The following results were obtained on the gas furnished by the city of Minneapolis:

	Determinations	Grains per 100 cu. ft.
April 15	1	14.13
April 15	2	14.16
April 19	1	12.30
April 19	2	12.42
April 23	1	12.68
April 23	2	12.60

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THE PROBABLE EFFICIENCY OF ACCIDENTAL GAS EXPLOSIONS.

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The amount of literature on this phase of gas explosions is apparently very small, as we were able to find no accounts of work done or tests made ; yet explosions of accidental nature can easily and do often occur, since the leakage from the gas mains and pipes is always considerable, averaging about fourteen per cent. and rarely less than seven. All that is necessary is a cavity protected so that the gas shall not escape from it too rapidly, and some method of ignition.

The object of this work was to determine what part of the energy of the gas, figured from its thermal value, shows itself in external or visible work. To imitate conditions occurring in practice, this work revealed itself by raising the weighted cover of a box. In the experiments about to be described two different shapes of boxes, cubical and prismatic, of three different sizes and two types of covers, outside and inside, were employed. They were made of wood, strongly built and provided with movable covers. Although these do not simulate accurately the conditions of practice where the hard ground forms the sides and bottom, yet if the boxes be well made with dovetailed bottoms, reinforced corners and sides well hooped with strap iron, the actual conditions are closely approached.

Description of Apparatus.

The various boxes used were cubical, of one foot, four feet and eight feet capacity, also a prismatic box four feet high and one foot square in section.

The smallest box was made of 7/8 inch whitewood and was dovetailed together very strongly. It was not hooped, yet nevertheless it stood a considerable number of explosions without injury. The other three boxes were made of $1^3/_8$ inch southern pine and were at first reinforced by wooden hoops of $1^1/_2$ inch stock dovetailed. One hoop was put on each box half way down the side. These were not strong enough and iron hoops had to be added. In the prismatic box a great deal of difficulty was experienced because of the leakage along the long side joints. This was remedied to a considerable extent by reinforcing the corners with triangular strips running the full height. The wood used in the boxes (Georgia pine) was not well adapted to resist the shocks to which it was subjected. It is a strong wood but is too brittle and splits too easily. A softer wood better hooped would have been as strong, and leakage could have been prevented more easily.

The gas used was Boston Illuminating Gas, of the following composition: carbon dioxide 3.4%, illuminants 8.5%, oxygen 1.1%, carbon monoxide 19.1%, methane 25.1% hydrogen 27.7% and nitrogen 16.2%. Its heating power is about 600 British thermal units. The ratio of gas to air used in all the experiments was 15 to 85. The gas was admitted by a tube which passed through a hole in one of the sides near the bottom. The air displaced by the gas escaped around the cover, but as the gas diffused pretty rapidly, an excess of ten per cent. was uniformly added, for a few explosions at the first showed that a maximum explosion was not obtained with the theoretical quantity only.

In order to insure a thorough mixing of the gas and air, each box was provided with stirrers. These consisted merely of brass rods, on the lower ends of which were riveted sheet iron discs, five or six inches in diameter, and were raised and lowered from the top after the right quantity of gas had been admitted. They passed through holes bored in the cover, and no particular provision was made to keep these holes air-tight, since the air inside had to be allowed some method of egress. The holes were bored 1/64 inch large and soon worked somewhat larger. The rods were just long enough to project above the cover, and easily slipped through when the latter rose, so their weight was not lifted.

To ignite the mixture two methods were employed. With the small box an induction coil was used—this worked very well, but considerable care was necessary in the adjustment of the wires of the secondary circuit. With the larger boxes three-ampere fuse wire on a fuse block was employed. This fuse could be blown, in the mixture by connecting with the 110-volt circuit. This made a very sure and satisfactory method of ignition.

The energy was measured by noting the maximum height to which the weighted cover rose during the explosion. To determine this the following method was used, which, although rather crude, worked very well. Two strips of hard wood about four feet long, carrying a row of small tacks an inch apart, were screwed to two opposite sides of the box. From these tacks, threads were strung across over the top of the box an inch apart near the point to which it was expected the cover would rise, and two inches apart a short distance above and below.

On the cover at the centre there was mounted a block about four inches high which carried at its top a sharpened knife blade, which, as it rose severed the threads in its path. This method did not give accurately the actual rise of the blade, for the threads, when they were being placed in position, could not be pulled very taut without breaking, but by putting an approximately equal tension on each, the constant distance the blade had to rise above a thread in order to sever it, was easily determined, and it was found in each case that the blade went half an inch higher; that is, half the distance to the next thread. In experiments where the rise of the cover was so slight that any error in these assumptions would be comparatively great, a light frame was fastened to the uprights over the cover, and was so constructed that the knife cut threads only six inches long, thus allowing little slack.

The greatest variation of results was caused by the use of two different kinds of covers; one an outside cover, that rested tightly on the top edges of the four sides, and the other an inside cover, one which fitted down inside so that its upper surface was flush with the top edges. The first is a much nearer approach to any probable actual condition, yet the latter case might be approximated.

For weights to regulate the height of the rise of the cover, zinc slabs were employed, weighing about thirty-five pounds apiece. On the largest box nine were used and it was on account of their thickness that the knife had to be mounted so high above the cover. A recently standarized dry meter measured the quantities of gas employed.

Experiments Made and Data Obtained.

TABLE 1.

Experiments with 1 cubic foot box, inside cover. Percentage gas in mixture—15. Calorific power 600 B. T. U.

	Weights (lbs.)	Height raised (ft.)	Foot lbs.	Efficiency Per cent.
(a)	21.4	1.75	37.5	0.054
(b)	33.6	2.00	67.2	0.096
(c)	33.6	2.41	81.2	0.116
(d)	33.6	2.00	67.2	0.096
(e)	33.6	1.83	61.5	0.088
(f)	52.3	1.67	87.3	0.125
			Average	0.096

The explosions (b) to (e) inclusive were made in order to ascertain how closely various explosions would check with each other if made under approximately the same conditions. It will be seen that the variation is small, and if explosion (c), in which the cover was fitted more tightly than in the others, be rejected, the deviation from the mean is very slight indeed. It will also be observed that the efficiency increased with increase of weight raised.

TABLE 2.
Experiments with one cubic foot box, outside cover.

Explosion	Weight (lbs.)	Rise (ft.)	Foot pounds	Efficiency Per cent.
(a)	25.1	0.17	4.3	0.006
(b)	37.3	0.17	6.3	0.009
(c)	37.3	0.13	4.8	0.007
(d)	56.5	0.08	4.5	0.007
(e)	56.5	0.13	7.3	0.010
(f)	25.1	0.17	4.3	0.006
(g)	18.6	0.33	6.1	0.009
			Average	0.008

The cubical box of four cubic feet capacity was next experimented with. In the first explosions made, the cover was warped sufficiently to caüse excessive leakage, but after being straightened by heavy cleats, the following data were obtained.

TABLE 3.
Four foot cubical box, inside cover.

Explosion	Weight lbs	Rise ft.	Foot pounds	Efficiency Per cent.
(a)	69.4	3.00	208	0.074
(b)	139.4	2.75	383	0.137
(c)	139.4	2.33	325	0.117
(d)	139.4	2.50	349	0.125
(e)	175.0	2.83	495	0.177
(f)	83.0	3.33	276	0.100
(g)	103.0	3.00	309	0.110
(h)	227.0	1.50	341	0.122
(i)	259.0	1.83	474	0.169
(j)	227.0	1.25	284	0.124
			Average	0.125

It will be seen with this box, as with the one cubic foot one under similar conditions, an increase of the weight to be lifted tended to increase the efficiency. Explosion (e) weakened the box at all the joints so that it had to be repaired and strengthened. It was largely owing to the excellence of these repairs that the high efficiencies obtained in the three last explosions were obtained.

TABLE 4.
Four foot cubical box, outside cover.

Explosion	Weight lbs	Rise (ft)	Foot lbs	Efficiency Per cent.
(a)	88	0.17	15.0	0.0053
(b)	18	0.29	5.2	0.0020
(c)	88	0.16	14.1	0.0050
(d)	158	0.25	39.5	0.0141
(e)	218	0.19	41.5	0.0146
			Average	0.0081

The cover used did not fit the box very closely and corrugated rubber strips were fastened to the cover to make the joints more nearly air-tight.

A considerable weight however was necessary to produce this condition, and thus the poor efficiency of the lightly loaded cover can be accounted for.

The next set of experiments were made with the prismatic four foot box. The particular object in the experiments with this box was to determine whether or not the position of the igniting flame caused any variation in the efficiency.

TABLE 5.

Four foot prismatic box, inside, (but poorly fitting) cover.

Distance of igniting flame from top	Weight lbs.	Height feet	Foot lbs.	Efficiency Per cent.
One foot	103	0.33	34.0	0.012
One foot	103	0.42	43.3	0.015
Two feet	103	0.33	34.0	0.012
Three feet	103	0.33	34.0	0.012
			Average	0.013

The cover was about an eighth of an inch small in each dimension and the results have little value except that they show how seriously a poorly fitting cover impairs the efficiency.

TABLE 6.

Four foot prismatic box, well fitting inside cover.

Distance of igniting flame from top of box	Weight lbs	Rise feet	Foot lbs.	Efficiency Per cent.	Average
One foot	148	0.58	86.	0.031	
One foot	148	0.50	74.	0.026	0.028
Two feet	148	0.75	111.	0.040	
Two feet	148	0.83	123.	0.045	
Two feet	148	0.75	111.	0.040	0.042
Three feet	148	1.00	148	0.053	
Three feet	148	0.92	136	0.049	0.051

Two explosions were made with the igniting spark at the bottom of the box, which was not sufficiently strong and burst apart each time. It will readily be seen, however, that the efficiency of the explosion increases with a considerable degree of uniformity, as the fuse is lowered in the box.

If we compare the efficiency obtained here with that obtained in the cubical box we see that the maximum here is 0.051 per cent. as against 0.125 with a cubical box of the same capacity. This is probably due to the difference in the rate of combustion of the gas, being more rapid in the cubical box.

The difficulties with the eight foot box with regard to getting efficient explosions were considerably greater than with the four foot cubical box. The great amount of energy developed by the explosion made it impossible to hoop or otherwise brace the sides sufficiently to prevent a large dissipation of energy.

TABLE 7.
Eight foot cubical box, inside cover.

Explosion	Weight lbs	Rise ft.	Foot lbs.	Efficiency Per cent.
(a)	163	2.08	340	0.061
(b)	163	2.25	366	0.065
(c)	236	2.08	492	0.088
(d)	301	1.50	452	0.081
(e)	301	1.33	400	0.072
(f)	341	1.33	454	0.082
			Average	0.075

Explosion (d) probably strained the box, and thereby some energy was lost by leakage, for at the next explosion one side of the box was blown completely off. When repaired the box was enough larger than before to make the cover very loose. After a few inefficient explosions had been made under these conditions, this difficulty was obviated by calking the spaces between the box and cover with cotton waste. This device although probably not as efficacious as joining the cover to fit would have been, at least prevented the escape of any undue amount of the mixture before explosion. Explosions (e) and (f) were made under these conditions and further work was prevented by their effect upon the box which needed a thorough overhauling for which there was not time.

Several attempts were made to get reliable data with an outside cover, but owing to the warped condition of the cover, a considerable weight had to be used, while an excessive weight was too likely to strain the box.

TABLE 8.
Eight foot cubical box, outside cover.

Weight lbs	Rise feet	Foot pounds	Efficiency Per cent.
243	.21	51.	0.0091
271	.21	56.9	.0101
		Average	0.096

It will be observed that these results are about an average between those of the four cubic foot and one cubic foot boxes, and it seems reasonable to conclude that with a moderately well fitting outside cover the efficiency will be about one one-hundredth of one per cent[1]. This value seems so incredibly low that the question immediately arises as to where the rest of the energy has gone. It is not easy to account for this. A large amount is wasted in heating the walls of the chamber, but probably most of it is dissipated into the atmosphere as the cover rises. The explosions in the prismatic box show incidentally that the gas does not burn instantaneously, and it can perhaps be considered that the cover is raised by the very first portion of the gas that burns, while the remainder escapes through the opening thus formed, and the fact that a large amount of gas can escape in that manner was shown by the poor efficiency of a cover which was loose fitting to a slight extent only.

[1] It has been calculated that the explosion in Expt. 1 should theoretically develop a pressure of 8 to 10 atmospheres; by calculating the force necessary to raise this cover two feet we find it to be 0.45 atmosphere. This would give an efficiency of about 5 per cent. (EDITOR).

The increased efficiency obtained by igniting the mixture at the bottom of the cavity over that resulting from ignition at other points is exactly what would be expected, and the increase might have been greater, if the box could have been made more rigid at the bottom.

It will also be observed that the efficiency resulting from the use of an inside cover was about ten times that from an outside one. The increase varied considerably with the perfection of fit of the cover and also with the load, heavier loads showing increased efficiency. Unfortunately all this power could not usually be measured, as an excessive load almost invariably resulted in the rupture of the box and consequent loss of energy.

To sum up, therefore, it appears from the foregoing results that, under ordinary conditions of explosion and covering, such as might occur in practice, an efficiency of about one one-hundredth of one per cent. is all that could be expected, that this efficiency increases with the excellence of the fit of the covering, with the load on the cover, to be raised, and also seems to increase if the point of ignition be near the bottom rather than near the top of the cavity. With an inside cover which has to be raised through a distance equal to the thickness of the cover, before vent is given to the box, the efficiency is about ten times as great.

The results obtained in the foregoing paper agree well with the experience which one of us, (A. H. G.) and also a colleague, has had in a series of experiments independently carried out on the large scale. Some fifty explosions were made, using boxes buried in the earth and also with covered pits from 80 to 7000 cubic feet capacity.

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A STUDY OF THE LIGNITES OF THE NORTHWEST. PARTS I. MOISTURE AND HYGROSCOPICITY.

BY G. B. FRANKFORTER.
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As a result of an investigation of the lignites from the west, northwest and north, the writer has reached the conclusion from experience extending over several years that in many respects they differ from bituminous coal to such an extent as to call for somewhat different methods of analysis and different interpretation of results. This seems to be largely due to the difference in composition and more especially to the large amount of moisture present. It has been found from analyses of a large number of samples ranging from the poorest to the best lignites of the country and from samples fresh from the mines to those exposed to the atmosphere for several months, that the moisture may vary from 6 to 40 per cent. and in a single instance 44.2 per cent. This variation is due partly to the condition underw hich the lignite exists in the seam and