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ENGINEERING AND INDUSTRIAL HYGIENE*

BY

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Industrial Disabilities and Compensation Insurance

Of the disabilities falling within the jurisdiction of our various State Compensation Boards in the United States roughly 97% are accidents; about 3% are chronic diseases like benzol poisoning or silicosis. Of these 3% about two-thirds are dermatoses. In cost of time lost and of medical care the occupational diseases rank high, and actually may assume the spotlight of attention.

Our compensation awards are covered by insurance placed by the employers through insurance companies or through State insurance. In Ohio, for example, compensation insurance is a State monopoly, while in New York an employer can insure either with a private company or with the State. If the employer posts a bond for an amount approved by the State he can be self-insured. The premiums paid are revised periodically according to the experience or record. When the experience is very bad the premium charges may be so high that the employing company cannot afford to insure, or the insurance company can simply refuse to accept the risk. In such an event the Insurance Commissioner of the State can pro-rate the policy among companies doing business in the State, and the companies then become the reluctant recipients of the business.

The result of this method of compensation insurance is that the companies writing the policies have developed first-class inspection schemes, with excellent staffs of industrially minded physicians, engineers, industrial hygienists, and chemists, and it is to the interest of insured and insurer to cut lost time to the minimum. In the policies freedom of entry and inspection is given to the insurance companies. Their men visit the insured companies and give them valuable consulting service.

The insurance companies' inspection scheme reminds one very much of your British Government inspectorate. Yours is more than a century old while ours is very young. But your Governmental inspectors, operating from your Ministry of Labour in London and distributed all over industrial Britain, have no opposite number in our Federal Government set-up. The industrial hygiene laboratories of the Public Health Service are available to industry for consultation and research. Their surveys of various industries have often set the

health standards under which the industry operates. The laboratories of the Bureau of Mines and the Bureau of Standards likewise function for the service of industry (employer and employee alike). None of these three Federal Bureaus is in any sense administrative, and they have not the right of entry or inspection. That last function is vested legally in the States, every one of which zealously guards its "States' rights" as granted under our constitution.

Your statistics of industrial illness are consistently better than ours. In fact, they are so much better that I use them as a guide in estimating our American industrial illnesses—a somewhat humbling admission. But our accident figures I think are as good as or perhaps better than yours.

Development of Industrial Hygiene in U.S.A.

In 1906 New York State provided for the appointment of a physician to be known as a medical inspector of factories. The staff was gradually increased, and in 1913 included a mechanical engineer and a chemist in addition to the physician. In 1924 the Division of Industrial Hygiene of New York was made an independent body as the "Bureau of Industrial Hygiene," and started publishing its *Industrial Hygiene Bulletin*. In 1936 Leonard Greenburg, a physician who started out as a sanitary engineer, became executive director of the Division. The various bulletins, codes, and rules formulated by New York have set the pattern for such things throughout all the States of the Union.

One of our oldest governmental departments is the Public Health Service. In 1914, within its Division of Scientific Research, there was created an office of Industrial Hygiene and Sanitation Investigations. This same year A. J. Lanza and others from the Bureau of Mines and the Public Health Service began their study of the silicosis problem in our tri-state district (Oklahoma, Kansas, and Missouri). From 1920 to 1930 the Office of Industrial Hygiene was under the direction of L. R. Thompson, a physician of great experience in the general field of public health. He initiated the Service's series of surveys of the dusty trades, which were continued and expanded by his successors. In 1937 the organization became the Division of Industrial Hygiene under the very able leadership of R. R. Sayers, who had been for some years surgeon for the Bureau of Mines. Sayers had taught electro-chemistry and physical chemistry at Buffalo, where he took his medical degree in 1914.

The Bureau of Mines was established in 1910 within the Department of the Interior. About 1917 during the first world war the Experiment Station at Pittsburgh was under the charge of a chemist, A. C. Fieldner. One of the

*Taken from papers presented at the London School of Hygiene and Tropical Medicine on April 20, 1953, and at the Annual Provincial Meeting of the Association of Industrial Medical Officers, Newcastle-upon-Tyne, on July 4, 1953.

Bureau's duties was the supervision of safety in mines, so it was natural that these should include the testing of safety equipment and the appraisal of masks for protection against gases. Its special knowledge was used by the Chemical Warfare Service, and after the first world war the Bureau began issuing its specifications for protective equipment of all kinds. Industry accepted these specifications with alacrity, and industrial hygiene benefited.

The *Journal of Industrial Hygiene* appeared in 1919. The chief editors were physicians—David L. Edsall for the United States, and Thomas M. Legge (later Sir Thomas) for Britain. My brother, Cecil K. Drinker, a physician and physiologist, and his wife, Dr. Katherine R. Drinker, carried the real responsibility, and the prompt success of this journal was due to them on our side of the ocean, and to Professor Edgar L. Collis in England. Early contributors included a few men in general public health, like Professor C.-E. A. Winslow, and, occasionally, chemists like Fieldner, Katz, and Yant, of the Bureau of Mines, but the general tone of the papers was medical. Dr. Alice Hamilton and Dr. C. K. Drinker, of Harvard School of Public Health, suggested that the journal's field should be expanded to include some engineering. I became managing editor, and we asked Yant to join the journal's editorial staff. From then on we took papers directed more towards industrial hygiene and industrial medicine and less towards industrial surgery.

In 1935 a group of industrialists, physicians, and industrial hygienists, with the Mellon Institute for Industrial Research, formed the Air Hygiene Foundation, later changed to the Industrial Hygiene Foundation as its scope and interests expanded. In 1938 the American Conference of Governmental Industrial Hygienists (A.C.G.I.H.), with J. J. Bloomfield, of the U.S. Public Health Service, as co-ordinating figure, formed a group which included all those in Federal and State industrial hygiene bureaus. In 1939 the American Industrial Hygiene Association was formed. From then on these last two societies have met annually with the much larger and older society, the Industrial Physicians and Surgeons. The combined programmes run over a period of about eight days and are usually held around mid-April. For a time the American Public Health Association had an active section devoted to industrial hygiene, but interest lapsed. Now it is again becoming an active unit. It meets in the autumn, as does the Industrial Hygiene Foundation.

The National Safety Council, with headquarters in Chicago, is supported by industry and concerns itself with accidents of all kinds, but especially with those of industry. Traffic accidents are a major problem in the United States. Many of our industrial physicians, our engineers, and our industrial hygienists are active in the field of accident prevention.

Establishing Standards of Industrial Hygiene

The word "hygiene" implies control of one's well-being, while "health" defines one's status at the moment. We are in good or bad health. The Surgeon General reports upon the health of the nation. The medical director of an industry reports upon the health of workers (and he may even include their families). These reports are based upon the results of medical practice.

Industrial hygiene is concerned primarily with prevention. It is the duty of the industrial hygienist to determine the causes of, and to prevent, industrial illnesses, not to diagnose and treat them. He reports upon the extent of the hazard, if any exists, and its control. The industrial hygienist may be able to define the aetiology of industrial illnesses better than the medical practitioner. If this state of affairs results in a little duplication, or confusion even, it does no harm. Clearly, the person held responsible for prevention must ferret out the cause if he is to see his preventive measures put into force.

The industrial hygienist's most convenient criterion of working conditions is the nearness with which the worker's environment approaches the ideal. We measure the quality

of the environment by our arbitrary specifications. In the United States these specifications are set up by different committees chosen from the qualified personnel of the nation.

About 1940 the American Standards Association, at the instigation of the late Steven R. Whiting, of Liberty Mutual Insurance Company, formed a committee to formulate "allowable concentrations" of such impurities as carbon monoxide, lead dust, and various solvent vapours. The series of approved reports began to appear in 1941. A few years later the governmental industrial hygienists started their less formal but more realistic series, "threshold limit values," which now are revised and published annually. As a practical guide to control of conditions they are most valuable, and are used all over the world. For some years the American Society of Mechanical Engineers has had specifications covering permissible stack emissions from power plants. The City of Los Angeles, troubled by a vexing smog problem, passed legislation covering emissions from chimneys: a reasonable minimum degree of cleanliness is required of all, while large plants are rated in terms both of the quantity of material charged into the process and of that emitted. In London, the large power plants like that at Battersea are required to control the emission of smoke and to scrub out sulphur dioxide gas from the stack gases, so that less than 35 p.p.m. escapes—a specification many times more severe than ours.

To-day we have specifications governing the purity of water, milk, food, and various drugs. These have the force of law behind them. Why should we not have the same degree of hygienic protection from air-borne contaminants and from unfavourable working conditions? One often meets with a timid reluctance on the part of some of our colleagues to set limits for pollution. I have no sympathy with such timidity. If you are practising industrial hygiene and refuse to state what conditions should be attained, you are simply evading your issues. If you ask your doctor what régime you should follow and he won't tell you, the chances are that you'll get another doctor. I am fully aware of our great lack of data in establishing, and of the many practical difficulties in attaining, satisfactory standards of air cleanliness, but I insist that standards must be sought if we are to make intelligent progress in this field.

Our opinions vary on the precise figures or limits we use, but most of us now adopt these limits in our routine work. Yet we recognize the limitations of these quantitative figures. I think we should supplement our appraisal of working conditions by personal observation and by every illustrative means at our disposal. The concept of dosage—time $\times$ concentration—in all of this work is now generally accepted. In our Atomic Energy Commission plants the environment of the workers, their clothing, and even their persons are inspected and checked thoroughly and carefully, usually one or more times daily. The result has been virtual freedom from the common industrial poisons as well as from the special radiation hazards for which these extra precautions were designed.

In industry the difficult problem is the instilling of a sensible routine to prevent chronic and cumulative occupational disease. Respect for acute poisons like carbon monoxide is much easier to teach and to achieve than respect for repeated—and often not unpleasant—exposure to substances such as benzol vapour. Too often men know of fellow-workers who have seemingly been unaffected by the very conditions we say should be drastically improved. Once management, and then labour, are convinced that something must be done and the new régime instituted, the bad condition can be corrected. But unfortunately an adverse decision in a lawsuit for a compensation case is often the spur to bringing about desired improvements. This is a little like saying that you must be hurt once in an accident in order to avoid future accidents, a concept that is repugnant to the intelligent individual.

It is very rarely necessary to eliminate completely the poison in question, because man's tolerance is such that he

can usually stand a trifling amount of poison, a condition we can generally attain in industry at a reasonable operating cost. If safe conditions cannot be brought about by a change that industry can pay for, then there is usually nothing to be done except to abandon the process entirely.

Some American Standards

We, as engineers, may set up conditions that we deem safe until so proved by the medical records of health in

Threshold Limit Values for 1953. Adopted at the Meeting of the American Conference of Governmental Industrial Hygienists in Los Angeles in April, 1953

Gases and Vapours		Substance	
Substance	P.P.M.	Substance	P.P.M.
Acetaldehyde	200	Ethyl silicate	100
Acetic acid	10	Fluorine	0.1
Acetic anhydride	5	Fluorotrichloromethane	1,000
Acetone	1,000	Formaldehyde	5
Acrolein	0.5	Gasoline (petrol)	500
Acrylonitrile	20	Heptane	500
Ammonia	100	Hexane	500
Amyl acetate	200	Hydrogen chloride	5
Isoamyl alcohol	100	Hydrogen cyanide	10
Aniline	5	Hydrogen fluoride	3
Arsine	0.05	Hydrogen selenide	0.05
Benzene (benzol)	35	Hydrogen sulphide	20
Bromine	1	Iodine	1
1,3-Butadiene	1,000	Isophorone	25
n-Butanol	100	Isopropyl alcohol	400
2-Butanone	250	Isopropyl ether	500
n-Butyl acetate	200	Mesityl oxide	50
Butyl cellosolve* (2-butoxy-ethanol)	200	Methanol	200
Carbon dioxide	5,000	Methyl acetate	200
Carbon disulphide	20	Methylal	1,000
Carbon monoxide	100	Methyl bromide	20
Carbon tetrachloride	25	Methyl butanone	100
Cellosolve* (2-ethoxy-ethanol)	200	Methyl cellosolve* (2-methoxyethanol)	25
Cellosolve* acetate	100	Methyl chloride	25
Chlorine	1	Methylcyclohexane	500
Chlorobenzene	75	Methylcyclohexanol	100
2-Chlorobutadiene	25	Methylcyclohexanone	100
Chloroform	100	Methyl formate	100
1-Chloro-1-nitropropane	20	Methyl iso-butyl ketone	100
Cresol	5	Naphtha (coal tar)	200
Cyclohexane	400	Naphtha (petroleum)	500
Cyclohexanol	100	Nickel carbonyl	1
Cyclohexanone	100	Nitrobenzene	1
Cyclohexene	400	Nitroethane	100
Cyclopropane (propene)	400	Nitrogen oxides (other than N ₂ O)	25
1,2-Dibromoethane (ethylene dibromide)	25	Nitroglycerin	0.5
o-Dichlorobenzene	50	Nitromethane	100
Dichlorodifluoromethane	1,000	2-Nitropropane	50
1,1-Dichloroethane	100	Nitrotoluene	5
1,2-Dichloroethane (ethylene dichloride)	100	Octane	500
1,2-Dichloroethylene	200	Ozone	1
Dichloroethyl ether	15	Pentane	1,000
Dichloromethane	500	Pentanone (methyl propanone)	200
Dichloromonofluoromethane	1,000	Phenol	5
1,1-Dichloro-1-nitroethane	10	Phosgene	1
1,2-Dichloropropane (propylene dichloride)	75	Phosphine	0.05
Dichlorotetrafluoroethane	1,000	Phosphorus trichloride	0.5
Diethylamine	25	Propyl acetate	200
Dimethylaniline	5	Stibine	0.1
Dimethyl sulphate	1	Stoddard solvent	500
Dioxane	100	Styrene monomer	200
Ethyl acetate	400	Sulphur chloride	1
Ethyl alcohol	1,000	Sulphur dioxide	10
Ethylamine	25	1,1,2,2-Tetrachloroethane	5
Ethyl benzene	200	Tetrachloroethylene	100
Ethyl bromide	200	Toluene	200
Ethyl chloride	1,000	Toluidine	5
Ethylene chlorohydrin	5	1-1-1-Trichloroethane (methyl chloroform)	500
Ethylene oxide	100	Trichloroethylene	100
Ethyl ether	400	Turpentine	100
Ethyl formate	100	Vinyl chloride	500
		Xylene	200

Toxic Dust, Fumes, and Mists

Substance	mg. per cu. m.	Substance	mg. per cu. m.
Antimony	0.5	Mercury	0.1
Arsenic	0.5	Pentachloronaphthalene	0.5
Barium	0.5	Pentachlorophenol	0.5
Cadmium	0.1	Phosphorus (yellow)	0.1
Chlorodiphenyl	1	Phosphorus Pentachloride	1
Chromic acid and chromates as CrO ₃	0.1	Phosphorus Pentasulphide	1
Cyanide as CN	5	Selenium, as Se	0.1
o,o-Diethyl-o-p-nitrophenyl thiophosphate ("parathion")	0.1	Sulphuric acid	1.0
Dinitrotoluene	1.5	Tellurium	0.1
o-Dinitrocresol	0.2	Tetrayl	1.5
Fluoride	2.5	Trichloronaphthalene	5
Iron oxide fume	15	Trinitrotoluene	1.5
Lead	0.15	Uranium (soluble compounds)	0.05
Magnesium oxide fume	15	Uranium (insoluble compounds)	0.25
Manganese	6	Zinc oxide fume	15

Mineral Dusts		Substance	
Substance	MPPCF†	Substance	MPPCF
Alundum	50	Silica:	
Asbestos	5	High (above 50% free SiO ₂)	5
Carborundum	50	Medium (5 to 50% free SiO ₂)	20
Dust (nuisance, no free silica)	50	Low (below 5% free SiO ₂)	50
Mica (below 5% free silica)	20	Slate (below 5% free SiO ₂)	50
Portland cement	50	Soapstone (below 5% free SiO ₂)	20
Talc	20	Total dust (below 5% free SiO ₂)	50

Radiations

Material or Radiation	Material or Radiation
Gamma (roentgens per week)	0.3
	Roentgen (roentgens per week)

† MPPCF = Millions of particles per cubic foot.

* Trade marked name.

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the industry in question. The figures from the A.C.G.I.H. Committee (see Table) are the result of the annual canvassing, by the committee, of persons known to be working with these various substances or to have had experience in their use in industry. Many of them are "guestimates" and are not based upon data scientifically arrived at. They represent what the committee regards as concentrations safe for eight-hour exposures. The persons exposed are presumed to be normal healthy individuals. The limits for gases are given in parts per million by volume, those for toxic dusts are given in milligrams per cubic metre, mineral dusts are measured in millions of particles per cubic foot, and radiations are appraised in the conventional units of roentgens per week. Of these the last are much the newest, and are certain to be revised almost yearly.

These figures should be thought of as the lowest limits in zones and not as precise values. They are no more precise than is the toxicological evaluation of various doses of inhalation, as of quartz dust or benzol vapour or carbon monoxide gas. It probably would be more scientific to give them as definite figures $\pm$ some number, thus showing the unimportance of slight variations.

It has been said to me often by colleagues, especially by Britons, that this idea of toxic limits is needless, and that better results can be had by watching the health of workers, as by blood or urine examinations. Consider for a moment what Sir Thomas Legge, Chief Medical Inspector of Factories, wrote in his memoirs in 1934: "If you can bring an influence to bear external to the workman (that is, one over which he can exercise no control) you will be successful; if you cannot or do not, you never will be wholly successful. Practically all industrial lead poisoning is due to the inhalation of dust and fumes; and if you stop their inhalation you will stop the poisoning."

Dr. Alice Hamilton has always supported this plea for prevention rather than cure. It is easier to prevent or control occupational illness (and even accidents) than it is to define the cause accurately.

Control of Noise

Considerable pressure is being brought on us in the U.S.A. to reduce noise in industry, or at least to isolate noisy jobs so that the number of persons exposed to excessive noise is kept to the minimum. Standards of noise levels concerning both frequency and volume are in the making, and are likely to be included in our standards in the reasonably near future. The trend is towards limits or noise levels which permit ordinary conversation.

This is a fruitful field for some good engineering. It is a nice challenge to ingenuity to devise ways of getting around the noise of a rivet hammer, a drop forge, a rock drill, or a spinning-frame or a loom in a textile mill. We wish we knew more about the expected or usual loss of hearing with advancing years in the life of the average worker. Perhaps physicians will supply the data needed.

Considering the speed with which these movements cross the Atlantic we wonder why you in Britain are not more concerned with the noise problem. A damage suit for

impairment to hearing "arising out of and in the course of a man's occupation" is not to be pooh-poohed. We are getting them, why shouldn't you?

Summary

Current methods of industrial insurance in the United States are described, and the value of the insurance companies' inspection schemes is stressed. The origin and development of industrial hygiene services in the United States are recounted.

The role of the industrial hygienist in establishing a safe working environment in industry is emphasized, and threshold limits for various toxic substances, adopted by the American Conference of Governmental Industrial Hygienists in 1953, are listed.

The control of noise in industry is referred to.

LATE RESULTS OF TRANSPLANTATION OF URETERS INTO THE PELVIC COLON*

BY

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After successful implantation of the ureters to the bowel late results will be determined by the type of lesion for which the operation was performed, by the continued integrity or otherwise of the upper urinary tract, and by the effects of chemical imbalance, if any, that may follow the urinary diversion. The nature of the lesion is a dominating factor, particularly in the initial years, when patients who have bladder cancer may die from localized recurrence or distant metastases, and those with genito-urinary tuberculosis may succumb to continued or renewed activity of the disease. When, on the other hand, there has been no constitutional disease, as in cases of trauma or congenital anomalies, results are largely influenced by a continuation of good renal function. I have carried out uretero-colic anastomosis on 162 patients, and all were followed up to April, 1953, or to the time of death. Approximately one-half of these operations had been performed during the previous five years and the remainder over the preceding 15 years. Sixty-nine patients were living in April, 1953, 26 of whom had survived for periods of 6 to 16 years (Table I), and 43 from a few weeks to five years. Six

patients now dead lived for periods of 5 to 17 years after operation. It is thus possible to discuss end-results from observation of an adequate number followed over a sufficient time interval. I shall not give full statistical tables, having already done so in a previous communication which dealt with 138 case records (Jacobs, 1952). Relevant data from my series and from the survey of 1,673 patients operated on by 137 surgeons made for the British Association of Urological Surgeons are quoted (Jacobs and Stirling, 1952).

Malignancy

Because of the increasing use of cystectomy as a method of treating bladder cancer malignant disease has become the most frequent indication for transplanting the ureters. It was the reason for operation on 1,181 (70%) of the B.A.U.S. series. Urinary diversion by itself may be carried out as a palliative measure and was in fact the sole procedure in 476 of these 1,181 patients. The mortality rate was surprisingly high (39.7%). It was obvious that an undetermined number for whom a second-stage cystectomy had been planned succumbed to a preliminary uretero-colic anastomosis, for cystectomy in addition to transplantation on the remaining 705 patients carried a very much lower mortality (15.2%). Uretero-colic anastomosis for malignant disease should not nowadays be associated with such a high mortality rate, and it is a useful method of easing the last months of suffering from bladder cancer when this is associated with intolerable pain and profuse bleedings. It may be difficult to decide whether or not a palliative operation should include cystectomy when obvious spread precludes any hope of a curative procedure, though the bladder is still removable. Thus in a man of 61 with a deeply penetrating sessile umbilicated tumour of only 2 cm. diameter on the left postero-superior wall, the bladder capacity was down to 2 oz. (57 ml.) and he had suffered a half-hourly frequency for nearly a year. Although enlarged glands were palpable alongside the left iliac vessels, the bladder, not being fixed, was removed. The patient died nine months later with a metastatic focus in the head of the right femur and in a lung. Equal relief might have been obtained from transplantation alone, but removal of the bladder made for greater certainty in ensuring against a continuance of vesical strangury as well as of haemorrhage.

A review of late results after transplantation and cystectomy reveals that as a curative measure this radical procedure has not fulfilled the hopes entertained from it. The B.A.U.S. survey showed that among the 705 patients so treated the operative mortality (death within four weeks) was 107, that 216 had failed to survive one year, and that a further 112 had succumbed before the elapse of another two years. Thus 61% of the total had died within three years of operation. Nevertheless evidence is available that cystectomy for early carcinoma with minimal infiltration not going beyond the muscularis can give good end-results, but so also do some of the more conservative measures. Misplaced enthusiasm should not blind us to established facts, which indicate that cystectomy can actually diminish a patient's defence against the malignant spread and that the operation should be employed only on a selective basis. My own series of transplantations for malignancy number 62. Six had extravesical malignant lesions, and 44 of the remainder with bladder cancer had cystectomy in addition to the urinary diversion.

In earlier years, when the tendency was to perform cystectomy for the advanced lesion, I became impressed by the futility of the operation as a curative procedure in such cases, for most of the patients soon developed pelvic recurrence or distal metastases and failed to survive a complete year. Accordingly I now reserve cystectomy for selected cases with multiple non-penetrating tumours of widespread distribution, for the broad-based sessile papillary growths on the lower zones which have not infiltrated, and as a palliative for tumours which have penetrated, when

TABLE I.—Uretero-colic Anastomosis. 26 Patients Living 6 to 16 Years

Years	No.	Trauma	Con-genital	Tuber-culous	Con-tracture	Malignant
16	1	1	—	—	—	—
15	—	—	—	—	—	—
14	—	—	—	—	—	—
13	3	2	1	—	—	—
12	—	—	—	—	—	—
11	2	1	—	1	—	—
10	4	3	—	—	1	—
9	1	—	1	—	—	—
8	3	1	—	2	—	—
7	6	3	—	3	—	—
6	6	3	—	1	1	1
Total	26	14*	2	7	2	1

* 11 of these 14 had a vesico-vaginal fistula.

*Part of a Urology Lecture delivered at the Royal College of Surgeons of England on April 22, 1953. (The indications for operation and the methods of uretero-colic anastomosis used were discussed in the preliminary sections of the paper.)