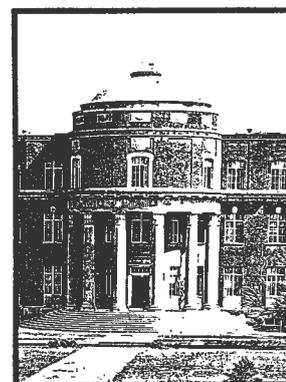


# EARTH AND MINERAL SCIENCES



VOLUME 40 NO. 7 APRIL 1971

## Air Pollution from Combustion Sources

ROBERT H. ESSENHIGH, *Professor of Fuel Science*

### Introduction

The majority of the man-made pollutants present in the air today originate from combustion sources. Table 1 illustrates this with a breakdown of data for 1966 and 1968 published recently by the National Air Pollution Control Administration. Five types of pollutants from five categories of sources are identified, and, of the five source types, the first four and a substantial fraction of the fifth originate in combustion chambers. The quantities listed account for more than 90 percent of the problem in the United States. The total weight of all emissions is, perhaps, the most startling figure of all. At 200 million tons or more, this is greater than one-third of the annual coal tonnage used as primary energy source, yet it is made up of components measured in the parts per million range. On the breakdown, certain category types of pollutants stand out — notably, carbon monoxide from transportation alone provides roughly 30 percent of the total, mostly representing inefficiency of automobile engines; next is  $SO_x$  from stationary combustion sources — mostly power stations — at 10 to 11 percent; hydrocarbons, i.e., unburned or part burned fuel from transportation, and carbon monoxide from miscellaneous sources tie for third place at about 8 percent each. These four account for over 50 percent of the total. The type totals amplify this in another way. Carbon monoxide from all sources provides about half the overall total; the remain-

ing types each provide only about 8 to 16 percent.

These figures underline the serious need for abatement; unfortunately, however, the necessary technology has not always been able to keep abreast of desirable legislative requirements. The purpose of this article is to point out some of the problems and difficulties of reducing pollution from combustion sources.

### Health Hazards

Quantity alone, however, is not necessarily the sole criterion of significance in assessing the impact of pollutants. Their physiological effect is what is at issue, and this is generally a function of exposure and concentration. The longer the exposure time the lower the concentration that can be permitted if ill effects are to be avoided. This is illustrated in Figures 1 and 2 for sulfur dioxide and carbon monoxide, respectively.

Figure 1 shows the exposure time required to produce stated physiological effects at a given concentration. Points of interest in this graph are the taste and odor thresholds (0.3 and 0.5 p.p.m.). These would seem to be good danger signals. Evidently, half-a-day to a day's exposure at these levels should cause discomfort, and a week to a month's exposure could be expected to produce adverse effects even in a healthy man. For comparison, average concentrations in cities in the

United States have been reported to range from near zero up to 0.16 p.p.m., but significantly higher values are occasionally reported. In London in December 1952, sulfur dioxide concentrations averaged 0.57 p.p.m. over a four-day period, during which time 4000 "excess" deaths occurred.

Figure 2 provides somewhat similar information for the effects of carbon monoxide. Hemoglobin has a greater affinity for CO than it has for oxygen (by a factor of 200), and the toxic effects follow from the reduced oxygen circulated by the hemoglobin. The percentage of hemoglobin saturation by CO (which fortunately is reversible) is a good indicator of the toxicity level. While Figure 2 also shows the saturation level achieved in a given time at a given CO percentage, it gives no information on the longer term exposures. If this should last for a day or more, physical sickness becomes evident at 25 to 50 p.p.m., and for longer terms (a week or more) human performance is probably impaired at anything above 10 p.p.m. This is possibly achieved by one-pack-a-day cigarette smokers.

Comparable graphs for  $NO_x$  do not seem to have been constructed. Of the six most commonly encountered nitrogen oxides,  $NO_2$  is evidently the most important since all the others tend to form it given time (from minutes to hours), although NO is the principal product in flames. At sufficient concentrations,  $NO_2$  is toxic and can cause severe damage, leading to death. The odor threshold is just over 1 p.p.m.,

and irritation starts in excess of 10 p.p.m. By contrast, an otherwise clear sky would just show slight discoloration at something under 1 p.p.m. The toxic levels, lying between 10 and 100 p.p.m., are not generally reached. However, at the lower levels,  $\text{NO}_2$  participates in the photochemical reactions leading to oxidant smog. This smog formation also involves hydrocarbons; hence the concern in reducing both  $\text{NO}_2$  and hydrocarbons.

Solid particulates usually have more of a smothering effect than a directly toxic effect, as most are biologically inert, particularly fly-ash and carbon, although they evidently play some part in coating the lungs and reducing the oxygen transfer surface which can be important in bronchial patients. This is usually accepted as having been a factor aggravating the  $\text{SO}_2$  effect during the London smog of 1952 when many of the "excess" deaths were among those with bronchial difficulties.

#### Processes of Pollutant Generation from Combustion

The gross processes generating the pollutants by combustion are quite simple, although their detailed mechanisms may be exceedingly complex.

The inorganic particulates are inert materials that enter the flame as minerals and emerge as fly-ash after partial alteration.

Organic particulates are carbon or carbonaceous solids formed by cracking the fuel (coal, oil, or gas) in the flame.

## EARTH & MINERAL SCIENCES

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### Effects of Sulfur Oxides on Human Beings

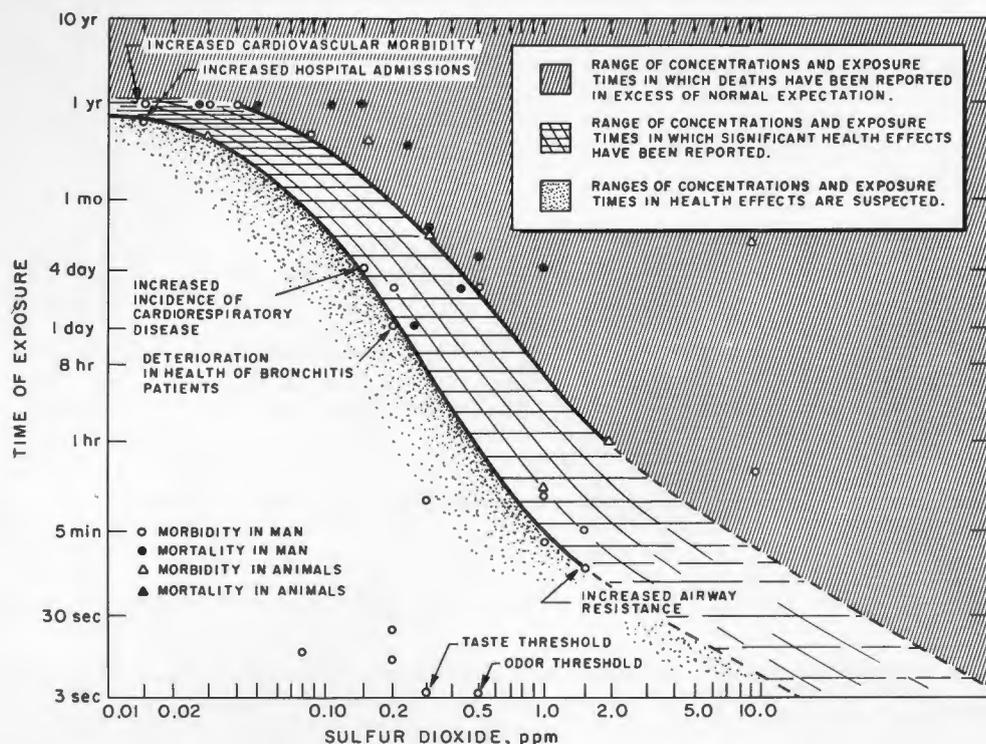


Fig. 1. Variation of health response with  $\text{SO}_2$  concentration and exposure time. (From U.S. Department of Health, Education, and Welfare Publication No. 1619.)

Their emission represents poor combustion control; at the higher concentrations, they are apparent in the combustor exhaust as "smoke." It is then common to find CO also present; and if a sample of the exhaust is cooled, condensable hydrocarbons may be found. Control of these pollutants obviously depends on good combustion.

By contrast,  $\text{NO}_x$  and  $\text{SO}_x$  are almost indicative of too good combustion.  $\text{SO}_2$  results, of course, from sulfur in the fuel, and a substantial fraction usually oxidizes further to  $\text{SO}_3$ . The  $\text{SO}_3$  conversion increases with excess air, so this can be controlled to a considerable extent by firing any furnace or combustor as near to stoichiometric conditions as possible.

Low to zero excess air also reduces the  $\text{NO}_x$  problem. The nitrogen oxides are formed primarily by reaction of oxygen with atmospheric nitrogen, although nitrogen in the fuel can also participate. In the initial flame reaction, NO predominates, being formed by what is known as the Zeldovich mechanism. The NO formation rate is approximately proportional to the square root of the oxygen concentration, so it is reduced by low excess air. The conversion of NO to  $\text{NO}_2$  then depends on relatively slow reaction in the atmosphere, at near ambient temperature, in a large excess of oxygen after escape of the effluent from the stack.

#### Flame Control of Pollutants

Although the potential for flame control of pollutants is obvious, the details of any procedure are less so. The reduction of excess air — to control  $\text{SO}_3$  formation and reduce  $\text{NO}_x$  — is only permissible when the combustion system is under such good control that there are no significant unburned combustibles in the effluent gas (CO, hydrocarbons, organic particulates) either before or after the excess air reduction. Table 1 shows that, as a generality, this is hardly the case.

The problem centers on the speed of mixing in the combustion chamber related both to the time required for reaction and to the average residence time of the reactants in the chamber. The mixing aspects may include mixing of the fuel and oxidant in the chamber, which are frequently supplied separately for safety or other reasons. The dominant mixing behavior in most cases, however, is between the fresh, incoming reactants and the part-burned combustion gases already in the combustor. This requires a "backmix" flow, in contrast, for example, with the bunsen burner, where the gas and air mix in the burner tube and then carry straight on through the flame and out into the surroundings without any feedback to the burner tube.

In most practical situations, however, the mixing is produced by a combina-

tion of turbulence and backmix. In general, there are locally identifiable streams, some moving in the same direction and some in the opposite direction to the main flow. These "forward" and "backmix" streams move gross quantities of reactants and products around in the mixing region of the combustor, and turbulence promotes cross-mix between the streams. Turbulence is frequently pictured as motion of small volume elements of fluid, or eddies formed by shear flow, with a finite but decaying eddy size. The eddies ultimately dissipate to purely molecular motion, finally representing absolute mixing, but during the eddy lifetime there are local inhomogeneities in concentration, and it is these that are likely to be important in pollutant formation.

If the backmix streams are large and few in number, the turbulence eddies must be correspondingly large with correspondingly long lifetimes so that they can survive for the necessary penetration distance into the backmix streams. In the limit of marginal backmix, with stirring dominated by turbulence, the mixing distance must be of the order of the combustor dimensions, and the eddy lifetimes must be comparable with the residence times in the chamber. However, since the lifetimes have distributions, there is, then, a finite probability that a significant proportion of eddies can escape from the chamber before final decay. If the eddy is almost pure fuel, it can emerge almost intact, or as a range of cracked fuel products, carbon monoxide, hydrocarbon intermediates, and carbon, depending on its temperature history. If the eddy is fuel and oxygen, the volume element might react explosively, and this may possibly be a source of combustion noise. Such localized "hot spots" can also contribute to NO formation because of the locally higher temperature.

Even if there is sufficient time for the eddies to decay, final burn-up may still not be complete. Intermediates formed (particularly carbon) may be so much less reactive that the reaction time is increased and exceeds the chamber residence time. This is further aggravated if the products are then quite rapidly cooled. In a small coal-fired boiler (of about 100,000 lb. steam/hr.), cooling of gases through the tube banks can approach  $10^4$  deg./sec., which is a rate found from post-flame studies that would effectively quench the CO conversion to  $\text{CO}_2$ . In reciprocating engines, the reaction time is substantially shorter, and the rate of cooling even faster. In consequence, the high level of CO and hydrocarbon emissions from transportation power units is almost

### Effects of Carbon Monoxide on Human Beings

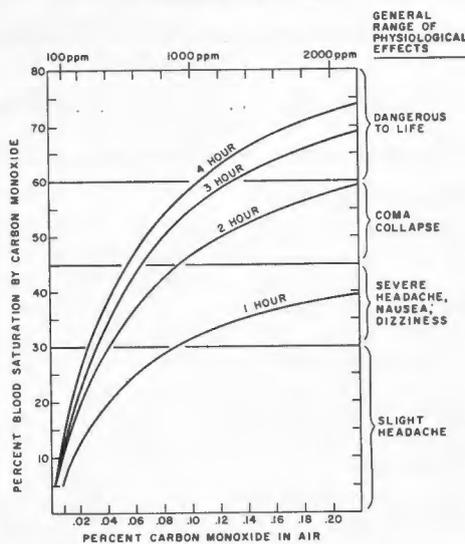


Fig. 2. Variation of percentage of hemoglobin saturation by CO with percentage concentration and exposure time.

inevitable (aggravated in many instances by bad maintenance).

This argument suggests that the objective should be to increase backmix while reducing the turbulence. The possible limit of this is mixing without turbulence — a process known as "blending." At the present time, however, the tendency seems to be to go in the opposite direction.

### Abatement

In principle, something can be done about potential contaminants by treatment before and after the flame. Five ways can be suggested, although not all are suitable for each of the five principal pollutant types.

(1) Pretreatment — Cleaning of the fuel would be aimed at removing mineral matter and sulfur. Removing mineral matter to cut down fly-ash applies only to coal. Cleaning coal is a well-developed technique, but for use in power stations it is usually omitted because of cost, particularly in mine mouth operations where the mined coal goes straight to the crushers. In this case, the inorganics are then removed from the stack gases as fly-ash.

If pretreatment of coal to remove sulfur is ever practiced (as it is on occasion for oil), simultaneous removal of mineral matter might be practicable. Desulfurization by hydrogenation is also potentially possible, with sulfur conversion to  $\text{H}_2\text{S}$ , and has the advantage over post-combustion cleaning in that the weights or volumes of gas to be handled are substantially smaller, with proportionately higher component con-

centrations. A possible reactor scheme to achieve this was published recently, but only the first steps have so far been taken to implement the proposal.

(2) Flame Control — This is altogether more promising, in spite of the problems outlined above (Sec. "Flame Control of Pollutants"), by the recycling of flue gas and staged air addition. These do not overcome the turbulence problems already mentioned, but are aimed rather at reducing overall temperature levels, and particularly temperature peaks, either by direct dilution (flue gas recycling) or by delaying the total air addition by staging. This staging is aimed particularly at the  $\text{NO}_x$  formation, although the staged air addition will reduce the local oxygen concentrations through the flame, which will also help to reduce the  $\text{SO}_3$  formation.

Flue gas recycling in sufficient quantities can also cut down smoke formation by a mechanism that has not yet been elucidated. Experiments some years ago showed that smoke from combustion of No. 2 oil could be eliminated by firing at 50 percent excess air, or at zero excess air but with 50 percent flue gas recirculation (and in a little more than direct proportion between these limits). Even more surprising was the discovery that when the flue gas recirculation was increased still further, the yellow flame turned blue. This behavior is now the basis for a number of attempts to commercialize a blue-flame oil burner for the domestic market with prospects for reduced noise and emissions.

(3) Exhaust Effluent Treatment — This has traditionally been practiced to cut down fly-ash and particulate emissions, particularly in power stations generally using cyclones and electrostatic precipitators. Additional treatment to include removal of sulfur and nitrogen oxides has been attempted more recently, particularly for  $\text{SO}_x$ , but success has not been widespread. Strauss describes several liquid absorption methods for  $\text{SO}_2$ , with three applied to power stations, but he also states that no really satisfactory solution of general applicability had been found. The alternative to liquid absorption is solid absorption with calcium oxide or calcined dolomite as possible choices. Activated carbon is a further possibility.

Treatment of automobile exhaust with its high level of CO and hydrocarbons has centered on catalysts to burn up both, but again these are still in the development stage.

(4) Dilution — If the exhaust effluent from a stack cannot be cleaned by existing techniques, the final resort is to dilution. This is achieved by building stacks so high that when the plume

reaches the ground the contaminants have been reduced, under most conditions, to below the statutory limit. The atmosphere has, of course, been the traditional sink for most effluents in any case, but the very high stack is the logical outcome of arguments that the atmosphere is still semi-infinite so far as current levels of contaminant generation are concerned. If, for example, it is true that the SO<sub>2</sub> average concentration as it exists naturally in the atmosphere would only double in 15 years at the present rates of SO<sub>2</sub> generation (and disregarding wash-out), then it would seem reasonable only to make sure that it was well dispersed by a high stack.

Such an operation would be satisfactory for most of the time, although lower sulfur fuels would have to be available for use under special atmospheric conditions such as inversions, or those allowing fumigation. It has been estimated that this would occur only about 2 percent of the time in England, but in some parts of the United States it could be a good deal more. The maritime climate of England would account for the relatively low figure of 2 percent but the continental climate of the United States could easily be responsible for a single pollution alert lasting a week or more.

(5) **Thermal Efficiency** — This is one final possibility for pollution abatement that deserves some attention. The rate of production of contaminants will be roughly proportional to the total fuel consumption, so reduction of this total by using the fuel more efficiently must reduce the rate of generation of pollutants. A breakdown of the energy market into four groups of users gives the following: (1) electricity generation and transmission — 15 percent; (2) residential and commercial — 20 percent; (3) transportation — 25 percent; and (4) industrial — 40 percent. There is not now too much scope for improvement in thermal efficiency in the electricity generation area without radical modification of existing methods, so this will leave the largest SO<sub>x</sub> and NO<sub>x</sub> sources as they are, with abatement based on other factors. There should, however, be room for improvement in the other three areas, and particularly in industry, which uses the largest fraction of energy and where there is considerable scope for addition of heat recovery equipment.

There has not usually been too much incentive to do this in the past because of the difficulty of justifying such equipment on the basis of recovery of costs. The fraction of manufacturing costs that is due to energy or fuel is only 3.5 percent for all manufacturing, although it is rather higher in heavy

**Table 1**  
**Emission Rates of Dominant Pollutant Types**  
**and Sources for 1966 and 1968**

Millions of Short Tons per Year

These data account for more than 90 percent of all emissions in the United States

Pollutant Source	Pollutant Type					Total by Source	Year
	CO	Hydrocarbons	NO <sub>x</sub>	SO <sub>x</sub>	Particulates		
Transportation	63.8	16.6	8.1	0.8	1.2	90.5	1968
	64.5	17.6	7.6	0.4	1.2	91.3	1966
Stationary Combustion Sources	1.9	0.7	10.0	24.4	8.9	45.9	
	1.9	0.7	6.7	22.9	9.2	41.4	1966
Industrial Processes	9.7	4.6	0.2	7.3	7.5	29.3	
	10.7	3.5	0.2	7.2	7.6	29.2	1966
Refuse Incineration	7.8	1.6	0.6	0.1	1.1	11.2	
	7.6	1.5	0.5	0.1	1.0	10.7	1966
Miscellaneous*	16.9	8.5	1.7	0.6	9.6	37.3	
	16.9	8.2	1.7	0.6	9.6	37.2	1966
Total by Type	101.1	32.0	20.6	33.2	28.3	214.2	
	101.6	31.5	16.7	31.2	28.6	209.8	1966

\*Includes such sources as forest fires, structural fires, coal refuse, agriculture, organic solvent evaporation, and gasoline marketing.

Data Source: National Air Pollution Control Administration

industry (ferrous and nonferrous metals, refractories, chemicals, etc.), where it ranges from 10 to 25 percent. The cost recovery situation might be improved, however, if manufacturers were to pay for the air they use directly or indirectly (traditionally regarded as free) by a tax on their fuel and electricity consumption.

Judging by Table 1, efficiency improvements would have only a small impact on the pollutant emissions since industry evidently generates only about 15 percent of the total — a surprisingly low figure — but it would provide a lead and would also contribute to alleviation of the power shortage.

### Conclusions

Air pollution from combustion sources is a problem, and in some areas of the country a serious one, but it has still not yet reached the uniformly catastrophic proportions that some of the self-appointed priests and policemen moralizing over the sins of industry would have us believe. However, such catastrophic proportions could well be achieved within a generation if effective uniform action is not taken very shortly. Unfortunately, what can be done is still somewhat limited as much of the needed technology is still undeveloped.

Of the five pollutant types listed in Table 1, particulates are the easiest to live with without further action, although here the removal techniques are also the most advanced; indeed, in a number of instances they depend only on payment for installation costs. The easiest to eliminate on the basis of cur-

rent knowledge ought to be the combustibles (CO, hydrocarbons, and sometimes organic particulates) emanating from all sources except transportation, although extensive supplementary development research may still be necessary in some cases, particularly in incineration. Knowledge of the basis for controlling NO<sub>x</sub> is gaining ground, although again extensive development research will probably be needed in a number of cases to apply the results. The biggest problems still seem to be: CO emissions, particularly from transportation, and SO<sub>x</sub> emissions, particularly from power stations. Elimination of CO by catalytic after-burning outside the engine is a stopgap answer at best. The problem really stems from the nature of the reciprocating engine, which cannot really be regarded as an example of elegant engineering design. Can a better unit be produced to displace it? And will society pay the cost in view of the immense capital investment already involved in reciprocating engines? Finally, SO<sub>x</sub> emissions still seem to be currently the most intractable. A number of promising possibilities exist, but there is still no commercial process that is simple, cheap, effective, and reliable. It is, perhaps, fortunate that the tall stack solution is available as a stopgap, as long as local ordinances are not unimaginatively rigid and as long as sufficient low-sulfur, stand-by fuel is available for periods when meteorological conditions are adverse.

Prodded by environmentalists, the research is slowly moving toward solutions, aided by much verbal encouragement from bystanders and occasional

(Continued on page 55)

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# The Role of X-Ray Diffraction in Metallurgy

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EARLE E. RYBA, *Associate Professor of Metallurgy*

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The techniques of x-ray diffraction have played an important role in the development of metallurgy ever since the effect was first discovered in 1912. X-ray diffraction studies have provided the metallurgist with an intimate knowledge of the internal structure of metallic materials, which is indispensable in solving problems concerned with their design and use. Because metals and alloys are crystalline, they diffract x-rays, with planes of atoms reflecting the radiation incident upon the sample at discrete angles; this results in a multi-peaked spectrum or pattern. Each pattern is characteristic only of the sample examined, and the positions and intensities of the reflection peaks are used to determine the internal structure of the solid.

The specific areas of application in metallurgy are numerous, but a few examples will serve to indicate the contributions that have been made. The first concerns the identification of materials. To accomplish this, the diffraction pattern from a polycrystalline sample can be recorded on a counter diffractometer. The pattern is usually then compared to those in a reference file for identification. In this way, for example, the phases produced by chemical reactions, such as the oxidation of the surface of metals, can be identified. This information leads to a description of exactly how oxidation occurs and, subsequently, to how it can be controlled.

Another type of information which can be obtained from x-ray diffraction studies is the description of the crystal structures of the metals and their compounds. From such studies the actual spatial locations of the atoms can be determined. This information was obtained for most of the metallic elements in the decade immediately following the discovery of x-ray diffraction. It was relatively easily accomplished because most of the pure metals have quite simple crystal structures and give simple diffraction patterns. Knowledge of the crystal structures is important for many reasons, among them being an understanding of how plastic flow takes place in metals. Because of their rather simple structures it is easy to visualize how slip occurs over planes of atoms, causing a permanent change in shape.

Another problem of early concern to metallurgists was the nature of what are now known as solid solutions. It was frequently found that alloying one metal with another does not change its appearance or properties appreciably. With the advent of x-ray diffraction, it was shown that the second metal merely "dissolves" in the first, usually by atom replacement, so that its crystal structure remains relatively undisturbed, and thus its diffraction pattern practically unchanged. Structural studies are still being carried out, but now on intermetallic compounds formed between two or more metallic elements. The structures of intermetallic compounds are more complex than those of pure metals and require the use of the more sophisticated single crystal x-ray diffraction techniques, in which the symmetry of the atom arrangements is more obvious from the diffraction pattern.

A third area of application is in the study of phase transitions and other solid state reactions, in which the objective is to detect and interpret changes in the diffraction pattern upon transition from one atomic arrangement to another. The earliest and probably the most important study of this type was on the allotropy of iron, which is the basis of the manipulation of the properties of steels. Prior to 1921, there were thought to be three allotropic modifications of iron,  $\alpha$ ,  $\beta$ , and  $\gamma$ . The magnetism of iron disappeared upon heating it through the  $\alpha \rightarrow \beta$  transition. However, it was shown in 1921, from x-ray diffraction patterns taken at various high temperatures, that  $\alpha$  and  $\beta$  iron have the same crystal structures; in addition, the structure of  $\gamma$  iron was determined. Another phase transition study frequently made on steels is the analytical determination of the amount of austenite, a high temperature solid solution of carbon in  $\gamma$  iron, that is unconverted to the low temperature form upon cooling. The presence of this retained austenite in steels results in poor mechanical properties. Quantitative analyses of this nature cannot be done by ordinary chemical techniques because there is no change in the composition of the steel. The x-ray diffraction technique, however, is sensitive to the differences in crystal structure between the high

and low temperature forms. The intensities of the peaks for both forms are obtained from a diffractometer pattern and then compared to determine the relative amounts of the two.

A fourth type of x-ray diffraction study is the determination of residual strain in manufactured parts. Because of certain cooling or mechanical working conditions, metal parts are frequently placed in a condition of internal compression or tension. These residual strains are often desirable, but, depending upon the application, a strain of the wrong kind (e.g., tension instead of compression) may result in premature failure of the piece. If a residual strain exists in a solid, the planes of atoms which reflect the x-rays are not separated by their normal distances. This results in a shift of the positions of the diffraction peaks on the pattern, which is the basis for the measurement.

A final example is the determination of the orientation of the crystals in a piece of metal. Ordinary metals are composed of many tiny crystals which are so positioned that some characteristic direction, such as the  $a$  axis, in each has a random orientation. However, under certain mechanical working conditions, the crystals are squeezed and pushed around until they all begin to line up with one another. This alignment is generally undesirable and results in poor working characteristics, wavy surfaces, and tearing. However, some applications, such as transformer cores, require strong alignment of the crystals in the metal sheets. Thus, it is important to know how to control the orientation, the determination of which is made by turning the sample in all possible positions and measuring the change in intensity of one single reflection. A random orientation would give no change.

A number of examples of how x-ray diffraction techniques have assisted the development of metallurgy during the last 60 years have been described. Contributions have been made by x-ray diffraction techniques to both the fundamental understanding of metallic solids and to their practical applications. There is no doubt that x-rays will continue to be employed in the study of metallic solids.

## New Scholarship for Mining

Greenwich Collieries Corp., Ebensburg, Pa., has established a new scholarship program in mining engineering at Penn State. The company has agreed to provide funds for two \$800 per year scholarships for the purpose of encouraging and helping students in the mining engineering field. A company spokesman said that Greenwich Collieries Corp. was initiating this new program in the hope of alleviating the shortage of technical and managerial personnel in the coal mining industry.

Inquiries concerning the scholarships may be made through the department of mining, 118 Mineral Industries Building, or the Office of Student Aid, 121 Grange Building, both at University Park, Pa. 16802.

## New Position for Maneval

Dr. David R. Maneval, who is on leave from the University where he is an assistant professor of mineral preparation, has been appointed acting deputy secretary for mines and mineral industries in the new Commonwealth of Pennsylvania Department of Environmental Resources in Harrisburg.

Dr. Maneval had served as state director of coal research and development since 1963 in the old mines and mineral industries department, which has now been absorbed into the new environment department.

## College News Notes

Dr. Robert E. Newnham, professor of solid state science, has been reappointed as associate editor of the *American Mineralogist* for 1971. Dr. Newnham is also the coauthor (with Dr. L. E. Cross, associate director, Materials Research Laboratory and professor of electrical engineering) of a chapter entitled "Ferroelectric, Piezoelectric, and Electrooptic Materials" which appears in *Digest of Literature on Dielectrics*, a publication of the National Academy of Sciences.

Dr. Roger Downs, assistant professor of geography, has been appointed to the Editorial Advisory Board of *Environment and Behavior*. Dr. Downs is also the author of an article entitled "Geographic Space Perception: Past Approaches and Future Prospects"



On March 8, 1971, Mr. Charles A. Brinkley, District Geologist of Texaco, Inc. in New Orleans, visited the College of Earth & Mineral Sciences to present a check for \$2000 to the department of geology and geophysics. The department has been selected to receive a grant of \$6000, payable over three years, under the Texaco Aid to Education program in recognition of its contributions to higher learning and with the aim of further strengthening its work. Shown above at the presentation are, from left to right: Dr. Robert Scholten, acting department head, Dean Charles L. Hosler, and Mr. Brinkley.

which appears in *Progress in Geography*, Vol. 2, pp. 65-108.

Dr. Peter A. Thrower, associate professor of material sciences, attended an AEC meeting on dimensional changes in graphite due to neutron irradiation held in San Diego, January 19-22.

Dr. G. W. Brindley, professor of mineral sciences, presented an invited lecture to Phi Lambda Upsilon, honorary chemical society, at Drexel University on March 2. The lecture was entitled "Silicate-Organic Complexes."

Dr. W. A. Weyl, Evan Pugh Research Professor Emeritus, has been elected to Honorary Life Membership in the American Ceramic Society. Presentation of the award, which is the highest the Society can bestow, will be made at the 73rd Annual Meeting during the inaugural session to be held April 26 in Chicago.

Dr. John D. Ridge, professor of economic geology and mineral economics, has been appointed by the AIME as a Krumb Lecturer for 1971. Each year, the Institute appoints three Krumb Lecturers who are available to address any of the AIME sections throughout the country on a topic each has selected. The costs of the program are borne

by the Krumb bequest to the AIME. This year, Dr. Ridge will speak on "The Politics and Economics of Mineral Exploration and Exploitation," emphasizing the problems that the increasing nationalism of developing nations has placed in the way of meeting the raw materials needs of industrial nations. He will then discuss the various solutions that can be applied to such problems. His first lecture will be on April 15 before the Alabama Section and the second before the Upper Peninsula Section on April 28.

Dr. Frank F. Aplan, head of the department of mineral preparation, has been appointed a member of the Rositer W. Raymond Award Committee of the American Institute of Mining, Metallurgical, and Petroleum Engineers. This committee, composed of nine members chosen from the 55,000 members of AIME, selects the best paper published by the Institute during 1970 by an author under 33 years of age, and also chooses the Institute's candidate for the Alfred Nobel Prize in Engineering.

Dr. Arnulf Muan, professor of mineral sciences and head of the department of geochemistry and mineralogy, was a visiting professor at the Technical Uni-

versity of Norway, Trondheim, Norway, March 15-26, during which time he presented a series of graduate seminars on heterogeneous equilibria at high temperatures as part of an International Applied Physical Chemistry Program sponsored by The Norwegian Agency for International Development. He also presented two lectures on his current research before a joint chemistry-metallurgy-geology colloquium on the topics "Equilibrium Measurements Involving Metal, Oxide and Silicate Phases" and "Terrestrial and Extraterrestrial Equilibrium Problems."

Dr. H. L. Barnes, professor of geochemistry and head of the Ore Deposits Research Section, and Dr. S. B. Romberger, of the University of Wisconsin, are the authors of an article entitled "Ore Solution Chemistry III. Solubility of CuS in Sulfide Solutions" which appeared in the December 1970 issue of *Economic Geology*.

Dr. Barnes also presented a talk entitled "Dispersion of Metals Near Ore Deposits" to the department of earth and planetary sciences of the University of Pittsburgh, March 18.

Dr. Charles P. Thornton, professor of petrology, presented a talk entitled "Magic Numbers: The Use of Chemical Parameters in Igneous Petrology" to the department of earth and planetary sciences of the University of Pittsburgh, March 11.

Dr. S. M. Farouq Ali, associate professor of petroleum and natural gas engineering, presented a paper entitled "Solvent Flooding Displacement Efficiency in Relation to Ternary Phase Behavior" at the 68th National Annual Meeting of the American Institute of Chemical Engineers held in Houston, Tex., March 1-4. The paper, which was co-authored by Dr. Ahmad Totonji, consulting petroleum engineer, Gary, Indiana, dealt with certain new aspects of solvent flooding method for enhancing oil recovery from depleted oil reservoirs, and in particular, proposed a procedure for devising solvent mixtures for a given hydrocarbon in such a way that maximum oil displacement efficiency is attained. Research in this area was pioneered at Penn State, and this is the first paper in the history of the department of petroleum and natural gas to be presented at a meeting of the American Institute of Chemical Engineers.

Dr. C. Gregory Knight, assistant professor of geography, is the author of an article entitled "Ethnogeography and Change" published in the *Journal of Geography*, Vol. 70 (1971), pp. 47-51.

## The John G. Miller Scholarship



In 1955, Gladys D. M. Snyder and her husband, the late Harry Snyder, established a scholarship in the College of Mineral Industries, now the College of Earth & Mineral Sciences, as a memorial to her father, John Gottlieb Miller.

Mr. Miller, who was born in Buffalo, N.Y., in 1871 and died in Philadelphia in 1927, filled his 56 years with a great many accomplishments. While still in high school, he decided to become a newspaper man and writer. However, he lost his right hand in a printing press accident, necessitating a change in his plans, so after completing a business course in Buffalo, he joined Rogers Brown Company, an iron and steel company of Cleveland, and worked for them in Buffalo and Philadelphia.

From 1903 to 1920 Mr. Miller served as sales manager for the Adrian Furnace Company of Falls Creek and Punxsutawney, Pa. During this period of his life he became very active in civic affairs and business side-lines, as well as personally helping many boys who would not otherwise have been able to go to college. He also developed a deep and abiding interest in the then School of Mines of The Pennsylvania State College. It is not strange, therefore, that he channeled most of his aid to students toward those in the School of Mines.

Mr. Miller became a coal, coke and iron broker in 1920, and remained so until his death. He also purchased, in 1925, coke ovens and a coal mine, which eventually became victims of the depression.

## Air Pollution

(Continued from page 52)

financial assistance from appropriate funding agencies. The problem exists, of course, very largely because of too little rather than too much science, although some of the more excitable members of the community advise a return to the primitive to eliminate both science and pollution. Such suggestions, however, miss the point. Man, like all living things, generates wastes. This he must live with. It is not the waste of itself that constitutes pollution but the generation of so much waste that adversely affects the environment. This is not unique to man. Even animals can so adversely affect their environment that they suffer for it; for example, by overbreeding when food is plentiful, they overgraze when it is not and many die. Man can do this, too, but he has also learned how to avoid it. Measures to control wastes are not new. One of the most significant steps in waste control ever taken was the production of cheap steel pipe, in quantity, that enabled the separation of drinking water from sewage, and it probably did as much for the general health and reduction of mortality as all medical research to date.

There is no reason to suppose that the current problem of air pollution cannot be solved, given the will and the means. Curiously, one of the big difficulties at present — in addition to the invariable shortage of research funds — is availability of trained manpower to undertake the necessary research. Preaching and legislation are useless without the technology. If those who are so vocal in criticizing the shortcomings of science, industry, and the universities in solving "relevant" problems were to take a hand in developing the necessary technical solutions, even if it means getting their hands dirty, we should get there a good deal faster.

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## E&MS Datebook

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**Ceramic Science Career Day (Conference):** May 8, 1971, University Park Campus. Contact Dr. Guy E. Rindone, Ceramic Science Section, Department of Material Sciences.

**Elements of Coal Mining I Short Course:** May 24-26, 1971, University Park Campus. Contact Professor R. B. Hewes, 119 Mineral Industries Building.

**Longwall Mining Short Course:** June 7-9, 1971, University Park Campus. Contact Dr. Robert Stefanko, 110 Mineral Sciences Building.

**Pennsylvania Ceramics Association Meeting:** June 16-18, 1971, University Park Campus. Contact Dr. Guy Rindone, Ceramic Science Section, Department of Material Sciences.

**Institute in Geochemistry and Petrology:** July 1-August 25, 1971, University Park Campus. Contact Dr. A. L. Boettcher, Department of Geochemistry and Mineralogy.

**Mine Electrical Power Short Course:** July 19-23, 1971, University Park Campus. Contact Dr. R. Stefanko, 110 Mineral Sciences Building.

**Combustion Seminar:** July 26-30, 1971, University Park Campus. Contact Dr. Howard B. Palmer, Fuel Science Section, Department of Material Sciences.

**Thermal Recovery of Oil Short Course:** July 26-30, 1971, University Park Campus. Contact Dr. S. M. Farouq Ali, Department of Petroleum and Natural Gas.

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## Reprints Available

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Recent publications of the College of Earth & Mineral Sciences are listed below. Those desiring reprints should address their requests to the author whose name appears in italics (if there is more than one), 5 Mineral Industries Building, University Park, Pa. 16802.

### Title, Author, and Source

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Separation of Phases by Spinodal Decomposition in the Systems  $Al_2O_3-Cr_2O_3$  and  $Al_2O_3-Cr_2O_3-Fe_2O_3$ . A. H. Schultz and V. S. Stubican. *Journal of the American Ceramic Society*, Vol. 53, No. 11, November, 1970.

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Rapid Excavation Demand in the Coming Decades: An Analysis of the OECD Report, Dr. T. P. Meloy and Dr. R. T. Newcomb,

SME Fall Meeting and Exhibit, St. Louis, Missouri, October 21-23, 1970.

The Methodology Employed to Estimate Potential Mineral Supply of the Canadian Northwest - Analysis Based upon Geologic Opinion and Systems Simulation, D. P. Harris, A. J. Freyman, and G. S. Barry, Mineral Resources Branch, Department of Energy, Mines and Resources, Ottawa, 1970.

Without Rudder, Compass, or Chart - The Problem of Energy Policy Guidelines, Richard L. Gordon, Quarterly of the Colorado School of Mines, Volume 64, No. 4, October 1969.

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