead to continued protection of the California and entire U.S. population.

Part A of the draft report correctly references our <u>previous</u> producer projections for a 1 to 2% growth in carbon tetrachloride through 1990, due to increased chlorofluorocarbon demand for automotive refrigerants and foaming agents for the housing industry. However, evolving environmental concern for the possibility of chlorofluorocarbons causing depletion of stratospheric ozone has led to manufacturers to be a no-growth industry.

With regard to carbon tetrachloride's stratospheric ozone depletion <u>potential</u>, a couple points should be noted. First, even the Rand Report <u>prepared under contract for the federal EPA on "Projected Use, Emissions, and Banks of Potential Ozone Depleting Substances" notes that greater than 90% of carbon tetrachloride is totally consumed in its manufacturing usage. Thus only a limited percentage of CCl_4 manufactured could ever be available for stratospheric interaction.</u>

The federal EPA, in conjunction with the United Nation's Environmental Programme (UNEP), is currently conducting research for use in future agency decisions on whether or not to regulate CFC's or other chemicals that may affect the ozone layer. Again, only a very small percentage of the CCl_4 produced could ever be available for stratospheric interaction. The EPA clearly stated in 51 Fed. Reg. 1257-1260, January 10, 1987, that any further decision on regulation in this area must be based on further research and analysis, and should be evaluated in the context of international actions. The EPA, again through the Rand Corporation, is also investigating the implications of immediate adoptions of regulations versus waiting for improved scientific understanding of this matter. We would ask CARB to remember these uncertainties in its consideration of carbon tetrachloride as a toxic air contaminant.

Due to time constraints, we have been unable to conduct a detailed review of Park B of the draft report on the health effects of carbon tetrachloride. We are, however, enclosing a section of a report explaining our position on the tumorigenicity of carbon tetrachloride in experimental animals.

Carbon tetrachloride has exhibited carcinogenic response in certain test animals. However, it has not demonstrated carcinogenicity in humans at low levels.

The usage of carbon tetrachloride is declining. As indicated, the federal EPA has proposed canceling registrations of fumigants products containing carbon tetrachloride. This is likely to lead to prohibition of such fumigants in California and even further reduction of carbon tetrachloride exposures to Californians. The remaining exposures from production and subsequent CFC manufacture are controlled as to protect the health of people. Current levels of regulation and federal EPA proposals to regulate fugitive emissions, process vents, and storage tanks in carbon tetrachloride manufacturing processes via a hazardous organics national emission standard will serve to effectively protect human health. It is not necessary for regulation to be so stringent as to eliminate the carbon tetrachloride industry and its beneficial end products.

Carol Niemi

Carol Niemi
Chemicals & Metals Department
Environmental Affairs
Phone: 517/636-1636

/slg

Note: On September 18, 1986, Mr. Todd Wong speaking in Gary Murchison's absence, granted The Dow Chemical Company an extention until September 23, 1986, for receipt of these comments.

2. Tumorigenicity of Carbon Tetrachloride in Experimental Animals

A number of studies in experimental animals have shown that carbon tetrachloride can induce liver tumors in various species. (Edwards, 1941; Edwards et al., 1942; Eschenbrenner and Miller, 1946; Della Porta et al., 1961; Reuber and Glover, 1967; Reuber and Glover, 1970; NCI, 1976). The dose levels administered in the studies on mice and rats which resulted in a tumorigenic response were in excess of 1000 mg/kg/day. A tumorigenic response in hamsters occurred at a level approximately 1/10 of that which was needed to produce a tumorigenic response in rats. A summary of the dose levels resulting in a tumorigenic response in the various studies are presented in Table 5.

TABLE 5

Dose Level Resulting in Tumorigenic Response in Animals Administered Carbon Tetrachloride

Species (Strain)	Dose Level mg/kg/day	Reference
Rat (Buffalo)	approx. 1000[a] (1.3 mg/kg of a 50% soln.)	Reuber and Glover, 1967
Rat (Japanese, Osborne-Mendel, Wistar)	2080	Reuber and Glover, 1970
Mice (C_3H)	approx. 1200[a] (0.1 ml of a 40% soln.; 50 g mouse)	Edwards, et al., 1942
Mice (Inbred strain L)	approx. 1200[a] (0.1 ml of a 40% soln.; 50 g mouse)	Edwards, 1942
Mice (Strain A)	2400, 4800, and 9600	Eschenbrenner & Miller, 1946
Mice ($B_6C_3F_1$)	1250, 2500	NCI, 1976
Hamster (Golden Syrian)	198 reduced to 99 (after 7 weeks)	Della Porta, 1961

[a]Calculated dose

a. Association with cirrhosis

The preponderance of the data in the literature indicates that the tumorigenic response to carbon tetrachloride occurred as a consequence of the induction of post-necrotic cirrhosis.

Carbon tetrachloride induced cirrhotic changes in experimental animals were observed as low as 47 mg/kg in rats, 159 mg/kg in mice and 199 mg/kg reduced to 99 mg/kg after 7 weeks in hamsters. The data from various studies are summarized in Table 6.

TABLE 6

Levels of Carbon Tetrachloride Producing Cirrhotic Changes in Experimental Animals

Species (Strain)	Route	Exposure Level-mg/kg	Reference
Rat (not identified)	Sub-cutaneous injection	2000	Cameron and Karunaratne, 1936
Rat (Buffalo)	Sub-cutaneous injection	approx. 1000	Rueber and Glover, 1967
Rat (Japanese, Osborne-Mendel, Wistar, Black & Sprague-Dawley)	Sub-cutaneous injection	2080	Reuber and Glover, 1970
Rat (Osborne-Mendel)	P.O.	94 & 47	NCI, 1976
Mice ($B_6C_3F_1$)	P.O.	1250 & 2500	NCI, 1976
Mice (C_3H,A,C,Y)	P.O.	159	Edwards and Dalton, 1942
Hamster (Golden Syrian)	P.O.	198 reduced to 99 (after 7 weeks)	Della Porta, 1961

b. Mechanism of Action

The occurrence of hepatomas (in mice) as a result of the induction of post-necrotic cirrhosis suggests that carbon tetrachloride is not a direct acting carcinogen (Louria and Bogden, 1980). This observation is not contraindicated by the results of various short-term mutagenicity tests nor by the preponderance of the evidence indicating little or no covalent binding to liver DNA. The short-term mutagenicity test results using Salmonella typhinurium TA100, TA1535, TA1538, and E. Coli K12 have been consistently negative (McCann et al., 1975; McCann and Ames, 1976; Uehleke et al., 1976; Uehleke et al., 1977, and Simmon and Tardiff, 1978). Rocchi et al., 1973, reported no evidence of covalent binding in vivo to nuclear DNA in the liver of mice and rats. Whereas, Diaz Gomez et al., 1975, reported small but significant in vivo binding of ^{14}C from ^{14}carbon tetrachloride to liver nuclear DNA of mice and rats; however, these investigators, and also Uehleke et al., 1977, concluded that it was possible that a non-genetic mechanism was relevant for carbon tetrachloride. Callen et al., 1980 reported increases in gene mutation and mitotic recombination on D7 strain of Saccharomyces cerevisiae at high toxic levels. Dean and Hodson-Walker, 1979, reported negative results in an in vitro chromosome assay using cultured rat liver epithelial cells. Craddock and Henderson, 1978, and Mirsalis and Butterworth, 1980, reported no induction of unscheduled DNA synthesis in hepatocytes of rats exposed in vivo.

B. Implications of Scientific Data in the Assessment of Risk/Safety for Man

The implications of the results of the various studies on carbon tetrachloride in the assessment of risk for man are two-fold: (1) because of the differences in the capacity to metabolize carbon tetrachloride to the toxic intermediate between the rodents and the rhesus monkey, the animal selected for use in the assessment of risk for man must be based on sound scientific rationale and/or data and (2) a tumorigenic response to carbon tetrachloride occurs as a consequence of the induction of post necrotic cirrhosis and levels and durations of exposure which do not cause significant tissue damage would not be expected to produce tumors.

Since the toxicity of carbon tetrachloride is associated with the metabolism of the chemical, the animal species that are capable of metabolizing the chemical most efficiently and rapidly will be most sensitive to its adverse effects. Mice and rats metabolize carbon tetrachloride more efficiently than the rhesus monkey; a finding which correlates with the level of the metabolizing enzyme cytochrome P-450 in the liver of these species. The rhesus monkey, the species and strain most like man in regard to the level of liver cytochrome P-450, has been reported to have a no-observed-effect-level in the range of 25 to <50 ppm in a chronic study.

The results of studies on all species have established the existence of species specific thresholds for the toxic effects of carbon tetrachloride. Adams et al., 1952 reported thresholds for the rat, guinea pig, rabbit and rhesus monkey in chronic inhalation studies, Prendergast et al., 1967 for the rat, guinea pig, rabbit and squirrel monkey in subchronic inhalation studies, and Alumot et al., 1976 for the rat in a chronic dietary feeding study. Furthermore, the lack of

significant toxicity in the rhesus monkey chronically exposed to carbon tetrachloride and the lack of reported evidence of the carcinogenicity in humans exposed to the chemical must be considered supportive of an alternate approach to the assessment of risk. In regard to the preliminary screening study on occupationally exposed cohorts in the dry cleaning industry (Blair et al., 1979), the study suffers from such environmental confounders as undefined exposure levels, concomitant exposure to other solvents, possibility of abuses in handling the solvent, high turnover rate among the dry cleaning employees potentially exposed to the highest levels, and the lack of an appropriate control group. Regarding the latter point, data from the U.K. on the risk of development of various forms of cancer between six different social classes indicate that there is a distinct social class trend for some forms of cancer with the higher levels being associated with the lower social (-economic) classes. These findings and the significance for the workers employed in dry-cleaning establishments must be considered in the evaluation of the study results. The types of cancer showing an increased incidence among the workers at the lower social (-economic) scale in the U.K. were cancer of lung, bladder, uterine cervix and rectum (Registrar General, 1971, 1978). Furthermore, the social class gradient in the incidence in lung cancer among the various social classes in the U.K. has been attributed to the increased indulgence in the cigarette-smoking habits among those at the lower end of the social (-economic) scale (Todd, 1976).

In conclusion, on the basis that there are thresholds for the toxic effects of carbon tetrachloride and the mechanism of tumor formation is nongenetic and all the supportive evidence that indicates man metabolizes carbon tetrachloride more like the monkey than the rodent, the assessment of risk/safety for man should be based on the adequacy of that margin which exists between man's exposure to carbon tetrachloride in the ambient environment and the no-observed-effect level

in the study on the most appropriate animal model, the rhesus monkey, with a safety factor to compensate for the lack of lifetime data. Since, however, risk assessment on the basis of the monkey data may be subject to criticism since the monkeys were not exposed for their lifetimes, the no-observed-effect level in the rat dietary feeding study may be used. In this case, it must be recognized that the differences in metabolism between the rat and man affords another safety margin.

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STATE OF CALIFORNIA GEORGE DEUKMEJIAN, Governor

AIR RESOURCES BOARD
1102 Q STREET
P.O. BOX 2815
SACRAMENTO, CA 95812

January 23, 1987

Ms. Carol Niemi
Environmental Affairs
Dow Chemical U.S.A.
The Willard H. Dow Center
Midland, MI 48674

Dear Ms. Niemi:

Comment on the Draft Carbon Tetrachloride Report

Your letter of September 18, 1986 concerning the Draft Report to the Scientific Review Panel (SRP) on Carbon Tetrachloride has been reviewed. The comments that pertains to Part A will be responded to by the Air Resources Board (ARB) staff. Comments pertaining to Part B were forwarded to the Department of Health Services (DHS). The DHS and ARB responses to your comments are attached to this letter. Your letter, the DHS response, and the ARB response will be included in Part C of the Final Draft Report to the SRP.

If you have any questions or comments, please feel free to contact Gary Murchison, Manager of the Compound Evaluation Section at (916) 322-8521.

Sincerely,

William V. Loscutoff

William V. Loscutoff, Chief
Toxic Pollutants Branch
Stationary Source Division

Attachment

cc: Peter D. Venturini
Michael Lipsett, DHS

Air Resource Board Staff Responses to Public Comments on the Draft Part A Report on Carbon Tetrachloride

Comment: The rigid 30 and 20 day comment periods may not always be long enough to review the draft and final draft reports.

Response: In order for the toxic air contaminant (TAC) identification process to proceed in a timely manner, it is necessary for the ARB to have the rigid comment periods. The ARB staff believes that the 30 day and 20 day comment periods allow sufficient time to review the report and identify major issues of concern. However, to ensure the maximum time possible is available for the review of the reports, the previous review process was modified in two ways. First, an announcement letter is sent out in advance of the draft report so that interested parties can be identified. This letter requests the name and address of the person reviewing the report so they can receive it in the most direct way. Second, extra time is allowed for the report to reach the reviewer before the comment period starts.

Comment: Part A correctly references previous projections of a 1 to 2 percent growth in carbon tetrachloride demand through 1990. However, Dow Chemical feels that because of environmental concerns, carbon tetrachloride demand will probably not increase as previously expected.

Response: The 1 to 2 percent growth for carbon tetrachloride demand was reported in the "Chemical Marketing Reporter", 1986. In the absence of more detailed information on why this estimate is no longer correct, the ARB staff believes the 1 to 2 percent growth is still the best estimate.

Comment: As stated in EPA research studies and the Federal Register, there are uncertainties involved in the decision to regulate chlorofluorocarbons and other chemicals that may affect the ozone layer. Dow Chemical requested that the uncertainties in this area be considered by the CARB during its consideration of carbon tetrachloride as a TAC.

Response: Stratospheric interaction of carbon tetrachloride and other chlorofluorocarbons with ozone is an important issue. However, carbon tetrachloride is being considered for identification as a TAC because of its potential danger to human health from inhalation and not because of its affect on the ozone layer.

Comment: The current level of regulation and federal EPA proposals to regulate carbon tetrachloride manufacturing processes are sufficient to protect human health. It is not necessary for regulations to be so stringent as to eliminate the carbon tetrachloride industry and its beneficial end products.

Response: The identification of carbon tetrachloride as a TAC will not in and of itself eliminate the use of this compound. If carbon tetrachloride is identified as a TAC, the ARB staff will then proceed to assess the need and appropriate degree of controls that would be required for carbon tetrachloride sources. Some of the factors which will be considered during this assessment are availability and feasibility of control, cost, availability of substitutes, exposure to the public, and risk to public health. It is only after this assessment that a decision will be made by the Air Resources Board as to the need for control measures. The ARB staff will continue to work closely with the public and the affected industries throughout the development of the carbon tetrachloride needs report.

III. E.I. du Pont de Nemours and Company

FORM LG-4878

DUPONT
REG. U.S. PAT. & TM. OFF.
ESTABLISHED 1802

E. I. DU PONT DE NEMOURS & COMPANY
INCORPORATED
WILMINGTON, DELAWARE 19898

LEGAL DEPARTMENT

September 24, 1986

VIA EXPRESS MAIL

Mr. William V. Loscutoff, Chief
Toxic Pollutants Branch
Air Resources Board
Attn: Carbon Tetrachloride
P.O. Box 2815
Sacramento, CA 95812

Dear Mr. Loscutoff:

We have reviewed the document entitled "Health Effects of Carbon Tetrachloride", dated May 6, 1986 prepared by the Epidemiological Studies and Surveillance Section of the California Department of Health Services (DHS). The primary source document for the DHS risk assessment is the United States Environmental Protection Agency (EPA) Health Assessment Document for Carbon Tetrachloride (1984). The approach and conclusions of DHS are not substantially different from those of EPA. Consequently, the concerns we expressed in our comments on EPA's approach and conclusions are also relevant to DHS's.

We agree with DHS that at current ambient levels "there is a reasonable margin of safety to expect that noncarcinogenic, chronic intoxication would not result." We disagree with DHS that carbon tetrachloride may contribute to an increase in cancer-related mortality at ambient levels. This is because the most likely mechanism for carbon tetrachloride carcinogenesis requires a toxic response prior to initiation of the carcinogenic response and no toxic response is expected at ambient levels.

Both DHS's and EPA's conclusions of carcinogenic risk are based on a series of conservative biological assumptions and mathematical procedures which most likely lead to overestimates of the true risk. We do not think these assumptions and procedures are appropriate for reasons which are given in our comments on EPA's risk assessment (copy attached).

I recognize that these comments are a few days late but I contacted Mr. Todd Wang of your office and he suggested that this timing would be acceptable. If you have any questions concerning the report, please feel free to contact me at 302/774-8720.

Very truly yours,

Pamela Meitner

Pamela Meitner

PM:cde
Attachment
CARBONTET

COMMENTS OF

E. I. DU PONT DE NEMOURS AND COMPANY

TO THE

ENVIRONMENTAL PROTECTION AGENCY

NOTICE OF INTENT TO LIST CARBON TETRACHLORIDE
AS A HAZARDOUS AIR POLLUTANT

DOCKET NO. A-84-04

February 17, 1986

INDEX

EXECUTIVE SUMMARY

E. I. du Pont de Nemours and Company (Du Pont) offers the following comments on the EPA's Notice of Intent to List Carbon Tetrachloride as a hazardous air pollutant under Clean Air Act Section 112, 50 Fed. Reg. 32621 (August 13, 1985).

Du Pont manufactures carbon tetrachloride in an enclosed process as an intermediate in the production of chlorofluorocarbons in which it is totally consumed, and uses carbon tetrachloride as a process solvent in an enclosed process with minimal emission. As both a manufacturer and consumer of carbon tetrachloride, Du Pont is vitally concerned that an intention to list and establish emission standards be based on accurate, up-to-date scientific information. To this end, Du Pont has reviewed EPA's announcement in the Federal Register and the documents referenced therein, and offers detailed comments on the following subjects:

- Health Effects - Health Assessment Document and quantitative risk assessment.
- Exposure Assessment - Comparison of Human Exposure Model (HEM) with Industrial Source Complex (ISC) model.

Based on our review of the information available on carbon tetrachloride and our own analysis, we find that there is insufficient evidence to support the premise that carbon tetrachloride is a human carcinogen. No adverse health effects

are expected to occur at carbon tetrachloride concentrations to which the U.S. population is currently exposed. Thus, carbon tetrachloride does not qualify as a hazardous air pollutant. If EPA persists in their intent to list carbon tetrachloride, then even conservative estimates indicate that the exposure from Du Pont plants does not warrant additional emission controls.

CARBON TETRACHLORIDE

The EPA's reasoning for intending to list CCl_4 as a hazardous air pollutant is primarily based upon results of potential cancer risk calculations performed by the Carcinogen Assessment Group of the EPA. These cancer risk estimates state that at the current ambient air levels of CCl_4 there is a possibility of a maximum of 69 excess cases of cancer in the United States per year attributable to this chemical. The health effects data base leading to this conclusion are four long-term rodent studies. EPA also used the conclusions of these animal studies to state that <u>if</u> they (EPA) used the classification scheme set forth by IARC, CCl_4 would be classified as a group 2B material "Sufficient animal data exists to classify as a probable human carcinogen." It is important to note that in the FR notice, the EPA found that "noncarcinogenic effects are unlikely to occur at concentrations that are expected in the ambient air", p. 32624.

The health effects of CCl_4 that the EPA reviewed are contained in the document entitled Health Assessment Document for Carbon Tetrachloride - Final Report PB85 - 124196, dated September 1984. It contains an assessment of the health effects literature available up to March, 1983.

In July of 1982, Du Pont submitted comments to the EPA on the Health Assessment Document for Carbon Tetrachloride

(EPA-600/8) 82-001 March, 1982. Detailed comments addressing toxicology, carcinogenicity in man, and cancer risk assessment were made. A copy of those comments is attached. The major points identified in that response are highlighted below.

- Rodents are more sensitive than primates to the toxic effects of carbon tetrachloride. In particular, hamsters seem to be the most sensitive to carcinogenic effects, followed by mice and then rats.
- The monkey may be the appropriate animal model for extrapolation to man.
- Mouse liver tumors are seriously questioned as useful estimators of potential tumorigenicity for man.

Since that time there have been over one thousand citations in the toxicology literature related to CCl_4, based upon our review of the National Library of Medicine toxicity data bases. A review of these citations shows that there are several articles relevant to cancer risk assessment of CCl_4 and we believe that the EPA should have reviewed these papers so that the most current findings are incorporated into their risk assessment. Where appropriate our comments will include such recent studies.

We are also including a copy of a recent Du Pont study on workers chronically exposed to carbon tetrachloride. In that study (J. Gooch, 1981) results of clinical biochemical and vision tests were evaluated from workers exposed to carbon

tetrachloride. Several of these biochemical tests are useful in evaluating target organ toxicity from CCl_4 exposure i.e., BUN, creatinine and electrolytes for kidney damage and SGPT, SGOT, alkaline phosphatase, total bilirubin and albumin for liver damage. Exposed worker values for these tests were no different than unexposed workers. In that study personal CCl_4 exposure data collected during the time period under examination showed that exposures were less than 5 ppm (30 mg/m3) and averaged 2 ppm (12 mg/m3) as an 8 hr time-weighted average. These results show that at long-term exposures at about 1/2 of the TLV, no toxicity effects were seen. This further supports the findings in the clinical studies by Stewart, 1961, which were short-term exposures at 63 mg/m3 (10 ppm), that the NOEL for target organ effects in man is at least at the PEL of 10 ppm and is probably higher. Stewart did see some elevation of SGOT at exposures of 309 mg/m3.

Du Pont has developed internal guidance on a community air level for carbon tetrachloride and that is discussed at the end of this document.

Since cancer risk is the primary reason EPA decided to list CCl_4, our comment will focus on this issue and will address the following key items.

- Cancer studies - lack of dose response
- Route of exposure - absorption
- Metabolism
- Mechanisms of cancer
- Mutagenicity
- EPA's Quantitative Risk Assessment - Extrapolation models, Data quality, Animal to Man dose conversions, Linearity of dose-response, Use of unit risk estimate to compare relative potency.

Cancer Studies

Human Studies

Human case reports and studies have not shown that excess liver tumors are caused by CCl_4 exposure. For example in a recently published epidemiology study on cancer mortality in the rubber industry by Wilcosky et al., 1984, the authors state "the observed positive findings for lymphosarcoma and lymphatic leukemia require cautious interpretation. The modest number of cases of these cancers, and the possible biases discussed above further accentuate the need for guarded conclusions." The study is useful for the generation of future hypotheses, but it is not useful for making definitive statements about the relationship between exposure to given solvents, i.e., CCl_4, and cancer mortality. The five primary reasons for this caution are the nature of the exposure data, the limited number of cases, the exploratory nature of the study design, that the cancers observed here have not been observed in animal studies, and animal studies do not indicate blood forming organs as target tissue for CCl_4 toxicity.

The only exposure information which is actually used in this study is whether or not a given solvent was authorized for a given stage of production during a given period of time. Nothing is known about whether the solvent was actually used and if so, how much. The length of exposure for a given case is an important variable which is not well-accounted for in this study. (Any exposure for at least one year is included, therefore one year exposure is treated equivalently to a 20 year exposure.) The solvents were also used simultaneously and therefore each case was likely exposed to a variety of solvents. It is therefore impossible to provide a direct link between a single solvent and a particular cancer.

The limited number of cases and the exploratory nature of this study also make it difficult to determine which observed associations are real and which are spurious. Because the study is exploratory numerous hypotheses are tested, consequently false positives are not unlikely.

The studies of Capuno (1979) and Blair (1979) do not show proof that excess human cancer is linked to CCl_4 exposure. Detailed comments are found in our initial critique submitted in 1982 (see attachment).

Animal Studies - There is no disagreement that under certain conditions of exposure in certain species of animals, CCl_4 produced tumors. However, the studies are extremely limited for risk assessment calculation. The major problems with each study are discussed below. It is obvious that the lack of a chronic inhalation study makes it difficult to make an adequate risk assessment. We note that EPA does recommend such a study.

Rat Studies

Rats developed occasional hepatocellular carcinomas after being given a subcutaneous injection of CCl_4 in corn oil. The incidence was very low - 1/14 in 52-week-old males and 1/10 in 24-week-old and 1/11 in 52-week-old female Buffalo rats at a dose level of about 1,300 mg/kg (Reuben & Glover (1967a). No control animals were used and rats in the other age groups, 4 and 12 weeks, did not develop any liver tumors. In another study by Reuber & Glover, 1970, five different rats strain were given subcutaneous injections of CCl_4 in corn oil at a dose of 2080 mg/kg. The incidence of liver cancer ranged from 0/17 to 12/15. Both of these studies are not suitable for making a cancer risk assessment for man. They lack control groups, the route of exposure is not relevant, there was only a single dose level used and the material was given all at once. These dose levels caused significant toxicity and early

mortality. The doses were massive in comparison to what a person might encounter by the inhalation route. For example, a dose of 2080 mg/kg is 145,600 mg per person or 14,560 mg/M3 (2427 ppm) or 485 times the TLV of 5 ppm.

In studies conducted by NCI (1976a, 1976b, 1977), CCl_4 was used as a positive control and was given by oral gavage, a route which to humans are not exposed. Two dose levels were used, and the tumor incidence was low; just slightly over background for males, but higher for females. There was no dose response for liver tumor incidence for males and an inverse dose response for females. The only increase which was statistically significant was that for low dose females. These studies indicate CCl_4 may not be carcinogenic under these conditions.

Mouse Studies

Several studies have been conducted which show the induction of liver tumors in mice.

In a gavage study by Andervont (1958) C3H mice developed hepatomas with varying incidence rates at a dose level of 213 and 320 mg/kg. Edwards (1941) conducted two studies on C3H or mice with CCl_4 given by gavage with olive oil. The incidence of tumors was 88% in treated C3H mice vs.

4.3% for the olive oil controls. For strain L mice, males had a range of 47 to 54% and females of 27 to 38% for these liver tumors (Edwards, 1942).

In a study by Eschenbrenner and Miller (1948) Strain A mice developed hepatomas after receiving CCl_4 in olive oil by gavage under different dosing regimens, but the dose-response was not linear.

In an NCI study (1976a, 1976b, 1977) CCl_4 was used as a positive control. B6C3F1 mice were given CCl_4 by oral gavage at 1250 or 2500 mg/kg. There was no dose response, but nearly all treated animals (96-100%) developed hepatocellular carcinomas.

Other studies in other strains (A, Y and C) of mice given CCl_4 by gavage showed an increased incidence of hepatomas, Edwards and Dalton, 1942.

Hamster Studies

In a study with Syrian Golden hamsters, CCl_4 was administered as a 5% solution in corn oil by gavage, Della Porta et al. (1961). This was a single dose level study, but the dose was changed after the first seven weeks of treatment. Liver-cell carcinomas were seen in all of the animals, 5 males

and 5 females, that died or were sacrificed 13-25 weeks after each treatment. The authors considered the results to be significant because the historical control incidence of hepatic tumors was zero.

From the above animal studies it is important to note that liver damage was associated with tumor formation and dose-response for tumors was limited.

Route of Exposure

It is clear that by different routes of exposure subcutaneous injection, oral gavage and rectal instillation, CCl_4 produced liver tumors in several different animal species. Furthermore in these instances, the CCl_4 was dissolved in either corn oil or olive oil.

It is also clear that these routes of exposure are distinctively different from the way people would commonly be exposed to CCl_4 in their daily life. The CCl_4 was not given as a pure compound but given with large amounts of vegetable oils.

When chemicals are given by these routes, they arrive at the site of contact almost immediately in amounts that are many orders of magnitude greater than a person might ingest.

In an urban scenario, a person encounters less than one ppb (1.0 ug/M3) in the air (ambient air measurements) during a day. Compared to the amount given to animals to cause cancer (1250 mg/kg bw in mice) the amount inhaled is about one billion times smaller. This factor of one billion plus the fact a person does not receive a daily exposure of CCl_4 all at once, suggest that these data are not useful for assessing the hazard of CCl_4 as an air pollutant.

Metabolism

Carbon tetrachloride has been shown to readily absorb through lungs, the gastrointestinal tract and the skin. It has also been shown that the metabolism of CCl_4 produces toxic intermediates, i.e. free radicals, which are considered responsible for the adverse health effects of CCl_4. Thus reduced metabolism would be beneficial for the organism which has been exposed to CCl_4. Since it has also been shown that the mixed function oxidase system, specifically cytochrome P-450 of the liver, is the key component in CCl_4 metabolism, the amount and distribution of this enzyme in various species would help determine the relative species sensitivity to CCl_4 intoxication. The mouse, followed by the rat, and then the monkey, seems to be the order of species sensitivity to CCl_4 toxicity. The limited data on cancer induction shows that the hamster may be the most sensitive followed by the mouse and

rat. As EPA points out species sensitivities vary depending upon the toxic lesion produced (see 8-46). However, it is also observed that the rodent is more susceptable to the toxic effects of CCl_4 than the primate. This has been discussed in more detail in our 1982 submission (see attached). We believe this is an important distinction and should be incorporated into risk assessment calculations.

Mechanism of Cancer

Although the exact mechanism whereby CCl_4 produces cancer in experimental animals is not known, several important findings have been made which help shape our perspective on the potency of this chemical.

Carbon tetrachloride has been classified as a carcinogen which acts by an epigenetic mechanism, according to Shank and Barrows (1985). They indicate it satisfies several of the criteria for this classification which are:

- it appears to induce cancer only at exposure levels which are near lethal doses (maximum tolerated dose which depresses growth rate 10 to 20%)
- it increases the incidence of spontaneous tumors but does not induce formation of tumors which are rarely seen in control populations of the test species
- cancers arise only after a long exposure relative to the life span of the test animal
- it does not form detectable levels of DNA adducts in in vivo tests

They have reviewed the animal carcinogenicity studies, the same ones the EPA relied upon, and concluded that the animals only developed liver tumors after receiving doses of CCl_4 which produced liver necrosis, but not when exposed to nonnecrotizing doses. They state that a single low-level exposure to an epigenetic agent would be less likely to induce cancer than a genetically active carcinogen because animal studies suggest greater difficulty in inducing cancer with an agent which appears to require repeated exposures to high doses.

Related to the above assessment are the studies on mutagenicity.

Mutagenicity

Mutagenicity studies for the most part have failed to give positive results with CCl_4. In the Ames test with and without activation, E. coli and in in vitro chromosome assay results were uniformly negative. In one study which used yeast cells, CCl_4 produced increased frequencies of gene conversion and mitotic recombination; but only at concentrations which were lethal to the cells. These results support the concept that only under conditions of exposure where lethal effects occur, does mutagenic alteration happen. Thus weak genotoxic or no genotoxic activity is present. These results favor a weak carcinogen classification.

Since the end of the EPA update on toxicity studies in March 1983 several studies have pursued the question of genotoxic activity for CCl_4. The major ones are described below.

Carbon tetrachloride did not induce unscheduled DNA synthesis in cultured mouse hepatocytes (Mirsalis, 1985) or rat hepatocytes (Mirsalis, 1982) but did increase DNA replication and hepatic cell proliferation. Furthermore a significantly larger increase in the level of hepatic cell proliferation was found in mice vs. the rat at the same in vivo dose level (Mirsalis, 1985).

In genotoxicity assay system where CCl_4 was considered positive, the positive results were weak. For example, in an assay measuring morphological transformation of Syrian Hamster embryo cells, only one of 2003 colonies was transformed by CCl_4, (Amacher, 1983); in an alkaline elution/rat hepatocyte assay positive effects were seen only at CCl_4 doses which produced significant (>30%) cell toxicity (Sina, 1983) and in a study examining mouse liver nuclear DNA syntheses, adaptive changes occurred following long-term CCl_4 oral gavage administration (Gans, 1984).

These recent findings provide additional support for the weak potency (if any) of CCl_4 as a carcinogen at low doses.

EPA's Quantitative Risk Assessment

Our primary concern with the risk assessment of carbon tetrachloride is the "consistently conservative, i.e,, tending toward high estimates of cancer risk" (Page A-11 of Health Assessment Document) approach taken by EPA. When a choice between two equally plausible assumptions is made EPA has consistently chosen the most conservative. This is contrary to the ideas of W. Ruckelshaus, who stated, while EPA Administrator that:

> This [piling up of conservative assumptions] is fine when the risks projected are vanishingly small; it's always nice to hear that some chemical is not a national crisis. But when the risks estimated through such assessments are substantial, so that some action may be in the offing, the stacking of conservative assumptions one on top of the other becomes a problem for the policy maker. If I am going to propose controls that may have serious economic and social effects, I need to have some idea how much confidence should be placed in the estimates. "Managing Risk in a Free Society." Princeton Alumni Weekly, 3/8/84, pp. 18-23.

EPA should present the risk manager with the range of possible estimates, including the most likely estimates, not just the most conservative estimates. Only with this information, can the risk manager make well-informed decisions.

Some specific areas of concern with the risk assessment of carbon tetrachloride include:

- the choice and implementation of extrapolation models
- the quality of the carcinogenicity data
- the conversion of doses within and across species
- the use of the unit risk to compare relative potency among various presumed carcinogens.

In the following discussion, we specifically address each of these areas.

Extrapolation Models

EPA states "There is currently no solid scientific basis for any mathematical extrapolation model that relates exposure to cancer risk at extremely low concentrations, including the unit concentration given above." (page A-1) We agree and this indicates to us that risk assessors should not rely heavily on the unit risk derived from the linearized-multistage model or any other single model. EPA has stated "The risk estimates presented in subsequent sections should not be regarded as accurate representations of the expected cancer risks ..." (Page A-10). Despite, EPA's recognition of the uncertainty and the lack of a solid scientific basis for the model, EPA has relied primarily on the unit risk derived from the linearized-multistage model. Given

this situation, the reduction of the estimate of risk to a single number is too simplistic.

The unit risk estimate as presented may serve to misinform. This is because the linearized multistage model is the only model used by EPA to estimate risk when in fact other models have been proposed for estimating risk. These alternative models are no less plausible since the underlying biological mechanisms for cancer are not known. Although they do not differ in plausibility they will provide different estimates of risk which will generally be lower. For example, if we assume all of EPA assumptions are true but use the best estimate rather than the upper limit, 14.2 extra cancers are expected rather than 69. The linearized multistage model is also the most conservative model since it is not actually a model, but rather an upper bound or confidence limit.

The unit risk, as calculated by EPA, represents "the most plausible upper-limit for the risk, i.e., the true risk is not likely to be higher than the estimate..." (Page A-2) It represents the worst case scenario, a scenario <u>not</u> likely to occur, thus it is not the type of number which is useful for well-informed decisions. Worst case scenarios have their place but so do <u>most likely</u> case scenarios.

As implemented by EPA, the multistage model has a numerical difficulty. "It [the linearized multistage model] is constrained to ensure linearity in the low dose region .." (Page A-2) That is, even if the data indicate non-linearity or sub-linearity the model does not allow for this possibility. This is an artificial constraint which requires that risk increases with increasing dose over the entire dose-range, regardless of what the data may suggest. The multistage model would be more useful if these constraints were removed, so that risk assessors could more accurately describe the known data.

Data Quality

By EPA's own admission the four studies used to estimate risk are "less than ideal for risk estimation for continuous daily exposure over a lifetime." (Page A-3) In fact, they are very poor for estimating risk at low doses. EPA recognizes the problems with these studies but nonetheless conducts a risk assessment using them; the consequence is that a good risk assessment is not likely from such poor data. Because of the limitations of each of the studies EPA has chosen to estimate unit risk by the geometric mean of the estimates from each of the studies. This does not solve the problem, the geometric mean of four poor estimates is still a poor estimate.

Animal to Man Dose Conversions

In determining human equivalent estimates of risk from animal data, EPA make adjustments for exposure duration and metabolic differences. Comments on these two items follow.

Exposure Duration

Calculating time-weighted average doses to convert from one dosing schedule to another has limited usefulness. Time-weighted conversions can be made when it is believed the biological effect is equivalent for the time-weighted average dose of two different dosing schedules. In three recent inhalation studies on carbon tetrachloride it has been demonstrated that this is not true. (Uemitsu, et al., 1985, David, et al., 1981 and Van Stee, et al. 1982). All three studies indicate that the severity of various toxic responses to carbon tetrachloride is more influenced by concentration than by time. The results of these studies suggest that at ambient exposure levels, where concentrations are low but exposures are long term, toxic responses will be less than predicted by the hypotheses of equivalence of time-weighted average doses. Even without information from these studies it is not reasonable to expect that the time-weighted conversions for two of the studies used by EPA to estimate risk are likely to be accurate because the actual dosing schedules used in the studies are not similar to ambient exposure schedules. In the

Della Porta et al. study (1961) the doses were administered once per week for only 30 weeks; the doses were converted to a daily dose for a lifetime (55 weeks). In the Edwards et al. (1942) study the doses were administered for 17 weeks and the study lasted 31 weeks; the doses were converted to a daily dose for a lifetime (78 weeks).

Metabolic Differences

EPA converts doses across species by assuming biologically equivalent doses can be obtained by correcting for the surface area differences among species. Two other methods are often used to make interspecies comparisons; correcting for body weight differences and doing no conversion. EPA has stated "the concept of equivalent dose for humans compared to animals on a mg/surface area basis is virtually without experimental verification." (page A-9) Given this uncertainty, EPA should provide estimates based on all three unless there is prior information which suggests that one method is most appropriate. In the case of CCl_4, EPA has not provided evidence for the appropriateness of the surface area conversion.

The risk calculation is very dependent on these assumptions. If we assume that mg/kg is a more appropriate inter-species adjustment (there is no scientific reason to

discount this assumption) the most likely estimate of the number of extra cancer cases is 19 times less than would be estimated by the surface area conversion.

Linearity of Dose Response

The unit risk approach assumes that the dose response for carcinogenesis is linear from zero dose up through the observed dose range of the studies used to estimate that risk. This is not likely to be true for carbon tetrachloride which is likely to have an epigenetic mechanism as discussed earlier.

Use of Unit Risk Estimate to Compare Relative Potency

Comparison of potency of presumed carcinogens by using the unit risk estimates is an entirely unvalidated procedure. That is, it is not known how well, if at all, these estimates of relative potency actually reflect the true differences in potency among carcinogens at 1 ug/m3, the arbitrary standard. Even if the relative potencies are accurate at this standard, they are not likely to be accurate over the exposure ranges where risk is estimated, since the dose response curves for each carcinogen will have different shapes over the exposure range.

Du Pont's Internal Guidance on a Community Air Leval for Carbon Tetrachloride

At Du Pont's Haskell Laboratory, health scientists have reviewed the available toxicological data base on carbon tetrachloride and recommended that Du Pont operations be controlled so as to limit surrounding community air levels to at or below 100 parts per billion (0.63 mg/m^3) averaged for a 24-hour period, a level at which no adverse human health effects are expected to occur.

It is recognized that 100 ppb is a conservative number and that it is based upon a limited amount of animal data which is pertinent to risk assessment. Furthermore, this value is not a demarkation between safe and unsafe but it is an exposure value that we believe presents no significant health risk for humans. This value is subject to revision when new data becomes available.

There are certain research gaps in the toxicity picture of carbon tetrachloride which preclude the establishment of a more precise value. Research is needed to explore the dose response relationship for tumor production in animals by the inhalation exposure route, the mechanism of action of carbon tetrachloride's carcinogenicity, pharmacokinetic differences in animals and man at low exposure

levels of carbon tetrachloride, the appropriate conversion for extrapolating from the oral to the inhalation route of exposure, and the role corn oil plays in liver toxicity.

ADDITIONAL REFERENCES

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APPENDIX A

DUPONT

I. DU PONT DE NEMOURS & COMPANY
INCORPORATED
WILMINGTON, DELAWARE 19898

LEGAL DEPARTMENT

July 1, 1982

Solvents Project Officer
Environmental Criteria and Assessment
Office (MD-52)
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Dear Sir:

Health Assessment Document for Carbon Tetrachloride
EPA-600/8-82-001 MARCH 1982

On behalf of E. I. du Pont de Nemours and Company (Du Pont), I am pleased to submit these comments on the above-referenced document. We appreciate the Agency affording us this opportunity to comment.

Du Pont manufactures carbon tetrachloride in an enclosed process as an intermediate in the production of chlorofluorocarbons in which it is totally consumed, and uses carbon tetrachloride as a process solvent in an enclosed process with minimal emission. As both a manufacturer and a consumer of carbon tetrachloride, Du Pont is vitally concerned that any Health Assessment Document (HAD) issued by the EPA on carbon tetrachloride be an accurate, up-to-date and objective presentation of the known information on the material. To this end, we have reviewed the HAD for carbon tetrachloride and offer detailed comments on the following subjects as they are presented in the HAD.

- PART 1 - EFFECT OF STRATOSPHERIC OZONE
- PART 2 - TOXICOLOGY
- PART 3 - CARCINOGENICITY-HUMANS
- PART 4 - APPENDIX: UNIT RISK ESTIMATE FOR CANCER

While our specific comments are directed to the above subjects, our lack of comments on other aspects of the HAD should not be interpreted as acceptance of the remainder as an unflawed presentation.

Based on our close review of the subjects as presented in the HAD, we find that the document does not include all available and extremely pertinent data, particularly recently published information, on the subjects. In some cases the review of the data has been sufficiently superficial to lead to questionable conclusions regarding its meaning. An especially obvious deficiency is the appearance of selective use of data to direct the reader toward the conclusion that there is need for stricter control of carbon tetrachloride. These concerns are amplified in more detail in the attached comments.

We trust the EPA will take note of our comments and review and revise the HAD so that a timely, technically accurate HAD with sound and practical policy implication is produced.

Very truly yours,

David T. Modi
Environment Division

DTM:scl
Attachments

PART 1

EFFECT ON STRATOSPHERIC OZONE

Although carbon tetrachloride has been associated with chlorofluorocarbons (CFCs) in concerns over calculated future depletion of stratospheric ozone since the theory was published in 1974, it should be recognized that most carbon tetrachloride is utilized as a chemical intermediate, and not released to the environment. Manufacturing emissions and emissions from non-intermediate uses where evaporation and release may be more significant constitute the major input to the atmosphere.

CALCULATED DEPLETION OF STRATOSPHERIC OZONE

Revisions in Calculations of Potential Future Depletion of Stratospheric Ozone

Since 1979, major revisions have occurred in modeling calculations of potential future depletion of stratospheric ozone and in our appreciation of the significance of analyses of actual ozone measurements.

- Reaction rates and other basic data in the computer models have been revised, with the result that calculated future depletion when CFCs are considered alone has been sharply reduced from 16.5 percent to 5-7 percent for most model calculations, or to about one-third the earlier values. A similar proportional decrease occurs for emission scenarios involving carbon tetrachloride.

- Modelers have recently recognized the importance of performing simultaneous calculation of the effect on stratospheric ozone

of the estimated future emissions of all the compounds presently thought to affect ozone. One "multiple perturbation" calculation included CFCs, other chlorinated compounds specifically including carbon tetrachloride, nitrogen oxides from aircraft exhaust, nitrous oxide from fertilizer denitrification, and carbon dioxide from fossil fuel combustion (Wuebbles et al. 1982).

On an individual basis, some of these compounds are calculated to decrease ozone, while others are calculated to increase it. When the compounds are considered together, important interactions and offsets occur. The simultaneous multiple perturbation scenario referred to above calculates no depletion of total stratospheric ozone during the period 1911-2100*. Similar results were reported recently by the World Meterological Organization (WMO 1982).

- It is now acknowledged (WMO, 1982; NAD, 1982) that measurements do not detect any depletion of total ozone and that analyses of these measurements (ozone trend analyses) can provide a measure of the upper limit of any ozone change (increase or decrease) that may be occurring.

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*In Wuebbles et al. (1982), it should be noted that carbon tetrachloride was specifically included in the multiple perturbation calculation, and is a part of the "CFC" scenario. Carbon tetrachloride is not a CFC and the CFC label for the group of chlorinated compounds could be misleading if not clearly and specifically explained. Note that the year 1911 was selected as representative of the stratosphere prior to anthropogenic chlorocarbon emissions.

Uncertainty

In 1979 The National Academy of Sciences (NAS, 1979 a,b) expressed confidence that model calculations of future ozone depletion reflected the real world effects of CFC and chlorocarbon emissions, thereby implying that regulatory action could be confidently based on the calculations. In fact, confidence limits were precisely stated for the calculated ozone depletion from CFCs.

In contrast, following the large revisions in model calculations since 1979, NAS cautions in 1982 as follows:

> "These results should be interpreted in light of the uncertainties and insufficiencies of the models and observations." (NAS, 1982, p.3)

and uncertainty ranges are not stated.

Revisions in the Potential Effects of Ozone Depletion

The NAS in 1979 (NAS, 1979b) listed four categories of effects anticipated from increased UV-B, which, in turn, would result from depletion of total ozone. They were:

(1) Increased incidence of nonmelanoma skin cancer in humans.
(2) Increased incidence of malignant melanoma skin cancer in humans.
(3) Significant crop yield reductions.
(4) Appreciable killing of marine organisms.

The assessment for three of these categories has changed substantially.

The current assessment on malignant melanoma is that the "association between sunlight and melanoma is not strong enough to make a prediction of increased incidence due to increased exposure to UV based on epidemiological data." (NAS, 1982, p.9).

The semiquantitative estimates of increased melanoma incidence and mortality which were made in 1979 have been dropped.

For crops, NAS finds "The potential for further adaptation [by food crops] to predicted increases in ambient UV-B is not known." (NAS, 1982, p.7)

The predictions of significant crop yield reductions which were made in 1979 have been dropped.

For marine organisms, NAS finds "Currently there is no information from which to predict the magnitude of adverse effects of enhanced UV-B on aquatic organisms." (NAS, 1982, p.7)

The prediction of appreciable killing of marine organisms at the base of the marine food chain, which was made in 1979, has been dropped.

Skin Cancer Trends

With recent revisions of calculated future ozone depletion, it is incorrect to allude that carbon tetrachloride may increase the incidence of certain forms of skin cancer. While epidemiological evidence indicates that the incidence of skin cancer is increasing, this increase has occurred in a period when there is no indication from actual measurements that total ozone

is being depleted, nor is there any indication of an increase in UV-B (Berger and Urbach, 1982). Thus there is no evidence or rational basis to connect current epidemiological trends in skin cancer incidence with ozone depletion or carbon tetrachloride emissions.

Climate Effects

NAS (1979b, p.116) discussed the likelihood of adverse changes in climate due to calculated depletion of ozone by CFC, should it occur. The report concluded that important changes in surface climate were not expected as a result of this effect. Similar arguments apply to carbon tetrachloride emissions if NAS had discussed them.

SIGNIFICANCE OF THE SCIENTIFIC REVISIONS FOR THE CARBON TETRACHLORIDE HEALTH ASSESSMENT DOCUMENT

Although the 1982 NAS report is cited, the draft review discusses the concepts of 1978 and then, as a second thought, mentions the sharply revised estimates and conclusions of 1982. Technical accuracy and the sound technical perspective necessary for the appropriate policy implications require the principal emphasis and stress to be on the 1982 data and the conclusions, and the considerable uncertainty associated with them, supplemented where appropriate with references to the recent history of the issue.

MISLEADING COMMENTS ON ENVIRONMENTAL EFFECTS OF CARBON TETRACHLORIDE

Examples of ways in which the HAD perspective misleads:

- The calculated effects of carbon tetrachloride alone are discussed ignoring the latest combined perturbation calculations. The combined perturbation calculations consider all the chemicals suspected of affecting stratospheric ozone simultaneously. Thus discussion of the effect of carbon tetrachloride alone, or even of atmospherically-stable chlorine compounds alone, presents a distorted picture of current scientific understanding of the stratospheric ozone question. The important issue is to determine the net effect of all human activities on ozone, not just a single group of chemical compounds.
- The HAD makes essentially no mention that analyses of actual measurements of total ozone do not detect any ozone depletion.
- Current scientific reports suggest that large uncertainties exist but there is time to reduce the uncertainties without significant risk. This situation has major policy implications, yet is not discussed.
- The estimated effects of ozone depletion, should it occur, have also been sharply revised in 1982. For instance, estimates of the effects of ozone depletion on the incidence of malignant melanoma, on crop yields, and marine organism survivability, specifically, have been significantly modified. Yet, again the most recent estimates are appended to earlier assessments rather than being given the principal emphasis

Collectively, these recent revisions not only greatly reduce or even essentially eliminate calculated future ozone depletion, but also lessen potential adverse effects from ozone depletion should it occur from any cause.

The HAD requires editing to reflect these technical developments. Without such editing the HAD does not provide either a technically accurate picture of environmental questions on carbon tetrachloride, nor does it provide appropriate policy implications.

Specific Locations of Misleading Comments on Environmental Effects on Carbon Tetrachloride Emissions

A. Carbon tetrachloride considered as the only emission affecting total ozone, and absence of discussion of multiple perturbation calculations.

HAD pages 2-2, 5-2, 6-5.

B. Failure to distinguish adequately between the real atmosphere and model calculation or attribution of predictive value to model calculations.

HAD pages 2-2, 6-5, 6-6, 6-7.

C. Use of early reports on effects of ozone depletion with inadequate mention of subsequent technical revision.

HAD pages 2-2, 4-3, 6-6, 6-7.

D. Misleading discussion on skin cancer.

HAD pages 2-2, 4-3, 11-36.

E. Lack of perspective on potential climate effects.

HAD page 4-3.

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PART 2

TOXICOLOGY

The toxicology, metabolism, and carcinogenicity portions of the HAD document for Carbon Tetrachloride (EPA-600/8-82-001, March, 1982) have been reviewed to assess the general usefulness of the document to allow evaluation of relative risk to man. The document frequently emphasizes certain exposure results over others without any objective reasons being given. The overall effect of this selection is to present carbon tetrachloride (CCl_4) in a light so as to make more strict control mandatory. This is unfortunate because in controlling for human exposures (setting exposure limits), a good portion of the data needs to be de-emphasized (rodent studies) while another part (monkey studies) needs more careful analysis. Here is a good example of the tenet that toxicological evaluations are most relevant when the information obtained from animal surrogates is in a species which handles the compound in a manner most like man. In this case we have the data (granted the information in monkey and man is considerably less complete than that in rodents) and should be willing to use it.

The literature has been collected and is presented for review in a not-altogether non-biased fashion. As an example, the long-term toxicity of carbon tetrachloride has been studied by a number of investigators whose work is cited. Paquet and

Kamphausen (1975) treated rats for 8 weeks with CCl_4 - their study is described in 2 pages (8-17 and 8-18). Similarly, Alumot (1976) fed rats CCl_4 for 5 or 6 weeks and described a number of effects - cited here in detail on pages 8-18 and 8-19. A chronic inhalation study conducted by Adams (1952) which looked at the subchronic effects of 7 concentrations ranging from 5 to 400 ppm in 4 species including the monkey is given in 1 paragraph on page 8-23. The HAD has not given the appropriate balance in this and any number of other specific cases. The instance cited here is highlighted by the fact that, although conducted in 1952, the Adams study is sound and stands today as a good reference point in assessing the subchronic toxicity of CCl_4.

The same oversight in terms of data presentation appears in the mutagenicity section (10) where at least 2 prominent studies, both showing that CCl_4 is inactive in genetic test systems, are omitted. Both Craddock and Henderson (Cancer Res., 38:2135:1978) and Mirsalis and Butterworth (Carcinogenesis, 1:621:1980) have shown that CCl_4 does not induce unscheduled DNA synthesis in in hepatocytes of rats exposed in vivo.

However, the greatest oversight in the toxicology/carcinogenicity portion is the presented point of view which relies almost exclusively on rodent data to predict the effects of CCl_4 in man. This clearly is not indicated when the available information is reviewed properly.

Prendergast (1967), Adams (1952), and Smyth (1936) have clearly shown that species-related susceptibility to CCl_4 toxicity exists. Prendergast ranked 5 species, each exposed to 82 ppm, 8 hours/day, for 6 weeks, according to the fatty changes seen in the liver - the guinea pig was the most sensitive (adversely affected) followed by the rat, rabbit, dog, and monkey (least affected). Similarly, Smyth showed the guinea pig to be more sensitive than the rat which, in turn , was far more sensitive than the Rhesus monkey. Adams also found a similar ranking - under his experimental conditions the no-observed-effect-level in the guinea pig and rat was 5 ppm, that in the rabbit was 10 ppm, and the monkey showed no effects at 25 ppm. If the endpoint in the Adams study is fatty changes in the liver observed microscopically, the quantitative differences are even more pronounced with the guinea pig and rat responding at 10 ppm, the rabbit at 25 ppm, and the monkey at 100 ppm.

Animal experiments have also demonstrated that the effects produced by CCl_4 are related both to the magnitude of the dose and the length of time the chemical is given. Other than the studies of Adams, Prendergast, and Smyth which demonstrate this nicely, Alumot (1976) showed that no liver changes, particularly elevations in lipid and triglyceride levels, were seen when CCl_4 was fed to rats at 22 mg/kg/day whereas the feeding of either 40 or 76 mg/kg/day produced increases (more pronounced at the higher

level). The same author determined that feeding equivalent doses of 10 to 18 mg/kg/day in rats did not lead to liver damage when rats were fed CCl_4 for approximately 2 years.

The time relationship with dose is best illustrated in the liver of rats in the experiment by Smyth. Rats exposed to either 100, 200, or 400 ppm developed cirrhosis of the liver following repeated cellular degeneration/regeneration. As the exposure level doubled, the time of observed cirrhosis essentially halved with cirrhosis developing in 173 exposures at 100 ppm, 115 exposures at 200 ppm, and 54 exposures at 400 ppm.

The reason for the difference in CCl_4 toxicity among species is related to its metabolism. Unmetabolized CCl_4 does not appear to be very toxic (Recknagel and Glende, 1973 and Sagai and Tappel, 1979 both cited in the HAD, Slater, Nature 209:36: 1977, Recknagel and Ghoshal, Lab. Invest. 15:132:1966, Cignoli and Castro, Exp. Mol. Pathol. 14:43:1971 not cited in the HAD). Studies have demonstrated that the toxic effects are mediated through reactive metabolite(s) generated by cytochrome P-450. The mechanism for toxicity can be either a direct attack on cell protein by the highly-reactive free radical products of homolytic cleavage of the CCl_3-Cl bond or, more likely, an indirect mechanism of lipid peroxidation. Since cytochrome P-450 is central to this metabolism, the relative amount of this enzyme among the various species is important. The literature contains several

references showing that activity in both man and monkey is between 0.30-0.40 nM cytochrome P-450/mg microsomal protein while that of the rat and mouse is 0.70 to 0.85. The quantity of CCl_4 metabolized at the cytochrome P-450 site is reflected in the toxic response of the liver, the mouse most damaged, followed closely by the rat, followed by the monkey (and man). This strongly suggests that the monkey may be the appropriate animal for extrapolation to man.

The carcinogenicity section points out that liver tumors can be induced in various species (rat, mouse, hamster) by CCl_4. The relative sensitivity appears to be: hamsters, most sensitive, followed by mouse, then rat. In contrast to the presentation in the HAD, the preponderance of the data in the literature indicates that the tumorgenic response occurs as a consequency of post-necrotic cirrhosis (Cameron and Karunaratne, 1936; Rueber and Glover, 1967 and 1970; NCI 1976; Della Porta, 1961; Edwards and Dalton, 1942).

In mice, the occurrence of hepatomas following necrosis suggests that CCl_4 is not a direct-acting carcinogen (Louria and Bogden, Crit. Rev. in Toxicology, CRC Press 7:177:1980). This is supported by consistent negative results from short-term mutagenicity tests (McCann, 1975; McCann and Ames, Proc. Natl. Acad. Sci. USA 73:950:1976, Simmon and Tardiff, 1978; Uehleke et al. 1976 and 1977). No evidence of covalent binding to nuclear DNA in mouse and rat liver tissue was found by Rocci (1973). Although

small but significant ^{14}C binding following exposure of rats and mice to ^{14}C-CCl_4 was reported by Diaz Gomez et al. (1975), the authors felt it possible that a non-genetic mechanism of action was relevant for carbon tetrachloride. This is also the conclusion reached by Uehleke (1977) following the study of CCl_4 and nucleic acid binding. The HAD document correctly states that all point mutation studies are negative. However, on the hypothetical base that the "mutagenic reactive intermediate of carbon tetrachloride" is so short-lived that it cannot interact in the test system studied, HAD suggests that "evidence is inadequate to conclude that CCl_4 is not genotoxic." Asking for additional tests here ignores the data already in hand (p. 10-6).

The teratogenicity and other reproductive effects section does a good job of reviewing the pertinent data. The review does not properly point out that when reproductive changes (testicular histology, aspermatogenesis) have been produced in experimental animals, the dose used was extremely high and the route of treatment sometimes not relevant (i.e. intraperitoneal). Changes seen regarding teratogenic, embryotoxic, or reproductive effects have been seen only following higher doses. Schwetz (1974) concludes that CCl_4 is not teratogenic nor is it highly embryotoxic. Indeed, in that study the authors point out that "CCl_4 at concentrations up to 100 times its TLV of 10 ppm was not teratogenic, and in fact, caused very little evidence of embryotoxicity." (Note: Current TLV is 5 ppm.)

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PART 3

CARCINOGENICITY - HUMAN

There are two types of human data that are presented in Section 11.4 on human carcinogenicity. Case reports are one type of evidence. EPA recognizes that "although interesting, these type of data are not suitable to quantitative analysis," and "furthermore, there usually are a number of uncontrolled variables (alcohol intake, age, simultaneous exposures) or unknown variables (exposure amount) making it difficult to attribute the outcome to CCl_4 exposure." Case reports are extremely weak evidence on which to base a judgment.

The second type of evidence comes from epidemiologic studies. The first study by Capurro (1979) reports on a series of cancer cases in a rural valley polluted by vapors from a solvent recovery plant. It was described only for the purpose of being "complete." According to EPA, "due to its lack of specificity and questionable statistical methods, the study is of limited value." Furthermore, "it should not be used as evidence of the carcinogenicity of CCl_4 due to the concomitant exposure and poor techniques."

A second study by Blair (1979) looked at causes of death in 330 laundry and dry cleaning workers. This study reported excess deaths due to cancer of the lung, cervix, and liver

and to leukemia. The study had several limitations that weaken its results and make it difficult to interpret.

- It was a PMR (proportionate mortality rate) study. PMR studies are recognized as being weak methodologically by the scientific community. They cannot measure mortality rates, or estimate relative risks and standardized mortality ratios. An excess of cancer deaths based on the PMR approach is consistent with a true deficit of cancer deaths based on other methods that are methodologically stronger and that have greater scientific validity. Results from PMR studies should be reviewed as preliminary evidence and should be confirmed by other prospective or retrospective studies.

- The dry cleaning workers were exposed to a variety of chlorinated solvents in addition to CCl_4.

- The expected number of cancer deaths in the dry cleaning workers was based on proportionate mortality rates for the entire U.S. population. Thus, the study did not take into account possible geographic or socioeconomic differences in mortality rates.

- There was no statistically significant excess of liver cancer deaths in the study (4 observed deaths vs. 1.7 expected).

- In only one of 4 liver cancer deaths was it possible to distinguish primary liver cancer from secondary (metastatic) liver cancer; that is, 3 of 4 "liver" cancers may in fact have originated in sites other than the liver.

- Due to questionable methods of case ascertainment, there were potential biases in the set of decedents studied. The decedents "do not represent a complete listing of deaths among individuals ever belonging to these two (dry cleaning workers) locals."

- The authors stated that "the small number of deaths, possible biases in the set of decedents obtained, and the general limitations of the PMR methodology necessitate cautious interpretation of the study results."

- The authors drew no conclusions concerning CCl_4's carcinogenic potential in humans. They concluded only that there was a "need for additional epidemiologic studies of this occupational group."

Thus, based on a closer look at the original article, support for the statement on p. 11-37 that "Human data as reported by Blair et. al. (1979), also are consistent with this conclusion" ["that CCl_4 is a potential human carcinogen"] is weak.

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PART 4

APPENDIX: UNIT RISK ESTIMATE FOR CANCER

This appendix is a good start on the development of a quantitative risk assessment for carbon tetrachloride (CCl_4); however, much more work must be done if this risk assessment is to be complete and useful in determining the risk to humans from CCl_4 exposure. In particular, the strengths and limitations of the data base and low-dose extrapolation model used must be better documented and the results of the quantitative risk assessment must be interpreted in light of available data on the mutagenicity, metabolism, and epidemiology of the substance.

The EPA should also consider whether to present any information at all on the quantitative risk assessment. On page A-6 of the appendix the authors conclude with respect to the estimates of potential risk

> "..., each upper bound of risk is presently regarded as having limited plausibility due to the inconclusive nature of the available evidence for the mutagenicity of CCl_4. Furthermore, because of the uncertainties in both the qualitative and quantitative aspects of risk assessment, the actual cancer risks may be lower than those indicated above and may approach zero."

Such low confidence in the results suggests that it may be better not to present any quantitative results stating the reasons given in the document. If the risk estimates are included, it is almost certain that they will be accepted as fact

with all the caveats ignored. In this situation, the presentation of a highly imprecise and inaccurate estimate may serve only as a source of misinformation.

Other suggestions on how this appendix might be improved are detailed below.

1. The linearized multistage model is only one of eight possible risk extrapolation models (i.e., probit, Mantel-Bryan, logit, Weibull, one-hit, multi-hit, linear, multistage) that could have been used in this analysis. This narrow approach should be pointed out to the reader, and it should be stated that the other models were not considered because of prior policy decisions. The reader should also be informed that the use of models, in general, and the linearized multistage model, in particular, is not widely accepted by the scientific community. For example, Squire (1981) points out that "no models can actually be based on biological events, since these are not known for any carcinogens."

2. The reasons for the unit risk estimates being "presently regarded as having limited plausibility" should be more fully documented. First, it should be pointed out that the data base is of poor quality for risk assessment because the doses were very high and produced essentially 100% response.

Exposures of 1 ug/l of water and 1 ug/m^3 of air are, by the document's calculations, equivalent to doses of 2.86 X 10^{-5} mg/kg/day and 1.14 X 10^{-4} mg/ky/day, respectively. These doses are more than 10^7 times less than the lowest tested dose of 1250 mg/kg/day. This, of course, results because the study was not designed for risk assessment but as a positive control in another study. We also emphasize that in the estimation of risk the relevant dose is that seen by the target tissue rather than the administered dose. This relevant dose is necessarily smaller than the administered dose.

It should also be pointed out that the linearized multistage model is the most conservative risk assessment model and that the estimates of potential risk are actually the upper 95% confidence limits on potential risk. This approach, in effect, uses mathematical sophistication to cover up two layers of conservatism. EPA has the right to use such overly conservative procedures; however, EPA also has an obligation to clearly describe their methodology to decision makers.

3. The unit risk estimate is meaningless without relating it to exposure. A potential hazard isn't a risk until there is exposure. The quantitative risk assessment is incomplete and of little value until exposure is quantified and evaluated in the risk assessment.

4. Quantitative risk assessment involves more than the dose-response modeling of tumor incidence data collected in animal studies. To be useful and have scientific meaning, the results of the animal studies must be related to the findings of mutagenicity, metabolism, and epidemiologic studies and the presence of no-observed-effect-levels (NOEL). This information is discussed in the health assessment document but is not considered in the risk assessment. The risk assessment is of very little value until such an overall evaluation is made. The following considerations should be added to the appendix to complete the risk assessment.

At the end of the appendix (page A-6) the authors conclude that "the actual cancer risks may be lower than those indicated above and may approach zero." Such a low risk is consistent with the mutagenicity and metabolism data reported to date. This will be discussed further in the following paragraphs. It is unfortunately impossible to reach any firm conclusions from the epidemiologic data because of inadequate study design and data analysis techniques. These limitations were also noted in the document.

The data reported in the document indicate that CCl_4 is not mutagenic. CCl_4 has been found not to interact with nucleic acids. The results of mutation studies with indicator

microorganisms are also negative, supporting this conclusion. Negative mutagenic studies are consistent with a nongenotoxic mechanism for tumor incidence and its associated no-effect threshold. The existence of a threshold is supported by the liver weight and liver damage no-observed-effect-levels (NOEL) reported for the rat, rabbit, guinea pig, and monkey by Adams, et. al., (1952) and the very low unit risk estimates reported in the document.

The metabolism data also support the low potential risk due to CCl_4 exposure. Adams, et. al., (1952) found that the monkey, which is most like man, had a NOEL of 50 ppm which is considerably higher (by a factor of 2 to 50 depending on species and response) than the NOEL of the rat, guinea pig, and rabbit.

The species that are able to metabolize CCl_4 most efficiently and rapidly will be most sensitive to its adverse effects because CCl_4 must be metabolized to exhibit its adverse effects. Data in the document show that mice and rats metabolize CCl_4 more efficiently than the monkey. The levels of the liver enzyme cytochrome T-450 responsible for CCl_4 metabolism are similar in man and monkey. This indicates that the toxicity of CCl_4 in man and monkey which metabolize CCl_4 slowly will be considerably different from that of mice and rats. The unit risk estimates quoted in the document were developed from a study of liver cancer incidence in male mice.

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APPENDIX E

BIOCHEMICAL AND PERIPHERAL VISION EVALUATION OF CARBON TETRACHLORIDE-EXPOSED WORKERS

James J. Gooch, DrPH
Epidemiologist

October, 1981

Medical Division
Employee Relations Department
E. I. Du Pont de Nemours and Company
Wilmington, Delaware 19898

ABSTRACT

Carbon tetrachloride is used at the Du Pont Company's Beaumont Plant in the manufacture of "Hypalon" synthetic rubber. In the "Hypalon" process, carbon tetrachloride is used as a solvent for the chlorosulfonation of polyethylene. Hepatic and renal toxicity and abnormal peripheral vision have been reported in the medical literature as a consequence of acute and chronic exposure to high concentrations of carbon tetrachloride. To assure that the health of "Hypalon" workers is being safeguarded, their biochemical profiles were analyzed and peripheral vision was assessed.

The mean biochemical test values of 123 exposed workers were compared to those of 104 workers never exposed to carbon tetrachloride. The data were analyzed by job classification and duration of exposure. In a paired analysis of 46 workers, their before carbon tetrachloride exposure biochemical test results were compared to their after exposure test results.

Except for some slight variations and differences, the biochemical test values observed for the exposed workers were statistically comparable to those observed for the workers never exposed to carbon tetrachloride. It was concluded that the health of workers in the "Hypalon" manufacturing area is being safeguarded with respect to conditions that can be detected by the biochemical tests.

Additionally, it was concluded from the visual field screening data that the peripheral vision of the carbon tetrachloride exposed workers was normal.

INTRODUCTION

Carbon tetrachloride (CCl_4), also known as tetrachloromethane, is a clear colorless liquid with a characteristic strong ethereal odor. It is widely used as a chemical intermediate in the manufacturing of a great many products. Its most serious toxicological problems have been introduced by its use as a solvent. The primary toxic effects occur through inhalation of carbon tetrachloride fumes.

Hepatic and renal toxicity resulting from acute and chronic exposures to carbon tetrachloride has been reported by many investigators (1-11). In their reports, mortality associated with carbon tetrachloride exposure was most often the result of pathologic effects on the liver and kidneys and subsequent organ failure. The concurrent intake of significant amounts of alcohol with exposure to carbon tetrachloride was reported to have increased the probability of liver or kidney injury.

Cases of visual disturbance among carbon tetrachloride exposed individuals have been reported in the medical literature (14-19). In those case reports, bilateral peripheral constriction was the eye defect most often reported.

The Occupational Safety and Health Administration's (OSHA) standard for employee exposure to carbon tetrachloride is 10 parts of carbon tetrachloride per million parts of air (ppm) averaged over an eight-hour shift, with an acceptable ceiling exposure concentration of 25 ppm, and maximum allowable peak of 200 ppm for no more than five minutes in any four hours

period. This standard is intended to prevent any adverse health effects known to occur from overexposure to carbon tetrachloride.

In the Du Pont Company, carbon tetrachloride is used at the Beaumont Plant in the manufacture of Hypalon® synthetic rubber. In the Hypalon® process, carbon tetrachloride is used as a solvent for the chlorosulfonation of polyethylene. Manufacturing practices at the Beaumont Plant have been established to maintain employee exposure to carbon tetrachloride vapors below the threshold limit value of 10 ppm and to avoid any exposures to liquid. In the Hypalon® area, protective equipment must be worn when airborne concentration of carbon tetrachloride are above 10 ppm.

To assure that the health of Hypalon® workers is being safeguarded, their biochemical profiles were analyzed and their peripheral vision was assessed. This report presents and discusses the findings of that investigation.

METHODS

Biochemical Evaluation

The study groups included male and female employees that were on the wage roll as of September 30, 1979. On the basis of their work histories, the workers were assigned to one of three defined study groups:

- Currently Exposed.* Workers assigned to the Hypalon® manufacturing area of the plant on September 30, 1979.

*See Supplement, attached.

- Not Currently Exposed Workers with a past work history of assignment to the Hypalon® manufcturing area of the plant.
- Never Exposed Workers with no work history of assignment to the Hypalon® manufacturing area of the plant.

Occupational exposure to carbon tetrachloride, for purposes of this study, was defined as having been assigned to the Hypalon® manufacturing area of the plant.

Three job classifications were associated with the Hypalon® process: operators, auxiliary workers, and mechanics. Operators were responsible for manufacturing Hypalon® . Their primary exposure to carbon tetrachloride occurred in the Hypalon® drum-drying operation. The auxiliary workers were responsible for packaging Hypalon®, disposal of waste, and the cleaning of the rollers in the drum-dryer operations. The mechanics were responsible for the general maintenance of equipment in the Hypalon® area. In general, equipment was cleaned before it was serviced. Therefore, mechanical workers had very low exposure to carbon tetrachloride.

All Hypalon® area workers were given a battery of biochemical tests in conjunction with their annual physical examinations. Biochemistry determinations resulting from testing done between 1977 and September 30, 1979 were analyzed in this study. During the study period, the majority of the workers were tested on at least two or more occasions.

From each worker, two 10 ml. fasting blood samples were collected using routine venipuncture procedures. The blood samples were allowed to clot at room temperature. Within 1-2 hours of collection, the blood samples were sent to a private contract clinical laboratory (Wilcox Pathology Laboratories, Inc.) where they were centrifuged and the serum removed.

The following battery of biochemical determinations were made from the serum: glucose, blood-urea-nitrogen (BUN), creatinine, sodium, potassium, chloride, uric acid, calcium, inorganic phosphate, total bilirubin, serum glutamic oxaloacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT), lactic dehydrogenase (LDH), and globulin. The biochemical measurements were made on a multichannel analyzer.

The biochemical test results were reported to the plant physician on standard report forms. These forms were placed in the worker's medical record. For this study, the biochemical test results were abstracted from the medical record and keypunched for computer tabulations.

Biochemical test results obtained prior to employment and exposure to carbon tetrachloride, with the unique exception of 46 currently exposed workers, were not included in this study. In the course of normal events, 46 of the 56 currently exposed workers were tested <u>before</u> and <u>after</u> being assigned to the Hypalon® manufacturing area. These laboratory data were <u>included in a paired analysis.</u>

The test data were analyzed according to a one-way analysis of variance (ANOVA). The F-statistic resulting from the ANOVA and its probability value were used to compare the test parameters. If the ANOVA probability value was less than 0.05, a two-tailed student t-test for groups of unequal size was used to determine which test parameters in the exposed group were significantly different from those of the never exposed groups. For the t-test, a p-value of less than 0.05 was considered to be statistically significant.

Lipid levels, especially cholesterol, tends to increase with age. Using covariance analysis, cholesterol and triglyceride levels were adjusted to take into account the age of the workers in the three study groups.

The biochemical test results obtained before exposure to carbon tetrachloride were compared to those obtained after exposure in the same currently exposed worker. This procedure of using a subject as his own control has the advantage of controlling many sources of variation in the data. The mean difference between the two measurements was tested by applying the t-test for paired comparisons calculated at the 0.05 significance level.

Peripheral Vision Assessment

Visual field assessments were made on 83 employees assigned to the Hypalon® area in November, 1980 with the potential for carbon tetrachloride exposure, and 90 employees who had never been assigned to the Hypalon® area and had no known exposure to carbon tetrachloride. The visual field was

measured using a tangent screen. The tangent screen was covered with black felt located 100 mm from the eyes of the employee. The tests were all administered by the plant nurse and interpreted by the plant physician. Employees found during the initial testing to have any visual field defects were referred to a consulting ophthalmologist. The peripheral isopter, the blind spot, and various scotomas can be demonstrated testing with the tangent screen. Standard criteria were used to define the above central or peripheral defects of the visual field.

RESULTS

The exposed group consisted of 123 wage roll workers, 117 (95%) males and 6 (5%) females. By time of exposure, 56 (46%) of the 123 workers were currently working in the "Hypalon" manufacturing area at the time of the study. The remaining 67 (54%) workers had previously worked in the "Hypalon" area for some period of time before the end of the study. The never-exposed group, the controls, consisted of 104 wage roll workers with 100 (96%) males and 4 (4%) females.

The mean age for the currently exposed workers was 33.0, for the not currently exposed 33.8, and for the never exposed groups 37.0 years. Overall, the three groups were comparable in ages.

The biochemical test results are summarized in Tables 1 through 4. In each table, the test values of the exposed workers are compared to those of the never exposed group.

Overall, the biochemical test values for the exposed workers did not differ significantly from the test values of the 104 never exposed workers (Table 1). On an individual test basis, the currently exposed workers have higher LDH and lower triglyceride levels than did the never exposed workers (Table 1). In Table 2 the test results among the currently exposed workers were analyzed by three job classifications. By job classification the test results among the currently exposed workers were very comparable overall to those of the never exposed workers in the study (Table 2). However, the operators had higher LDH values compared to the never exposed workers. The auxillary workers has higher alkaline phosphatase values but lower triglyceride levels than did the never exposed workers (Table 2).

Duration, defined as the time between first exposure to carbon tetrachloride and the end of the study in September 1979, was strafied into less than 25 months, 25 to 48 months, and greater than 48 months in Table 3. In the data analysis, duration of exposure was not associated overall with abnormal biochemical test results (Table 3). Thus, compared to never exposed workers, the test values among the currently exposed workers did not overall show significant deviations with increased duration of exposure to carbon tetrachloride.

Blood-Urea-Nitrogen (BUN). Each study group had a mean BUN value of around 16 mg/dl (Tables 1-3). The frequency

of deviant values for the not currently exposed workers did not differ significantly from the never exposed (Table 1).

Creatinine. The creatinine determinations averaged 1.2 mg/dl for each study group (Tables 1-3). No significant differences were noted. The total exposed group had significantly more deviant values when compared to the controls (Table 1).

Sodium. The sodium determinations averaged 141 meq/L for each study group (Tables 1-3). No significant differences were noted.

Potassium. The potassium levels for each study group averaged 4.4 meq/L (Tables 1-3). No significant differences were noted.

Chloride. The three study groups each had a chloride level which averaged approximately 104 meq/L (Tables 1-3). No significant differences were noted.

Uric Acid. Uric acid measurements averaged for each study group about 6 mg/dl (Tables 1-3). No significant differences were noted.

Calcium. For each study group, calcium averaged around 10 mg/dl (Tables 1-3). No significant differences were noted.

Inorganic Phosphorous. For each study group, inorganic phosphorous averaged around 3.0 mg/dl (Tables 1-3). Significant differences were not noted.

Cholesterol. When the cholesterol values were analyzed by exposure group, significant differences among the

unadjusted means were noted (Tables 1-3). After adjusting the cholesterol levels for age of the workers, the previous noted differences were no longer present (Tables 1-3). With the age adjustment, the never exposed groups had a mean cholesterol level of 186 mg/dl, the total exposed group a mean level of 191 mg/dl with those currently exposed at 187.3 mg/dl and not currently exposed at 194.7 mg/dl (Table 1).

Triglyceride. Triglyceride differed significantly among the three study groups (Tables 1-3). Age-adjusting the triclyceride levels did not change the noted differences. By exposure group, the currently exposed workers' triglyceride level of 119.6 mg/dl was significantly different from the 132.2 mg/dl found among the control group (Table 1). Among active workers, the auxiliary workers had a triglyceride level significantly less than that of the control group (Table 2). Workers with 48 months or less time in the Hypalon® area had significantly lower triglyceride values compared to the controls (Table 3). The frequencies of deviant values were comparable among the study groups.

Total Protein. Total protein measurements averaged about 7 g/dl, for each study group (Tables 1-3). No significant differences were noted.

Albumin. The albumin levels were 4.4 g/dl for each study group (Tables 1-3). No significant differences were noted.

Alkaline Phosphatase. The 87.1 U/L level of alkaline phosphatase among the auxiliary workers was significantly

greater than the 75.6 U/L level observed for the control group (Table 2). All other levels of alkaline phosphatase analyzed were comparable to that of the control group (Tables 1-3). The frequencies of deviant values were comparable among the study groups.

Serum Glutamic Oxaloacetic Transaminase (SGOT). The SGOT values averaged around 24 U/L for each study group (Tables 1-3). No significant differences were noted.

Serum Glutamic Pyruvic Transaminase (SGPT). The never exposed group had a mean value of 23.6 U/L while the exposed groups had SGOT values which were comparable.

Lactic Dehydrogenase (LDH). Among the actively exposed workers the LDH level of 176.0 U/L was significantly higher than the 165.2 U/L level seen among the controls. By job classification, the elevation in LDH was restricted to the operators (Table 2). When analyzed by duration, the significant elevation was found among the workers with less than 12 months in the Hypalon® area (Table 3). The total exposed group had significantly more deviant LDH values than did the control group (Tables 1-3).

Globulin. The three groups each had a globulin mean value of approximately 2.7 g/dl. Although the means were the same, the exposed workers had significantly more deviant globulin values compared to the control group.

Paired Analysis. When individual comparisons were made for the 46 workers before and again after their first assignment to the Hypalon® manufacturing area, no statistically

significant changes were noted among the battery of biochemical determinations (Table 4). The 46 workers spent an average of 16.4 months in the Hypalon® area.

Peripheral Vision Assessment

No peripheral vision field defects were found among the Hypalon® workers potentially exposed to carbon tetrachloride. Among the 90 employees in the control groups, two employees upon initial screening had visual fields which deviated slightly from the normal pattern. These two employees were referred to a consulting ophthalomologist for retesting and evaluation. The results were that both employees had normal visual fields, as assessed by the ophtholomologist. Thus, the control groups of employees were found to all have normal visual fields.

DISCUSSION

The biochemical test results presented in this report indicate that the health of Hypalon® area workers is being safeguarded with respect to conditions that can be detected by those tests. Overall, biochemical test values obtained in the exposed groups were statistically comparable to those values obtained from the never exposed workers. The test values for the exposed group tended to cluster about the mean values of the never exposed with no gross elevations or decreases. Further, job classification and or time since first assigned to the Hypalon® manufacturing area appeared to have had no adverse influence on the normality of test results. No relationship

between the frequency of deviant values and exposure to carbon tetrachloride was found.

The most significant finding in the study came from the paired analysis of 46 active Hypalon® area workers. In that analysis, the workers' biochemical test values obtained before exposure to carbon tetrachloride were compared to those taken following exposure. When comparisons were made, no statistically significant changes were noted between the before and after measurements. This finding is enhanced by the fact that each worker served as his own control.

Carbon tetrachloride has been recognized for many years as a very toxic solvent to man (12). Studies to date would indicate that physiological alterations occurred only at exposure to high concentrations of carbon tetrachloride (12). Furthermore, those individuals affected usually had skin contact with the liquid as well as the vapor. In the current study, potential exposure to carbon tetrachloride ranged from 0 to 10 ppm void of direct contact with liquid. Thus, the Hypalon® workers were not exposed to carbon tetrachloride levels which pose serious threats to health.

Functional and destructive injury of the liver and kidneys have most often been the reported result of overexposure to carbon tetrachloride (12). Liver function parameters analyzed in the present study included serum bilirubin, SGOT, SGPT, LDH, and alkaline phosphatase. Bilirubin, SGOT and SGPT levels observed among the exposed workers were very comparable to those of the controls. Slight,

but statistically significant mean differences were noted when the alkaline phosphatase and LDH levels when analyzed. These differences are not interpreted to be, however, medically significant. Moderate elevations, two to fourfold increases, are generally regarded as diagnostic (13). Elevations of such magnitude were not evident in the current study.

LDH and alkaline phosphatase levels alone do not provide a sensitive measure of hepatic disease (13). The diagnostic usefulness of LDH and alkaline phosphatase levels are detracted somewhat due to the large number of conditions which can elevate them. The diagnostic usefulness of LDH and alkaline phosphatase is enhanced by observing the patterns of abnormalities obtained by measuring SGOT and SGPT. No abnormal patterns occurred in the current study with SGOT and SGPT.

Renal function evaluations are generally made using creatinine and BUN tests. In this study, no abnormal creatinine or BUN levels were observed.

The current study, using a tangent screen to obtain precise measurement of the visual field, found no visual field defects among workers with potential exposure to carbon tetrachloride. The peripheral vision defects cited in the literature (14-19) appeared to have occurred among individuals exposed to carbon tetrachloride vapors many folds higher than the 10 ppm limit presently maintain in the Hypalon® area. It is concluded from visual field screening data that the peripheral vision of the Hypalon® workers is normal.

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TABLE 1

BIOCHEMICAL TEST RESULTS BY STUDY GROUPS

Laboratory Test	Never Exposed (N=104)	Currently Exposed (N=56)	Currently Exposed (N=67)
Glucose (mg/dl)	93.7	91.8	93.8
BUN (mg/dl)	15.4	16.1	14.8
Creatinine (mg/dl	1.2	1.2	1.2
Sodium (meq/L)	141.4	141.6	141.4
Potassium (meq/L	4.4	4.4	4.3
Chloride (meq/L	103.9	103.9	103.6
Uric Acid (mg/dl)	6.2	5.9	6.2
Calcium (mg/dl)	9.8	9.7	10.2
Inorganic Phosphorous (mg/dl)	3.0	3.2	3.1
Total Protein (g/dl)	7.1	7.1	7.1
Albumin (g/dl)	4.4	4.4	4.4
Alkaline Phosphatase (U/L)	75.6	79.7	70.4
Total Bilirubin (mg/dl)	0.6	0.5	0.5
SGOT (U/L)	24.0	23.2	23.5
SGPT (U/L)	25.6	23.1	23.8
LDH (U/L)	165.2	176.0*	165.1
Globulin (g/dl)	2.7	2.7	2.7
Chloresterol (mg/dl)	186.0	187.3	194.7
Triglyceride (mg/dl)	132.2	119.6*	145.3

*$p < 0.05$

TABLE 2

BIOCHEMICAL TEST RESULTS FOR CURRENTLY EXPOSED WORKERS
BY JOB CLASSIFICATION

Laboratory Test	Never Exposed (N=104)	Currently Exposed Operators (N=32)	Currently Exposed Auxiliary (N=17)	Currently Exposed Mechanic (N=7)
Glucose (mg/dl)	93.7	90.3	91.9	97.1
BUN (mg/dl)	15.4	15.6	16.6	17.3
Creatinine (mg/dl	1.2	1.2	1.1	1.2
Sodium (meq/L)	141.4	141.7	140.7	143.1
Potassium (meq/L	4.4	4.5	4.3	4.4
Chloride (meq/L	103.9	103.7	103.9	104.6
Uric Acid (mg/dl)	6.2	6.0	5.8	5.6
Calcium (mg/dl)	9.8	9.7	9.7	9.8
Inorganic Phosphorous (mg/dl)	3.0	3.2	3.4	2.7
Total Protein (g/dl)	7.1	7.1	7.2	6.8
Albumin (g/dl)	4.4	4.4	4.5	4.2
Alkaline Phosphatase (U/L)	75.6	75.8	87.1*	79.1
Total Bilirubin (mg/dl)	0.6	0.5	0.6	0.5
SGOT (U/L)	24.0	21.9	24.7	25.8
SGPT (U/L)	25.6	34.4	19.9	25.3
LDH (U/L)	165.2	177.6*	171.1	180.0
Globulin (g/dl)	2.7	2.7	2.7	2.6
Chloresterol (mg/dl)	187.1	190.1	195.1	180.4
Triglyceride (mg/dl)	132.4	124.3	97.9*	152.9

*$p < 0.05$

TABLE 3
BIOCHEMICAL TEST RESULTS FOR CURRENTLY EXPOSED WORKERS
BY DURATION OF EXPOSURE

Laboratory Test	Never Exposed (N=104)	Currently Exposed 25 Months Duration	Currently Exposed 25 to 48 Months Duration	Currently Exposed 48 Months Duration
Glucose (mg/dl)	93.7	94.9	90.2	89.9
BUN (mg/dl)	15.4	16.4	16.0	16.0
Creatinine (mg/dl	1.2	1.2	1.2	1.2
Sodium (meq/L)	141.4	141.3	141.5	142.1
Potassium (meq/L	4.4	4.3	4.5	4.5
Chloride (meq/L	103.9	103.5	104.3	103.7
Uric Acid (mg/dl)	6.2	5.9	6.0	5.5
Calcium (mg/dl)	9.8	9.7	9.8	9.8
Inorganic Phosphorous (mg/dl)	3.0	3.2	3.3	3.2
Total Protein (g/dl)	7.2	7.2	7.1	6.9
Albumin (g/dl)	4.4	4.4	4.4	4.4
Alkaline Phosphatase (U/L)	75.6	79.6	81.4	76.7
Total Bilirubin (mg/dl)	0.6	0.5	0.5	0.5
SGOT (U/L)	24.0	24.8	23.0	21.1
SGPT (U/L)	25.6	21.6	24.0	23.8
LDH (U/L)	165.2	179.9*	171.3	178.4
Globulin (g/dl)	2.7	2.8	2.7	2.5
Chloresterol (mg/dl)	184.5	179.2	192.9	182.2
Triglyceride (mg/dl)	132.0	105.8*	120.3	139.2

*$p < 0.05$

TABLE 4
BIOCHEMICAL TEST RESULTS FOR WORKERS BEFORE AND AFTER ASSIGNMENT TO THE HYPALON® MANUFACTURING AREA (N=46)

Laboratory Test	Before	After
Glucose (mg/dl)	93.3	92.7
BUN (mg/dl)	14.2	15.0
Creatinine (mg/dl	1.2	1.2
Sodium (meq/L)	141.9	141.2
Potassium (meq/L	4.6	4.3
Chloride (meq/L	103.7	103.9
Uric Acid (mg/dl)	6.0	5.9
Calcium (mg/dl)	10.0	9.6
Inorganic Phosphorous (mg/dl)	3.1	3.1
Total Protein (g/dl)	7.1	7.1
Albumin (g/dl)	4.4	4.3
Alkaline Phosphatase (U/L)	78.2	78.4
Total Bilirubin (mg/dl)	0.6	0.5
SGOT (U/L)	24.0	24.2
SGPT (U/L)	28.4	23.1
LDH (U/L)	167.0	168.3
Globulin (g/dl)	2.8	2.7
Chloresterol (mg/dl)	193.6	189.3
Triglyceride (mg/dl)	139.8	133.8

SUPPLEMENT

"HYPALON" EXPOSURE ASSESSMENT
BEAUMONT PLANT

A review of the personal breathing zone samples collected for employees assigned to the Beaumont "Hypalon" Area during the period 1977-1979 showed that routine carbon tetrachloride exposures, excluding maintenance tasks and some filter change work where respiratory protection is worn, were less than 5 ppm and averaged 2 ppm as 8-hour time-weighted averages.

Patricia G. Gilby
Industrial Hygienist
CIH 1352

PGG:lrg
2/14/86

EXPOSURE ASSESSMENT

Three of the five Du Pont plants for which predicted carbon tetrachloride exposures were listed in EPA's August 1985 Exposure and Risk document were dispersion modeled using the most current plant specific data. The other two Du Pont plants were not modeled because sufficient meteorological data were not in our computer files. However, we believe conclusions drawn from the modeled plants will be generally applicable.

Using the Industrial Source Complex (ISC) short-term model, the highest off-plant annual and 24-hour average concentrations were predicted. Comparisons of these ISC model results with model results reported in EPA's Exposure and Risk document and with a pertinent health effect criterion are given in Tables 1 and 2. (Computer output sheets listing data and results for the ISC model are attached.)

Table 1 shows that, for the most exposed person off plant, the Human Exposure Model (HEM) model prediction is about a factor of 100 too high. Table 2 shows that all the off-plant exposures predicted by ISC are well below Haskell Lab's health effects criterion.

Two reasons for the large ISC and HEM differences in predicted concentration are apparent. First, the HEM model assumes the most exposed person lives about 200 yards from the emission points. In most cases, this would equate to someone living on the plant site. In contrast, the ISC model results

are based on locations where someone could live. In addition to excluding areas within the plant boundary, other terrain features likely to prevent housing were considered in the ISC results. For instance, all three plants are located on major waterways (i.e., the Gulf of Mexico) where it appears unlikely that houses will ever be built. Secondly, EPA apparently assumes that fugitive emission (i.e., leaks) are very high for these plants. It is our experience that EPA fugitive emission estimates frequently overestimate leaks from our plants by factors of 10 to 100. We have reviewed design and operating practices at our plants to determine a better way to predict fugitive emissions from Du Pont plants and have discussed our conclusions with EPA. We plan to collect additional supporting data through field testing. Briefly, our position on fugitive emission estimation is as follows:

EPA's fugitive emission estimates are based on data from a wide cross section of industry with greatly different design and operating characteristics (i.e., petroleum refineries and chemical plants, non-toxic and toxic materials) commodity chemicals and specialty products, etc.). Consequently, EPA s estimating factors may he reasonable for national estimates but are unlikely to be accurate for a specific plant or industry subgroup.

We believe Du Pont processes can be divided into four categories based on design specifications and two categories

based on operation and maintenance practices. Thus, there is a matrix of eight categories of Du Pont plants. It should be possible to quantify the fugitive emissions from each of these categories.

Field data collected so far show that processes with similar design and maintenance practices to those of carbon tetrachloride using plants have much lower fugitive emissions than predicted using EPA's factors. We believe future field tests will verify this. The results of these field tests will be shared with the agency when they are available.

In conclusion, maximum off-plant exposures predicted using the ISC model do not agree with predictions made by the HEM model. We believe the ISC results are more realistic predictions of maximum exposure. Furthermore, maximum off-plant exposures predicted using the ISC model are well below levels associated with possible health concerns.

TABLE 1

COMPARISON OF ISC AND HEM MODEL RESULTS FOR THE HIGHEST OFF-PLANT, ONE-YEAR AVERAGE EXPOSURE

	Maximum Off-Plant, One-year Average Exposure (μ grams/m^3)	
	HEM Model	ISC Model
Beaumont Plant		
Carbon Tetrachloride	120	1.4
Chambers Works		
Carbon Tetrachloride	11	0.3
Corpus Christi Plant		
Carbon Tetrachloride	110	1.3

TABLE 2

COMPARISON OF ISC MODEL PREDICTED OFF-PLANT, 24-HOUR EXPOSURES VERSUS HASKELL LAB COMMUNITY AIR LEVEL

	Maximum Off-Plant, 24-Hour Exposure (μ grams/m^3)	
	ISC Predicted Concentration	Haskell Lab Community Air Level
Beaumont Plant		
Carbon Tetrachloride	16	600
Chambers Works		
Carbon Tetrachloride	10	600
Corpus Christi Plant		
Carbon Tetrachloride	24	600

*** BEAUMONT CARBONTETRACHLORIDE CONCENTRATION 1984 EMISSIONS ***

CALCULATE (CONCENTRATION=1,DEPOSITION=2)	ISW(1) =	1
RECEPTOR GRID SYSTEM (RECTANGULAR=1 OR 3, POLAR=2 OR 4)	ISW(2) =	2
DISCRETE RECEPTOR SYSTEM (RECTANGULAR=1,POLAR=2)	ISW(3) =	2
TERRAIN ELEVATIONS ARE READ (YES=1,NO=0)	ISW(4) =	0
CALCULATIONS ARE WRITTEN TO TAPE (YES=1,NO=0)	ISW(5) =	0
LIST ALL INPUT DATA (NO=0,YES=1,MET DATA ALSO=2)	ISW(6) =	1
COMPUTE AVERAGE CONCENTRATION (OR TOTAL DEPOSITION)		
WITH THE FOLLOWING TIME PERIODS:		
HOURLY (YES=1,NO=0)	ISW(7) =	0
2-HOUR (YES=1,NO=0)	ISW(8) =	0
3-HOUR (YES=1,NO=0)	ISW(9) =	0
4-HOUR (YES=1,NO=0)	ISW(10) =	0
6-HOUR (YES=1,NO=0)	ISW(11) =	0
8-HOUR (YES=1,NO=0)	ISW(12) =	0
12-HOUR (YES=1,NO=0)	ISW(13) =	0
24-HOUR (YES=1,NO=0)	ISW(14) =	1
PRINT 'N'-DAY TABLE(S) (YES=1,NO=0)	ISW(15) =	1
PRINT THE FOLLOWING TYPES OF TABLES WHOSE TIME PERIODS ARE		
SPECIFIED BY ISW(7) THROUGH ISW(14):		
DAILY TABLES (YES=1,NO=0)	ISW(16) =	0
HIGHEST & SECOND HIGHEST TABLES (YES=1,NO=0)	ISW(17) =	1
MAXIMUM 50 TABLES (YES=1,NO=0)	ISW(18) =	0
METEOROLOGICAL DATA INPUT METHOD (PRE-PROCESSED=1,CARD=2)	ISW(19) =	1
RURAL-URBAN OPTION (RURAL=0,URBAN MODE 1=1,URBAN MODE 2=2)	ISW(20) =	0
WIND PROFILE EXPONENT VALUES (DEFAULTS=1,USER ENTERS=2,3)	ISW(21) =	1
VERTICAL POT. TEMP. GRADIENT VALUES (DEFAULTS=1,USER ENTERS=2,3)	ISW(22) =	1
SCALE EMISSION RATES FOR ALL SOURCES (NO=0,YES>0)	ISW(23) =	0
PROGRAM CALCULATES FINAL PLUME RISE ONLY (YES=1,NO=2)	ISW(24) =	1
PROGRAM ADJUSTS ALL STACK HEIGHTS FOR DOWNWASH (YES=2,NO=1)	ISW(25) =	20
NUMBER OF INPUT SOURCES	NSOURC =	12
NUMBER OF SOURCE GROUPS (=0,ALL SOURCES)	NGROUP =	0
TIME PERIOD INTERVAL TO BE PRINTED (=0,ALL INTERVALS)	IPERD =	0
NUMBER OF X (RANGE) GRID VALUES	NXPNTS =	3
NUMBER OF Y (THETA) GRID VALUES	NYPNTS =	36
NUMBER OF DISCRETE RECEPTORS	NXYPT =	0
SOURCE EMISSION RATE UNITS CONVERSION FACTOR	TK =	.10000+07
ENTRAINMENT COEFFICIENT FOR UNSTABLE ATMOSPHERE	BETA1 =	.600
ENTRAINMENT COEFFICIENT FOR STABLE ATMOSPHERE	BETA2 =	.600
HEIGHT ABOVE GROUND AT WHICH WIND SPEED WAS MEASURED	ZR =	10.00 METERS
LOGICAL UNIT NUMBER OF METEOROLOGICAL DATA	IMET =	12
DECAY COEFFICIENT FOR PHYSICAL OR CHEMICAL DEPLETION	DECAY =	.000000
SURFACE STATION NO.	ISS =	12918 Lake Charles
YEAR OF SURFACE DATA	ISY =	84
UPPER AIR STATION NO.	IUS =	3937 Houston
YEAR OF UPPER AIR DATA	IUY =	84
ALLOCATED DATA STORAGE	LIMIT =	43500 WORDS
REQUIRED DATA STORAGE FOR THIS PROBLEM RUN	MIMIT =	3483 WORDS

*** BEAUMONT CARBONTETRACHLORIDE CONCENTRATION 1984 EMISSIONS ***

*** METEOROLOGICAL DAYS TO BE PROCESSED ***
(IF=1)

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1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1
```

*** UPPER BOUND OF FIRST THROUGH FIFTH WIND SPEED CATEGORIES ***
(METERS/SEC)

1.54, 3.09, 5.14, 8.23, 10.80,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00
B	.15000+00	.15000+00	.15000+00	.15000+00	.15000+00	.15000+00
C	.20000+00	.20000+00	.20000+00	.20000+00	.20000+00	.20000+00
D	.25000+00	.25000+00	.25000+00	.25000+00	.25000+00	.25000+00
E	.30000+00	.30000+00	.30000+00	.30000+00	.30000+00	.30000+00
F	.30000+00	.30000+00	.30000+00	.30000+00	.30000+00	.30000+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000	.00000	.00000	.00000	.00000	.00000
B	.00000	.00000	.00000	.00000	.00000	.00000
C	.00000	.00000	.00000	.00000	.00000	.00000
D	.00000	.00000	.00000	.00000	.00000	.00000
E	.20000-01	.20000-01	.20000-01	.20000-01	.20000-01	.20000-01
F	.35000-01	.35000-01	.35000-01	.35000-01	.35000-01	.35000-01

*** BEAUMONT CARBONTETRACHLORIDE CONCENTRATION 1984 EMISSIONS ***

*** RANGES OF POLAR GRID SYSTEM ***
(METERS)

550.0, 1000.0, 1600.0,

*** RADIAL ANGLES OF POLAR GRID SYSTEM ***

(DEGREES)

10.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0, 80.0, 90.0, 100.0,
110.0, 120.0, 130.0, 140.0, 150.0, 160.0, 170.0, 180.0, 190.0, 200.0,
210.0, 220.0, 230.0, 240.0, 250.0, 260.0, 270.0, 280.0, 290.0, 300.0,
310.0, 320.0, 330.0, 340.0, 350.0, 360.0,

*** BEAUMONT CARBON TETRACHLORIDE CONCENTRATION 1984 EMISSIONS ***

*** SOURCE DATA ***

SOURCE NUMBER	TYPE	WAKE	NUMBER PART. CATS.	EMISSION RATE TYPE=0,1 (GRAMS/SEC) TYPE=2 (GRAMS/SEC) *PER METER**2	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	HEIGHT (METERS)	TEMP. TYPE=0 (DEG.K); VERT.DIM TYPE=1 (METERS)	EXIT VEL. TYPE=0 (M/SEC); HORZ.DIM TYPE=1,2 (METERS)	DIAMETER TYPE=0 (METERS)	BLDG. HEIGHT TYPE=0 (METERS)	BLDG. LENGTH TYPE=0 (METERS)	BLDG. WIDTH TYPE=0 (METERS)
176	2	U	0	.66000-05	-15.0	-390.0	.0	1.00	.00	175.00	.00	.00	.00	.00
114	2	U	0	.27200-03	83.0	-376.0	.0	1.00	.00	2.50	.00	.00	.00	.00
277	2	U	0	.53000-03	15.0	-266.0	.0	1.00	.00	1.50	.00	.00	.00	.00
112	C	U	0	.12900+01	23.0	-271.0	.0	34.10	316.00	8.50	3.05	.00	.00	.00
14	C	U	0	.19300+00	99.0	-423.0	.0	9.15	263.00	.10	.10	.00	.00	.00
151	C	U	0	.14700+00	23.0	-362.0	.0	18.90	302.00	20.90	.76	9.15	68.60	30.50
15234	C	U	0	.36300+00	.0	-339.0	.0	18.90	302.00	22.80	.67	9.15	68.60	30.50
15567	C	U	0	.21600+00	-11.0	-320.0	.0	18.90	302.00	9.90	.76	9.15	68.60	30.50
1589	C	U	0	.14600+00	-23.0	-317.0	.0	18.90	302.00	9.90	.76	9.15	68.60	30.50
234	2	U	0	.60000-06	143.0	-223.0	.0	1.00	.00	400.00	.00	.00	.00	.00
284	2	U	0	.12500-04	-200.0	-285.0	.0	3.00	.00	20.00	.00	.00	.00	.00
302	2	U	0	.36000-03	-190.0	-250.0	.0	3.00	.00	20.00	.00	.00	.00	.00

*** BEAUMONT CARBONTETRACHLORIDE CONCENTRATION 1984 EMISSIONS ***

* SOURCE-RECEPTOR COMBINATIONS LESS THAN 100 METERS OR THREE BUILDING HEIGHTS IN DISTANCE. NO AVERAGE CONCENTRATION IS CALCULATED *

SOURCE NUMBER	- - RECEPTOR LOCATION - - X OR RANGE (METERS)	Y (METERS) OR DIRECTION (DEGREES)	DISTANCE BETWEEN (METERS)
234	550.0	70.0	47.79
234	550.0	80.0	5.63
234	550.0	90.0	-17.40
234	550.0	100.0	-14.21
234	550.0	110.0	14.07
234	550.0	120.0	59.41

N-DAY
366 DAYS
SGROUP# 1

*** BEAUMONT CARBONTETRACHLORIDE CONCENTRATION 1984 EMISSIONS ***

* 366-DAY AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) *

* FROM ALL SOURCES *
* FOR THE RECEPTOR GRID *

* MAXIMUM VALUE EQUALS 8.83453 AND OCCURRED AT (550.0, 170.0) *

DIRECTION / (DEGREES) /	RANGE (METERS) 550.0	1050.0	1500.0
360.0 /	3.64363	2.19464	1.50627
350.0 /	3.81926	2.32463	1.51589
340.0 /	4.44845	2.53349	1.73496
330.0 /	4.35736	2.48059	1.51022
320.0 /	3.98257	2.03671	1.25420
310.0 /	4.19720	2.07422	1.37661
300.0 /	3.77150	2.21726	1.42091
290.0 /	4.22898	2.30518	1.32389
280.0 /	4.67497	2.09058	1.05805
270.0 /	4.91079	1.65266	.82539
260.0 /	4.48185	1.48070	.98212
250.0 /	4.00784	1.51413	.69220
240.0 /	4.16700	1.35041	.80669
230.0 /	5.13015	1.74732	1.00832
220.0 /	5.65246	1.92035	.99024
210.0 /	5.41567	1.68928	.76292
200.0 /	7.13174	1.40595	.64922
190.0 /	6.85216	1.87595	.96680
180.0 /	6.72860	2.56213	1.36612
170.0 /	8.83453	2.72197	1.37553
160.0 /	6.72412	2.16648	1.21280
150.0 /	4.43973	1.73336	.88717
140.0 /	3.95489	1.20212	.65895
130.0 /	3.66638	1.10092	.53847
120.0 /	2.34992	1.07810	.62894
110.0 /	1.90650	1.04349	.47655
100.0 /	1.72763	.96800	.61150
90.0 /	1.41025	.92605	.51160
80.0 /	1.32077	.91699	.47296
70.0 /	1.29738	.80449	.51046
60.0 /	2.39115	.76929	.43373
50.0 /	2.51045	.80167	.45197
40.0 /	2.62596	.88187	.47196
30.0 /	2.56221	1.23667	.69466
20.0 /	2.78910	1.31904	.81820
10.0 /	3.47700	1.76322	1.00803

could be developed

marsh

HIGH
24-HR
SGROUP# 1

*** BEAUMONT CARBONTLTRACHLORIDE CONCENTRATION 1984 EMISSIONS ***

* HIGHEST 24-HOUR AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) *
* FROM ALL SOURCES *
* FOR THE RECEPTOR GRID *

* MAXIMUM VALUE EQUALS 76.39106 AND OCCURRED AT (550.0, 200.0) *

DIRECTION / (DEGREES) /	RANGE (METERS) 550.0	1000.0	1500.0
360.0 /	17.05154 (92, 1)	11.81561 (54, 1)	11.98942 (54, 1)
350.0 /	29.66660 (316, 1)	18.69719 (316, 1)	13.39256 (316, 1)
340.0 /	33.76847 (316, 1)	22.28638 (316, 1)	17.23629 (316, 1)
330.0 /	32.71018 (316, 1)	21.31725 (316, 1)	10.36035 (316, 1)
320.0 /	30.04691 (316, 1)	13.42992 (197, 1)	8.32577 (215, 1)
310.0 /	32.35473 (242, 1)	14.46879 (197, 1)	8.61185 (130, 1)
300.0 /	24.55381 (215, 1)	12.46728 (307, 1)	12.12847 (76, 1)
290.0 /	24.02946 (214, 1)	17.55556 (76, 1)	13.12499 (266, 1)
280.0 /	27.78714 (76, 1)	21.09559 (137, 1)	11.81021 (210, 1)
270.0 /	46.15883 (266, 1)	20.25728 (210, 1)	7.62028 (210, 1)
260.0 /	40.02137 (306, 1)	16.08029 (265, 1)	16.18208 (325, 1)
250.0 /	30.20821 (71, 1)	14.61454 (178, 1)	9.24873 (178, 1)
240.0 /	43.09166 (51, 1)	11.84137 (49, 1)	10.02888 (48, 1)
230.0 /	57.59985 (343, 1)	18.05512 (343, 1)	14.66219 (343, 1)
220.0 /	63.67666 (343, 1)	25.00345 (343, 1)	8.95701 (336, 1)
210.0 /	52.13167 (303, 1)	17.81172 (286, 1)	11.22510 (286, 1)
200.0 /	76.39106 (343, 1)	19.33754 (33, 1)	8.64737 (342, 1)
190.0 /	59.46055 (342, 1)	16.40954 (120, 1)	13.68380 (33, 1)
180.0 /	41.96233 (326, 1)	20.91711 (280, 1)	10.64529 (297, 1)
170.0 /	47.24961 (341, 1)	20.87218 (280, 1)	11.65533 (348, 1)
160.0 /	43.86863 (6, 1)	16.36571 (65, 1)	10.03028 (59, 1)
150.0 /	51.18594 (312, 1)	15.63598 (6, 1)	9.48522 (350, 1)
140.0 /	17.72174 (53, 1)	20.72038 (115, 1)	7.99870 (157, 1)
130.0 /	45.19592 (190, 1)	15.22067 (312, 1)	9.58675 (312, 1)
120.0 /	25.00657 (60, 1)	15.67533 (190, 1)	10.57626 (312, 1)
110.0 /	22.81148 (60, 1)	11.67558 (218, 1)	9.36799 (190, 1)
100.0 /	32.41092 (60, 1)	14.85608 (60, 1)	13.20932 (255, 1)
90.0 /	13.70987 (330, 1)	20.60566 (60, 1)	15.21350 (60, 1)
80.0 /	12.00953 (79, 1)	14.99455 (25, 1)	10.59317 (25, 1)
70.0 /	12.75844 (79, 1)	8.53818 (39, 1)	8.29402 (25, 1)
60.0 /	13.89985 (222, 1)	9.14122 (79, 1)	6.71302 (79, 1)
50.0 /	28.23134 (315, 1)	6.72338 (194, 1)	5.35527 (62, 1)
40.0 /	30.13459 (315, 1)	9.17793 (222, 1)	5.01264 (357, 1)
30.0 /	18.34649 (360, 1)	22.71020 (315, 1)	16.70508 (315, 1)
20.0 /	19.60399 (54, 1)	11.51738 (360, 1)	9.18462 (360, 1)
10.0 /	25.89062 (54, 1)	16.47065 (54, 1)	8.93751 (54, 1)

could be developed

2ND HIGH
24-HR
SGROUP# 1

*** BEAUMONT CARBONTETRACHLORIDE CONCENTRATION 1984 EMISSIONS ***

* SECOND HIGHEST 24-HOUR AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) *
* FROM ALL SOURCES *
* FOR THE RECEPTOR GRID *

* MAXIMUM VALUE EQUALS 54.58133 AND OCCURRED AT (550.0, 220.0) *

DIRECTION (DEGREES)	RANGE (METERS) 550.0	1000.0	1500.0
360.0	14.21198 (174, 1)	11.67631 (92, 1)	7.99798 (26, 1)
350.0	18.10803 (172, 1)	11.83400 (244, 1)	7.36438 (244, 1)
340.0	21.41244 (71, 1)	13.21522 (242, 1)	10.09985 (242, 1)
330.0	27.65481 (242, 1)	14.10980 (242, 1)	10.31332 (242, 1)
320.0	18.66661 (322, 1)	12.43265 (215, 1)	7.95368 (197, 1)
310.0	30.04987 (316, 1)	11.16241 (145, 1)	7.92268 (197, 1)
300.0	19.46966 (214, 1)	12.26207 (214, 1)	11.23387 (71, 1)
290.0	23.99640 (307, 1)	14.03501 (266, 1)	13.09227 (137, 1)
280.0	27.04095 (214, 1)	19.19456 (266, 1)	16.33736 (306, 1)
270.0	43.12777 (137, 1)	11.43706 (88, 1)	6.47112 (331, 1)
260.0	34.93087 (210, 1)	12.25619 (266, 1)	14.25625 (265, 1)
250.0	29.73413 (265, 1)	14.47346 (306, 1)	8.12502 (146, 1)
240.0	42.23664 (178, 1)	11.20069 (178, 1)	8.54895 (254, 1)
230.0	50.74813 (254, 1)	13.14961 (254, 1)	8.26148 (342, 1)
220.0	54.58133 (10, 1)	18.67173 (342, 1)	8.70744 (343, 1)
210.0	47.42510 (120, 1)	17.56975 (342, 1)	8.81549 (342, 1)
200.0	43.89002 (105, 1)	19.14667 (286, 1)	8.45687 (120, 1)
190.0	46.01748 (334, 1)	15.70487 (341, 1)	8.30906 (302, 1)
180.0	41.76697 (342, 1)	18.30979 (141, 1)	10.33135 (280, 1)
170.0	46.64656 (280, 1)	20.27820 (153, 1)	11.45363 (280, 1)
160.0	41.54346 (284, 1)	15.82624 (59, 1)	9.79012 (179, 1)
150.0	36.43504 (154, 1)	13.49168 (157, 1)	9.42332 (6, 1)
140.0	37.54560 (312, 1)	15.29958 (312, 1)	7.80342 (49, 1)
130.0	26.53009 (290, 1)	13.52759 (154, 1)	7.75442 (329, 1)
120.0	23.85152 (266, 1)	12.53188 (53, 1)	10.55554 (53, 1)
110.0	20.04432 (25, 1)	11.62878 (255, 1)	6.81050 (350, 1)
100.0	21.75927 (330, 1)	14.15656 (255, 1)	7.65935 (218, 1)
90.0	13.50069 (25, 1)	11.68586 (305, 1)	6.19317 (180, 1)
80.0	11.37269 (25, 1)	10.27737 (330, 1)	6.99598 (305, 1)
70.0	12.02232 (62, 1)	8.12747 (330, 1)	6.37646 (330, 1)
60.0	13.27685 (116, 1)	7.91822 (313, 1)	5.34091 (311, 1)
50.0	16.31564 (193, 1)	6.22583 (289, 1)	5.00122 (79, 1)
40.0	19.97545 (360, 1)	8.17589 (193, 1)	4.70127 (222, 1)
30.0	17.24207 (315, 1)	12.35543 (193, 1)	9.61161 (193, 1)
20.0	16.99561 (360, 1)	9.71310 (193, 1)	8.30733 (315, 1)
10.0	25.33868 (315, 1)	10.53833 (360, 1)	7.35354 (360, 1)

*** CHAMBERS WORKS CARBONTETRACHLORIDE CONCENTRATIONS USING 1964 ***

CALCULATE (CONCENTRATION=1,DEPOSITION=2)	ISW(1) =	1
RECEPTOR GRID SYSTEM (RECTANGULAR=1 OR 3, POLAR=2 OR 4)	ISW(2) =	2
DISCRETE RECEPTOR SYSTEM (RECTANGULAR=1,POLAR=2)	ISW(3) =	2
TERRAIN ELEVATIONS ARE READ (YES=1,NO=0)	ISW(4) =	0
CALCULATIONS ARE WRITTEN TO TAPE (YES=1,NO=0)	ISW(5) =	0
LIST ALL INPUT DATA (NO=0,YES=1,MET DATA ALSO=2)	ISW(6) =	1
COMPUTE AVERAGE CONCENTRATION (OR TOTAL DEPOSITION)		
WITH THE FOLLOWING TIME PERIODS:		
HOURLY (YES=1,NO=0)	ISW(7) =	0
2-HOUR (YES=1,NO=0)	ISW(8) =	0
3-HOUR (YES=1,NO=0)	ISW(9) =	0
4-HOUR (YES=1,NO=0)	ISW(10) =	0
6-HOUR (YES=1,NO=0)	ISW(11) =	0
8-HOUR (YES=1,NO=0)	ISW(12) =	0
12-HOUR (YES=1,NO=0)	ISW(13) =	0
24-HOUR (YES=1,NO=0)	ISW(14) =	1
PRINT 'N'-DAY TABLE(S) (YES=1,NO=0)	ISW(15) =	1
PRINT THE FOLLOWING TYPES OF TABLES WHOSE TIME PERIODS ARE		
SPECIFIED BY ISW(7) THROUGH ISW(14):		
DAILY TABLES (YES=1,NO=0)	ISW(16) =	0
HIGHEST & SECOND HIGHEST TABLES (YES=1,NO=0)	ISW(17) =	1
MAXIMUM 50 TABLES (YES=1,NO=0)	ISW(18) =	0
METEOROLOGICAL DATA INPUT METHOD (PRE-PROCESSED=1,CARD=2)	ISW(19) =	1
RURAL-URBAN OPTION (RURAL=0,URBAN MODE 1=1,URBAN MODE 2=2)	ISW(20) =	0
WIND PROFILE EXPONENT VALUES (DEFAULTS=1,USER ENTERS=2,3)	ISW(21) =	1
VERTICAL POT. TEMP. GRADIENT VALUES (DEFAULTS=1,USER ENTERS=2,3)	ISW(22) =	1
SCALE EMISSION RATES FOR ALL SOURCES (NO=0,YES>0)	ISW(23) =	0
PROGRAM CALCULATES FINAL PLUME RISE ONLY (YES=1,NO=2)	ISW(24) =	2
PROGRAM ADJUSTS ALL STACK HEIGHTS FOR DOWNWASH (YES=2,NO=1)	ISW(25) =	1
NUMBER OF INPUT SOURCES	NSOURC =	11
NUMBER OF SOURCE GROUPS (=0,ALL SOURCES)	NGROUP =	0
TIME PERIOD INTERVAL TO BE PRINTED (=0,ALL INTERVALS)	IPERD =	0
NUMBER OF X (RANGE) GRID VALUES	NXPNTS =	5
NUMBER OF Y (THETA) GRID VALUES	NYPNTS =	36
NUMBER OF DISCRETE RECEPTORS	NXWYPT =	0
SOURCE EMISSION RATE UNITS CONVERSION FACTOR	TK =	.10000+07
ENTRAINMENT COEFFICIENT FOR UNSTABLE ATMOSPHERE	BETA1 =	.600
ENTRAINMENT COEFFICIENT FOR STABLE ATMOSPHERE	BETA2 =	.600
HEIGHT ABOVE GROUND AT WHICH WIND SPEED WAS MEASURED	ZR =	10.00 METERS
LOGICAL UNIT NUMBER OF METEOROLOGICAL DATA	IMET =	12
DECAY COEFFICIENT FOR PHYSICAL OR CHEMICAL DEPLETION	DECAY =	.000000
SURFACE STATION NO.	ISS =	13739 ph.l.
YEAR OF SURFACE DATA	ISY =	76
UPPER AIR STATION NO.	IUS =	93734
YEAR OF UPPER AIR DATA	IUY =	76
ALLOCATED DATA STORAGE	LIMIT =	43500 WORDS
REQUIRED DATA STORAGE FOR THIS PROBLEM RUN	MIMIT =	3846 WORDS

*** CHAMBERS WORKS CARBONTETRACHLORIDE CONCENTRATIONS USING 1964 ***

*** METEOROLOGICAL DAYS TO BE PROCESSED ***
(IF=1)

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1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
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*** UPPER BOUND OF FIRST THROUGH FIFTH WIND SPEED CATEGORIES ***
(METERS/SEC)

1.54, 3.09, 5.14, 8.23, 10.80,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00
B	.15000+00	.15000+00	.15000+00	.15000+00	.15000+00	.15000+00
C	.20000+00	.20000+00	.20000+00	.20000+00	.20000+00	.20000+00
D	.25000+00	.25000+00	.25000+00	.25000+00	.25000+00	.25000+00
E	.30000+00	.30000+00	.30000+00	.30000+00	.30000+00	.30000+00
F	.30000+00	.30000+00	.30000+00	.30000+00	.30000+00	.30000+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000	.00000	.00000	.00000	.00000	.00000
B	.00000	.00000	.00000	.00000	.00000	.00000
C	.00000	.00000	.00000	.00000	.00000	.00000
D	.00000	.00000	.00000	.00000	.00000	.00000
E	.20000-01	.20000-01	.20000-01	.20000-01	.20000-01	.20000-01
F	.35000-01	.35000-01	.35000-01	.35000-01	.35000-01	.35000-01

*** CHAMBERS WORKS CARBONTETRACHLORIDE CONCENTRATIONS USING 1964 ***

*** RANGES OF POLAR GRID SYSTEM ***
(METERS)

730.0, 1230.0, 1730.0, 2230.0, 2730.0,

*** RADIAL ANGLES OF POLAR GRID SYSTEM ***

(DEGREES)

10.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0, 80.0, 90.0, 100.0,
110.0, 120.0, 130.0, 140.0, 150.0, 160.0, 170.0, 180.0, 190.0, 200.0,
210.0, 220.0, 230.0, 240.0, 250.0, 260.0, 270.0, 280.0, 290.0, 300.0,
310.0, 320.0, 330.0, 340.0, 350.0, 360.0,

*** CHAMBERS WORKS CARBONTETRACHLORIDE CONCENTRATIONS USING 1984 ***

*** SOURCE DATA ***

SOURCE NUMBER	TYPE	WAKE	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC) TYPE=0 (GRAMS/SEC *PER METER**2	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	HEIGHT (METERS)	TEMP. TYPE=0 (DEG.K); VERT.DIM TYPE=1 (METERS)	EXIT VEL. TYPE=0 (M/SEC); HORZ.DIM TYPE=1,2 (METERS)	DIAMETER TYPE=0 (METERS)	BLDG. HEIGHT TYPE=0 (METERS)	BLDG. LENGTH TYPE=0 (METERS)	BLDG. WIDTH TYPE=0 (METERS)
10431	D	0	0	.23000-04	-579.0	-244.0	.0	21.30	283.00	4.20	.60	15.20	122.00	15.20
10432	D	0	0	.76000-03	-579.0	-244.0	.0	21.30	283.00	10.20	.03	15.20	122.00	15.20
10433	D	0	0	.76000-03	-579.0	-244.0	.0	21.30	283.00	10.20	.03	15.20	122.00	15.20
10434	D	0	0	.53000-03	-579.0	-244.0	.0	20.10	283.00	13.60	.60	15.20	122.00	15.20
10435	D	0	0	.17600-01	-579.0	-244.0	.0	12.20	283.00	7.00	.51	15.20	122.00	15.20
10791	C	0	0	.55000-03	152.0	-37.0	.0	4.60	283.00	.60	.10	.00	.00	.00
10792	D	0	0	.72000-03	152.0	-37.0	.0	1.00	283.00	.60	.10	.00	.00	.00
351	C	0	0	.54000-01	-457.0	244.0	.0	8.20	283.00	2.20	.25	8.00	54.00	54.00
352	D	0	0	.54000-01	-457.0	244.0	.0	8.20	283.00	2.20	.25	8.00	54.00	54.00
353	D	0	0	.27000-01	-457.0	244.0	.0	6.10	283.00	.03	.25	8.00	54.00	54.00
1	2	0	0	.10000-05	-457.0	244.0	.0	1.00	.00	200.00	.00	.00	.00	.00

'N'-DAY
366 DAYS
SGROUP# 1

*** CHAMBERS WORKS CARBONTETRACHLORIDE CONCENTRATIONS USING 1984 ***

* 366-DAY AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) *

* FROM ALL SOURCES *
* FOR THE RECEPTOR GRID *

* MAXIMUM VALUE EQUALS 1.54143 AND OCCURRED AT (730.0, 320.0) *

DIRECTION / (DEGREES) /	RANGE (METERS) 730.0	1230.0	1730.0	2230.0	2730.0
360.0 /	1.08168	.15983	.08259	.05225	.03439
350.0 /	.88803	.17224	.11619	.08974	.06814
340.0 /	.64624	.28732	.17118	.10707	.07900
330.0 /	.86265	.35516	.15123	.09115	.06467
320.0 /	1.54143	.30413	.12819	.08546	.05629
310.0 /	1.50706	.29535	.14143	.08256	.05374
300.0 /	1.16656	.21629	.10031	.06051	.04069
290.0 /	.98335	.22239	.10529	.06292	.04296
280.0 /	.61821	.20151	.09386	.05850	.04260
270.0 /	.60059	.16119	.11913	.07560	.04848
260.0 /	.21856	.12020	.07038	.04461	.03467
250.0 /	.24694	.10723	.05952	.03706	.02562
240.0 /	.19442	.05130	.04672	.03398	.02434
230.0 /	.32674	.04196	.02189	.01771	.01333
220.0 /	.35908	.06288	.02139	.01751	.01434
210.0 /	.38984	.11468	.04711	.02113	.01194
200.0 /	.36664	.17331	.07923	.04580	.03327
190.0 /	.28802	.18725	.12246	.07800	.05416
180.0 /	.27815	.15242	.11636	.08808	.06555
170.0 /	.30976	.15082	.09751	.06735	.05025
160.0 /	.28609	.18374	.11492	.07962	.06016
150.0 /	.29003	.17322	.11046	.08194	.06698
140.0 /	.27455	.15569	.10743	.08162	.06529
130.0 /	.25168	.15085	.10368	.07758	.06075
120.0 /	.25544	.15002	.10189	.07450	.05757
110.0 /	.25337	.15447	.10638	.07812	.06047
100.0 /	.29128	.17761	.12015	.08666	.06933
90.0 /	.30902	.19764	.13558	.09925	.07903
80.0 /	.34168	.18901	.11941	.08157	.06018
70.0 /	.33410	.15047	.09751	.07367	.05914
60.0 /	.28907	.16835	.10149	.07184	.05716
50.0 /	.31570	.16994	.12709	.10428	.08795
40.0 /	.32165	.24578	.21000	.17647	.13979
30.0 /	.41538	.40888	.26916	.15119	.10410
20.0 /	.63611	.40651	.18845	.09094	.05085
10.0 /	1.03914	.28279	.09974	.04838	.03107

HIGH
24-HR
SGROUP# 1

*** CHAMBERS WORKS CARBONTETRACHLORIDE CONCENTRATIONS USING 1984 ***

* HIGHEST 24-HOUR AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) *
* FROM ALL SOURCES *
* FOR THE RECEPTOR GRID *

* MAXIMUM VALUE EQUALS 25.16731 AND OCCURRED AT (730.0, 290.0) *

DIRECTION (DEGREES)	RANGE (METERS) 730.0	1230.0	1730.0	2230.0	2730.0
360.0	6.49288 (238, 1)	4.04068 (258, 1)	2.68214 (46, 1)	1.80649 (190, 1)	.70808 (298, 1)
350.0	12.50959 (332, 1)	4.59699 (190, 1)	3.10153 (248, 1)	2.53932 (248, 1)	1.48226 (126, 1)
340.0	11.08122 (258, 1)	6.90759 (246, 1)	2.51533 (87, 1)	2.81536 (87, 1)	1.91307 (338, 1)
330.0	13.60614 (190, 1)	6.70503 (338, 1)	2.90688 (35, 1)	1.67023 (35, 1)	1.24733 (259, 1)
320.0	15.25122 (126, 1)	4.81153 (248, 1)	2.69779 (247, 1)	2.73646 (51, 1)	1.61795 (51, 1)
310.0	17.15203 (259, 1)	5.25305 (52, 1)	3.41976 (107, 1)	2.36825 (107, 1)	1.60205 (107, 1)
300.0	15.81065 (269, 1)	5.15620 (269, 1)	2.73195 (269, 1)	1.74687 (269, 1)	1.25324 (269, 1)
290.0	25.16731 (331, 1)	6.26243 (282, 1)	2.47142 (282, 1)	1.61907 (44, 1)	1.37863 (44, 1)
280.0	9.15390 (276, 1)	4.12159 (331, 1)	3.43287 (331, 1)	2.05274 (282, 1)	2.22190 (282, 1)
270.0	7.04646 (363, 1)	2.68376 (116, 1)	2.17621 (341, 1)	2.33696 (282, 1)	2.29141 (282, 1)
260.0	7.09733 (34, 1)	2.08587 (363, 1)	1.36607 (116, 1)	1.18136 (116, 1)	.88787 (116, 1)
250.0	4.26918 (156, 1)	3.77223 (273, 1)	1.44920 (363, 1)	1.04432 (116, 1)	.68949 (116, 1)
240.0	2.99784 (25, 1)	2.56874 (34, 1)	3.82425 (273, 1)	.85049 (273, 1)	.58540 (363, 1)
230.0	4.75184 (180, 1)	1.47822 (156, 1)	.54206 (331, 1)	1.14829 (34, 1)	.88494 (274, 1)
220.0	5.08723 (286, 1)	1.34874 (25, 1)	.69252 (186, 1)	1.18829 (331, 1)	1.58338 (331, 1)
210.0	6.95936 (351, 1)	2.19335 (180, 1)	1.01672 (145, 1)	.47515 (25, 1)	.36903 (253, 1)
200.0	7.84296 (341, 1)	2.03021 (197, 1)	1.48208 (286, 1)	1.08467 (180, 1)	.90426 (215, 1)
190.0	4.64920 (251, 1)	4.08260 (341, 1)	2.12971 (351, 1)	1.03252 (197, 1)	.96789 (286, 1)
180.0	6.59223 (340, 1)	2.13283 (267, 1)	3.19336 (341, 1)	2.39705 (341, 1)	1.67600 (341, 1)
170.0	9.93707 (340, 1)	3.83811 (340, 1)	3.23306 (251, 1)	1.50838 (251, 1)	1.03480 (267, 1)
160.0	6.96384 (340, 1)	6.62073 (340, 1)	3.55336 (340, 1)	2.49870 (340, 1)	2.23213 (340, 1)
150.0	4.28089 (340, 1)	4.31986 (340, 1)	2.84763 (340, 1)	1.94478 (340, 1)	1.62292 (340, 1)
140.0	3.03807 (358, 1)	1.47382 (340, 1)	1.50419 (293, 1)	1.34643 (293, 1)	1.13554 (293, 1)
130.0	2.76502 (117, 1)	2.11849 (117, 1)	1.68341 (117, 1)	1.38883 (117, 1)	1.18133 (117, 1)
120.0	3.97722 (267, 1)	2.61543 (267, 1)	1.92484 (267, 1)	1.52900 (267, 1)	1.25100 (267, 1)
110.0	6.17880 (355, 1)	4.40144 (355, 1)	3.27260 (355, 1)	2.57884 (355, 1)	2.09718 (355, 1)
100.0	9.48636 (355, 1)	4.55991 (355, 1)	2.11683 (355, 1)	1.09661 (355, 1)	.69069 (338, 1)
90.0	2.76068 (355, 1)	2.05913 (238, 1)	1.29003 (149, 1)	.99659 (149, 1)	.79741 (57, 1)
80.0	2.72242 (149, 1)	1.91551 (143, 1)	1.60986 (332, 1)	1.58250 (332, 1)	1.07439 (332, 1)
70.0	3.14419 (57, 1)	2.58986 (105, 1)	2.19924 (333, 1)	1.69442 (333, 1)	1.09886 (333, 1)
60.0	4.09864 (105, 1)	2.74343 (333, 1)	1.89016 (287, 1)	1.27245 (287, 1)	.96666 (213, 1)
50.0	5.54088 (333, 1)	2.33490 (213, 1)	1.41257 (289, 1)	.89253 (107, 1)	.92328 (107, 1)
40.0	4.99689 (287, 1)	2.06247 (107, 1)	1.73921 (225, 1)	1.56408 (238, 1)	1.26106 (41, 1)
30.0	3.81979 (97, 1)	3.44131 (238, 1)	2.90899 (179, 1)	1.20851 (238, 1)	.97385 (121, 1)
20.0	5.22628 (304, 1)	2.66150 (56, 1)	3.38250 (107, 1)	2.18220 (332, 1)	.74180 (136, 1)
10.0	7.08215 (236, 1)	5.45254 (332, 1)	3.15961 (258, 1)	.74960 (308, 1)	.48515 (99, 1)

2ND HIGH
24-HR
SGROUP# 1

*** CHAMBERS WORKS CARBONTETRACHLORIDE CONCENTRATIONS USING 1964 ***

* SECOND HIGHEST 24-HOUR AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) *
* FROM ALL SOURCES *
* FOR THE RECEPTOR GRID *

* MAXIMUM VALUE EQUALS 14.36824 AND OCCURRED AT (730.0, 300.0) *

DIRECTION / (DEGREES) /	RANGE (METERS) 730.0	1230.0	1730.0	2230.0	2730.0
360.0 /	6.09217 (56, 1)	3.62476 (274, 1)	1.66568 (274, 1)	1.01912 (298, 1)	.65624 (190, 1)
350.0 /	9.64635 (107, 1)	2.36809 (41, 1)	2.39541 (109, 1)	1.58838 (109, 1)	1.31014 (109, 1)
340.0 /	10.14335 (274, 1)	4.14262 (109, 1)	2.26484 (258, 1)	1.83286 (338, 1)	1.55870 (211, 1)
330.0 /	7.39100 (298, 1)	5.52988 (87, 1)	2.82729 (281, 1)	1.46918 (259, 1)	1.20572 (122, 1)
320.0 /	12.71863 (298, 1)	3.79824 (122, 1)	2.55326 (346, 1)	2.22527 (247, 1)	1.07482 (6, 1)
310.0 /	13.94041 (122, 1)	5.20740 (268, 1)	3.03397 (221, 1)	1.98849 (221, 1)	1.24688 (6, 1)
300.0 /	14.36824 (347, 1)	5.11136 (46, 1)	2.51182 (46, 1)	1.57292 (46, 1)	1.09631 (46, 1)
290.0 /	12.50139 (95, 1)	3.01799 (294, 1)	1.66705 (44, 1)	1.05642 (282, 1)	.73310 (330, 1)
280.0 /	7.83297 (151, 1)	3.68288 (309, 1)	1.86770 (95, 1)	1.62872 (331, 1)	.76734 (331, 1)
270.0 /	6.54882 (309, 1)	2.46030 (151, 1)	1.47127 (13, 1)	1.77100 (72, 1)	.92018 (72, 1)
260.0 /	3.43027 (274, 1)	1.91821 (116, 1)	1.03711 (269, 1)	.73696 (151, 1)	.53921 (151, 1)
250.0 /	3.42904 (331, 1)	2.03611 (32, 1)	1.16232 (116, 1)	.72464 (363, 1)	.42498 (276, 1)
240.0 /	2.95723 (277, 1)	1.22865 (274, 1)	1.44746 (274, 1)	.84641 (32, 1)	.49353 (348, 1)
230.0 /	4.14640 (277, 1)	1.18883 (331, 1)	.53237 (34, 1)	.78096 (274, 1)	.51323 (273, 1)
220.0 /	4.28167 (186, 1)	1.08638 (301, 1)	.51088 (156, 1)	.98949 (156, 1)	.80268 (156, 1)
210.0 /	4.00294 (341, 1)	1.74474 (277, 1)	.96589 (144, 1)	.44757 (286, 1)	.33184 (286, 1)
200.0 /	4.03720 (253, 1)	1.81771 (187, 1)	1.22094 (186, 1)	.76056 (277, 1)	.68229 (180, 1)
190.0 /	4.18054 (107, 1)	3.46051 (351, 1)	1.45583 (61, 1)	.90515 (187, 1)	.91578 (197, 1)
180.0 /	3.13604 (236, 1)	1.98774 (256, 1)	1.42208 (339, 1)	1.75264 (253, 1)	1.53611 (351, 1)
170.0 /	5.49976 (350, 1)	1.83242 (349, 1)	2.43209 (107, 1)	1.39372 (267, 1)	.89688 (120, 1)
160.0 /	3.00793 (326, 1)	3.31448 (356, 1)	2.69057 (350, 1)	1.64617 (350, 1)	.85161 (236, 1)
150.0 /	3.70938 (293, 1)	2.45365 (293, 1)	1.27434 (320, 1)	1.04989 (251, 1)	1.15954 (251, 1)
140.0 /	2.98500 (285, 1)	1.41304 (293, 1)	1.21277 (340, 1)	.98958 (340, 1)	.84252 (340, 1)
130.0 /	2.51802 (354, 1)	1.89331 (354, 1)	1.46844 (285, 1)	1.17978 (285, 1)	.96423 (285, 1)
120.0 /	3.59447 (344, 1)	2.42406 (344, 1)	1.76372 (344, 1)	1.37949 (344, 1)	1.11713 (344, 1)
110.0 /	2.98320 (266, 1)	1.70588 (266, 1)	1.09526 (266, 1)	.77207 (266, 1)	.60706 (325, 1)
100.0 /	3.18135 (108, 1)	1.76774 (83, 1)	1.15646 (258, 1)	.88349 (258, 1)	.65744 (258, 1)
90.0 /	2.27345 (338, 1)	1.71798 (316, 1)	1.13903 (238, 1)	.94488 (57, 1)	.68316 (149, 1)
80.0 /	2.25420 (57, 1)	1.88528 (57, 1)	1.35301 (105, 1)	1.20915 (256, 1)	.96710 (105, 1)
70.0 /	3.06245 (105, 1)	1.53423 (281, 1)	1.53342 (57, 1)	.94307 (57, 1)	.70223 (75, 1)
60.0 /	2.75113 (333, 1)	2.01154 (75, 1)	1.60790 (94, 1)	1.03426 (213, 1)	.65747 (326, 1)
50.0 /	2.81589 (307, 1)	1.74190 (326, 1)	1.41088 (97, 1)	.87928 (162, 1)	.92077 (304, 1)
40.0 /	2.93142 (354, 1)	1.95813 (336, 1)	1.49162 (238, 1)	1.42515 (106, 1)	1.21529 (235, 1)
30.0 /	3.48340 (354, 1)	2.98889 (106, 1)	1.84972 (75, 1)	1.12567 (121, 1)	.89233 (108, 1)
20.0 /	5.10160 (264, 1)	2.43088 (238, 1)	1.94018 (332, 1)	1.41414 (240, 1)	.61810 (240, 1)
10.0 /	6.40805 (41, 1)	3.96160 (107, 1)	3.07091 (274, 1)	.64009 (258, 1)	.45477 (46, 1)

*** CORPUS CARBONTET CONCENTRATION 1984 EMISSIONS ***

CALCULATE (CONCENTRATION=1,DEPOSITION=2)	ISW(1) =	1
RECEPTOR GRID SYSTEM (RECTANGULAR=1 OR 3, POLAR=2 OR 4)	ISW(2) =	2
DISCRETE RECEPTOR SYSTEM (RECTANGULAR=1,POLAR=2)	ISW(3) =	2
TERRAIN ELEVATIONS ARE READ (YES=1,NO=0)	ISW(4) =	0
CALCULATIONS ARE WRITTEN TO TAPE (YES=1,NO=0)	ISW(5) =	0
LIST ALL INPUT DATA (NO=0,YES=1,MET DATA ALSO=2)	ISW(6) =	1
COMPUTE AVERAGE CONCENTRATION (OR TOTAL DEPOSITION)		
WITH THE FOLLOWING TIME PERIODS:		
HOURLY (YES=1,NO=0)	ISW(7) =	0
2-HOUR (YES=1,NO=0)	ISW(8) =	0
3-HOUR (YES=1,NO=0)	ISW(9) =	0
4-HOUR (YES=1,NO=0)	ISW(10) =	0
6-HOUR (YES=1,NO=0)	ISW(11) =	0
8-HOUR (YES=1,NO=0)	ISW(12) =	0
12-HOUR (YES=1,NO=0)	ISW(13) =	0
24-HOUR (YES=1,NO=0)	ISW(14) =	1
PRINT 'N'-DAY TABLE(S) (YES=1,NO=0)	ISW(15) =	1
PRINT THE FOLLOWING TYPES OF TABLES WHOSE TIME PERIODS ARE		
SPECIFIED BY ISW(7) THROUGH ISW(14):		
DAILY TABLES (YES=1,NO=0)	ISW(16) =	0
HIGHEST & SECOND HIGHEST TABLES (YES=1,NO=0)	ISW(17) =	1
MAXIMUM 50 TABLES (YES=1,NO=0)	ISW(18) =	0
METEOROLOGICAL DATA INPUT METHOD (PRE-PROCESSED=1,CARD=2)	ISW(19) =	1
RURAL-URBAN OPTION (RURAL=0,URBAN MODE 1=1,URBAN MODE 2=2)	ISW(20) =	0
WIND PROFILE EXPONENT VALUES (DEFAULTS=1,USER ENTERS=2,3)	ISW(21) =	1
VERTICAL POT. TEMP. GRADIENT VALUES (DEFAULTS=1,USER ENTERS=2,3)	ISW(22) =	1
SCALE EMISSION RATES FOR ALL SOURCES (NO=0,YES>0)	ISW(23) =	0
PROGRAM CALCULATES FINAL PLUME RISE ONLY (YES=1,NO=2)	ISW(24) =	1
PROGRAM ADJUSTS ALL STACK HEIGHTS FOR DOWNWASH (YES=2,NO=1)	ISW(25) =	20
NUMBER OF INPUT SOURCES	NSOURC =	14
NUMBER OF SOURCE GROUPS (=0,ALL SOURCES)	NGROUP =	0
TIME PERIOD INTERVAL TO BE PRINTED (=0,ALL INTERVALS)	IPERD =	0
NUMBER OF X (RANGE) GRID VALUES	NXPNTS =	3
NUMBER OF Y (THETA) GRID VALUES	NYPNTS =	36
NUMBER OF DISCRETE RECEPTORS	NXWYPT =	0
SOURCE EMISSION RATE UNITS CONVERSION FACTOR	TK =	.10000+07
ENTRAINMENT COEFFICIENT FOR UNSTABLE ATMOSPHERE	BETA1 =	.600
ENTRAINMENT COEFFICIENT FOR STABLE ATMOSPHERE	BETA2 =	.600
HEIGHT ABOVE GROUND AT WHICH WIND SPEED WAS MEASURED	ZR =	10.00 METERS
LOGICAL UNIT NUMBER OF METEOROLOGICAL DATA	IMET =	12
DECAY COEFFICIENT FOR PHYSICAL OR CHEMICAL DEPLETION	DECAY =	.000000
SURFACE STATION NO.	ISS =	12924 Corpus Christi
YEAR OF SURFACE DATA	ISY =	64
UPPER AIR STATION NO.	IUS =	12919 Brownsville
YEAR OF UPPER AIR DATA	IUY =	64
ALLOCATED DATA STORAGE	LIMIT =	43500 WORDS
REQUIRED DATA STORAGE FOR THIS PROBLEM RUN	MIMIT =	3913 WORDS

*** CORPUS CARBONTET CONCENTRATION 1984 EMISSIONS ***

*** METEOROLOGICAL DAYS TO BE PROCESSED ***
(IF=1)

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1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1   1 1 1 1 1 1
```

*** UPPER BOUND OF FIRST THROUGH FIFTH WIND SPEED CATEGORIES ***
(METERS/SEC)

1.54, 3.09, 5.14, 8.23, 10.80,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00
B	.15000+00	.15000+00	.15000+00	.15000+00	.15000+00	.15000+00
C	.20000+00	.20000+00	.20000+00	.20000+00	.20000+00	.20000+00
D	.25000+00	.25000+00	.25000+00	.25000+00	.25000+00	.25000+00
E	.30000+00	.30000+00	.30000+00	.30000+00	.30000+00	.30000+00
F	.30000+00	.30000+00	.30000+00	.30000+00	.30000+00	.30000+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000	.00000	.00000	.00000	.00000	.00000
B	.00000	.00000	.00000	.00000	.00000	.00000
C	.00000	.00000	.00000	.00000	.00000	.00000
D	.00000	.00000	.00000	.00000	.00000	.00000
E	.20000-01	.20000-01	.20000-01	.20000-01	.20000-01	.20000-01
F	.35000-01	.35000-01	.35000-01	.35000-01	.35000-01	.35000-01

*** CORPUS CARBONTET CONCENTRATION 1984 EMISSIONS ***

*** RANGES OF POLAR GRID SYSTEM ***
(METERS)

900.0, 1800.0, 2700.0,

*** RADIAL ANGLES OF POLAR GRID SYSTEM ***

(DEGREES)

10.0,	20.0,	30.0,	40.0,	50.0,	60.0,	70.0,	80.0,	90.0,	100.0,
110.0,	120.0,	130.0,	140.0,	150.0,	160.0,	170.0,	180.0,	190.0,	200.0,
210.0,	220.0,	230.0,	240.0,	250.0,	260.0,	270.0,	280.0,	290.0,	300.0,
310.0,	320.0,	330.0,	340.0,	350.0,	360.0,				

*** CORPUS CARBONTET CONCENTRATION 1984 EMISSIONS ***

*** SOURCE DATA ***

SOURCE NUMBER	TYPE	WEEKDAY	NUMBER PART. CATS.	EMISSION RATE TYPE=0,1 (GRAMS/SEC) TYPE=2 (GRAMS/SEC *PER METER**2	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	HEIGHT (METERS)	TEMP. TYPE=0 (DEG.K); VERT.DIM TYPE=1 (METERS)	EXIT VEL. TYPE=0 (M/SEC); HORZ.DIM TYPE=1,2 (METERS)	DIAMETER TYPE=0 (METERS)	BLDG. HEIGHT TYPE=0 (METERS)	BLDG. LENGTH TYPE=0 (METERS)	BLDG. WIDTH TYPE=0 (METERS)
30	2	0	0	.79000-03	193.0	-1583.0	.0	7.00	.00	10.00	.00	.00	.00	.00
96	2	0	0	.56000-04	231.0	-1020.0	.0	3.00	.00	25.00	.00	.00	.00	.00
97	0	0	0	.46000-02	244.0	-1085.0	.0	15.24	283.00	22.90	.15	.00	.00	.00
100	0	0	0	.10400+00	183.0	-1079.0	.0	14.60	283.00	.10	.25	.00	.00	.00
101	0	0	0	.10400+00	171.0	-1059.0	.0	14.60	283.00	.10	.25	.00	.00	.00
103	0	0	0	.10400+00	201.0	-1101.0	.0	14.60	283.00	.10	.25	.00	.00	.00
121	0	0	0	.18700+00	332.0	-927.0	.0	26.60	283.00	18.30	.20	.00	.00	.00
134	0	0	0	.19000-01	587.0	-846.0	.0	9.80	283.00	.10	.05	.00	.00	.00
135	0	0	0	.10400+01	480.0	-854.0	.0	6.10	300.00	16.20	.61	.00	.00	.00
140	2	0	0	.41000-04	462.0	-884.0	.0	5.00	.00	75.00	.00	.00	.00	.00
144	0	0	0	.61000-01	361.0	-841.0	.0	11.40	283.00	.10	.08	.00	.00	.00
145	0	0	0	.12600+00	434.0	-838.0	.0	7.60	297.00	.10	.25	.00	.00	.00
146	0	0	0	.12800+00	434.0	-848.0	.0	7.60	297.00	.10	.25	.00	.00	.00
147	0	0	0	.12800+00	450.0	-848.0	.0	7.60	297.00	.10	.25	.00	.00	.00

*** CORPUS CARBONTET CONCENTRATION 1984 EMISSIONS ***

* SOURCE-RECEPTOR COMBINATIONS LESS THAN 100 METERS OR THREE BUILDING HEIGHTS IN DISTANCE. NO AVERAGE CONCENTRATION IS CALCULATED *

SOURCE NUMBER	- - RECEPTOR LOCATION - - X OR RANGE (METERS)	Y (METERS) OR DIRECTION (DEGREES)	DISTANCE BETWEEN (METERS)
121	900.0	160.0	84.80
135	900.0	150.0	80.38
140	900.0	150.0	41.05
144	900.0	150.0	92.48
144	900.0	160.0	73.33
145	900.0	150.0	60.72
146	900.0	150.0	70.42
147	900.0	150.0	68.58

N-DAY
366 DAYS
SGROUP# 1*

*** CORPUS CARBONTET CONCENTRATION 1984 EMISSIONS ***

* 366-DAY AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) *

* FROM ALL SOURCES *
* FOR THE RECEPTOR GRID *

* MAXIMUM VALUE EQUALS 13.13320 AND OCCURRED AT (900.0, 160.0) *

DIRECTION / (DEGREES) /	RANGE (METERS) 900.0	1800.0	2700.0
360.0 /	1.90225	.83390	.54913
350.0 /	2.55366	1.17829	.67928
340.0 /	2.58880	1.49301	1.01292
330.0 /	2.75543	1.57515	1.04118
320.0 /	2.96775	1.63074	1.09180
310.0 /	3.02381	1.73476	1.08060
300.0 /	3.03256	1.40880	.88802
290.0 /	2.60003	1.27928	.85408
280.0 /	2.63521	1.22188	.50786
270.0 /	2.69854	.84672	.41570
260.0 /	2.52621	.71511	.47541
250.0 /	1.99149	.85524	.46607
240.0 /	2.10936	.83914	.27004
230.0 /	2.32097	.55041	.21537
220.0 /	2.79044	.49521	.20759
210.0 /	3.29559	.52797	.44580
200.0 /	3.89697	.99750	.57629
190.0 /	4.83522	1.49734	.77670
180.0 /	6.61164	2.68079	.92936
170.0 /	10.69942	2.71646	1.13124
160.0 /	13.13320	1.93491	.78006
150.0 /	.70007	1.27970	.48397
140.0 /	4.95661	.75105	.27212
130.0 /	2.55758	.62272	.36583
120.0 /	1.58068	.32162	.29654
110.0 /	1.12679	.31595	.14289
100.0 /	.89322	.43989	.12837
90.0 /	.78303	.42364	.23721
80.0 /	.73286	.36061	.23619
70.0 /	.74797	.25010	.18145
60.0 /	.74962	.24285	.13718
50.0 /	.78564	.24811	.13918
40.0 /	1.14935	.31542	.14695
30.0 /	1.45163	.33373	.20918
20.0 /	1.49946	.62314	.24910
10.0 /	1.53853	.84976	.50890

*** CORPUS CARBONTET CONCENTRATION 1984 EMISSIONS ***

* SECOND HIGHEST 24-HOUR AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) *
* FROM ALL SOURCES *
* FOR THE RECEPTOR GRID *

* MAXIMUM VALUE EQUALS 124.98201 AND OCCURRED AT (900.0, 160.0) *

DIRECTION (DEGREES)	RANGE (METERS) 900.0	1800.0	2700.0
360.0	9.85516 (196, 1)	9.37077 (222, 1)	6.84849 (222, 1)
350.0	16.49278 (31, 1)	6.70542 (252, 1)	4.18412 (196, 1)
340.0	11.07141 (31, 1)	8.57345 (31, 1)	6.91248 (157, 1)
330.0	13.63689 (291, 1)	8.27979 (291, 1)	5.90248 (291, 1)
320.0	13.99859 (286, 1)	12.19684 (245, 1)	8.85885 (245, 1)
310.0	22.47788 (245, 1)	13.50388 (245, 1)	12.54329 (247, 1)
300.0	25.60769 (247, 1)	18.30679 (282, 1)	9.47037 (282, 1)
290.0	34.54330 (282, 1)	9.22761 (282, 1)	9.63193 (305, 1)
280.0	18.49042 (181, 1)	15.73811 (154, 1)	3.46239 (135, 1)
270.0	22.17330 (251, 1)	7.34299 (135, 1)	5.11828 (28, 1)
260.0	24.45590 (154, 1)	9.67326 (286, 1)	5.65801 (298, 1)
250.0	12.87574 (147, 1)	11.57970 (284, 1)	8.69033 (65, 1)
240.0	20.18779 (267, 1)	13.14785 (65, 1)	5.34003 (71, 1)
230.0	27.53189 (143, 1)	9.46725 (71, 1)	4.54505 (199, 1)
220.0	23.23332 (284, 1)	9.16318 (199, 1)	4.33730 (87, 1)
210.0	28.66107 (258, 1)	5.63997 (101, 1)	7.60487 (210, 1)
200.0	39.64485 (257, 1)	15.96328 (8, 1)	8.23194 (246, 1)
190.0	33.10665 (286, 1)	15.96578 (335, 1)	6.82721 (298, 1)
180.0	44.16308 (121, 1)	20.05011 (341, 1)	10.71833 (276, 1)
170.0	74.13754 (121, 1)	23.71299 (276, 1)	11.29454 (13, 1)
160.0	124.98201 (248, 1)	21.05065 (350, 1)	19.16989 (5, 1)
150.0	9.86000 (254, 1)	19.15759 (345, 1)	9.25398 (176, 1)
140.0	56.82959 (356, 1)	18.70662 (133, 1)	6.56902 (346, 1)
130.0	54.96087 (254, 1)	17.86933 (315, 1)	8.78656 (345, 1)
120.0	29.87482 (37, 1)	9.08982 (17, 1)	13.56511 (330, 1)
110.0	28.19943 (250, 1)	12.56409 (16, 1)	4.80972 (17, 1)
100.0	20.93646 (250, 1)	18.86090 (216, 1)	6.15207 (16, 1)
90.0	14.90367 (360, 1)	11.51197 (333, 1)	12.98802 (216, 1)
80.0	13.78634 (223, 1)	8.99461 (295, 1)	7.57855 (17, 1)
70.0	9.64986 (80, 1)	5.69131 (2, 1)	5.09892 (295, 1)
60.0	23.13575 (206, 1)	7.38771 (37, 1)	3.55426 (2, 1)
50.0	12.16117 (206, 1)	4.78859 (191, 1)	4.14507 (37, 1)
40.0	19.39661 (314, 1)	4.66021 (148, 1)	3.12446 (223, 1)
30.0	21.00538 (263, 1)	8.20550 (206, 1)	6.94936 (206, 1)
20.0	14.83749 (11, 1)	9.35680 (270, 1)	3.97063 (207, 1)
10.0	14.39657 (222, 1)	10.53770 (154, 1)	9.20488 (270, 1)

HIGH
24-HR
SGROUP# 1

*** CORPUS CARBONTET CONCENTRATION 1984 EMISSIONS ***

* HIGHEST 24-HOUR AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) *
* FROM ALL SOURCES *
* FOR THE RECEPTOR GRID *

* MAXIMUM VALUE EQUALS 132.78583 AND OCCURRED AT (900.0, 160.0) *

DIRECTION / (DEGREES) /	RANGE (METERS) 900.0	1800.0	2700.0
360.0 /	12.92289 (31, 1)	13.33096 (142, 1)	15.07054 (142, 1)
350.0 /	23.96689 (205, 1)	9.02782 (31, 1)	4.95263 (31, 1)
340.0 /	17.15593 (26, 1)	10.61453 (26, 1)	7.90474 (205, 1)
330.0 /	19.05630 (198, 1)	13.65413 (198, 1)	10.35887 (198, 1)
320.0 /	17.91101 (245, 1)	17.00735 (247, 1)	14.95548 (247, 1)
310.0 /	32.30156 (247, 1)	18.60923 (247, 1)	14.67592 (282, 1)
300.0 /	28.38977 (282, 1)	23.87755 (156, 1)	28.04258 (156, 1)
290.0 /	34.97801 (156, 1)	11.05661 (156, 1)	11.97179 (251, 1)
280.0 /	46.28261 (156, 1)	18.24469 (251, 1)	4.16140 (251, 1)
270.0 /	23.56467 (154, 1)	7.84673 (203, 1)	8.24930 (143, 1)
260.0 /	32.42746 (251, 1)	13.21889 (143, 1)	7.44318 (284, 1)
250.0 /	14.68864 (156, 1)	12.62766 (248, 1)	12.15901 (155, 1)
240.0 /	20.52443 (26, 1)	18.14066 (155, 1)	8.74410 (246, 1)
230.0 /	27.71280 (286, 1)	11.55299 (246, 1)	5.87227 (198, 1)
220.0 /	31.80392 (251, 1)	9.38512 (198, 1)	4.35158 (118, 1)
210.0 /	53.13469 (248, 1)	7.33743 (45, 1)	8.89268 (157, 1)
200.0 /	41.71954 (155, 1)	16.30558 (259, 1)	10.83712 (285, 1)
190.0 /	34.92819 (71, 1)	20.21833 (285, 1)	10.18770 (275, 1)
180.0 /	54.64593 (268, 1)	26.88159 (275, 1)	13.05921 (31, 1)
170.0 /	83.93459 (268, 1)	31.23164 (301, 1)	13.86982 (253, 1)
160.0 /	132.78583 (121, 1)	23.09526 (4, 1)	19.61605 (346, 1)
150.0 /	13.38003 (255, 1)	24.14291 (281, 1)	16.33374 (281, 1)
140.0 /	81.19286 (255, 1)	21.10072 (19, 1)	6.76696 (19, 1)
130.0 /	65.61731 (255, 1)	19.50598 (330, 1)	12.68189 (50, 1)
120.0 /	31.53257 (255, 1)	19.58327 (39, 1)	13.73883 (296, 1)
110.0 /	28.53326 (37, 1)	13.65036 (356, 1)	10.38108 (39, 1)
100.0 /	21.46343 (37, 1)	24.88420 (304, 1)	6.36262 (356, 1)
90.0 /	15.04285 (184, 1)	28.80371 (290, 1)	17.74656 (304, 1)
80.0 /	16.38233 (191, 1)	17.78389 (255, 1)	20.83493 (290, 1)
70.0 /	11.52795 (191, 1)	6.20086 (41, 1)	7.97697 (255, 1)
60.0 /	31.56363 (314, 1)	8.74025 (250, 1)	4.73860 (41, 1)
50.0 /	32.01107 (314, 1)	4.90944 (184, 1)	5.60337 (250, 1)
40.0 /	25.89028 (11, 1)	5.31970 (206, 1)	3.58392 (191, 1)
30.0 /	21.56571 (249, 1)	16.92371 (314, 1)	8.27840 (314, 1)
20.0 /	19.38905 (142, 1)	16.56249 (11, 1)	14.44568 (314, 1)
10.0 /	19.70264 (142, 1)	11.23895 (155, 1)	11.19150 (249, 1)

STATE OF CALIFORNIA
GEORGE DEUKMEJIAN, Governor

AIR RESOURCES BOARD
1102 Q STREET
P.O. BOX 2815
SACRAMENTO, CA 95812

January 23, 1987

Ms. Pamela Meitner
E. I. du Pont de Nemours and Co.
Wilmington, Delaware 19898

Dear Ms. Meitner:

Comments on the Draft Carbon Tetrachloride Report

Thank you for your comments on the Draft Carbon Tetrachloride Report. We referred your comments on "Part B - Health Effects of Carbon Tetrachloride" to the Department of Health Services (DHS). Their response to your comments are attached to this letter. Your comments and the DHS response will be included in Part C of the Final Draft Report on Carbon Tetrachloride.

We will have the Final Draft Report on Carbon Tetrachloride (Part A with the Overview, Part B, and the completed Part C) available for review within the next month. A copy of this will be sent to you when it becomes available.

If you have any further questions on this matter, please contact Gary Murchison, Manager of the Compound Evaluation Section, at (916) 322-8521.

Sincerely,

William V. Loscutoff

William V. Loscutoff, Chief
Toxic Pollutants Branch
Stationary Source Division

Attachment

cc: Peter D. Venturini
Michael Lipsett, DHS

IV. Air Resources Board Responses to Part A - Related Comments

Air Resource Board Staff Responses to Public Comments on the Draft Part A Report on Carbon Tetrachloride

Comment: The rigid 30 and 20 day comment periods may not always be long enough to review the draft and final draft reports.

Response: In order for the toxic air contaminant (TAC) identification process to proceed in a timely manner, it is necessary for the ARB to have the rigid comment periods. The ARB staff believes that the 30 day and 20 day comment periods allow sufficient time to review the report and identify major issues of concern. However, to ensure the maximum time possible is available for the review of the reports, the previous review process was modified in two ways. First, an announcement letter is sent out in advance of the draft report so that interested parties can be identified. This letter requests the name and address of the person reviewing the report so they can receive it in the most direct way. Second, extra time is allowed for the report to reach the reviewer before the comment period starts.

Comment: Part A correctly references previous projections of a 1 to 2 percent growth in carbon tetrachloride demand through 1990. However, Dow Chemical feels that because of environmental concerns, carbon tetrachloride demand will probably not increase as previously expected.

Response: The 1 to 2 percent growth for carbon tetrachloride demand was reported in the "Chemical Marketing Reporter", 1986. In the absence of more detailed information on why this estimate is no longer correct, the ARB staff believes the 1 to 2 percent growth is still the best estimate.

Comment: As stated in EPA research studies and the Federal Register, there are uncertainties involved in the decision to regulate chlorofluorocarbons and other chemicals that may affect the ozone layer. Dow Chemical requested that the uncertainties in this area be considered by the CARB during its consideration of carbon tetrachloride as a TAC.

Response: Stratospheric interaction of carbon tetrachloride and other chlorofluorocarbons with ozone is an important issue. However, carbon tetrachloride is being considered for identification as a TAC because of its potential danger to human health from inhalation and not because of its affect on the ozone layer.

Comment: The current level of regulation and federal EPA proposals to regulate carbon tetrachloride manufacturing processes are sufficient to protect human health. It is not necessary for regulations to be so stringent as to eliminate the carbon tetrachloride industry and its beneficial end products.

Response: The identification of carbon tetrachloride as a TAC will not in and of itself eliminate the use of this compound. If carbon tetrachloride is identified as a TAC, the ARB staff will then proceed to assess the need and appropriate degree of controls that would be required for carbon tetrachloride sources. Some of the factors which will be considered during this assessment are availability and feasibility of control, cost, availability of substitutes, exposure to the public, and risk to public health. It is only after this assessment that a decision will be made by the Air Resources Board as to the need for control measures. The ARB staff will continue to work closely with the public and the affected industries throughout the development of the carbon tetrachloride needs report.

V. Department of Health Services Responses to Part B - Related Comments

DEPARTMENT OF HEALTH SERVICES
STAFF RESPONSES TO PUBLIC COMMENTS
ON THE "HEALTH EFFECTS OF CARBON TETRACHLORIDE" (MAY 1986)

Comment: Carbon tetrachloride has been classified as a carcinogen which acts by an epigenetic mechanism, according to Shank and Barrows (1986). [Their review article] indicates it satisfies several of the criteria for this classification which are:

It appears to induce cancer only at exposure levels which are near lethal doses (maximum tolerated dose which depresses growth rate 10 to 20%);

It increases the incidence of spontaneous tumors but does not induce formation of tumors which are rarely seen in control populations of the test species;

Cancers arise only after a long exposure relative to the lifespan of the test animal;

It does not form detectable levels of DNA adducts in in vivo tests. (Dupont)

Response:

Mechanism. Although the above authors have hypothesized that carbon tetrachloride acts via an epigenetic mechanism, this classification is debatable. Other authors have indicated that it cannot be classified as an epigenetic carcinogen (Williams GM and Weisburger JH, "Chemical Carcinogens," in Casarett and Doull's Toxicology, Klaassen CD et al., eds., 1986, pp. 99-173).

Dose levels. Carbon tetrachloride has been tested at high doses, but not at maximum tolerated doses. An adequate study of carbon tetrachloride's carcinogenicity has not been conducted at low concentrations. Thus, it cannot be stated with certainty that carbon tetrachloride induces tumors only at "near-lethal doses."

Absence of spontaneous tumors. Carbon tetrachloride produced a 100% incidence of tumors in hamsters where the control incidence was zero. The control incidence rate for tumors in mice in six studies was zero while the dosed animals had tumor incidence rates ranging from 38 to 100% (Edwards, 1941; Edwards and Dalton, 1942; Eschenbrenner and Miller, 1943; Eschenbrenner and Miller, 1946). In all the other studies with mice the liver tumor incidence rate ranged from 1 to 5% for the control animals but 47 to 100% for the exposed animals (Edwards, 1941; Edwards and Dalton, 1942; Edwards et al., 1942; NCI 1976a,b, 1977). In all studies with rats, the control rate of liver tumors was zero while the hepatic carcinoma incidence in treated animals ranged as high as 80% (Reuber and Glover, 1967; Reuber and Glover, 1970; NCI, 1976a,b, 1977). Thus, the argument regarding increasing the rate of spontaneous tumors is spurious.

Exposure relative to lifespan. Studies with mice showed development of tumors after 8 weeks of biweekly exposure (8% of lifespan). Studies with rats indicated that tumors can develop after 12 weeks of biweekly exposure (12% of lifespan). The criterion of a "long exposure relative to lifespan" has not been met, since a tumor incidence of greater than 88% had occurred after approximately 16 doses.

Detectable levels of DNA adducts in in vivo tests. Metabolically activated carbon tetrachloride has been found to bind with DNA in vivo (Diaz Gomez and Castro, 1980a; Rocchi et al. 1973).

Consequently, even using the criteria of Shank and Barrows, there appears to be no basis to classify carbon tetrachloride as an epigenetic carcinogen.

Comment: What constitutes sufficient valid data upon which to base a quantitative risk assessment? (Chevron)

Response: Studies used in the quantitative risk assessment for carbon tetrachloride were conducted over a period of almost 40 years, and the studies did not follow a standard format. Each study was evaluated individually by the Department of Health Services' (DHS) staff to determine whether it was scientifically valid and whether it could contribute to our understanding and evaluation of the carcinogenicity of carbon tetrachloride. DHS staff evaluated each study using the Department's Guidelines for Chemical Carcinogen Risk Assessments and Their Scientific Rationale (1985), and reviewed the Health Assessment Document for Carbon Tetrachloride (US Environmental Protection Agency, 1984). The results of this evaluation are presented in Section 9.2.2 of the Health Effects of Carbon Tetrachloride (May, 1986) prepared by DHS staff (hereafter referred to as "Part B" of the Report to the Scientific Review Panel). The staff of DHS determined that the three studies used in the quantitative risk assessment contained sufficiently valid data and that the best available data were used in the risk assessment. The major criteria included: publication of the study in the scientific literature following peer review, a clear description of the protocol indicating that the study was designed to evaluate the potential tumorigenicity of carbon tetrachloride, and a significant increase in tumors over controls. The same studies were used by EPA in its risk assessment for carbon tetrachloride.

Comment: Data presented by Condie et al. (1986) raise concerns over the appropriateness of using the results of animal gavage studies which utilize an oil vehicle to predict the carcinogenic risk encountered by humans from the inhalation of ambient concentrations of carbon tetrachloride. The use of oil as a vehicle was found to significantly increase both the incidence and severity of carbon tetrachloride's hepatotoxicity over that encountered when the agent is administered in water. (Chevron)

Response: Condie et al. (1986) examined the effect of the vehicle on hepatotoxicity and found that the toxicity was greater when the compound was administered in oil compared to an aqueous Tween-60 emulsion (not in water as indicated in the comment). This potentiating effect is not expected to occur for inhalation exposures. Condie et al. concluded that the effect could have resulted from decreased total absorption of carbon tetrachloride when administered in aqueous solution due to micelle formation, or from a slower rate of absorption (allowing more compound metabolism during the first pass through liver) when administered in corn oil. While it is also possible that the corn oil itself could have increased the toxicity of carbon tetrachloride, the mechanism of this effect has not been elucidated. This study consisted of subchronic experiments looking at hepatotoxicity, not carcinogenicity. Increased hepatotoxicity may or may not have any bearing on the carcinogenicity of carbon tetrachloride, as discussed below.

Comment: Why was the Kotin et al. (1962) study excluded from the DHS discussion of the carcinogenicity studies performed in mice? (Chevron)

Response: The Kotin et al. (1962) study evaluated the influence of carbon tetrachloride on benzo(a)pyrene metabolism and tumorigenicity. Consequently, the study is discussed in Section 8.1.2 of Part B, which considers synergistic effects. The study was not discussed further in the carcinogenicity section since it involved subcutaneous injection of 40 μl in 30 mice without controls, and it was not designed to examine the tumorigenicity of carbon tetrachloride.

Comment: Carbon tetrachloride has elicited a carcinogenic response in certain test animals. There is insufficient evidence to support the premise that carbon tetrachloride is a human carcinogen; it has not demonstrated carcinogenicity in humans at low levels. (Dupont, Dow)

Response: The commenters are correct, but the qualitative assessment of carbon tetrachloride's carcinogenicity in animals and humans has already been discussed by DHS staff. The summary of Section 7 of Part B states in part: "Animal studies demonstrate that carbon tetrachloride produces hepatocellular carcinomas in the mouse, rat and hamster; human evidence is inconclusive. IARC evaluated [carbon tetrachloride] and concluded that it is an animal carcinogen. The IARC classification would place [carbon tetrachloride] in group 2B, indicating that it is probably carcinogenic to humans. DHS staff members concur with this assessment, based on the evidence cited in the preceding subsections... there is sufficient animal data to conclude that [carbon tetrachloride] is a potential human carcinogen..." Furthermore, as indicated in Section 7.4 of Part B, there have been some reports linking increased tumor incidence in humans with carbon tetrachloride, but a causal relationship could not be established.

Comment: The preponderance of the data in the literature indicates that the tumorigenic response to carbon tetrachloride occurred as a consequence of the induction of post-necrotic cirrhosis. The most likely mechanism for carbon tetrachloride carcinogenesis requires a toxic response prior to initiation of the carcinogenic response and no toxic response is expected at ambient levels. (Dupont, Dow)

Response: There is no study that "indicates that the tumorigenic response to carbon tetrachloride occurred as a consequence of the induction of post-necrotic cirrhosis." In several of the studies cirrhotic changes were reported concomitantly with tumorigenesis; however, no cause-effect relationship has been demonstrated. In fact, as shown by Eschenbrenner and Miller (1946), discussed in Part B, Section 7.0, liver necrosis was not a required precondition for the production of tumors with carbon tetrachloride.

Comment: The dose levels administered in the studies on mice and rats which resulted in a tumorigenic response were in excess of 1000 mg/kg/day. Compared to the amount given to animals to cause cancer (1250 mg/kg bw in mice) the amount inhaled [less than one ppb in ambient air] is one billion times smaller. (Dupont, Dow)

Response: Tumorigenic responses were also observed in mice at 20, 30, 40, 80, 159, 160, 260, 315 and 625 mg/kg (Edwards and Dalton, 1942;

Eschenbrenner and Miller, 1943; Eschenbrenner and Miller, 1946), in rats at 47, 80, and 94 mg/kg (NCI 1976a, b, and 1977), and in hamsters at 190 and 380 mg/kg (Della Porta et al., 1961). Thus, the implication that only doses above 1000 mg/kg produce tumors is incorrect. The 20 mg/kg-day level is roughly equivalent to 28 ppm in air. Thus, the range of extrapolation of the tumorigenic response is approximately four orders of magnitude, not nine. Noncarcinogenic, subchronic effects have been observed following inhalation of concentrations approximately three orders of magnitude higher than ambient levels of carbon tetrachloride (Prendergast et al. 1967).

Comment: The occurrence of hepatomas (in mice) as a result of the induction of post-necrotic cirrhosis suggests that carbon tetrachloride is not a direct-acting carcinogen (Louria and Bogden, 1980). This observation is not contradicted by the results of various short-term mutagenicity tests nor by the preponderance of the evidence indicating little or no covalent binding to liver DNA....a tumorigenic response to carbon tetrachloride occurs as a consequence of the induction of post-necrotic cirrhosis and levels and durations of exposure which do not cause significant tissue damage would not be expected to produce tumors. (Dow)

Response: As stated above, Eschenbrenner and Miller (1946) showed that liver necrosis is not required for the induction of tumors with carbon tetrachloride. Thus, the conclusions drawn from the "post-necrotic cirrhosis" hypothesis are unsubstantiated. In the absence of data that the carcinogenic process would result only if post-necrotic cirrhosis occurs, the above comments represent speculation, not established fact. The genotoxicity of carbon tetrachloride was reviewed in Part B, Section 5, and results and limitations of test systems were discussed. The DHS staff concluded that carbon tetrachloride has genotoxic potential.

Comment: The rhesus monkey, the species and strain most like man in regard to the level of liver cytochrome P-450, has been reported to have a no-observed effect level [NOEL] in the range of 25 to 50 ppm in a chronic study. (Dow)

Response: The Dow study (Adams et al., 1952) does not establish a no-effect level for monkeys. The authors of the study reported that "the maximum vapor concentrations without adverse effect were 25 ppm for monkey..." However, a NOEL cannot be established on the basis of a single monkey tested at 25 ppm. This is particularly important since a later study (Prendergast et al. 1967) with much shorter exposure times demonstrated toxicity at concentrations 5 to 25 times lower for the rat, guinea pig and rabbit when compared to similar species in the Adams et al. (1952) study.

Comment: [On] the basis that there are thresholds for the toxic effects of carbon tetrachloride and the mechanism of tumor formation is nongenetic and all the supportive evidence that indicates man metabolizes carbon tetrachloride more like the monkey than the rodent, the assessment of risk/safety for man should be based on the adequacy of the margin which exists between man's exposure to carbon tetrachloride in the ambient environment and the no-observed effect level in the study on the most appropriate animal model, the rhesus monkey, with a safety factor to compensate for the lack of lifetime data (emphasis in original). (Dupont, Dow)

Response: As indicated above, the mechanism of carbon tetrachloride's carcinogenicity has not been elucidated. The metabolism of carbon tetrachloride has not been studied across species. The study proposed as the basis for carcinogenic risk assessment of carbon tetrachloride did not examine the test animals for carcinogenic effects. It would be inappropriate to base a carcinogenic risk assessment on a study with one monkey at the target concentration, exposed to carbon tetrachloride for less than three percent of its lifetime, where tissues were not evaluated for carcinogenic effects.

Comment: Rodents are more sensitive than primates to the toxic effects of carbon tetrachloride. In particular, hamsters seem to be the most sensitive to carcinogenic effects, followed by mice and then rats.... this is an important distinction and should be incorporated into risk assessment calculations. (Dupont)

Response: The toxicity or carcinogenicity of carbon tetrachloride has not been adequately tested in primates. Although there may be some metabolic differences between rodents and primates in the handling of carbon tetrachloride, differences in susceptibility to carcinogenesis have not been evaluated. In addition, no epidemiologic study has been identified that clearly examines the carcinogenic effects of carbon tetrachloride in humans. Several case reports indicated the development of liver cancer following exposure to carbon tetrachloride, but (as noted in the response to a previous comment) a cause-effect relationship could not be established. There is no additional information to be incorporated at this time.

Comment: Mouse liver tumors are seriously questioned as useful estimators of potential tumorigenicity for man. (Dupont)

Response: The conclusion that carbon tetrachloride is potentially tumorigenic in man is based not only on mouse liver tumors, but also on cancers reported in rats and hamsters.

Comment: We are including a copy of a recent Du Pont study on workers chronically exposed to carbon tetrachloride...These results show that at long-term exposures at about 1/2 of the TLV, no toxic effects were seen. (Dupont)

Response: The document submitted, authored by J. Gooch (1981), apparently was never published in the peer-reviewed literature. It is the opinion of DHS staff that if the study had been sufficiently rigorous to demonstrate the absence of effects as alleged, it would have been published. In any case, the report examined biochemical indices, not carcinogenicity.

Comment: It is obvious that the lack of a chronic inhalation study makes it difficult to make an adequate risk assessment. (Dupont)

Response: It would be preferable to use an inhalation study for risk assessment purposes, but none is available. Consequently, gavage studies must be used for risk assessment purposes. A number of assumptions and adjustments to data were made to estimate inhalation absorption, as described in Section 9.2.2 of Part B. Since carbon tetrachloride is a systemic toxin, once absorbed it should act similarly independent of the route of exposure. Similar toxic (noncarcinogenic) effects have been

observed when carbon tetrachloride is administered by inhalation and by the oral route.

Comment: Dose-response for tumors was limited. (Dupont)

Response: This statement is potentially misleading since carbon tetrachloride has not been tested at low doses. Furthermore, at the doses that carbon tetrachloride has been tested, it has fairly consistently produced a high number of tumors.

Comment: EPA converts doses across species by assuming that biologically equivalent doses can be obtained by correcting for the surface area differences among species. Two other methods are often used to make interspecies comparisons: correcting for body weight differences and doing no conversion. (Dupont)

Response: There are a number of methods to make interspecies extrapolations. In the risk calculation the interspecies conversion was based on metabolic differences using the body surface area adjustment. This approach is consistent with practices generally followed by regulatory agencies and is supported in the published literature. Correcting for body weight differences is an alternate approach which is somewhat less health-conservative. The suggestion that no conversion be made appears inappropriate for gavage studies. If no conversion were made, then a given quantity of a substance would be considered to produce identical effects in different organisms regardless of variations in weight or metabolism.