to coal, based upon clean coal, ranges from 10.9 to 35.6. The thickness of the coal bed, character of the overburden, and stripping ratios are similar to those in an area in Ohio, where the opening of a strip mine was considered by an operator, who requested a loan from the Smaller War Plants Corporation. A report on the area, including the estimated cost of operations at the Ohio mine, was prepared for the Smaller War Plants Corporation.

Extraction of Pillars

The extraction of pillars in mines developed in steeply dipping beds presents many problems. The methods used at a mine in Washington were studied. The dip of the bed at this mine ranges from 47 to 60 degrees. A section of the bed is as follows:

Interbedded coal and shale	3' 0" to 4' 0"
Shale parting	1' 6" to 3' 0"
Clean coal	5' 0"
Boney coal (left in footwall)	0' 6"

Rooms in a panel are driven approximately 300 feet long on the strike of the bed. A panel usually comprises three rooms driven 8 feet high on 50-foot centers. The full width of bed between foot and hanging walls is extracted on advance in the lower room in the panel. In the two upper rooms, the 5-foot section of clean coal in the bed is extracted on the advance. Coal in these two upper rooms is transported by scrapers to chutes spaced approximately on 50-foot centers, and the coal passes to a shaking conveyor in the lower room. This conveyor transports the coal to the main chute of the panel. Extraction of the full thickness of the bed in the two upper rooms and the pillars between rooms is done on retreat from the panel.

Mine Mechanization

The improvement in technique of mining coal and the relation of this progress to increased extraction and, hence, conservation of coal deposits were reviewed.10/

The technique of coal mining progressed slowly until the advent of mechanized mining. The introduction of the cutting machine was a step forward, but this machine had little effect upon improving the percentage of recovery of coal. Previously, the physical fitness of the loaders and the total output of the miners fixed the output of a mine. The miner was an independent contractor, and supervision over the miner's working place was superficial. The increased cost of labor with the resultant rising cost of production, which necessitated higher selling prices for the product, and the inroads of substitute fuels (oil and gas) presented the problem of increasing the output per individual with the view of reducing the production cost per ton. Since 1923, the amount of coal loaded mechanically underground

10/ Toenges, Albert L., Mechanization in Coal Mining Makes Rapid Progress: Min. and Met., vol. 27, No. 475, July 1946, pp. 393-395.

1792

has increased from 0.3 percent to 48.9 percent of the total production from underground mines.

The investment necessary to equip a mine for mechanical loading is great, and in order to reduce the fixed charges per ton, multiple-shift operations were instituted, and the working area was planned so that the maximum tonnage can be obtained from a given territory. In some areas this resulted in changes in the mining system that effected a higher percentage of recovery than was possible when hand-loading methods were used. Hence, the introduction of mechanical loading has been a factor in improving the percentage of recovery in some districts.

Mechanization has brought problems to the industry, particularly in reference to production of a product free from foreign impurities. Where hand loading is used, the miner is able to discard the impurities such as partings, boney coal and clay veins, at the time the coal is loaded. The mobile loading machine is not capable of making this separation at the face but loads the broken coal irrespective of the impurities in the bed. This necessitates erection of mechanical cleaning plants at the mines. The output from these plants is not only of higher quality than the hand-cleaned coal but the coal cuttings from the cutting machines, which had been discarded at some mines, are now loaded underground and successfully cleaned mechanically. The recovery per acre at such properties is increased materially.

Where pillars were not extracted, the rapid advance of faces made possible by the use of mechanical equipment resulted in extraction of all the coal in the working places. This was not always possible in some sections because of roof falls. This increased percentage of extraction was due principally to the shorter time the roof was exposed, and caves were reduced to a minimum.

Various types of mechanical loading devices are in use. These types include mobile loading machines (either track- (fig. 8) or crawler-mounted), conveyors (with or without self-loading heads), and scrapers.

Mobile loading machines are best-suited to the mining of level beds of coal or to working on the strike of pitching beds. However, they have had limited use in working places where the pitch was as much as 12-1/4 percent upgrade and 23 percent downgrade.

Conveyors are either the chain or shaking type and are particularly suited to mining thin beds of coal but are used to advantage in mining thick beds on heavy pitches. As conveyors can be operated in a narrow space, they can be used where the roof is not good. In Alabama, the Southwest, parts of Pennsylvania, West Virginia, and other States where there are thin beds of coal, the use of conveyors has made possible the recovery of coal that could not be mined economically by other methods at this time.

Scraper operation is best adapted to places where the roof does not require close timbering at the face. Irregular bottom or floor, however, is disadvantageous to scraper work. This device is also suited to the extraction

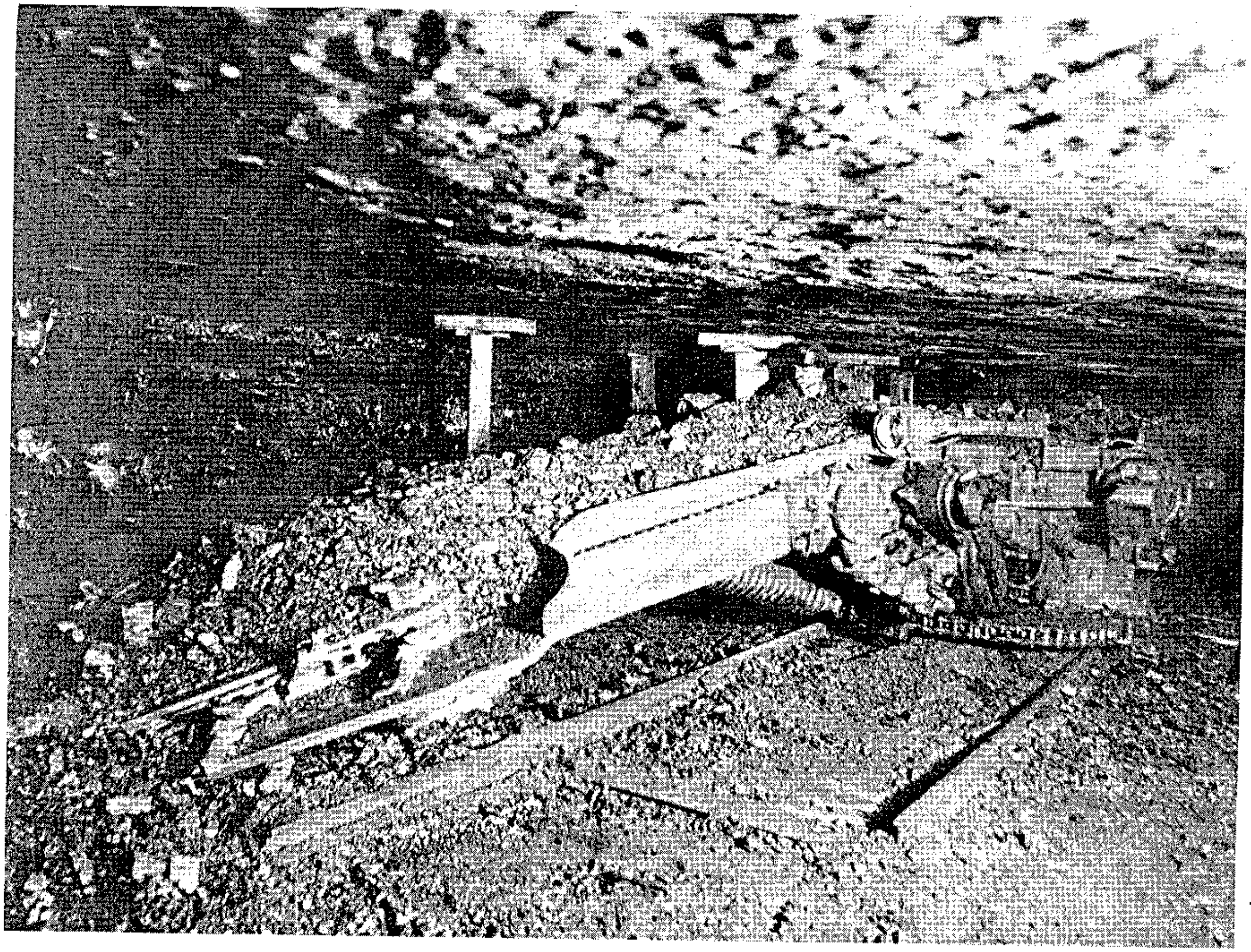

Figure 8. - Mobile coal-loading machine, track-mounted.

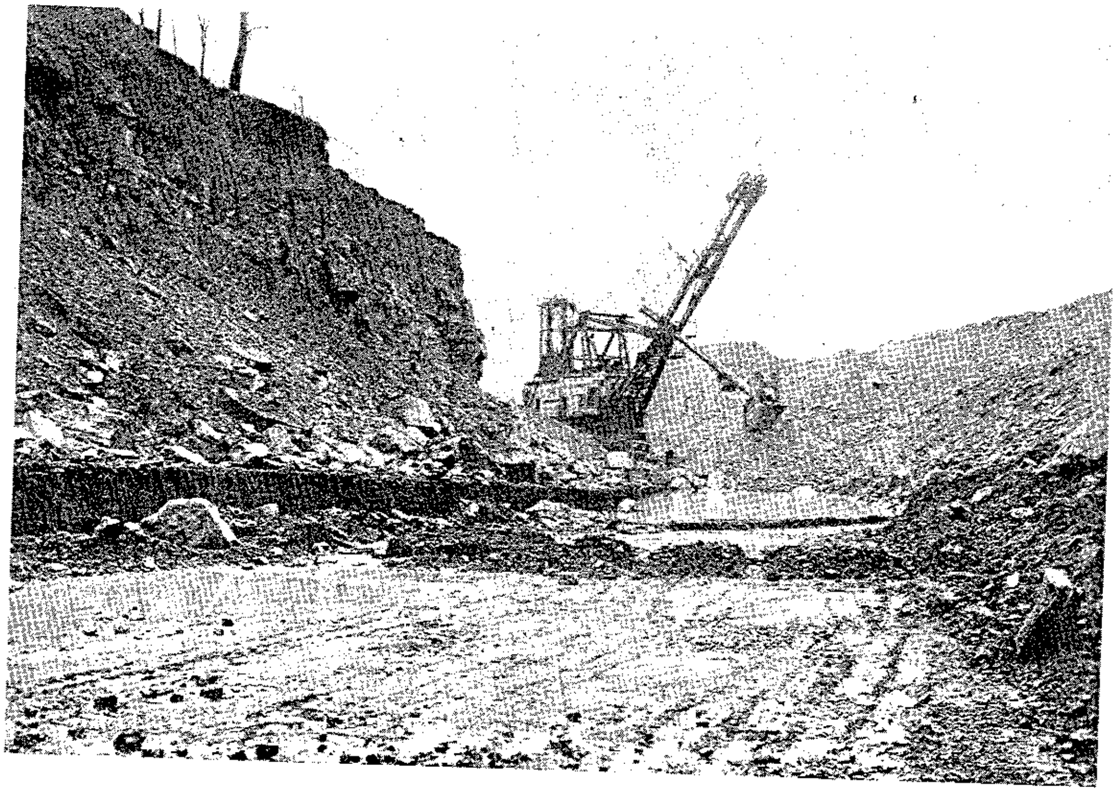

Figure 9. - Electric stripping shovel.

Figure 10. - Planned reforestation of spoil banks.

of coal from thick, pitching beds where physical conditions do not permit the use of other types of equipment. In order to obtain maximum tonnages per man in a scraper operation, the production from scraper walls and development should be so balanced that a large output per man on walls is not offset by a small production per man from narrow work on development. In thin beds, where scrapers can be used, headings should be driven wide in order to obtain maximum tonnage per foot of entry and to provide space for gob brushing (roof or bottom rock). It would appear that if conditions are suited to scrapers (good roof, hard and smooth bottom with no excessive dips, market for smaller sizes of coal), these will show a low total cost per ton (slightly less labor cost but considerably less investment) than conveyors in coal beds of the same thickness.

As the thicker beds of coal approach depletion, thin beds may be mined economically with mechanized devices for loading the coal. The rapid development of loading equipment, however, has added to the complexity of mechanical mining. Careful planning is required for the return of capital invested in equipment before obsolescence occurs. Coordination of every operation is necessary. A study of methods coordinating transportation with loading is essential and should show the way to increase the output per unit and, hence, reduce the cost per ton. The men working with the machines should be properly trained and educated to conduct the operations safely.

In recent years there has been rapid progress in the technique of mining coal by the stripping method, which is considered mechanical mining. Where the topography of the area and the depth to the coal bed are favorable for stripping, a large percentage of the total production of coal is obtained by this method. The production of strip coal has increased rapidly in some States, and for the United States it has increased from 2.8 percent in 1924 to 13.5 percent in 1943.

In 1943, strip mines in Alabama produced 427,039 tons, which was 2.5 percent of the total output of coal mined in the State.

Technique in strip mining has advanced from the use of teams and scrapers in the early days to electric-powered shovels of large capacity (35 cubic yards) of today. (Refer to fig. 9.) Electric coal-loading equipment has been instituted to replace hand loading. Both rail and motorized equipment are used today to transport the coal from the mines to the tipple, and the coal is prepared mechanically.

Strip mining is particularly adapted to areas where the coal bed outcrops or lies at comparatively shallow depths - 60 feet or less (at greater depths for short distances). The thickness, physical and chemical characteristics, and dip of the coal bed, the composition of the overburden, and the topography govern the extent of mining in strip areas.

From the layman's point of view, strip mining appears a simple procedure. However, this method of mining has many pitfalls, and unless a thorough and extensive study is made of the many factors involved, the venture is bound to fail. The investment in equipment is great; therefore, the proven reserves must be large to reduce the fixed charges. Exploration should be thorough, especially on beds known to be irregular in thickness and extent. The character of the overburden should be studied to determine the proper method of breaking this material. The many other phases of this method, including drilling, stripping, loading, transportation, and preparation must be given consideration.

The advance made in strip mining have made this method of mining a decided factor in conservation of coal deposits.

The recovery of coal in underground mining in the States where strip mining is important ranges from approximately 50 to 60 percent. Strip mining recovers the maximum amount of coal from a given area, approximately 75 to 95 percent, and is a means of preventing waste of a natural resource that cannot be replaced.

A contraphase of conservation in strip mining is the overturning of the land, which makes it useless for a time. Erosion, weathering, and natural vegetation usually will make lands useful for grazing, recreational areas, forest reserves, and, in some places, agriculture. Years are required to reclaim land by these means, and it has been proved that planned reforestation is a profitable investment.

Experiments in systematic tree planting in Indiana and Illinois showed that this method of reclaiming spoil banks is successful. (Refer to fig. 10.) Operators in other States have followed the example set by operators in these States. Not only can the reclaimed surface be converted to timber lands, but these lands have been used for grazing and fruit orchards. New industries should follow strip mining in these areas where reclamation has been instituted.

Strip mining (which is mechanized mining) and the application of mechanical loading devices in underground coal mines have been factors in improving technique in extraction of coal and in improving recovery, which results in conservation of coal deposits.

Australian Coal Mining

One of the Bureau's mining engineers with recent and extensive experience in Australia described the coal-mining industry of that country in the technical press.11/

He pointed out that Australian coal mining has drawn heavily on the American industry for both mining practice and machinery. The mines are highly mechanized, though results are not equivalent to those in this country.

11/ Hawkins, R. A., Australian Coal Mining: Min. and Met., August 1945, vol. 26, No. 464, pp. 382-4.

Demands for coal are primarily industrial, freeing the industry of much of its dependence upon climatic and seasonal fluctuations.

The States of Tasmania and Victoria generate hydroelectric power; the remainder of the country must depend on an annual supply of 10 to 13 million long tons of bituminous coal, 5 million long tons of brown coal, and on charcoal, wood, and imported fuel oil.

The brown coal comes from a State-operated open pit at Yallourn, Victoria. Approximately 75 percent of the output is consumed by the Victorian Government power stations, and the other 25 percent is briquetted by the State and sold to the general public.

The coal deposits are widely distributed, but most of the tonnage to supply a continent-wide market comes from three districts near Sydney, New South Wales. A large proportion of the production possesses excellent coking properties. Generally, the seams are horizontal, 6 to 14 feet thick, and have frequent local undulations.

The universal system of mining is known as "bord-and-pillar," which is similar to the American block system.

Surface handling consists only of sizing and loading, and sometimes hand picking. In 1945, one company started to construct a heavy-media cleaning plant.

High-grade coal reserves are large, both in pillars and in undeveloped known areas, and could be increased further by the introduction of modern coal-cleaning methods for the lower-grade coals.

Eickhoff Shearing Machine

In introducing and developing new types of equipment and methods for underground anthracite mines to improve the competitive position of anthracite by lowering production costs and to enhance the safety of the mine workers through improved working conditions that will accompany underground modernization, advantage was taken of an opportunity offered by the Technical Industrial Intelligence Committee, G-2 Division, SHAEF, for Bureau of Mines personnel to visit British and German mines and plants of mine-equipment manufacturers. Two lightweight German shearing machines, which are unlike chain cutting machines manufactured in the United States, were received, completely overhauled, and are now ready for underground testing. These machines are thought to be especially suitable for winning coal in thin, steeply pitching beds as soon as gangway development into a separate working section has been completed.

The Coal Planer

The rigid-blade German coal planer, which was uncovered by the Bureau's investigators as the principal European wartime development in underground mining equipment,[12] operated along a face 750 feet long and mined 900 tons per shift, is not suitable for planing anthracite without alteration. However, design, manufacture, and development of a new type of vibrating-blade coal planer have been arranged for by the Bureau of Mines. The selection of a location for experimental longwall mining is under consideration. Designed for longwall work only, in beds of moderate pitch, the possibilities of its basic principle of simultaneous mechanical winning and loading without cutting or blasting can be determined only after it is proved that anthracite can be planed and an opportunity is given engineers to study the coal planer in actual operation. Its successful development would open the way for attainment of the continuous mining principle and would eliminate frequent unproductive shifts.

Scraper-Slide and Shaker-Conveyor Loading Machine

Delay in delivery of steel parts and stock for the manufacture of the Bureau of Mines combination scraper-slide and shaker-conveyor loading machine for use in developing gangways in thin, steeply pitching beds made it necessary to postpone underground tests in the 1946 fiscal year. This loading machine is designed to eliminate transportation delays at the working face by providing for multiple car loading and in this way make possible one complete cycle of drilling, blasting, timbering, and loading each shift for twice the present rate of advance. Final development of this equipment should make possible the providing of more working places by the additional territory opened each year.

Effect of Scrubbing upon the Odorous and Irritating Constituents of Diesel Exhaust Gas

In field studies of the use of Diesel locomotives underground, it has been observed that the odor of Diesel exhaust gas can be detected in the underground atmosphere even when the ventilation supplied is sufficient to dilute each harmful constituent of the exhaust to a concentration considerably less than its permissible maximum. Because the odor of Diesel exhaust gas is objectionable to some individuals, it appeared desirable to obtain information on the feasibility of minimizing or removing the odorous constituents by scrubbing with water or water solutions containing suitable chemicals. Full-scale tests have been made to determine the effect of scrubbing Diesel exhaust gas with water. Bench-scale laboratory tests have been made to determine the effectiveness of solutions of sodium sulfite in water and to study methods for inhibiting the oxidation of sodium sulfite solutions.

From information available at present, it is not possible to state definitely which compounds or constituents of Diesel exhaust gas are responsible for the odor. Aldehydes are present in the exhaust and are known to have odorous and irritating properties. However, other constituents of the exhaust gas, such as unburned or partly oxidized fuel, which are present in

12/ Buch, John W., Mining Thin, Steeply Pitching Seams with the Coal Planer in the German Ruhr District: Mechanization, November 1945, pp. 92-97.

low concentrations, may also contribute to the odorous and irritating properties of the exhaust gas. Until more information is available, it is necessary to relate the odor and irritation of Diesel exhaust gas to the concentration of aldehydes in the exhaust gas. This is at best an approximation, not only for the reasons outlined above, but also because of analytical difficulties in detecting and differentiating between the different aldehydes that may be present. In the tests described here, total aldehyde concentration was determined by a modification of a method[13] based upon the reduction of silver nitrate by aldehydes, and the result is expressed as equivalent formaldehyde.

Although the limitations of water as a scrubbing medium for Diesel exhaust gas could have been predicted from theoretical considerations, it was considered advisable to obtain experimental data on these limitations to answer numerous inquiries on this subject. Furthermore, the data are of interest in connection with the development of permissible Diesel locomotives, as these will be equipped with water scrubbers for cooling the exhaust gases and quenching sparks.

In the studies described, the exhaust gases from a four-stroke-cycle, four-cylinder, commercial Diesel engine (engine B) were bubbled through a scrubbing tank containing approximately 10 gallons of water for a period of approximately 6 hours. Arrangements were made to replace, continuously, the water lost by saturation of the exhaust gas. Samples of gas taken before and after the scrubber were analyzed for carbon dioxide, carbon monoxide, oxides of nitrogen, and aldehydes. Observations of odor intensity and nasal and eye irritation were made on both the raw and scrubbed gases.

The effect of water scrubbing upon the removal of aldehydes from Diesel exhaust gas is shown in table 3. The results indicate that a portion of the aldehydes present may be removed by water scrubbing. The fraction removed depends on the concentration of aldehydes in the inlet gas, the concentration of aldehydes dissolved in the water, the temperature of the scrubbing water, the surface of scrubbing water exposed, and the time of contact of the exhaust gas in the scrubber. In full-scale tests it is not possible to control many of these variables, and therefore direct comparisons are difficult to make. However, the results of tests at 1,400 r.p.m. indicate that at higher scrubbing temperatures (greater than approximately 134°F.) the removal of aldehydes is negligible when the inlet concentration is of the order of 20 p.p.m. The effect of reduced time of contact is also indicated in comparisons of results of tests at 700 and 1,400 r.p.m. For example, at comparable scrubbing-water temperatures, the percentage removal of aldehydes is considerably less in the tests at the lower time of contact (higher engine speed). Scrubbing the exhaust gas with water removed no carbon monoxide and only a very small fraction of the carbon dioxide. The removal of oxides of nitrogen was negligible.

[13] American Gas Association Research Bull. 15, 1942.

TABLE 3. - Results of tests on the scrubbing of Diesel exhaust gas with water

Test No.	Engine speed r.p.m.	Engine load, b.h.p.	Volume of dry exhaust gas, cu.ft. per hr.1/	Temperature of scrubbing water, °F.	Concentration of aldehydes, p.p.m. by vol.2/		Aldehydes removed; percent of aldehydes in inlet gas
					Inlet3/	Outlet3/	
11	596	0.2	2,100	80	38.3	10.4	73
16	684	3.6	2,130	99	10.6	5.7	46
12	699	9.7	2,150	115	27.9	5.8	79
13	706	9.8	2,060	117	14.0	4.0	71
14	1,467	.4	4,400	98	101.6	65.2	36
17	1,429	8.9	4,200	122	51.0	31.8	39
15	1,386	19.2	3,870	134	23.7	22.9	3

1/ Dry gas at 29.92 mm. of mercury and 60°F.
2/ Expressed as equivalent formaldehyde.
3/ Weighted average for 6-hour test.

The results of observations of odor intensity, nasal irritation and eye irritation of the raw and scrubbed gas are shown in figure 11 as a function of concentration of aldehydes in the exhaust gas. The average intensity of each stimulus represents an average of observations of at least five individuals. The intensity of odor or irritation is arbitrarily defined as follows:

Odor intensity

0 - No odor.

1 - Very faint; minimum odor, but positively perceptible.

2 - Faint, weak odor, readily perceptible.

3 - Easily noticeable, moderate intensity.

4 - Strong, cogent, forcible odor.

5 - Very strong, intense effect, may bite or irritate.

Eye and nasal irritation

0 - No irritation.

1 - Faint, just perceptible, threshold, not painful.

2 - Moderate.

3 - Strong, discomforting, painful, but may be endured.

4 - Intolerable, cannot be endured.

Figure 11 indicates that both odor and irritation are related to the concentration of aldehydes in the exhaust. In every instance a slight reduction in intensity of odor or irritation was observed when aldehydes were removed by water scrubbing. Figure 11 also indicates that the threshold of odor (as indicated by aldehyde concentration) occurs at a concentration of the order of 0.3 p.p.m. and that the threshold of nasal and eye irritation occurs at a concentration of 1 to 2 p.p.m. If we assume that an atmosphere containing 0.3 p.p.m. of aldehydes would be odorless, then exhaust gas containing 30 p.p.m.

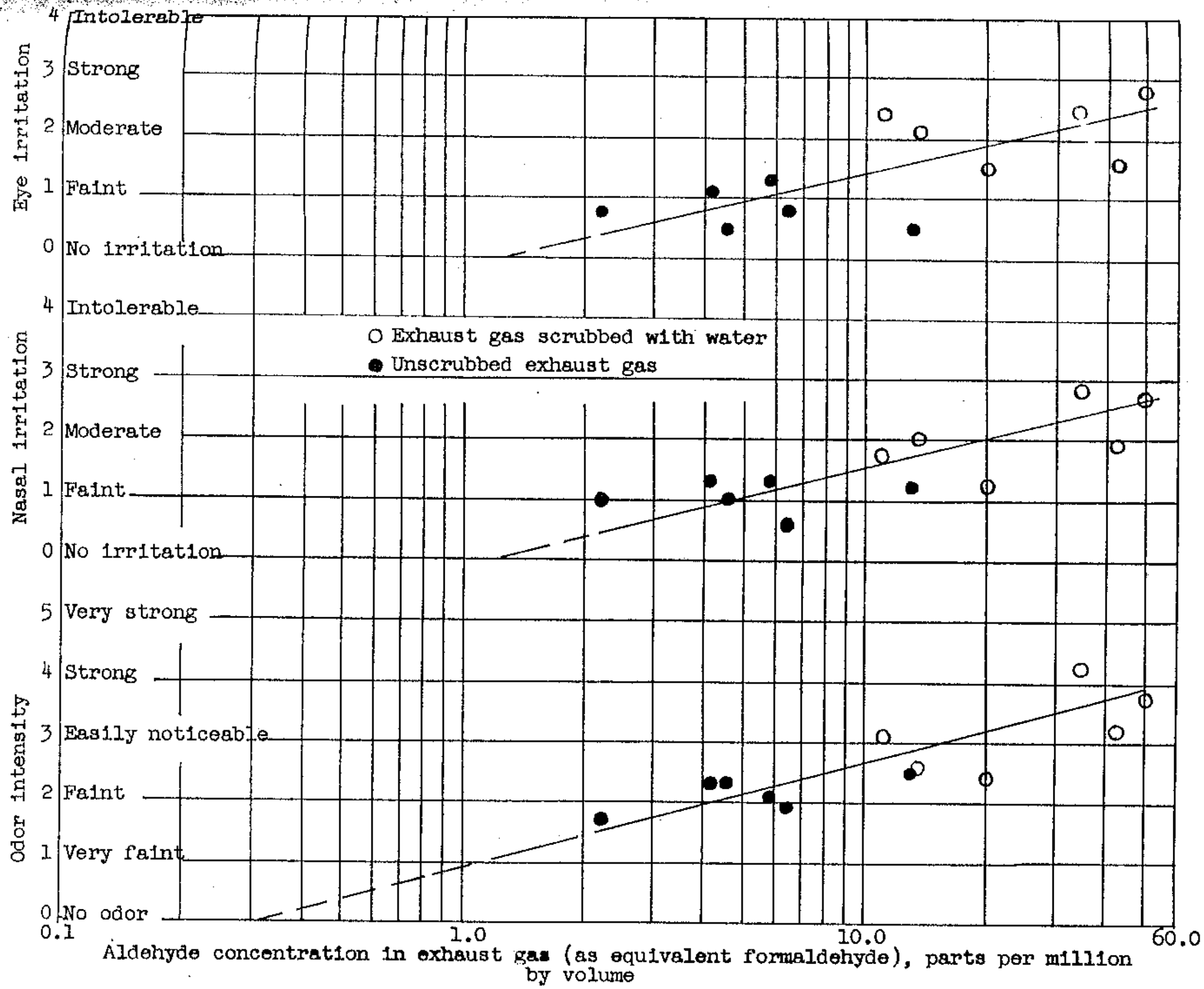

Figure 11. - Relationship between aldehyde concentration and odor intensity and nasal and eye irritation of Diesel exhaust gas.