irritation, it seems likely that this
lso be applicable to other pharma-
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SUMMARY

blet impregnated with cellulose
llose nitrate has been developed.
s membranous cellular structure,
lves very slowly and liberates its
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dissolving impregnated tablet
tly less gastrointestinal symptoms
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ACKNOWLEDGMENTS

press our gratitude to Capt. E. G.
), USN, who early recognized the
ontributions in this field, to Capt.
MC), USN, and Drs. J. Murray
Pfeiffer for their assistance and
suggestions during the course of
n, and to those men who although
ive to salt, subjected themselves
ital conditions.

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THE CONTROL OF LEAD EXPOSURE IN STORAGE BATTERY MANUFACTURE*

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DURING the past ten years, the program for the control of lead exposure of workers at Delco Battery Operations has undergone a number of changes, each change resulting from attempts to improve working conditions and to refine the methods of detecting abnormal absorption of lead before physical symptoms develop. Originally, only atmospheric contamination was measured by means of "dust checks". Later, the program was expanded to include blood analyses and still later urinalyses were introduced. That an adequate control of lead exposure has been maintained is indicated by the fact that in these ten years, only four cases of lead intoxication have been reported even though some 300 men are employed in jobs which, with no control, would be hazardous. The success of the program has been and is in large measure due to the sincere cooperation of both the management and the employees.

The program at the present time consists of two general phases: reduction of air contamination to a minimum by the application of good engineering principles and the early detection of abnormal absorption by every means available. The engineering phases of the program have been discussed in a previous paper and will not be considered here. At the time a new employee is hired he is subjected to a thorough pre-employment examination which includes chest X-ray, blood count, physical examination and medical history. Evidences of lung, kidney or hepatic disorders as well as poor blood picture or mouth breathing are prime factors considered in placing the man in positions involving work with lead or its compounds. The data obtained in this examination serve the second and equally important function of furnishing a "normal" picture for comparison with data collected in later examinations.

Before assignment to a position in the plant, the new employee is carefully instructed concerning personal hygiene and good health practices necessary in relation to work in the lead industry. When he reports at his job, his foreman specifically points out those potential hazards which must be considered on that particular operation. Instruction by various methods continues throughout the worker's term of employment. It should be noted that one of the most effective means of teaching the new employee is through his observation of and association with the more experienced employees.

The position a man may hold in the plant is determined on the one hand by the results of his pre-employment examination and on the other by the rating of that position as determined by the periodic dust checks. At approximately one month intervals, surveys of the plant are made. The extent to which the atmosphere of workrooms is contaminated by lead dust is determined at 35–50 points throughout the plant; each type of operation involving the handling of lead is checked. Every operation in the plant is thus catalogued as to the relative potential hazard to the operator. These periodic surveys also serve a second purpose in two ways: (a) higher than average dust checks for an individual operation lead to prompt investigation to discover and correct the cause, (b) values consistently over the safe limit lead to the improvement of engineering control in order to reduce the exposure of the worker.

All workers who are employed in potentially hazardous positions are required to report periodically to the hospital for blood checks. The frequency of these checks is determined by the relative potential hazard of the position at which the man works and varies from two week intervals to sixty day intervals. All men, whether working in catalogued positions or not are checked twice a year. These blood checks include a count for stippled erythrocytes, red blood cells and a determination of the percent hemoglobin. The man weighs himself and is interrogated by the nurse for subjective symptoms.

As is well known, a poor blood picture, i.e. high stipples, low hemoglobin and red cell count, may result from a number of causes other than lead absorption. Therefore, whenever the blood checks

* Received for publication January 15, 1947. A paper presented at the Ninth Annual Meeting of the American Industrial Hygiene Association, Chicago, April 9–11, 1946.

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indicate an abnormality, or when interrogation indicates any possibility of subjective symptoms, an immediate request is made for the collection of a urine sample. This is either a twelve or twenty-four hour sample collected at home by the man and analyzed for lead by use of the dithizone procedure. If the urinary output of lead is in the normal range, the medical department investigates further to discover the organic disorder and the man is referred to his family physician for treatment. A high urinary output of lead is checked by the analysis of a second sample collected as soon as possible. Confirmation of the high urinary lead excretion results in prompt action. This action will vary according to the individual case, ranging from investigation and correction of mechanical failures or disregard of good personal hygiene practices to actual removal of the worker to a position of minimum potential exposure.

One problem, involving an operation which remains somewhat hazardous despite repeated attempts to reduce the exposure by engineering means, has been solved by using alternate work crews. Thus, a crew works one month on this job and one month on a job entirely removed from lead.

The analytical data accumulated during this ten year period have yielded information which has proved useful in controlling lead exposure. In Figure 1 are plotted the time-relationship curves for the average blood counts for 115 men who worked more or less continuously over this period. It is apparent that, in general, a close correlation exists between the stippled cell count and the percent hemoglobin; it is equally apparent that no corresponding relationship exists between these values and the average of red blood cell counts. It thus follows that, at best, the red blood cell count is unreliable evidence for establishing the existence of excessive absorption of lead. The curves clearly reflect a definite improvement in conditions from 1935 to 1940 with maintenance of good conditions thereafter, excepting for a slight backslide during the latter two years of the war. This latter variation was due to the very rapid labor turnover, accelerated production and the introduction of new manufacturing processes.

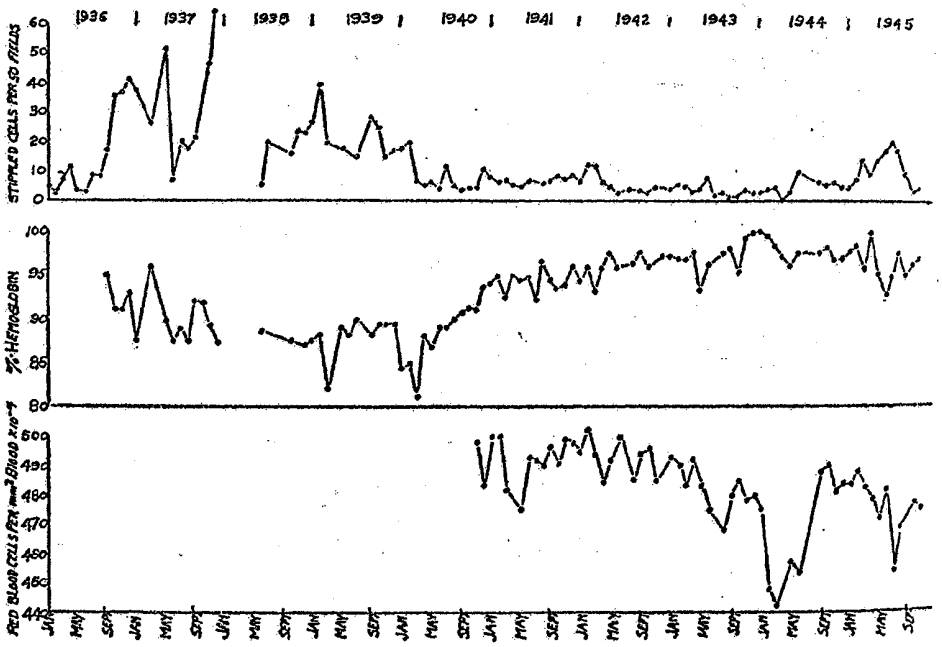

FIG. 1. Blood count average for 115 men working in lead.

In Figure 2 are plotted the time-relation-

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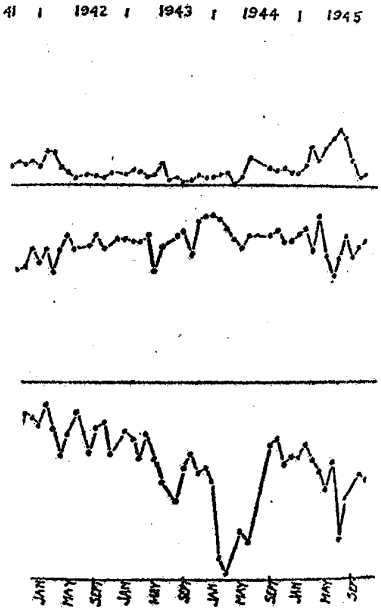

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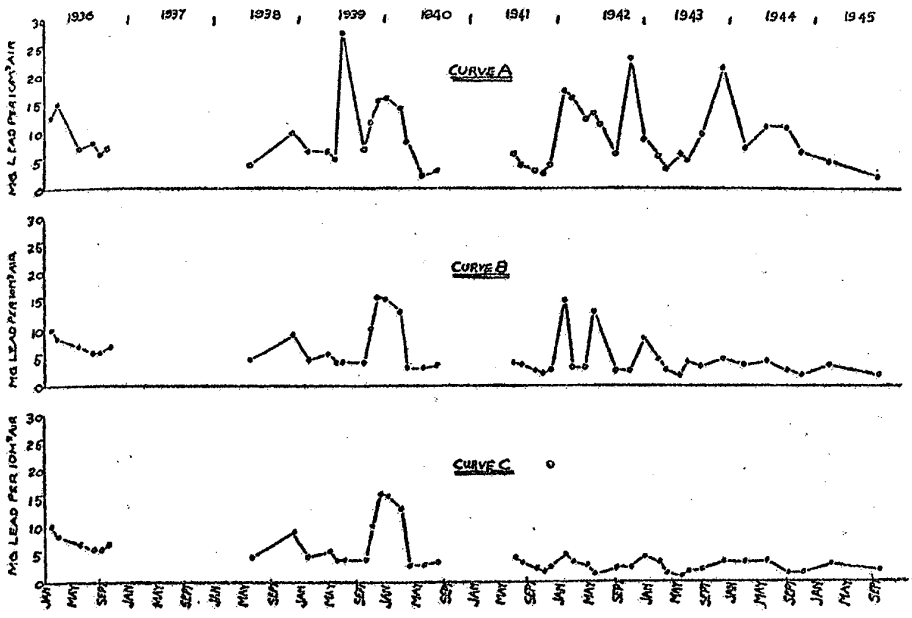


FIG. 2. Average atmospheric contamination of work rooms.

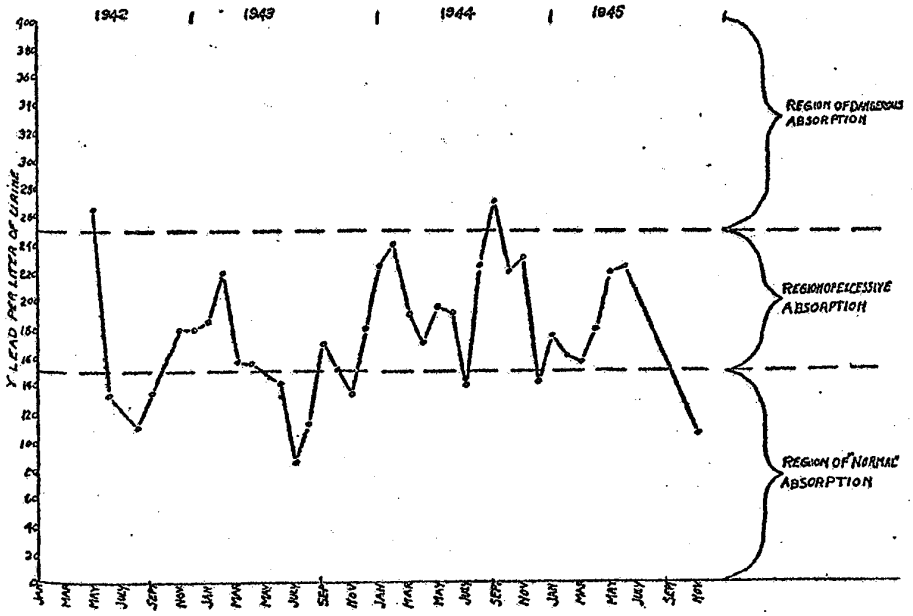


FIG. 3. Averages of urinary excretion of lead.

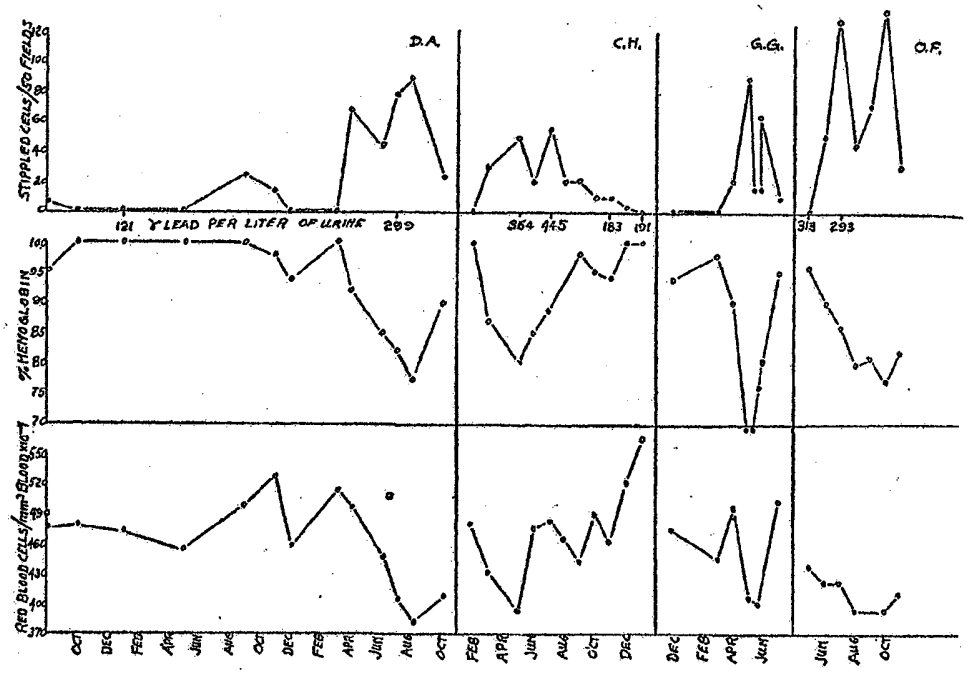


FIG. 4. Typical blood pictures resulting from excessive absorption of lead.

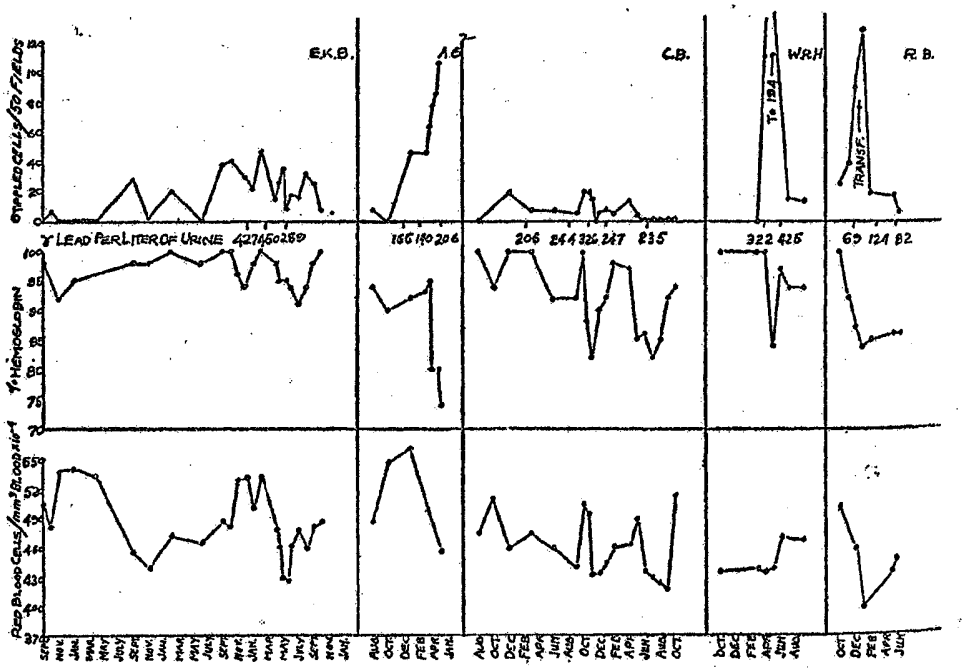
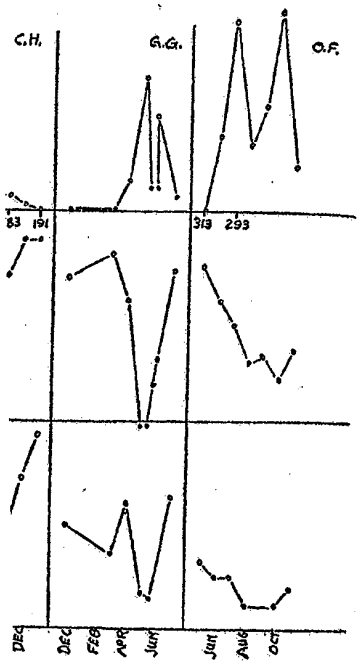


FIG. 5 .Atypical blood pictures resulting from absorption of lead.



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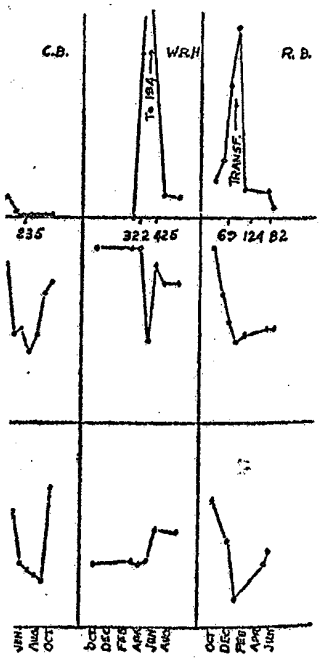

ption of lead.

curves for the concentration of lead dust in the atmosphere of workrooms in the plant. Curve A is a general average of all dust checks taken in the plant. This curve is somewhat misleading, however, since two of the operations in the plant, because of their nature, have proven difficult to protect by exhaust ventilation. They are for this reason, completely isolated from the rest of the plant and from each other. The workers in these two areas, numbering less than a score of men, are required to wear respirators. A more accurate picture of the actual condition of the plant is indicated by Curve B which shows the average contamination of the work room atmosphere if these two areas are omitted. The improvement noted after 1942 is ascribed to the installation of new exhaust systems and overall improvement of processes necessary after the introduction of so-called "permanized batteries" which are composed of charged plates and are of necessity assembled bone dry. Since this was essentially a war-time product, it is of interest to construct Curve C which omits both the isolated areas previously mentioned and also operations involving permanized plates. In other words, Curve C represents the conditions in the plant under normal circumstances. On the basis of this curve, and considering the record achieved in the past ten years, it is

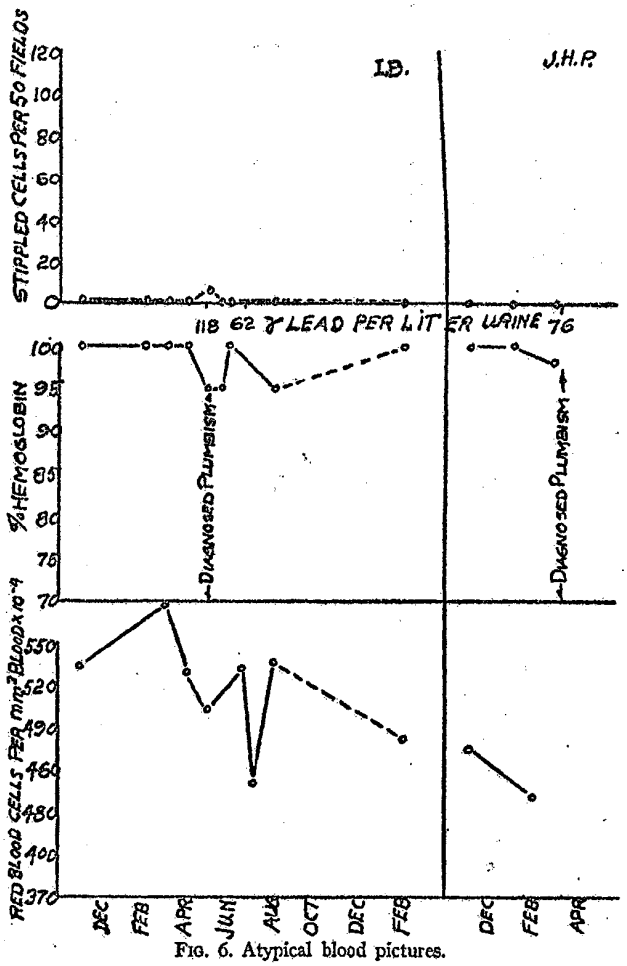

FIG. 6. Atypical blood pictures.

considered that the maintenance of an average of no more than 5 mg. of lead per 10 cubic meters of air, with the proper function of the additional program outlined, assures adequate control of the lead hazard. The presently accepted safe limit for the concentration of lead in work room air is admittedly a desirable goal, but a higher concentration can be safely tolerated when accompanied by a supplementary program such as the one outlined above. It will be noted that the dust checks as shown in this curve are in general agreement with the data for blood counts.

Since urine samples were analyzed only in cases of suspected abnormal lead absorption, the data from these do not portray the average of all of the exposed workers, but a value probably considerably higher. Consequently, from these data it is not possible to correlate urinalyses with dust checks and blood counts. However, it has been possible, as indicated in Figure 3, to set up approximate maximum limits for the rate of urinary excretion of lead, beyond which transfer of the worker is advisable.

Experience at this plant has led to the following conclusions: (a) 0–150 micrograms of lead per liter of urine is the "normal" range for men working under conditions of controlled industrial exposure; (b) the range from 150–250 micrograms of lead per liter of urine is abnormal for industrially exposed workers and in such cases the involved workers should be kept under observation until the cause is found and corrected; (c) whenever the urinary excretion exceeds 250 micrograms per liter, immediate steps should be taken to reduce the lead intake—usually the man is transferred to a position of minimum exposure until the cause of the abnormality is discovered and corrected.

It should be emphasized that a diagnosis of dangerous lead absorption cannot be made upon the basis of any one type of data. This is illustrated by a number of case histories from our files. Figure 4 shows the typical picture expected in cases of excessive absorption, i.e. increased stippling and urinary excretion with concurrent drop in percent hemoglobin and red blood count. However, atypical cases, in which is found every possible variation, are of frequent occurrence. This is illustrated in Figure 5 by the following examples:

CASE	URINE	STIPPLES	HB.	R.B.C.
EKB.....	High	Mod.	High	High
AG.....	Mod.	High	Low	Mod.
CB.....	High	Mod.	Mod.	Low
WRH.....	High	High	Mod.	Mod.
RB.....	Low	High	Mod.	Low

The last two cases, shown in Figure 6, are of particular interest since both were diagnosed as cases of lead intoxication by local physicians although obviously these data do not substantiate such a diagnosis.

It is not intended to imply that the program outlined is perfect, nor that it cannot be improved. As it has been changed frequently in the past, so we expect to continue making changes in order to incorporate new methods and improve old ones.