An investigation of circumstances surrounding an alleged case of lead poisoning

Lead poisoning can cause such a bewildering array of disabilities and infirmities that even an interested observer might not see the connection; things such as, learning disabilities,[1 2 3 4 5 6 7] speech,[8 9 10 11] hearing[12 13] and behavioral problems,[14] mental depression,[15 16] headaches,[17] bad teeth,[18 19 20] high blood pressure,[21 22 23] cataracts, [24 25] impotence,[26 27] and juvenile delinquency. [28 29] So when every one of these events occurred in the author's family beginning in the 1940s - and every family member except one was affected [i] - family members assigned a variety of causes to them. Lead poisoning however was never discussed.

There were no obvious sources of lead in the family's environment even in hindsight. There was no peeling paint in the home, rumors of lead in the water pipes, community gossip about the dangers of lead at home or at work, or reports of suspicious illnesses or deaths. The nearest industry of any type was miles away, and there was very little of that in the 1940s. But looking back it is clear now that there was exposure to lead through the father's work, which was installing central office telephone equipment and cable for the Western Electric Co., a part of the Bell System. The telephone industry had a variety of uses for lead throughout the 1940s and early '50s, things such as rosin-core solder and lead-sheathed cable. To put this into perspective, the Bell System used 3 million pounds of lead solder a year according to a 1941 article in the New York Times.[30]

Fast-forward 60 odd years. A serendipitous glance at the label on a spool of rosin-core solder showed that the solder contained lead. Beginning with that single clue the author tried to determine whether family events that everybody once had assumed were unrelated, were in fact the result of lead poisoning. Were these events - most appearing while exposure was taking place, some later, and all deserving close examination - the result of lead poisoning? Sadly there is no final answer. More than 50 years after exposure ended all that is left in place of absolute proof are clues. Family members have died from unrelated causes, and lead has long since been eliminated from the bodies of survivors, assuming that it was ever there. So the charge that these events were the result of lead poisoning cannot be proven suspicious though they are. What can be shown however is that for at least the first five decades of the Twentieth Century, and despite published warnings, the Bell System (and its labor unions) failed to protect a number of employees (and labor union members) from the dangers of lead. As will be seen these dangers increased significantly for the author's father as well as for hundreds of other unsuspecting Bell System workers beginning as early as the late 1930s, and they did not diminish until the early '50s, if then.

The changing nature of solder in the Bell System and elsewhere, circa 1939

Today many solders are lead-free. In 1939, however, most solders were alloys of lead and tin, together with small amounts of other metals as required in proportions that ensured proper levels of durability, utility, ease of application, and cost. Although tin admirably fulfilled its role in solder as a wetting agent, there were two qualities that tin did not have, affordability and, as war loomed in the Pacific and tin supplies became increasingly scarce, availability. These were the very qualities that lead possessed

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[i] Within this family of three children and two adults, all living under one roof, the severity of symptoms generally followed the severity of exposure, with younger members being more severely affected.

Although solder was extensively used in manufacturing of all types, two of the biggest consumers were the telephone and automobile industries. In addition to the presence of lead in solder the Bell System used lead as a protective covering (known as 'sheathing') on underground telephone cable. The telephone industry used two types of solder. One, termed "rosin solder" and named for the core of rosin at the center of this wire-shaped solder, was used to weld together two or more components of a telephone circuit already in intimate contact, two bare wires twisted together for example. A small amount of molten solder was allowed to flow over and around the wires in the example forming a 'solder joint'. Once cooled and hardened the solder ensured that the wires remained in contact. The other type, termed "wiping solder" and named for the wiping motion workers used when applying it, provided a watertight seal over a lead sleeve that covered the joined ends of two telephone cables. In the automobile industry solder was used in manufacturing automobile radiators and in automotive bodywork.[31] [32] This industry's struggle with the high lead content of solder will be alluded to later.

At the outbreak of World War II domestic supplies of tin ore in the U.S were entirely lacking. As a result, the nation received all of its tin from sources outside the country, mainly from mines in what today are Malaysia, Indonesia, and China. The Japanese ended shipments of tin to the U.S from these territories early in World War II just as the war pushed up demand for the metal. Because the nation's main supply of tin had been cut off, the U.S. government asked the National Academy of Sciences' National Research Council to come up with ways to conserve and/or find substitutions for tin in industry.[33]

The Council studied the ways tin was used including the use of tin in solder. In 1941 it concluded that it was at least theoretically possible to eliminate tin completely from all solders and replace it with silver. Since silver has wetting qualities that are far superior to those of tin, a much smaller percentage of silver could be used, thus keeping unit costs approximately the same according to the Council. A solder containing 2.5% silver would have nearly the same wetting ability as a solder containing at least 45% tin for example.[34] In some industries substituting silver for tin in solder was more than theoretical. Because of it superior heat tolerance silver solder was already being used in the manufacture of aircraft engines. As a result of these recommendations, and under pressure due to supply constraints, by 1942 the U.S. government had forbidden the use of all solders containing more than 30% tin.[35] [36] By mid-1944 that percentage had been lowered to 20%. [37]

Thus the lead content of Bell System solder, typically 66% or less before the war [i], increased to 70% or more after Pearl Harbor. In cases where silver was substituted for tin, the lead content increased to more than 95%.

Although increasing the concentration of lead in solder increases the risk of exposure and ultimately of poisoning, concentration and risk are not linearly related. For example, increasing the concentration of lead in solder from 20% to 40% (a 20% increase) doubles the amount of lead, that is, it increases it by 100% (40 minus 20 divided by 20). By comparison increasing the concentration of lead from 70% to 90% (also a 20% increase), increases the amount of lead by 28% (that is, 90 minus 70 divided by 70). When these percentages are graphed it is clear that as concentration rises the rate of increase in quantity, and thus the rate of increase in risk, slows significantly. What all

[i] By the outbreak of World War II 50/50 rosin-core solder (that is, 50% tin and 50% lead), in common usage for many years, had been largely replaced by solder that was 67% lead and 33% tin (*Bell Laboratories Record, vol 14 (3), p89, November 1935*). Through the early part of the '40s the lead content of wiping solder varied between about 64% and 66% (*Bell Laboratories Record, vol 22 (11), p 472, July 1944*.)

this suggests is that while the increase in lead concentration was an important determinant of the increased risk of exposure, it is unlikely that it explained all of the change in risk. There were other factors at work as will be seen later.

Although the information presented thus far offers broad hints, it does not tell us directly what the lead content of solder used by the Bell System was during this period.[i] Assuming that there is no direct answer to this question other approaches must be tried.[ii] The first is to calculate an estimate based on statistics supplied by the American Telephone and Telegraph Company in its annual reports, with help from numbers provided by Bell System spokespersons in published interviews. The System's biggest use of lead was in the sheathing of underground phone cable. In many of its annual reports during the 1940s, the Company reported miles of wire laid for the year in the form of underground cable. Thus for a three year period beginning in 1941 the Company reported the number of miles of cable laid as approximately 4,596. Most of the buried wire was laid in 1941. Far fewer miles were laid in 1942, and only a small fraction of the total was laid in 1943.[38] In the Company's annual report for 1941, management reported that in response to the war the System had reduced its rate of use of lead by 89% and tin by 90% compared to peak use in 1941. Although fewer miles of underground cable laid did mean less need for wiping solder to cover cable splices, demand for rosin-core solder probably increased. The Bell System manufactured and installed more than one million new telephones a year in 1942 and '43, the first two full years of the War, an average increase of 22% over 1940 and an average decrease of 12% over 1941. The number of new phones installed fell to a little more than 300,000 in 1944. These numbers do not include work done in the name of national defense [iii]. In addition, from 1942 through 1944 the System built central offices at a rate 30% faster than from 1938 through 1941.[39 40] Both of these activities, but especially the wiring of central offices, required large quantities of rosin-core solder.

In an interview with the _*New York Times*_ in July 1941, a Bell System spokesperson told the paper that the System used about three million pounds of solder in 1941. Of the three million pounds approximately 2.5 million were used for wiping solder (_*Telephone Engineer*_, p 31, April, 1942). That left 500,000 pounds available for rosin-core solder. Adjusting this number upward by 30% to take into account the increased rate at which central offices were being built, an annual figure of 650,000 pounds of rosin-core solder is arrived at. However, because that figure fails to take into account national defense needs, the final figure was undoubtedly much higher. [iv]

In 1942 a Bell System spokesperson stated that tin consumption had been reduced to 291,000 lbs System-wide in response to the war effort.[41] Of this amount several thousand pounds would have been required for manufacturing (for example, the tinning of lugs and terminals); some would always have been recyclable scrap; some would have been set aside for repair purposes; and a small

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[i] The concept of lead content is an important one because it is a surrogate measure of how quickly a solid film of lead oxide could form on the surface of solder, all things, such as temperature, atmosphere, and humidity being equal. The higher the lead content the faster the process could proceed.

[ii] The most direct answer would have been provided on an official Bell System document or obtained directly from a Bell System official. Obviously neither is possible.

[iii] "*Since the beginning of the national defense program,*" noted W.V. Kahler, chief engineer for Illinois Bell in a speech before the 30th National Safety Congress, October 1941, "*this country has gained the equivalent of more than 100 medium-sized cities – army cantonments, new industrial communities*". (Transactions of the 30th National Safety Congress, Vol 1, General Subject and Industrial Sessions, p 611, National Safety Council,1941.)

[iv] From 1942 through 1945 Western Electric supplied $2.3 billion worth of equipment for the War effort. During the same period spending on equipment for the civilian market amounted to only $ 6 million. (from; _Western Electric and the Bell System; A Survey of Service_, page 35; NY, NY, 1964).

amount would have been used for wiping solder. The remainder would have been available for rosin-core solder. These figures suggest that the lead content of rosin-core solder could easily have ranged as high as 90 + % depending on how tin supplies were parsed and on the amount of solder the System used. [42] For example if instead of increasing 30% the amount of rosin-core solder used actually doubled (say from 500,000 to 1,000,000 lbs which is not an outlandish assumption given the huge increase in Bell System services and manufacturing that were provided in the name of national defense) at the same time that the amount of available tin was reduced from 291,000 to 150,000 lbs (due to competing demands for tin supplies), then the percent of lead in rosin-core solder could have reached 85%, that is, 850,000 lbs of lead in every million lbs of solder.

The second way to get at the question is to acquire old Bell System rosin-core solder and have it analyzed for lead and tin content. Just such an analysis yielded a lead and tin content of 70% and 30% respectively [43]. Although the analysis is helpful it probably does not provide the final word on the lead content of Bell System solder during this period. In response to the tin shortage there is evidence to suggest that the lead content of solder rose higher still. [44] Thus, following Pearl Harbor exposure to lead, already substantial, increased for Bell System workers whose jobs required them to use rosin-core solder. This increase came about due to the increased use and lead content of rosin-core solder and, as will be seen, longer hours at work (see ref 61).

Exposure in the work place and in the home to Bell System lead

Exposure to lead dust

Lead in any form is poisonous, whether it is an alloy of lead, such as solder, or lead that is chemically combined with another substance, such as lead additives in gasoline. Metallic lead, the type of lead found in solder, must be ingested or inhaled as dust or as fumes to be dangerous, it cannot be absorbed through the skin. There were several potential sources of lead dust at a telephone work site. There was dust generated from trimming, cutting, and otherwise manhandling lead sheathed telephone cable, dust from deconstructing and hauling off old outmoded equipment, dust deposited on factory-new equipment at the time of manufacturing or shipping, and dust from solder waste deposited on floors, bench tops, and clothing. Dust could be raised into the air by dry sweeping floors, wiping off equipment with dry rags, or simply kicking it up during the course of the workday. Dust could be deposited on clothes, in the hair, or on the skin. Lead oxide covering leaded surfaces as a tarnish could be loosened during handling, generating airborne dust in the process. [45] Lead dust from dirty hands could be transferred to food or cigarettes and ingested. Dust on clothing and shoes could be shaken off onto the floor and carpet at home, picked up by toddlers crawling around on their hands and knees and ingested. Laundering of contaminated clothing could expose the launderer to lead hazards.

Exposure to molten solder

"*The quantities of lead vapors that are given off from … molten [solder] at temperatures under [1832°F], are probably insufficient in themselves to create an important lead hazard*", wrote the authors of the 1943 American Public Health Association report on occupational lead exposure, "*…even at the lower temperatures, however, a slight contribution made by lead vapors to the total lead exposure may have sufficient importance to warrant its elimination.*" [46] Both wiping solder and rosin-core solder were heated to a molten state prior to use. Wiping solder was kept in a small pot and heated to around 800 ° F. [47] [i] As is true today, heating of rosin-core solder to the molten stage and construction of a solder joint was done with a hand-held device known as a soldering iron. Millions of these joints were constructed or deconstructed annually by Bell System workers. With every construction/deconstruction of a joint came a degree of exposure to lead.

Because the soldering iron must not only melt solder but must quickly heat the metals to be soldered up to a temperature that is at least equivalent to the melting temperature of the solder, soldering takes place at temperatures higher than the melting point of solder. Modern electric soldering irons can operate up to temperatures as high as 750 ° F.[48] Because delicate electronics easily damaged by heat were not part of the telephone systems of the 1940s, there is no reason to believe that the soldering irons used during the period operated at cooler temperatures. They may in fact have operated as much as 100 ° F hotter due to the higher melting temperature of high-lead solders. [49] [ii]

Pure lead melts at about 620° F. If tin is added, the melting temperature of the resulting alloy is lowered in rough proportion to the amount of tin present. For example an alloy of 30% tin and 70% lead melts at about 491° F, while an alloy of 5% tin and 95% lead melts at about 594 ° F.[50] The vapor pressure of lead, a measure of the tendency of the metal to form a vapor at any given temperature, steadily increases with increasing temperature, although at temperatures less than about 1,472° F this pressure is less than 0.1 mmHg. [51] Vapors generated at any pressure can be inhaled of course, contributing to potential health problems. However for exposed, non-factory Bell System employees lead vapors from molten solder was probably the least important risk. More important was lead oxide. A lead oxide film forms quickly over a wide range of temperatures and conditions. When the film of oxide is disturbed, as for example when a ladle is dipped into a pot of molten wiping solder, or when solid rosin-core solder is handled or manipulated, some of the oxide can be dislodged or aerosolized and inhaled or ingested (see also “A determination of the rapidity with which lead oxide forms on the surface of solid 70/30 Bell System rosin-core solder” at www.bellsystemleadpoisoning.com). [52]

Bringing lead home from work

The purchasing power of telephone workers declined dramatically during the first half of the 1940s relative to workers in industries that were directly involved in war production.[iii] The reasons for this along with supporting evidence have been presented elsewhere and will not be discussed here.[53] What will be discussed is what the decline meant for the author’s family. And what it meant was that family members threw nothing away, especially not broken electrical appliances, which the father repaired if at all possible. The repair usually involved soldering using Bell System solder. Burning rosin-core lead solder gave off a wonderful odor for a young child, a slightly sweet smell mixed with the smell of burning pine logs. As a young child the author was always trying to get a whiff. Perhaps these behaviors were unique, but it is more likely that they were repeated in the families of other Bell System employees across the country.

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[i] Wiping solder was often used in close confines where any lack of ventilation could result in a dangerous buildup of poisonous fumes and dust.

[ii] There was concern about burning off the insulation from wires with too hot an iron. This along with concerns about oxidation of metals from the heat probably served to temper somewhat the heat output of irons.

[iii] In contrast Bell System operating revenue for the same period did very well, increasing from $1,298,689,000 in 1941 to $1,769,705,000 in 1944, a 36% increase [AT&T annual reports]. This was the fastest increase in revenue for the Bell System since 1900, the year the System first began publishing such numbers.

There were other ways that lead could come home. Two of these involved lead deposited on skin, hair, and clothing.[54] [55] [56] One, lead oxide, has already been mentioned. The other way that lead came home on skin, hair, and clothing was as sweat. Significant quantities of lead could be excreted in the sweat of affected individuals. A close correlation has been shown between the intensity of exposure, the body burden of lead, and the lead content of sweat. [57]

Lead safety at Bell System and other worksites

What was the state of industrial hygiene within the Bell System at the time? In a 1922 bulletin the U.S. Department of Labor identified soldering as a cause of lead poisoning and suggested several ways of reducing the risk.[58] In 1930 the American Public Health Association's Committee on Lead Poisoning published a comprehensive safety program for occupational lead exposure.[59] Much of the program was an elaboration on the recommendations contained in the 1922 bulletin. The Committee recommended practices such as posted safety notices, safety training, proper ventilation in the workplace, good personal hygiene, maintaining separate sets of work clothes and street clothes, showers, locker rooms, separate lunch facilities, control of smoking, eating and drinking in the work place, etc. Adopting most of these standards would have significantly reduced the risks of lead toxicity. However, there is no evidence that the Bell System had even minimal safeguards in place, at least not for employees in the field (see endnote # 85 for a comment on Bell System factory safety).

In a Western Electric field employee's handbook titled "Safety Code" (1930), the only mention made of lead safety is the following; "*while handling [lead covered cable] avoid putting hands to nose, mouth, or eyes, and wash hands thoroughly before eating. This is a general precaution used by all who work with lead or lead paints and, if followed, no danger exists*" [60]. This is the type of statement "whose primary purpose seemed to be to provide a jury with evidence that the workers should have known and followed [the rules], permitting [employers] to blame scofflaws for poisoning themselves".[i] In the handbook there is no mention made of the dangers of lead dust in the air (a danger that clearly existed as there is an instruction to "*use a brush for removing [excess] solder [from equipment]*"), of the dangers of raising lead dust into the air through the use of inappropriate house cleaning methods such as dry sweeping floors, of the dangers of wiping lead contaminated hands on pants or shirts (gloves were used infrequently and work clothes were worn home), or of the need to wash hands before smoking as well as eating. In letters he wrote to his bride-to-be, the author's mother, in 1940-'41 the father described working as a Western Electric installer 6 days a week as well as nights, up to 90 hours some weeks, and of being exhausted as a result.[61] Expecting a sleep-deprived employee to remember not to scratch an itchy nose or rub an irritated eye is completely moronic.

Did the Bell Telephone System's attitude toward lead safety change with time? The U.S. Army Signal Corps requested and received extensive training from the Bell System during World War II on the construction, operation and maintenance of telephone systems.[62] [63] The Corps was in charge of land-based telephone service for all branches of the U.S. military. A record of Signal Corps procedures during the period can be found in U.S. Army field manuals archived at the U.S. Army

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[i] Christian Warren, Brush with Death: A Social History of Lead Poisoning The Johns Hopkins University Press, 2000, Baltimore. (N.B.; Although originally in reference to posted safety notices in a paint factory before World War I, the statement conveys an attitude towards lead safety that seems to apply equally well to the Bell System of the 1920s and later)

Military History Institute, Carlisle, Pennsylvania. Two field manuals are of particular interest in this regard; one entitled "Shop Work" (TM11-453) and dated March 11, 1942 (revised March 20, 1944), [64] and the other entitled "General Safety Manual" (TM20-350) dated January 1946. [65] "Shop Work" includes a 10-page section on how to properly solder using a soldering iron. However neither the section nor its revision contains any information on the safe handling of either solder or lead. The "General Safety Manual" does alert the reader to the dangers of lead fumes but only in the context of welding or in the use of the acetylene torch.

If the Signal Corps did not have a comprehensive lead safety program - as is implied by these field manuals - then by implication neither did the Bell System. As late as 1965 there was the suggestion that the Bell System did not yet have an occupational lead safety program in place for employees working in the field. [66] [67]

Outside the Bell System lead poisoning from wire soldering had a face as well, as in the following report from 1951 published in the *New York State Medical Journal* in 1957.

> *"A…woman was employed in the wiring room on an assembly line where radio and phonograph wires were soldered to contact spots. Ventilation was good, but the girls did not wear masks. For seven years she worked at the soldering bench. During the last three years of her employ she was supervisor of her department. In the line of her duties she demonstrated the method of soldering to the new employees…She moved about the assembly line freely and wore no mask. Fumes of the molten solder would come up into her face and she inhaled them. In March, 1951 she complained of abdominal cramps, constipation, and a general run down feeling….she remained at her job… In January, 1952 she stopped working [due to ill health]…a diagnosis of plumbism [that is, lead poisoning] was made. [the diagnosis was supported by the finding of abnormal amounts of lead in her blood and urine]"* [68]

Two additional cases of lead poisoning from soldering, unrelated to the case just presented, were also published, one in 1958 and one in 1962.[69]

The Bell System can claim its share of published cases of lead poisoning. Three cases involving cable splicers were reported in a 1983 issue of the journal *Medicine*. [70]A study of 90 cable splicers published in 1980 in the *American Journal of Public Health* showed that 51% had some evidence of elevated levels of lead in the blood, ranging from mild to severe. Twenty nine percent had lead-associated central nervous symptoms while 21% lead-related gastrointestinal symptoms.[71] Why are there no published cases of lead poisoning involving Bell System employees other then cable splicers (who used wiping solder), such as Western Electric Co. installers (who used rosin-core solder) for example? The author believes for the reasons found in this report under "A Lead Exposure Model for the Bell System" (see page 9).

Warning flags

In 1940 the risks of lead exposure must have become very apparent to a few. Leonard Middlebrooks, a worker who polished and shaped lead-covered caskets, sued his employer when it was discovered that he had contracted lead poisoning due to his employer's negligence. The employer had failed to provide Middlebrooks with protection from a work environment that was full of lead dust and had failed to inform him of the risks associated with lead exposure. The Georgia court in siding with the plaintiff included the following language in its ruling: [72]

> *"As to the latent dangers, incident to the employment, unknown to the [employee], of which the [employer] knows or ought to know, the [employer] must give the [employee] warning in respect thereto",*
>
> and this;
>
> *"[An employee] is not charged with knowledge of latent defects and dangers, and has the right to assume that the [employer] has provided for his safety and care".*

Far from an obscure Georgia courtroom the American Public Health Association's Committee on Lead Poisoning made a remarkable decision when it decided to rush to publication the partially completed monograph Lead Poisoning: The Recognition of Hazardous Industrial Lead Exposure in 1942.[73] Having published nothing of like substance on the subject since 1930, the Committee acknowledged that a sharp upsurge in the number of cases of lead poisoning due to occupational exposure had forced them to publish ahead of schedule. The same committee published an expanded but otherwise identical monograph one year later in 1943.[74] In both manuscripts the authors made the following observation:

> *"The decrease in the number of cases [of lead poisoning] has not been so great or so consistent as has the decline in fatalities, and certain industries with a low or negligible incidence of fatal cases show relatively high rates of occurrence of non-fatal poisoning."*

The timing of the monographs is of interest coming as they did soon after levels of lead exposure increased significantly for some Bell System workers as well as for workers in other industries. The Committee cited "inexperience in the handling of lead compounds" as one reason for the up tick in the number of cases. This was especially true, they said, for industries where the metal had not been used before. That same argument could have applied to organizations that had long included lead in their work but that had been caught off-guard by the sudden increase in the lead content and use of lead-containing material such as solder. This may have been true for the Bell System. The sudden increase in risk may have surprised management, leaving the System with lax controls and its workers with inadequate safeguards. When adequate safeguards are in place then one observer's belief that "the potential health hazards to the soldering operators are minimal" [75] is probably true.

In 1945, two years following the publication of the second American Public Health Association monograph, yet another group put out a warning. This time it was the State of Michigan Department of Labor and Industry, and the warning specifically addressed soldering.[76] [i] In the introduction to a pamphlet titled Health Hazards in Soldering Operations the authors wrote,

[i] Three years earlier, in October 1942, a virtually identical warning was issued from the podium of the 31st annual Safety Congress; "*The great restrictions placed upon tin have required the substitution of …40 % tin and 60 % lead solder by solders containing much less tin and much more lead…the increase in lead content [of tin-lead solder], and the consequent significantly higher operating temperatures have created a potentially hazardous condition…*" noted Dr James Sterner, Director, Laboratory of Industrial Medicine, Eastman Kodak Co. (Transactions of the 31st annual Safety Congress, p. 146).

"Although soldering always has been widely used, conversion to war production has [changed the nature and risks of soldering]. In order to keep pace with these changes, those industries which have controlled the hazards in the past will have to reappraise the adequacy of their control measures, and those industries which have not controlled their soldering operations in the past, as well as new users of the process, must reacquaint themselves with the [risks and controls associated with soldering]…..Yet many industries have neglected to control this hazard. Nor have surveys of the lead hazard in soldering operations been reported in the industrial hygiene literature."

The authors suggested many of the same control measures first put forth in 1922 by the U.S. Department of Labor and later expanded on by the American Public Health Association in 1930 and again in 1942, that is, good hand washing, no eating, drinking, or smoking near lead-related operations, lunchrooms and washrooms separate from lead-related operations, frequent vacuum cleaning of surfaces, good exhaust systems, etc. The authors made additional suggestions specific to the use of the electric soldering iron. They indicated a need for good local exhaust if many irons were in use in the same area, and that special care be shown in cleaning metallic oxide off of coated irons so as not to disperse lead dust into the air. In this regard the authors wrote;

"Where large numbers of irons are used in the same area or where housekeeping is not good, we have found as high as 3.2 milligrams of lead per 10 cubic meters of air [where a safe limit is 1.5 mg of lead]."

A Lead Exposure Model for the Bell System

Potential sources of lead exposure for Bell System employees, circa 1940s and early '50s

Source of Exposure	Comment
Dust and dirt kicked up while laying cable inside a telephone building. This was a physically strenuous activity involving the installation of 100s of feet of heavy cable vertically and horizontally throughout a multistory building	Dust may have been contaminated with lead from solder or from equipment and cable contaminated with lead residue at the time of manufacturing, shipment, or storage
Solder and soldering; rosin-core solder	
Solder and soldering; wiping solder	
Handling, cutting, and trimming lead-sheathed telephone cable.	Western Electric installers could be exposed to lead-sheathed cable in the cable vault, a room in the telephone building that housed the intersection of outside lead-sheathed cable and inside plastic or cloth-covered cable
Unprotected cleaning and reconditioning of soldering irons	For further discussion see note posted on page 71 of the Bell Canada safety manual on this web site.

Models of occupational lead exposure developed during the '30s,'40s, and '50s appear to have been based on the assumption that virtually all exposure occurred with predictable frequency and intensity. The models probably reflected what physicians saw in their practices, which were patients whose medical histories suggested steadily rising levels of lead in blood and tissue ending in illness or death.

However not all occupational exposure was predictable, even in industries that routinely used lead. This was true for certain jobs in the Bell System. A Western Electric installer in the 1940s and '50s for example may put in three weeks of 12 hour days handling lead solder and lead-sheathed cable all day long every day. This might be followed by reduced exposure to lead, or no exposure at all, for a day, a week, or a month or more as the installer, whose job required him to be a jack-of-all-trades, was temporarily assigned other duties. Sooner or later however intense exposure was likely to reoccur.

It is reasonable to believe that where exposure waxed and waned, perhaps even stopped completely and then restarted, any resultant poisoning would likewise wax and wane, maybe disappear completely and then reappear as the same complaint or as a different complaint.[77] Health complaints that appeared to be nothing more than a jumble of random events, occurring in an era where young and old alike often succumbed to disease in unrelenting and dramatic fashion, must have seemed like nonsense to a physician not alert to the risk. To confuse things even more, if lead was brought home from work the rhythms of exposure as well as the rhythms and patterns of symptoms among family members may have been completely out of sync with the health complaints of the wage earner. For example, because children have been estimated to be 4 times more sensitive then adults to the effects of lead, [78] the rhythm and severity of symptoms in the youngest members of the family may not have been comparable to those seen in the family's adults. This may help to explain why it took so long to suspect that lead poisoning had occurred in the author's family.[i] [ii]

Other forces within the Bell System may have been at work indirectly influencing the way employees coped with the reality of lead in the workplace. The Bell System work force was predominantly white collar during the '40s and early '50s. The System considered its workers a cut above those of other manufacturers and this elitism worked its way into the rank and file. One result was that white-collar divisions whose employees received monthly salaries were said to look down with suspicion on blue-collar divisions whose employees received weekly wages. [79] The feeling was probably mutual. Never-the-less, one can imagine that for those divisions holding the lowest rungs of the social ladder this may have sparked a desire for upward mobility. As a result, in certain blue collar divisions management and peer pressure on employees to behave in a "white collar" manner may have been intense. Such pressures may have led to; reduced hand washing (white collar workers do not get dirty hands), no use of work gloves (white collar workers do not need gloves), no coveralls, no work hats, no face masks, no goggles, etc., even though the risks associated with lead exposure may have suggested the wisdom of using some or all of these items. These pressures may also explain why the author's father went to work everyday in a dress shirt and tie even though he essentially did manual labor.

The End of a Poisonous Era

The span that includes the decade of the 1940s but begins somewhere in the 1930s and ends in the early 1950s, brought with it increased exposure to lead and increased risk of lead poisoning for a group of Bell System workers. Although for these individuals a certain amount of exposure and risk

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[i] "The vagueness of plumbism's [that is, lead poisoning's] symptoms and the ability of the disease to go undetected for years continued to complicate matters long after states began compensating occupational illness." (Warren, page 81).

[ii] "The diagnosis of plumbism [that is, lead poisoning] requires a high index of suspicion, as the symptoms are protean, non-specific, and often insidious", quoted from G.W. Bruyn, Frederik A. De Wolff *in* "Plumbism", chap 27, Handbook of Clinical Neurology, Vol 20, (64), Elsevier Science, 1994.

preceded and followed this period, never again would the danger from lead reach such levels. For workers in other industries, and even in other areas of the Bell System, the opportunities for lead exposure were even greater. However many of these individuals, especially those working in factories, were protected from lead poisoning by aggressive lead-safety programs. Such was not the case for a group of Western Electric field employees whose work sometimes took them to remote parts of the country.

Caught up in this dangerous environment was the author's father, a Western Electric equipment installer whose job included soldering, as well as handling lead-sheathed cable in the field. Lacking meaningful guidance from his employer, he brought lead home to his young family in the form of dust and rosin-core solder. In so doing he unknowingly exposed his wife and their two toddlers to the dangers of lead, resulting in what the author believes was lead poisoning, not only for the children and their mother but for the wage earner as well. A third child may have escaped this fate, perhaps because as a toddler this individual did not crawl as much as the other two siblings, was not as close to soldering operations at home, and engaged in less hand-to-mouth activity.

By 1952 the Bell System was moving away from a major source of lead exposure, rosin-core solder. Solder as a means of securing electrical connections was largely being replaced by solder-less technologies.[80] Wiping solder however would continue to be associated with cases of lead poisoning for almost another 30 years. Also in 1952 the Lead Industries Association (LIA), a trade group representing producers and users, including the Western Electric Co.,[81] published a monograph, Lead in Modern Industry.[82] The document, which mainly extolled the virtues of lead, was also in part an exercise in damage control as more and more criticism was being directed toward use of the metal in both industry and consumer goods. A good discussion of the role that the LIA assumed in defending the metal against its critics can be found in Brush with Death: A Social History of Lead Poisoning.[83] According to the author of that book, chapter 25 of the monograph "The Safe Handling of Lead and its Products" was included only after the LIA's newly hired director of safety prevailed upon the association's board.[84] It is clear from a close reading of this section of the monograph that the LIA was acknowledging that occupational lead poisoning had become a problem in recent years. To help remedy the situation the LIA proposed that lead users and producers implement a program of industrial hygiene based on standards first proposed 30 years before. [i]

Why did those with power to implement a System-wide lead safety program so poorly serve so many Bell System employees? Was it, for example, because management felt that a comprehensive System-wide lead safety program was not cost-effective? [(ii)] [85] [(iii)] And where were the voices of the

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[i] Throughout the 1940s and beyond the LIA worked to actively thwart public awareness of a disease that had roots in Antiquity (see Warren, page 136). The fact that the Bell System still had not implemented a comprehensive System-wide occupational lead safety program 30 years or more after the Department of Labor published the basic elements of such a program is perhaps, in part, a testament to the LIA's success.

[ii] A very informative and scholarly discussion of this question as it applied to the debate over the setting of industry-wide lead-safety standards by OSHA in the late 1970s, including a mention of Western Electric Co., can be found in a paper recently published by Ana-Maria Gonzalez Wahl Ph.D and available at http://www.wfu.edu/~caron/ssrs/Wahl.doc.

[iii] The lack of a comprehensive lead safety program seems to have been part of a myopic attitude toward occupational safety in general within the Bell System. For example, in the early part of the 1940s Bell companies were successfully sued twice over their disregard for the safe use of carbon tetrachloride, a highly toxic solvent that was widely used in the System until its use in the United States was banned in the early 1960s. In one case the employee died as a result of

labor unions and workers in all this?[86] An examination of the archives of the Communications Workers of America located at New York University shows that the union issued no public statements on occupational lead exposure before 1981.[87] [88] As for the exposed worker George Beeker of the United Steel Workers of America, addressing a symposium on the health effects of occupational lead exposure in 1975, perhaps spoke for all of them;

"It is important that we understand the problems of lead contamination as viewed from the eyes of the people who actually work in these types of operations.…the nagging fear that perhaps something could be poisoning them, in spite of the company's reassurance that they have nothing to worry about. They bury their fears that the stomach cramps, aching joints, and headaches they suffer are connected with their work. They have the company's assurance…that there is no real health problem in the [industry]…Where do these workers turn for help? They must work to survive, to support their families, so they eagerly grasp whatever assurance is offered to them." [89]

Whatever reasons the Bell System had for neglecting this threat to the workers' welfare, the outcome was lives damaged or destroyed by a disease that should never have happened.

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on the job use of this poison (*Mitchell vs. Mountain States Telephone; 61 Ariz. 436; 150 P.2d 355; 1944 Ariz. LEXIS 143*). In the other case a Bell company was successfully sued for not warning an injured employee of the dangers of carbon tetrachloride (*Buttner v. American Bell Telephone Co. (1940) 41 CA2d 581, Second Appellate District, Division One Nov 22, 1940*). The toxicity of carbon tetrachloride had been known since at least the late '20s.

Annotated Bibliography (and other source material)

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[1] Two siblings in the family, both male, had difficulty with schoolwork beginning in grade school. Both had problems concentrating on their lessons in class. In addition the younger child had behavioral problems that today would probably satisfy criteria for the hyperactivity component of Attention Deficit Hyperactivity Disorder (ADHD) (*Diagnostic and Statistical Manual of Mental Disorders, 4th Ed., American Psychiatric Association, 1994, pp 78-85*). The older child did not experience hyperactivity as defined by the criteria. In the older child the problems necessitated repeating the first grade. In the younger child the problems necessitated repeating the seventh grade.

Both children grew up in the same household and had the same mother. Although she smoked cigarettes around her young children her smoking habit during either pregnancy is not known. Did maternal smoking contribute to the children's disabilities? Some have claimed that maternal smoking in and of itself can result in hyperactivity and disturbed behavior in children (see "additional reading" at the end of the reference section), while others have disputed this saying that smoking is not a cause of ADHD once other factors, particularly family history, are taken into account (Knopik, *Psychological Medicine 35, 625-635, 2005*). Baghurst and others have shown that in homes where children were exposed to lead, blood lead levels were higher if the parents smoked than if they did not (see Baghurst, *Archives of Environmental Health, 1992*). Several studies in animals reported finding unique biologic mechanisms that supported either lead or smoking as causative for hyperactivity and attention deficit (see Silbergeld, Sauerhoff, Gross-Selbeck, Winneke, among others, in "additional reading", and below). In the family under discussion several things argue against smoking being the sole cause if it made a contribution at all. The first is that the older child did not show hyperactivity, a hallmark of ADHD allegedly due to maternal smoking. The second is that the younger child also developed a motor speech disorder at about the same time that the behavior disorder appeared. Motor speech disorders in children have not been related to maternal smoking but have been tied to lead poisoning. The third is that since smoking related damage and damage from lead poisoning occur by different proposed mechanisms, smoking and lead could theoretically have acted synergistically to produce the children's problems. The fourth is that there is an explanation for the differences observed between the two siblings in the severity of their disabilities. And that is that the greater hand-to-mouth activity of the younger juvenile, arguably the one with the greater disability, may have resulted in greater ingestion of lead. Finally, according to Biederman "Family studies of ADHD have consistently supported its strong familial nature" (Biederman, *Biol. Psychiatry 57, 1215-1220, 2005*). In the family under discussion there was no history of ADHD except for the two siblings. This suggests that their cases of ADHD were not genetic in origin, heredity being the most common cause, but rather environmental. However no large well-controlled study has ever supported smoking as a stand-alone cause of ADHD despite its on-again, off-again popularity as one of the leading, but still unproven, contributors to this disorder.

[2] Winneke, Gerhard, "Animal Studies", in Lead Toxicity: History and Environmental Impact, Johns Hopkins Press, 1986. (N.B.: from page 231; "it is important, however, that these animal studies have shown that lead is considered causative for neurobehavioral deficit, that, furthermore, such deficit is observed in the absence of overt signs of toxicity, i.e. in 'assymptomatic' animals, and that some of the neurobehavioral deficit resembles cognitive deficit in man".)

[3] Baghurst P.A., et.al. "Environmental exposure to lead and children's intelligence at the age of seven years: The Port Pirie Cohort Study", *New England Journal of Medicine* 327(18),:1279-84, 1992. (N.B.: an oft-quoted study, it found an inverse relationship between IQ at the age of seven years and average blood lead concentrations).

[4] Needleman, H.L. et.al "Deficits in psychological and classroom performance of children with elevated dentine lead levels", *New England Journal of Medicine*, 300, pp 689-694, 1979. (NB: Of interest was an evaluation of each child's behavior in the classroom by the teacher. The teacher was blinded to the child's lead level. Measures of distractibility, persistence, dependence, disorganization, hyperactivity, impulsiveness, frustration, daydreaming, and inability to follow directions were made. In 95% of the above categories, as well as overall, low lead subjects scored significantly better than high lead subjects.)

[5] Needleman, H.L. "The long-term effects of exposure to low doses of lead in childhood: an 11 year follow-up Report", *New England Journal of Medicine*, 322, pp 83-8, 1990. (NB: a follow-up of lead-exposed individuals first tested as fifth-graders in 1979. Higher lead levels were associated with lower class standing in high school, increased absenteeism, lower vocabulary and grammatical-reasoning scores, poorer hand-eye coordination, and longer reaction times.)

[6] Pocock, S.J. et.al. "Environmental lead and children's intelligence: a systematic review of the epidemiological evidence"; *British Medical Journal*, 309, 1189-1197; November, 1994. (N.B.; The authors undertook an analysis of 26 published epidemiological studies " so as to quantify the overall magnitude of the relation between full scale I.Q. in children aged 5 years of more and their body burden of lead" [page 1189]. The authors conclude, " Our systematic review of the overall evidence shows a small but potentially important deficit in full scale I.Q. among children with raised body lead burden. However, the inherent limitations of observational epidemiology…means that uncertainty remains as to the…impact that lead makes on children's neuropsychological development" [page 1196].

[7] Byers, R.K., Lord, E.E. "Late Effects of Lead Poisoning on Mental Development", *American Journal of Diseases of Children*, 66 (5), 471-494, 1943. (N.B.; an anecdotal study of 20 children initially hospitalized with lead poisoning in the Boston area. Following hospital discharge these children, part of a larger cohort of victims of lead poisoning, then entered the school system at some point. From page 479, "it was the opinion of the medical staff that these were normal children at the time they were originally seen in the hospital. It was obvious that 1 or 2 unsatisfactory children might be found in any group of "normal children" picked in this way at such an early age [all but one was 4 years or younger at the time of hospitalization, one was age 6 ½], but on the whole, the expectation of reasonable average progress in school was justifiable for the group……with one definite and a second possible exception, none of the 20 children succeeded in school".)

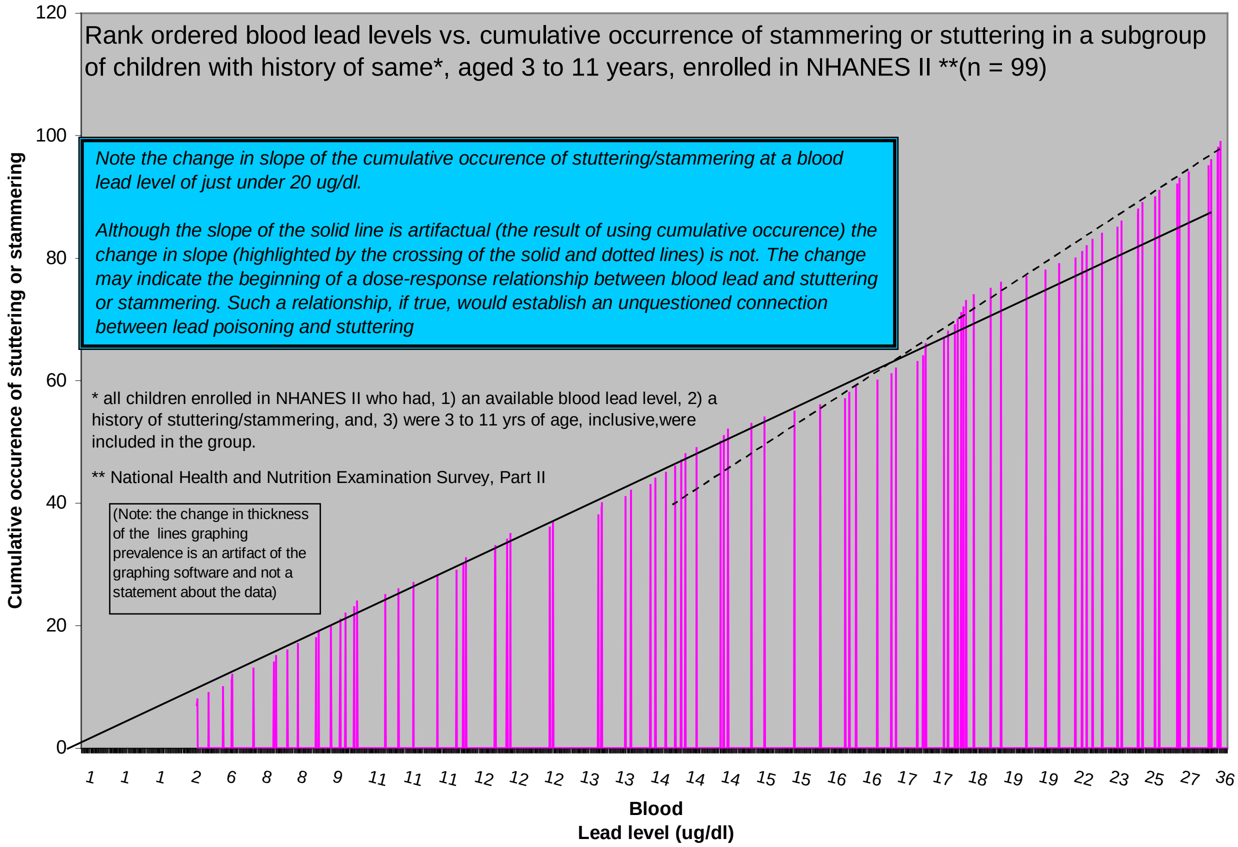
[8] Stuttering in the younger of the two boys. While it gradually diminished in intensity it was still evident from time to time in his fifth decade. There is some evidence that in this case the stuttering was acquired (that is, "neurogenic") rather than being developmental even though the individual does not remember a time when he did not stutter. The stuttering was never accessorized with grimaces or "tics", was noted for repetition of the initial syllable, and included 'blocked speech' on occasion, that is, brief periods where he was unable to vocalize at all. Damage to the innervation of the muscles of the larynx has been a noted characteristic in some cases of lead poisoning (Cantarow, page 131) and dynamic dysfunction of the larynx in victims of stuttering has been noted by some investigators (Adams MR, Freeman JF, Conture EG, "Laryngeal dynamics of stutterers" in Nature and Treatment of Stuttering: New Directions [Curlee RF, Perkins WH; eds], College Hill Press, San Diego, 1984; chap 6).

[9] Mellins, RB, Jenkins, CD, "Epidemiological and psychological study of lead poisoning in childhood", JAMA 158 (1), 15- 20, May 7, 1955. (N.B. from page 18 " During the acute illness several children lost speech entirely, but they gradually regained this ability as recovery proceeded…six [of 21 studied with ages up to 47 months] had speech impediments acquired during the acute illness…thus, on both motor and conceptual levels, language development has been affected.")

[10] Although a relationship between speech impediments and lead poisoning has been mentioned by more than one author (see Mayfield, Mellins), very little if anything has been written about a specific relationship between stuttering or stammering and lead poisoning. In 1976, however, the Centers for Disease Control (CDC) launched the second National Health and Nutrition Examination Survey (NHANES-II). The CDC posted the study data, study protocol, and manual of study operations to the their website http://www.cdc.gov/nchs/about/major/nhanes/nhanesii.htm). In that survey which combined data from health questionnaires with data from physical examinations and laboratory work in over 20,000 U.S. residents, individuals aged 6 mos to 11 years (n = 6,839) were asked if they suffered from stammering or stuttering at the time of the interview. The study plan called for determining blood lead levels in all sample persons 6 months to 6 years of age, and in 50% of all sample persons 7 years to 70 years of age. Although blood lead samples were drawn and reported in over 10,000 individuals, there were an additional 2,000 for whom blood lead levels were to have been reported but for whom levels were missing or otherwise unreported. Blood lead determinations were said to be missing for a variety of reasons, such as refusal by an individual to have blood drawn, a sample aliquot insufficient for analysis or inadvertently destroyed, etc. Partly for this reason, and partly as a result of no lead being found, of the 162 children aged 6 mos to 11 years who suffered from stuttering or stammering, only 99 were documented to have lead in their blood.

In a paper titled "Blood lead, hearing thresholds, and neurobehavioral development in children and youth" (Schwartz J, Archives of Environmental Health 42,2; pp 153-160, 1987), the author concludes that "lead was not associated with the probability of a child having a diagnosed speech difficulty", although he presents no data to support this conclusion. While after examining the NHANES II data the author of this report agrees that there is not a statistically significant relationship in the study between stuttering or stammering and blood lead levels, the author believes that overall the data say a good deal more than that. When the average blood lead levels for the 99 children previously referred to are compared to the average blood lead levels for 254 children aged 6 mos to 11 years who had no history of stuttering or stammering and who also had evidence of lead in their blood, the former group was found to have a higher mean blood lead level (15.5ug/dl) than the latter (14.4 ug/dl), as would be expected if the hypothesis that lead poisoning is a cause of stuttering and stammering is true. By both the t-test and the f-test the difference between the means was not significant (p=.08 to .09 depending on the test used). This is not to say that a relationship between blood lead and stuttering or stammering does not exist (see also discussion below). Rather it states that for this sample the odds that the relationship is by chance alone is approximately one in ten rather than one in twenty or less as standard inference testing requires before statistical significance can be claimed. Although this result may be an accurate representation of the entire population of persons who have both speech impediments and detectable blood lead levels, it may also reflect the relatively low blood lead levels found in the study.

When rank ordered blood lead levels on 3314 individuals aged 6 mos to 11 years (this includes all individuals in this age group who had a detectable lead level regardless of the presence or absence of stuttering or stammering) are plotted against the cumulative percent prevalence of stuttering or stammering for the same group, an unexpected jump in the prevalence rate at just under 20ug/dl suggests the beginning of a dose-response curve. (see graph representing a subset of this data, next)



Together with the difference in mean blood lead levels (see above) as well as previously published empirical observations and neurological mechanisms (see Cantarow, page 131), these data hint that a significant relationship between stuttering or stammering and blood lead levels might well exist. The NHANES II data reveal two other findings. Of the 6839 children for whom there are data on stuttering or stammering, there was zero prevalence of stuttering or stammering under the age of 3 years, suggesting perhaps that a child's language skills are not sufficiently developed for these impediments to be detected in younger children. The other finding is that between the ages of 6 months and 11 years there is an inverse relationship between age and blood lead level. There are at least two possible explanations for this. One is that the mouthing activities of younger children lead to higher blood lead levels due to greater ingestion of lead. The other is that as older children began accelerated growth, to a great extent lead is taken out of the blood and deposited in bone and teeth.

[11] Mayfield, S.A. "Language and Speech Behaviors of Children with Undue Lead Absorption: A review of the Literature"; *Journal of Speech and Hearing Research*, 26, pp 362-368, 1983.

[12] The male parent, and the older male sibling after reaching adulthood, both suffered from high frequency hearing loss.

[13] Repko, John D; The Effects of Inorganic Lead on Behavior and Neurologic Function; Final Report, U.S. Department of Health, Education, and Welfare, Public Health Service, January, 1978. (N.B.: the experiment was conducted using volunteers from a manufacture of battery cases. The control group were volunteers who had no known exposure to toxins. Mean blood Pb levels of test subjects was 46ug/100cc; mean blood Pb levels of controls was 18ug/100cc. Compared to controls there was significantly greater high frequency hearing loss in test subjects.)

[14] See also note # 1. The male parent in particular had a very irritable personality during the 1940s and '50s. He seemed unable to tolerate the everyday noises and activities of his children. He was often short-tempered. This in and of itself was perhaps not remarkable except for the fact that for no obvious reason his irritability did a complete about face and he became much calmer beginning in the late '50s. To a lesser extent this behavior was true of the female parent as well, who at one time had described herself as "high strung". Irritability, impotence, headache, neurosis, and depression are some of the hallmarks of chronic lead intoxication according to Cullen, Baker, and others.

[15] Baker E.L., Feldman R.F., et.al "The role of occupational lead exposure in the genesis of psychiatric and behavioral disturbances" Acta Psychiatrica Scandinavica 67, Suppl 303; pp38-48, 1983. (N.B.: from page 42 " As increased concentrations of lead in blood occurred, increased reports of tension, anger,..fatique,…depression…and confusion were noted")

[16] Schottenfeld RS, Cullen MR "Organic affective illness associated with lead intoxication" *American Journal of Psychiatry* 141:11, pp1423-1426, 1984. (N.B.: from page 1424, "the relationship of depression to lead intoxication was clarified by subsequent clinical course in all patients. Two patients had a clear-cut resolution of symptoms after [treatment for lead poisoning] and removal from lead exposure and the two others experienced subjective improvement after removal from exposure. One patient who had complete resolution..of depression…was accidentally re-exposed to lead….and his severe depression recurred in [association with renewed elevation of his blood lead level].")

It is interesting to speculate on the role that perseveration may have played in the genesis of the depression in these two patients, since perseveration can be a precursor to mental depression in humans. Perseveration describes any behavior that an individual or animal is unwilling or unable to end despite there being no hope that the behavior will ever be rewarded. In well-controlled studies perseveration has repeatedly been documented in animals with lead intoxication. For example, in a reinforced response experiment testing cognitive behavior a poisoned animal (a monkey in this case) continuously and repeatedly pressed the wrong button for hours on end (*Rice DC, Karpinski KF. "Lifetime low-level lead exposure produces deficits in delayed alternation in adult monkeys." Neurotoxicol. Teratol. 1988; 10:207-214).*

[17] Headaches occurring in the male parent and in the older male sibling sometime between 1950 and 1957. The headaches were severe frontal and for the older male sibling required a controlled substance for alleviation. Headaches were frequent over perhaps a 3-year period and then completely subsided. Frontal headaches never recurred except on rare occasion and then never with such severity.

[18] The male parent was completely edentulous by 1965 although a 1941 picture shows him with apparently healthy teeth. The younger male sibling was completely edentulous by 2002. The female parent was 90% edentulous by the time of her death at age 89. Both male siblings had extensive dental work done as children to treat carious teeth.

[19] Cantarow A., Trumper M., Lead Poisoning, The Williams and Wilkins Co., Baltimore, 1944. (N.B.; from pages 79-80, "it has been remarked frequently that the teeth of lead workers are in notoriously poor condition….although a direct relationship between the deposition of lead and the development of caries has not been demonstrated…this relationship is suggested by the rapid occurrence of caries in cats exposed to lead in view of the fact that this species invariably has perfect teeth under normal conditions.")

[20] Moss, M.E. et.al., "Association of dental caries and blood lead levels", JAMA, 281(24), 2294-2298, 1999. (N.B.; authors examined the association between log of blood lead level and caries status in 24,901 individuals participating in the Third National Health and Nutrition Examination Survey (NHANES III). A statistically significant association was found among all age groups in both adjusted and unadjusted analysis.)

[21] The older male sibling developed high blood pressure as an adult. There is no history of high blood pressure, stroke, or heart attack in any family member, relative, or ancestor.

[22] Schwartz, Joel, "The relationship between blood lead level and blood pressure in the NHANES II survey", Environmental Health Perspectives 78, pp15-22, 1988.

[23] Moel DI, Sachs HK, et.al., "Renal function 9 to 17 years after childhood lead poisoning". *The Journal of Pediatrics* 106: 729, 1985. (NB: systolic blood pressure was found to be significantly elevated in study subjects compared to controls, although the authors caution that confounding variables may account for the difference. If confirmed this finding would suggest that hypertension may develop years after an episode of poisoning.)

[24] The female parent developed cataracts necessitating their removal. The older male sibling has been diagnosed with early cataracts.

[25] Schaumberg, DA, et.al. "Accumulated lead exposure and risk of age-related cataract in men", *Journal of the American Medical Association* 292(22); 2750-2754, 2004. (N.B.: in this epidemiological study there was the suggestion of a relationship between lead levels in bone, age, and the development of cataracts).

[26] Lead poisoning can inhibit the parasympathetic nervous system, a system over which there is no voluntary control. The parasympathetic nervous system also controls the erection of the male penis. Failure to achieve an erection (that is, impotence), a problem that the author's father suffered from for a time in the early 1940s while he was working in a high lead environment, can be the result of lead poisoning.

[27] Cullen, M.R., page 240; "epidemiologic studies indicate that continuous or repeated exposure to excessive amounts of inorganic lead results in….dysfunction…of various organs. …..Clinically these may be dramatic…but far more often are subtle and nonspecific with symptoms of irritability..impotence, headache..and signs of depression…..".

[28] Needleman HL, Riess JA, et.al "Bone lead levels and delinquent behavior". JAMA 275(5), pp 363-369, 1996. (NB: a positive correlation noted)

[29] Dietrich KN, Ris MD, et.al. "Early exposure to lead and juvenile delinquency", Neurotoxicology and Teratology 23, pp 511-518, 2001. (NB: a positive correlation noted)

[30] "Reclamation unit helps in defense: Bell System utilizes old equipment for own purposes and for national program", The New York Times, July 20, 1941. (N.B.: the reporter wrote that a Bell System spokesperson indicated that the System used about 3,000,000 [three million] pounds of solder a year)

[31] Memo to Dr. Frank B. Jewett, President, National Academy of Sciences from the Advisory Committee on Metals and Minerals – Metals Conservation & Substitution Group, National Academy of Sciences, National Research Council, Advisory Committee on Metals and Minerals, June 12, 1941. Archives of the United States National Academy of Sciences.

[32] Department of Labor and Industry, State of Michigan, Health Hazards in Soldering, Lansing Michigan, March, 1945. (N.B.; The auto industry used large amounts of solder for automotive bodywork and for manufacturing radiators. In this booklet the authors discuss soldering of all types, including rosin-core solder of the type used by the telephone industry. They point out that tin conservation efforts put in place as a result of wartime shortages had increased the lead content of some solders to as much as 98%. It describes the various types of soldering irons in use at the time and the advantages and disadvantages of each. It gives detailed descriptions of good workplace practices for the safe handling of solder. (As an aside, the incidence of disabling work-related injuries for the years 1943 through 1945 for all U.S. industry, available from the U.S. Bureau of Labor Statistics [see *'Work injuries in the U.S. during 1943-1945'; United States Bureau of Labor Statistics Bulletins # 802,849,889. U.S. Government Printing Office*.], documents that for the years in question Bell System safety programs were not as successful as Detroit's in controlling the incidence of all disabling work-related injuries.)

[33] Jewett, Frank B.

[34] Jewett, Frank B., page 20.

[35] Memo to file, War Department, Office of the Director of Material Production Division, Commodities Branch; Record Group 107, The National Archives (ARC identifier 588565), Washington, DC. (N.B.: Sometime during 1941-'42 the War Production Board issued an order that said that all U.S. industries were prohibited from using solders containing more than 30% tin except by special permission. Following this order typical solders according to the Board were (tin/lead): 30%/70%, 25%/75%, 20%/80%, 15%/85%, 10%/90%, 5%/95%. In some industries silver might have been substituted for tin. This allowed for the use of up to 99% lead in solder.)

[36] McHugh, K.S. "War Activities of the Bell Telephone System " *Bell Telephone Magazine*, November 1942. (N.B.: McHugh reports that the System had an intense conservation of materials effort underway in order to free up as much material as possible for the war effort. To this end the System reduced tin usage from 980 long tons to 130 long tons. There seemed to be no shortage of lead at the time.)

[37] Investigation of Industrial Uses of Tin-Free and Low-tin Solder: Part III. C.A. Reichelderfer, B.W. Gonser; War Metallurgy Committee, National Academy of Sciences, National Research Council, Washington DC, July, 1944. (Copy of report found in the stacks of the Linda Hall Library, call # TK7870. N38 1944 ESL). A copy of the report is posted on this web site

[38] The number of miles of underground telephone wire (bundled into telephone cable) laid for the year was reported in the Annual Reports of the American Telephone and Telegraph Company. There were 5,568,000 miles laid for the three-year period ending in 1943. Beginning in late 1940 and ending in late 1942 the System installed an underground transcontinental phone cable 1630 miles long. The cable (two of them actually) contained a total of approximately 140 telephone wires (*Bell Telephone Magazine*, November 1941). This totaled 228,200 miles (1630 miles X 140). The balance of underground wire for the three years was assumed to be cable composed of 1800 telephone wires (prior to the introduction of coaxial cable 1800 wire lead-covered cable had become a standard for the System [*Bell Telephone Quarterly, January, 1929*]). 5,339,803 (that is, 5,568,003 – 228,200) divided by 1800 equals 2966 miles of cable. Together with the 1630 miles of transcontinental cable this totals 4596 miles of buried telephone cable.

[39] According to American Telephone and Telegraph Co annual reports, "total plant" (that is, the Company's fixed tangible assets) increased from $5,047,880,000 in 1941 to $5,512,395,000 in 1944, an increase of 8%. Total plant investment increased every year during the war. Overall, the Bell System's infrastructure (that is, wiring, cable, telephone offices, exchanges, etc.) grew at an annual rate that varied between 4% and 8% (in dollar terms) during the war years.[39] This was versus an 11% increase (also in dollar terms) between 1935 and 1940.

[40] According to the "Bell System Statistics" sections of the AT&T Annual Reports for the years 1938 through 1944, the number of new telephones installed in the U.S. during the year were: 429,112; 774,709; 948,177; 1,357,151; 1,171,800;1,233,697; 333,716. For the same years the number of new central offices built each year were: 30; 26; 51; 76; 76; 107; 31.

[41] McHugh, K.S., page 12.

[42] There was in fact a fair amount of experimenting with solder alloys by several companies including Western Electric. Various combinations and strengths of copper, bismuth, silver, lead, tin, cadmium, and antimony, were tried, and always with the goal of using the least amount of tin possible. However many of the alloys were found wanting and were therefore rejected. There is good evidence that by 1944 the Bell System had settled on a rosin-core solder that contained 77% lead and 20% tin together with small amounts of other metals, and a wiping solder that contained somewhat less lead and more tin (see endnote 37).

[43] Vintage Bell System solder often did not come stamped with a date of manufacture. Never-the-less a range of dates can be arrived at based on characteristics of the printed label affixed to the spool, as well as on the lead and tin content of the solder. One of these characteristics comes from the fact that Nassau Smelting and Refining Works Ltd. was purchased by the Western Electric Company in 1931 and renamed Nassau Smelting and Refining Co, Inc.[43] Thus "Nassau Smelting and Refining Co, Inc." printed on the label indicates that the solder was manufactured after 1931. Another characteristic is that after the ZIP code was introduced the Company placed its full street address and ZIP code on the label. So the absence of a ZIP code and street address indicates that the solder was manufactured before 1963. Yet a third characteristic is that the lead content of solder hovered near the 68 % mark before the war. So a lead content

of 70% or more indicates that the solder was probably manufactured after the outbreak of WWII. A final characteristic comes from the assumption that once tin became plentiful again, the tin content of solder would have returned to pre-war levels. In the Company's annual reports it is stated that raw materials including lead and tin remained in short supply, and under government control, throughout the early and mid 1940s. They were perhaps briefly available again late in the decade but were scarce during the Korean buildup beginning in 1949. Thus a spool of rosin-core solder with "Nassau Smelting and Refining Co, Inc" printed on the label without a ZIP code or address, and wound with solder containing 70% lead and 30% tin (the actual result of a certified analysis of vintage Bell System solder), is likely to have been manufactured between 1941and 1953, the year the Korean armistice was signed.

[44] See ref # 37, table 3, page 35ff (PDF page 42ff). [N.B.: The archivist at the National Academies of Science (NAS) informed the author in an email that the War Metallurgy Committee failed to retain copies of many of its own reports, including the report cited as reference # 37. Thus one is asked to believe that despite the fact that as many as 100 different individuals and institutions received copies of this report, (see PDF pages 5/6 of the copy posted on this web site) including, ultimately, the Linda Hall Library, not a single copy found its way into NAS files! It is ironic that as one quasi-governmental agency, in this case the NAS, was formulating (without a word of warning to the American worker!) industrial policy that would ultimately pose a major health threat in the form of lead poisoning, another quasi-governmental agency, in this case the American Public Health Association, was working to neutralize that threat. This outcome could have been avoided, or at least minimized, had the NAS only taken on at the outset the responsibility to stress to all participants the need for lead-safety training. One suspects that if the contents of all three parts of the Reichelderfer report were ever to become widely known (Parts I and II apparently remain classified assuming they can even be located) it could prove to be a major embarrassment, not only for the NAS but for the companies involved as well. The complete report would likely reveal in some detail the plan to expose thousands of blue collar workers to high levels of lead, probably without the worker's knowledge and certainly without adequate safety training.]

[45] Lead Poisoning, Committee on Lead Poisoning, p 28; American Public Health Association, NY, NY, 1930.

[46] Occupational Lead Exposure and Lead Poisoning. Committee on Lead Poisoning, p 8; American Public Health Association, NY, NY, 1943.

[47] Fischbein, A et.al. "Health Status of Cable Splicers with Low-Level Exposure to Lead: Results of a Clinical Survey", *American Journal of Public Health*, 70(7), p 697-700,1980.

[48] Milpitas Amateur Radio and Electronics Society, "Safe Soldering Work Practices"; (www.w6mlp.org).

[49] Metallurgy Committee, July, 1944.

[50] Burgess, W.A., Recognition of Health Hazards in Industry: A Review of Materials and Processes, John Wiley & Sons (pub), 1981. (N.B.: Goes into detail concerning the different types of solders available, their melting temperatures and their compositions. Discusses the safe handling of solders. The most common solder in use at the time of publication was composed of 65% tin and 35% lead along with traces of bismuth, copper, iron, aluminum, zinc, and arsenic. In general as the lead content of solder goes up so does its melting temperature. 30% lead solder melts at 373° F while 95% lead solder melts at 594° F. Of course the soldering iron must be hotter than that to both melt the solder and to heat the metal to which the solder must stick The higher the temperature at which solder becomes a liquid the higher the vapor pressure of lead. This leads to more lead escaping into the atmosphere.)

[51] Lead Poisoning; The Recognition of Hazardous Industrial Lead Exposure. Committee on Lead Poisoning, p 7; American Public Health Association, NY, NY, 1942.

[52] Committee on Lead Poisoning, page 5, 1943.

[53] Schacht, John N., The Making of Telephone Unionism: 1920-1947; Rutgers University Press, New Brunswick, New Jersey, 1985. (N.B.; on page 104 the author writes "From the mid-1930s through 1941, average earnings in the telephone industry had been much higher than those for the manufacturing workforce as a whole. …but in 1942 average wages in manufacturing leaped ahead of those in telephone….by March 1945 the average telephone worker had straight time-earnings of $0. 90 an hour and $40.60 a week while the average factory worker earned $0.97 and hour and $47.51 a week")

[54] Pueschel, S.M. et.al (editors), Lead Poisoning in Childhood; Paul H. Brookes (pub), 1996. (N.B.: from p 166: "it is now recognized that a significant number of children with lead poisoning are poisoned by lead-contaminated dust ingested through normal childhood hand-to-mouth activity. On occasion, this dust….is tracked into the house or from the clothes of a parent who works in a lead-related industry.")

[55] Burgess, W.A., page 113

[56] Studies have shown that blood lead levels in young children correlate quite closely with the quantity of lead dust found on floors and in carpets in the home. Isotope signature determination has demonstrated that lead can originate from outside the home - brought in on shoes and clothing - and, if lead paint was used in the home, from inside as well (*Manton, Environmental Research, Section A 82***,** *60-80 (2000)*) . Analysis of stool samples for lead, obtained from children with known poisoning of a defined duration, suggests that ingestion of one to two milligrams of metallic lead a day for six months can result in poisoning *(Barltrop, The Lancet; p 1017, November 11, 1967)*. This was corroborated in two other studies, one being a study where 1 mg of lead was fed to normal adult human volunteers for 120 days resulting in blood lead levels of around 30 ug/dL (*Kehoe, Food and Chemical Toxicology, 25; p 439 –453, 1987*), the other where juvenile primates were given 100ug/kg of oral lead for 200 days. This regimen resulted in peak blood lead levels of 25ug/dL in the animals as well as cognitive dysfunction (*Rice DC, Toxicol Appl Pharmacol 77:201-210, 1985*). Such blood levels have resulted in long-term neurologic damage in children. If 100ug/kg/day of lead were ingested by a 30 lb child this would be the equivalent of approximately 1.3mg of lead/day. To help put this into perspective consider that 2 milligrams of lead dust (a powder as fine as talc) if piled up would be no larger than the head of a pin and probably considerably smaller, if spread over the floor would be virtually invisible, would be difficult to pick up off of hard-surfaced floors using standard home dust mops (as would most fine powders), and would have undoubtedly passed straight through the cloth filtering systems of most home vacuum cleaners in use during the 1940s and '50s.

[57] Castellino, Nicolo; Castellino, Pietro; Sannolo, Nicola (Eds): Inorganic Lead Exposure: metabolism and intoxication. Lewis Publishers, London, 1994; pages 189-190.

[58] Dublin, Louis, "Occupational Hazards and Diagnostic Signs: a guide to impairments to be looked for in hazardous occupations", Bulletin of the United States Bureau of Labor Statistics No. 306, U. S. Department of Labor, Bureau of Labor Statistics, U.S. Government Printing Office, 1922.

[59] Lead Poisoning , 1930.

[60] Western Electric Company, Safety Code (ID-271 [7-30]); Installation Department, Telephone and Telegraph Building, 195 Broadway, NY, NY. 1930.

[61] There was a decline of approximately 14% in the number of telephone equipment installers (referred to as "Central Office Installation and Maintenance Men" before 1944, or "Installation and Exchange Repair Craftsman" after 1944) employed by Class A Communications Common Carriers (predominantly the Bell System), from 1941 to 1944 (*Federal Communications Commission, Statistics of Communications Common Carriers, 1941 (p.15), 1942 (p.18), 1943 (p.18), 1944 (p. 21)*). This was despite the fact that between 1940 and 1944 Bell System switching centers (that is, central offices and private branch exchanges) were being built at a rate twice as fast as the rate at which they had been built between 1935 and 1940 (*American Telephone and Telegraph Co., Annual Report for the Year 1944*). For Western Electric equipment installers this meant longer hours at work during the war years. Longer hours meant more exposure to higher levels of lead by employees who because of chronic fatigue from overwork and lack of appropriate safety training were at an even greater risk of lead contamination and subsequent poisoning.

[62] Memos on file, The War Department, The National Archives, Washington D.C.

[63] American Telephone and Telegraph Company Annual Report, 1943.

[64] War Department Technical Manual, Shop Work, TM 11-453, U.S. Army, March 11, 1942. (N.B.: In technical manual TM 11-453, there is an in-depth discussion of how to solder telephone equipment. However there is nothing in the manual about the dangers of lead in solder, and, except for an admonition not to shake solder from the end of a soldering iron, there are no cautionary statements at all.)

[65] War Department Technical Manual, General Safety Manual, TM20-350, January, 1946. U.S. Army Military History Institute, Carlisle, Pennsylvania.

[66] By 1965 the main sources of lead exposure for Bell System employees were lead-sheathed cable and wiping solder. Rosin-core solder had been largely replaced by solder-less technologies. In a statement before the 1965 session of the New York State Legislature, the Communications Workers of America (CWA) commented on proposed man-hole safety legislation. A man-hole was where a large proportion of cable splicing took place and where wiping solder was used. In their statement the CWA listed many of the dangers of man-hole work both for the public as well as for the Bell System employee. Although they listed the dangers of; burns from molten lead, electrical shock, flooding, explosive gas, and oxygen deficiency, they did not list lead poisoning as a risk, even though it was a very serious threat. (from the CWA archives, Tamiment Library and Robert F. Wagner Labor Archives, New York University, NY, NY.)

[67] Bell System Practices of 1948 (Diamond State Telephone) on man-hole safety likewise fails to give any advice on lead safety. Copy found in the CWA archives, Tamiment Library and Robert F. Wagner Labor Archives, New York University, NY, NY.

[68] Greenfield, Irving, "Lead Poisoning – X: effects of lead absorption on the Products of Conception", *New York State Journal of Medicine* , pp 4032-4034, December 15, 1957. (N.B.: Included here because it reports a case of lead poisoning following the use of rosin-core solder. There are other published case reports of lead poisoning following the use of solder although it is unclear whether rosin-core solder was used. The other cases found were: *Duchateau "A mild case of occupational lead poisoning", Archives Belges de Medecine Sociale, Hygiene, Medecine du Travail et Medecine Legale 16(4) pp 175-7, 1958* and, *Lachnit, V, "The Problem of Lead encephalopathy", Weiner Zeitschrift fur inner Medizin 43: 507-14, 1962*. The fact that the Greenfield case occurred in the early 1950s is significant in that the lead content of the solder was probably high at the time due to wartime shortages.

It was difficult to find even a single published report in the English language literature of lead poisoning due to occupational exposure to rosin-core lead solder. The Greenfield and subsequent Masci reports (see *"Blood Lead Concentration and Biological Effects in Workers Exposed to Very Low Lead Levels" Masci, Oliviero MD; Carelli, Giovanni PhD; Vinci, Francesco MD; Castellino, Nicolò MD; Journal of Occupational and Environmental Medicine, 40(10), October 1998, pp 886-894*, in addition to Greenfield reference) were serendipitous finds. It is worth pausing a moment to reflect on why this may have been so (see also "A lead exposure model for the Bell System" on page 12 of this document). Among victims of lead exposure a telephone worker could expect to experience significantly lower levels of toxicity than a worker in a lead smelter, for example. That was because the opportunities for ingesting or inhaling lead in large quantities were far greater at a smelter than at the average telephone work site. Furthermore until sometime in the 1950s if a victim of lead poisoning was not in a coma, paralyzed, withering in pain from colic, or dead (all the result of exposure to high levels of lead), and did not have a blood lead level of at least 80ug/dL (a level more likely to occur in a lead smelter worker than in a telephone worker) then the decision makers (mainly but not exclusively the medical community) judged such people to be free of the toxic effects of lead. This was true even if the workers had known and ongoing occupational exposure to lead, elevated blood lead levels, impotence, speech impediments, learning disabilities, multiple carious teeth, cataracts, mood disorders, high blood pressure, etc, all of which can occur at much lower levels of toxicity. Although many, but certainly not all, of the conditions just mentioned were not tied to lead poisoning until later, the thought that perhaps not everything was known about lead poisoning and for that reason caution should be exercised apparently never entered the minds of U.S. decision makers. This included Bell System management. As Dr. Jane Lin-Fu pointed out in her New England Journal article (see references), conclusions reached about what constituted a "normal" blood lead level were for decades completely nonsensical. Such incautious behavior was not universal however. For example European industry was decades ahead of the U.S. in reducing exposure to lead even though Europe's medical community was no more knowledgeable about the dangers of lead then were U.S. physicians (see Warren, page 68).

[69] Greenfield, Irving

[70] Cullen M.R., et.al. "Adult Inorganic Lead Intoxication: Presentation of 31 New Cases and a Review of Recent Advances in the Literature", Medicine 62(4), p 221-247, 1983. (N.B.: three cable splicers were included among the 31 cases).

[71] Fischbein, A et.al. (N.B.: The authors found that 29% of 90 telephone cable-splicers examined had lead-associated CNS symptoms while 21% had lead-associated G.I. symptoms.)

[72] Court of Appeals of Georgia, Middlebrooks v. Atlantic Metallic Casket Co., 63 Ga. App. 62011 S.E.;2d 682; 1940 Ga App. LEXIS 508.

[73] Committee on Lead Poisoning, 1942.

[74] Committee on Lead Poisoning, 1943.

[75] Burgess, W.A. page 113

[76] Department of Labor and Industry, State of Michigan.

[77] Goetz, Christopher; Washburn, Kurt; Kompoliti, Katie: "Metal intoxication: lead", chap 20, in Clinical Neurology, vol 2, page 2, Lippincott, Williams, and Wilkins, 1998. (N.B.; from, page 3, "Not only is there a lack of correlation between blood concentrations and clinical symptoms, but both humans and animals may exhibit differing symptom severity with identical exposure.")

[78] Chisholm JJ, Barltrop D, " Recognition and management of children with increased lead absorption", Archives of Diseases in Childhood 54; pp 249-262, 1979. (N.B.; from page 251, "although there are no data on dose response for ingested lead in children, it is of interest to compare studies by Kehoe [*Journal of the Royal Institute of Public Health and Hygiene*, 24, 101-120, 129-143, 177-203; 1961] on chronic adult volunteer lead feeding, with the information in children [provide by *Mahaffey; Pediatrics, 59, 448-456, 1977*]. Kehoe found that raised [average blood lead] levels to 80 [micrograms] and a likelihood of symptomatic poisoning could be induced after 3 or 4 months with a daily dose of 4 mg lead. From data on fecal lead, Barltrop and Killala [*Lancet, 2, 1017-1019, 1967*] and Chisholm and Harrison [*Pediatrics, 18, 943-958, 1956*] calculated that the comparable dose in young children was about 1 mg/day – i.e. 25% of the adult dose.")

[79] Schacht, John N., page 22.

[80] American Telephone and Telegraph Company Annual Report, 1951.

[81] Personal communication from a spokesperson for The LEAD Group, Summerhill, Australia, based on information provided to them by Mr Rick Rabin, who provided the following; "Western Electric Co. was a member of the LIA in the 1940s and 1950s. The Company is listed as attending board of directors or membership meetings several times from at least 1944 to 1951."

[82] Lead in Modern Industry: Manufacture, Applications and Properties of Lead, Lead Alloys, and Lead Compounds; The Lead Industries Association, New York, 1952. (N.B.: Describes all the ways lead is used in the telephone industry: lead sheathing for telephone toll cables, 'wiping solder' for making air-tight connections between cables, rosin-core solder. Chapter 25 is titled "The Safe Handling of Lead and Its Products". In that chapter it is stated "….lead if improperly used and handled may be a health hazard..…methods for handling lead and its products with complete safety are well understood. In spite of all this, however, erroneous and alarming statements are still made from time to time and unfounded prejudices exist…..Certain principles have been laid down which are helping immeasurably [implying perhaps that there was an earlier problem – ed.] in the prevention of lead intoxication in industrial operations where lead is used. Probably the one factor which has contributed most is the adoption of good housekeeping methods. These include…personal cleanliness…providing showers .….clean lunch rooms….keeping the floor well swept…preventing careless handling of materials. Processes have been revamped….to reduce the duration of exposure. Newer equipment is being constructed with exhaust devices…Lead fumes are being suppressed.)

[83] Warren, Christian

[84] Warren, page 161

[85] Writing about the state of occupational lead safety in the years between the Wars, Warren states, "…*the most dramatic changes took place in large factories. There, economies of scale permitted ongoing investments in hygiene, and greater participation by middle-management specialists such as company doctors encouraged these investments*." (Warren, page 85). Theoretically the repetitive and predictable nature of assembly line work (in this case manufacturing

telephone equipment) could have easily lent itself to the adoption of an occupational lead safety program; air quality and worker compliance could have been monitored on an ongoing basis, assembly line workers could easily have been accessed for training purposes, equipment failures could have been quickly detected and corrected. However it is not until 1946 that this optimistic scenario was borne out for workers at Western Electric's Hawthorne plant. The only acknowledgement of the hazards of lead in a 1943 plant safety handbook was an admonition to wash hands before eating (*Safety Handbook; for tool makers, machinists, welders, inspectors, mechanical, maintenance, oilers, crib-keepers, Western Electric Co. Hawthorne Works, revised edition, November 1943*). A 1946 safety handbook for workers in Hawthorne's wire products shops follows much more closely APHA's 1930 guidelines on lead safety (*Safety Handbook, Wire Products Shops, Western Electric Co., June 1946*).

If anything lead presented an even greater hazard for workers installing telephone equipment in the field then it did for workers at Western Electric's Hawthorne Works, and not because there was greater exposure (ironically there was probably less), but because the risk that existed was largely ignored.

To begin with, assumptions about air quality at a remote, rural, unmonitored telephone work site (that might not be equipped for air handling, especially if the site was still under construction) would have involved unlimited guesswork. Furthermore, unlike factory workers who often did not work in the same clothing they wore home, the employee in the field often did work in the same clothing. This provided a ready means of transporting lead dust from the work place to the home. Yet another issue was that employees might frequently be moved from one remote work site to another, spending only a few days at the home office while in transit. This would have resulted in job demands that might easily have compromised the time needed for safety training and monitoring. Still another issue was that fieldwork often took place in sparsely populated, rural, states that had no legislative statutes, or very weak statutes, covering occupational health and safety. For example, a state might have required that employers report only accidents or injuries that resulted in death. This meant that a company had no requirement to report a case of non-lethal lead poisoning occurring within the state, thus depriving the company of an important incentive to improve working conditions. *I would like to stress again*", Dr. Elston L. Belknap said in a talk given at the 29th Annual Safety Congress, October, 1940, "*the danger here is one of non-recognition* [of uncontrolled lead exposure], *that we have our trouble in the small* [industrial] *plant, not the large* [industrial] *plant*…" (Transactions of the 29th Annual National Safety Congress, p. 174). Each telephone equipment installation worksite could fit the definition of "small industrial plant".

To protect employees in the field from the hazards of lead a dedicated on-site occupational health safety staff, willing to travel to remote locations in order to monitor compliance and employee health, along with a budget for personnel and equipment, would have been required. This would have resulted in a considerable expense that Western Electric might not have been willing to shoulder based on 'unproven' concerns about the safety of exposure to 'low levels' of lead.

[86] Petersen, Joseph L., Communications Workers of America, District Seven, Health and Safety Staff Representative, Email correspondence, March 28, 2005. (N.B.: According to Mr. Petersen CWA kept no records regarding lead poisoning among Bell System workers)

[87] Communications Workers of America, "Opening address of the first regional conference of the union's occupational safety and health", January 12, 1981." Archives of the Communications Workers of America, Tamiment Library, Robert F. Wagner Labor Archives, New York University, NY, NY.

[88] Maybe the Communications Workers of America was too busy negotiating wages to worry about the health and safety of the rank and file. Also, the union's apparent lack of voice when it came to occupational lead safety is consistent with Warren's opinion that "the experience of the lead industry suggests that organized labor played only a minor role in the birth of professionalized occupational hygiene." (Warren, page 66).

[89] Health Effects of Occupational Lead and Arsenic Exposure: A Symposium, Bertram Carnow, U.S. Department of Health Education and Welfare, February, 1976., page 19.

Additional Reading

Selected clinical reference sources on ADHD and smoking;

Linnet KM, Dalsgaard S., et.al " Maternal Lifestyle Factors in Pregnancy Risk of Attention Deficit Hyperactivity Disorder and Associated Behaviors: Review of the Current Evidence". *Am. J. Psychiatry* 160 (6), June 2003. (N.B.; this review article from 2003 concludes that 24 published studies failed to establish a cause - effect relationship between smoking and ADHD beyond a reasonable doubt. Some of the studies failed to find any relationship at all whereas others did find a relationship. None were able to effectively eliminate the possibility that smoking, caffeine and alcohol consumption may in fact be surrogate stand-ins for genetically determined psychopathology in the mother. In fact cigarette smoking and drinking large amounts of coffee may be pharmacological ways of coping with the psychopathology linked to ADHD. Smoking is known to be prominent among ADHD patients.)

Weitzman M, Gortmaker S, Sobol A, "Maternal Smoking and Behavior Problems of Children". *Pediatrics*, 90 (3), p 342, September 1992. (N.B.; this is a study of a group of women and some of their children. The women were part of a group that participated in the National Longitudinal Survey of Young People in 1979 (NLSY79), a National Bureau of Labor Statistics (BLS) sponsored study. Subsequent to that study some of the women bore children and it is these women and some of their children who are the subjects of this study. Of the 6283 women originally interviewed in 1979, 2922, now mothers, were interviewed again in 1986. By 1986 these 2922 women had bore 5255 children. This paper is based on the valid assessment of the Behavior Problems Index for 2256 of these children, aged 4 through 11. A key part of the report is the result of the Behavior Problems Index (BPI), an instrument developed by Zill and Petersen to measure selected childhood behavior problems, including hyperactivity. The authors of this paper matched up a history of maternal smoking with the elements of the BPI and reported that they found statistical significance. That is they report that mothers who smoked during and following their pregnancy (there were too few numbers of women who smoked only during their pregnancy to allow an analysis) were more likely to have children who scored badly on one or more elements of the BPI.

The results and interpretation of these data are problematic and do not allow comparison to other studies of maternal smoking and hyperkinesis in offspring (see Linnet, 2005 in particular). To begin with, reports of hyperactivity were solely based on an interview of the mother. The children were labeled hyperactive or not on the mother's say. So this is not hyperactivity that has been validated by any sort of diagnostic criteria, for example. Secondly, although the authors, as well as the BLS, claim that the BPI has been validated, there is no public information on how, where, or when this might have been done. One does not know, for example, whether reports of hyperactivity led to difficulties in school, whether others beside the mother also noticed the hyperactivity, whether the child ever received therapy for the hyperactivity, etc. Lastly, as in all studies to-date on this topic, there was no data collected on potential exposure to toxic metals.).

Williams GM, O'Callaghan M, et.al. "Maternal Cigarette Smoking and Child Psychiatric Morbidity: A Longitudinal Study". *Pediatrics*, 102 (1), July, 1998. (N.B.; this is one of several studies that looked at the relationship between maternal smoking and childhood behavior problems. In this longitudinal study of 5342 mothers a strong relationship was found between smoking and "externalizing" childhood deviant behaviors based on a scale found in an instrument called the Child Behavior Check List (CBCL). There are two other scales in this instrument that were used in this study, the Social, Attentional, and Thought scale (SAT), and the Internalizing scale. The latter scales include measures of hyperactivity and learning disability, poor concentration, etc., disabilities that have commonly been seen with lead poisoning. These latter scales held a much weaker relationship with smoking. There was no determination of levels of toxic metals in this study.)

Linnet KM, Wisborg K, et.al. "Smoking During Pregnancy and the Risk for Hyperkinetic Disorder in Offspring". *Pediatrics* 116 (2), August 2005. (N.B.; this is a case-control study of 170 subjects with hyperkinetic disorder compared to 3765 subjects without such a diagnosis. The age of the children when diagnosed varied between 2 and 8 yrs. The diagnosis was based on criteria found in ICD-10. Since ICD-10 criteria are not diagnostic criteria, they are similar to but not the same as ADHD criteria found the Diagnostic and Statistical Manual of Mental Disorders (DSM-III). The DSM III includes references to school performance, the ICD-10 does not. After adjustment for confounding variables (with no consideration given to the possibility of exposure to toxic metals) there remained a > 2 fold higher risk for hyperkinesis if the mother smoked during pregnancy (RR 1.9; 95% CI: 1.4-2.7). There was no information collected on post-natal smoking, ADHD without hyperactivity (a category that included nail biting and thumb sucking) or on school performance, specifically the presence or absence of learning disability.)

Gant, Arnett " Lead Poisoning; its Prevalence, Diagnosis, Prophylaxis, and Treatment" a PhD thesis from the Graduate School of the University of Illinois, 1938. Reprinted in Industrial Medicine, 7 (10), p 608, 1938.(N.B.: Provides information on the lead content (in mg Pb per 100gm/tissue) of liver, kidney, and bone of people who died of various causes and who then underwent autopsy. Some cases had very definite evidence of both exposure and lead poisoning prior to death and some had absolutely no evidence of either exposure or of poisoning.)

Baghurst PA, Tong SL, et.al "Determinants of blood lead concentrations to Age 5 years in a birth cohort study of children living in the lead smelting city of Port Pirie and surrounding areas". Archives of Environmental Health, 47 (3), p 203-210, 1992.

Sauerhoff MW, Michaelson IA, "Hyperactivity and brain catecholamines in lead-exposed developing rats" Science, 182, pp 1022-1024, December, 1973.

Silbergeld EM, Goldberg AM, "A lead-induced behavioral disorder". Life Sciences, 13, pp1275-1283, 1973.

Gross-Selbeck E, Gross-Selbeck M, "Changes in operant behavior of rats exposed to lead at the accepted no-effect level". Clinical Toxicology, 18 (11) pp 1247-1256, 1981.

Johnson, B.L., et.al "A review of public health regulations on lead", Neurotoxicology 5 (3): 43-52, 1984.

Chisholm, J.J. "The continuing hazard of lead exposure and its effects on children", Neurotoxicology 5 (3): 23-42, 1984.

Siegfried, M.P. et.al (editors), Lead Poisoning in Children; Paul H. Brookes (pub), 1996.

Waldron, H.A., Sub-clinical Lead Poisoning, Academic Press (pub), 1974.

Aub, C.A. et.al. Lead Poisoning; Medical Monographs, vol VII, (With a Chapter on the Prevalence of Industrial Lead Poisoning in the United States), Williams and Wilkins (pub), 1926. (N.B.: Of interest mainly because it includes bibliographic references to 500 publications on lead poisoning, some dating back to the 1800s)

Chapter 20, "Neurotoxic Agents" in, Clinical Neurology, vol 2, pp2-10. (N.B.: a general discussion of lead poisoning)

Bruyn, G.W. and De Wolff, Frederik A., "Plumbism", in Handbook of Clinical Neurology, Intoxications of the Nervous System, Part I; Vol 20, (64), Elsevier Science B.V., 1994.

Gross, Stanley B. et.al. "Lead in Human Tissue",. in Toxicology and Applied Pharmacology, 32, 638-651, 1975.

Hirano, Asao and Iwata, Makoto "Neuropathology of Lead Intoxication", in Handbook of Clinical Neurology, Vol 36, 35-64, 1979.

From the historical archives of the New York Times;

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"Curb on tin uses extended by OPM: Nelson issues order barring the metal for twenty nine civilian products". The New York Times, January 1, 1942.

"Tin supply in U.S. presents problem: 90% of metal used here in recent years imported from far east", The New York Times, January 2, 1942.

"Asks substitutes in place of tin: report to OPM says consumption of metal could be cut three-quarters", The New York Times, July 10, 1941.

"Reclamation unit helps in defense: Bell System utilizes old equipment for own purposes and for national program", The New York Times, July 20, 1941.

"Develops new alloy", The New York Times, February 9, 1942. (N.B.: "The American Smelting and Refining Company announces that it has developed three new lead base alloys which the Company estimates may save up to 20,000 tons of tin annually….the new alloys will replace tin to a major degree in solder, babbitt, metal and coating alloys".)