year to year as new equipment and new standards are evolved. A revised sched-ule for testing and approving permissible electric equipment was published.

Permissible Mine Equipment

The Bureau continued to investigate electrical equipment used in mines in connection with the prevention of explosions and fires. A list of permissible mine equipment tested and approved under Schedule 2D during the calendar year 1944 was published.35/

Hazards of Auxiliary Fans in Coal Mines

The auxiliary fan as commonly used is intermittently operated and as frequently installed causes recirculation of mine atmosphere, which results in the accumulation of methane that may be ignited by an electric spark or other means. Use of electrically driven auxiliary blowers has resulted in a number of explosion disasters. The experience and observations of field safety Bureau engineers condemn the use of this system in coal mines. Proponents of the system outside the Bureau believe that such blower fans can be safely used if certain regulations and restrictions are imposed, but satisfactory rules have not yet been proposed. Reports of inspected coal mines in which blower fans are employed show that 95 percent were operated by electricity and that in a majority of these cases definite hazards existed.36/ The circumstances of a number of coal-mine explosions where blower fans were a contributory factor are reviewed, and the conclusion is drawn that general use of such fans is not justified.

Design of Ventilation Air-Injectors

The injector system of tunnel ventilation usually realizes only a little more than half the efficiency obtainable with a correct relation of jet size to tunnel area. Methods of designing injectors and predicting their performance under low-pressure air-flow conditions were developed, based on the constant-momentum theory of Prof. W. S. Weeks and confirmed by experiments in low-pressure-jet designs.37/ With high-pressure-jet designs, agreement of the formulas presented in the paper with experiments is approximate but sufficient for purposes of design. Formulas are presented for facilitating the design of compressed air-operated injectors, and a Venturi design is proposed for general utility in mines for auxiliary injector-pipe ventilation.

34/ Bureau of Mines, Procedure for Testing Junction Boxes and Electric Motor-Driven Mine Equipment for Permissibility: Sched. 2E, approved February 15, 1945, 19 pp.; Federal Register, vol. 10, No. 41, Feb. 27, 1945, pp. 2230-2240. (Typographic errors in the Federal Register were corrected in Sched. 2E.)

35/ Hooker, A. B., Permissible Mine Equipment Approved During 1944: Bureau of Mines Inf. Circ. 7316, 1945, 4 pp.

36/ Harrington, D., and Warncke, R. G., Some of the Hazards of Auxiliary Fans in Coal Mines: Bureau of Mines Inf. Circ. 7298, 1944, 27 pp.

37/ McElroy, G. E., Design of Injectors for Low-Pressure Air Flow: Bureau of Mines Tech. Paper 678, 1945, 50 pp.

Injectors can be designed for high efficiency or for high ratio of total air flow to jet air flow but not for both, as a reciprocal relation exists between efficiency and quantity.

Application of air jets to mine ventilation is surveyed in another publication.[38] Examples of applications of injector methods to ventilation problems in other industries are described, and new applications can be expected to evolve from the information presented. A method is proposed for using easily constructed injectors to regulate split air flow in coal mines in a way that conserves some of the energy now lost at regulators. The pressure change in a diverging discharge to atmosphere offers a means of securing pressure and exhaust in close juxtaposition.

Coal-Mine Health Hazards

Laboratory and field investigations of health conditions in anthracite and bituminous-coal mines were carried out in connection with requirements of the Federal Coal Mine Inspection Act. Dust and gas samples were collected and analyzed. Plans were made for the development and study of a wet-type auger drill for use in bituminous mines. Substitution of a quartz-free or low-quartz material for the high-quartz sand used under the wheels of mine locomotives is probably the best method of controlling this silicosis hazard. Dust from sand used for this purpose is disseminated into the air by handling during unloading, drying, transporting, sprinkling on the rails, passage of trains over the tracks where sand has been used, or walking over deposits of sand on haulageways.[39] Medical examinations of miners and tests of sand being used establish a definite connection of this material and the contraction of silicosis.

A filter-paper method[40] was developed for obtaining dust-concentration results comparable to those obtained by the widely used impinger method. The new method consists of the removal of dust from air by drawing the air, with a hand-operated pump, through special filter paper; removal of the dust from the paper by simple shaking in a dust-free liquid; and counting the dust by the same procedure used for impinger samples. Lintless, high-wet-strength, hardened filter paper is used. Light-transmission determinations may be made on the paper before and after sampling to obtain an estimate of dust concentration at the time of sampling. Comparative determinations on silica dust in the air of a test chamber and on coal dust in the air of a coal-sampling room showed that the results of regular light-field counts on the filter-paper samples agreed with the average of the results of two simultaneous midget-impinger samples, each collected within 5 cm. distance of the filter-paper

38/ McElroy, G. E., The Role of Air Jets in Mine Ventilation: Am. Inst. Min. and Met. Eng. Tech. Pub. 1912, July 1945, 16 pp.
39/ Brown, C. E., and Schrenk, H. H., Control of Silicosis Hazard by Substitution of Quartz-Free or Low-Quartz Material for Sand Used Under Mine Locomotives: Bureau of Mines Inf. Circ. 7297, 1944, 5 pp.
40/ Brown, C. E., Filter-Paper Method for Obtaining Dust-Concentration Results Comparable to Impinger Results: Bureau of Mines Rept. of Investigations 3788, 1944, 20 pp.

sample. Results of dark-field counts on the filter-paper samples were up to two times higher than those on the corresponding impinger samples, indicating a higher efficiency by the filter-paper method for collecting finer particles. The filter-paper sampler is simpler, cheaper, more rugged, and more convenient to use than the midget impinger. It may be used, if desired, for collecting samples of other unhygienic particulate matter than pneumoconiosis-producing dusts and should facilitate industrial hygiene activities, particularly efforts on the control of pneumoconiosis.

Use of Explosives and Gaseous Explosions

Increase in Charge Limit of Permissible Explosives

As one means of increasing coal production, the coal-mining industry in 1943 requested that the Bureau of Mines consider the use of permissible explosives in charges greater than the then permissible limit of 1.5 pounds. Since then, a continuing study has been conducted in the Experimental coal mine by the Experimental Coal Mine Section, with the advice and collaboration of the Explosives and Coal Mine Inspection Divisions, to determine factors affecting the ignition of gas and dust in a coal mine using higher weights of explosives. Preliminary studies have established tentatively safe conditions under which permissible explosives may be used in quantities up to 3 pounds per shot. These conditions are incorporated in the latest permissibility schedule.41/ This schedule is a revision of Schedule 1E, approved June 15, 1944, and sets forth the conditions under which a 3-pound charge of explosive can be used in coal mines. Tests required for approval of a sheathed explosive are described. Under Schedule 1F stemming is no longer required for use with a blasting device. For charges over 1.5 pounds certain additional safety precautions as to depth of hole, method of charging the explosive, testing for gas before and after firing a shot, and limits on toxic gas emission, must be observed.

The investigation was continued during this fiscal year, and 224 additional tests were made in the Experimental mine. The chief objective was to establish the limiting conditions under which a highly-inflammable gas mixture (8 to 9 percent methane - air) near the coal face will or will not be ignited by the flame or products of detonation from the explosive. A high-rate gelatin-type permissible explosive was used in most of the tests. This explosive was chosen because, under severe experimental conditions, ignitions of surrounding inflammable gas-air mixtures were obtained and therefore it was possible to determine the additional precautions necessary to prevent such ignition. The explosive cartridges used were 1.25 inches in diameter and 8 inches long, and each weighed about 0.47 pound. The explosive in all instances was loaded to the rear of the borehole, and was fired by a No. 6 detonator at the rear of the charge. In "file loading" the cartridges were placed in the

41/ Bureau of Mines, Procedure for Testing Explosives (Including Sheathed Explosives) and Blasting Devices for Permissibility and Suitability: Sched. 1F, Approved January 20 and March 14, 1945, 15 pp.; Duplicated from Federal Register, vol. 10, No. 26, Feb. 6, 1945, pp. 1476-1483; No. 60, Mar. 24, 1945, p. 3131.

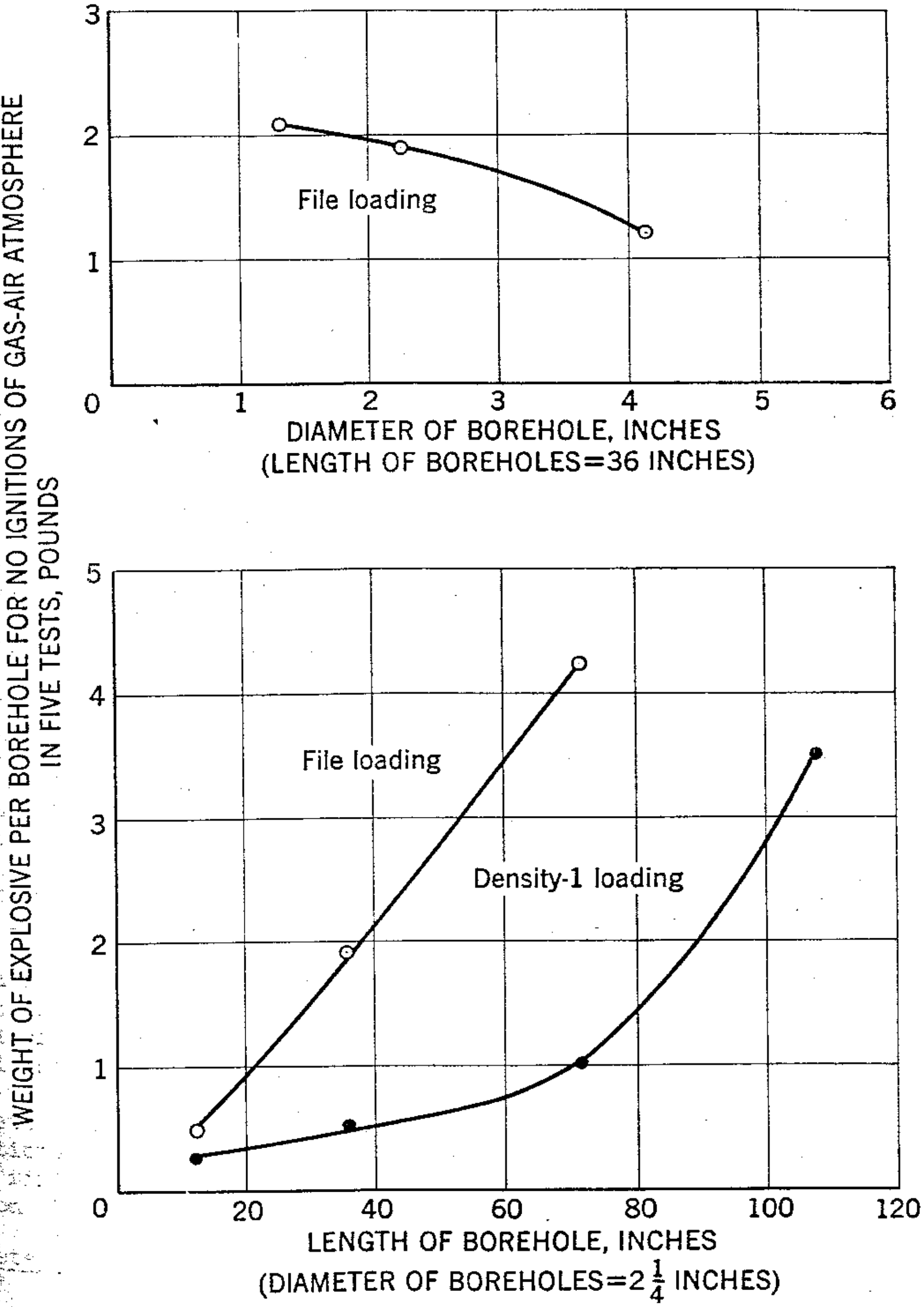

Figure 9. - Relation of dimensions of unstemmed boreholes to limiting charge of gelatin-type permissible explosive to prevent ignition of gas at coal face.

borehole end to end without being deformed; in "density 1" loading they were deformed to fill the cross section of the borehole without changing appreciably the density of the explosive. Tests were made under four sets of conditions: (1) Blow-outs, in which flame and products of the explosive are ejected mainly parallel with the axis of the borehole in solid coal; (2) blow-throughs, in which the products are ejected through the rupture of a weak sidewall of a borehole in solid coal, either to an adjacent undercut or to a shear; (3) fissures, in which the products are ejected largely through fissures in the coal or through openings simulating fissures; and (4) suspended charges, in which the explosive is not confined by coal, but is fired directly within a gas zone. Five successive tests were made under each set of conditions.

Figure 9 shows the relation for blow-out tests without stemming between the dimension of the unstemmed borehole and the maximum allowable weight of a gelatin-type permissible explosive to prevent ignition of gas at the coal face (based on five trials). In general, shots with file-loaded charges are less likely to ignite gas at the face than charges of the same weight packed into the boreholes (loading density 1). Preliminary tests with unstemmed charges also showed that an inflammable gas mixture in the borehole, intentionally introduced in some tests, has no significant effect on the probability of gas-ignition at the coal face.

In the blow-through tests, all made with stemming in 2.25-inch-diameter boreholes, no ignitions were obtained with any quantity of explosive up to 8 pounds, the highest tried, with thickness of wall of the borehole as low as 3 inches. These results applied to both under-cut and shear-cut faces. An earlier test gave ignition with a 6-inch wall, but this may have been caused by a fissure in the wall.

Preliminary tests with artificial fissures, in the form of circular holes introduced between the shear cut and the borehole, indicate that such openings constitute a definite hazard when explosives are fired in the presence of gas at the coal face, regardless of the amount of stemming in the borehole. Ignitions of gas resulted, with a fissure of 2.25-inch diameter through an intervening wall of coal 18 inches long and with a fissure of 1.25-inch diameter through 6 inches of coal.

In tests with charges of explosives suspended in the center of a gas-filled zone, ignitions of the gas resulted with as little as 0.09 pound of explosive. Accidental firing of explosives under such conditions presents a very grave gas-ignition hazard in a coal mine.

Gallery Tests of Permissible Explosives

In connection with the studies in the Experimental mine it has been necessary to make gallery tests for correlation purposes and to provide more satisfactory answers to certain specific questions than could be obtained by mine tests. Gallery tests were made to determine the effects of (a) type of stemming, (b) condition of borehole, (c) length of borehole, (d) method of loading the charge in the test cannon, and (e) weight of charge for weights of explosives so small that the detonator has an appreciable effect on the ignition probability of 8-percent natural gas-air mixtures. Preliminary tests indicated that the type of stemming has a marked effect on ignition probability. Results, based on 10 trials each, for a 200-gram charge of high-rate gelatin permissive explosive with single file loading, back initiation, and stemmed with various materials, showed that the more loosely packed, coarser particle size stemmings seem to be more effective in reducing ignition probability. Shots fired from a borehole expanded by previous shot firings at the position of the charge indicated very definitely that ignition is less likely than from shots fired from new undeformed boreholes. Results of tests to determine the effect of the length of the borehole showed that only slightly greater ignition probability is indicated for a 12-inch than for a 21.5-inch borehole. To investigate the effect of method of loading a technique of alternate shooting was adopted because of the marked effect of borehole condition. The tests were made in groups of five shots, and the order of shooting is indicated in the last column of table 5. After the tenth group of shots the borehole had started to expand markedly, and the ignition probabilities thereafter are probably too low. The results are far from complete but indicate that the density-of-1 loading presents an increased ignition hazard for this high-rate gelatin-type permissible explosive and are in contradiction to results previously obtained with two low-rate explosives, for which the air-spaced shots gave greater ignition probabilities.

TABLE 5. - Effect of method of loading explosive on ignition of 8-percent natural gas-air mixtures in gallery. Explosive D-7383, 200 grams.

Method of Loading	Weight of stemming, gm.	Probability of ignition	Order of tests (group of 5 shots)	
Single file, Back-initiated, Asbestos disk, Fire-clay stemming.	200	0.2	(1)	(4)
	225	.1	(9)	(12)
	250	.0	(15)	(17)
Density-of-1, Back-initiated, Air space of 4-7/8 inch, Asbestos disk, Fire-clay stemming.	200	.2	(2)	(5)
	225	.0	(10)	(13)
Density-of-1, Back-initiated, Asbestos disk, Fire-clay stemming.	200	.5	(3)	(6)
	275	.0	(11)	(14)
	250 (7 shots)	.0	(16)	
Single file, Back-initiated, Asbestos disk, Fire-clay stemming, Wire placed over charge.[1]	200	.1	(7)	(8)

1/ To determine whether wire in the spacer might introduce an appreciable effect, these shots were made with a weight of wire equivalent to that of a spacer placed over the charge.

Tests of the dependence of ignition probability on weight of charge for low-rate gelatin-type permissible explosive presented a very anomalous behavior. Accurate distribution curves are being obtained for both high-rate and low-rate permissibles, gelatin and nongelatin types, to determine whether the above noted behavior is noticeable for other types of permissible explosives. The explosives selected represent the four common types of permissibles: Explosive A - high-rate gelatin-type explosive; explosive B - low-rate gelatin-type explosive; explosive C - high-rate nongelatin-type explosive; and explosive D - low-rate nongelatin-type explosive. Distribution curves for A, B, and C have been completed and definitely indicate that the ignition probability first decreases then increases as the charge weight is increased. To determine whether the ignitions at the lower charge weights may be due to burning detonator fragments, distribution curves were also obtained using special No. 6 electric blasting caps with essentially the same explosive ingredients as the Standard No. 6 blasting cap, but with the combustible materials in the electric blasting cap plug replaced by a noninflammable glass plug. In all instances, the results indicate that the anomalously high ignition probabilities at the lower charge weights are probably due, at least partly, to burning of the combustible materials in the electric-blasting-cap plug. However, since the anomalous trend of the distribution curve is shown for both types of detonators, the presence of combustible material in the detonator plug does not entirely account for such a trend. One possible explanation might be that, due either to the geometry of placement of the detonator or because it is not strong enough to detonate the explosive completely, burning fragments of explosive are thrown into the gallery atmosphere and ignite the gas-air mixture.

Demonstrations of Safety of Explosives

Conducted tours of the Explosives Testing Station at Bruceton, Pa., were made for individuals, among them representatives of the Government of Brazil and of the Government Purchasing Commission of the Soviet Union. Demonstrations were made to illustrate the safety of permissible explosives when used properly and the danger of using black blasting powder because of the ease with which it will ignite bituminous-coal dust when fired into it.

Routine and Special Tests on Explosives

In all, 4,746 routine tests of various kinds were made under the Bureau of Mines schedule and for various investigations during the fiscal year.

Special tests were made for manufacturers of permissible explosives upon request and for general information. These tests included: Approval in size of permissible explosives not previously approved for particular brands; determination of gaseous products on six samples of 40-percent ammonia-gelatin dynamites of various compositions; determination of rate of detonation in tubes of five samples of dynamite; and ballistic pendulum tests and a charge test with the explosive suspended in the gallery on five samples of explosives.

The explosives chemical laboratory analyzed 419 samples during the fiscal year. This work included chemical analyses of explosives, blasting supplies, and detonators, and examination of enemy munitions.

Consumption of Permissible Explosives

A permissible explosive is one that is similar in all respects to a basic sample of the explosive that has passed certain required approval tests of the Bureau of Mines. In blasting coal permissible explosives should be used exclusively; otherwise disastrous explosions may occur. The consumption of permissible explosives for blasting coal during the fiscal year 1945 approximated 97,300,000 pounds. In addition, for the same purpose, approximately 37,500,000 pounds of black blasting powder were used. However, the use of this extremely dangerous explosive has declined rapidly since 1939, when about 48,000,000 pounds of black blasting powder were used as compared with only about 44,000,000 pounds of permissible explosives. In addition to the quantities of permissible explosives and black blasting powder consumed during the fiscal year 1945, there were also used approximately 81,700,000 pounds of high explosives other than permissibles. The total quantities of all explosives used in coal mines totaled 216,500,000 pounds, which is about 49 percent of the explosives used in industry for all purposes.

Lists of Permissible Explosives

After an explosive or blasting device has passed all the required tests it may be placed on the permissible list. This list is constantly being revised due to additions of explosives and blasting devices which have passed the tests and to transfers between the active and inactive lists. As of June 30, 1945, the active lists contained the names of 178 explosives and 9 blasting devices. This represents an increase of 4 explosives over the list for the previous fiscal year. Six explosives were submitted for tests, 5 passed the required tests, and 1 failed to pass. Two were transferred from the active to the inactive list, and 1 was placed on the active list as an additional name for an explosive already on the list. One sample was also submitted for complete tests to establish new basic data. The same 9 models of Cardox remain on the list; the safety of these devices with a heater element with a change in its composition was established by new tests. A new type of match assembly for igniting the Cardox heater element was submitted and approved.

Gallery Tests of Sheathed Explosives

Fifteen brands of permissible explosives with sheaths of various compositions were tested in the gallery. Most of these were in cartridges 1.25 inches in diameter; a few were 1.5 inches in diameter. Except for the gelatin-type permissible explosives and one of the granular type, all samples passed the suspended test with a differential of at least 100 grams between the sheathed and unsheathed cartridges. One permissible semigelatin-type explosive passed the test when the cartridge diameter was 1.25 inches but failed when it was 1.50 inches. For the larger-diameter cartridge the weight of sheathing material was less than that for the smaller cartridge; this may be one reason why the larger-diameter cartridge was not as safe as the smaller

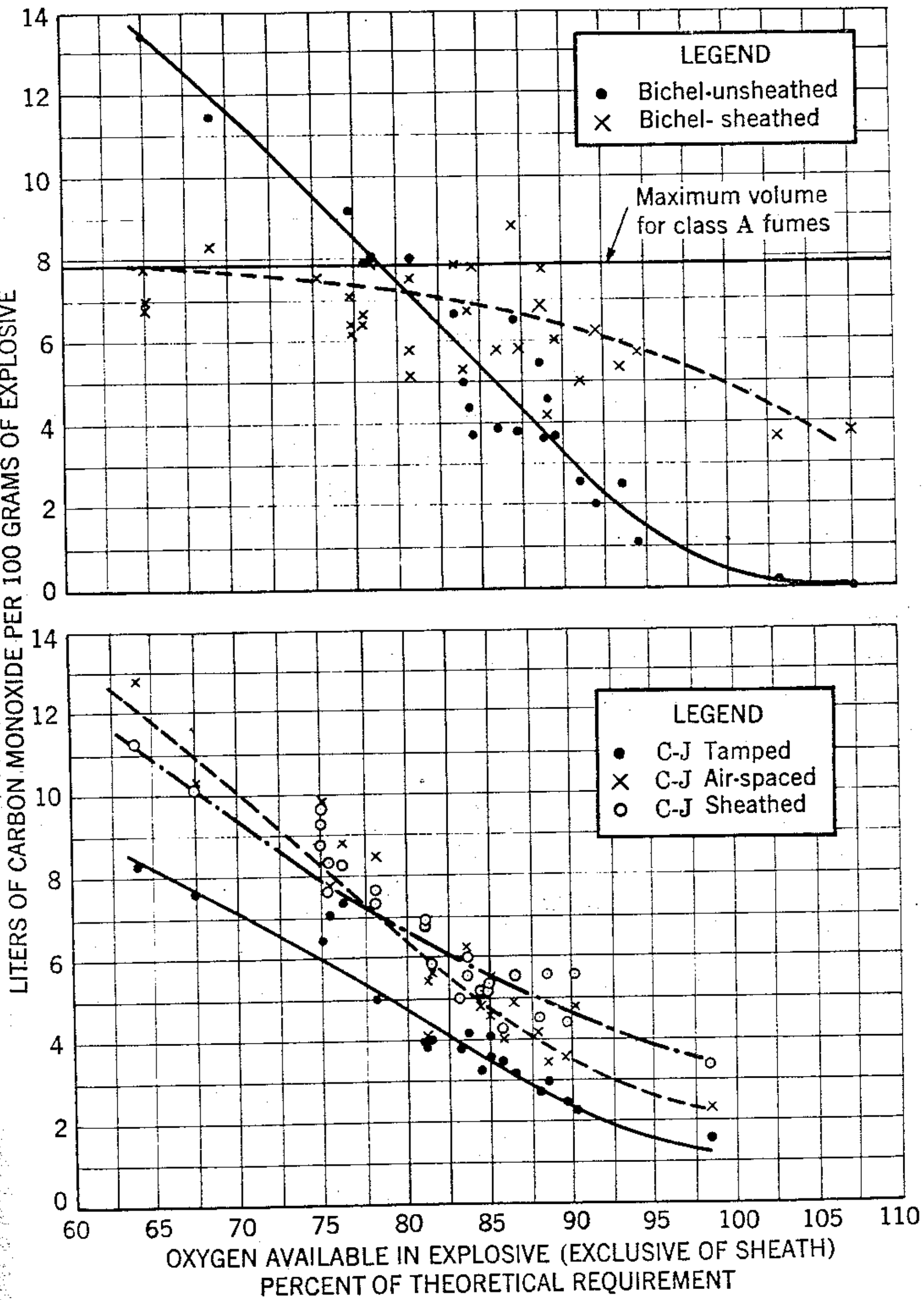

Figure 10. - Effects of sheaths on production of carbon monoxide.

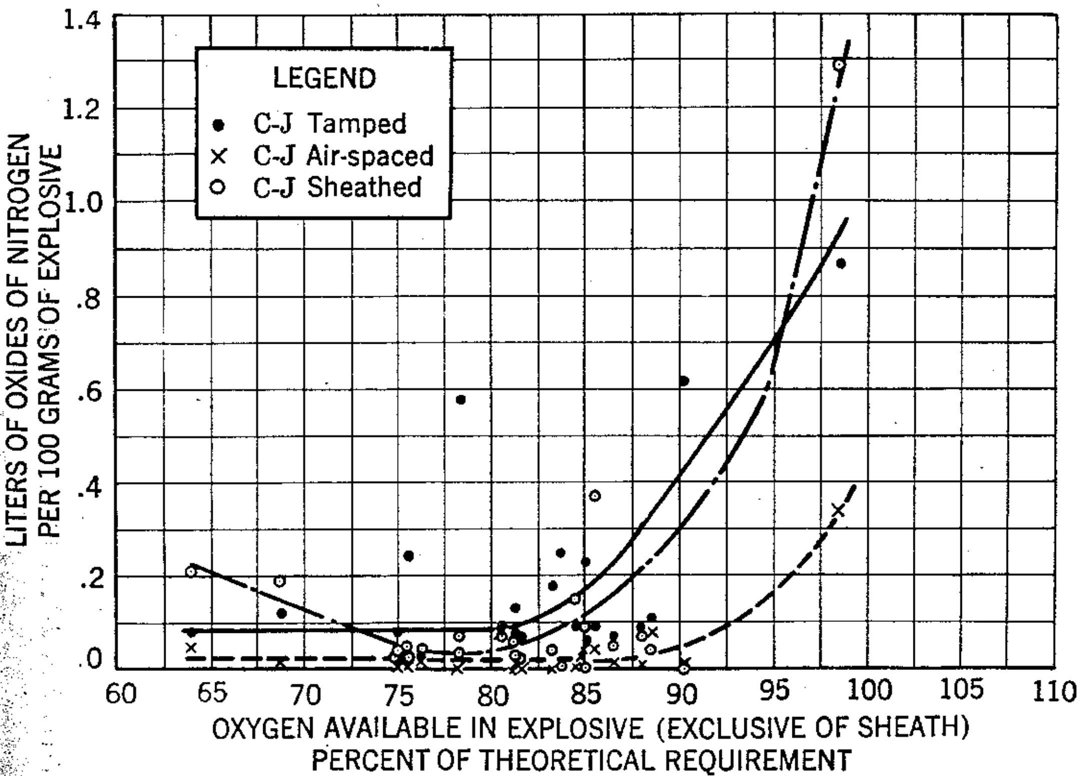

Figure 11. - Effects of sheaths on production of oxides of nitrogen.

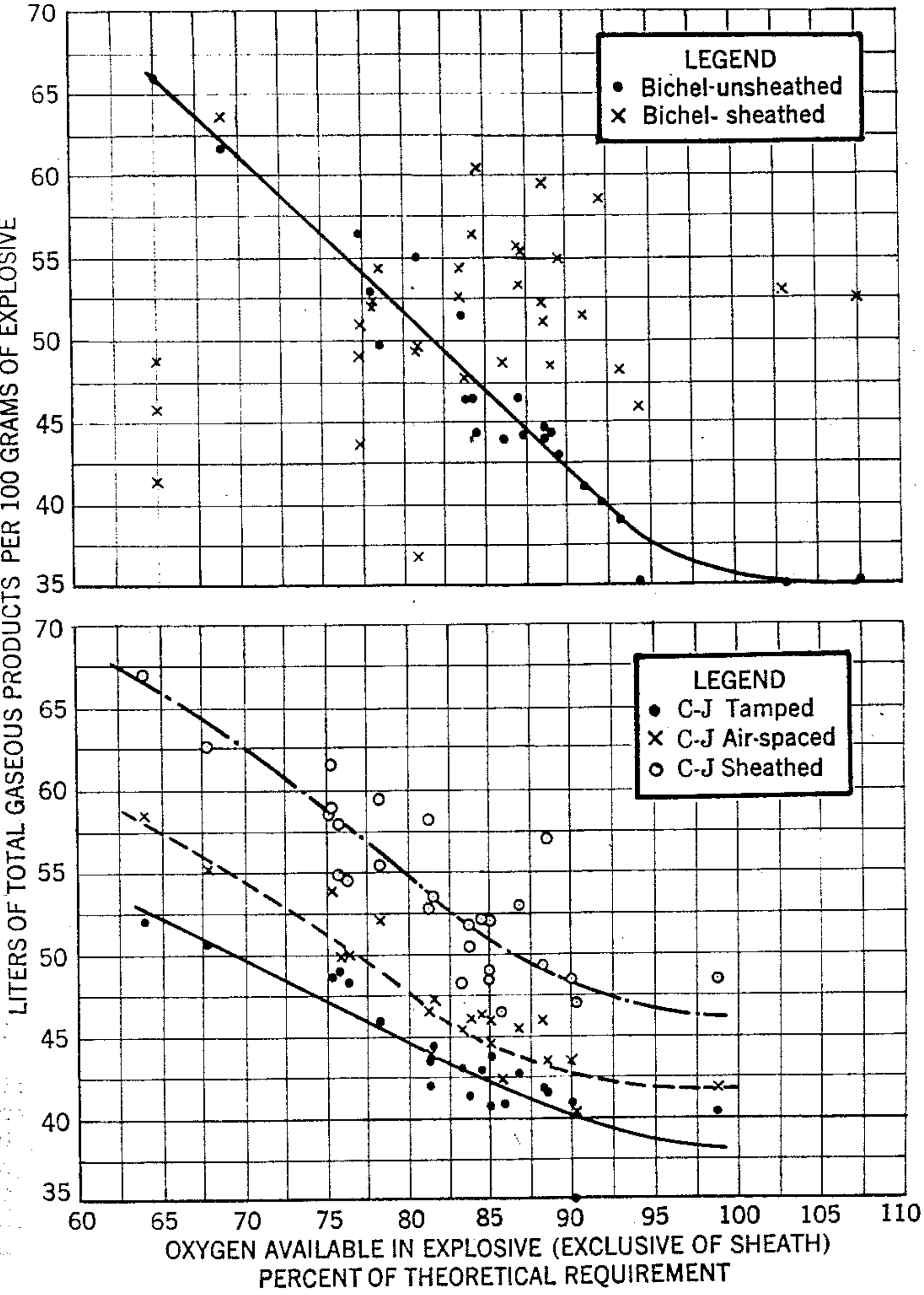

Figure 12. - Effects of sheaths on production of total volume of gaseous products.