

**LIVER STUDY OF WASHINGTON WORKS EMPLOYEES EXPOSED TO C-8:
RESULTS OF BLOOD BIOCHEMISTRY TESTING**

WILLIAM E. FAYERWEATHER

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Summary

Dr. Y. L. Power assembled biochemical data on some recent Washington Works employees. Based on a crude analysis of these data, the results suggested that certain workers with potential ammonium perfluorooctanoate (C-8) exposure might be showing liver effects. Also, several unpublished animal studies have shown that C-8 produces liver damage when it is given at moderate or high doses. As a consequence of these findings, a more detailed assessment of C-8's health effects in Washington Works employees was undertaken.

Data from routine blood tests were collected and compared among groups of Teflon® area and non-Teflon® area workers. SGOT, LDH, AP, and bilirubin were studied, since these tests are generally good for detecting liver disease. Within the Teflon® area, C-8 exposure groups were defined by work history and by blood organic fluoride level.

These data provided no conclusive evidence of an occupationally related health problem among workers exposed to C-8. Although initial analyses suggested that there might be liver effects attributable to C-8 exposure, further analyses did not support this position.

Background

The Teflon® area consists of two divisions: the Teflon® Polymers Division and the Teflon® Copolymers Division. The Teflon® Polymers Division produces tetrafluoroethylene (TFE) and hexafluoropropylene (HFP) monomers and Teflon® polymers. These polymers are made by batch processes. Ammonium perfluorooctanoate (C-8) is a dispersing agent added to nearly all of the polymer processes. The monomers do not contain C-8.

The Teflon® Polymers Division makes three types of polymer products: fine powder, dispersion, and granular. More C-8 is used for dispersion than for fine powder products. Granular products use less C-8 than do dispersion products. Two continuous driers remove nearly all the C-8 from fine powder, and washing and drying processes remove essentially all of the C-8 from granular products. Dispersion products contain roughly 0.3 percent C-8 based on solids.

The Teflon® Copolymers Division produces four copolymers, all of which contain TFE. Three of these copolymers are made by batch processes. The fourth, Tefzel®, is made by a continuous process. C-8 is added as a dispersing agent for all of the copolymers except Tefzel®. Fluorinated ethylene propylene (FEP), the major copolymer, makes up about 60 percent of the copolymer produced. FEP consists of TFE and hexafluoropropylene (HFP).

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The FEP polymerization process also generates an in situ dispersing agent. In June, 1976 the plant began adding C-8 dispersing agent to increase the reaction rate. This change reduced the amount of time needed for the process and also reduced the amount of in situ dispersing agent that was formed. However, some in situ dispersing agent is still formed in all FEP batches.

Until the FEP polymer reaches the humid heat treating ovens, it contains in situ as well as C-8 dispersing agent. FEP polymer is very dusty. So, in the processing steps between the FEP polymerizers and the ovens, there is significant potential for exposure to C-8 and in situ dispersing agents. FEP dispersion products contain in situ dispersing agent and about 0.1 percent C-8 based on solids.

In situ dispersing agent is not well characterized. It is believed to be a mixture of homologs of low molecular weight TPE - HPP compounds, some with acid end groups. On a weight basis it is less surface active than C-8.

Several unpublished animal toxicity studies done at 3M Corporation and at Du Pont have found that moderate and high dose levels of C-8 produced liver damage. Both reversible and irreversible liver damage, elevated liver enzyme tests, and enlarged livers were found. Study results depended on the dose level, exposure route, sex and species tested.

Dr. Y. L. Power assembled biochemical data on some current Washington Works employees who had had company physical examinations in 1978. Based on a preliminary analysis of these data, the results suggested that certain workers with potential C-8 exposure might be showing liver effects.

As a consequence of the previous animal studies of C-8 and of Dr. Power's preliminary findings, a more detailed assessment of C-8's health effects in Washington Works employees was undertaken.

Study Objective

The objective was to determine whether occupational exposure to C-8 adversely affects liver functions as measured by blood levels of glutamic oxaloacetic transaminase (SGOT), lactic dehydrogenase (LDH), alkaline phosphatase (AP), and bilirubin.

Note: These blood tests are neither 100% sensitive nor 100% specific for detecting liver disease. There are a number of circumstances under which the test may give false positive or false negative results. These circumstances are discussed at the end of the paper under Liver function tests: limitations.

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Methods

1. General design

Recent blood test results for SGOT, AP, LDH, and bilirubin were compared between C-8 exposed and non-exposed workers at Washington Works. Test results were studied by specific Teflon® area job and by blood fluoride level.

2. Selection of study groups

The initial group consisted of 96 Washington Works employees who were in one of the following Teflon® area jobs as of October, 1979:

- TFE process operator
- FEP process operator
- TFE service operator
- FEP service operator
- Laboratorian; monomer operator; Teflon® area engineer, chemist, or foreman.

This group included 78 workers who had been tested earlier in the year for blood fluoride levels.

Only TFE/FEP process and service operators were considered to have had significant potential for exposure to C-8. Monomer operators, semi-works laboratorians, and Teflon® area foremen were kept as a separate comparison group, since they worked in the Teflon area but had only limited C-8 exposure potential.

The number in this group was later dropped to 88, since 8 workers had not worked in the Teflon® area prior to their most recent blood test. These 8 workers were added to the non-exposed group (i.e., the control group).

For these 88 employees, J. P. Doughty gathered detailed Teflon® area work histories from plant records and from personal interviews. Work histories were copied to code sheets (table 1).

3. Selection of a nonexposed control group

The control group consisted of a 10% systematic sample of all active Washington Works employees who, as of August, 1979, had never worked in the Teflon® area. Mechanics and laboratorians were excluded from the controls, since their exposure potentials could not be well documented.

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The group was selected in the following manner: Dr. Y. L. Power pulled every tenth record from the plant's alphabetized medical files for active employees. These workers' names were then given to J. F. Doughty. From plant records and through personal interviews, Doughty obtained these workers' work histories. Workers who had worked in the Teflon® area or who had worked as mechanics or laboratorians were then dropped from the list. The remaining workers constituted the control group. Eight more workers were later transferred from the exposed to the control group, because these 8 had had no potential C-8 exposure prior to their most recent blood test.

4. Biochemical blood tests

As a part of routine physical examinations, each worker's blood is tested for 12 biochemical markers. These 12 tests are called the SMA-12.

From plant medical records, every SMA-12 on the exposed and control workers was copied to code sheets (table 2). All SMA-12 tests had been performed by the same laboratory and by the same methods. Very few SMA-12's had been done before 1974-75. Every worker's most recent SMA-12 had been done since 1977. Only tests pertaining to the liver were studied. These included the SGOT, AP, LDH, and bilirubin.

5. Blood fluoride levels

Prior to this study, blood fluoride levels had been measured on 78 of the plant's Teflon® area workers and on 25 Wilmington office workers. Blood fluoride measurements had been made at Jackson Laboratory by the 3M (bomb) method. Most of the workers tested at the plant had had potential C-8 exposure. Liver function test results were analyzed according to blood fluoride levels.

6. Statistical methods

SMA-12 results were studied by exposure status, by specific Teflon® area job, and by blood fluoride decile. Analyses were based on (1) test means and (2) the proportion falling into the highest liver function test decile. The highest decile was defined as the range in which the top 10 percent of all control and exposed groups' test values lie. On the average, then, one would expect that 10 percent of the control group's values would fall into this decile. Unless stated otherwise, test values were from the worker's most recent SMA-12.

Group differences in Biochemistry test means were studied by analysis of covariance and least significant difference tests (LSD). This analysis adjusted for any group differences in age or sex. The statistical significance of differences in proportions was assessed by Fisher's exact test. Two-tail tests were performed, and p-values less than 0.10 were reported.

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Results

1. Test validation

Dr. Y. L. Power provided preliminary data on the SMA-12 results for 1978 (table 3). These data showed that the plant population as a whole had an unusually large percentage of elevated SGOT's. SGOT's were elevated in 19 percent of the workers whereas elevations would only have been expected in about 5% based on random statistical variation. AP, bilirubin, and LDH tests showed plant-wide elevations in 8, 4, and 3 percent of the workers, respectively.

The large, plant-wide elevations in SGOT's suggested one of two things. Either workers in many different areas were affected, or the plant's SGOT test was invalid.

Dr. Power took two steps to validate the SGOT test. First, he took blood samples from about 100 workers and sent half of each blood sample to the standard laboratory (General Consultants, Inc.) and the other half to an Upjohn Laboratory to be tested. When the results of the standard laboratory were plotted against the results of Upjohn (figure 1), the two laboratories were correlated. High SGOT's at the standard laboratory were high at Upjohn, and low SGOT's at the standard were low at Upjohn.

However, at all SGOT levels the standard laboratory's value was higher than Upjohn's. Furthermore, about 16 percent of the standard laboratory's values were "abnormal," whereas none from Upjohn fell in the "abnormal" range.

Dr. Power also had the standard laboratory use a second method (manual enzymatic) to reanalyze samples that showed elevated SGOT's by the first method (automated colorimetric). In the 22 retested samples, only one sample was found to be elevated by the second method (table 4). When the results of the first method were plotted against the second, the results were correlated (figure 2).

The interlaboratory and intermethod comparisons suggested that

- SGOT's measured at the standard laboratory by the standard method were systematically higher than the true blood levels.
- By the standard method the standard laboratory's observed range for "normal" SGOT values was considerably higher than the stated normal range.
- Valid SGOT level comparisons can be made between exposed and nonexposed groups, provided that test

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means or the proportion falling into the highest test decile are used. Since SGOT levels were correlated between laboratories and between methods, valid between-group comparisons are possible.

2. Liver tests by job

TFE process workers' mean SGOT of 45 was higher than the control group's mean of 39. FEP service and process workers' mean AP's of 101 and 81, respectively, were higher than the control group's mean of 64. These differences were statistically significant at the 0.05 probability level (table 5). Similarly, FEP process and FEP service workers had significantly ($p < 0.05$) larger proportions of the AP values falling into the highest test decile (table 6).

There were no other significant differences between Teflon® area workers and controls with respect to SGOT, AP, bilirubin, or LDH.

3. Liver tests by blood fluoride level

The mean SGOT for the highest blood organic fluoride decile was significantly higher than the mean for the lower nine deciles (52 vs 40, respectively). However, when the data were broken down into individual organic fluoride deciles, the data did not show a typical, steadily rising dose-response curve (tables 7 and 8). In fact, the second and third highest mean SGOT's were found in the first and third deciles. It is still possible, however, that the high SGOT's seen in the highest decile are somehow related to these workers' organic fluoride levels -- the highest decile could be the effect/no effect threshold.

AP, LDH, and bilirubin showed no unusual elevations when compared by organic fluoride decile. Likewise SGOT, AP, LDH, and bilirubin showed no relationship to inorganic fluoride levels.

4. Blood fluoride level by job

TFE process operators made up about one third of the 78 workers tested for blood fluorides. But when the 16 workers from the two top organic fluoride deciles were listed by Teflon® area, 12 of the workers had been TFE process operators at the time they were tested. Four others had worked as TFE process operators within 1 to 2 years prior to the time they were tested. The number of years of working with C-8 or of working in the Teflon® area did not appear to be related to organic fluoride level (table 9). In fact, the third highest organic fluoride level was measured in a worker having less than 3 years experience with C-8.

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These data suggest that TFE process operators have the highest potential for exposure, and that only 3 years of C-8 contact may be sufficient to elevate blood organic fluoride levels. TFE process operators usually have more service than TFE service operators.

Blood inorganic fluoride level and Teflon area assignment appeared to be unrelated. The highest inorganic fluoride levels occurred in TFE and FEP process operators, monomer operators, and semiworks laboratorians (table 10). Wilmington office workers' blood fluoride levels have been included for comparison; their levels should represent the norm for workers who are not occupationally exposed to fluorides (table 11).

5. Liver tests by job: differences between before and after exposure

Very few workers had liver tests that were done before and after exposure began. Since the workers having both before and after tests may have been a select group, the results of these comparisons should be treated with caution.

The before and after C-8 exposure comparisons weakly suggest that FEP process and FEP service workers' AP levels may have risen following C-8 exposure (table 12). This result supports the earlier observation that FEP workers' most recent AP levels were higher than the control mean. However, these two observations are not independent.

TFE process and TFE service operators showed no unusual before and after differences with respect to SGOT, AP, LDH, or bilirubin. The result does not support the earlier observation that SGOT was elevated in TFE process workers.

All "after" tests were based on the worker's most recent physical examination. For exposed workers, the "before" tests were based on the worker's most recent physical examination prior to moving into the C-8 exposed job. In the control group, the "before" tests were based on the worker's physical examination immediately prior to his 1979 physical.

Discussion

Based on the data above, there is no conclusive evidence of an occupationally related health problem among workers exposed to C-8.

Some of the SGOT data suggested that there might be a liver effect among certain C-8 exposed workers. The mean SGOT for the TFE process operators was significantly ($p < 0.05$) higher than the non-Teflon® area control mean. TFE process operators as a group had considerably higher organic fluoride blood levels than other Teflon® area workers. Workers in the highest organic fluoride decile had a significantly higher SGOT mean than workers in the lower nine deciles.

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However, in other respects SGOT showed poor correlation with organic fluoride level and with C-8 exposure.

- Teflon® area workers with little or no C-8 exposure had a mean SGOT that was nearly as high as the TFE process operators' mean. Since Teflon® area workers with little or no C-8 exposure also had the lowest blood organic fluoride levels, their elevated SGOT could not realistically be caused by C-8 exposure.
- Workers from the third lowest blood organic fluoride decile had an SGOT mean that was nearly as high as the top decile's mean.

Other puzzling findings were that neither AP, LDH, nor bilirubin means were elevated among TFE operators. If a patient truly had a chemically induced liver disease, one would expect one or more of these other blood tests to be elevated.

Mean AP was significantly ($p < 0.05$) higher among FEP service and FEP process operators. Yet none of the other blood tests were elevated among these workers, and AP did not correlate with blood organic fluoride levels.

It seems very unlikely that a single material would raise only SGOT levels in one worker group and raise only AP levels in another worker group. More likely explanations for the SGOT and AP elevations are:

- The elevations resulted from chance events and were not causally related to C-8 exposure.
- Certain unmeasured confounding factors such as alcohol consumption or drug use may have influenced the blood test results.

It is also possible, however remote, that occupational exposures to other toxic materials were responsible for the observed elevations. For instance, acute and chronic exposure to inorganic fluorides can produce osteomalacia, a bone disease. This bone disease is often associated with elevated levels of serum AP.

Liver function tests: limitations

Bilirubin, SGOT, AP, and LDH assess different components of a liver's health and function. Only serum bilirubin is a true liver function test. SGOT, AP, and LDH are actually enzymes that are normally present at moderate levels in the serum. They may attain higher levels after various types of liver damage have occurred. SGOT and LDH leak out of damaged liver cells and into the blood stream. Elevated AP levels, on the other hand, appear to result from damaged liver cells synthesizing and releasing more enzyme.

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When assessing positive and negative test results, several points should be kept in mind:

- The liver has a large functional reserve and a great capacity to regenerate itself after it has been damaged. Studies have shown that within about a week after having removed over 80 percent of a rat's liver, one can find a liver of essentially normal weight and function. Consequently, mild and sometimes moderate liver injury often may not be accurately reflected by changes in liver function tests.
- Some liver functions are much more sensitive to injury than others. Thus, some liver functions (and function tests) may show changes while others do not.
- There is no one single test or procedure that effectively measures the total function of the liver.
- There is no direct quantitative correlation between the amount of liver cell injury and the height of serum enzyme levels. However, higher levels are generally found with more severe injury.
- If the serum enzymes are measured sometime after the acute insult or injury, the initial rise may have been missed. Thus, normal or low serum enzyme levels may be found as a consequence of a decreased functioning liver cell mass. Similarly, certain types of cirrhosis are associated with only slightly elevated or even normal SGOT levels.
- SGOT, AP, and LDH may be elevated from causes other than liver damage. For instance, most of the AP present in normal serum is derived from the bone. High levels of AP occur in patients with bone diseases characterized by osteoblastic activity. These include rickets, osteomalacia, and healing fractures. Growing children and pregnant women in the third trimester have elevated serum AP levels.

SGOT and LDH may also be elevated in patients during episodes of acute myocardial infarction, cardiac arrhythmias, congestive heart failure, pericarditis, and pulmonary infarction.
- There are other enzyme tests that are more sensitive to certain types of liver disease than are SGOT, AP, and LDH. One of these is gammaglutamyl transpeptidase (GGT). This enzyme is elevated in

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the serum of almost all patients with hepatobiliary disorders. It is the most sensitive test for alcoholic liver disease.

- A liver test's sensitivity can be defined as the ability to correctly identify persons who have liver disease. Specificity can be defined as the ability to correctly identify persons who do not have liver disease. Sensitivity and specificity have not been adequately studied for liver function tests.

"While a large amount of information is available concerning biochemical measures of acute hepatic injury, we have limited data about the effects of chronic lesions on the biochemical tests and on the sensitivity of these tests in detecting chronic injury or the sequelae of acute injury" (Guidelines for the Detection of Hepatotoxicity Due to Drugs and Chemicals. NIH Publication No. 79-313. Oct. 1979. pp. 33-34).

- Liver function tests are most useful if they can be used serially to assess health before, during, and after exposure. So-called "abnormal" values for one individual may be "normal" for another.

Normal/abnormal dichotomy vs the continuous approach

The basis for classifying a liver test value as normal or abnormal can be either functional or statistical. On a functional basis, any value could be considered normal if there were no increased risk associated with it. On a statistical basis, a normal value could be any one that fell within the limits in which X percent (e.g., 95%) of the population fell.

There is a major disadvantage to classifying continuous measurements as normal or abnormal: it oversimplifies a complex problem. Disease and health lie along a continuum. For instance, even within the central 95% of the total range of blood pressures, there is a gradient such that persons at the upper end are at a greater risk of coronary heart disease or stroke than those at the lower end. A similar situation may also hold for liver function tests. Thus, analyses based on group means most often use the data more efficiently than analyses based on the percent "abnormal".

A possible theoretical advantage to the dichotomous approach is that it might be more sensitive to "outliers", values on the high side of normal, than is an analysis of means. However, in animal toxicity studies practically all statistical analyses of biochemical tests are based on means rather than on the proportion above or below a certain value. Furthermore, the number of experimental observations needed to detect a real effect is considerably less when the analysis is based on means than when it is based on proportions (all else being equal and assuming an underlying continuous variable).

TABLE 1:
C-8 STUDY CODE SHEET FOR WORK HISTORIES

Payclass (1 = wage, 2 = salary): _____

Date hired (month/year): _____ / _____

Name (last, first initial, middle initial): _____

Sex (1 = male, 2 = female): _____

Current C-8 exposure
(0 = no; 1 = yes): _____

Org. P = _____

Inorg. P = _____

SS #: _____

Birth date (month/year): _____ / _____

Present or past Teflon area jobs or mechanic-type jobs (0 = no; 1 = yes): _____

Potential present or past C-8 exposure (0 = no, 1 = yes): _____

Number of jobs listed below (list all Teflon area and/or mechanic jobs): _____

<u>Job</u>	<u>C-8 Potential</u> (0=none; 1=some)	<u>Job code</u>	<u>Date in</u> (no./yr.)	<u>Date out</u> (no./yr.)	<u>Comments</u>
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					

TABLE 3: WASHINGTON WORKS
1978 Blood Test Results

Group	No. of Tests 1978	SGOT (Normal = 10-50) Total > 50	ALK. PHOS. (Normal = 30-85) Total > 85	BILL (Normal = 0-1.0) Total > 1.0	LDB (Normal = 100-225) Total > 225
Butacite®	119	30 (25%)	14 (12%)	6 (5%)	2 (3%)
CFP	78	16 (21%)	6 (8%)	4 (5%)	6 (8%)
Deltrin®	82	15 (18%)	7 (9%)	1 (1%)	1 (1%)
FLJaments	131	23 (18%)	11 (8%)	7 (5%)	4 (3%)
Lucite®	71	14 (20%)	7 (10%)	3 (4%)	2 (3%)
Teflon®	212	34 (16%)	23 (11%)	5 (2%)	5 (2%)
Zytal®	241	29 (12%)	8 (3%)	11 (5%)	6 (2%)
Mechanical	390	79 (21%)	27 (7%)	16 (4%)	10 (3%)
Research	77	16 (21%)	4 (5%)	4 (5%)	0 (0%)
Technical	251	50 (20%)	15 (6%)	11 (4%)	6 (2%)
Bus. Ser.	103	14 (14%)	8 (8%)	4 (4%)	1 (1%)
Empl. Rel.	32	7 (22%)	3 (9%)	3 (9%)	0 (0%)
Power & Ser.	63	14 (22%)	7 (11%)	2 (3%)	5 (8%)
Total Plant	1840	341 (19%)	140 (8%)	77 (4%)	48 (3%)
Total Plant Less Teflon®	1628	307 (19%)	117 (7%)	72 (4%)	43 (3%)

**TABLE 4: SGOT RESULTS FROM TWO DIFFERENT METHODS
PERFORMED AT THE SAME LABORATORY (GENERAL CONSULTANTS, INC.)**

<u>Subject</u>	<u>Date</u>	<u>Standard SMA-12 (1) SGOT (normal = 10-50)</u>	<u>Alternate Method (2) SGOT (normal = 0-27)</u>
1	11/12/79	60*	19
2	11/14/79	58*	17
3	11/26/79	150*	42*
4	11/27/79	60*	18
5	12/10/79	55*	21
6	12/10/79	54*	14
7	12/10/79	51*	15
8	12/10/79	60*	15
9	12/10/79	62*	19
10	12/10/79	55*	13
11	12/11/79	54*	14
12	12/11/79	55*	17
13	12/11/79	63*	19
14	12/11/79	57*	23
15	12/11/79	85*	23
16	12/12/79	73*	21
17	12/18/79	52*	15
18	12/20/79	82*	24
19	12/26/79	57*	15
20	12/28/79	89*	24
21	12/31/79	60*	19
22	12/31/79	75*	27

(1) Automated colorimetric method

(2) Manual enzymatic method

*Abnormally high based on limits set by the laboratory

TABLE 5: AGE AND BLOOD CHEMISTRY^(a) MEANS BY OCCUPATIONAL GROUP^(b)

<u>Group</u>	<u>Group Size</u>	<u>Age</u>	<u>SGOT</u>	<u>AP</u>	<u>Bili</u>	<u>LDH</u>
Control (no Teflon [®] mechanic or laboratory work) ^(c)	80	38	39	64	0.7	156
FEP process	13	49	37	81*	0.5	154
FEP service	3	37	41	101*	0.6	146
TFE process	25	45	45*	64	0.5	158
TFE service	25	37	35	59	0.5	160
Monomer operator, semi-works laboratorian, foreman	22	47	44	69	0.7	151

(a) Based on most recent SMA-12 as of October, 1979

(b) Based on job title at the time of the worker's most recent SMA-12

(c) Ten percent sample of current wage roll employees plus eight workers currently exposed to C-8 but who had never worked in Teflon[®] at the time of their most recent physicals.

* Significantly ($p < 0.05$) higher than the control group after adjusting (by analysis of covariance) for age.

**TABLE 6: BLOOD CHEMISTRY (a) BY OCCUPATIONAL GROUP (b):
PROPORTION OF TEST VALUES FALLING INTO THE HIGHEST DECILE**

<u>Group</u>	<u>Group Size</u>	<u>Mean Age</u>	<u>Proportion in Highest Decile</u>			
			<u>SGOT</u>	<u>AP</u>	<u>Bili</u>	<u>LDH</u>
Control (no Teflon®, mechanic or laboratory work) ^(c)	80	38	0.10	0.05	0.18	0.10
FEP Process	13	49	0.08	0.31*	0.0	0.08
FEP Service	3	37	0.0	0.67*	0.0	0.0
TFE Process	25	45	0.20	0.12	0.08	0.12
TFE Service	25	37	0.04	0.12	0.0	0.16
Monomer operator, semi-works laboratorian, foreman	22	47	0.23	0.14	0.18	0.09

(a) Based on most recent SMA-12 as of October, 1979.

(b) Based on job title at the time of the worker's most recent SMA-12.

(c) Ten percent sample of current wage roll employees plus eight workers currently exposed to C-8 but who had never worked in Teflon® at the time of their most recent physicals.

* Significantly ($p < 0.05$) higher than the control group by Fisher's exact test (two tail).

TABLE 7: WORKERS GROUPED BY ORGANIC FLUORIDE DECILES - BIOCHEMISTRY TEST MEANS

<u>OF^(a)</u> <u>Decile</u>	<u>Group Size</u>	<u>OF^(a)</u> <u>Limits</u>	<u>Mean No. of</u> <u>Years in C-8</u>	<u>Mean No. of Yrs.</u> <u>in Teflon</u>	<u>Mean</u> <u>Age</u>	<u>Mean</u> <u>SGOT</u>	<u>Mean</u> <u>AP</u>	<u>Mean</u> <u>Bili</u>	<u>Mean</u> <u>LDH</u>
1	6	0.08-0.30	5	12	40	46	69	0.7	184
2	8	0.35-0.45	2	17	49	40	67	0.7	131
3	9	0.47-0.69	9	18	47	49	67	0.6	166
4	7	0.70-1.17	5	7	41	34	73	0.5	161
5	8	1.31-1.80	7	12	41	40	71	0.5	165
6	8	1.81-2.30	6	11	40	36	68	0.6	154
7	8	2.33-3.55	10	14	45	37	64	0.5	152
8	8	3.70-4.64	9	16	44	36	72	0.5	152
9	8	4.84-6.66	15	18	47	39	62	0.5	149
10	8	6.84-21.69	14	18	47	52*	63	0.5	169

*Significantly ($p < 0.05$) higher than the mean of the lower 9 deciles. The data were age-adjusted by analysis of covariance before comparisons were made.

(a) OF = organic fluoride

TABLE 8: WORKERS GROUPED BY ORGANIC FLUORIDE DECILES - PROPORTION OF TEST VALUES FALLING INTO THE HIGHEST LIVER FUNCTION TEST DECILE

OF Decile	Group Size	OF Limits	Mean No. of Years in C-8	Mean No. of Years in Teflon®	Mean Age	Proportion in Highest Decile			
						SGOT	AP	Bili	LDH
1	6	0.08- 0.30	5	12	40	0.17	0.17	0.33	0.33
2	8	0.35- 0.45	2	17	49	0.0	0.13	0.25	0.0
3	9	0.47- 0.69	9	18	47	0.33	0.0	0.22	0.11
4	7	0.70- 1.17	5	7	41	0.0	0.14	0.0	0.14
5	8	1.31- 1.80	7	12	41	0.0	0.25	0.13	0.13
6	8	1.81- 2.30	6	11	40	0.0	0.25	0.13	0.13
7	8	2.33- 3.55	10	14	45	0.0	0.13	0.13	0.13
8	8	3.70- 4.64	9	16	44	0.0	0.0	0.0	0.0
9	8	4.84- 6.66	15	18	47	0.13	0.0	0.25	0.0
0	8	6.84-21.69	14	18	47	0.38*	0.13	0.13	0.13

Significantly ($p < 0.06$) higher than the lower 9 deciles by Fisher's exact test (two tail).

* = organic fluoride

TABLE 9: TEFLON AREA WORKERS WITH THE 16 HIGHEST ORGANIC FLUORIDE LEVELS

<u>Worker</u>	<u>Age</u>	<u>Years in C-8</u>	<u>Years in Teflon®</u>	<u>Blood Organic Fluoride Level</u>	<u>Job</u>
A	50	20.5	23.4	21.69	TFE process
B	59	23.8	25.8	20.81	TFE process
C	36	2.8	4.1	16.89	TFE process
D	60	23.2	23.9	14.38	TFE process
E	53	4.0	22.3	9.63	TFE process
F	48	23.4	23.4	8.89	TFE process
G	42	2.6	4.8	6.91	TFE process
H	35	13.4	14.6	6.84	TFE process
I	49	21.7	23.9	6.66	TFE process till 10/78
J	53	20.3	20.3	5.90	TFE process
K	44	16.1	17.2	5.64	TFE process till 11/77
L	56	24.5	24.5	5.61	TFE process
M	42	14.8	17.5	5.29	TFE process till 5/77
N	37	5.6	13.6	4.97	TFE process till 10/78
O	42	11.8	20.4	4.96	FEP process
P	55	3.2	3.2	4.84	TFE service

**TABLE 10: TEFLON AREA WORKERS WITH THE 16 HIGHEST
BLOOD ORGANIC FLUORIDE LEVELS**

<u>Worker</u>	<u>Age</u>	<u>Years in C-8</u>	<u>Years in Teflon®</u>	<u>Blood Organic Fluoride Level</u>	<u>Job</u>
A	35	4.0	12.5	0.42	TFE process
B	48	19.9	23.1	0.41	TFE process
C	51	7.8	25.8	0.40	Monomer
D	58	11.3	26.3	0.39	FEP process
E	49	3.5	3.5	0.39	Semiworks laboratorian
F	53	1.8	24.0	0.38	Monomer
G	53	20.3	20.3	0.37	TFE process
H	61	11.8	22.3	0.37	FEP process
I	42	11.5	13.8	0.34	TFE process
J	26	3.2	3.2	0.31	TFE service
K	30	0.7	3.0	0.29	TFE process
L	56	0.4	29.7	0.28	Monomer
M	35	4.8	4.8	0.27	TFE service
N	24	3.1	3.1	0.26	TFE service
O	35	4.3	11.7	0.25	TFE service
P	51	2.6	2.6	0.24	Semiworks laboratorian

TABLE 11:

TABULATION
OF
BLOOD SAMPLES FROM WILMINGTON
PERSONNEL (25 TOTAL)

Sample #	Total P ppm	Inorganic P ppm	Organic P ppm (by difference)
60	0.28	0.19	0.09
61	0.31	0.09	0.22
66	0.23	0.16	0.07
72	0.20	0.10	0.10
73	0.23	0.12	0.11
76	0.23	0.17	0.06
77	0.33	0.15	0.08
78	0.24	0.25	-0.01
79	0.30	0.24	0.06
80	0.19	0.14	0.05
81	0.21	0.15	0.06
82	0.18	0.27	-0.09
92*	10.6	0	10.6
93	0.18	0.12	0.06
94	0.18	0.03	0.15
95	0.49	0.11	0.38
96	0.25	0.05	0.20
97	0.18	0.16	0.02
101	0.26	0.16	0.10
102	0.30	0.16	0.14
103	0.26	0.10	0.16
106	0.23	0.17	0.06
107	0.31	0.22	0.09
109	0.12	0.11	0.01
111	1.13	0.35	0.78

*Values obtained 3/15/79. Resample and recheck of this person's blood on 6/13/79 showed the following:

Recheck #92

Total P ppm	Inorganic P ppm	Organic P ppm
0.33	0.09	0.24

TABLE 12: MEAN DIFFERENCES IN SGOT AND AP RESULTS WHEN THE FIRST TEST IS BEFORE ^(a) MOVING INTO A C-8 EXPOSURE JOB AND THE SECOND TEST IS AFTER ^(b) EXPOSURE ^(c)

<u>Group</u>	<u>Group size</u>	<u>AP^(d)</u>	<u>SGOT^(d)</u>
Control	45	- 3.3	- 4.7
FEP process operator	3	+ 11.7	- 4.0
FEP service operator	2	+ 8.0	+ 7.5
TFE process operator	2	- 3.0	- 11.5
TFE service operator	7	- 0.4	- 8.1

(a) Most recent SMA-12 prior to starting C-8 exposure job

(b) Most recent (primarily 1979) SMA-12

(c) C-8 exposures ranged from 5 months to five years between tests

(d) Second test minus first test

STANDARD LABORATORY SGOT

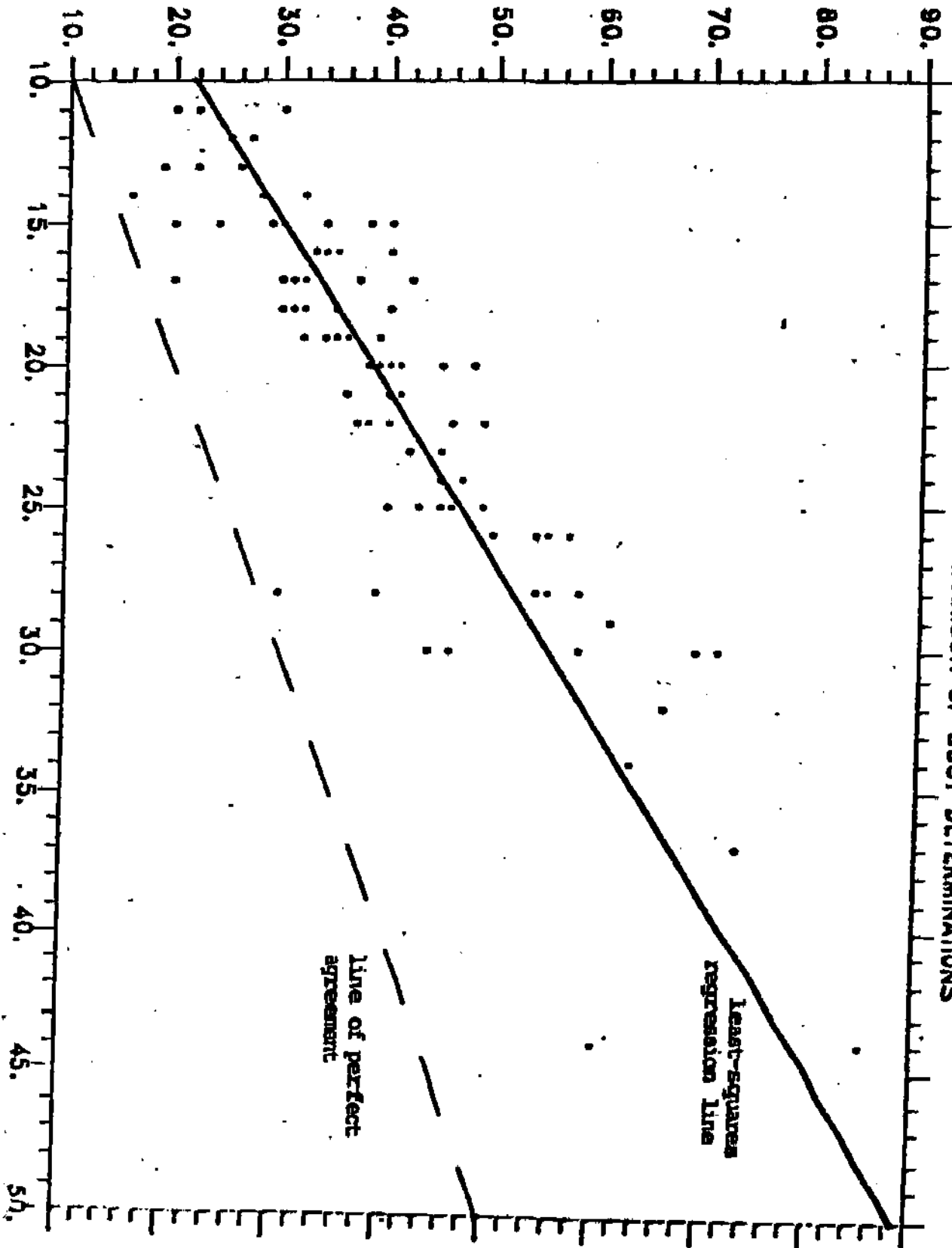
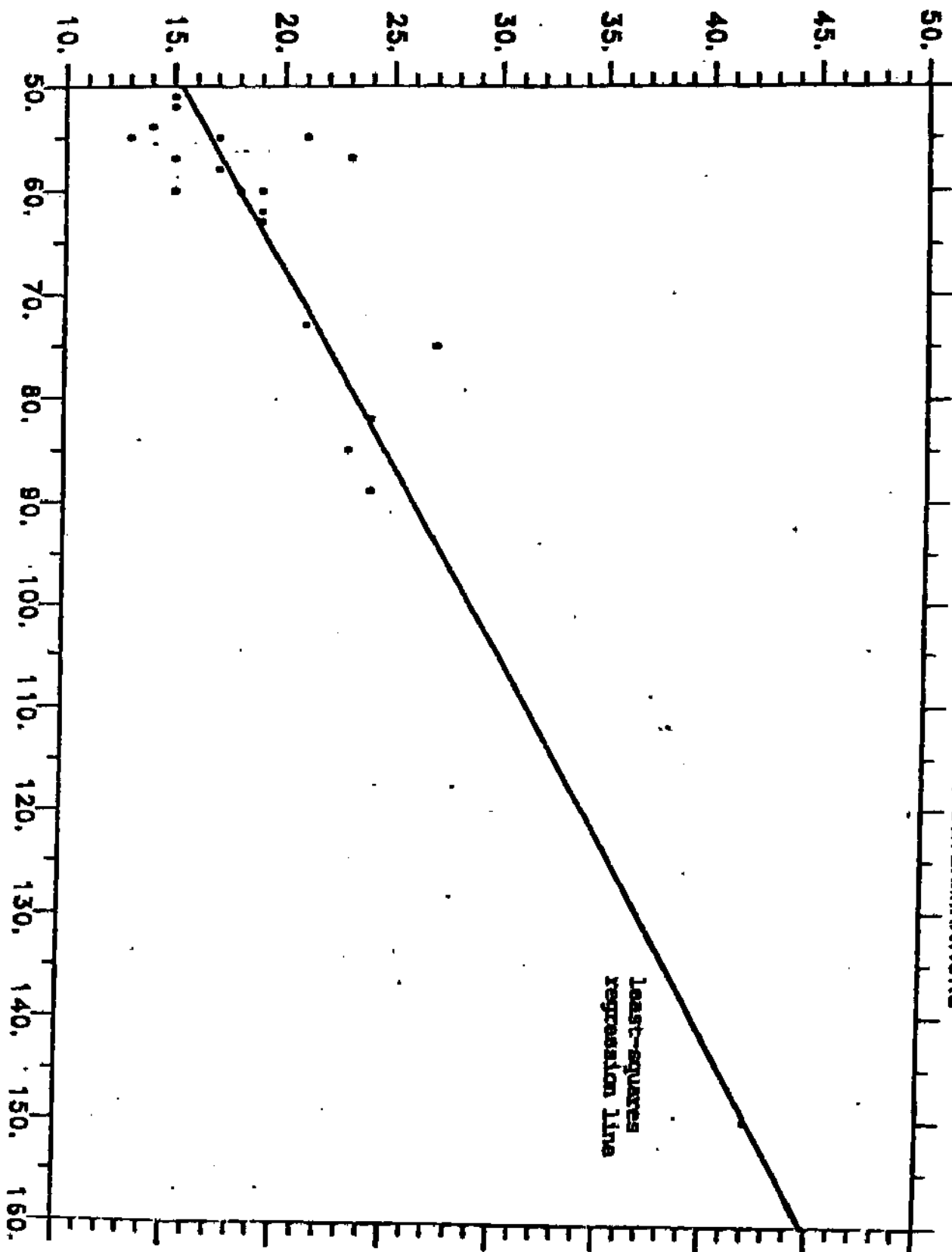


FIGURE 1: INTERLABORATORY COMPARISON OF SGOT DETERMINATIONS.



SGOT LEVEL BY ALTERNATE METHOD AT STANDARD LAB



INTRALABORATORY COMPARISON OF SGOT DETERMINATIONS

QUEST