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# Effect of compression and transmission on the illuminating and heating value of carburetted water-gas

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# EFFECT OF COMPRESSION
# AND TRANSMISSION ON
# THE
# ILLUMINATING AND HEATING VALUE OF
# CARBURETTED WATER-GAS

BY

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# THE EFFECT OF COMPRESSION

upon the

**HEATING VALUE AND**
ILLUMINATING POWER OF CARBURETTED WATER GAS

by HORACE H. CLARK

The object of this series of tests was to determine the effect of compression upon the candle power of carburetted water gas, as made in the daily operation of a three piece water gas machine, cooled in condensers, passed through shavings, scrubbers and oxide material, and thence into a storage holder, ready for compression and distribution.

The apparatus consisted of a small Westinghouse air compressor; nine storage tanks of six inch wrought iron pipe; transfer pump; pressure regulator; standard one hundred inch bar photometer, complete, with regulators, clock, meter, pentane lamp, etc., gas analysis outfit, complete; also gages, thermometers, etc.

The compressor was fastened to the wall of the Boiler Room, adjoining the building in which the tests were made, so that the gas was not exposed to cold. No outside pipe being necessary.

The gas supply line from the holder was two hundred feet of two inch pipe, well protected from frost. The line from the compressor to the storage tanks was of two inch pipe, reduced to one inch at the header for the nine storage tanks.

This line was run indoors and protected from frost. The header for the tanks was made up as shown in Fig. I. All unions were ground joint; and all cocks were brass, of the high pressure type.

The nine storage tanks, which were of six inch threaded pipe, were designed theoretically so that the longest tank would hold enough gas for all tests. This eliminated any possibility of variation of the gas supply which might have occurred had samples for different pressures been taken from the works Holder. The dimensions of the storage tanks are given in Table I.

The pump used for transferring the gas from one tank to the next, was a simple brass hand pump, having brass check valves, both inlet and outlet being below the piston. The piston was solid with large cup leathers, and had a diameter of three inches with a three and one-half inch stroke. A water gage was placed on the inlet of the pump and by slowly opening the stop cock, the relative pressure in the tank being exhausted could be seen. At no time was a negative pressure allowed; th tis, a pressure below atmospheric. On the outlet of the pump was placed a pressure gage reading to fifty pounds by half pounds, and a thermometer. Any heating of the gas was corrected so that the desired pressure at 60° F. was obtained.

A Williamson Regulator was used to reduce the pressure in the tanks from pounds to inches water. This was placed in the line to the photometer room as shown in Fig. II This regulator handled all pressures from five pounds to forty-five pounds without variation.

The Photometer Room and Laboratory were situated on the same floor and convenient to the storage tanks, as shown in Fig. II. These rooms, as well as the room in which the tanks were located, were properly heated, so that a minimum temperature of 60° F. could be maintained.

In starting the Westinghouse Compressor, considerable variation was noted in the flame at the photometer. From Fig. II. it will be seen that this fluctuation was caused by the compressor. A water gage on the inlet to the compressor showed holder pressure before the stroke, but a pressure of one inch below atmospheric pressure during the stroke. As there was danger of air leaks, and to avoid the fluctuations of the flame at the photometer; a storage tank or reciever, made of a piece of eight inch threaded pipe eight feet long, was placed in the gas line at the inlet to the compressor. The water gage now showed not less than two inches water pressure above atmospheric. This receiver removed the danger of air leaks but only partially overcame the fluctuations of the gas flame. This variation of the gas to the photometer room was avoided by putting in a by-pass between the compressor outlet and the receiver. In this by-pass was placed a stop cock so that the amount of gas, returned from the compressor to the receiver, could be regulated. After the first full stroke of the compressor, no fluctuation of the gas was noted, when the by-pass was properly regulated. See Fig. II.

Much difficulty was experienced in making the storage tanks gas tight. When the nine tanks were assembled and subjected to fifty pounds per square inch air pressure, eighty per cent of the joints leaked. This was due to the fact that standard caps and couplings were used on threads cut by a local machine on which the taper was too great. The leaky fittings were removed and replaced with litharge and glycerine on the threads. The air test showed twenty per cent of the joints.still leaking. These were removed and put on with red lead and shellac. Live steam was admitted into the tanks and all joints baked for three hours. After cooling, the air test showed ten per cent of the joints leaky. A number of these were stopped with standard six inch leak clamps and the smaller ones were calked. Air test and soap suds showed no leaks other than a pin hole here and there after the last remedy.

The nine storage tanks were tapped in the center of each cap on the header end, and in the lowest point of the caps at the far end. The latter taps were used for purging. It was the intention to remove drip and condensation from these openings but as the quantity deposited was so small, all efforts in that direction were abondoned.

After starting the compressor and regulating to about forty strokes per minute, all gas pipes, tanks, etc. were purged until an analysis showed no air present. All cocks opening to the atmosphere were closed and the by-pass at the compressor regulated so that in ten minutes, five pounds gage pressure at 60° F. was noted in each of the nine storage tanks.

During this period, photometric tests were made on the gas from the inlet side of the compressor, and a sample taken for analysis. The corrected candle power thus found was taken as the value of the gas before compression.

A chart showing the relation between temperature and pressure was available so that any increase of temperature above 60° F. could be noted, and the increased pressure considered, so that the actual pressure desired would exist at 60° F.

When after ten minutes the pressure had reached five pounds, all stop cocks then open were closed, and the compressor stopped. The stops in the line to the photometer were now opened and the gas from the five pound tank (1) turned on. The gas passed through ten feet of three-quarter inch pipe to the regulator, thence through five feet of half-inch pipe to the low pressure regulator, the previous regulator being of the high pressure type for reducing from pounds to inches. From the low pressure regulator the gas passed through a wet balance governor, test meter, and thence to the photometer burner, which was a seven foot flat flame burner through which the gas flowed at the rate of five cubic feet per hour. No dry governor was used in the line between the meter and the burner; this might account for the slight variation in some of the readings of the Bar.

The gas was ignited at the burner and ten observations were made at intervals of thirty seconds. Previous to making these tests, the test flame was allowed to burn for ten minutes and the pentane standard regulated. The object in burning the gas ten minutes was to obtain the gas, from the tank, at the burner. The temperature of the gas at the meter, barometric pressure, rate of flow of gas, were noted. During this test a sample of the gas was taken for analysis.

The gas from tank (1) was now shut off, and the stop to the photometer closed. The plugs in the street tees to tanks (1) and (2) were removed and the connections for the transfer pump screwed in. The cocks on tanks (1) and (2) in Fig. III were opened slightly to purge the pump and fittings through the union - (26) Fig. III. The union was now closed and the cocks to tanks (1) and (2) opened wide. The transfer operation was now begun. During this operation the analysis of the gas sample taken from the previous test, was made. The transferring was continued until the gage on the ten pound tank (2) showed ten pounds at 60° F. All stops wer closed, pump and connection removed, and plugs replaced. The stops to the photometer were opened and the gas from tank (2) turned on. The line was purged for ten minutes as before, and ten, half minute readings taken of the candle power of the gas. A sample was taken for analysis as in the first test of the series.

This operation was repeated for each succeeding pressure or test in the series. For pressures above thirty pounds, tank (6) was used, the gas supply being obtained from tanks (7) - (8) - (9). The stops (10 -11) Fig. III, etc. were used for equalizing the pressure between tanks if necessary. The by-pass S. Fig II. was put in to help distribute the incoming gas more evenly.

After each series, all tanks were opened to the atmosphere through the header and cock (M), (Fig. II), whence the gas escaped into the open through the hose (V). Before beginning a next series, the entire system was purged as in the first series.

The gages and thermometers used during these tests were new and accurate.

The entire system of tanks was supported on six by six timbers. This clearance gave ample room to manipulate stop cocks, etc.

All tests were made as soon after compressing as possible. That is, as soon as the gas had cooled to 60° F. As these tests were made during January and February (1909), no difficulty was experienced in obtaining as low as 60° F. in the test room.

## -- OBSERVATIONS --

### Candle-Power and Analyses of the Gases

| Holder | | 5 lbs. Pressure | | 10 lbs. Pressure | |
|---|---|---|---|---|---|
| 23.9 | Meter -.991 | 23.8 | .991 | 23.3 | .999 |
| 23.9 | Temp. 69° | 23.5 | 69° | 23.5 | 69° |
| 23.7 | Barom.29.85" | 24.1 | 29.85" | 23.4 | 29.84" |
| 24.0 | Tabular.972 | 24.2 | .972 | 23.5 | .971 |
| 24.0 | | 24.0 | | 23.1 | |
| 24.2 | Corrected | 23.6 | | 23.1 | |
| 24.1 | C. P. 24.87 | 23.8 | 24.70 | 23.4 | 24.02 |
| 24.0 | | 24.0 | | 23.5 | |
| 23.8 | 25 Candle | 23.9 | | 23.4 | |
| 23.9 | Standard | 23.8 | | 23.0 | |
| 23.95 | 25.00 | 23.87 | 24.83 | 23.32 | 24.14 |

Analysis

| | | | | |
|---|---|---|---|---|
| $CO_2$ | --- 3.9% | $CO_2$ | --- 3.6 | 3.5 |
| Illts | 11.6% | Illts | 11.4 | 11.2 |
| $O_2$ | 1.0% | $O_2$ | 1.0% | 1.0 |
| CO | 30.3% | CO | 30.4% | 30.4 |

**15 lbs. Pressure**

| | |
|---|---|
| 22.4 | 1.000 |
| 22.5 | 69° |
| 22.3 | 29.83" |
| 22.5 | .971 |
| 22.4 | |
| 22.5 | |
| 22.5 | 23.07 |
| 22.5 | |
| 22.0 | |
| 22.4 | |
| 22.40 | 23.17 |

3.3
11.1
1.0
30.5

**20 lbs pressure**

| | |
|---|---|
| 21.4 | 1.001 |
| 21.5 | 69.5° |
| 21.3 | 29.81" |
| 21.5 | .970 |
| 21.1 | |
| 21.4 | |
| 21.5 | 22.00 |
| 21.5 | |
| 21.2 | |
| 21.4 | |
| 21.38 | 22.12 |

3.2
11.1
1.0
30.5

**25 lbs. Pressure**

| | |
|---|---|
| 20.9 | .994 |
| 20.8 | 70° |
| 20.8 | 29.81" |
| 20.5 | .967 |
| 20.6 | |
| 20.5 | |
| 20.8 | 21.46 |
| 20.8 | |
| 20.4 | |
| 20.3 | |
| 20.64 | 21.58 |

3.1
11.0
1.0
30.7

**30 lbs. Pressure**

| | |
|---|---|
| 20.1 | .999 |
| 20.2 | 70° |
| 20.3 | 29.80" |
| 20.3 | .967 |
| 20.5 | |
| 20.8 | |
| 20.4 | 21.11 |
| 20.8 | |
| 20.4 | |
| 20.3 | |
| 20.41 | 21.22 |

3.0
11.0
1.0
30.7

**35 lbs. Pressure**

| | |
|---|---|
| 18.8 | .992 |
| 19.6 | 70° |
| 19.7 | 29.79" |
| 19.4 | .967 |
| 19.8 | |
| 19.2 | |
| 19.2 | 20.02 |
| 19.0 | |
| 18.7 | |
| 18.7 | |
| 19.21 | 20.11 |

3.0
10.9
1.0
30.8

**40 lbs. Pressure**

| | |
|---|---|
| 18.5 | 1.000 |
| 18.2 | 70° |
| 18.8 | 29.77" |
| 19.0 | .966 |
| 18.5 | |
| 18.4 | |
| 18.6 | 19.27 |
| 18.4 | |
| 19.0 | |
| 18.7 | |
| 18.61 | 19.38 |

2.9
10.9
1.0
30.8

Series 2

Holder

| | |
|---|---|
| 24.2 | .988 |
| 24.0 | 65° |
| 24.5 | 29.60" |
| 24.3 | .973 |
| 24.2 | |
| 24.3 | |
| 24.5 | 25.28 |
| 24.5 | |
| 24.1 | |
| a 24.0 | |
| 24.26 | 25.00 |

4.2
11.4
.1.4
30.4

5 lbs. Pressure

| | |
|---|---|
| 23.8 | .979 |
| 24.0 | 66° |
| 23.8 | 29.62" |
| 24.0 | .971 |
| 23.9 | |
| 23.9 | |
| 24.4 | 25.19 |
| 23.9 | |
| 24.0 | |
| 24.0 | |
| 23.97 | 24.91 |

4.0
11.2
1.4
30.5

10 lbs. Pressure

| | |
|---|---|
| 23.7 | 1.000 |
| 24.0 | 67° |
| 23.6 | 29.63" |
| 24.0 | .968 |
| 24.2 | |
| 24.2 | |
| 24.0 | 24.70 |
| 23.8 | |
| 24.0 | |
| 23.6 | |
| 23.91 | 24.43 |

3.9
11.0
1.4
30.6

15 lbs. Pressure

| | |
|---|---|
| 23.2 | .996 |
| 23.2 | 67.5° |
| 23.0 | 29.62" |
| 23.0 | .967 |
| 22.9 | |
| 23.1 | |
| 23.4 | 23.90 |
| 22.8 | |
| 22.9 | |
| 22.9 | |
| 23.04 | 23.64 |

3.7
10.9
1.4
30.6

20 lbs. Pressure

| | |
|---|---|
| 21.0 | .982 |
| 20.9 | 68° |
| 21.3 | 29.61" |
| 21.0 | .966 |
| 21.5 | |
| 21.3 | |
| 21.2 | 22.33 |
| 21.8 | |
| 21.2 | |
| 21.7 | |
| 21.29 | 22.09 |

3.5
10.7
1.4
30.7

25 lbs. Pressure

| | |
|---|---|
| 20.7 | 1.000 |
| 21.0 | 69° |
| 21.2 | 29.61" |
| 21.2 | .963 |
| 21.3 | |
| 21.3 | |
| 21.0 | 22.01 |
| 20.7 | |
| 20.9 | |
| 20.7 | |
| 21.00 | 21.77 |

3.3
10.6
1.4
30.8

| 30 lbs. Pressure | | 35 lbs. Pressure | | 40 lbs. Pressure | |
|---|---|---|---|---|---|
| 20.1 | .984 | 18.8 | .989 | 18.7 | .988 |
| 20.0 | 69° | 19.2 | 69° | 18.3 | 70° |
| 20.4 | 29.61" | 19.2 | 29.61" | 18.2 | 29.62" |
| 20.5 | .963 | 19.0 | .963 | 18.0 | .960 |
| 20.5 | | 18.5 | | 18.3 | |
| 20.2 | | 19.2 | | 18.0 | |
| 20.1 | 21.28 | 19.0 | 20.00 | 18.6 | 19.37 |
| 20.1 | | 19,2 | | 18.3 | |
| 19.9 | | 19.0 | | 18.3 | |
| 20.0 | | 19.2 | | 18.9 | |
| 20.18 | 21.05 | 19.03 | 19.78 | 18.36 | 19.16 |

| 30 lbs. | 35 lbs. | 40 lbs. |
|---|---|---|
| 3.2 | 3.1 | 3.0 |
| 10.4 | 10.2 | 10.1 |
| 1.4 | 1.4 | 1.4 |
| 30.9 | 31.0 | 31.0 |

| 45 lbs. Pressure | |
|---|---|
| 18.5 | .992 |
| 18.1 | 70° |
| 18.5 | 29.61" |
| 18.0 | .960 |
| 18.0 | |
| 18.6 | |
| 18.1 | 19.22 |
| 18,3 | |
| 18.6 | |
| 18.3 | |
| 18.30 | 19.00 |

3.0
10.1
1.4
30.9

Series 3

| Holder | | 5 lbs. Pressure | | 10 lbs. Pressure | |
|---|---|---|---|---|---|
| 26.0 | 1.000 | 25.5 | .988 | 25.0 | 1.000 |
| 25.6 | 29.69" | 25.0 | $68.5^{\circ}$ | 25.0 | $70^{\circ}$ |
| 25.8 | $62^{\circ}$ | 25.2 | 29.69" | 24.8 | 29.69" |
| 26.0 | .984 | 25.0 | .968 | 24.7 | .964 |
| 25.7 | | 25.2 | | 24.9 | |
| 25.9 | | 25.5 | | 24.8 | |
| 25.6 | 26.21 | 25.3 | 26.11 | 24.8 | 25.75 |
| 25.6 | | 25.3 | | 24.7 | |
| 26.0 | | 25.3 | | 24.7 | |
| 25.6 | | 25.5 | | 24.7 | |
| 25.78 | 25.00 | 25.28 | 24.91 | 24.82 | 24.56 |
| 4.0 | | 3.9 | | 3.8 | |
| 12.3 | | 12.2 | | 12.0 | |
| 1.0 | | 1.0 | | 1.0 | |
| 31.2 | | 31.2 | | 31.3 | |

| 15 lbs. Pressure | | 20 lbs. pressure | | 25 lbs. Pressure | |
|---|---|---|---|---|---|
| 23.8 | .990 | 22.5 | .995 | 22.0 | .996 |
| 24.3 | $74^{\circ}$ | 22.7 | $75^{\circ}$ | 22.0 | $75^{\circ}$ |
| 24.3 | 29.68" | 22.5 | 29.67" | 22.1 | 29.67" |
| 23.5 | .952 | 23.1 | .946 | 22.1 | .946 |
| 24.2 | | 22.3 | | 22.2 | |
| 24.2 | | 22.7 | | 22.2 | |
| 23.5 | 25.38 | 23.0 | 24.13 | 22.3 | 23.44 |
| 24.3 | | 22.6 | | 22.0 | |
| 24.2 | | 23.0 | | 22.0 | |
| 24.0 | | 23.0 | | 22.0 | |
| 24.03 | 24.21 | 22.74 | 23.02 | 22.09 | 22.35 |
| 3.7 | | 3.5 | | 3.4 | |
| 11.8 | | 11.7 | | 11.5 | |
| 1.0 | | 1.0 | | 1.0 | |
| 31.3 | | 31.3 | | 31.2 | |

| 30 lbs. Pressure | | 35 lbs. Pressure | | 40 lbs. Pressure | |
|---|---|---|---|---|---|
| 21.3 | .992 | 21.0 | 1.000 | 21.1 | .991 |
| 21.8 | 74° | 20.8 | 72° | 20.8 | 71.5° |
| 21.8 | 29.67" | 20.9 | 29.68" | 20.6 | 29.68" |
| 21.8 | .953 | 21.4 | .958 | 20.5 | .960 |
| 21.8 | | 21.1 | | 20.3 | |
| 21.8 | | 21.0 | | 20.0 | |
| 21.7 | 22.86 | 21.2 | 22.00 | 20.6 | 21.60 |
| 21.6 | | 21.4 | | 20.7 | |
| 21.3 | | 21.0 | | 20.6 | |
| 21.3 | | 21.0 | | 20.2 | |
| 21.62 | 21.81 | 21.08 | 20.98 | 20.54 | 20.60 |

| 30 lbs. | 35 lbs. | 40 lbs. |
|---|---|---|
| 3.2 | 3.1 | 3.0 |
| 11.4 | 11.3 | 11.2 |
| 1.0 | 1.0 | 1.0 |
| 31.1 | 31.1 | 31.1 |

| 45 lbs. Pressure | |
|---|---|
| 21.4 | 1.014 |
| 21.0 | 70° |
| 21.0 | 29.69" |
| 21.2 | .964 |
| 21.2 | |
| 20.8 | |
| 20.9 | 21.58 |
| 21.1 | |
| 21.00 | |
| 21.0 | |
| 21.06 | 20.58 |

3.0
11.2
1.0
31.0

Series 4

| Holder | | 5 Lbs. Pressure | | 10 Lbs. Pressure | |
|---|---|---|---|---|---|
| 25.3 | .992 | 23.9 | 1.000 | 24.2 | 1.004 |
| 24.7 | 29.60" | 23.9 | 75° | 24.1 | 76° |
| 25.0 | 69° | 24.3 | 29.41" | 24.1 | 29.41" |
| 24.9 | .963 | 24.3 | .940 | 24.0 | .938 |
| 24.9 | | 24.3 | | 24.5 | |
| 24.9 | | 24.5 | | 24.1 | |
| 24.6 | 26.00 | 24.5 | 25.81 | 24.1 | 25.59 |
| 24.7 | | 24.5 | | 23.6 | |
| 24.7 | | 24.2 | | 24.2 | |
| 24.5 | | 24.2 | | 24.2 | |
| 24.82 | 25.00 | 24.26 | 24.82 | 24.11 | 24.61 |

| Holder | 5 Lbs. Pressure | 10 Lbs. Pressure |
|---|---|---|
| 3.8 | 3.8 | 3.8 |
| 12.0 | 12.0 | 11.3 |
| 0.4 | 0.4 | 0.4 |
| 30.4 | 30.3 | 30.5 |

| 15 Lbs. Pressure | | 20 lbs. Pressure | | 25 lbs. Pressure | |
|---|---|---|---|---|---|
| 23.4 | 1.000 | 22.3 | 1.000 | 22.1 | .996 |
| 23.5 | 76° | 22.4 | 75° | 21.6 | 75.5° |
| 23.3 | 29.41" | 21.5 | 29.38" | 22.1 | 29.38" |
| 23.3 | .938 | 22.3 | .940 | 21.9 | .939 |
| 23.3 | | 22.4 | | 22.0 | |
| 23.1 | | 22.0 | | 21.2 | |
| 23.0 | 24.84 | 22.3 | 23.54 | 21.6 | 23.22 |
| 23.5 | | 22.0 | | 22.0 | |
| 23.5 | | 22.0 | | 21.3 | |
| 23.1 | | 22.0 | | 21.4 | |
| 23.30 | 23.89 | 22.12 | 22.64 | 21.72 | 22.33 |

| 15 Lbs. Pressure | 20 lbs. Pressure | 25 lbs. Pressure |
|---|---|---|
| 3.7 | 3.7 | 3.5 |
| 11.2 | 11.1 | 11.1 |
| 0.4 | 0.4 | 0.4 |
| 30.6 | 30.7 | 30.4 |

30 lb. Pressure

| | |
|---|---|
| 20.8 | .994 |
| 20.7 | 77° |
| 21.2 | 29.36" |
| 21.2 | .933 |
| 21.1 | |
| 21.0 | |
| 20.8 | |
| 20.9 | 22.58 |
| 21.0 | |
| 20.9 | |
| 20.96 | 21.72 |

3.2
11.0
0.5
30.9

Series 5.

| Holder | | 5 Lbs. Pressure | | 10 lbs. Pressure | |
|---|---|---|---|---|---|
| 24.0 | 1.000 | 24.8 | 1.000 | 23.6 | .990 |
| 24.7 | 69.5° | 24.0 | 69.5° | 23.8 | 69° |
| 24.7 | 29.44" | 24.4 | 29.44" | 23.5 | 29.44" |
| 24.5 | .955 | 24.0 | .955 | 23.2 | .958 |
| 24.6 | | 24.3 | | 23.0 | |
| 24.3 | | 24.6 | | 23.4 | |
| 24.3 | 25.61 | 24.5 | 25.49 | 23.0 | 24.58 |
| 24.5 | | 24.3 | | 23.0 | |
| 24.5 | | 24.0 | | 23.5 | |
| 24.5 | | 24.6 | | 23.1 | |
| 24.46 | 25.00 | 24.35 | 24.90 | 23.31 | 24.01 |
| 3.4 | | 3.4 | | 3.3 | |
| 12.0 | | 12.0 | | 12.0 | |
| 0.9 | | 0.9 | | 0.9 | |
| 30.6 | | 30.6 | | 30.6 | |

| 15 lbs. Pressure | | 20 lbs. pressure | | 25 lbs. pressure | |
|---|---|---|---|---|---|
| 22.1 | .994 | 21.7 | .994 | 21.8 | 1.000 |
| 22.6 | 69° | 21.4 | 29.44" | 21.1 | 69° |
| 22.9 | 29.44 | 21.4 | 69° | 21.1 | 29.44" |
| 22.5 | .958 | 21.6 | .958 | 21.2 | .958 |
| 22.4 | | 21.7 | | 21.2 | |
| 22.4 | | 21.6 | | 21.4 | |
| 22.1 | | 21.4 | 22.64 | 21.4 | 22.25 |
| 22.8 | 23.62 | 21.4 | | 21.5 | |
| 22.6 | | 22.0 | | 21.8 | |
| 22.5 | | 21.4 | | 21.6 | |
| 22.49 | 23.08 | 21.56 | 22.12 | 21.41 | 21.74 |
| 3.1 | | 2.9 | | 2.9 | |
| 12.0 | | 11.8 | | 11.8 | |
| 0.9 | | 0.9 | | 0.9 | |
| 30.6 | | 30.7 | | 30.7 | |

30 lbs. Pressure

| | |
|---|---|
| 20.4 | .980 |
| 20.9 | 69.5° |
| 21.0 | 29.45" |
| 21.0 | .955 |
| 20.0 | |
| 20;3 | |
| 21.0 | 22.09 |
| 20.7 | |
| 20.6 | |
| 20.8 | |
| 20.67 | 21.59 |

2.9
11.8
0.9
30.8

Series 6

| Holder | | 5 lbs. pressure | | 10 lbs. pressure | |
|---|---|---|---|---|---|
| 24.0 | 1.000 | 23.5 | .996 | 23.4 | 1.000 |
| 24.0 | 69° | 23.6 | 69° | 22.7 | 72° |
| 23.9 | 29.60" | 23.6 | 29.60 | 22.7 | 29.56" |
| 23.8 | .963 | 23.7 | .963 | 22.7 | .953 |
| 23.8 | | 23.4 | | 22.8 | |
| 23.8 | | 23.8 | | 23.0 | |
| 23.8 | | 23.7 | 24.63 | 23.0 | 24.00 |
| 23.9 | 24.86 | 23.6 | | 23.0 | |
| 24.0 | | 23.4 | | 22.8 | |
| 24.4 | | 23.9 | | 22.6 | |
| 23.94 | 25.00 | 23.62 | 24.78 | 22.87 | 24.14 |
| 3.1 | | 3.1 | | 3.0 | |
| 12.0 | | 12.0 | | 11.6 | |
| 0.9 | | 0.9 | | 1.0 | |
| 30.9 | | 30.9 | | 30.9 | |

| 15 lbs. pressure | | 20 lbs. pressure | |
|---|---|---|---|
| 21.4 | 1.000 | 21.2 | 1.000 |
| 22.0 | 72° | 21.0 | 71° |
| 22.1 | 29.56" | 21.1 | 29.49" |
| 22.2 | .953 | 21.2 | .954 |
| 22.2 | | 21.0 | |
| 22.2 | | 21.0 | |
| 22.3 | 23.05 | 21.0 | |
| 22.0 | | 21.1 | 22.10 |
| 21.8 | | 21.1 | |
| 21.5 | | 21.1 | |
| 21.97 | 23.18 | 21.08 | 22.23 |
| 3.0 | | 3.0 | |
| 11.6 | | 11.6 | |
| 1.1 | | 1.1 | |
| 30.8 | | 30.9 | |

Series 7

| Holder | | 5 lbs. pressure | | 10 lbs. pressure | |
|---|---|---|---|---|---|
| 21.4 | 1.000 | 21.2 | .993 | 21.5 | .997 |
| 21.6 | 72° | 21.4 | 72.5° | 21.4 | 72.5° |
| 21.2 | 29.36" | 21.0 | 29.34" | 21.3 | 29.34" |
| 21.0 | .947 | 21.2 | .945 | 21.4 | .945 |
| 22.0 | | 21.2 | | 20.7 | |
| 22.0 | | 21.1 | | 20.7 | |
| 21.9 | 22.65 | 21.0 | 22.58 | 21.0 | 22.30 |
| 21.0 | | 21.4 | | 20.9 | |
| 21.0 | | 21.3 | | 20.4 | |
| 21.4 | | 21.2 | | 20.8 | |
| 21.45 | 25.00 | 21.20 | 24.92 | 21.01 | 24.62 |

| Holder | 5 lbs. pressure | 10 lbs. pressure |
|---|---|---|
| 2.3 | 2.3 | 2.3 |
| 11.7 | 11.7 | 11.7 |
| 0.7 | 0.7 | 0.7 |
| 29.8 | 29.8 | 29.9 |

| 15# pressure | | 20# pressure | | 25# pressure | |
|---|---|---|---|---|---|
| 20.6 | .995 | 20.0 | 1.000 | 19.7 | .994 |
| 20.0 | 72.5° | 20.6 | 72.5° | 19.8 | 72° |
| 20.5 | 29.34" | 19.9 | 29.34" | 19.4 | 29.35" |
| 20.3 | .945 | 20.6 | .945 | 19.4 | .946 |
| 20.4 | | 20.7 | | 19.0 | |
| 20.2 | | 20.2 | | 19.5 | |
| 20.6 | 21.73 | 20.3 | 21.51 | 19.8 | 20.82 |
| 20.6 | | 20.5 | | 19.6 | |
| 20.7 | | 20.5 | | 19.8 | |
| 20.4 | | 20.0 | | 19.5 | |
| 20.43 | 23.99 | 20.33 | 23.75 | 19.55 | 22.99 |

| 15# pressure | 20# pressure | 25# pressure |
|---|---|---|
| 2.3 | 2.3 | 2.2 |
| 11.7 | 11.6 | 11.5 |
| 0.7 | 0.7 | 0.7 |
| 29.8 | 29.8 | 30.0 |

30# pressure

| | |
|---|---|
| 19.5 | .994 |
| 19.3 | 72° |
| 19.2 | 29.36" |
| 19.4 | .947 |
| 19.1 | |
| 19.7 | |
| 19.1 | 20.50 |
| 19.2 | |
| 18.9 | |
| 19.2 | |
| 19.26 | 22.63 |

2.1
11.5
0.7
31.0

35# pressure

| | |
|---|---|
| 18.5 | .986 |
| 18.2 | 72° |
| 19.2 | 29.36 |
| 18.5 | .947 |
| 18.4 | |
| 18.5 | |
| 18.5 | 19.89 |
| 18.5 | |
| 19.0 | |
| 18.5 | |
| 18.58 | 21.96 |

2.0
11.4
0.7
31.1

40# pressure

| | |
|---|---|
| 19.0 | 1.000 |
| 18.9 | 71° |
| 18.7 | 29.37" |
| 18.8 | .950 |
| 18.5 | |
| 19.2 | |
| 18.8 | 19.80 |
| 18.7 | |
| 18.8 | |
| 18.7 | |
| 18.81 | 21.86 |

2.0
11.4
0.7
31.1

45# pressure

| | |
|---|---|
| 18.5 | .996 |
| 18.4 | 72° |
| 18.6 | 29.36" |
| 18.7 | .947 |
| 18.5 | |
| 18.4 | |
| 18.4 | 19.73 |
| 18.4 | |
| 18.6 | |
| 18.7 | |
| 18.52 | 21.78 |

2.0
11.4
0.7
31.0

Series 8

**Holder**

| | |
|---|---|
| 19.6 | 1.000 |
| 19.4 | 28.74" |
| 19.3 | $67.5^\circ$ |
| 19.4 | .937 |
| 19.4 | |
| 19.5 | |
| 19.3 | 20.71 |
| 19.2 | |
| 19.2 | |
| 19.7 | |
| 19.40 | 25.00 |

4.9
10.3
1.4
30.7

**5# pressure**

| | |
|---|---|
| 19.3 | 1.000 |
| 19.3 | $67.5^\circ$ |
| 19.6 | 28.74" |
| 18.7 | .937 |
| 18.7 | |
| 19.0 | |
| 19.3 | 20.46 |
| 19.3 | |
| 19.3 | |
| 19.2 | |
| 19.17 | 24.70 |

4.9
10.3
1.4
30.7

**10# pressure**

| | |
|---|---|
| 18.6 | 1.000 |
| 18.2 | $67.5^\circ$ |
| 18.0 | 28.65" |
| 18.3 | .933 |
| 18.0 | |
| 18.5 | |
| 18.2 | 19.56 |
| 18.7 | |
| 18.0 | |
| 18.0 | |
| 18.25 | 23.62 |

4.8
10.2
1.4
30.8

**15# pressure**

| | |
|---|---|
| 17.8 | 1.000 |
| 17.5 | $67.5^\circ$ |
| 17.6 | 28.65" |
| 17.0 | .933 |
| 17.3 | |
| 17.0 | |
| 16.8 | 18.47 |
| 17.0 | |
| 17.0 | |
| 17.3 | |
| 17.23 | 22.30 |

4.6
10.1
1.4
30.9

**20# pressure**

| | |
|---|---|
| 16.8 | .998 |
| 16.4 | $67.5^\circ$ |
| 16.0 | 28.68" |
| 15.8 | .934 |
| 15.2 | |
| 16.4 | |
| 15.9 | 17.25 |
| 16.1 | |
| 16.2 | |
| 16.0 | |
| 16.08 | 20.83 |

4.4
10.0
1.4
30.9

**25# pressure**

| | |
|---|---|
| 16.1 | .990 |
| 15.5 | $67.5^\circ$ |
| 15.5 | 28.64" |
| 15.2 | .933 |
| 15.3 | |
| 16.1 | |
| 15.6 | 17.04 |
| 15.7 | |
| 16.2 | |
| 16.2 | |
| 15.74 | 20.57 |

4.3
10.0
1.4
31.0

30# pressure

| | |
|---|---|
| 16.6 | 1.000 |
| 15.8 | 67.5° |
| 15.3 | 28.64" |
| 15.8 | .933 |
| 15.5 | |
| 15.4 | |
| 16.2 | 16.87 |
| 15.1 | |
| 16.0 | |
| 15.7 | |
| 15.74 | 20.37 |

4.2
10.0
1.4
31.1

35# pressure

| | |
|---|---|
| 15.2 | 1.000 |
| 15.3 | 67.5° |
| 15.5 | 28.64" |
| 15.6 | .933 |
| 15.4 | |
| 15.0 | |
| 15.8 | 16.55 |
| 16.0 | |
| 15.6 | |
| 15.0 | |
| 15.44 | 20.00 |

4.1
9.9
1.4
31.1

40# pressure

| | |
|---|---|
| 15.0 | 1.000 |
| 15.6 | 67.5° |
| 15.2 | 28.64" |
| 15.0 | .933 |
| 15.0 | |
| 15.6 | |
| 15.3 | 16.36 |
| 15.3 | |
| 15.0 | |
| 15.6 | |
| 15.26 | 19.85 |

4.0
9.9
1.4
31.1

45# pressure

| | |
|---|---|
| 15.8 | 1.000 |
| 15.5 | 67.5° |
| 14.5 | 28.64" |
| 14.6 | .933 |
| 15.0 | |
| 15.0 | |
| 15.4 | 16.08 |
| 14.4 | |
| 14.5 | |
| 15.3 | |
| 15.00 | 19.42 |

4.0
9.9
1.4
31.1

Series 9

Holder

| | |
|---|---|
| 22.3 | 1.000 |
| 22.2 | 72.5° |
| 22.0 | 29.23" |
| 22.2 | .940 |
| 22.0 | |
| 22.3 | |
| 21.9 | 23.50 |
| 21.8 | |
| 22.2 | |
| 22.0 | |
| 22.09 | 25.00 |

4.7
11.2
1.0
30.2

5# pressure

| | |
|---|---|
| 21.8 | .987 |
| 21.6 | 73.5° |
| 21.3 | 29.19" |
| 21.2 | .938 |
| 21.2 | |
| 21.2 | |
| 21.5 | 23.15 |
| 21.4 | |
| 21.6 | |
| 21.6 | |
| 21.44 | 24.63 |

4.6
11.2
1.0
30.3

10# pressure

| | |
|---|---|
| 20.6 | .990 |
| 20.5 | 73° |
| 20.3 | 29.20" |
| 20.4 | .940 |
| 20.4 | |
| 20.3 | |
| 20.1 | 21.90 |
| 20.6 | |
| 20.5 | |
| 20.1 | |
| 20.38 | 23.30 |

4.6
11.0
1.0
30.3

15# pressure

| | |
|---|---|
| 19.4 | .990 |
| 19.4 | 73° |
| 19.2 | 29.22" |
| 19.3 | .940 |
| 19.4 | |
| 19.6 | |
| 19.0 | 20.74 |
| 19.5 | |
| 19.0 | |
| 19.2 | |
| 19.30 | 22.06 |

4.3
10.9
1.0
30.5

20# pressure

| | |
|---|---|
| 19.0 | .990 |
| 18.8 | 73° |
| 18.7 | 29.22" |
| 19.0 | .940 |
| 19.0 | |
| 18.9 | |
| 19.2 | 20.32 |
| 18.7 | |
| 18.6 | |
| 19.1 | |
| 18.90 | 21.62 |

4.3
10.9
1.1
30.6

25# pressure

| | |
|---|---|
| 18.3 | .990 |
| 19.0 | 73° |
| 18.4 | 29.22" |
| 18.3 | .940 |
| 19.1 | |
| 18.2 | |
| 18.6 | 20.05 |
| 18.7 | |
| 19.3 | |
| 18.7 | |
| 18.66 | 21.33 |

4.2
10.9
1,1
30.7

30# pressure

| | |
|---|---|
| 18.3 | 1.005 |
| 17.8 | 72.5° |
| 18.3 | 29.23" |
| 18.0 | .940 |
| 17.7 | |
| 18.1 | |
| 18.1 | 19.07 |
| 18.0 | |
| 17.8 | |
| 18.0 | |
| 18.01 | 20.29 |

4.2
10.7
1.1
30.7

35# pressure

| | |
|---|---|
| 17.0 | .996 |
| 17.3 | 72.5° |
| 17.3 | 29.24" |
| 17.2 | .941 |
| 16.9 | |
| 17.4 | |
| 17.0 | 18.33 |
| 17.0 | |
| 17.5 | |
| 17.1 | |
| 17.17 | 19.50 |

4.0
10.6
1.1
30.7

40# pressure

| | |
|---|---|
| 17.2 | 1.000 |
| 17.1 | 72.5° |
| 17.0 | 29.24" |
| 17.1 | .941 |
| 17.4 | |
| 17.3 | |
| 17.0 | 18.22 |
| 16.8 | |
| 17.5 | |
| 17.0 | |
| 17.14 | 19.38 |

4.0
10.6
1.2
30.7

45# pressure

| | |
|---|---|
| 17.5 | 1.006 |
| 17.0 | 72.5° |
| 17.4 | 29.24" |
| 16.9 | .941 |
| 17.0 | |
| 16.9 | |
| 16.9 | 18.05 |
| 16.9 | |
| 17.0 | |
| 17.0 | |
| 17.05 | 19.20 |

4.0
10.6
1.2
30.5

Series 10

| Holder | | 5# pressure | | 10# pressure | |
|---|---|---|---|---|---|
| 19.9 | 1.000 | 20.0 | 1.000 | 19.3 | .991 |
| 20.0 | 68.5° | 19.9 | 68.5° | 19.0 | 68° |
| 19.8 | 28.59" | 19.9 | 28.59" | 18.0 | 28.58" |
| 19.9 | .930 | 19.3 | .930 | 18.7 | .930 |
| 20.0 | | 19.6 | | 19.0 | |
| 20.0 | | 19.5 | | 18.7 | |
| 20.0 | 21.40 | 19.2 | 21.11 | 18.5 | 20.35 |
| 19.9 | | 19.7 | | 18.5 | |
| 19.7 | | 20.0 | | 19.3 | |
| 19.8 | | 19.2 | | 18.5 | |
| 19.90 | 25.00 | 19.63 | 24.67 | 18.75 | 23.78 |
| 5.3 | | 5.1 | | 5.1 | |
| 10.3 | | 10.2 | | 10.1 | |
| 2.0 | | 2.0 | | 2.0 | |
| 30.0 | | 30.0 | | 30.1 | |

| 15# pressure | | 20# pressure | | 25# pressure | |
|---|---|---|---|---|---|
| 18.0 | .997 | 17.0 | .992 | 15.8 | .988 |
| 18.6 | 68° | 16.4 | 68° | 15.9 | 67.5° |
| 18.0 | 28.56" | 16.6 | 28.56" | 15.9 | 28.56" |
| 17.7 | .930 | 16.4 | .930 | 15.8 | .932 |
| 18.0 | | 16.0 | | 15.8 | |
| 17.6 | | 16.7 | | 16.0 | |
| 17.6 | 19.35 | 16.6 | 17.78 | 16.0 | 17.18 |
| 17.7 | | 16.0 | | 15.5 | |
| 18.0 | | 16.0 | | 15.7 | |
| 18.0 | | 16.3 | | 15.8 | |
| 17.92 | 22.43 | 16.40 | 20.78 | 15.82 | 20.08 |
| 5.1 | | 4.6 | | 4.5 | |
| 10.0 | | 10.0 | | 9.9 | |
| 2.0 | | 2.0 | | 2.0 | |
| 30.1 | | 30.2 | | 30.2 | |

| 30# pressure | | 35# pressure | | 40# pressure | |
|---|---|---|---|---|---|
| 15.8 | .985 | 15.4 | .990 | 15.3 | .985 |
| 15.0 | 67° | 15.1 | 67° | 15.0 | 67° |
| 15.6 | 28.56" | 15.2 | 28.56" | 14.9 | 28.56" |
| 15.6 | .933 | 15.0 | .933 | 14.9 | .933 |
| 14.9 | | 15.6 | | 15.1 | |
| 15.6 | | 15.1 | | 15.0 | |
| 15.6 | 16.84 | 15.0 | 16.51 | 15.0 | 16.42 |
| 15.4 | | 15.2 | | 15.0 | |
| 15.4 | | 15.2 | | 15.3 | |
| 15.8 | | 15.6 | | 15.4 | |
| 15.47 | 19.68 | 15.24 | 19.28 | 15.09 | 19.18 |
| 4.5 | | 4.4 | | 4.0 | |
| 9.9 | | 9.9 | | 9.8 | |
| 2.0 | | 2.0 | | 2.0 | |
| 30.2 | | 30.3 | | 30.4 | |

| 45# pressure | |
|---|---|
| 15.0 | .990 |
| 14.9 | 67° |
| 14.8 | 28.56" |
| 15.0 | .933 |
| 15.2 | |
| 15.1 | |
| 14.7 | 16.25 |
| 15.0 | |
| 15.2 | |
| 15.1 | |
| 15.00 | 19100 |
| 4.0 | |
| 9.8 | |
| 2.0 | |
| 30.5 | |

Series 11

| Holder | | 5# pressure | | 10# pressure | |
|---|---|---|---|---|---|
| 24.5 | 1.000 | 24.4 | .994 | 24.0 | .995 |
| 24.8 | 77° | 24.5 | 77° | 23.8 | 79° |
| 24.6 | 29.33 | 24.0 | 29.33" | 23.9 | 29.30" |
| 24.6 | .933 | 24.4 | .933 | 23.6 | .926 |
| 24.5 | | 24.1 | | 23.8 | |
| 24.2 | | 24.2 | | 23.5 | |
| 24.2 | 26.24 | 24.1 | 26.14 | 23.8 | 25.79 |
| 24.2 | | 24.3 | | 23.7 | |
| 24.6 | | 24.2 | | 23.9 | |
| 24.6 | | 24.1 | | 23.5 | |
| 24.48 | 25.00 | 24.23 | 24.91 | 23.75 | 24.58 |
| 3.4 | | 3.4 | | 3.4 | |
| 12.5 | | 12.4 | | 12.4 | |
| 0.6 | | 0.6 | | 0.6 | |
| 30.0 | | 30.0 | | 30.6 | |

| 15# pressure | | 20# pressure | | 25# pressure | |
|---|---|---|---|---|---|
| 23.7 | .995 | 22.5 | 1.000 | 21.8 | 1.000 |
| 23.3 | 79° | 22.2 | 79° | 21.6 | 81° |
| 23.4 | 29.30" | 22.4 | 29.30" | 21.5 | 29.33" |
| 23.6 | .926 | 22.5 | .926 | 21.7 | .922 |
| 23.5 | | 22.7 | | 21.6 | |
| 23.3 | | 22.7 | | 21.8 | |
| 23.3 | 25.45 | 22.6 | 24.38 | 21.8 | 23.45 |
| 23.7 | | 22.7 | | 21.4 | |
| 23.6 | | 22.7 | | 21.4 | |
| 23.1 | | 22.7 | | 21.6 | |
| 23.45 | 24.25 | 22.57 | 23.23 | 21.62 | 22.34 |
| 3.2 | | 2.6 | | 2.6 | |
| 12.2 | | 12.0 | | 11.8 | |
| 0.6 | | 0.7 | | 0.7 | |
| 31.6 | | 31.4 | | 30.5 | |

30# pressure

| | |
|---|---|
| 21.0 | 1.800 |
| 21.3 | 81° |
| 21.2 | 29.33" |
| 21.1 | .922 |
| 21.5 | |
| 21.5 | |
| 21.6 | 23.09 |
| 21.3 | |
| 21.1 | |
| 21.3 | |
| 21.29 | 22.00 |

2.6
11.6
0.7
30.8

Series 12

| Holder | | 5# pressure | | 10# pressure | |
|---|---|---|---|---|---|
| 25.0 | 1.003 | 24.6 | 1.000 | 24.0 | 1.000 |
| 24.8 | 67° | 24.9 | 67° | 24.3 | 65° |
| 25.0 | 29.90" | 24.5 | 29.90 | 24.5 | 29.95" |
| 24.7 | .979 | 25.0 | .979 | 24.5 | .986 |
| 25.0 | | 25.0 | | 24.4 | |
| 25.0 | | 24.9 | | 24.5 | |
| 24.9 | 25.37 | 24.9 | 25.28 | 24.4 | 24.78 |
| 24.7 | | 24.7 | | 24.5 | |
| 24.5 | | 24.6 | | 24.5 | |
| 24.9 | | 24.5 | | 24.4 | |
| 24.85 | 25.00 | 24.76 | 24.92 | 24.40 | 24.42 |

| Holder | 5# pressure | 10# pressure |
|---|---|---|
| 2.5 | 2.5 | 2.5 |
| 11.4 | 11.4 | 11.3 |
| 1.0 | 1.0 | 1.0 |
| 30.2 | 30.3 | 30.3 |

| 15# pressure | | 20# pressure | | 25# pressure | |
|---|---|---|---|---|---|
| 23.4 | .996 | 22.5 | .984 | 22.9 | .986 |
| 23.2 | 67° | 22.6 | 67° | 22.9 | 67° |
| 23.3 | 29.90" | 22.4 | 29.92" | 22.4 | 29.93" |
| 23.2 | .979 | 23.1 | .980 | 22.5 | .980 |
| 23.4 | | 22.4 | | 22.4 | |
| 23.3 | | 22.5 | | 22.4 | |
| 23.5 | 24.00 | 22.8 | 23.50 | 22.4 | 23.36 |
| 23.5 | | 23.1 | | 22.4 | |
| 23.4 | | 22.6 | | 22.5 | |
| 23.7 | | 22.6 | | 22.9 | |
| 23.39 | 23.65 | 22.66 | 23.16 | 22.57 | 23.02 |

| 15# pressure | 20# pressure | 25# pressure |
|---|---|---|
| 2.5 | 2.4 | 2.4 |
| 11.2 | 11.2 | 11.2 |
| 1.0 | 1.0 | 1.0 |
| 30.4 | 30.4 | 30.5 |

30# pressure

| | |
|---|---|
| 22.7 | 1.000 |
| 22.3 | 65° |
| 22.5 | 29.95" |
| 22.7 | .986 |
| 22.4 | |
| 22.5 | |
| 22.8 | 22.90 |
| 22.8 | |
| 22.8 | |
| 22.3 | |
| 22.58 | 22.57 |

2.3
11.1
1.0
30.5

Series 13

| Holder | | 5# pressure | | 30# pressure | |
|---|---|---|---|---|---|
| 25.8 | 1.000 | 25.7 | 1.000 | 22.9 | 1.000 |
| 25.1 | 58° | 25.0 | 58° | 22.8 | 59° |
| 25.6 | 29.90" | 26.1 | 29.90" | 22.5 | 29.90" |
| 25.1 | 1.002 | 25.5 | 1.002 | 22.5 | .999 |
| 26.2 | | 25.0 | | 22.8 | |
| 26.2 | | 25.0 | | 22.5 | |
| 26.8 | 25.58 | 25.4 | 25.47 | 22.6 | 22.60 |
| 25.5 | | 26.1 | | 22.3 | |
| 25.2 | | 25.7 | | 22.6 | |
| 25.3 | | 25.2 | | 22.4 | |
| 25.58 | 25.00 | 25.47 | 24.90 | 22.59 | 22.09 |
| 3.0 | | 3.0 | | 2.5 | |
| 12.1 | | 12.0 | | 11.8 | |
| 0.8 | | 0.8 | | 0.8 | |
| 30.1 | | 30.1 | | 30.3 | |

## Conclusions

The results obtained show that there is a loss of from 9.49 to 21.31 per cent of the candle power of the gas when compressed to 30 lbs. per sq. in. gage pressure. When compressed to 45 lb. per sq. in. the loss is from 12.88 to 24.07 per cent. Referring to Charts 1 and 2, we note that the greatest loss occurs between 5 and 20 lbs. pressure. Above 20 lbs. the loss decreases, until between 40 and 45 lbs. the drop in candle power per pound increased pressure is very small. Evidently compression may be carried to 45 or 50 lbs. without greatly increasing the drop in candle power over that noted at 30 lbs.

Referring to Table II, Series 7, we note a loss of 9.49% of the initial candle power when the gas is compressed to 30 lbs. When compressed to 45 lbs. the additional loss is only 3.39 per cent. The heats were good when this gas was made, the per cent $CO_2$ is low, and the gas stands compression well. By "Good heats" is meant, proper heat in the generator to decompose the steam; heat enough in the carburettor to properly vaporize the oil; and a high and carefully regulated temperature in the superheater in order to thoroughly fix the gases.

Next consider Series 10, Table II. Here we have a gas made while the heats were poor. This gas contains considerable $CO_2$ and lost 21.31 per cent of its candle power when compressed to 30 lbs. When compressed to 45 lbs. the additional loss is 2.76 per cent. This gas is hardly suitable for compression for distribution at 30 lbs. although if distributed at 55 or 60 lbs. the total loss at 60 lbs would be only slightly greater than the loss at 60 lbs. of the gas in Series 7, Series 7 and Series 10 represent the extremes of observations. All other tests came within these limits.

Evidently, gas may be compressed to 45 lbs. for transmission without much additional loss above that lost in compressing to 30 lbs. There is an additional loss in candle power due to transmission which is not considered in this report. When gas is transmitted, two factors, low temperature and age, must be considered; as well as the factor of compression. In this series of tests the minimum temperature was 60° F. and candle power tests were taken immediately after compressing the gas.

The effect of transmission upon the candle power of the gas, may be great or little, depending upon conditions. Many precautions must be taken while making observations on high pressure distributing systems; that is, in systems where the gas is reduced to water pressure at the consumers house. A gas which tested 25 candles uncompressed at the works might give only half that amount at a point ten or twelve miles from the works under unfavorable conditions.

An unfavorable condition would be one in which there was frost in the ground and the test flame, a flat flame burner, was supplied from the dead end of a long latteral say 2000 ft. of 2 in. pipe, supplying only a few consumers. Here the factors, low temperature and age, must be considered.

With a gas of the average quality and showing 25 candle power before compression, we may expect a loss of about 3.50 candles, when the gas is compressed to 30 lbs. If the only varying factor is the quantity of gas oil used, then the loss at any other initial candle power is proportional. Upon this theory is based Chart II.

Compression decreases the percentage of $CO_2$ in the gas. This $CO_2$ probably dissolves in the vapor condensed. The decrease is small, however, ranging from 0.2 to 1.0 per cent as noted in the analysis, or from 8.7 to 23.8 per cent of the $CO_2$ present in the uncompressed gas, pressure 30 lbs.

The decrease in illuminants is not at all in proportion to the drop in candle power. No relation apparently exists. The greatest drop in candle power noted was 5.45 at 45 lbs. with a loss of only 0.6 per cent in illuminants. A gas which lost only 2.92 candles when compressed to 45. lbs. dropped 0.3 per cent of illuminants according to the analysis. Compressed gas constituents seem to be less active, chemically, than the same constituents in uncompressed gas. If we conpare the illuminants with "dust or heavy vapor and say that they settle out more quickly in the more dense, compressed gas, causing the gas to "age" quickly, we might explain one point, but the high percentage of illuminants in the compressed gas is still unexplained.

The fact that the illuminants present in compressed gas do not burn with the same intensity as when present in uncompressed gas, should condemn candle power observations upon carburetted water gas. Calorific tests would be more reliable as a method of comparison.

All analyses contained in this report were made in a Morehead Gas Burette, under exactly the same conditions for all tests, so that the results obtained would be comparable.

The results obtained show almost conclusively that the loss in candle power due to compression can be reduced to a minimum by proper manipulation of the blast and steam in the gas machine. That is assuming the coke in the generator is low in sulphur and ash and high in fixed carbon; and that the checker brick in carburetter and superheater are clean. All operations which tend to increase the percentage of non-combustible gases in the finished gas should be avoided. When the percentage of $CO_2$, O and N is high, the loss due to compression is greatest, especially if the percentage of $CO_2$ is high. See Chart #3.

To obtain the maximum candle power efficiency from a high pressure system in which the gas pressure is reduced to inches water at the consumers house, the following points, if observed, would lead to high efficiency if not the maximum. They are: Good fuel in generator, proper manipulation of blast and steam in the gas machine so as to give lowest possible percentage of non-combustible gases, especially of $CO_2$; purification at about 85°F. with a smallest possible amount of added oxygen; storage holder water at a temperature which will not give off vapor in cold weather; transmission in pipes well protected from frost; gas consumed in Bunsen burner or equivalent such as incandescent burner, etc. Rapid movement of the gas in the mains might overcome the so-called ageing effect due to gas remaining in pipes for a considerable length of time.

Chart 4 shows the comparison of Candle Power and heating value of the gas. These curves are the average of over two thousand observations. A few results were found to vary as much as 20% from the curve, but the average is well represented (The original investigations for this subject were made by the undersigned during January and February 1909. The comparison of Illuminating Power and Heating Value was made in January 1915 and covers observations for a period of several years.)

RESPECTFULLY SUBMITTED

Horace H. Clark

MARCH 25th, 1915

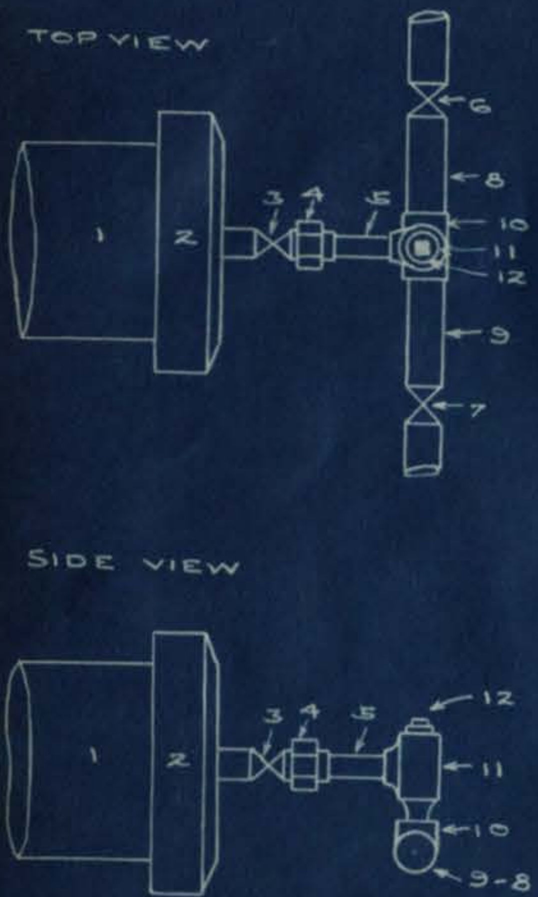
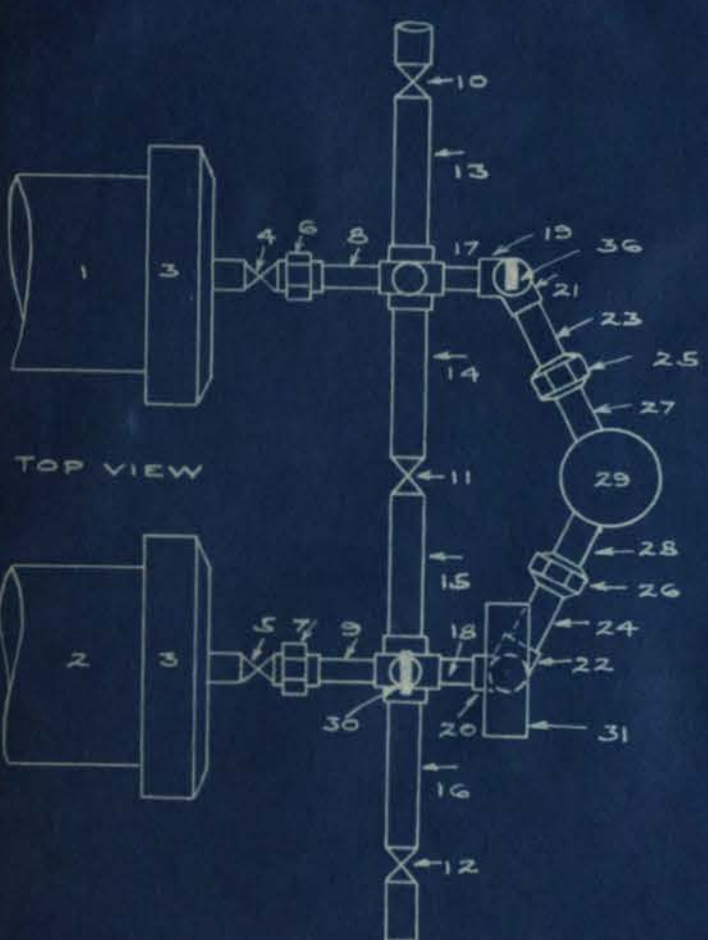
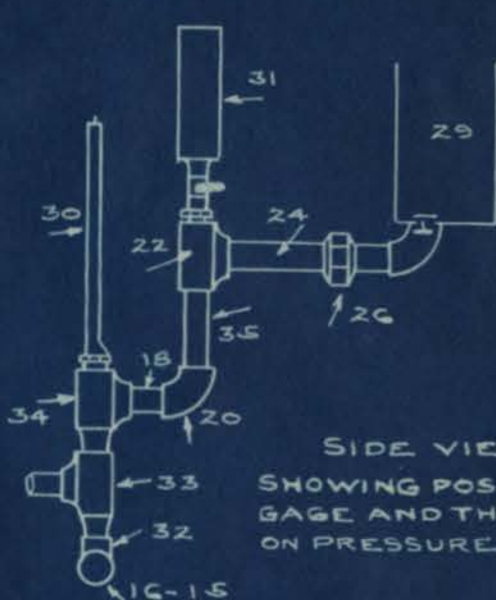



FIG. I.

№ 1 - STORAGE TANK (6" PIPE)
2 - CAP (6")
3 - CORPORATION COCK (½")
4 - GROUND JOINT UNION (½")
5 - NIPPLE (½" - 3" LONG).
6 - HIGH PRESSURE COCK (1")
7 - " " " "
8 - NIPPLE (1" - 4" LONG)
9 - " " " "
10 - PLAIN TEE. (1" x 1" x ½")
11 - STREET TEE (½")
12 - PLUG. (½").

FIG. III



SIDE VIEW
SHOWING POSITION OF GAGE AND THERMOMETER ON PRESSURE SIDE

1. TANK #1.
2. TANK #2.
3. CAPS (6")
4-5. CORPORATION COCKS
6-7. GROUND JOINT UNIONS.
8-9. NIPPLES.
10-11-12. HIGH PRESSURE COCKS
13-14-15-16. NIPPLES
17-18. - NIPPLES.
19-20. - PLAIN ELLS.
21-22. - PLAIN TEES.
23-24 NIPPLES
25-26 GROUND JOINT UNIONS.
27-28. NIPPLES
29. TRANSFER PUMP
30 THERMOMETER
31 GAGE
32. PLAIN TEE
33. STREET TEE
34. " "
35. NIPPLE
36 WATER GAGE

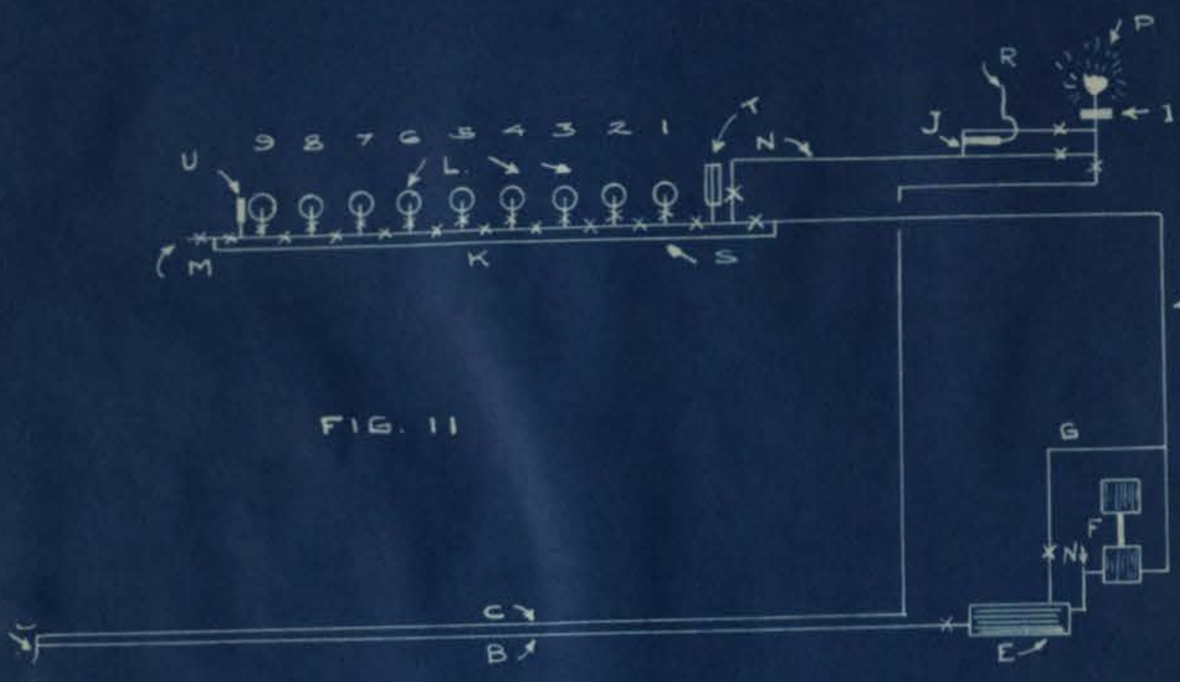



FIG. 11

VERTICAL PLAN

A. - HOLDER OUTLET LINE.

B - LINE TO COMPRESSOR - 2" PIPE, 200' LONG

C - LINE TO PHOTOMETER - 3/4" PIPE, 220' LONG

D - STREET TEE FROM WHICH A AND B COME OFF.

E - RECEIVER 8" DIAM 8' LONG

F - SMALL WESTINGHOUSE COMPRESSOR.

G. - BY - PASS - 3/4" PIPE

H. - STOP FOR ATTACHING WATER GAGE

I - LOW PRESSURE REGULATOR

J - WILLIAMSON HIGH PRESSURE REGULATOR.

K. - HEADER FOR TANKS

L - TANKS, END VIEW

M. - OPENING TO OUT-DOOR BLOW-OFF

N. - LINE TO PHOTOMETER ROOM - 3/4" PIPE

O. - LINE FROM COMPRESSOR TO TANKS

P. - PHOTOMETER FLAME

R. - REGULATOR VENT

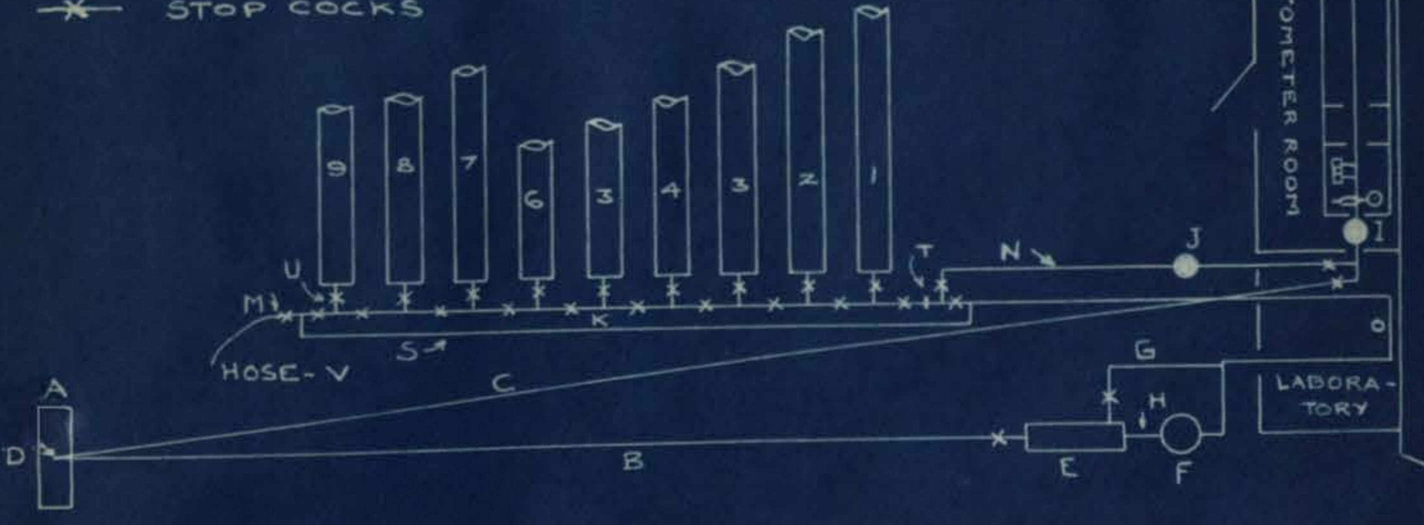
S. - PRESSURE EQUALIZER FOR HEADER

T. - THERMOMETER

U. - PRESSURE GAGE

—✕— STOP COCKS

HORIZONTAL PLAN



# TABLE II

| SERIES No | CANDLE POWER BEFORE COMPRESSION | CANDLE POWER AFTER COMPRESSING TO 30 LBS. GAGE | LOSS IN CANDLE POWER DUE TO COMPRESSION | PERCENTAGE LOSS AT 30# OF CANDLE POWER | PERCENT $CO_2$ BEFORE COMPRESSION | HEATS IN GAS MACHINE | CANDLE POWER WHEN COMPRESSED TO 45 LBS GAGE | LOSS IN CANDLE POWER | PERCENTAGE LOSS AT 45 LBS GAGE |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 24.87 | 21.11 | 3.76 | 15.12 | 3.9 | POOR | | | |
| 2 | 25.28 | 21.28 | 4.00 | 15.82 | 4.2 | POOR | 19.22 | 6.06 | 23.98 |
| 3 | 26.21 | 22.86 | 3.35 | 12.78 | 4.0 | GOOD | 21.58 | 4.63 | 17.66 |
| 4 | 26.00 | 22.58 | 3.42 | 13.15 | 3.8 | FAIR | | | |
| 5 | 25.61 | 22.09 | 3.52 | 13.75 | 3.4 | POOR | | | |
| 6 | 24.86 | | | | 3.1 | GOOD | | | |
| 7 | 22.65 | 20.50 | 2.15 | 9.49 | 2.3 | GOOD | 19.73 | 2.92 | 12.88 |
| 8 | 20.71 | 16.87 | 3.84 | 18.54 | 4.9 | POOR | 16.08 | 4.63 | 22.35 |
| 9 | 23.50 | 19.07 | 4.43 | 18.85 | 4.7 | POOR | 18.05 | 5.45 | 23.19 |
| 10 | 21.40 | 16.84 | 4.56 | 21.31 | 5.3 | POOR | 16.25 | 5.15 | 24.07 |
| 11 | 26.24 | 23.09 | 3;15 | 12.00 | 3.4 | FAIR | | | |
| 12 | 25.37 | 22.90 | 2.47 | 13.67 | 2.5 | GOOD | | | |
| 13 | 25.58 | 22.60 | 2.98 | 11.65 | 3.0 | GOOD | | | |
| A | B | C | D | E | F | G | H | I | J |
| | AVERAGE | " | " | " | " | " | " | " | " |
| | 24.45 | 20.98 | 3.47 | 14.19 | 3.78 | GENERAL | 18.48 | 4.81 | 20.65 |

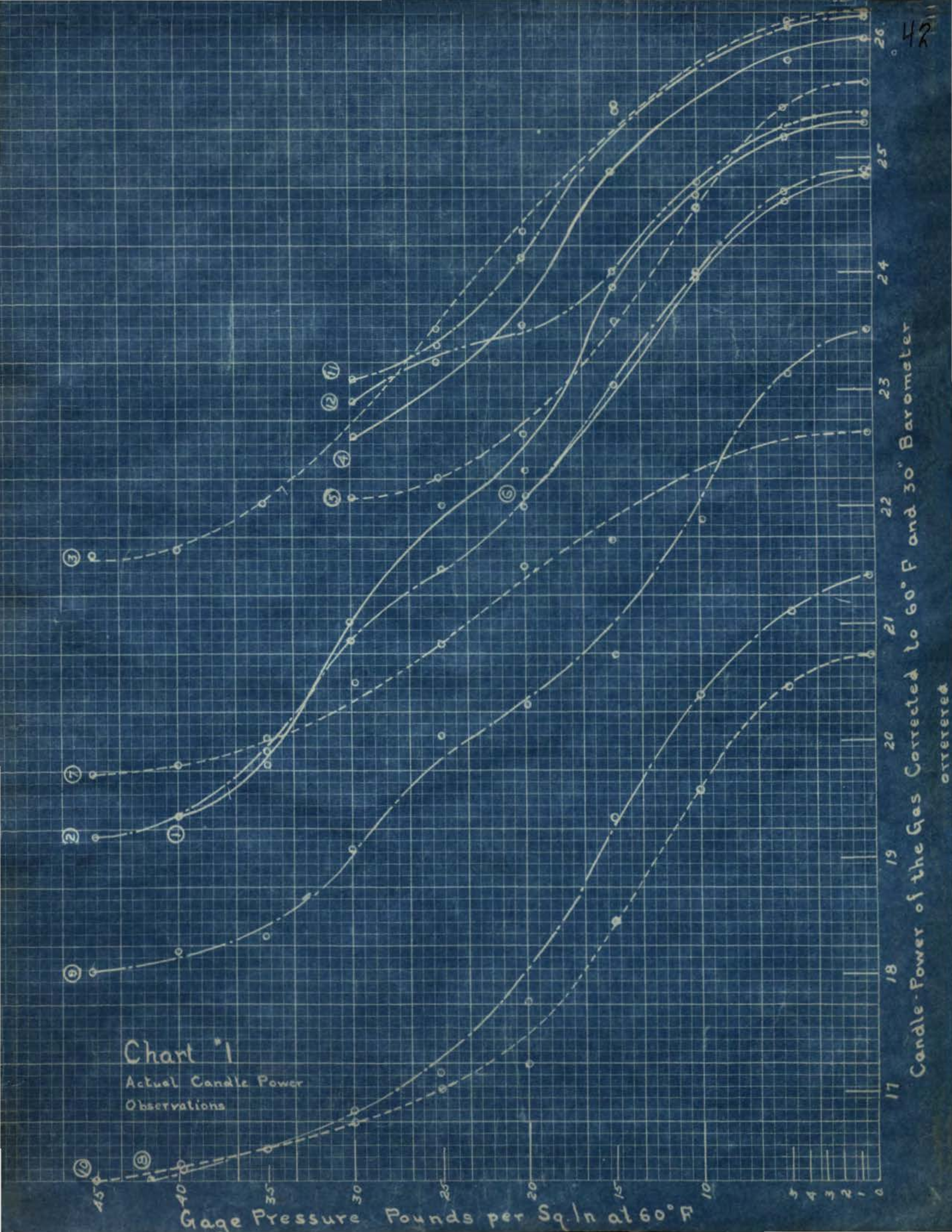


Chart 1
Actual Candle Power
Observations
Gage Pressure Pounds per Sq In at 60° F
Candle-Power of the Gas Corrected to 60° F and 30" Barometer
45
40
35
30
25
20
15
10
5
4
3
2
1
0
17
18
19
20
21
22
23
24
25
26

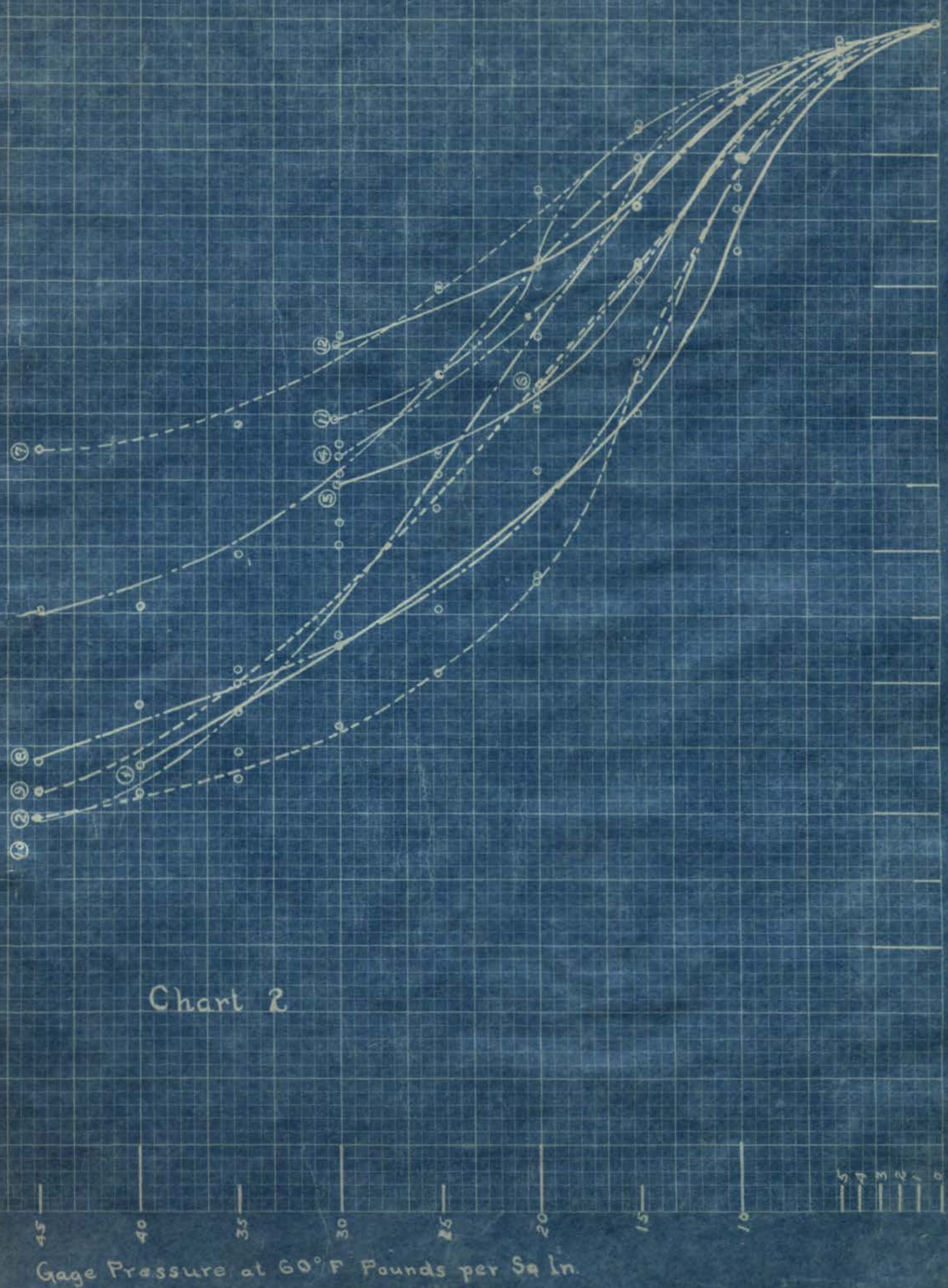

Candle Power Corrected to 60°F and 30" Hg. and Reduced to 25 Candles for Comparison.
18
19
20
21
22
23
24
25
Gage Pressure at 60° F Pounds per Sq In.
45
40
35
30
25
20
15
10
5
4
3
2
1
0
1
2
4
5
6
7
8
9
10
11
12

Chart 2

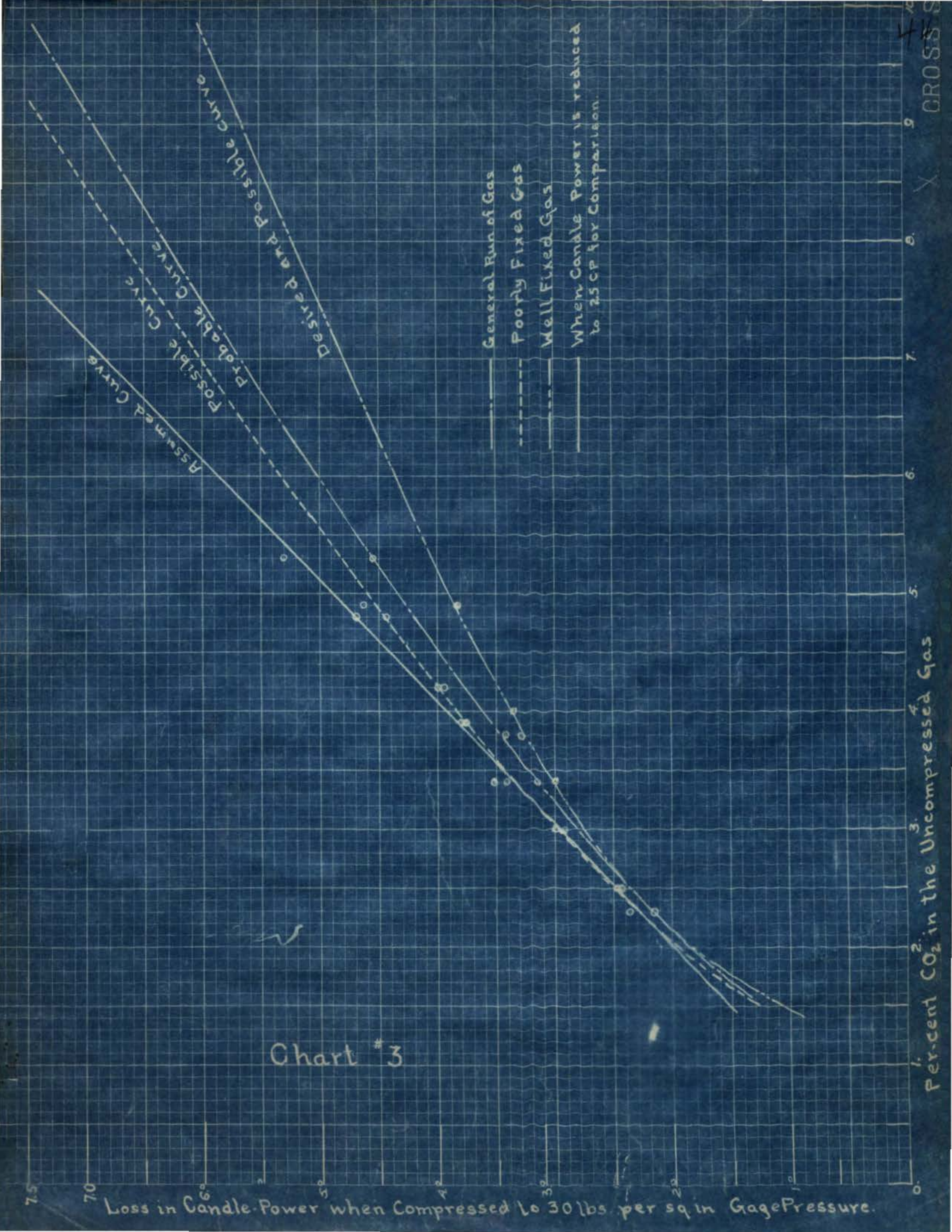


Chart #3
Loss in Candle-Power when Compressed to 30 lbs. per sq in Gage Pressure.
Per-cent $CO_2$ in the Uncompressed Gas
General Run of Gas
Poorly Fixed Gas
Well Fixed Gas
When Candle Power is reduced to 25 CP for Comparison.
Desired and Possible Curve
Probable Curve
Possible Curve
Assumed Curve
7.5
7.0
6.0
5.0
4.0
3.0
2.0
1
0
1.
2.
3.
4.
5.
6.
7.
8.
9.

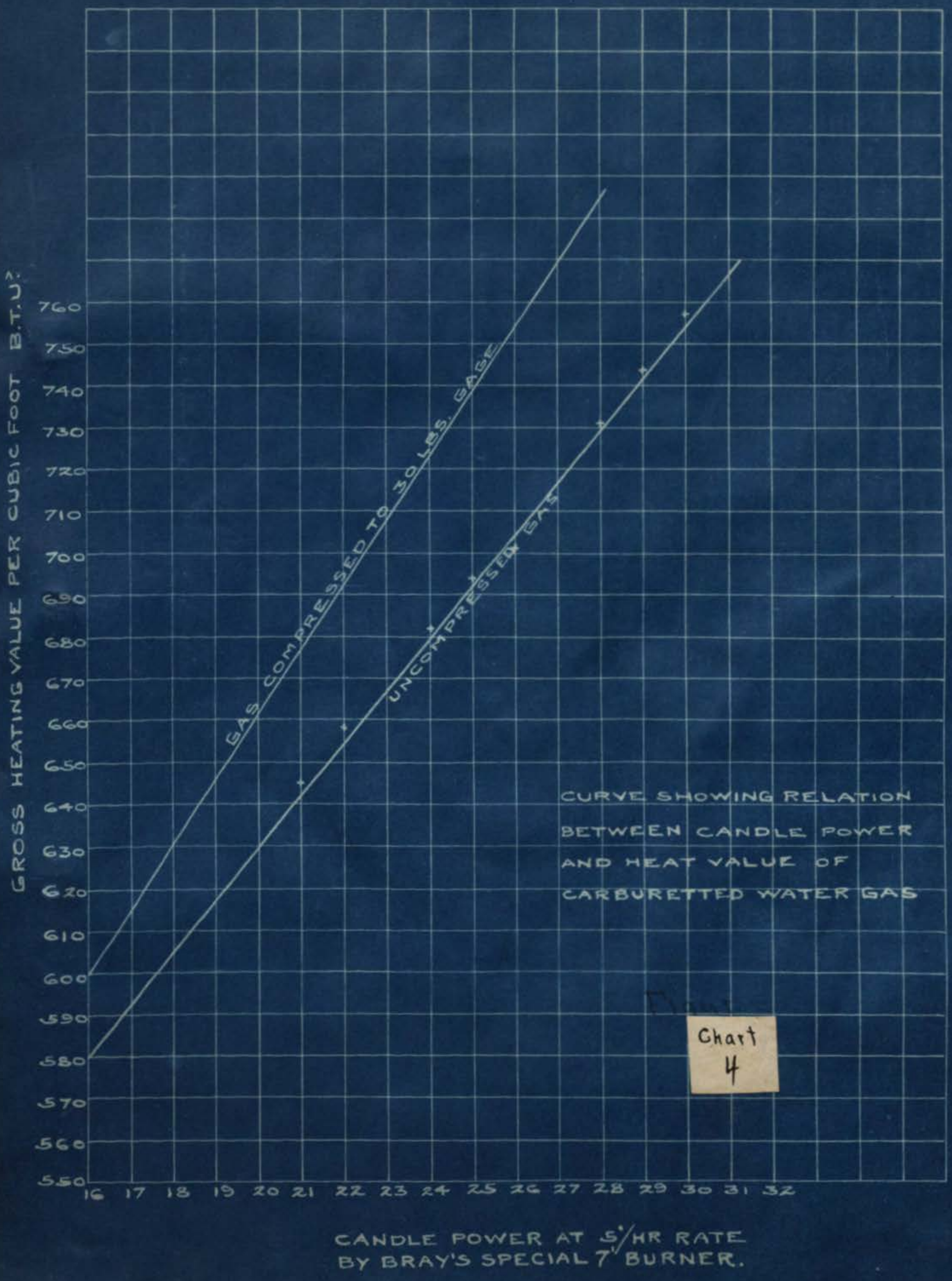

GROSS HEATING VALUE PER CUBIC FOOT B.T.U.
760
750
740
730
720
710
700
690
680
670
660
650
640
630
620
610
600
590
580
570
560
550
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
GAS COMPRESSED TO 30 LBS. GAGE
UNCOMPRESSED GAS
CURVE SHOWING RELATION
BETWEEN CANDLE POWER
AND HEAT VALUE OF
CARBURETTED WATER GAS
CANDLE POWER AT 5'/HR RATE
BY BRAY'S SPECIAL 7' BURNER.

Chart 4

# TABLE-I-

| TEST Nº | TANK Nº | VOLUME OF GAS AT 5.75 INS. WATER PRES. REQUIRED FOR THE TESTS. CU. FT. | LOSS ASSUMED DUE TO LEAKAGE ETC. CU. FT. | ALLOWED FOR TEST CU. FT. | GAGE PRESSURE POUNDS PER SQ. IN. | LENGTH OF TANK INSIDE DIMENSION CAP TO CAP FEET. | VOLUME OF GAS AT GAGE PRESSURE CONTAINED IN TANK. CU. FT. | VOL. OF GAS AT 0.2# CONTAINED IN TANK CU. FT. | VOL. USED AT 0.2# FOR TEST. CU. FT. | VOL. AT 0.2# LEFT IN TANK CU. FT. | VOL. AT 0.2# REQUIRED FOR COMPRESSION CU. FT. | SURPLUS GAS AT 0.2# REMAINING IN TANK | TEMPERATURE DEG F. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | 0.00 | 1.25 | 0.2 | | | | | | | | |
| 2 | 1 | 11.85 | 0.00 | 1.25 | 5.0 | 58.000 | 11.600 | 15.55 | 1.25 | 14.30 | 15.55 | 2.33 | 60 |
| 3 | 2 | 10.60 | 0.02 | 1.25 | 10.0 | 35.647 | 7.1293 | 14.30 | 1.27 | 13.03 | 11.97 | 3.09 | 60 |
| 4 | 3 | 9.33 | 0.04 | 1.25 | 15.0 | 24.597 | 4.9193 | 13.03 | 1.29 | 11.74 | 9.94 | 3.86 | 60 |
| 5 | 4 | 8.04 | 0.06 | 1.25 | 20.0 | 16.690 | 3.3380 | 11.74 | 1.31 | 10.43 | 7.88 | 4.63 | 60 |
| 6 | 5 | 6.73 | 0.08 | 1.25 | 25.0 | 10.739 | 2.1477 | 10.43 | 1.33 | 9.10 | 5.80 | 5.41 | 60 |
| 7 | 6 | 5.40 | 0.10 | 1.25 | 30.0 | 6.083 | 1.2166 | 9.10 | 1.35 | 7.75 | 3.69 | 3.63 | 60 |
| 8 | 6 | 4.05 | 0.10 | 1.25 | 35.0 | 6.083 | 1.2166 | 7.75 | 1.35 | 6.40 | 4.12 | 1.88 | 60 |
| 9 | 6 | 2.70 | 0.10 | 1.25 | 40.0 | 6.083 | 1.2166 | 6.40 | 1.35 | 5.05 | 4.52 | 0.10 | 60 |
| 10 | 6 | 1.35 | 0.10 | 1.25 | 45.0 | 6.083 | 1.2166 | 5.05 | 1.35 | 3.70 | 4.95 | 3.70 | 60 |
| — | 7 | | | | 5.0 | 20.000 | 4.0000 | | | | | 5.36 | 60 |
| — | 8 | | | | 5.0 | 17.000 | 3.4000 | | | | | 4.56 | 60 |
| — | 9 | | | | 5.0 | 16.000 | 3.2000 | | | | | 4.29 | 60 |
| A | B | C | D | E | F | G | H | I | J | K | L | M | N |

REMARKS:- BAROMETRIC PRESSURE 14.5 LBS PER SQ. IN.

WITH A 5FT. BURNER, THE GAS USED IN THE TIME OF A TEST (15 MINUTES) WOULD BE 1.25 CU.FT. APPROXIMATELY COLUMN (C) SHOWS THE VOLUME OF GAS NECESSARY FOR THE TEST BEING MADE, AND FOR ALL SUBSEQUENT TESTS IN A SERIES

COLUMN (F.) SHOWS THE GAGE PRESSURE AT 60° F. TO WHICH THE GAS IN THE CORRESPONDING TANK WAS COMPRESSED.

COL (H) IS THE CAPACITY OF THE PIPE, USING 0.2 CU. FT PER LINEAR FOOT AS THE CAPACITY OF 6" WROUGHT IRON PIPE

COL. (I) SHOWS THE CAPACITY OF THE TANK IN CU. FT. AT 0.2 LBS. GAGE. THESE FIGURES WERE FOUND BY THE FORMULA, $V : V_1 :: P_1 : P$, WHERE V AND $V_1$ ARE VOLUME AND $P_1$ P THE ABSOLUTE PRESSURES.

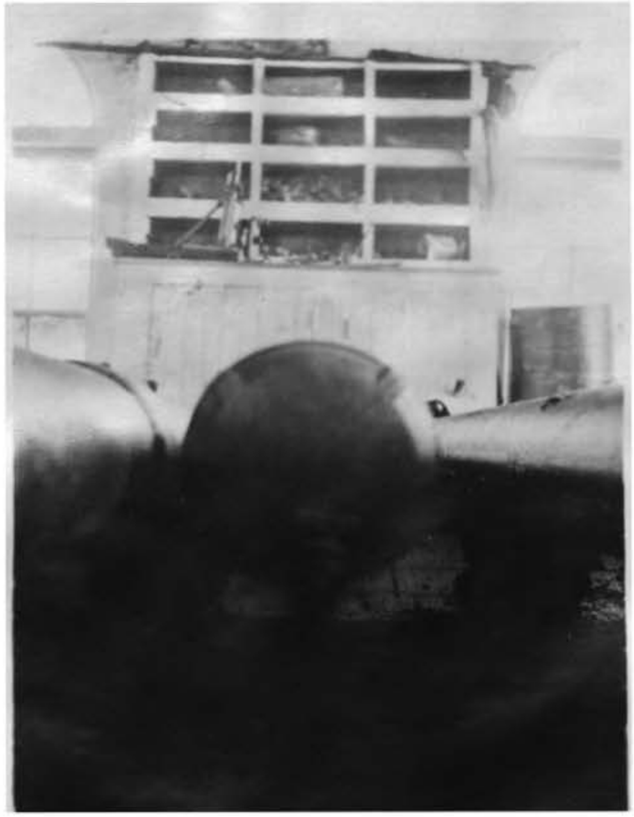
IN COL (J) THE FIGURES ARE DERIVED BY ADDING THE GAS CONSUMED AND THE LEAKAGE FOR THE CORRESPONDING PRESSURE

COL. (K) GIVES THE QUANTITY OF GAS REMAINING IN THE TANK AFTER A TEST AND AVAILABLE FOR COMPRESSION FOR THE NEXT TEST.

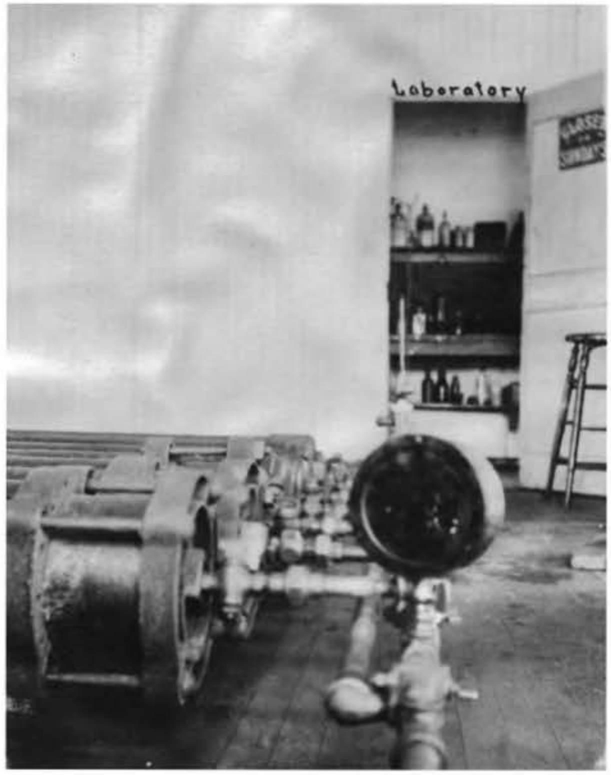
COL (L) SHOWS THE QUANTITY OF GAS AT 0.2# PRESSURE, WHICH WHEN FORCED INTO A TANK OF THE SIZE SHOWN, WILL GIVE THE DESIRED PRESSURE AT 60° F.

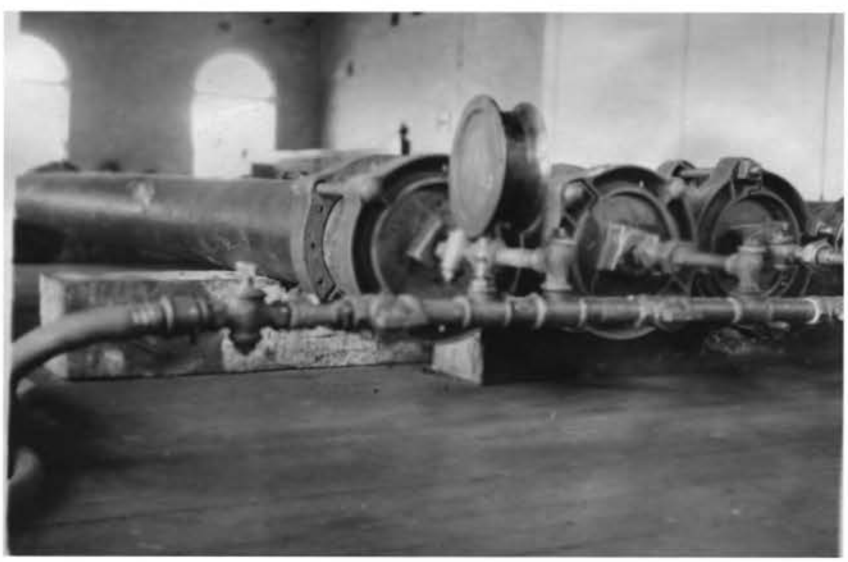
COL (M.) SHOWS THE QUANTITY OF GAS REMAINING IN EACH TANK AFTER A TEST HAS BEEN MADE AND THE DESIRED QUANTITY REMOVED FOR COMPRESSION INTO THE NEXT TANK.

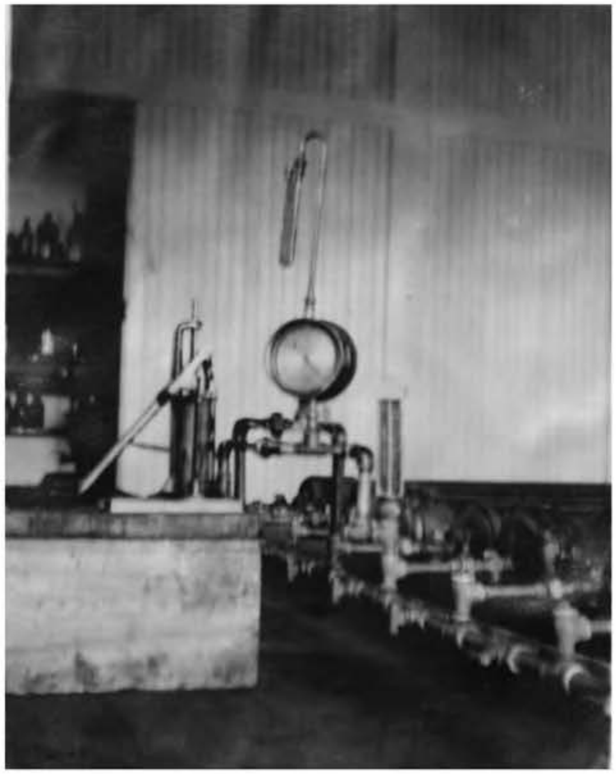

Photometer Room
Laboratory



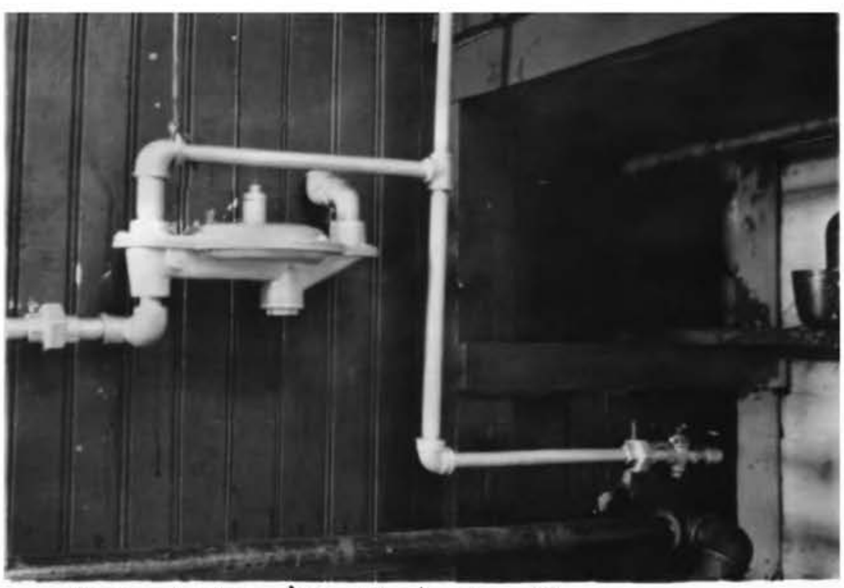

Photometer Room.


Laboratory





Transfer Pump, Gage, Thermometer, etc.



Regulator for Reducing Pressure.