ESTIMATE OF HISTORIC BENZENE EXPOSURES AT TWO PETROLEUM REFINERIES

SHELL OIL COMPANY
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I. INTRODUCTION AND BACKGROUND

On July 29, 1983, Shell Oil Company (Shell) announced the results of a recently completed Standardized Mortality Ratio (SMR) study. The study was performed using mortality data for manufacturing location active employees and retirees whose date of death was between January 1, 1973, and December 31, 1982. The study indicated a greater number of deaths due to leukemia than expected for two Shell locations, the Wood River Manufacturing Complex (WRMC) and the Deer Park Manufacturing Complex (DPMC). The observed excesses are more pronounced for the acute myelogenous type of leukemia. The excesses were statistically significant only for the Wood River location.

To assist in evaluation, Shell had contracted with Dr. Phillip Cole, Professor and Chairman, Dept. of Epidemiology at the University of Alabama. Dr. Cole reviewed the data, evaluated the involved methodologies, and confirmed the findings.

This information was submitted to NIOSH via a letter to the Director dated July 28, 1983. Copies were also provided to OSHA, both directly and as an attachment to the August 22, 1983, Shell Oil Company submittal to OSHA's Request for Information on Occupational Exposure to Benzene (Docket H-059B). Employees from the two locations were also advised via written communications.

The excess in these leukemia deaths was not proven to be linked to benzene exposure, but a presumptive association was suggested by the lack of knovledge of any other potentially causal associations. As part of the submittals to OSHA and HIOSH, Shell announced its intent to characterize the benzene exposure of the leukemia cases, and in various refining jobs encountered in the past. This effort has been identified as the Benzene Historic Exposure Study. An outline of the proposed study objectives and methodology was submitted to NIOSH/OSHA for review. The study vas implemented for the two locations in the period August-October 1983.

The objectives of the study were (1) *to* assess the historic occupational benzene exposure for the diagnosed cases of leukemia, and (2) to estimate benzene exposure potentials for various jobs where benzene may have been encountered.

The study has been completed, and is reported on herein. Estimates for 23 diagnosed leukemia cases are presented. Because these cases are diverse in terms of work histories, careful study of the information presented in the Case History Summaries *is* necessary. The study also produced estimates of benzene exposure potential for 150 jobs at the Wood River Refinery, and 96 jobs at the Deer Park Refinery, spanning more than four decades from about 1940 to present. These jobs are the ones most likely to have encountered benzene exposure.

The study represents a massive undertaking to ascertain probable inhalation exposures of individuals based upon a study of the types of equipment, processes, and procedures used in the two petroleum refineries. The study process also included recollection of work practices, subjective estimates of benzene odors, and some validation of the accuracy of such estimates. An iterative technique was used to review the estimates and to refine them. Details of the procedure are given in the body of the report. The study was assisted by Knowlton Caplan, P. E., CIH, President of Industrial Health Engineering Associates, Inc., of Minneapolis, Minnesota.

Most of the benzene exposures are associated with specific tasks or conditions, and hence are intermittent in nature. Consequently, the estimated benzene exposures are presented in the Case History Summaries as TWA's, or short-term exposures, or both, as appropriate for each job worked. Careful study of this information is urged, with appropriate consideration of intensity and intermittency of exposure.

In performing this study, a system has been created for estimating historic benzene exposures for diagnosed leukemia cases. This system, specific for benzene and the two locations, required substantial developmental effort. It can be used in the future with modest effort for the same two locations, but extension to other locations or other substances would require effort similar to that already invested.

II. INTERPRETATION OF RESULTS

Because of the study method used, there is no question that the figures given as inhalation exposures are estimates. Therefore, the numbers discussed in the report and in this interpretation section are not claimed to be, nor should they be taken as, true or absolute exposures. We can reasonably be certain, however, that the assignment of exposure categories, both by job and by individual, are in correct relation to each other. Thus, if a particular job is estimated as being an order of magnitude greater in potential benzene exposure than a second job, we are reasonably certain that that relation does exist. Further, while the numbers are not exact there is a category of exposures to benzene which is labeled "Nil." The interpretation of this category is that no benzene exposure is known to have existed or would be demonstrated for the circumstances depicted.

The data in the report lend themselves to attempts to correlate levels of benzene exposure and the medical condition, acute myolegenous leukemia (AML) as recorded on death certificates. All leukemias which fit ICDA classification 205 (8th Revision) are considered to be of the AML variety. It is important to note, however, that there is an absence of medical and pathology records which verify the identification of a particular case as a true AML or ICDA 205. Therefore, at this writing a definitive diagnosis cannot be confirmed.

The historic exposure study by itself cannot answer the question as to the causative agent of the leukemias, AML and others. There are several basic questions which can be examined in the light of this study. These are:

(1) If there is an association between AML and/or other leukemias and benzene, is it evident in the cases studied?

(2) If there is an association between AML and/or other leukemias and benzene, is a dose response relation evident?

(3) Does it appear that a negative or inverse association between benzene and AML and/or other leukemias exists?

(4) Do the vork histories give any clue or credence for an hypothesis that other causal mechanisms may be operative?

The exposure data, as determined by the study teams and given in the report, can be viewed in either of tvo vays: as integrated or peak exposures. Integrated exposures comprise exposures from all sources (background, short-term, peak) and may be expressed as ppm-days per year (ppm-days/yr) or total (career) ppm-days. Tables 5 and 7 in Section IV of the report present the distribution of leukemia cases (AML plus others) based on total (career) estimated benzene exposure. These tables show that nine of the total 23 cases had nil exposure attributed to them.

In an attempt to interpret these findings, Table 1 in this section presents the same data somewhat differently. The distribution of leukemia cases is presented for various integrated exposure categories in ppm-drys. These integrated exposures actually represent the summation of a11 estimated benzene exposures, from a variety of jobs over each case's career. Because the number of years of exposure of each individual varied widely, as did the time period over which such exposure occurred, it becomes necessary to handle the data Lo that the different exposures might readily be compared. One way is to view the career exposures as if they had occurred in a single year. This method is a conservative means of handling the data. When this is done, the Table 1 categories can be viewed as follows:

Category

1. Nil:	No exposure could be demonstrated nor is knovn to have occurred.
2. <2500 ppm-days:	2500 ppm-days is equivalent to a 10 ppm daily time-weighted average (TWA) for 250 working days per year for one year.
3. 2500-6250 ppm-days:	The upper figure is equivalent to a 25 ppm daily TWA each working day for a year.
4. 6250-25000 ppm-days:	The upper figure is equivalent to a 100 ppm daily TWA each working day for a year.

In Table 1 the ppm-days are given separately for the AML and non-AML cases. It is evident from the table that almost half the A!! cases (5/11) and one-third (4/12) the non-AML cases shoved Nil exposure. There is no pattern in the distribution of leukemia cases (either AML or non-AML) implying a dose-response relation between leukemia and integrated benzene exposures.

TABLE 1

DISTRIBUTION OF LEUKEMIA CASES BASED ON CAREER PPM-DAYS

CATEGORY (PPM-DAYS)	AML				NON-AML					TOTAL	
	WOOD RIVER	DEER PARK	TOTAL NO.	%	WOOD RIVER	DEER PARK	RESEARCH	TOTAL NO.	%	NO.	%
1. Nil	3	2	5	45	4	0	0	4	33	9	39
2 <2500	3	0	3	27	2	1	0	3	25	6	26
3 2500-6250	1	1	2	18	0	2	0	2	17	4	17
4 6250-25000	0	0	0	0	0	1	1	2	17	2	9
5 >25000	0	0	1	9	0	0	1	1	8	2	9
TOTAL	8	3	11	99	6	4	2	12	100	23	100

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When one looks At perk exposures, similar results can be seen. To examine possible relationships between peak exposures and leukemia, exposures for each case were calculated from the information presented in Attachments 3, 6, and 7 by multiplying the estimated short-term exposure level (highest value) times the estimated duration (minutes per day) and frequency (days/year), for any year in which short-term exposures occurred. The resultant, peak ppm-minutes per year, was tabulated for each of the years that short-term exposures were deemed to have occurred. The highest peak ppm-minutes/year figure for each case is used in Table 2. The categories in Table 2 are:

Category

1. Nil:	No exposure could be demonstrated nor is known to have occurred.
2. <18750 ppm-min/yr:	18,750 ppm-min/yr is equivalent to a 25 ppm peak occurring over a 15 minute period one day per week each week in the year.
3. 18750-125000 ppm-min/yr:	The upper figure is equivalent to the current OSHA allowable peak of 50 ppm for no more thaa 10 minutes in any one day, 5 days per week, each week.
4. 125000-1.25×10^6 ppm-min/yr:	This represents a one order of magnitude range over the next lower category.

For the AML cases in Table 2, 6/11 or 55% are in the Nil category. For the non-AML's 5/12 or 42% had no known or calculable exposure. Even if one eliminates the Nil category in Table 2 and looks only at the data vhere exposure is deemed to have occurred, there is no suggestion of dose response within either the AML cases or non-AML cases. The range of peak ppm-min/yr exposures in the AML categories are from 9,000 to 1.4×10^6.

TABLE 2

DISTRIBUTION OF LEUKEMIA CASES BASED ON
PEAK PPH-MINUTES/YEAR

CATEGORY (PPH-MINUTES/YEAR)	AML				NON-AML					TOTAL	
	WOOD RIVER	DEER PARK	TOTAL NO.	%	WOOD RIVER	DEER PARK	RESEARCH	TOTAL NO.	%	NO.	%
1. Nil	4	2	6	55	4	1	0	5	42	11	48
2 <10750	1	0	1	9	1	0	0	1	8	2	9
3. 18750-125000	1	1	2	18	1.	3	1	5	42	7	30
4 125000-1 25 x 10^{C}	1	0	1	9	0	0	0	0	0	1	C
5 >1 25 x 10^{6}	1	0	1	9	0	0	1	1	8	2	9
TOTAL	8	3	11	100	6	C	z	12	100	Z3	100

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Of potential significance is that the highest benzene exposure jobs are not reflected in the work records of the diagnosed leukemia cases. For example, only one of the Wood River leukemia cases worked in the highest exposure jobs relating to the Cumene Plant (1943-45), or the Dodecyl Benzene Unit (1950-54). Conversely, individuals who did work these jobs are not among the leukemia cases revealed by the 1972-1983 study.

An additional observation from this study relates to latency period. When latency is defined as the time betveen first exposure to benzene and date of death, the average latency period for AML cases is 37 years (range 33-46). This is noteworthy since this latency is far longer than commonly reported in literature relating benzene to AML.

From all of the above, the folloving inferences can be made:

1. The exposure estimates, as presented in Tables 1 and 2 do not establish a causal relationship betveen benzene exposure and development of Acute Myelogenous Leukemia (A!!) at either the Wood River or Deer Park refineries.

2. There is no statistically significant dose-response relationship observed betveen level of exposure and development of AML at the Wood River refinery. Even when the Nil exposure category is eliminated, this observation remains evident.

3. At the Deer Park refinery, an inverse relationship between level of exposure and development of AML is observed.

4. At the Wood River Research Laboratory, the two cases of non-AML leukemia are noted to have occurred in the higher categories of exposures, while none occurred at the Nil level. The significance of these tvo cases is not known.

Given these observations, it becomes useful to investigate the Nil cases to see if there is anything that suggests some common association. Of the AML cases there is no apparent common employment pattern to the individuals. Of the non-AML cases, two have a history of working in the Wood River compounding house, where lubricants were made. One of the AML cases also worked in that same area, where no benzene vas encountered. Further study will be needed to see what relation there is, if any, between these cases. We are now conducting a case control study to this end. From the data available, however, we can not determine either within the A!! and non-AML groups (or even combining both groups) with Nil exposure, what elements there are in common that may be postulated as a correlate or causal relation to leukemia.

At this time the excess leukemias are unexplained.

III. STRUCTURE OF STUDY

- Objectives

  The objectives of this study were to assess the historic occupational benzene exposure for (1) the diagnosed cases of leukemia at the Wood River and Deer Park refineries; and (2) the jobs where benzene may have been encountered at these two refineries.

- scope

  The structure of the study vas congruent with the scope of the Standardized Hortality Ratio study for the two refinery locations where excess incidence of leukemia was revealed.

  With regard to diagnosed leukemia cases (objective No. 1), the study includes:

  - Employees or pensioners of both locations who died vith leukemia (regardless of type) between the January 1, 1973, and December 31, 1982, period of the SMR study. Not included are those who may have died from leukemia outside the ten-year study period, or terminees.

  - Employees or pensioners vith diagnosed leukemia who were still living at the time of study, if they became known early enough to be included (two such cases exist).

  The study included both the refinery and the contiguous reserrch laboratories at both locations. The research activities were closed at both sites about 1975.

  With regard to jobs (objective No. 2), the study was structured to include:

  - Jobs or activities vhere benzene exposure vas most likely, in both refining and research. Criteria were benzene concentration in the process stream, and the nature of the particular jobs or tasks. Operations, maintenance, and the quality control laboratory were included.

  - For the identified benzene jobs or activities, the study spanned the time from the inception of that particular job until current, or until the job vas discontinued if that came first. When changes occurred in a job that influenced benzene exposures, such changes were taken into account. The earliest job addressed began in 1936 at Deer Park.

- **Observations**

At the outset, the following observations concerning the study were made:

(1) The study, by its very nature, would be subjective, because it would be based on employee recollections of workplace situations and activities and sensory perception of the presence of benzene, without any supporting monitoring data. Because of this subjectivity, the study was structured to build in maximum objectivity.

(2) During the study, and after its completion, the methodology would be closely scrutinized by other interested parties. This argued not only for maximum objectivity, but also for a methodology that is both well-understood locally, and communicated to all interested parties.

(3) While the studies at the two refineries must be performed separately, they must also be "harmonized" to ensure compatibility.

(4) The studies must be performed expeditiously, consistent with the requirements for maximum objectivity, a well-understood methodology, and compatibility.

(5) It is not possible to reach objective No. 1 vithout first accomplishing objective No. 2.

- Overview

The study was structured into separate tasks, or elements, to be performed by separate groups at each location, under the direction of a Steering Committee comprising representatives from all interested departments. Members are listed in Appendix A. Structuring separate tasks vith written descriptions helped provide maximum objectivity and a well-understood methodology, while also expediting the process at each location. The study consisted of three separate areas of endeavor. These arc designated:

Task 1 - Study Development
Task 2 - Reconstructing Benzene-Related Information
Task 3 - Estimating Benzene Exposure at Each Location

Discussion follows.

- Task 1 - Study Development

A sub-group of the Steering Committee developed criteria, common terminology, and specific descriptions for the various tasks. This included:

(a) Developing criteria for assessing historic benzene exposure by inhalation and direct contact. Criteria developed were to key on sensory detection of benzene, and vere to consider level, duration, and frequency of exposure.

A literature search (Table 1, Appendix F) showed no definitive sensory data for benzene so an empirical table vas developed and checked against known exposure levels for specific operations. This information (Tables 2a and 2b, Appendix F) vas used by the task groups in filling out the worksheets.

Direct contact vith benzene vas considered in estimating inhalation exposures. Dose estimates were not made for benzene absorbed through the skin when direct contact may have occurred. This is based in part on the fact that protective clothing reduced such exposures, coupled with the absence of a valid method for making such estimates.

A preliminary validation of the overall approach was done by comparing the first worksheets for current jobs against actual monitoring data, A final validation vas done with the data from the final worksheets. This validation (Table 3, Appendix F) shows a reasonably good correlation between estimates based on the sensory data and actual exposure levels.

Appendix G also contains a review of the way in which the sensory perception approach was applied at Uood River and Deer Park.

(b) Developing task descriptions for the remaining tasks.

These task descriptions are provided in Appendix O.

(c) Developing guidelines for what constitutes a benzene unit or a benzene job.

For purposes of this study, a benzene unit was defined as any manufacturing or storage operation that involved (contained) benzene in excess of 5% concentration in the raw materials, intermediate streams, or products. Also included were any such operations vith benzene in excess of 1% concentration, if that operation involved "open" handling of the benzene-containing substances, such as in loading of common carriers or marine vessels.

Task 2 - Reconstructing Benzene Related Information

This task was divided into four parts, performed concurrently at Vood River and Deer Park, by eight separate work groups. The four were :

2A - Identify benzene areas and units.

Identify areas and units vhere benzene was handled, the concentrations encountered, the appropriate time frames, and any relevant information on emission sources or process changes that could have affected worker exposure.

2B - Identify benzene jobs and tasks.

Based on the 2A work product, identify the operating, maintenance, and laboratory jobs in those areas and units that could have encountered benzene, and qualify the frequency, duration, and degree of exposure, using the previously developed criteria for assessing historic benzene exposure.

2c - Identify benzene work practices or procedures.

Review past work practices to determine potential benzene exposures that would not necessarily be discovered by Task 2B.

2D - Develop work histories and potential exposures for diagnosed cases of leukemia.

Identify the type and location of work for each diagnosed leukemia case, with supporting information.

Task 2A was performed first at each location, and as a pre-requisite for Task 2B. Tasks 2C and 2D commenced at earliest opportunity and progressed independently. In addition to using all available records, the work groups relied heavily on employee interviews, seeking out those experienced employees and retirees with historic experience. To assist efficiency and harmony, representatives from the Steering Committee met with each work group to explain their task, and hear their report. Consultation was provided as necessary. The written reports of each of these work groups (i.e., Task 2 Work Products) comprise the documented infomation on which this study vas based.

As previously stated, the research laboratories contiguous to the two refineries are included in the scope of this study. Since these laboratories were shut down and restructured into the Shell Development activity centered at the Westhollow Research Center

near Houston, it became necessary to conduct the research study there. This effort, designated Task 2E, performed the equivalent tasks 2A, B, C, and D, using separate work groups addressing the Wood River and Deer Park Research activities. The approach was the same as that used at the two refineries, except that a single work group performed all four tasks, for each research location. Participants were all alumni of the respective locations, and retiree interview were again used extensively to supplement available records.

- Task 3 - Estimating Benzene Exposure at Each Location

Following completion of the Task 2 information gathering, separate panels were convened at Wood River and Deer Park to integrate all the information and assess historic benzene exposures. These panels included active and retired employees with a mix of staff/hourly, operations/maintenance, and technical/non-technical. The Steering Committee was represented on each panel, and the consulting industrial hygienist participated on both. A professional facilitator vas used to assist the deliberations and ensure appropriate group dynamics. The makeup of each panel is provided in Appendix C. The task description vas prepared by the Steering Committee sub-group. The suggested structure for the week-long exercise is provided in Appendix D. Task 3 vas successfully performed at each location in five working days. Additional industrial hygiene support was provided at both locations to facilitate the calculation of estimated exposure information, in accord with the panel's deliberations. For the research activities, the Task 3 function was carried out separately. The resulting Task 3 reports for Wood River, Deer Park, and the Research Activities provide the basis for this report.

- Task 4 - Exposure Simulation Studies

from the outset, it was recognized that exposure simulation experiments could be conducted, using monitoring devices to quantify benzene exposures to simulated workplace tasks. It vas decided to defer such experiments because (1) the desire for an expeditious study was not consistent with an experimental program that may take months to complete, and (2) identification of the most prevalent and important exposure sources could be a product of this study, leading to better design of any such exposure simulation experiments.

IV. RESULTS

A. Methodology

1. Benzene exposure potential in various jobs

The 2B task force at each location identified and characterized each job studied, recording the potential benzene exposure in terms of frequency, duration, and intensity on a Task 2B: Exposure Description Worksheet. These "2B worksheets" constitute the basic "data" for the entire study. A sample 2B worksheet is shown in Appendix E. The first estimate of benzene exposure potential for each job studied vas calculated based on the information reported on the 2B worksheet, and the criteria discussed previously (see Section III and Appendix F). This calculation produced an estimate expressed *in* ppm-days per year for the specific job. The estimate is presented as a "range," vith the lowest number reflecting the smallest estimates of time, frequency, and intensity, and the highest number the largest. Typically the "high" estimate turns out to be tvo to three times larger than the "low" estimate. A calculation sheet is provided with the sample 2B worksheet.

The task 3 work group reviewed each of these 2B worksheets, issuing additional instructions as deemed necessary to adjust the exposure information for benzene work practices, mixtures, background levels, and peak exposures. This resulted in recalculating the estimates to reflect the work group's deliberations. The resulting final (rounded) estimate is presented as a range, in ppm-days per year. The completed 2B worksheets for the various jobs vith the estimated ranges constitute one portion of the final product from this study. They are summarized in Attachment 1 (Wood River) and Attachment 4 (Deer Park). The entire set of completed 2B worksheets and supporting calculations are contained in the task 3 work product for each location.

2. Benzene exposure for diagnosed cases

Work histories for each of the diagnosed leukemia cases were prepared by the 2D task force at each location, and presented to the task 3 work group on a Report 2 Case Exposure Summary form. The task 3 panel was then able to direct the calculation of a total dose for the diagnosed case, by using the job estimates previously prepared. Men assignments were encountered for which no estimated exposure potential had been prepared (i.e., no 2B worksheet), the task 3 vork group made estimates based upon their inherent knovledge of the uorkplacc, and their acquired familiarity with the range of potential exposures. The career-dose exposure for each case was summed in ppm-days. These completed Report 2 Case Exposure Summary forms are contained in the

task 3 vork product for each location, and are the basis for the Case History Summaries presented in this report.

Typically, many of the cases had periods (sometimes extended periods) when estimated benzene exposure was nil. Further, since none of the jobs were typical "assembly line" jobs, benzene exposure was normally intermittent, and often associated with specific tasks or conditions. For these reasons, it was decided that career dose in ppm-days may not be the most relevant measure of exposure. In this regard, it would be inappropriate for others to calculate average daily exposures by dividing the estimated career dose in ppm-days by the total days worked. Consequently, it vas decided to present the estimated exposures in another format, designated Case History Summary. These Case History Summaries characterize benzene exposures for diagnosed leukemia cases as TWA's, or short-term exposures, or both, as appropriate for each job worked. They were prepared using information from the 2B worksheets to estimate TWA's and short-term exposures. The Case History Summaries were compiled as part of the report preparation, and constitute the second portion of the study product.

B. Wood River Refinery

1. Benzene exposure potential in various jobs

The study identified nine units or areas in the Wood River Refinery where benzene vas encountered, spanning four decades from 1941 to current. These are as follows:

°	Cumene Plant	1943-45
°	Dodecyl Benzene	1950-54
°	HDU/Reformers	1966-current
°	Deisohexanizer	1960-current
°	Toluene Plants 1 & 2	1942-1960 (Later called Aromatics Recovery Unit)
°	Aromatics Recovery Unit	1960-66 (Later called Benzene Extraction Unit)
°	Benzene Extraction Unit	1966-79
°	Benzene Extraction Unit	1980-current
°	Dispatching	1943-current
°	Laboratory	1941-current

Background information on these is contained in the Wood River Task 2A and 2B Reports, and the Task 3 work product. Prior to 1941, benzene was not encountered above the 5% level selected as criterion for this study. While it was not produced at Wood River, commercial benzene was purchased by tank car for the Cumene Plant (1943-45) and the Dodecyl Benzene Unit (1950-54). This product was probably distilled from coke oven benzene. In addition, coke oven benzene was delivered by tank truck during the period 1966-1963 (ceased early 1983). This product contained

65-88% benzene, with other substances, including toluene, xylene, and gum.

Estimates of benzene exposure potentials vert prepared for a total of 150 operating and maintenance jobs associated with the nine units, during the spanned time periods. These estimates are presented as ppm-days per year in two formats. As noted, it is inappropriate to divide these figures by the total number of workdays per year to derive a daily estimated dose.

In Attachment 1, the estimated exposure potentials are presented for jobs associated with the particular unit or area, for the time period specified. This format may be the most useful, as it permits appraisal of benzene exposure on a unit-by-unit basis, for both operations and maintenance personnel. For operations, the estimates represent the exposure of an operator working an entire year (250 days). for maintenance, two estimates are sometimes presented. The higher numbers represent the exposure potential range for a craftsman working in the benzene exposure area for an entire year (250 days). An example is a zone pipefitter, postulated as being assigned every work-day to the benzene exposure area in the zone. The more usual case is a zone craftsman who works in benzene areas on some days, but not on others. Recognizing this where appropriate, the exposure potential range for the maintenance job has been divided by the estimated number of craftsmen that could have been assigned to that job, giving a lover unit estimate. In general, this lover estimate vould more likely represent the exposure potential of such a zone craftsman.

The estimated exposure potential for the 150 operating and maintenance jobs presented in Attachment 1 are also presented in a rank-ordered format in Attachment 2. for each job, a range of estimates is given. Attachment 2 is based on the higher end of the range. The following table summarizes the Attachment 2 information by both the lowest and highest estimated range values.

table 6

Estimated Job Exposure Potential Based on Lou and High Ends of Estimates for Each Job (ppm-days/yr)	Wood River Refinery			
	Lovest		Highest	
	No.	%	No.	%
C 500	99	66	77	51
500-2500	38	25	36	24
2500-5000	13	9	23	15
> 5000	0	0	14	10
	150	100	150	100

The highest estimate is 6900-10,200 ppm-days/yr. In general, highest exposures were associated vith earliest jobs.

Estimated benzene exposure potentials for quality control laboratory jobs are also presented in Attachment 1, and rank-ordered separately in Attachment 2. These estimates are quite similar to those for operations and maintenance, although one job has the highest estimated exposure of 6,100-12,500 ppm-days per year.

2. Case History Benzene Exposures

The study produced estimates of benzene exposure for *14* diagnosed leukemia cases, of which 12 are deceased. These estinated benzene exposures, and other information of epidemiologic relevance for each case, are presented in Attachment 3, the Case History Summaries. The development of this particular format is discussed in this part (Section IV. (A)(2)].

Because the cases are diverse in terms of the reconstructed exposure history, careful study of the Case History Summaries is necessary. Nevertheless, from the limited perspective of estimated total (career) benzene exposure, the results for the Wood River Refinery diagnosed cases are as follows:

Table 5

Total (Career) Exposure ppm-days	Number of Cases
Nil	7
25-1,000	3
1,000-5,000	2
5,000-10,000	1
21,000-43,000	1
TOTAL	14

C. Deer Park Refinery

1. Benzene exposure potential in various jobs

The study identified nine units or areas in the Deer Park Refinery where benzene vas encountered (above the 5% level selected as the criterion for this study), spanning the period 1936 to current. These are as follows:

- Refinery Lab 1936-current
- Thermal Cracking 1942-1977
- Dispatching and Shipping 1946-current
- Environmental 1946-current
- Lube B and C 1948-1950
- Aromatics 1952-current
- Catalytic Reforming (CR3) 1970-current
- Hydroprocessing 1971-current
- Phenol Acetone 1977-current

Prior to 1936, benzene was not encountered above the 5% level. Background information is contained in the Deer Park Task 2A and 2B Reports, and the Task 3 work product.

Estimates of exposure potential vere prepared for a total of 96 operating, maintenance, and laboratory jobs associated with these nine units, during the spanned time periods. These estimates are presented as ppm-days per year in tvo formats. As noted, it is inappropriate to divide these figures by the total number of workdays per year to derive a daily estimated dose.

In Attachment 4, the estimated exposure potentials are presented for jobs associated with a particular unit or area, and for selected maintenance crafts. The approach to estimating maintenance exposures for Deer Park vas somewhat different from that used for Wood River. At Deer Park, exposures were estimated for the overage maintenance worker, while at Wood River estimates were

made for the job, and only in some instances for the average worker, as discussed in Appendix G.

The estimates for the 96 operating, maintenance, and laboratory jobs presented in Attachment 4 are also presented in a rank-ordered format in Attachment 5. For each job, a range is given. Attachment 5 is based on the higher end of the range. The following table summarizes the Attachment 5 information by both the lowest and highest estimated range values.

Table 6

Estimated Job Exposure Potential Based on Low and High Ends of Estimates for Each Job (ppm-days/yr)	Deer Park Refinery			
	Lowest		Highest	
	No.	%	No.	%
< 500	72	75	50	52
500-2500	23	24	37	39
2500-5000	1	1	5	5
> 5000	0	0	4	4
	96	100	96	100

The highest estimate is 1,400-9,800 ppm-days per year. In general, highest exposures were associated with earliest jobs.

2. Case History Benzene Exposures

The study produced estimates of benzene exposure for seven diagnosed leukemia cases, all deceased. These estimates, and other information of epidemiologic relevance for each case, are presented in Attachment 6, the Case History Summaries. The development of this particular format is discussed in this part [Section IV.(A)(2)].

Because the cases are diverse in terms of reconstructed exposure history, careful study of the Case History Summaries is necessary. Nevertheless, from the limited perspective of estimated total (career) benzene exposure, the results for the Deer Park Refinery diagnosed cases are as follovs:

Table 7

Total (Career) Exposure ppm-days	Number of Cases
Nil	2
25-1,000	1
1,000-5,000	2
5,000-10,000	1
7,000-22,000	1
TOTAL	7

D. Research Laboratories at Both Sites

Estimates of benzene exposures for research activities at both Wood River and Deer Park were performed by two groups of research alumni, following essentially the same procedures used for the refinery part of the study. Appropriate modification for this procedure included (1) identifying historic benzene exposure potential by "activities", instead of by units and jobs, and (2) using a single group to perform the several tasks involved for each site. A benzene concentration of 1% was used as a study criterion, based on the assumption of "open" handling.

1. Uood River Research Laboratory

The Wood River Research Laboratory operated as an entity from 1933 to 1975, when it was shut down and all activities traosferrtd to another (non-refinery) location. Some laboratory support activities began as early as the 1920's. Throughout its history, the Research Laboratory was administratively a part of the Wood River Refinery; hence the standardized mortality ratio study revealed two diagnosed cases among researchers. Consequently, the historic benzene exposure study was structured to include the research activity.

The study identified four major research activities with potential for exposure to benzene in liquid concentrations exceeding one percent. These span the period 1933 to 1975. They are broadly defintd as:

- certain engine studies
- analytical lab and instrument product tvaluation vork
- asphalt studies
- organic synthesis of additives and base stocks

Each of these broad areas of activity has subparts. Background information on these is contained in the Wood River Research task 2A and 2B reports. Potential benzene exposure for each of the activities is reported on 2B worksheets, providing a data base

from which benzene exposures can be estimated. Supplemental infonnation was compiled on personnel count and rosters, work practices involving benzene, and facility description. All this information assisted the preparation of the estimates for the particular jobs worked by the two diagnosed leukemia cases. This information is all contained in the Aestarch Activities Task 3 Work Product.

As a result of this work, it became apparent that historic benzene exposure for researchers is a function of the particular activities engaged in over the years, (and background levels), rather than a function of job title. Consequently (and unlike the refinery portion of the study), no attempt was made to estimate historic benzene exposure by job. Rather, reconstructed work histories were prepared to identify the activities of the two diagnosed cases. Supplemental 2B worksheets were then prepared for each specific activity, and exposure ranges estimated. These estimates were then consolidated onto a Report 2 Case Exposure History form, presenting estimated total benzene exposures for each of the two diagnosed cases. These Report 2 forms are contained in the Research Activity Task 3 Work Product.

In keeping with the approach for the refinery portion of the study, the estimated benzene exposures for the diagnosed cases are presented in Attachment 7, the Case History Summaries, along with other infomation of epidemiologic relevance. From the limited perspective of estimated career benzene exposure, the two cases have exposure ranges of ca. 1,300-10,400, and 10,000-26,000 ppm-days. As noted, it is inappropriate to divide these figures by the total number of workdays to derive a daily estimated dose.

2. Deer Park Research Laboratory

The Deer Park Research Laboratory operated from 1933-1975, vhen it vas shut down and all activities transferred to another (non-refinery) location. At the time of this study, no diagnosed cases of leukemia were known to exist among Deer Park research alumni.

The study identified 13 major research activities with potential for exposure to benzene in liquid concentrations exceeding one percent, spanning the period 1933-1975 (the shutdown date). These are:

- Wax technology
- Large-scale chromatographic separations
- Catalytic reforming for aromatics production
- Catalytic reforming for motor gasoline production
- Analytical distillation
- Miscellaneous analytical operations
- Lube oil pilot plant

- Aromatic synthesis by iodine dehydrogenation (IDAL)
- Thermal cracking and reforming
- Catalytic repassing of aviation base-stock
- Catalytic cracking for motor gasoline production
- Large-scale hydrogenation of aviation base-stock
- Heavy oil flashing

Background infomation on these is contained in the Deer Park Research task 2A and 2B worksheets. Potential benzene exposure for each is reported on 2B Worksheets, providing a data base from which benzene exposures could be estimated. Supplemental information was compiled on vork practices involving benzene, short-term projects with benzene exposure, and facility description. Altogether, this provides an information base on which benzene exposures for specific persons (i.e., diagnosed cases) could be estimated. This information is all contained in the Research Activities Task 3 Work Product.

Because no diagnosed cases of leukemia vere knovn among Deer Park research alumni, no further work in this group was performed as a part of this study.

V. DISCUSSION

A. Results

An historic exposure study such as this had not previously been attempted within Shell Oil Company. It was recognized at the outset that the study would be somewhat subjective, and that both the methodology and the results would be carefully scrutinized. Consequently, an attempt has been made in this report to provide understanding of how the estimates vere generated. The attachments to this report are intended to assist this understanding.

- Benzene exposure potential in various jobs

  This study presents estimates of benzene exposure potential for 150 jobs at Wood River Refinery and 96 jobs at Deer Park Refinery, spanning more than four decades from circa 1940 to present. The jobs selected are the most likely to have encountered benzene exposure, and represent a fraction (perhaps 5-20%) of the "field" jobs at the tvo sites. It is important to note that "job" as used in this report represents a particular assignment for a particular time period. Therefore, a given assignment for which benzene exposure changed over time might constitute several "jobs" for purposes of this report.

  The estimated benzene exposures are presented in Attachments 1-2 and 4-5 in two formats, grouped by unit or area, and rank ordered. For each job, an exposure range is presented, consisting of the "lowest" estimate and the "highest" estimate. In Attachments 2 and 5 the rank ordering is based on the high end of the exposure estimate for each job. Equal credence must be given to the low end estimates. The previously presented Tables 4 and 6 summarize the results by both high end and low end estimated values.

  Inspection of Table 4 indicates that 13-37 of the 150 jobs considered at Wood River exceed an estimated exposure potential of 2500 ppm-days per year. Table 6 indicates that 1-9 of the 96 jobs at Deer Park are in this category. The rank order lists reveal that in general the greatest benzene exposure potentials are associated vith earliest jobs (e.g., during the 1940's and 50's).

- Case history benzene exposures

  The study presents estimates of benzene exposure for 23 diagnosed leukemia cases, 14 from Wood River Refinery, seven from Deer Park Refinery, and tvo from Vood River Research. This information is presented in Attachments 3, 6, and 7. Because the cases are diverse in terms of reconstructed exposure history, careful study of the Case History Summaries is necessary. Many of the cases had periods (sometimes extensive) vhen estimated benzene exposure vas nil. Further, benzene exposure was normally intermittent, and

associated with specific tasks or conditions. Such exposures are more correctly identified as short-term or peak. For these reasons, career dose in ppm-drys may not be the most appropriate measure of exposure. As already noted, considering a ppm-day report as being representative of • daily time-weighted average (TWA) exposure is not necessarily correct. Consequently, the case history estimated exposures are presented in another format, designated Case History Summary. These case history summaries characterize benzene exposures for diagnosed leukemia cases as TWA's, or short-term exposures, or both, as appropriate for each job worked.

The predominant feature of the aggregate information is that likely benzene exposure vas nil to very low for a substantial portion of the cases, even if the highest exposure estimates are used. This is illustrated in the preceding Tables 5 and 7.

As previously cautioned, careful study of the exposure estimates in the Case History Summaries is necessary, giving appropriate consideration to intensity and intermittency of exposure, as well as latency periods. This is examined in more detail in Section II, Interpretation of Results.

- Highest benzene exposure jobs not reflected in leukemia cases

Of potential significance is that the highest benzene exposure jobs are not reflected in the work records of the diagnosed leukemia cases. For example, inspection of the rank order listing for Wood River Refinery (Attachment 2) reveals that certain jobs relating to the Cumenc Plant and Dodecyl Benzene Unit provided the greatest benzene exposures (i.e., in the range of 2000-10,000 ppm-days per year). Yet only one of the Wood River leukemia cases worked in these areas. Conversely, individuals who did work these jobs arc not among the leukemia cases revealed by the 1973-1982 study. This is somewhat surprising given the previous reports of positive associations between benzene exposure and the induction of leukemia in humans.

- Other factors

This study vas structured to estimate benzene exposure. Nevertheless, it is recognized that other workplace exposures may be of etiologic interest. In this regard, several observations are noteworthy.

(1) Three of the deceased leukemia cases from Wood River (one A!!) bad extensive work histories in an area known as the compounding house. In addition, tvo other cases had short-term (e.g., 3-6 months) assignments in compounding, one in 1931 (deceased) and the other in 1948-49 (living). Although no benzene vas encountered

in the compounding operations, opportunity for multiple-substance exposurt existed. This cluster Suggests additional study be directed towards compounding. No similar compounding operation exists at Deer Park.

(2) Commercial benzene (probably derived from coke oven benzene) was purchased by tank car at Wood River during 1943-45, and again during 1950-54. Additionally, coke oven benzene was delivered by tank trucks to Wood River during the period 1966-1963. The significance of this is not knovn.

B. Process

At the completion of task 3 at both Wood River and Deer Park, the participants were asked to critique the study. This yielded subjective comments, some presented herein to convey the "sense" of the participants.

- a general level of comfort with the estimated exposures, and the entire process.
- some concern that peak exposures may have been "over-remembered", possibly resulting in over-statement of "highest" exposure estimate. Consequently, there was generally more comfort with the "lowest" exposure estimate.
- some uneasiness regarding the relatively high estimated exposures for insulators (Wood River) and operator helpers, laborers, and pipefitters (Deer Park).
- Once the estimates of exposure for various jobs had been coc-pleted, the exposure estimates for the diagnosed cases was a relatively easy operation.

ATTACHMENTS

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ATTACHMENT 1

JOB EXPOSURE POTENTIAL ESTIMATES - WOOD RIVER REFINERY

JOB	PERIOD FROM	PERIOD TO	ESTIMATED RANGE - PPM-DAYS/YEAR JOB	TYPICAL INDIVIDUAL
CUMENE PLANT:				
OPERATOR	1943	1945	3600-8500	
OPERATOR HELPER	1943	1945	1800-4200	
SHIFT FOREMAN	1943	1945	1800-3800	
PIPEFITTER (ZONE)	1943	1945	2800-3900	350-750
INSTRUMENT MAN	1943	1945	2600-5400	650-1300
LABORER (ZONE)	1943	1945	3000-6400	200-450
INSULATOR (ZONE)	1943	1945	3000-6400	750-3300
MACHINIST (ZONE)	1943	1945	3500-7600	300-650
LABORER FOREMAN	1943	1945	800-1600	
PIPEFITTER FOREMAN	1943	1945	900-1600	
PIPEFITTER (S.D.)	1943	1945	300-600	
LABORER (S.D.)	1943	1945	350-650	
PF FOREMAN (S.D.)	1943	1945	250-550	
LABORER FMN (S.D.)	1943	1945	250-550	
CARPENTER	1943	1945	100-250	
DODECTL BENZENE:				
OPERATOR	1950	1954	4900-10,200	
OPERATOR HELPER	1950	1954	1700-3900	
SHIFT FOREMAN	1950	1954	2400-4800	
PIPEFITTER	1950	1954	2900-5800	450-900
INSTRUMENT MAN	1950	1954	1800-3800	
LABORER	1950	1954	1600-3600	250-600
INSULATOR	1950	1954	3400-7800	850-2000
MACHINIST	1950	1954	3300-6900	550-1100
LABORER FOREMAN	1950	1954	1300-2700	
PIPEFITTER FOREMAN	1950	1954	1300-2700	
CARPENTER	1950	1954	100-200	
COKE OVEN BENZENE RACK:				
LABORER (AROM. E. ZONE)	1966	1983	50	
OPERATOR (AROM. E.)	1966	1983	50-100	
PIPEFITTER (AROM. E. ZONE)	1966	1978	<50	
MACHINIST (AROM. E. ZONE)	1966	1978	<50	

NOTE: Shutdovn jobs are designated S.D.

ATTACHMENT 1 (cont'd)

JOB EXPOSURE POTENTIAL ESTIMATES - WOOD RIVER REFINERY

JOB	PERIOD FROM	PERIOD TO	ESTIMATED RANGE - PPM-DAYS/YEAR JOB	ESTIMATED RANGE - PPM-DAYS/YEAR TYPICAL INDIVIDUAL
LT. REFORMATE FROM CR-1 & CR-3 TO BEU:				
OPERATOR (LT. REFOR.) Aro E or W	1960	1963	<50	
OPERATOR (STAB. BTMS) Aro E or W	1960	1983	<50	
PIPEFITTERS Aro E or W	1960	1963	≤50	
MACHINISTS Aro E or W	1960	1963	<50	
DEISOHEXANIZER:				
OPERATOR	1960	1983	50-100	
PIPEFITTER	1960	1983	<50	
MACHINIST	1960	1963	<50	
TOLUENE 1 & 2:				
OPERATOR	1942	1960	850-1900	
OPERATOR HELPER	1942	1960	600-1300	
SHIFT FOREMAN	1912	1960	*400-950*	
INSULATOR	1942	1960	*400-950*	100-250
PIPETITTER	1942	1960	700-1500	100-250
BOILERMAKER	1942	1960	≤50	
MACHINIST	1942	1960	1150-2900	200-500
LABORER	1942	1960	300-800	50-150
INSTRUMENT MAN	1942	1960	200-550	50-150
CRAFT FOREMAN	1942	1960	250-550	
MACHINIST FOREMAN	1942	1960	250-550	
CARPENTER	1942	1960	≤50	

ATTACHMENT 1 (cont'd)

JOB EXPOSURE POTENTIAL ESTIMATES - WOOD RIVER REFINERY

JOB	PERIOD FROM	PERIOD TO	ESTIMATED RANGE - PPM-DAYS/YEAR JOB	ESTIMATED RANGE - PPM-DAYS/YEAR TYPICAL INDIVIDUAL
ARU UNIT:				
OPERATOR	1960	1966	3700-8100	
OPERATOR HELPER	1960	1966	1700-3600	
SHIFT FOREMAN	1960	1966	2000-3900	
PIPEFITTER	1960	1966	3200-6400	500-1000
BOILERMAKER	1960	1966	150-350	50-100
INSTRUMENT MAN	1960	1966	950-1900	
LABORER	1960	1966	1400-2800	300-550
MACHINIST	1960	1966	3000-6100	500-1000
INSULATOR	1960	1966	1900-3900	
CRAFT FOREMAN	1960	1966	1250-2500	
MACHINIST FOREMAN	1960	1966	1250-2500	
PIPEFITTER (S.D.)	1960	1966	100-300	
INSTRUMENT MAN (ZONE S.D.)	1960	1966	50-100	
LABORER (S.D.)	1960	1966	100-300	
MACHINIST (S.D.)	1960	1966	50-150	
INSULATOR (AREA S.D.)	1960	1966	<50	
BOILERMAKER (S.D.)	1960	1966	100-300	
PF FOREMAN (S.D.)	1960	1966	50-150	
BOILERMAKER FMN (S.D.)	1960	1966	50-150	
MACHINIST FMN (S.D.)	1960	1966	50-150	
LABORER FMN (S.D.)	1960	1966	50-150	
INSULATOR FMN (S.D.)	1960	1966	<50	

NOTE: Shutdown jobs are designated S.D.

ATTACHMENT 1 (cont'd)

JOB EXPOSURE POTENTIAL ESTIMATES - WOOD RIVER REFINERY

JOB	PERIOD FROM	PERIOD TO	ESTIMATED RANGE - PPM-DAYS/YEAR JOB	ESTIMATED RANGE - PPM-DAYS/YEAR TYPICAL INDIVIDUAL
BEU - 1966/74:				
OPERATOR	1966	1974	2100-5300	
OPERATOR HELPER	1966	1974	500-1150	
SHIFT FOREMAN	1966	1974	400-1050	
PIPEFITTER	1966	1974	1400-3500	300-700
BOILERMAKER	1966	1974	150-350	
INSTRUMENT MAN	1966	1974	550-1450	150-400
MACHINIST	1966	1974	1250-3200	200-550
LABORER	1966	1974	1400-2800	350-700
INSULATOR	1966	1974	1850-4400	950-2200
CRAFT FOREMAN	1966	1974	200-550	
MACHINIST FOREMAN	1966	1974	200-550	
PIPEFITTER (S.D.)	1966	1974	100-300	
MACHINIST (S.D.)	1966	1974	50-150	
BOILERMAKER (S.D.)	1966	1974	100-300	
INSTRUMENT MAN (ZONE S.D.)	1966	1974	≤50	
LABORER (S.D.)	1966	1974	100-300	
INSULATOR (ZONE & AREA S.D.)	1966	1974	≤50	
PF FOREMAN (S.D.)	1966	1974	≤50	
BOILERMAKER FMN (S.D.)	1966	1974	≤50	
MACHINIST FMN (S.D.)	1966	1974	≤50	
LABORER FMN (S.D.)	1966	1974	≤50	
INSULATOR FMN (S.D.)	1966	1974	≤50	

NOTE: Shutdown jobs are designated S.D.

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ATTACHMENT 1 (cont'd)

JOB EXPOSURE POTENTIAL ESTIMATES - WOOD RIVER REFINERY

JOB	PERIOD FROM	PERIOD TO	ESTIMATED RANGE - PPM-DAYS/YEAR JOB	TYPICAL INDIVIDUAL
BEU - 1975/79:				
OPERATOR	1975	1979	1100-2700	
OPERATOR HELPER	1975	1979	350-750	
STRAIGHT DAY OPER.	1977	1979	350-750	
SHIFT FOREMAN	1975	1979	200-050	
PIPEFITTER	1975	1979	800-1600	250-550
BOILERMAKER	1975	1979	150-350	
INSTRUMENT MAN	1975	1979	200-550	50-200
MACHINIST	1975	1979	750-1450	150-350
LABORER	1975	1979	900-2000	250-500
INSULATOR	1975	1979	1600-3200	800-1600
CRAFT FOREMAN	1975	1979	100-250	
MACHINIST FOREMAN	1975	1979	100-250	
PIPEFITTER (S.D.)	1975	1979	100-300	
MACHINIST (S.D.)	1975	1979	50-150	
BOILERMAKER (S.D.)	1975	1979	100-300	
INSTRUMENT MAN ZONE (S.D.)	1975	1979	50	
LABORER (S.D.)	1975	1979	100-300	
INSULATOR (ZONE AND AREA S.D.)	1975	1979	<50	
PF FOREMAN (S.D.)	1975	1979	≤50	
BOILERMAKER FMN (S.D.)	1975	1979	≤50	
MACHINIST FMN (S.D.)	1975	1979	≤50	
LABORER FMN (S.D.)	1975	1979	≤50	
INSULATOR FMN (S.D.)	1975	1979	<50	

NOTE: Shutdovn jobs are designated S.D.

ATTACHMENT 1 (cont'd)

JOB EXPOSURE POTENTIAL ESTIMATES - WOOD RIVER REFINERY

JOB	PERIOD FROM	PERIOD TO	ESTIMATED RANGE - PPM-DAYS/YEAR JOB	ESTIMATED RANGE - PPM-DAYS/YEAR TYPICAL INDIVIDUAL
BEU - 1980/83:				
OPERATOR	1980	1983	200-700	200-700
DAY OPERATOR	1980	1983	<50-100	<50-100
SHIFT FOREMAN	1980	1963	100-350	100-350
PIPEFITTER	1980	1963	100-350	<50-100
BOILERMAKER	1980	1963	50	50
MACHINIST	-1960	1983	550-1100	150-300
INSULATOR	1980	1983	350-1200	200-600
LABORER	1980	1963	200-600	100-300
INSTRUMENT MAN	1980	1983	200-650	100-300
HACHIKIST FOREMAN	1980	1963	150-300	150-300
CRAFT FOREMAN	1980	1983	150-300	150-300
PIPEFITTER (S.D.)	1980	1983	<50	<50
BOILERMAKER (S.D.)	1980	1983	<50	<50
LABORER (S.D.)	1980	1983	<50	c50
PF FOREMAN (S.D.)	1980	1983	<50	<50
BOILERMAKER FMN (S.D.)	1980	1983	<50	<50
MACHINIST FMN (S.D.)	1980	1963	<50	<50
LABORER FMN (S.D.)	1980	1983	<50	<50
INSULATOR FMN (S.D.)	1980	1963	<50	<50
DISPATCHING MAINT.:				
MACHINIST	1976	1963	<50	
MACHINIST	1966	1578	2050-2800	1000-1400
PIPEFITTER	1976	1983	<50	
PIPEFITTER	1966	1978	1100-2800	350-950
MAIN OIL 1 & 2 - DISPATCHING DEPT.:				
M.O. 1 & 2 OPERATOR & C-21 & C-22 GASOLINE OPERATOR (N.P. - COB)	1966	1972	250-800	
GASOLINE OPERATOR E-31 COB	1972	1982	50-100	
DISPATCHING (NORTH PROPERTY):				
BUTANE OPERATOR	1979	1983	<50	
BUTANE OPERATOR	1961	1979	150-300	

NOTE: Shutdown jobs are designated S.D.

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ATTACHMENT 1 (cont'd)

JOB EXPOSURE ESTIMATES - WOOD RIVER REFINERY

JOB	PERIOD FROM	PERIOD TO	ESTIMATED RANGE - PPM-DAYS/YEAR JOB	TYPICAL INDIVIDUAL
DISTILLATE OPERATOR - NORTH PROPERTY:				
DISTILLATE OPERATOR F-60	1979	1983	<50	
DISTILLATE OPERATOR F-60	1966	1978	100-300	
DISTILLATE OPERATOR A-138	1979	1963	<50	
DISTILLATE OPERATOR A-138	1960	1978	<50	
BENZENE TANK CAR UNLOADING:				
PUMPER 2ND	1943	1945	900-1950	
PUMPER 2ND OLD NATO RACK:				
LOADING TRUCKS	1960	1965	3600-9600	
BARGE LOADING OF BENZENE VIA TRUCKS & PIPELINE:				
LOADING OPERATORS	1960	1963	<50-100	
BARGE LOADING OPERATOR	1966	1979	*150-450*	
BARGE LOADING OPERATOR	1966	1965	50-150	
BARGE LOADING PIPEFITTER	1960	1966	100-300	
LOADING TANK CARS:				
LOADING RACK OPERATOR	1963	1978/79	500-900	
LOADING BENZENE TRUCKS:				
OPERATOR	1966	1979	1400-3300	

ATTACHMENT 1 (cont'd)

JOB EXPOSURE ESTIMATES - WOOD RIVER REFINERY

JOB	PERIOD FROM	PERIOD TO	ESTIMATED RANGE - PPM-DAYS/YEAR JOB	ESTIMATED RANGE - PPM-DAYS/YEAR TYPICAL INDIVIDUAL
CHEMIST - LUBE:	*1940*	1941	50-100	<50
	1942		100-150	50-100
	1943	1944	250-500	100-200
	1945		300-600	100-200
	1946	1949	100-250	50-100
	1950		650-1550	350-850
	1951		600-1500	350-800
	1952	1954	600-1500	350-850
	1955	1973	<50-100	<50
CHEMIST - ANALYTICAL:	1950		50-150	50-100
	1951	1954	50-100	50
	1955		350-850	50-150
	1956	1958	350-850	50-100
	1959	1960	50-100	<50
	1961	*1964*	200-400	<50
	1965		150-300	50
	1966	1970	150-300	50-100
	1971	1973	150-300	100-150

ATTACHMENT 1 (cont'd)

JOB EXPOSURE ESTIMATES - WOOD RIVER REFINERY

JOB	PERIOD FROM	PERIOD TO	ESTIMATED RANGE - PPM-DAYS/YEAR JOB	ESTIMATED RANGE - PPM-DAYS/YEAR TYPICAL INDIVIDUAL
1ST CLASS TESTERS:				
LUBE	1943	1954	1700-3500	1100-2200
	1955	1962	800-1600	150-300
ANALYTICAL	1943	1954	50-100	
	1955	1962	<50	
MOTOR LAB	1943	1948	4400-8750	1450-2900
	1949	1954	550-1050	200-400
	1955	1962	350-750	50-100
INSPECTION LAB	1943	1954	LOO-950	250-600
	1955	1962	150-400	50-100
SPECIAL TESTERS:				
LUBE	1943	1954	900-1800	250-500
	1955	1957	800-1600	150-250
INSPECTION	1943	1954	750-1450	500-1000
	1955	1957	250-500	50
	1960	1983	550-1100	50-150
HOTOR LAB	1949	1954	550-1050	250-450
	1955	1968	350-750	50-100
	1968	1963	100-200	<50
ANALYTICAL	1943	1954	200-2300	
	1955	1957	100-150	
	1960	1965	<50	
	1966	1983	50	
2ND CLASS TESTER:				
LUBE	1941	1955	1900-3750	
	1943	1954	1300-2600	1050-2100
	1955	1960	300-600	50-100
INSPECTION	1943	1954	1100-2200	800-1600
	1955	1960	400-800	100-200
ENTRY LEVEL (5TH CLASS) INSPECTION:	1941	1942	3400-6700	
	1963	1945	3000-9000	1400-3000
	1946	1954	6100-12,500	4300-6700
	1955	1960	2350-5100	600-1250
	1961	1963	900-2400	300-800
	1964	1970	750-1950	350-1000
	1971	1983	400-1250	

ATTACHMENT 2

JOB EXPOSURE POTENTIAL ESTIMATES - RANK ORDERED - OPERATIONS AND MAINTENANCE

WOOD RIVER REFINERY

Ranked By High End of Job Exposure Estimate

JOB TITLE	YEARS	PPY-DAYS PER YEAR JOE	PPY-DAYS PER YEAR TYPICAL INDIVIDUAL
DODECTL BENZENE OPERATOR	50-54	4900-10,200	
DISP. (NATO) 2ND C. PUMPER	60-65	3600-9600	
CUMENE OP.	43-45	3600-8500	
ARU OP.	60-66	3700-8100	
DODECTL BENZENE INSULATOR	50-54	3400-7800	850-2000
CUMENE MACHINIST ZONE	43-45	3500-7600	300-650
DODECPL BENZENE MACHINIST	50-54	3300-6900	550-1100
CUMENE LABORER ZONE	43-45	3000-6400	200-450
ARU PIPEFITTER	60-66	3200-6400	500-1000
CUMENE INSULATOR ZONE	43-45	3000-6400	750-3300
ARU HACHIKIST	60-66	3000-6100	500-1000
CUMENE PIPEFITTER ZONE	43-45	2800-5900	350-750
DODECYL BENZENE PIPEFITTER	50-54	2900-5800	450-900
CUMENE INSTRUMENT MAN	43-45	2600-5400	650-1300
BEU OPERATOR	66-74	2100-5300	
DODECTL BENZENE SHIFT FOREMAN	SO-54	2400-4800	
BEL' INSCWTOR	66-74	1850-4400	950-2200
CUMENE OPERATOR HELPER	43-45	1800-4200	
DCDECYL BENZENE OPERATOR HELPER	50-54	1700-3900	
ARC SHIFT FOREMAN	60-66	2000-3900	
ARU INSULATOR	60-66	1900-3900	
DODECYL BENZENE INSTRUMENT MAN	50-54	1800-3800	1750-3600
CUMENE SHIFT FOREMAN	43-45	1600-3800	
ARU OPERATOR HELPER	60-66	1700-3600	
DODECYL BENZENE LABORER	50-54	1600-3600	250-600
BEU PIPEFITTER	66-74	1400-3500	300-700
DISP. (TRUCKS) LOAD. OPER.	66-79	1400-3300	
BEU INSULATOR	75-79	1600-3200	800-1600
BEU MACHINIST	66-74	1250-3200	200-550
TOLUENE 1 & 2 HACHIKIST	L2-60	1150-2900	200-500
DISP HACHIKIST	66-78	2050-2800	1000-1400
ARU LABORER	60-66	1400-2800	300-550
DISP. PIPEFITTER	66-78	1100-2800	350-950
BEU LABORER	66-74	1400-2800	350-700
DODECYL BENZENE PIPEFITTER FOREMAN	50-54	1300-2700	
DODECYL BENZENE LABORER FOREMAN	50-54	1300-2700	
BEU OPERATOR	75-79	1100-2700	
ARU HACHIKIST FOREMAN	60-66	1250-2500	
ARU CRAFT FOREMAN	60-66	1250-2500	

ATTACHMENT 2 (cont'd)

JOB EXPOSURE POTENTIAL ESTIMATES - RANK ORDERED - OPERATIONS AND MAINTENANCE
WOOD RIVER REFINERY

Ranked By High End of Job Exposure Estimate

JOB TITLE	YEARS	PPH-DAYS PER YEAR JOB	PPH-DAYS PER YEAR TYPICAL INDIVIDUAL
BEU LABORER	75-79	900-2000	250-500
DISP. (NATO) PUMPER 2ND	43-45	900-1950	
ARU IKST. MAN	60-66	950-1900	950-1900
TOLUENE 1 & 2 OPERATOR	42-60	850-1900	
CUMENE PIPEFITTER FOREMAN	43-45	900-1600	
CUMENE LABORER FOREMAN	43-45	800-1600	
BEU PIPEFITTER	75-79	800-1600	250-550
TOLUENE 1 & 2 PIPEFITTER	42-60	700-1500	100-250
BEU INSTRUMENT MAN	66-74	550-1450	150-LOO
BEU MACHINIST	75-79	750-1450	150-350
TOLUENE 1 & 2 OPERATOR HELPER	h2-60	600-1300	
BEU INSULATOR	80-83	350-1200	200-600
BEU OPERATOR HELPER	66-74	500-1150	
BEL' HACHIKIST	80-83	550-1100	150-300
BEU SHIFT FOREMAN	66-74	600-1050	
TOLUENE 1 & 2 INSULATOR	42-60	400-950	100-250
TOLUENE 1 & 2 SHIFT FOREMAN	42-60	400-950	
DISP. Y/C LOAD RACK OP.	63-78/79	500-900	
TOLUENE 1 & 2 LABORER	42-60	300-800	50-150
DISP. MAIN OIL 1 & 2 OPERATOR-	66-72	250-800	
BEU ST. DAY OPERATOR	77-79	350-750	
BEU OPERATOR HELPER	75-76	350-750	
BEU OPERATOR	80-83	200-700	200-700
BEU INSTRUMENT MAN	80-63	200-650	100-300
CUMENE LABORER (S.D.)	43-45	350-650	
CUMENE PIPEFITTER (S.D.)	43-45	300-600	
BEU LABORER	80-83	200-600	100-300
CUMENE PF FOREMAN (S.D.)	43-45	250-550	
CUMENE LABORER FOREMAN (S.D.)	43-45	250-550	
TOLUENE 1 & 2 CRAFT FOREMAN	42-60	250-550	
TOLUENE 1 & 2 HACHIXIST FMN.	42-60	250-550	
BEU INSTRUMENT MAN	75-79	200-550	50-200
TOLUENE 1 & 2 INSTRUMENT PERSON	42-60	200-550	SO-150
BEU MACHINIST FOREMAN	66-74	200-550	200-550
BEU CRAFT FOREMAN	66-74	200-550	200-550
BEU SHIFT FOREMAN	75-79	200-450	
DOCK DISP. BARGE LOAD. OP.	66-79	150-450	
BEU BOILERMAKER	66-74	150-350	150-350
BEU BOILERMAKER	75-79	150-350	150-350
ARU BOILERMAKER	60-66	150-350	50-100
DISP. (N. PROP.) BUTANE OPER.	61-79	150-300	

NOTE: **Shutdown jobs are designated S.D.**

ATTACHMENT 2 (cont'd)

JOB EXPOSURE POTENTIAL ESTIMATES - RANK ORDERED - OPERATIONS AND MAINTENANCE

WOOD RIVER REFINERY

Ranked By High End of Job Exposure Estimate

JOB TITLE	YEARS	PPH-DAYS PER YEAR JOB	PPH-DAYS PER YEAR TYPICAL INDIVIDUAL
BEU SHIFT FOREMAN	80-83	100-3so	100-350
BEU PIPEFITTER	80-83	100-350	<50-100
BEU MACHINIST FOREMAN	80-83	150-300	150-300
BEU CRAFT FOREMAN	80-83	150-300	150-300
ARU BOILERMAKER (S.D.)	60-66	100-300	
BEU BOILERMAKER (S.D.)	66-74	100-300	
BEU PIPEFITTER (S.D.)	66-74	100-300	
BEU LABORER (S.D.)	66-74	100-300	
ARU PIPEFITTER (S.D.)	60-66	100-300	
BEU LABORER (S.D.)	75-79	100-300	
ARU LABORER (S.D.)	60-66	100-300	
BEU BOILERMAKER (S.D.)	75-79	100-300	
BEU PIPEFITTER (S.D.)	75-79	100-300	
DOCK DISP. BARGE LOAD. PIPEFITTER	60-66	100-300	
DISP. (N. PROP.) DISTIL. OPER. F-60	66-78	100-300	
BEU CRAFT FOREMAN	75-79	100-250	100-250
BEU MACHINIST FOREMAN	75-79	100-250	100-250
CUMENE CARPENTER	43-45	100-250	
DODECYL BENZENE CARPENTER	50-54	100-200	
ARU MACHINIST (S.D.)	60-66	50-150	
BEU MACHINIST (S.D.)	75-79	50-150	
BEU MACHINIST (S.D.)	66-74	50-150	
DOCK DISP. BARGE LOAD. OP.	60-65	50-150	
ARU BOILERMAKER FMN (S.D.)	60-66	50-150	
ARU PIPEFITTER FOREMAN	60-66	so-150	
ARU LABORER FMN (S.D.)	60-66	50-150	
ARU HACHINIST FMN (S.D.)	60-66	50-150	
DEISOHEX OPERATOR	60-83	50-100	
DISP. GASO. OPER.	72-82	50-100	
COKE OVEN BENZENE RACK OPERATOR AROH. E. ZONE	66-83	50-100	
BEU DAY OPERATOR	80-83	<50-100	<SO-100
DOCK DISP. BARGE LOAD. OP.	80-83	<50-100	
COKE OVEN BENZENE RACK LABORER AROH. E. ZONE	66-63	SO	
TOLUENE 1 & 2 CARPENTER	42-60	≤50	
BEU BOILERMAKER	80-83	50	50
BEU INSTRUMENT MAN ZOhZ (S.D.)	75-79	50	
BEU LABORER FMN (S.D.)	66-74	≤50	

NOTE: Shutdovn jobs are designated S.D.

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ATTACHMENT 2 (cont'd)

JOB EXPOSURE POTENTIAL ESTIMATES - RANK ORDERED - OPERATIONS AND MAINTENANC

WOOD RIVER REFINERY

Ranked By High End of Job Exposure Estimate

JOB TITLE	YEARS	PPM-DAYS PER YEAR JOB	TYPICAL INDIVIDUAL
BEU LABORER FMN (S.D.)	75-79	<50	
BEU PIPEFITTER FMN (S.D.)	66-74	<50	
BEU HACHIKIST FMN (S.D.)	66-74	<50	
BEU PIPEFITTER FMN (S.D.)	75-79	<50	
BEU MACHINIST FMN (S.D.)	75-79	<50	
BEU BOILERMAKER FMN (S.D.)	66-74	<50	
BEU BOILERWR FMN (S.D.)	75-79	<50	
LY. REF. CR-1/CR-3 PIPEFITTERS	60-83	<50	
TOLUENE 1 & 2 BOILERMAKER	42-60	<50	
DISP. (W. PROP.) DISTIL. OPER. F-60	79-83	<50	
BEU BOILERMAKER (S.D.)	80-83	<50	<50
BEU PF FOREMAN (S.D.)	80-83	<50	<50
BEU INSULATOR (ZONE AND AREA S.D.)	75-79	<50	
BEU BOILERMAKER FMN (S.D.)	80-83	<50	<50
BEU HACHIKIST FMN (S.D.)	80-83	<50	<50
BEU LABORER FMN (S.D.)	80-83	<50	<50
COKE OVEN BENZENE RACK HACHINIST AROM. E. ZONE	66-78	<50	
DEISOMEX MACHINIST	60-83	<50	
COKE OVEN BENZENE RACK PIPEFITTER AROM. E. ZONE	66-78	<50	
DISP. (N. PROP.) DISTIL. OPER. A-138	60-78	<50	
BEU INSULATOR FMN (S.D.)	66-74	<50	
ARU INSULATOR FMN (S.D.)	60-66	<50	
BEU INSULATOR FMN (S.D.)	75-79	<50	
DEISOMEX PIPEFITTER	60-63	<50	
LT. REF. CR-1/CR-3 BEU HACHIKIST	60-63	<50	
DISP. HACHIKIST	76-83	<50	
BEU LABORER (S.D.)	80-83	<50	<50
BEU INSULATOR FMN (S.D.)	80-83	<50	<50
BEU PIPEFITTER (S.D.)	80-83	<50	<50
LT. REF. CR-1/CR-3 BLU OPER. (LT. REF.)	60-83	<50	
DISP.. PIPEFITTER	76-83	<50	
LT. REF. CR-1/CR-3 BEU OPER. STAB. BTMS.	60-83	<50	
DISP. (N. PROP.) DISTIL. OPER. A-138	79-63	<50	
DISP. (N. PROP.) BUTANE OPER.	79-83	<50	

NOTE: Shutdovn jobs are designated S.D.

ATTACHMENT 2 (SUPPLEMENT)
JOB EXPOSURE POTENTIAL ESTIMATES - RANK ORDERED - LABORATORY
WOOD RIVER REFINERY

Ranked By Highest Job Exposure Estimate

JOB TITLE	YEARS	PPH-DAYS PER YEAR JOB	PPH-DAYS PER YEAR TYPICAL CRAFTSMAN
ENTRY LEVEL - INSPECTION	46-54	6100-12,500	4300-8700
ENTRY LEVEL - INSPECTION	43-45	3000-9000	1400-3000
1ST CLASS TESTER - MOTOR LAB	43-48	4400-8750	1450-2900
ENTRY LEVEL - INSPECTION	41-42	3400-6700	
ENTRY LEVEL - INSPECTION	55-60	2350-5100	600-1250
2ND CLASS TESTER - LUBE	41-55	1900-3750	
1ST CLASS TESTER - LUBE	43-54	1700-3500	1100-2200
2ND CLASS TESTER - LUBE	43-54	1300-2600	1050-2100
ENTRY LEVEL - INSPECTION	61-63	900-2400	300-800
SPECIAL TESTERS - ANALYTICAL	43-54	200-2300	
2ND CLASS TESTER - INSPECTION	43-54	1100-2200	800-1600
ENTRY LEVEL - INSPECTION	64-70	750-1950	350-1000
SPECIAL TESTERS - LUBE	43-54	900-1800	250-500
SPECIAL TESTER - LUBE	55-57	800-1600	150-250
1ST CLASS TESTER - LUBE	55-62	800-1600	150-300
CHEMIST - LUBE	1950	650-1550	350-850
CHEMIST - LUBE	52-54	600-1500	350-850
CHEMIST - LUBE	1951	600-1500	350-800
SPECIAL "ESTERS - INSPECTION	43-54	750-1450	500-1000
ENTRY LEVEL - INSPECTION	71-83	400-1250	
SPECIAL TESTER - INSPECTION	60-83	550-1100	50-150
1ST CLASS TESTER - MOTOR LAB	49-54	550-1050	200-400
SPECIAL TESTER - HOTOR LAB	49-54	550-1050	250-450
1ST CLASS TESTER - INSPECTION LAB	43-54	400-950	250-600
CHEMIST - ANALYTICAL	56-58	350-850	50-100
CHEMIST - ANALYTICAL	1955	350-850	50-150
2ND CLASS TESTER - INSPECTION	55-60	000-800	100-200
1ST CLASS TESTER - HOTOR LAB	55-62	350-750	50-100
SPECIAL TESTER - HOTOR LAB	55-68	350-750	50-100
CHEMIST - LUBE	1945	300-600	100-200
2ND CUSS TESTER - LUBE	55-60	300-600	50-100
CHEMIST - LUBE	43-44	250-500	100-200
SPECIAL TESTER - INSPECTION	55-57	250-500	50
1ST CUSS TESTER - INSPECTION LAB	55-62	150-400	50-100
CHEMIST - ANALYTICAL	61-64	200-400	<50
CHEMIST - ANALYTICAL	66-70	150-300	50-100
CHEMIST - ANALYTICAL	1965	150-300	50
CHEMIST - ANALYTICAL	71-73	150-300	100-150
CHEMIST - LUBE	46-49	100-250	50-100

ATTACHMENT 2 (SUPPLEMENT) (cont'd)
JOB EXPOSURE POTENTIAL ESTIMATES - RANK ORDERED - LABORATORY
WOOD RIVER REFINERY

Ranked By Highest Job Exposure Estimate

JOB TITLE	YEARS	PPM-DAYS PER YEAR JOB	TYPICAL CRAFTSMAN
SPECIAL TESTER - MOTOR LAB	68-83	100-200	<50
SPECIAL TESTER - ANALYTICAL	55-57	100-150	
CHEMIST - LUBE	1942	100-150	50-100
CHEMIST - ANALYTICAL	1950	50-150	50-100
CHEMIST - LUBE	40-41	50-100	≤50
CHEMIST - ANALYTICAL	51-54	50-100	50
CHEMIST - ANALYTICAL	59-60	50-100	<50
1ST CLASS TESTER - ANALYTICAL	43-56	50-100	
CHEMIST - LUBE	55-73	<50-100	
SPECIAL TESTER - ANALYTICAL	60-65	≤50	

ATTACHMENT 3

CASE HISTORY SUMMARIES
WOOD RIVER

Case history benzene exposure summaries are attached for the 14 diagnosed cases of leukemia at Wood River Refinery. The information presented is derived from the Report 2 Case Exposure forms prepared by the location task forces, and from detailed evaluation of the task 2B worksheets for the particular benzene exposure jobs. The following explanations are keyed to the superscript references in the summaries. Comment codes for the specific cases are at the end of the tables.

(1) Jobs uith no benzene exposure are not listed in the attached summaries. The complete job history for each case is available on the Report 2 Case Exposure forms, backed up by detail in the task 2D reports. Hovever, only those jobs with potential benzene exposure are listed in the Summaries. Consequently, some cases have no entry in the job column.

(2) Years in A particular benzene job are presented by month/year job began, month/year job ended, and (duration in years). For example, 6/48-9/52 (4.3).

(3) Since there was an attempt to identify all benzene exposures for a particular job, the 8-hour TWA calculation assumes no exposure for the balance of a shift when total time of exposure reported is less than a full shift. Short term exposures reported separately in the Case History Summaries are not included in the 8-hour TWA calculations.

(4) "Calculation Not Applicable" is entered in TWA or short-term exposure columns when a TWA or short-term exposure is not representative of the exposure pattern.

(5) "Could Not Be Estimated" is entered in the TWA or short-term exposure columns when the available infomation vas not sufficient to permit calculation.

(6) "None Determinable" is entered in the total exposure summary slot, when there is no basis to believe any career exposure existed. There will be a corresponding absence of numerical estimates in the Estimated Exposure (ppm-days) column.

(7) "Very slight" replaces "None Determinable" when exposure was possible, but too small to be calculated.

(8) This column represents total estimated exposure. When rounded and summed, it equals career total exposure.

Cases II and IX from Wood River are Research Laboratory cases. They are presented in Attachment 7.

The exposure estimates reported as 8-hour TWA or short-term levels are based on detailed evaluation of the Task 2(B) worksheets on the particular job. If the exposure from a particular task included > 3 hours, an 8-hour TWA was calculated. If the task occurred in a short time it was recorded as a short-term level. The 8-hour TWA estimates are not based on the peak data. They are two entirely separate estimates.

Also, it is possible in some casts that the exposure could not be characterized as either 8-hour TWAs or short-term levels, and does not show up in these tables. In those cases one cannot calculate the ppm-days based on the individual task exposure estimates.

Location
- ___ Deer Park
- X Wood River
- ___ Research

BENZENE HISTORICAL EXPOSURE STUDY
CASE HISTORY SUMMARY

CASE DATA				BENZENE EXPOSURE INFORMATION								
		Job(1)	Years(2)	Est.(8) Exposure ppm-days	8-Hour TWA(3) ppm	days/yr	Short Term ppm	min.	times/day	days/year	Comment Code
Case No.	I										
Years Worked	16 years										
Year 1st/Last Exp.	1956-1973										
Death Year/Age	1973/51										
Cause of Death	Acute myelomonocytic leukemia* (6)										
Tot. Exp. (ppm-Days)	None determinable (7) to very slight										
Case No.	III										
Years Worked	34 years										
Year 1st/Last Exp.	Not applicable										
Death Year/Age	1974/62										
Cause of Death	Chronic myelogenous leukemia										
Tot. Exp. (ppm-Days)	None determinable										
Case No.	IV	Carpenter	41/45 (2)	15-30	Calculation Not Applicable (4)		25-50	120	1	1	(A)
Years Worked	21 years						25-50	60	1	1	
Year 1st/Last Exp.	1942/1951	Carpenter	42/5-51 (7.3 excluding 43-45)	10-40	1.5-5 <1 (average)		1.5-5	120	1	1.5	(A)
Death Year/Age	1975/65				5-10 <1 (average)			Could Not Be Estimated (5)			
Cause of Death	Subacute myelocytic leukemia*							Could Not Be Estimated			
Tot. Exp. (ppm-Days)	25-70										

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Location
- ___ Deer Park
- X Wood River
- ___ Research

BENZENE HISTORICAL EXPOSURE STUDY
CASE HISTORY SUMMARY

CASE DATA — BENZENE EXPOSURE INF[illegible]

		Job[1]	Years[2]	Est. Exposure ppm-days	8-Hour TWA[3] ppm	8-Hour TWA[3] days/yr	Short Term ppm	Short Term min.	Short Term times/day	Short Term days/year	Comm. Cod.
Case No.	V										
Years Worked	30 years										
Year 1st/Last Exp.	Not Applicable										
Death Year/Age	1976/70										
Cause of Death	Acute monomyelocytic leukemia*										
Tot. Exp. (ppm-Days)	None determinable										
Case No.	VI	Electrical Draftsman, Elec. Motor Oiler	3-48/9-75	Very slight							
Years Worked	28 years										
Year 1st/Last Exp.	1948/1975										
Death Year/Age	1976/51										
Cause of Death	Leukemia										
Tot. Exp. (ppm-Days)	Very slight										
Case No.	VII	Asst. Boilermaker	42/1-47 (5)	75-150	5-10	2-3	Could Not Be Estimated				(B)
Years Worked	34 years	Foreman Boilermaker	1-47/3-54 (7.2)	110-210	5-10	2-3	Could Not Be Estimated				(B)
Year 1st/Last Exp.	1942/1957	Foreman Craft Foreman Boilermakers	3-54/1-57 (2.8)	45-120	5-10	2-3	Could Not Be Estimated				(B)
Death Year/Age	1977/75										
Cause of Death	Acute granulocytic leukemia*										
[illegible]	[illegible]										

*Classified AML

Location
- ___ Deer Park
- X Wood River
- ___ Research

BENZENE HISTORICAL EXPOSURE STUDY
CASE HISTORY SUMMARY

BENZENE EXPOSURE INFORMATION

		Job[1]	Years[2]	Est. Exposure ppm-days	8-Hour TWA[3] PPM	8-Hour TWA[3] days/yr	Short Term PPM	Short Term min.	Short Term times/day	Short Term days/year	Comm. Code
Case No.	VIII	Laborer/Yardman	43/45 (2)	630-930	11-26	20	10-25	15	3	20	(C)
Years Worked	18 years						50-150	15	2	20	
Year 1st/Last Exp.	1942/1961				0.25	20	Could Not Be Estimated				
Death Year/Age	1977/76		8-42/7-50 (6)	870-970	1-3	50	5-10	60	1	50	
Cause of Death	Acute myelocytic leukemia*		(excluding 43/45)		5-10	<1	Could Not Be Estimated				
Tot. Exp. (ppm-Days)	800-1900										
Case No.	X	Bottlewasher - Control Lab	5-40/6-40 (1 week)	50-100		--	50-100	120	1	250	
Years Worked	37 years						10-20	45	1	250	
Year 1st/Last Exp.	1940/1962										
Death Year/Age	1978/59	Inspection Tester 5th Control Lab	6-40/8-40 (2 months)	550-1100		--	50-100	120	1	250	
Cause of Death	Acute myelomono-cytic leukemia*						10-20	45	1	250	
Tot. Exp. (ppm-Days)	2500-5800	Special Tester/ Tester 1st, Inspection	5-48/54 (6.7)	1700-4000	1.5-3.8	50	5-10	5	1	50	
					1-2	200	10-25	5	2	50	
							10-25	10	2	50	
			55/62 (7)	200-600	7-17	50	5-10	5	1	50	
							10-25	5	2	50	
							10-25	10	2	50	

*Classified AML

BENZENE HISTORICAL EXPOSURE STUDY
CASE HISTORY SUMMARY

Location
- ___ Deer Park
- X Wood River
- ___ Research

CASE DATA		BENZENE EXPOSURE INFORMATION								
	Job(1)	Years(2)	Est. Exposure ppm-days(8)	8-Hour TWA(3) ppm	8-Hour TWA(3) days/yr	Short Term ppm	Short Term min	Short Term times/day	Short Term days/year	Comment Code
: No. XI	Yardman	42/60 (18)	360-950	1-3	20	5-10	60	1	20	(D)
rs Worked 31 years				5-10	<1	Could Not Be Estimated				
r 1st/Last Exp. 1941/1974										
th Year/Age 1978/65										
se of Death Chronic lymphocytic leukemia										
. Exp. (ppm-Days) 360-950										
e No. XII										
rs Worked 30 years										
r 1st/Last Exp.										
th Year/Age 1979/81										
se of Death Acute leukemia										
. Exp. (ppm-Days) None determinable										
e No. XIII	Laborer/Yardman	43-45 (2)	6000-13,000	11-26	250	10-25	15	3	250	(E)
rs Worked 24 years						50-150	15	2	250	
r 1st/Last Exp. 1943/1967	Labor Foreman	50-54 (4)	5200-11,000	Calculation Not Applicable		25-50	30	3	250	(F)
th Year/Age 1981/73						10-25	15	2	250	
se of Death Acute myelocytic leukemia*	Craft Foreman	1-57/60 (3)	800-1600	Calculation Not Applicable		5-10	45	2	250	(G)
						1.5-5	15	2		
				5-10	2-3	Could Not Be Estimated				
		60/7-66 (6.5)	8200-16000	Calculation Not Applicable		25-50	45	2	250	(G)
						5-10	15	2	250	
				10-25	2-3	Could Not Be Estimated				
	Engineering Foreman	7-66/2-67 (.6)	800-1400	Calculation Not Applicable		25-50	45	2	250	(H)
						5-10	15	2	250	
				10-25	1	Could Not Be Estimated				

*lassified AML

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Location
- ___ Deer Park
- X Wood River
- ___ Research

BENZENE HISTORICAL EXPOSURE STUDY
CASE HISTORY SUMMARY

CASE DATA		BENZENE EXPOSURE INFORMATION									
		Job[1]	Years[2]	Est.[8] Exposure ppm-days	8-Hour TWA[3] ppm	8-Hour TWA[3] days/yr	Short Term ppm	Short Term min.	Short Term times/day	Short Term days/year	Comments Code
Case No.	XIV										
Years Worked	22 years										
Year 1st/Last Exp.	Not applicable										
Death Year/Age	1982/64										
Cause of Death	Acute promyelocytic leukemia*										
Tot. Exp. (ppm-Days)	None determinable										
Case No.	XV										
Years Worked	26 Years										
Year 1st/Last Exp.	Not applicable										
Death Year/Age	Alive										
Diagnosis	Leukemia**										
Tot. Exp. (ppm-Days)	None determinable										
Case No.	XVI	Oper. 1st Aromatics East	10-66/2-83 (16.3)	640-1300	Calculation Not Applicable		5-10	30	1	120	(1)
Years Worked	33 years										
Year 1st/Last Exp.	1966/1983										
Death Year/Age	Alive										
Diagnosis	Chronic Lymphatic Leukemia										
Tot. Exp. (ppm-Days)	640-1300										

*Classified AML
**Diagnosis not confirmed.

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ATTACHMENT 4 (cont'd)

JOB EXPOSURE POTENTIAL ESTIMATES - DEER PARK REFINERY

JOB	PERIOD FROM	PERIOD TO	ESTIMATED RANGE PPM-DAYS/YEAR
GLC Tester	1960	1970	300-800
GLC Tester	1970	1983	<50
Cas Oil Tester	1952	1970	100-200
Gas Oil Tester	1970	1983	<50
R. I. Tester	1952	1970	50-200
R. I. Tester	1971	1973	<50
R. I. Tester	1973	1983	<50
Vapor Pressure Tester	1963	1970	150-350
Vapor Pressure Tester	1970	1983	<50
Sample Carrier	1936	1947	950-1650
Sample Carrier	1952	1956	250-450
Sample Carrier	1956	1970	50-400
Sample Carrier	1970	1973	150-500
Sample Carrier	1973	1979	<50
Sample Carrier	1979	1963	<50
Tester #5	1947	1952	600-1400
Tester #5	1952	1960	100-200
Tester #5	1960	1963	100-200
Recovery Operator	1948	1950	450-1400
Refrigeration Oper.	1948	1950	400-1650
Operator Helper (Lube)	1948	1950	900-9600
Filter Operator (Lube)	1948	1950	1400-9800
Rackman and Loader	1948	1950	<50

ATTACHMENT 4 (cont'd)

JOB EXPOSURE POTENTIAL ESTIMATES - DEER PARK REFINERY

JOB	PERIOD FROM	PERIOD TO	ESTIMATED RANGE PPM-DAYS/YEAR
Gauger (Lube C)	1948	1950	100-200
Pipefitter	1948	1950	150-300
Pipefitter	1950	1969	1900-3850
Pipefitter	1970	1975	2800-6300
Boilermaker	1948	1950	600-7S0
Boilemaker	1952	1970	800-1250
Laborer	1946	1952	800-3800
Laborer	1952	1963	1600-7600
Welder	1946	1963+	200
Carpenter	1948	1963	200
Instrument Men	1946	1983	700
fainter	1948	1963	550
Safety Inspector	1946	1975	250-750
Cargo Inspector	1952	1963	150-250
Cargo Inspector	1963	1980	200-350
Separator Treater Oper.	1946	1948	300-800
Separator Treater Oper.	1948	1950	350-850
Separator Treater Oper.	1952	1963	50-800
Separator Treater Oper.	1963	1976	750-950
CWT Pumper/Oil Rec.	1963	1977	150-350
Oil Recovery Operator	1963	1977	550
Oil Recovery Operator	1977	1963	850
Treater Oper./Env.	1976	1983	150

ATTACHMENT 4 (cont'd)

JOB EXPOSURE POTENTIAL ESTIMATES - DEER PARK REFINERY

JOB	PERIOD FROM	PERIOD TO	ESTIMATED RANGE PPM-DAYS/YEAR
Rover Operator	1976	1983	150-350
Pumphouse Pumper	1969	1975	200
Pumphouse/Tank Farm Pumper Gauger	1942	1976	300-1000
Dubbs 9 Operator	1944	1977	400

ATTACHMENT 5

JOB EXPOSURE POTENTIAL ESTIMATES - RANK ORDERED - DEER PARK REFINERY
Ranked By High End of Job Exposure Estimate

JOB TITLE	YEARS	PPH-DAYS PER YEAR
FILTER OPR (LUBE)	48-50	1400-9800
OPR HLPR (LUBE)	48-50	900-9600
LABORERS	52-63	1600-7600
PIPEFITTER	70-75	2800-6300
TREATER/GAUGER	56-65	1500-4600
TREATER OPR (ACU)	52-56	1150-4200
PIPEFITTER	50-69	1900-3850
ACU EAST-OPR	52-65	1300-3800
LABORERS	46-52	800-3800
SAMPLE CARRIER	36-47	950-1650
REFRIGERATION	48-50	400-1650
TANK CAR LOADER	60-78	800-1550
TESTER #5	47-52	600-1400
RECOVERY OPR	48-50	450-1400
ACU WEST OPR	55-65	1050-1300
ACU WEST OPR	52-55	1050-1300
BOILERMAKER	52-70	800-1250
CUMENE OPER	77-78	450-1200
ACU WEST OPR	65-76	750-1100
PUMP HOUSE/TANK FARM PUMPER GAUGER	42-76	300-1000
SEP. TREAT OPR	63-76	750-950
GAUGER/TF	Si-63	600-950
ACU EAST OPR	65-68	550-950
ACU E S T OPR	76-63	550-950
OIL RECOV. OPR	77-63	850
SEP. TREATER OPR	46-50	350-850
GLC TESTER	60-70	300-800
CUMENE OP (SHUTDOWN YEAR)	79-63	300-800
SEP. TREATER OPR	46-48	300-800
SEP. TREATER OPR	52-63	50-800
BOILERMAKER	48-50	600-750
ACU LAST OPR	68-76	500-750
SAFETY INSPECTOR	46-75	250-750
OFFSITE OPR	71-77	100-750
PLAT #2 GAUGER	56-71	100-700
INSTRUMENT MEN	48-63	700
REGENERATOR OPR	70-63	200-650
ACU GAUGER	65-75	400-600
ACU GAUGER	52-56	400-600

ATTACHMENT 5 (cont'd)

JOB EXPOSURE POTENTIAL ESTIMATES - RANK ORDERED - DEER PARK REFINERY
Ranked By High End of Job Exposure Estimate

JOB TITLE	EARS	PPH-DAYS PER YEAR
CUMENE OPR.	77-78	150-600
PAINTER	48-83	550
OIL RECOVERY OPR	63-77	550
BOTTLEWASHER	52-70	200-500
SAMPLE CARRIER	70-73	150-500
OFFSITE OPR	77-83	100-500
SAYPLE CARRIERS	52-56	250-450
FEED PREP OPR	70-81	250-450
T/T LOADING	72-78	200-450
T/T LOADING	60-72	200-450
FEED PREP. OPERATOR	70-81	250-450
GAUGER/TF	52-57	350-400
BEU OPERATOR	76-81	200-L00
DOCKMAN (BZ + PY. GAS)	77-83	150-400
BOTTLEWASHER	70-77	100-GO0
CUMENE OPR	79-83	100-400
SAYPLE CARRIER	56-70	50-400
DUBBS 9 OPR	44-77	400
PUMPER/GAUGER MAIN OIL	52-77	400
CARGO INSPECTOR	63-80	200-350
VAP. PRESS. TESTER	63-70	150-350
ROVER OPR	76-83	150-350
CWT PUMPER/OIL REC.	63-77	150-350
T/C LOADER	52-60	200-300
PIPEFITTER	48-50	150-300
ACU GAUGER	75-83	50-300
BOTTLEWASHER	47-52	150-250
CARGO INSPECTOR	52-63	150-250
GAUGER/TF	63-72	100-250
PIPEFITTER DUBBS 9(S/D)		50-250
GAS OIL TESTER	52-70	100-200
ACU EAST OPR	78-80	100-200
GAUGER (LUBE C)	48-50	100-200
TESTER #5	52-63	100-200
R.I. TESTER	52-70	50-200
WELDER	46-63	200
CARPENTER	46-83	200
PUMPHOUSE PUMPER	69-75	200
PIPEFITTER PLAT 1(S/D)	52-62	100-150
REACTOR OPERATOR	70-83	50-150
DOCKMAN	55-78	50-150
T/T LOADING	52-60	150
PLATFORMER #1 OPR	52-70	150
TREATER OPR/ENV.	76-83	150
PIPEFITTER-ACU(S/D)	52-60	50-100

ATTACHMENT 5 (cont'd)

JOB EXPOSURE POTENTIAL ESTIMATES - RANK ORDERED - DEER PARK REFINERY
Ranked By High End of Job Exposure Estimate

JOB TITLE	YEARS	PPH-DAYS PER YEAR
UVA TESTER	65-70	100
BOTTLEWASHER	77-83	<50-100
R.I. TESTER	71-73	<50
SAMPLE CARRIER	73-79	<50
GAUGER/TF	72-83	<50
RACKMAN/LOADER	48-50	<50
R.I. TESTER	73-03	<50
GAS OIL TESTER	70-83	<50
SAMPLE CARRIER	79-83	<50
CLC TESTER	70-83	<50
WA TESTER	70-83	<50
VAPOR PRESS. TESTER	70-83	<50

ATTACHMENT 6

CASE HISTORY SUMMARIES
DEER PARK

Case history benzene exposure summaries are attached for the seven diagnosed cases of leukemia at Deer Park Refinery. The information presented is derived from the Report 2 Case Exposure forms prepared by the location task forces, and from detailed evaluation of the task 2B worksheets for the particular benzene exposure jobs. The following explanations are keyed to the superscript references in the summaries.

(1) Jobs with no benzene exposure are not listed in the attached summaries. The complete job history for each case is available on the Report 2 Case Exposure forms, backed up by detail in the task 2D reports. However, only those jobs with potential benzene exposure are listed in the Summaries. Consequently, some cases have no entry in the job column.

(2) Sears in a particular benzene job are presented by month/year job began, month/year job ended, and (duration in years). for example, 6/48-9/52 (4.3).

(3) Since there was an attempt to identify all benzene exposures for a particular job, the 8-hour TWA calculation assumes no exposure for the balance of a shift when total time of exposure reported is less than a full shift. Short term exposures reported separately in the Case History Summaries are not included in the 8-hour TWA calculations.

(4) "Calculation Not Applicable" is entered in TWA or short-term exposure columns when a TWA or short-term exposure is not representative of the exposure pattern.

(5) "Could Not Be Estimated" is entered in the TWA or short-term exposure columns when the available information was not sufficient to permit calculation.

(6) "None Determinable" is entered in the total exposure summary slot, when there is no basis to believe any career exposure existed. There will be a corresponding absence of numerical estimates in the Estimated Exposure (ppm-days) column.

(7) "Very slight" replaces "None Determinable" when exposure was possible, but too small to be calculated.

(8) This column represents total estimated exposure. When rounded and summed, it equals career total exposure.

The exposure estimates reported as 8-hour TWA or short-term levels are based on detailed evaluation of the Task 2(B) worksheets on the particular job. If the exposure from a particular task included > 3 hours, an 8-hour TWA was calculated. If the task occurred in a short time it was recorded as a short-term level. The 8-hour TWA estimates are not based on the peak data. They are two entirely separate estimates.

Also, it is possible in tome cases that the exposure could not be characterized as either 8-hour TWAs or short-term levels, and does not show up in tbese tables. In those cases one cannot calculate the ppm-days based on the individual task exposure estimates,

ocation
X Deer Park
Wood River
Research

BENZENE HISTORICAL EXPOSURE STUDY
CASE HISTORY SUMMARY

		Job[1]	Years[2]	Est. Exposure ppm-days[8]	8-Hour TWA[3] ppm	8-Hour TWA[3] days/yr	Short Term ppm	Short Term min.	Short Term times/day	Short Term days/year	Comment Code
Case No.	1	Wldr Hlpr	11/52-6/62 (9.6)	900	0.75	20	200	15	1	12	
Years Worked	27 years	Disp-Log Rk	1962 (10 dys)	~38	12.5	10					
Year 1st/Last Exp.	1952/1981	Cat Cracker	1962 (1 mo)	2							(C)
Death Year/Age	1981/56	Coding Sys.	7/62-8/63 (1)	13-29							
Cause of Death	Chronic myelocytic leukemia	Docks (Hlpr)	1963 (2 mo)	8						250	
Tot. Exp. (ppm-Days)	3100-5100	Dubbs Dump Hse	1/64-9/66 (2.7)	825-2750	2.5	250	1.5-5	30	1	250	
		Aromatics/Plat 2	2/67-2/81 (14)	350	Calculation Not Applicable		50	5	2	250	
							50	15	1		
Case No.	II										
Years Worked	10 years										
Year 1st/Last Exp.											
Death Year/Age	1974/54										
Cause of Death	Acute myeloblastic leukemia*										
Tot. Exp. (ppm-Days)	None determinable										
Case No.	III	Clerk	2/56-2/60 (4)	<5 - 0							(D)
Years Worked	24 years										
Year 1st/Last Exp.	1956/1960										
Death Year/Age	1980/52										
Cause of Death	Preleukemia										

COMMENT CODES: (C) Subtracted strike time (~ 1 yr) as no exposure period.
(D) [illegible] during period worked as internal auditor with minimal exposure.

*Classified AML

Location
X Deer Park
___ Wood River
___ Research

BENZENE HISTORICAL EXPOSURE STUDY
CASE HISTORY SUMMARY

CASE DATA		BENZENE EXPOSURE INFORMATION									
		Job[1]	Years[2]	Est.[8] Exposure ppm-days	8-Hour TWA[3] ppm	8-Hour TWA[3] days/yr	Short Term ppm	Short Term min.	Short Term times/day	Short Term days/year	Comm. Cod.
Case No.	IV										
Years Worked	18 years										
Year 1st/Last Exp.											
Death Year/Age	1977/84										
Cause of Death	Acute myelogenous leukemia*										
Tot. Exp. (ppm-Days)	None determinable										
Case No.	V	Carpenter	2/41-1950 (9)	1800	50	20	200	15	1	12	
Years Worked	22 years				5	5					
Year 1st/Last Exp.	1941/1964	Carpenter	1950-4/64 (13)	1000	Calculation Not Applicable		200	15	1	12	(C)
Death Year/Age	1978/72	(Shop)									
Diagnosis	Chronic lymphatic leukemia										
Tot. Exp. (ppm-Days)	2800										
Case No.	VI	Welder Hlpr	7/35-2/39 (3.6)	90	*		200	15	1	12	
Years Worked	30 years										
Year 1st/Last Exp.	1935/1966		2/39-10/43 (4.7)	110							
Death Year/Age	1981/71										
Cause of Death	Acute myeloblastic leukemia*		1/46-9/66 (19.7)	3950	0.75	20	200	15	1	12	(C)
Tot. Exp. (ppm-Days)	4150				12.5	10					

COMMENT CODES: (C) Subtracted strike time (~ 1 yr) as no exposure period.

*Classified AML

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Location
X Deer Park
___ Wood River
___ Research

BENZENE HISTORICAL EXPOSURE STUDY
CASE HISTORY SUMMARY

CASE DATA				BENZENE EXPOSURE INFORMATION					
	Job[1]	Years[2]	Est.[8] Exposure ppm-days	8-Hour TWA[3] ppm	days/yr	Short Term ppm	min.	times/day	days/year	Comment Code
										(A)
No. VII	Numerous Short	3/34-9/43 (10.2)	250	Calculation Not						
rs Worked 39 years	Term Jobs in			Applicable						
r 1st/Last Exp. 1934/1973	Labor Pool/Disp.									
th Year/Age 1978/67										
se of Death Acute monocytic leukemia	Fire & Saf. Insp.	5/44-12/73 (28.5)	7150-	Calculation Not Applicable		25	15	as	96	(B)
. Exp. (ppm-Days) 7,400-21,700										
e No.										
rs Worked										
r 1st/Last Exp.										
th Year/Age										
se of Death										
se No.										
ars Worked										
ar 1st/Last Exp.										
ath Year/Age										
ause of Death										
ot. Exp. (ppm-Days)										

COMMENT CODES: (A) Est. exposure dose <50 ppm days/yr.
(B) Inspector issues permits/responds to emergencies/significant time in field--potential for peak exposures but difficult to characterize.

Classified AML

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ATTACHMENT 7

CASE HISTORY SUMMARIES
WOOD RIVER RESEARCH

Case history benzene exposure summaries are attached for the two diagnosed cases of leukemia at the Wood River Research Laboratory. The information presented is derived from the Report 2 Case Exposure forms prepared by the location task forces, and from detailed evaluation of the task 28 worksheets for the particular benzene exposure jobs. The following explanations are keyed to the superscript references in the summaries.

(1) Jobs with no benzene exposure are not listed in the attached summaries. The complete job history for each case is available on the Report 2 Case Exposure forms, backed up by detail in the task 2D reports. However, only those jobs with potential benzene exposure are listed in the Summaries. Consequently, some cases have no entry in the job column.

(2) Years in a particular benzene job are presented by month/year job began, month/year job ended, and (duration in years). For example, 6/48-9/52 (4.3).

(3) Since there was an attempt to identify all benzene exposures for a particular job, the 8-hour TWA calculation assumes no exposure for the balance of a shift when total time of exposure reported is less than a full shift. Short term exposures reported separately in the Case History Summaries are not included in the 8-hour TWA calculations.

(4) "Calculation Not Applicable" is entered in TWA or short-term exposure columns when a TWA or short-term exposure is not representative of the exposure pattern.

(5) "Could *Not* Be Estimated" is entered in the TWA or short-term exposure columns when the available information was not sufficient to permit calculation.

(6) "None Determinable" is entered in the total exposure summary slot, vhen there is no basis to believe any career exposure existed. There will be a corresponding absence of numerical estimates in the Estimated Exposure (ppm-days) column.

(7) "Very slight" replaces "None Determinable" when exposure was possible, but *too* small to be calculated.

(8) This column represents total estimated exposure. When rounded and summed, it equals career total exposure.

The exposure estimates reported as 8-hour TWA or short-term levels are based on detailed evaluation of the Task 2(B) worksheets on the particular job. If the exposure from • particular task included > 3 hours, an 8-hour TWA was Calculated. If the task occurred in a short time it—was recorded as a short-term level. The 8-hour TWA estimates are <u>not</u> based on the peak data. They are two entirely separate estimates.

Also, it is possible in tome cases that the exposure could not be Characterized as either 8-hour TWAs or short-term levels, and does not show up in these tables. In those cases one cannot calculate the ppm-days based on the individual task exposure estimates.

Location
- ___ Deer Park
- ___ Wood River
- X Research

BENZENE HISTORICAL EXPOSURE STUDY
CASE HISTORY SUMMARY

				BENZENE EXPOSURE INFORMATION							
						8-Hour TWA[3]		Short Term			
Case No.	Job[1]	Years[2]	Est. Exposure[8] ppm-days	ppm	days/yr	ppm	min.	times/day		Comment Code
Years Worked	11					Could Not Be Estimated				
Year 1st/Last Exp.	25 years	48/2-49 (1.1)	20-190	1.5-5	12					
Death Year/Age	1948/1973			<.5	238				238	
Cause of Death	1974/53	49/12-55 (6.8)	170-1700	<.8	238	1.5-5	10-30	1		
	Lymphocytic leukemia in acute blastic phase			1.5-5	12	Could Not Be Estimated				
Tot. Exp. (ppm-Days)	1300-10,400	56/12-59 (4)	300-3000	0.1-2	238	4.5-15	10-30	1	238	
				.5-15	12	Could Not Be Estimated				
		60/9-73 (13.8 excluding 5 mths)	840-5500	.8	200	1.5-5	10-30	1	200	
				.5-5	50	Could Not Be Estimated				

Location
___ Deer Park
___ Wood River
X Research

BENZENE HISTORICAL EXPOSURE STUDY
CASE HISTORY SUMMARY

CASE DATA		BENZENE EXPOSURE INFORMATION									
				Est.[8] Exposure	8-Hour TWA[3]		Short Term				Comments
		Job[1]	Years[2]	ppm-days	ppm	days/yr	ppm	min.	times/day	days/year	Code
Case No.	IX	Jr. Chemist,	6-41/9-43 (2.3)	1400-	1-14	225	5-50	60-120	1	275	
Years Worked	29 years	Analytical Bench		10,000	7-26	50	50-100	60	1	50	
Year 1st/Last Exp	1941/1970	Chemist									
Death Year/Age	1977/62	Synthesis Chemist	10-43/12-46 (3.2)	5300-	10-16	16 (total)	25-50	120	1	20 (total)	
Cause of Death	Leukemia reticulo-		(excluding 6	6300	16-28	4 (total)	50-100	60	1	50	
	endotheliosis		(weeks in 1944)		5	275		Could Not Be Estimated			
Tot. Exp. (ppm-Days)	10,000-26,000					(minus 20					
						days total					
						& changing					
						to 250 for					
						1946)					
		Project 100 Cetane	1944 (6 weeks)	240-1200	5-30	31.5 (total)	5-100	120	1	37.5 (total)	
		# Diesel Fuel			10-40	6 (total)	50-100	60	1	6 (total)	
		Cat Cracked Slurry	1947 (2 months)	260-1300	5-30	32 (total)	5-100	120	1	40 (total)	
		Oil Process			10-40	8 (total)	50-100	60	1	8 (total)	
		Lacquer Formation	1-47/12-49 (2.8)	870-1300	Calculation Not		50-100	60	1	12	
		Project	Also see 1974		Applicable						
			above								
		Rubber/TCP	1-50/12-51 (2)	1300-	4-8	100 (total)	25-50	60	1	125 (total)	
		Isomer		2800	10-20	25 (total)	50-100	60	1	50	
					1-4	16 (total)	5-25	60	1	20 (total)	
					7-16	4 (total)					
					0.5-1.5	284 (total)					
					7-14	71 (total)					

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Location
___ Deer Park
___ Wood River
X Research

BENZENE HISTORICAL EXPOSURE STUDY
CASE HISTORY SUMMARY

CASE DATA		BENZENE EXPOSURE INFORMATION							
	Job(1)	Years(2)	Est.(8) Exposure ppm-days	8-Hour TWA(3) ppm	days/yr	Short Term ppm	min.	times/day	days/year	Common Code
IX (cont.)	Combustion Chamber	·52/12-55 (4)	450-1600	0.5-1.5	250 (up to 6-54)	Could Not Be Estimated				
				<0.5-1	250 (after 6-54)					
	Electron Microscopy	1-56/9-62 (6.8)	<800	<0.5	250	Could Not Be Estimated				
	Strike Duty - Oper., Distillate Hydrotreater	9-62/1-63 (5 months)	<25	Could Not Be Estimated		Could Not Be Estimated				
	Electron Microscopy	2-63/12-70	200	0.1	250	Calculation Not Applicable				

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APPENDICES

TABLE OF CONTENTS

APPENDIX A

STEERING COMMITTEE FOR HISTORIC EXPOSURE STUDY

The Historic Exposure Study was performed under the direction of a Steering Committee comprising:

Head Office

D. S. McCraw - Corporate Medical
C. F. Phillips - Safety and Industrial Hygiene, P.E., CIH
J. D. Ransdell - Operations Safety and Health, CIH
J. L. Rivard - Safety and Industrial Hygiene

Wood River

W. M. Cunningham - P.E., CIH
R. M. Gerth - Management Representative

Deer Park

R. R. Erickson - Management Representative
P. J. Snyder - CIH

Consultant

K. J. Caplan - P.E., CIH - Industrial Health Engineering Associates

The Steering Committee reported to J. S. Szymanowski, Manager, Health and Safety, Manufacturing. The location work groups reported to the Steering Committee. A sub-group of the Steering Committee performed Task I - Study Development. This sub-group was comprised of D. S. McCraw, C. F. Phillips, J. D. Ransdell, J. L. Rivard, W. M. Cunningham and P. J. Snyder.

APPENDIX B

TASK DESCRIPTIONS FOR HISTORIC EXPOSURE STUDY

Attached are task descriptions for the benzene historic exposure study at Wood River and Deer Park, as originally prepared by the Steering Committee sub-group.

Task No.	TASK TITLE
2A	Conduct process reviews for units containing benzene
2B	Identify benzene related jobs
2C	Identify benzene related work practices
2D	Develop occupational personal histories of diagnosed leukemia cases
3	Perform historic exposure study

GUIDELINE
TASK 2(A) - CONDUCT PROCESS REVIEWS FOR UNITS CONTAINING BENZENE

Task 2(A) Purpose: Identify Benzene-containing units/areas and their respective histories for use by Task 2(B) in the evaluation of job exposures.

(1) Identify process streams and associated units (or portions of unit) or process areas (including shipping) with benzene content of: (1) <1%; (2) 1-5%; (3) 5-50%; and (4) 50-100%. This should be attempted from the earliest possible year and continued forward to the start of the Health Surveillance/JEP System, _____ (date for Wood River or Deer Park). Complete steps 2-7 for units/areas containing 75'6 benzene (5-50% and 50-100% groups), and for any unit or area in the 1-5% range that involved benzene loading operations (T/C, T/T, drums, marine) or similar "open" process. For validation, complete steps 2-7 for a selected unit/area in the 1-5% group.

(2) Record the period of operations (start-up to shutdown) for each benzene-containing unit or portion of unit identified. For units using or shipping benzene, establish the period of use or shipping by recording the beginning and ending (if applicable) dates.

(3) Identify; major emission sources in benzene-containing units, such as (specify dates):

(a) unflared vents and relief systems

(b) open top vessels/tanks/pits

(c) equipment subject to leaks, drips

(d) tank car/tank truck/drum and marine loading operations

(e) by-product/waste disposal

(f) process sample points (quality control testing)

(4) Identify major process changes in benzene-containing units, such as (specify dates):

(a) changes in capacity/throughput (expansions)

(b) changes in feedstock/products as related to benzene content

(c) changes in operating parameters like temperature and pressure

(d) changes in equipment--e.g., packing glands to mechanical seals for pumps, tie-in of vents and relief systems to flare systems, addition of closed-pipe maintenance-drop-out and decontamination systems, or any other changes to the emission sources identified in (3).

(e) changes in control rooms (open, closed, air conditioned, pressurized).

(5) Identify process flow diagrams, etc., which could facilitate steps (3) and (4). (Specify dates.)

(6) Estimate the mejor maintenance turnaround schedule for the benzene-containing units/processes.

(7) Use the attached worksheet as a suggested format for data reporting. Complete this step and provide data to other task groups.

(8) Identify adjacent or nearby industries that may have contributed to ambient exposure, with estimated dates (years), and principal exposure agents, including benzene, if known.

(9) Estimate number of emission sources in selected benzene units, per separate instructions to be supplied later (for fugitive emissions calculations).

TASK 2(A) WORKSHEET
(Suggested Format)

(1) Unit: _____

Start-up: _____

Shutdown: _____

(2) Major Modifications: (List with relevant date of change.)

(3) Benzene Sources:

(Equipment or Section)	% Bz	(List with relevant dates of any significant changes in benzene concentrations or process changes.)

(4) Major Emissions:

	% Bz	Relevant Dates

(5) Equipment Change:

	Date of Change

(6) Maintenance Turnarounds -- Estimated Frequency:

GUIDELINE
TASK 2(B) - IDENTIFY BENZENE-RELATED JOBS AND TASKS

(1) Using the infomation developed by Task 2(A), identify the jobs (operating, maintenance, and laboratory) over the years associated with the units/areas identified as containing benzene (5-50% and 50-100% groups, plus those 1-5% units involving "open" process).

(2) Using the "Exposure Description Worksheet", compile job/job ttsk information describing the sensory levels, frequency, and duration of tasks with exposures. (It should be noted that one job could have more than one worksheet, if there is either a major change in the unit with time, or a mcjor change in job duties with time). (Note: Begin this task by completing a worksheet on a modern-day, high-concentration benzene unit for which monitoring data rea available but do not review the monitoring data. Provide this first completed worksheet to the Steering Committee.)

TASK 2(D): EXPOSURE DESCRIPTION WORKSHEET (Maintenance)

For Job: _____ Unit/Area: _____ Years Covered: _____

Straight Days: _____ Rotating Shift: _____ Average Hours/Week: _____

Activities	Task Frequency[1]	Degree of Exposure[2] A	B	C	D	E	F	G	U	Total Time[3] of Task	Use of Personal Protective Equipment & Other Comments
1 Time in Control Room	___ per ___										
2 Time in Process Area (general).	___ per ___										
3 Time in Maintenance Shop	___ per ___										
4 Decontaminating Equipment	___ per ___										
5 First Opening of Equipment	___ per ___										
6 Entering Equipment	___ per ___										
7. In Vicinity of Spills, Leaks, etc.	___ per ___										
8. Clean-up of Spills, Fires, etc.	___ per ___										
9. Other:	___ per ___										

(1) Times per shift (S), day - 24 hrs. (D), week (W), month (M, year (Y). Enter "0" for none, or "U" for unknown.

(2) A: closed, no odor
B: odor present
C: visible liquid
D: eye irritation
E: respiratory irritation
F: narcotic effects such as headaches, nausea, dizziness, tiredness, loss of coordination, "drunk" or "high" feeling
G: liquid contact
U: unknown

(3) Total time (minutes, hours, or days) for the time period used in task frequency.

Summary (For Task 3 Use Only)

(1) Total Job exposure range _____ ppm-yr.

(2) Average worker exposure range _____ ppm-yr

(3) Noteworthy peak exposures (list):

_____

_____

_____

_____

TASK 2(D): EXPOSURE DESCRIPTION WORKSHEET (Operations)

For Job: _____ Unit/Area: _____ Years Covered: _____

Straight Days: _____ Rotating Shift: _____ Average Hours/Week: _____

Routine Activities	Task Frequency[1]	Degree of Exposure[2] A	B	C	D	E	F	G	U	Total Time[3] of Task	Use of Personal Protective Equipment & Other Comments
1. Control Room work.	____ per ____										
2. Time in process area (general)	____ per ____										
3. Gauging tanks	____ per ____										
4. Lab analysis	____ per ____										
5. Sampling	____ per ____										
6. Draining liquid for operations or maintenance.	____ per ____										
7. Drum/TT/TC loading.	____ per ____										
8. Other:	____ per ____										
Non-Routine Activities											
9. Bring unit up.	____ per ____										
10. Decontaminating equipment for shutdown.	____ per ____										
11. Entering vessels.	____ per ____										
12. Work in the vicinity of spills or leaks	____ per ____										
13. Other:	____ per ____										

(1) Times per shift (S), day - 24 hrs. (D), week (W), month (M), year (Y). Enter "0" for none, or "U" for unknown.

(2) A: closed, no odor
B: odor present
C: visible liquid
D: eye irritation
E: respiratory irritation
F: narcotic effects such as headaches, nausea, dizziness, tiredness, loss of coordination, "drunk" or "high" feeling
G: liquid contact
U: unknown

(3) Total time (minutes, hours, or days) for the time period used in task frequency

Summary (For Task 3 Use Only)

(1) Total job exposure range _____ ppm-yr.

(2) Average worker exposure range _____ ppm-yr.

(3) Noteworthy peak exposures (list):

_____

_____

_____

_____

GUIDELINE

TASK 2(C) - IDENTIFY BENZENE-RELATED WORK PRACTICES

1. Identify work practices which involved or related to benzene exposure and which would not necessarily be identified in Task 2(B). To assist in the identification, a listing of "Areas of Investigation" and example questions is attached. This listing is probably not complete, and the task force should not restrict its thinking to only the listing.

2. Using the "Work Practices Worksheet" record exposure information by job, craft, or units. A separate worksheet for each work practice is requested. A one-paragraph description of the work practice should be included on the worksheet. The description should identify such things as the amount of benzene used, how It was handled, where it was used, etc.

TASK 2(C) AREAS OF INVESTIGATION FOR IDENTIFYING WORK PRACTICES INVOLVING BENZENE OR BENZENE-RICH SUBSTANCES

- Use of benzene as a cleaning agent.
  - -- Degreasing.
  - -- Asphalt clean-out.
  - -- Washing hands/clothes/shoes/boots/gloves/coveralls.
  - -- Clerning too7s.

Ouestion

- Did we ever use benzene as a degreesing solvent? (When? Where? How?)
- Did we ever use benzene to clean tools or clothing?

- Employee take-home samples.

Question

- Did we ever take home samples of benzene or other substances for home use, either authorized or unauthorized? (If so, describe. Who used?)

- Use of benzene in T/T, T/C, drum lording.

Question

- Did we ever clean Ti's, TC's, or drums which contained benzene?
- Did we ever use benzene to clean TT's, TC's, or drums?

- Maintenance Shop usage.

Question

- Did Maintenance Shops use benzene as a cleaning/degreasing solvent?
- Did any maintenance shops have degreasing tanks or vats containing benzene?

- Use of benzene as a thinner.

Question

- Was benzene ever used as a paint thinner?
- Was benzene used as a paint stripper/remover?

- Laboratory usage.
  - Sample bottle washing.

Question

- Was benzene ever used in the bottle-washing process?
- Was benzene ever used in the laboratory for cleaning glassware?

- Oil and asphalt clean-up.

Question

- Was benzene ever used in the cleanup of asphalt or oil spills?

- Purchase/drumming for own use.

  -- Who used drums of benzene?

Question

- Did we ever purchase benzene? (If so, when, how much, who used?)
- Did we ever drum benzene for our own use?

- Use in a decontamination system or process.

Question

- Did we ever use benzene to decontaminate equipment, e.g., process equipment?

- Procedure for vessel entry.

Question

- What were the procedures for permitting entry into vessels/tanks in benzene service?
- How did we determine when conditions were safe for entry?

TASK 2(C) WORK PRACTICES WORKSHEET (Suggested Format)

Work Practice: _____ Description: _____

Jobs/Units Involved	Period From	Period To	Task Frequency(1)	Degree of Exposure(2) A	B	C	D	E	F	G	U	Total Time(3) of Practice	Use of Personal Protective Equipment & Other Comments
			___ per ___										
			___ per ___										
			___ per ___										
			___ per ___										
			___ per ___										
			___ per ___										
			___ per ___										
			___ per ___										
			___ per ___										
			___ per ___										
			___ per ___										

(1) Times per shift (S), day - 24 hrs. (D), week (W), month (M), year (Y). Enter "0" for none, or "U" for unknown.

A: closed, no odor
B: odor present
C: visible liquid
D: eye irritation
E: respiratory irritation
F: narcotic effects such as headaches, nausea, dizziness, tiredness, loss of coordination, "drunk" or "high" feeling
G: liquid contact
U: unknown

(3) Total time (minutes, hours, or days) for the time period used in task

GUIDELINE
TASK 2(D) DEVELOP OCCUPATIONAL PERSONAL HISTORIES OF DIAGNOSED LEUKEMIA CASES

(1) Develop specific infomation about each case's job history at Shell.

(a) Determine for each case:

- Job titles and dates of each.
- Areas where worked and the associated dztes.
- The type of work, duties, etc. In each job/area.
- Strike duty If applicable (staff).
- Any periods of layoffs, or absences due to military leave, strikes, etc. (specify dctes).

(b) Summarize the information from (a) into a profile of the case's Shell job history. Identify those portions of the job history asscciated with benzene exposure.

(2) Determine other workplace expcsures.

(a) Identify any exposure to materials from the "Suspect Leukemogen List" (attached).

(b) Identify the three most prevalent exposures (by 10-year periods).

(c) Identify any other exposures which seem significant.

(3) Determine case's work practices.

(a) Any use of benzene as a cleaning solvent, and if so, when and how used?

(b) Were product samples of benzene taken home for use?

(c) In general, how careful was the case in the handling of chemicals?

(4) Determine the following activities.

(a) Military duty if applicable (branch of service, where stationed, Type of duty).

(b) Employment prior to Shell.

(c) Employment during strike(s) and layoffs.

(d) Post-Shell employment.

(5) The information in (1) through (4) should be sought from employees and pensioners only.

(6) If in the course of completing (1) through (4) information about hobbies, part-time work, smoking history, etc., is volunteered, then such information should be noted. However, there should be no direct effort to discover infomation in those types of subject areas.

GUIDELINE
TASK 3 - PERFORM HISTORICAL EXPOSURE STUDY

(1) Full panel reviews the results (worksheets) of Tasks 2(B) and 2(C), merging 2(C) results with 2(B) results on a job basis for an overall job description of exposure.

(2) Selected panel memebers (at least I.H. consultant and location I.H.) calculate for eerh job the possible range of cumulative expcsure (dose) per year (e.g., ppm-days per year, ppm-hours per year, etc., whichever basis is most useful). These calcuations will be based on the sensory detection levels provided by Task 1. These dose estimates will be imprecise and will probably cover a wide range for most jobs. However, the dose estimates will provide a common basis for initially differentiating and rating job exposures in the step (3).

(3) The full panel reviews all estimated doses from (2) for rezsonableness by comparing and grouping jobs into logical categories of relative exposure. The number of categories will be determined by the panel. The panel must initially categorize on the basis of the dose estimates. After that step, the panel may adjust the categorization of any job which they feel can justifiably be moved from one category to another.

(4) The full panel assigns a dose-estimate (per year basis) to each category in (3). The dose-estimate for each category can be considered the most representative range for the jobs it includes. It should reflect the objective calculated doses from step (2) with modification by the panel's interpretations of the data and its underlying assumptions.

(5) The full panel should make basic judgements and rate (i.e., fill out a worksheet) other operating, meintenance, and laboratory jobs not already included in steps (1) through (4). These ratings should be based on the categories from step (3). An overview of information from Tasks 2(A), 2(B), and 2(C) will be necessary. The inclusion of these remcining jobs in the rating process is necessary in order to complete the evaluation of each case's work history from Task 2(D).

(6) The full panel should develop the exposure history for each case using the information from steps (3) through (5) and the results from Task 2(D).

APPENDIX C

TASK 3 PARTICIPANTS FOR HISTORICAL EXPOSURE STUDY

Wood River (Refinery)	Deer Park (Refinery)
K. J. Caplan	I. O. Baumgart
W. M. Cunningham	W. F. Bergerman
J. S. Fisher	W. P. Bourland
M. D. Hubbard	R. L. Bryan
K. E. Kieffer	K. J. Caplan
H. J. Leamy	C. R. Callaghan
P. J. Ltininger	C. W. Dorflinger
J. R. McNally	C. F. Phillips
J. D. Ransdell	M. W. Smith
J. N. Weshinskey	P. J. Snyder
L. A. Winterrowd	B. Starker

Discussion facilitator for both panels was P. Parker.

Outline For Task 3
Historic Exposure Study

Complete the benzene historic exposure study at Wood River and Deer Park by providing a panel at each location to evaluate and integrate the information gathered pertaining to benzene jobs (Task 2B), work practices (Task 2C), and case work histories (Task 2D). These panels will require five working days each, with Deer Park scheduled October 17-21, and Wood River October 24-28.

The following activities have been identified to structure the panels' deliberations. Suggested timing is approximate.

Activity	By	Time
Monday		
(1) Deliver "charge" to the panel	JLR	1.0 hours
(2) Overview of Task 2 work products– for familiarization	Loc. Rep.	0.3 hours
(3) Introduce 2B worksheets and product • review an example worksheet in detail • review dose calculation method and discuss limitations/problems • Present and explain approximate rank order listing of the jobs evaluated.	Loc. Rep.	0.7 hours
(4) Introduce 2C worksheets and product • review an example worksheet in detail • review titles of all worksheets - post • lead overview discussion of work practices	Loc. Rep.	1.0 hours
(5) "Process" the 2B worksheets • review each worksheet (use view-graph), discuss, and approve or adjust, per Report 1 form (adjustment calculations by IH's) • identify and consider applicable work practices for each job. Adjust per Report 1 form (adjustment calculations by IH's). • Continue, sheet by sheet, completing Report 1 form as you progress.	Facilitator	5.0 hours

Tuesday			
(5)	Continue activity (5) until complete.	Facilitator	8 hours
(6)	Prepare revised list per adjusted dose estimates (offsite, by others)		
Wednesday			
(7)	Review revised list	Facilitator	1 hour
(8)	Final review of benzene exposure jobs (a) Can you rank the benzene jobs from highest to lowest exposure? If yes, do so. (b) If no to (1), can you classify the benzene jobs into ranges of exposure? If yes, do so. (c) Can you provide comments for certain jobs, flagging such things as: • jobs that appear to be improperly placed • jobs where unusual peak exposures may have been encountered • other? (d) Prepare comments about list, in general (i.e. - how "good" is it? What are *it's* weaknesses? What could be done better?)	Facilitator	3 hours
(9)	Study 2D work product (2D work product handed out at this time)	(Private)	2 hours
(10)	Prepare case exposure history for each diagnosed case • review procedure that will be used • consider each case - prepare Report 2 form	Facilitator	2 hours
Thursday			
(10)	Continue activity (10) until complete	Facilitator	8 hours
Friday			
(11)	Prepare comments about case exposure history effort (i.e. - how "good" is it? What are it's weaknesses? Uhat could we have done better, or differently?)	Facilitator	2 hours
(12)	Review entire effort and prepare comments to assist interpretation, and identify weaknesses or areas for additional work	Facilitator	2-4 hours

APPENDIX E

SAMPLE 2B WORKSHEET AND CALCULATION

The attached Task 2(B) worksheet and calculation is a sample of the information processed for each job in the study.

In general a total dose estimate per year was arrived at for each job. Dose calculations were based on the following equation:

$$\frac{[C_1T_1F + C_2T_2F...]}{[T_1 + T_2.....]}[S]\ CAI\ [250\ days/year]$$

Where:

C = Reported benzene level in PPM for each task (0-200+ ppm)

T = Time estimated for each task (1-480 Minutes)

F = Frequency of task per shift

S = Fector used to adjust for frequency per shift

Tasks occurring each shift	S = 1
Tasks occurring 1X/day (3 shifts/day)	S = .33
Tasks occurring 1X/month	S = .01

A = An adjustment made to the estimates to either increase or decrease the dose value based on underestimated peak exposures. olfactory fatigue, workpractices, etc.

250 dayslyear was used as a standard index of days worked per year.

SAMPLE WORKSHEET

LETTER DESIGNATIONS UNDER "3" REFER TO AN ODOR RANKING INDEX, Eg. A = 1.5-5.0 PPM B = 5-10 PPM,..... AS DESCRIBED IN APPENDIX F, TABLES 2a AND 2b.

TASK 2(a): EXPOSURE DESCRIPTION WORKSHEET

For Job: Operator Unit Area: BTU Years Covered: 1976 to 1981

Straight Days: ____ Rotating Shift: X Average Hours/Week: 40

Activities	Task Frequency[1]	Degree of Exposure[2] A	B	C	D	E	I	G	H	Total Time[3] of Task	Use of Personal Protective Equipment & Other Comments
1 Control Room Work	1x per S		X							6 Hr.	
2 Outside Surveillance	1 per S		A							5-10 min. Ea. Time	
3 Sampling	2 per S			C	X					1 Min.	Samples run on GLC in Control Room Until Jan. 1983. Sample now run in unit lab. Vent hood provided but not always used.
Finished Benzene	___ per ___										
	___ per ___										
Equipment	per ___										
4 Pump Seal Failures	1 per H			C	X					5-10 min.	Drain to process sewer until MOV installed in 1979. No breathing equipment used unless massive leakage occurred.
	___ per ___										
5 Shutdown	1x per 2 Y			A	X					2 Hrs.	The operator is exposed to benzene odors in "A" range for 2 hrs. per shift during shutdown.
	___ per										
6 Start-up	1x per 2 Y			A-C						3 Hrs.	The operator is exposed to benzene odors in A-C range for 3 hrs. per shift during start-up.
	___ per										
11/82 Approx. 7 Unusual Massive Leakage	1x per U			A-D	X					each 8 Hr. 30 min.	Benzene tops air coolers developed a leak that continued for 3 or 4 days, area roped off, removed by vacuum truck. Breathing air equipment used in roped area.
	___ per ___										

(1) Times per shift (S), day = 24 hrs. (D), week (W), month (M), year (Y). Enter "0" for none, or "U" for unknown.

(2) A: closed, no odor
B: odor present
C: visible liquid
D: eye irritation
E: respiratory irritation
F: narcotic effect; such as headaches, nausea, dizziness, tiredness, loss of coordination, "drunk" or "high" feeling
G: liquid contact
H: unknown

Summary (for Task 3 Use Only)

(1) Total job exposure range ____ ppm-yr.

(2) Average worker exposure range (1)-386 ppm-yr.

(3) Noteworthy peak exposures (list):

Adjustments To Original Worksheet
-125 ppm-D/Yr. Background added
-25/4 Rule applied to 3,4,5,6
-Omit #7
-A's changed to B's for 2,5,6

OPERATOR - BEU
1976-1981

MAX

TASK	CONC	TIME	FREQ/SHIFT	FACTOR	CTA	FACTOR	DAILY AV./S. (125)
1	(0.5 ppm for 250)						
2	10	10	4		400		208.
3	25	1	2		50	1.75	45.57
4	25	10	.0.01		25	1.75	2.28
5	10	120	0.001		1.2	1.75	1.09
6	25	180	0.001		4.5	1.75	4.10
						TOTAL	386

- ADJUSTMENT ADDED FOR BACKGROUND LEVELS NOT DETECTED BY ODOR
- RANGE CALCULATED TO REFLECT MINIMUM AND MAXIMUM VALUES
- "S" FACTOR USED TO ACCOUNT FOR FREQUENCY PER SHIFT. 0.01 IS EQUIVALENT TO ONCE PER MONTH

MIN

TASK	CONC	TIME	FREQ/SHIFT	FACTOR	CTA	FACTOR	DAILY AV./S. (125)
1	(0.5 ppm for 250 days)						
2	5	5	4		100		52.08
3	10	1	2		20	1.75	1E.23
4	10	5	0.01		0.5	1.75	0.46
5	5	120	0.001		0.6	1.75	0.52
6	5	180	0.001		0.9	1.75	0.82
						TOTAL	197

- "A" ADJUSTMENT FACTOR APPLIED. A GROUP DISCUSSION CONCLUDED THAT 25% OF THE TIME THE EXPOSURE WAS 4X THE REPORTED VALUE.

→ 1976-1981 MAX · 386 ppm days/yr

MIN · 197 ppm days/yr.

(ROUNDED TO 200-400 RANGE IN FINAL REPORT)

APPENDIX F

BENZENE HISTORIC EXPOSURE STUDY

SENSORY PERCEPTION METHOD AND VALIDATION

Since no benzene monitoring data vere available for either location prior to the mid-70's, estimates of actual exposures were required. A search was conducted on information relating to human sensory effects of benzene but the limited data found dealt mostly vith exposures of 1-8 hours and very high exposures. The data gleaned from the search, Table 1, attached, were not very definitive, and of limited value. With the exception of the eye/nose irritation reference, no effects from short-term exposures were found.

In order to provide a consistent basis for the exposure estimates, empirical data, Tables 2a and 2b, were developed by the industrial hygienists and used as the basis for estimating benzene exposures. The table was developed by review of known exposure conditions and data, and also confirmed by checks with a Miran analyzer. The Table 2 data were adapted during use at both locations. These adaptations are discussed in Appendix G.

A validation study of this approach is presented in Table 3 attached.

In general, industrial hygiene monitoring data fit a log normal distribution where the geometric mean is the best estimate of average exposure and the geometric standard deviation is a measure of intraday variability. The 95% UCL (upper confidence level) will contain the true average exposure. The comparisons of the actual data vs. the estimates indicate a reasonable correlation and shows that they are in the same order of magnitude. In most cases the TWA ranges based on the estimates are higher than actual data.

In addition to the validity checks on the estimates, a data audit using an hygienist not involved in the study was also conducted to ensure consistency of data calculation and to spot check for mathematical errors.

TABLE I

BENZENE SENSORY DATA

	BENZENE CONC., PPM	DURATION Of EXPOSURE	EFFECT
(1)	1.5	Immediate	Odor Threshold
(2)	25	8 Hours	None
(3)	50-150	6 Hours	Headache, Lassitude, Weariness
(4)	100	Several Hours	Headache, Fatigue
(5)	500	1 Hour	Headache
(6)	1500	1 Hour	Depression
(7)	3000	Few Minutes	Eye/Nose Irritation (Tolerated for 30-60 Minutes)

REFERENCES:

(1) Handbook of Environmental Data on Organic Chemicals, K. L. Verschoeren

(2) Toxicology and Biochemist— of Aromatic Hydrocarbons, H. W. Gerarde

(3) Toxicology and Biochemistry of Aromatic Hydrocarbons, H. W. Gerarde

(4) Effects of Vapor Phase Pollutants on Nervous System and Sensory Function, R. I. Henkin, M.D.

(5) Toxicology and Biochemistry of Aromatic Hydrocarbons, H. W. Gerarde

(6) Effects of Vapor Phase Pollutants on Nervous System and Sensory Function, R. I. Henkin, M.D.

(7) Toxicology and Biochemistry of Aromatic Hydrocarbons, H. W. Gerarde

Effects of Vapor Phase Pollutants on Nervous System and Sensory Function, R. I. Henkin, M.D.

BASIS FOR SENSORY PERCEPTION
BENZENE EXPOSURE ESTIMATES

DEER PARK

DESCRIPTION OF ODOR EVENT	PPM ESTIMATE TO BE USED
A, NO LIQUID VISIELE BUT ODOR OF BENZENE IS DETECTABLE EXAMPLES DOWNWIND ODORS FUGITIVE EMISSIONS	1.5 - 5.0 PPM (3.0)
B. NO LIQUID VISIBLE BUT *AN* OBVIOUS SOURCE OF BENZENE VAPOR IS NEARBY EXAMPLES VESSELS, TANKS VENTS	5.0 - 10.0 PPM (7.5)
C. NO LIQUID VISIBLE, POSSIBLY STRONG OGOR AT TIMES	10 - 25 PPM 17.5
D. LIQUID VISIELE AND ODOR OF BENZENE IS PRESENT, POSSIBLY STRONG AT TIMES EXAMPLES T.T. LOADING CAUGING SAMPLE COLLECTION	25 - 50 PPM (37.5)
E. LIQUID VISIBLE, STRONG ODOR PRESENT, CONTACT WITH LIQUID	50 - 100 PPM (75.0)
F. ODOR AND/OR LIQUID CONTACT SO SIGNIFICANT SO AS TO REQUIRE "BACKING OUT OF IT" OR GETTING FRESH AIR	100 PPM + (200)
G. NO DETECTABLE ODOR	< 1.5 PPM

TABLE 2(b)

BASIS FOR SENSORY PERCEPTION BENZENE EXPOSURE ESTIKATES

WOOD RIVER

		PPM ESTIMATE TO BE USED
1.	NO LIQUID VISIBLE BUT ODOR OF BENZENE IS DETECTABLE. EXAMPLES: DOWNWIND ODORS FUGITIVE EMISSIONS	1.5 - 5.0 PPM (3.0)
2.	NO LIQUID VISIBLE BUT AN OBVIOUS SOURCE OF BENZENE VAPOR IS NEARBY. EXAMPLES: VESSELS, TANKS, VENTS	5.0 - 10.0 PPM (7.5)
3.	NO LIQUID VISIBLE, POSSIBLY STRONC ODOR AT TIMES.	10 - 25 PPM (17.5)
4.	LIQUID VISIBLE AND ODOR OF BENZENE IS PRESENT, POSSIBLY STRONG AT TIMES	4A. 25 - 50 PPM (37.5)
		4S. [redacted] - 75 PPM (50.0)
5.	LIQUID VISIBLE, STRONG ODOR PRESENT, CONTACT WITH LIQUID.	5A. 50 - 100 PPM (75.0)
		5E. 50 - 100 PPM (100.0)
6.	ODOR AND/OR LIQUID CONTACT SO SIGNI-FICANT SO AS TO REQUIRE "BACKING OUT OF IT" OR GETTING FRESH AIR.	&A. 150 - 200 PPM (175.0)
		6B. 150 - 400 PPM (275.0)
7,	NO DETECTABLE ODOR.	<1.5 PPM

TABLE 3
VALIDATION

JOB	ESTIMATED DATA: TIME PERIOD	ESTIMATED DATA: 28 DOSE RANGE PPM-DAYS/YR	ESTIMATED DATA: CALC. TWA RANGE PPM	MONITORING DATA: SAMPLES: TIME PERIOD	SAMPLES: NUMBER	SAMPLES: ARITH. AVG.	SAMPLES: MEDIAN	SAMPLES: TWA RANGE	$\bar{X}$ GEO. MEAN	SD GEO. TD. DEV.	UPPER RANGE $\bar{X}$ + 2SD	95% UPPER CONF. LIMIT OF X
Deer Park:												
BEU Operator	76-81	197-386	0.78-1.52	77-81	76	0.46	0.3	0.1-2.7	0.31	2.31	4.9	0.37
Coke Operator	77-78	150-586	0.6-14.8	77-78	20	0.83	0.1	0.1 9.5	0.18	2.99	6.2	0.28
Coke Operator	79-83	106-393	0.3-8.6	79-80	12	0.25	0.1	0.1-2.6	0.17	2.11	4.4	0.19
Dockman (Benzene)	75-83	157-362	0.4-8.0	78-81	15	3.01	1.85	0.2-10.0	1.96	2.86	7.7	3.07
Dockman (Pry. Gas)	79-83	9-53	0.42-2.75	80-83	20	0.83	0.1	0.1-5.4	0.19	3.40	7.0	0.30
ACU Gauger	75-83	36-275	0.14-1.10	77-83	94	0.27	0.2	0.1-1.5	0.20	2.16	4.5	0.23
Bottlecrisher	77-83	12-78	0.09-0.60 0.05-0.31	78-83	40	0.11	0.1	0.1-0.2	0.11	1.23	2.6	0.11
Wood River:												
BEU Operator	75-79	1,089-2,666	4.2-10.3	76-77	8	1.24	0.50	0.1-7.66	0.49	4.04	8.6	0.91
BEU Operator	80-83	195-648	0.75-2.5	80	2	0.35	0.35	0.1-0.6	0.24	3.55	7.3	1.07
Barge Load Oper	66-79	158-472	0.63-1.89	77-80	5	1.24	1.1	0.7-1.8	1.16	1.50	4.2	1.57
Op. Load Beck. Trucks	66-79	1,406-3,281	5.6-13.1	77-78	4	0.23	0.15	1.05	0.18	2.14	4.5	0.33
I/C Load Rack Operator	63-78/77	950 1 9	3.8-6.8	76-79	4	1.32	1.22	0.6-2.2	1.21	1.64	4.5	1.82
Spec Testers I A	60/66-83	67-134 25-70	0.1-0.54	77-83	8	0.41	0.3	0.1 1.0	0.30	2.39	5.1	0.50

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APPENDIX G

REVIEW OF SIMILARITIES/DIFFERENCES IN TASK 3 AT THE TWO LOCATIONS

Groups 2(b) and 3 used somewhat different approaches at the two locations to achieve similar end results. The folloving discussion covers the various aspects involved in applying the "sensory" factors.

1. Olfactory fatigue: Both Task 3 groups discussed the problem of clearly defining sensory perception because of potential influence of olfactory fatigue on the lower limit of detection. A specific literature search during the project development phase had not turned up any applicable information.

   Deer Park took olfactory fatigue into account in the Aromatics Unit where there were mixed exposures by upgrading the 2(B) sensory data level by one (i.e., the reported 'A' exposure was upgraded to a 'B' level). Wood River did not use any factor.

2. Benzene/hydrocarbon mixtures: Both locations realized that in situations where benzene was only a small percent of a mixed hydrocarbon stream the sensory reports could be significantly different than a pure or high percent benzene stream due to impact of the other components.

   Deer Park decided that if the streams had >5% benzene they would treat it as a benzene odor reaction but with <5% they would reduce the sensory category by one (or two in a few special cases). Wood River took the same approach but used A 15% benzene cut-off (they had almost no streams between 15 and 50%).

3. Peak or short-term exposures: Both Task 3 groups determined that the peak exposure sensory data on the 2(B) worksheets were not sufficiently indicative of the potential for higher peaks that probably occurred during a portion of the task reported. Both developed a factor to indicate a higher total dose from many of the tasks reported. These factors were applied on a case-by-case basis.

   Deer Park used what became known as the "25 and 4" Rule - 25% of reported exposure duration was calculated to be 4X the reported exposure level. This adjustment is equivalent to using A multiplication factor of 1.75 on the original exposure estimate.

   Wood River took a different approach that yielded very similar results. Categories 4, 5 and 6 were expanded on the high end and designated 4b, 5b and 6b (see Wood River table in Appendix F).

4. Background levels: Both locations considered the potential impact of lov level background levels of benzene, particularly where it would be belov the odor detection level.

Laboratory situations: Both considered laboratory operations which release benzene into the atmosphere. Dissipation is dependent on the air changes for the room. A general decay formula was used:

$$T = \frac{V}{Q} \ln \frac{C}{Co}$$

T = time
C = Conc.
Q = cfm
V = room volume, cf

Wood River used three air changes/hour for the period up to 1955, vhen significant ventilation changes were made in the lab. Deer Park used six air changes/hour up to 1970 vhen significant lab ventilation improvements were installed. Deer Park also added in a constant background level of 100 ppm-days/yr for certain situations; this factor was also used for some jobs known to be downwind of high benzene use units. In addition, in the Aromatics Unit a background level of 375 ppm-days/year (1.5 ppm 8-hour TWA for 250 days) was added in prior to installation of a pressurized control house and a level of 0.5 ppm (8-hr. TWA) on days when there were tasks involving gasoline handling operations.

Wood River also considered the impact of fugitive emissions from pumps and related equipment located in enclosed pump houses. These background levels were estimated.

5. Respirator use: Deer Park did not take respirator use into account and so all data reported are potential exposure without regard to respirator use. Wood River did take into account respirator use in the more current time frame.

6. Maintenance jobs: While there vas a difference(a) in the way 2(B) forms were filled out by the task groups, the final results are equivalent. For maintenance jobs, Deer Park calculated the exposure range for the average employee in that job category assuming random assignment to units. Wood River was more structured in terms of zone assignments and recognized the potential for an employee in a job category to spend significant time in a potential high benzene area. This resulted in two reported ranges; one for the job and one for the average employee (assuming more rotation). The job exposure would be the worst case situation for any given employee.

Wood River also reports specific shutdown exposure levels as separate jobs because Wood River craftsmen were assigned to special shutdown teams. In Attachments I and II, shutdown jobs are designated SD. In Deer Park, shutdown situations were included in calculating the average exposure.

(a) Deer Park reported total time for the task (i.e., task X freq/day). Wood River reported time per task. The final calculations would be the same in each situation.