# APPLIANCES FOR THE USE OF COMPRESSED AIR

...BY...

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

WALLACE KENNETH WILEY

ENTITLED APPLIANCES FOR THE USE OF COMPRESSED AIR

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering

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HEAD OF DEPARTMENT OF Mechanical Engineering

Contents.

# Appliances for the use of Compressed Air.

## Historical Review.(x)

The use of air in its lower conditions of compression for power and for mechanical purposes has been known from the earliest ages, and antedates by many generations any knowledge we posess of steam.

The reduction of metals from their ores and the forging of iron and steel brought the forge and the blast furnace, with the use of air and pressure, into existence as a mechanical appliance more than two thousand years before Christian Era.

Evidences of the use of the air blast under compression are plainly seen depicted on the sculptured walls of the structures of the oldest civilization, and are made still more manifest in its endurated paintings and in the legend of the early historians.

Air power seems to have been less progressive in its uses than other mechanical arts. For nearly two thousand years before and more than two thousand years after the Christian Era the methods

(x)Extract from "Compressed Air and its Applications" by Hiscox.

of compressing seem to have taken a crude and nearly stationary form and in some parts of China, India and Africa, may be seen in operation today, where the air treading bags, the wooden cylinder and the piston and the Chinese wind box are the common devices for producing an air blast.

The only further progress which appears on record in regard to the production of compressed air and its use for power purposes has been handed down in fragmentary history and mostly contained in the pneumatics of Heron[a] of Alexandria. Heron seems to have been the first to invent or to describe the pressure air pump or compressor for pressures greater than the forge blast, and to have applied it in the famous fountain attributed to him. The description of the fire engine of the Egyptians, as given in Heron's "Spiritalla", shows very plainly that the use of air compression and its elasticity in the air chamber of a hydraulic pump were well understood in the second century before the Christian Era.

The devices of the Egyptian priesthood for exciting the wonder amd awe of the people, were no doubt derived from a general know-

[a] Heron's name is so shrouded in mystery, that some writers feel they are justified in omitting the final "n".

ledge of the expansion and contraction of air by heat and cold. The movement of the statue of Sirapis and the altar tricks of the Pharaonic priesthood are other examples of the designed antics, due to the use of compressed air and the vapor of water.

The condensing air pump or compressor must have been used in charging the wind guns of Ctesibius of Alexandria about 120 B. C., as described by Vitruvius. No improvements seem to have been made for more than a thousand years, when the arrow discharged under air pressure by Clesibius finally developed into the pneumatic gun of Marin in France, which was presented to Henry 1V in 1600. A more perfected compressed air gun was brought out by Guter at Nuremberg in 1656, which had attached to the stock, in musket form, all the appliances for charging and discharging by air compression. But little further progress was made in this line until near the middle of the nineteenth century, when compressed-air guns took a wide range of design; their most useful and effective outcome being the pneumatic guns of Zalinski and others.

While the mechanic arts slumbered through the dark ages in Europe, the Chinese seem to have improved the original piston blower by a more perfect action and finish, in an instrument styled by them the "wind-box".

The water trombe, or trompe, for compressing air by a fall of water in a tube was known to Heron and was mentioned by Pliny in his "Natural History". In an improved form the tromp has held its place for two thousand years, and is in use at the present day in Europe and the Orient.

The principle of Heron's pneumatic fountain for raising water was carried out on a large and useful scale in the Pneumatic pumping engine at the mines of Chemnitz, in Hungary, erected by M. Hoell in 1755; there was probably first illustrated the refrigerating power of air when expanded from great pressure. In the chamber of this apparatus the discharge of air and its expansion with water produced hail, or pellets of ice.

The use of compressed air for submarine work was no doubt known in the earliest ages. Aristotle (350 B.C.) describes a kettle in which divers supplied themselves with fresh air under water. The legend of the descention of Alexander the Great to the bottom of the sea in a vessel called acolympia, is no doubt an allusion to the use of the diving-bell. Nothing further appears on record in regard to submarine work with a bell for more than fifteen hundred years when mention of its use in Spain in 1538 is met with. Bacon describes it (1620) as a machine used to assist persons laboring under water upon wrecks, affording a reservoir of air into which they could enter to take a breath. From this time on the diving bell was largely used in Europe in recovering wreckage and treasure. Doctor Halley suggested the present system of submarine armor by using a cap or helmet with a tube leading to the surface through which fresh air was forced to the diver. The submarine armor continued to be improved along the lines of its present form for deep sea work, in which depths of 148 feet have been attained, involving work under an air pressure of 65 pounds per square inch for hours.

The compressed-air vacuum pump was greatly improved by Otto Van Guericke about 1650, and it has been claimed as his invention.

Savary increased the pressure of air for blast furnaces by the use of more substantial blowers, in the latter part of the seventeenth century.

Denys Papin was the first to propose and make, in 1653 an actual trial of the transmission of power to a distance by compressed air. He reccommended the use of water power for compressing air and forcing it to a distance for useful work, thus foreshadowing the now common practice of the long transmission and distribution of air through mines for the operation of machinery. His system of an air pump driven by a water wheel, operating on air and water chambers at a distance, was in the right direction, but failed in its practical operation by the elasticity of the air, which he had intended to use as a long piston in transmitting power from an air-working piston to a distant water piston. It was Papin who first conceived the idea of the pneumatic tube for transmitting parcels by air pressure.

In 1757, Wilkinson, in England, patented a method of compressing air by use of a column of water, effecting his object by means of a series of chambers or water compressors, used one after another so as to keep up a regular pressure; thus in a crude way, preceding by a hundred years the water compressor of Sommeiller at the Mont Cenis tunnel.

Many vague descriptions of apparatus for the use of compressed air in the mechanic arts and for its compression are found in the

English patents during the eighteenth century, but either their practical applications were never realized or else no record was made of their operation.

The application of compressed air to practical uses and its transmissions for power purposes seem to have commenced an era of advancement in the last years of the eighteenth century. Professor St. Clair, of the Edinburg University, in 1785, proposed attaching bags to sunken vessels beneath the surface of the water and inflating them by air pumps. The most successful trials were made in 1864 in raising a steamer sunk in Lake Boden, and in raising the vessels sunk at Sebastopol during the Crimean War. From that time on many patents have been issued for various devices for raising vessels by inflating floats by air pressure, and for compressing air and its use in diving bells and submarine armor.

Medhurst, a Danish engineer in England, in 1799 compressed air to 15 atmospheres (210 pounds), stored and transmitted it to a motor in a mine; he patented a pneumatic system for conveying persons and parcels in tubes in 1810, followed by publications during a period of several years on tubular transmission by compressed air.

Medhurst also took out a patent in 1800 for propelling carriages by means of compressed air from a reservoir.

Compressed air for tramway cars appears to have received an impulse in Wright's English patent, in 1828; he also proposed the use of iron cylinders beneath the cars, with an additional cylinder for heating the air by a small furnace, to increase its expensive force before entering the working cylinder and to mingle steam generated by the same furnace with the hot air.

The air brake seems to have first taken shape at thei time in Wright's patent with an escentric on a wheel shaft, connected with a piston, which was to be operated as a brake on down grades by pumping air into the air chambers; but it was not until 1869 that air brakes began to take a practical form under the patents of Westinghouse.

In 1823, Bompass, in England, patented and built a compressed air locomative.

Parsey, in 1847 , built and ran a vehicle in which an intermediate reservoir was provided for reducing and equalizing its air pressure to the cylinders. Baron von Rathlen built and ran a vehicle in England in 1848, attaing a speed of 12 miles per hour on the best roads of the day; he also suggested an increased pressure to 750 pounds per square inch and advised compound compression and intercooling.

The earliest known appliances for making ice by the expansion of compressed air was invented and put into actual practice by Dr. Garrie, and is in use in the meat and fruit transportation service.

In the early part of the nineteenth century the subject of tube transmission was again agitated but it was not until about 1865 that the Parcel Dispach Company of London achieved sucess; since then the use of this system for parcel and postal transmission has been greatly developed in Europe and in the United States. The trials of Mr. A. E. Beach in New York in 1867 with an eight-foot subway under Broadway for the propulsion of passengers cars by air pressure are interesting and seem to have failed on account of lack of financial support. At the present time the pneumatic tube system, of which there are three or four general types, is largely in usefor the interpostal and telegraphic office connections also for parcel and express transmission. Quite an elaborate system has been installedfor use at the Louisiana Purchase Exposition. The store cash syatems, in their intricate detail, promptness and accuracy, are modern wonders.

Compressed air for machine driving, crane-hoisting, and other mechanical purposes was agitated in 1840 and on, with patents on detail plants for the transmission of compressed air from a central station to distant hoisting-engines in warehouses and on docks. Ericsson, in 1858, compressed air by the power of caloric engines, for operating hoisting engines in warehouses in New York, followed by a practical system of running sewing-machines in large numbers from a central plant by the transmission of compressed air to small motors on the machines.

The direct pressure system was brought into use by Sommeiller at the Mont Cenis tunnel in 1872, and did good work at that time, but as it required as much water to compress the air as was equal to the amount of free air compressed, the system was applicable only in favorable localities.

The trompe system has been greatly improved and extended for high pressure, with a large flow of water with moderate head, by making a deep pit with an air chamber at the bottom and returning water to the foot-fall as in an inverted siphon. This was first demonstrated in experiments by Mr. J. P. Fizell, of Boston, in 1877 and patented in 1878. It has finally been put in practical operation by Mr. C.H. Taylor in large instalments of hydraulic plants at Magog, near Montreal, and at Amsworth, British Columbia.

The introduction of compressed-air-hauling locomotives in the St. Gothard tunnel was a successful turn in favor of compressed air for railway work; it was soon followed by the Mekarski and Beaumont compressed air railway systems in Europe, with increased air pressures and better appliances for economical compression and motor use.

The use of compressed air machinery for quarrying, mining and tunnelling, and means of compressing air along economical lines, have been greatly extended by the inventive genius of Burleigh, Ingersoll, Sergeant, Rand, Clayton, and others, who have contributed to and promoted the economy of practical operation in rock-boring machinery that has so greatly aided in excavating the vast system of railway tunnels of the United States, and in sinking and drifting in the mines of all countries during the past quarter of a century.

Every implement required in the generation of compressed air power and its uses has overflowed its earlier and narrow field of work, and is now encompassing a wide area of usefulness in our work shops, factories, and in hundreds of industrial operations: transportation, railway appliances, refrigeration--even unto painting of buildings and structural work, and the dusting of furniture, carpets and clothing.

The later developments and actual application of compressed air at extremely high pressure, and its economical use by reheating, derived from the persistent efforts of Mekarske, Beaumont and others in Europe, and of Judson, Hoadley, Knight and Hardie in the United States, have brought the use of compressed air to a new condition of application, and a high pressure storage of 2,500 or more pounds per square inch in a condensed space of from 170 to 180 colume in one volume. This allows for sufficient storage volume within the li limit of passenger-car and vehicle capacity for runs of reasonable distances.

The number of United States patents for compressed-air appliances is now nearly five thousand.

## Percussive Tools[a]

In the last few years the use of compressed air as a motive power for machinery has wonderfully increased, especially for portable tools. This is mainly due to the advantageous qualities of compressed air over steam, the principal of which are:

First: Stability, or in other words, non-condensation, permitting it to be stored indefinitely, or to be transported long distances without loss of pressure other than that due to leakage and friction of conduit.

Second: Low temperature at which it can be used in hand tools.

Third: The exhaust consists of fresh cool air, adding to the ventilation and comfort of work room or mine.

Fourth: It can be used at any pressure and is easily produced. Its expansive qualities while not on a par with steam, never the less can be utalized with good results.

With these few reminders of the qualities of compressed air, the subject of its application to percussive tools comes up.

[a] Extract from "Compressed Air Information", by W.L.Saunders.

Percussive force, as regards the actual work done upon the object struck, is applied in two ways:

First: Directly, when the tool itself is propelled through space and strikes the object, when practically all of the energy of the moving mass is expended on the object struck.

Second: Indirectly, when the moving mass strikes an interposed tool, through which the energy is transfered to the object.

Examples of the first class are the hand hammer, sledge, steam hammer and rock drill.

Examples of the second class are the mason striking his stationary chisel, and the chisel struck by the piston of a pneumatic hammer.

Trip hammers of a crude form were used as early as 1600. In 1849, Couch as American patented a rock drill, which while it was a cumbersome machine, requiring cranes to handle it, was in its essential feature the rock drill of today.

There are three methods of automatically controlling the admission of the motive fluid.

First: The tappet valve type, in which projections attached to the reciprocating part, strike triggers or other devices which in turn move the valve.

Second: The fluid moved valve type, wherein the piston itself, at certain parts of its travel, admits a supply of motive fluid to move the valve, or to move a supplementary piston which in turn moves the valve.

Third: The so called valveless type, in which the moving piston acts as its own valve, as in its stroke, it alternately opens and closes certain ports so that the motive fluid acts on each end of the piston in turn.

The "O and C"tools which are quite well known are examples of the valveless type. For work within their range they are admirable owing to their simplicity of design, small size and great rapidity of short stroke blows. For light chipping, caulking and stone carving work they can hardly be excelled.

For heavy chipping, riveting and other work, the blow of the valveless tool is not heavy enough to do the work well, and tools with a controlling valve are used, allowing a much longer stroke, and higher velocity of piston travel.

Of the fluid-moved valve type, the Boyer hammer, made by the

Chicago Pneumatic Tool Co., and the Little Giant hammer, made by the Standard Pneumatic Tool Co., are the best known. In these a small valve, located in a chamber in the rear of the piston, traveling parallel or at right angles to the axis of the piston, is actuated by air pressing on different areas, moving it alternately to and fro, opening and closing ports controlling the admission and exhaust to the cylinder. Suitably placed, small ports are closed and opened by the piston in its travel, that permits air to act on and move this valve.

Excellent work is accomplished by these tools, and a skilled workman can do from four to six times as much as can be done by hand tools alone. They are in use in nearly all the progressive machine, boiler, bridge and ship works in this country, and in a great many abroad.

Tests for Determining the Air Consumption of Small Tools.

Description -- Tests for determining the air consumption of small tools were made in the M.E.Laboratory. The compressed air was furnished by a 10 X 10 class E. Ingersoll-Sergeant air compressor. The air was delivered from the compressor to the receiver, from which it was taken out by a short pipe line and used as delivered.

Method of Procedure -- The cubical contents of the receiver was found by filling it full of water and then drawing the water out, from a cock in the bottom of the receiver into a small tank on scales, thus getting the weight of water, from which the volume was easily calculated, making corrections for the specific gravity of the water used and for temperature. This was repeated and the second result agreed very closely with the first.

The gauge on the receiver was carefully calibrated and reset so that it read exactly.

It was decided that the best method available for obtaining the air consumption of the smallest tools, such as the "O & C" hammer, was to fill the receiver with compressed air to a pressure of about 95 pounds and then shut off the compressor and closed the valve in the feed pipe so that there was no chance for air to leak back through the compressor. The only escape for the air, neglecting small valve leakage, was through the pipe to the tool being tested. This tool was run until the pressure in the receiver fell to about 80 pounds. At the begining and at the end of the tests the time, pressure and temperatures were taken and recorded. The temperatures were obtained by placing thermometers in small tubes which extend into the receiver. There are five tubes equally spaced one above the other from the bottom to the top of the receiver. In the record of the tests only the average temperatures are given.

Calculation of Air Consumption. -- From the data taken the weight of air in the receiver at the beginning and at the end of the test was calculated and the difference minus the leakage was what the tool consumed during the test. The cubic feet of free air was found by dividing the weight by 0.0762, which is the weight of one cubic foot of free air at 62 degrees faharenheit, when using 53.18 as the value of R. The calculations were made by means of the following formula.

M equals weight in pounds.

V " volume, taken as 89.36 cubic feet.

P " absolute pressure in pounds.

T " absolute temperature.

R " constant, taken as 53.18.

$$M \text{ equals } \frac{P\ V}{R\ T}$$

Calibration of Compressor -- For some of the larger tools, such as the Rand Rock Drill, it was thought that it would be necessary to run the compressor part of time. As the compressor is a belt compressor an ordinary revolution counter could not be used to count the number of compression strokes because the fly wheel is always revolving while only part of the strokes are compression strokes. In order to count the true compression strokes an electric revolution counter was used. It was so arranged that when the regulator was up and the compressor doing no work the circuit was broken and the strokes were consequently not counted, but when the regulator was down and the compressor doing work the circuit was made and the strokes counted. This arrangement was carefully adjusted so that it worked exactly.

In order to find the amount of air compressed per stroke it was necessary to calibrate the compressor. The air in the receiver was let out until there was only atmospheric pressure, which registered zero on the guage. The exhaust was then closed and the compressor started. Readings of gauge pressure were taken every minute, and temperature readings every two menutes. Strokes were counted by the electric revolution counter.

From this data, taking for the temperatures not recorded, the me mean of the temperatures of the preceding and succeeding minutes, the weight of air in the receiver for every minute was calculated using the formula, M equals $\frac{P\ V}{R\ T}$, as before. Dividing the increase in weight for each minute by the number of strokes per minute gave the air compressed for each minute. The weight was reduced to cubic feet of free air.

After this calibration test had been run it was found that leakage of air back through the compressor, when not compressing, was so great that no test for air consumption could be run with the valve (A) in the pipe to the air compressor open. It was of course necessary that this valve be open if the compressor was run at all. Consequently the Rand Rock Drill which consumes more air than could be furnished by the mere expansion of air in the receiver could not be tested.

## Calibration of Compressor.

To determine air compressed per stroke at different pressures.

### Test No. 1.

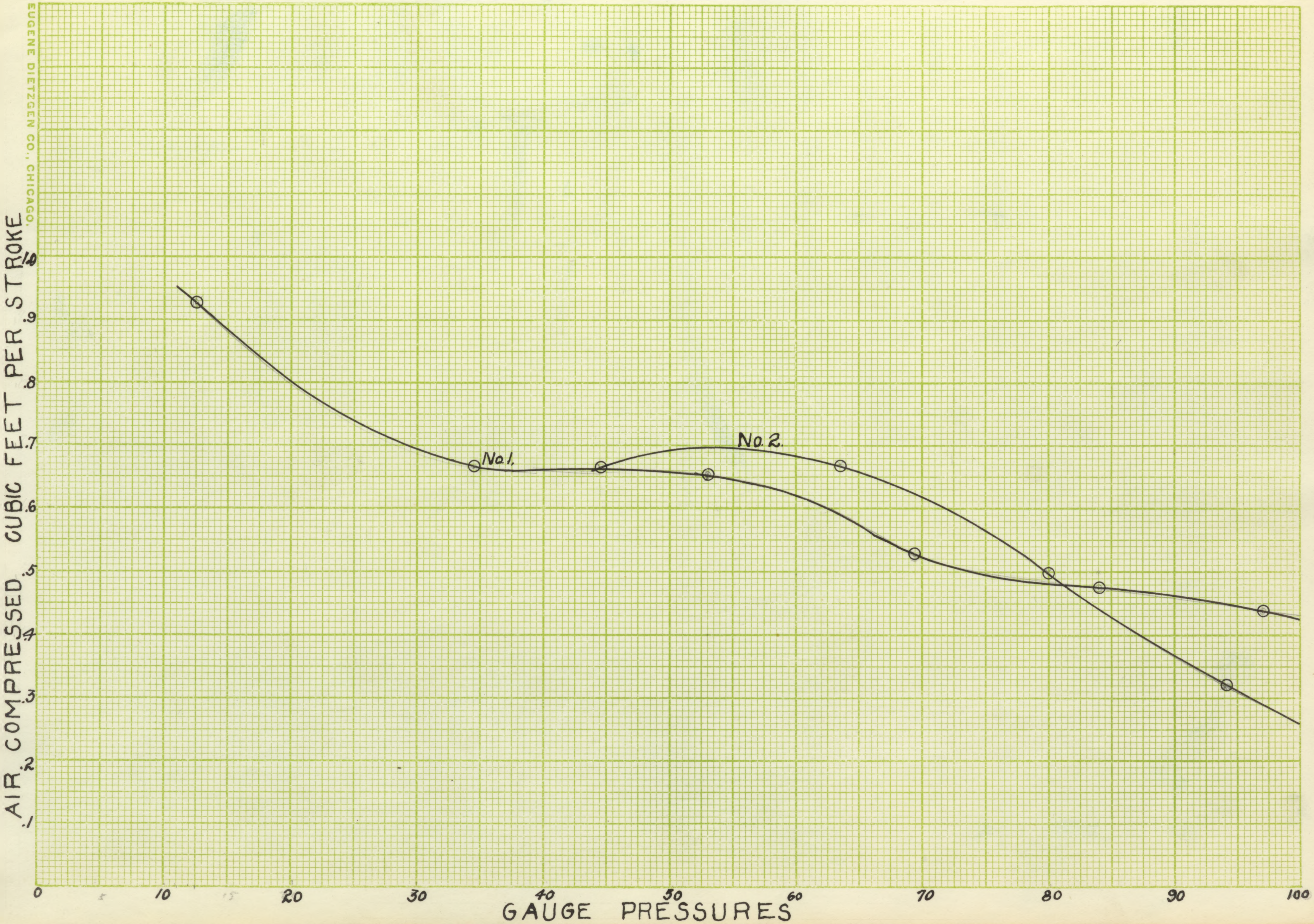
| Time. | Gauge Pressure. | Temperature. | Compressor Strokes. | Wt. of Air in Receiver. | Air compressed Per stroke. cu. ft. |
|---|---|---|---|---|---|
| 1:44 | 0 | 86 | 0 | 6.51 | |
| | | | | | .925 |
| 1:45 | 25 | | 152 | 17.22 | |
| | | | | | .664 |
| 1:46 | 44 | 108 | 304 | 24.9 | |
| | | | | | .656 |
| 1:47 | 62 | | 456 | 32.5 | |
| | | | | | .523 |
| 1:48 | 77 | 115 | 609 | 38.6 | |
| | | | | | .472 |
| 1:49 | 91 | [illegible] | 762 | 44.1 | |
| | | | | | .438 |
| 1:50 | 103 | 119 | 915 | 49.2 | |

### Test No. 2.

| Time. | Gauge Pressure. | Temperature. | Compressor Strokes. | Wt. of Air in Receiver. | Air compressed Per stroke. cu. ft. |
|---|---|---|---|---|---|
| 1:59 | 35 | 87 | 0 | 22.18 | |
| | | | | | .664 |
| 2:00 | 54 | | 155 | 30.0 | |
| | | | | | .67 |
| 2:01 | 73 | 100 | 310 | 37.9 | |
| | | | | | .50 |
| 2:o2 | 87.5 | | 465 | 43.8 | |
| | | | | | .416 |
| 2:o3 | 101 | 112 | 620 | 49.0 | |

### Test No. 3.

| Time. | Gauge Pressure. | Temperature. | Compressor Strokes. | Wt. of Air in Receiver. | Air compressed Per stroke. cu. ft. |
|---|---|---|---|---|---|
| 2:09 | 37 | 84 | 0 | 23.2 | |
| | | | | | .608 |
| 2:10 | 55 | | 151 | 30.2 | |
| | | | | | .615 |
| 2:11 | 74 | 104 | 302 | 38.0 | |
| | | | | | .495 |
| 2:12 | 88 | | 453 | 43.7 | |
| | | | | | .608 |
| 213 | 102 | 117 | 604 | 50.7 | |



EUGENE DIETZGEN CO., CHICAGO.
AIR COMPRESSED. CUBIC FEET PER STROKE
GAUGE PRESSURES
No.1.
No.2.
0
10
20
30
40
50
60
70
80
90
100
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0

23.

## Test for Leakage of Air.

The receiver was filled to 99 pounds pressure and all valves closed except the one in the pipe leading to the tool, but the tool was not operated. Readings of time, presure, and temperature were taken, and in ten minutes the readings were taken again. From this data the leakage was found to be 1.4 cubic feet of free air per minute. The calculations were made by means of the formula $M = \frac{P\ V}{R\ T}$ as explained before.

In the tables of tests the leakage has been subtracted so that the actual air consumption is given.

Test for Leakage.

| Time | Gaage Pressure | Temperature | Cubic feet free air in Receiver |
|---|---|---|---|
| 2:45 | 99 | 84 | 665 |
| 2:55 | 96 | 81 | 661 |

Results. The total leakage was 14 cubic feet or 1.4 cubic per minute.

## Tests of "O & C" Hammer.

These tests were run with the hammer working at its maximum capacity, chipping a heavy peice of cast iron. In tests numbers 1 and 2, which were the first ones taken, the hammer was stopped for a second or two, more than once, which probably accounts for the lower air consumption.

The air comsumption in test number 3, which is the most reliable, was found to be nearly seventeen cubic feet of free air per minute, however in practice it would be almost impossible to run the hammer at full valve opening and do good work, so that the actual consumption of the hammer working in a shop would probably not be over ten cubic feet per minute.

### Tests of "O & C" Hammer.

| Time | Gauge Pressure | Temperature | Cubic feet of free air. In Receiver | Total used | Used per Min. |
|---|---|---|---|---|---|
| | | | Test No. 1. | | |
| 2:35 | 97 | 85 | 650.0 | | |
| 2:42 | 80 | 83 | 558.5 | 96.8 | 13.8 |
| | | | Test No. 2. | | |
| 2:59 | 95 | 80 | 644.5 | | |
| 2:03 1/2 | 85 | 70 | 590. | 49.6 | 14.2 |
| | | | Test No. 3. | | |
| 2:45 | 95 | 80.7 | 642.5 | | |
| 2:55 | 85 | 78.3 | 588.0 | 50.3 | 16.8 |

Tests of Boyer Air Drill. Number, M, 31.050.

Description of Drill.

This machine consists of three main parts: (1) The upper housing into which the throttle valve and steadying handle are screwed, and which forms a live-air chamber carrying the motor: (2) The diaphram which forms the lid or cover of the upper housing or live chamber and through which the hollow exhaust spindle projects (3) The low r housing secured to the upper housing by means of screws, and containing the gear wheel racks, bearings for drill, spindle, etc. The motor is in the form of a three-cylinder single acting oscillating engine, the cylinders being carried in the rotary frame. This frame consists of an upper and lower plate, and is triangular in shape and is free to revolve around its center on two bearings, the lower one being a hollow shaft, and connected by gearing to an internally toothed wheel in the lower half of the casing. The admission of air to the cylinders is regulated by the valves formed in the pivots upon which the cylinders oscillate. The cylinders are single acting and inner ends are open, and therefore air under pressure, of which the upper casing is always full, has free axcess to the pistons on that side. It would siim, therefore that air being admitted through the pivot valves would only produce equilibrium, but since one of the cylinders is always open to the exhaust through the hollow bearing of the triangular frame, this equilibrium becomes disturbed, and the compressed air has full effect upon each piston as the valve comes in line with the exhaust. The cylinders are constructed of steel tubes, and are fitted with trunk pistons having their connecting-rod ends attached to a fixed crank pin common to them all; the pistons having been set in motion by the introduction of compressed air into the upper casing, and into the cylinder as already described, has the effect of causing the three cylinders, together with their triangular framing, to rotate around the fixed crank pin, and thus transmit rotary motion to the spindle by means of the gearing before referred to. This class of machine is fitted with a regulator by means of which the power and speed of the drill can be varied as desired.

Object: The object of these tests was to determine the air consumption of the drill where in actual operation.

Method: The drill was located close to the receiver and connected to the pipe by a short hose. The drill used was one inch and the material drilled was cast iron. The drillwas kept operating at its maximum capacity, that is, the full air pressure was on and the drill was fed just fast enough to drill a maximum amount of material all the time.

Air Consumption: The determination of air consumption of the drill was made in the same manner as for the hammer. The results show an air consumption of about 30 cubic feet of free air per minute.

Tests of Boyer Air Drill.

Test No. 1.

| Time | Gauge Pressure | Temperature | Cubic feet of free air. In Receiver | Cubic feet of free air. Total Used | Cubic feet of free air. Used per Min. |
|---|---|---|---|---|---|
| 3:15 | 100 | 90 | 664 | | |
| 3:18 2/3 | 80 | 85 | 547 | 112 | 30 |
| | | | Test No. 2. | | |
| 3:4o | 99 | 88 | 658 | | |
| 3:44 | 78 | 84 | 535 | 118 | 29.5 |
| | | | Test No. 3. | | |
| 4:20 | 100 | 91 | 662 | | |
| 4:24 | 78 | 86 | 534 | 123 | 30.7 |

Note. The drill was fed into the iron just fast enough to do the maximum amount of drilling.

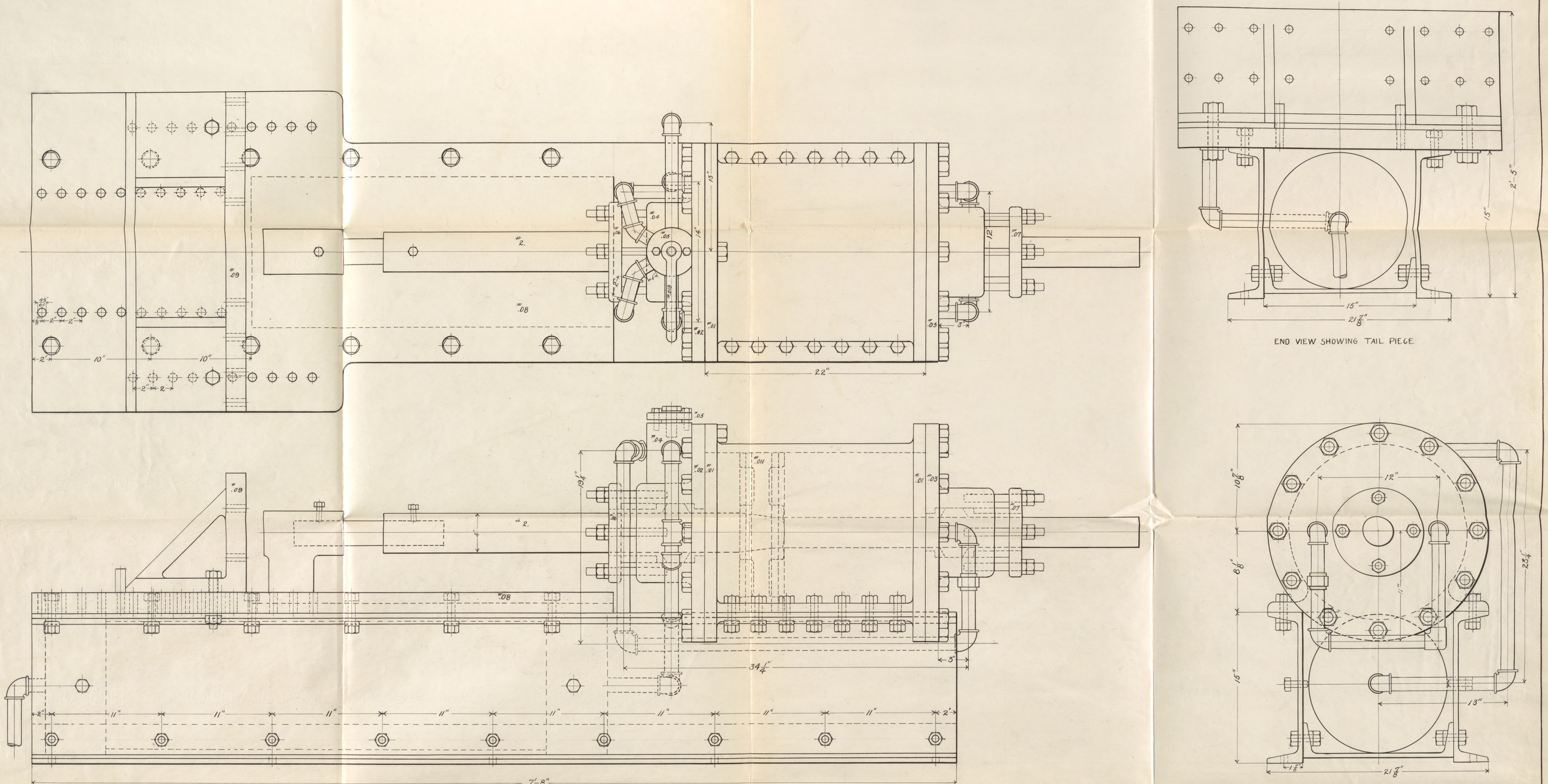
## Design of a Pneumatic Bulldozer.

The pneumatic bulldozer was designed to be built in the University shops. It is to be placed in the forge shop.

When the bulldozer is not in use the handle used to operate it should be taken off.

If the piston head hits the cylinder head too hard on the return stroke a reducer should be screwed onto the end of the exhaust pipe. By thus reducing the size of the exhaust the piston speed will be reduced.

A valve should be placed in the feed pipe so that the air can be shut off from the bulldozer.




THESIS DRAWING

PNEUMATIC BULLDOZER

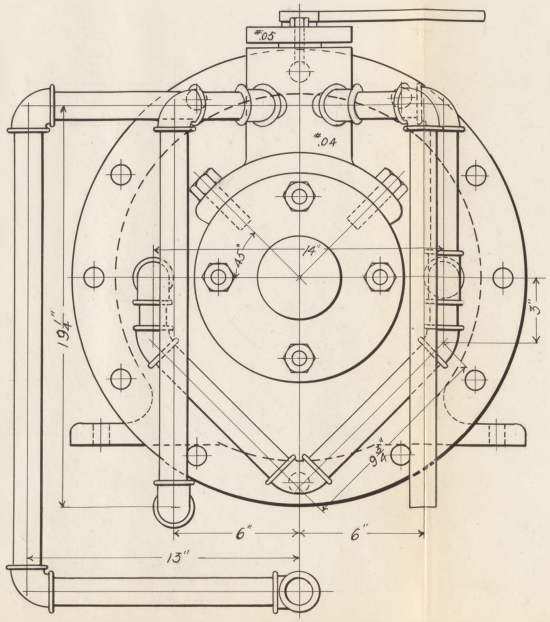
ASSEMBLED DRAWING

MECH. ENG. DEPT. UNIV. OF ILL.

SCALE 3"=1'-0"

MAY 10, 1904. PLATE No. I

W. K. Wiley '04.




END VIEW OF CYLINDER HEAD SHOWING PIPING
SCALE 3"=1'-0"

## BILL OF MATERIALS

| NO. OF PIECE | MATERIAL | NO. REQUIRED | DETAIL PLATE |
|---|---|---|---|
| .01 | Cast Iron | 1 | III |
| .02. | " | 1 | III |
| .03 | " | 1 | III |
| .04 | " | 1 | II |
| .05 | " | 1 | II |
| .06 | " | 1 | III |
| .07 | " | 1 | III |
| .08 | " | 1 | V |
| .09 | " | 1 | IV |
| .011 | " | 1 | IV |
| .012 | " | 2 | IV |
| .013 | " | 1 | II |
| 2. | Forged Steel | 1 | III |
| 3. | " | 1 | IV |
| 10. | Mild Steel | 1 | II |
| 20. | " | 1 | II |
| 30. | " | 2 | IV |
| 100. | Brass | 1 | II |
| 200. | " | 1 | III |
| 300. | " | 1 | III |
| 400. | " | 2 | III |
| 500. | " | 2 | III |

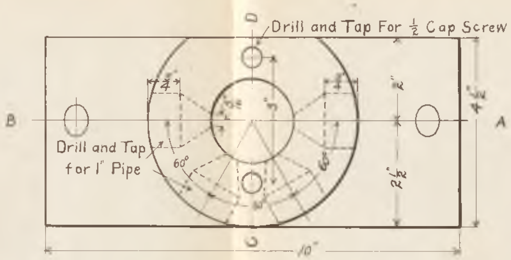
| BOLTS | |
|---|---|
| Size | No. Required |
| [illegible] 3½ | 12 |
| [illegible] | [illegible] |
| [illegible] | [illegible] |
| **STUD BOLTS** | |
| ¾ x 3½ | 24 |
| [illegible] | [illegible] |
| **CAP SCREWS** | |
| [illegible] | [illegible] |
| **SET SCREWS** | |
| ½ x 1½ | [illegible] |
| [illegible] | [illegible] |
| **NUTS** | |
| [illegible] | 56 |
| ¾" Lock | 8 |
| **TAPER WASHERS** | |
| ¾ | 34 |

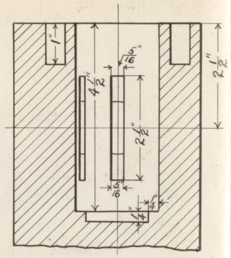
| 1" PIPE | |
|---|---|
| Length | No. Required |
| 2 | 6 |
| 3 | 6 |
| 6½ | 1 |
| 8½ | 2 |
| 10 | 1 |
| 6 | 1 |
| 21½ | 2 |
| 18' | 1 |
| 11½ | 1 |

15" STANDARD CHANNEL WT. 33 LBS.
7'-8" LONG 3 REQUIRED

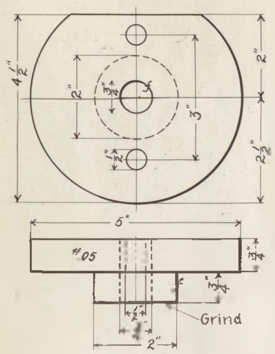
1"-90° ELBOWS 12 REQUIRED
1"-45° " 4 "
1" TEE 1 "
1" SIDE OUTLET ELBOW 1 "

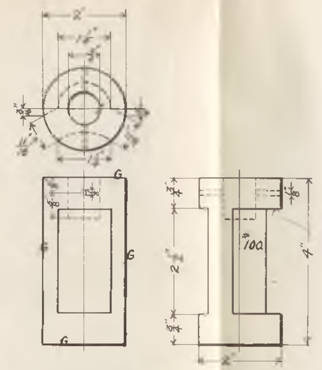
12" PIPE 5'-6" Long
2" CAP 2 REQUIRED



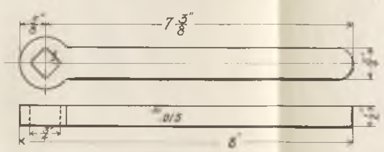



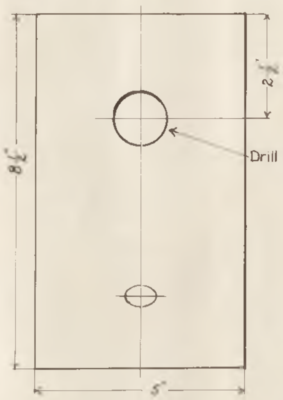
SECTION THROUGH C, D.

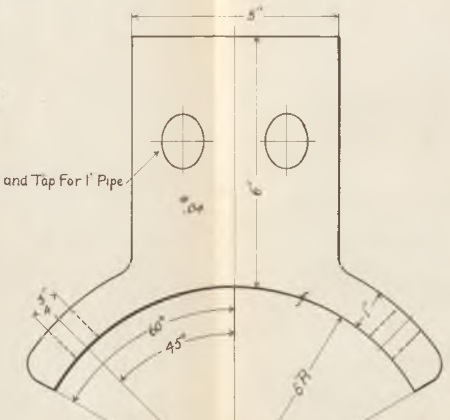


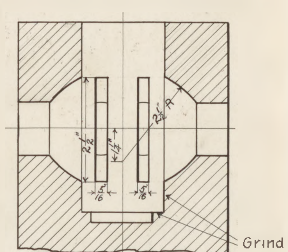




Grind Surfaces Marked G



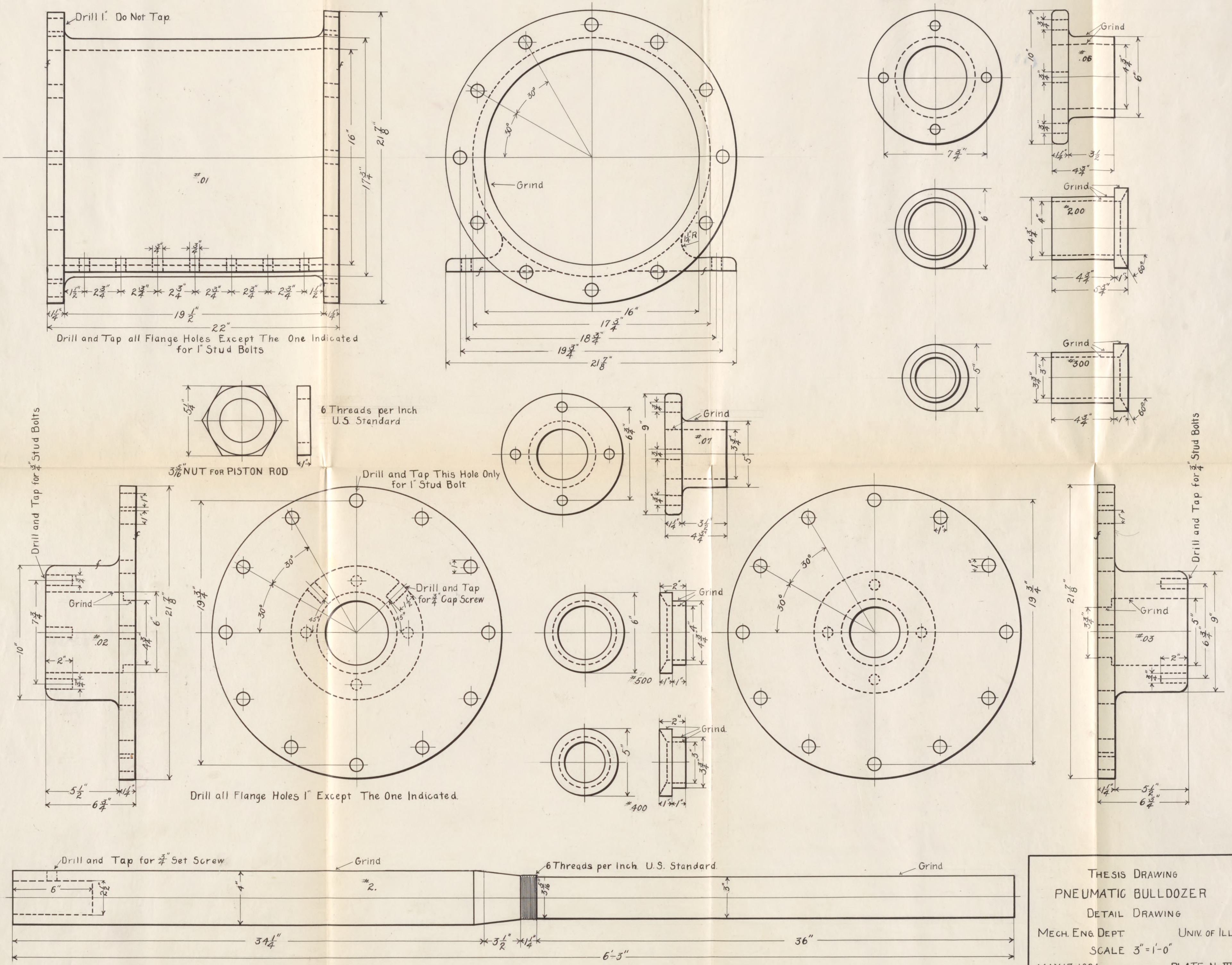




SECTION THROUGH A, B


DETAIL OF VALVE AND VALVE SEAT
SCALE 6"=1'-0"

THESIS DRAWING
PNEUMATIC BULLDOZER
DETAIL DRAWING
MECH. ENG DEPT. UNIV. OF ILL.
SCALE 3"=1'-0", 6"=1'-0"
MAY 16, 1904 PLATE No. II
W. K. Wiley '04




THESIS DRAWING

PNEUMATIC BULLDOZER

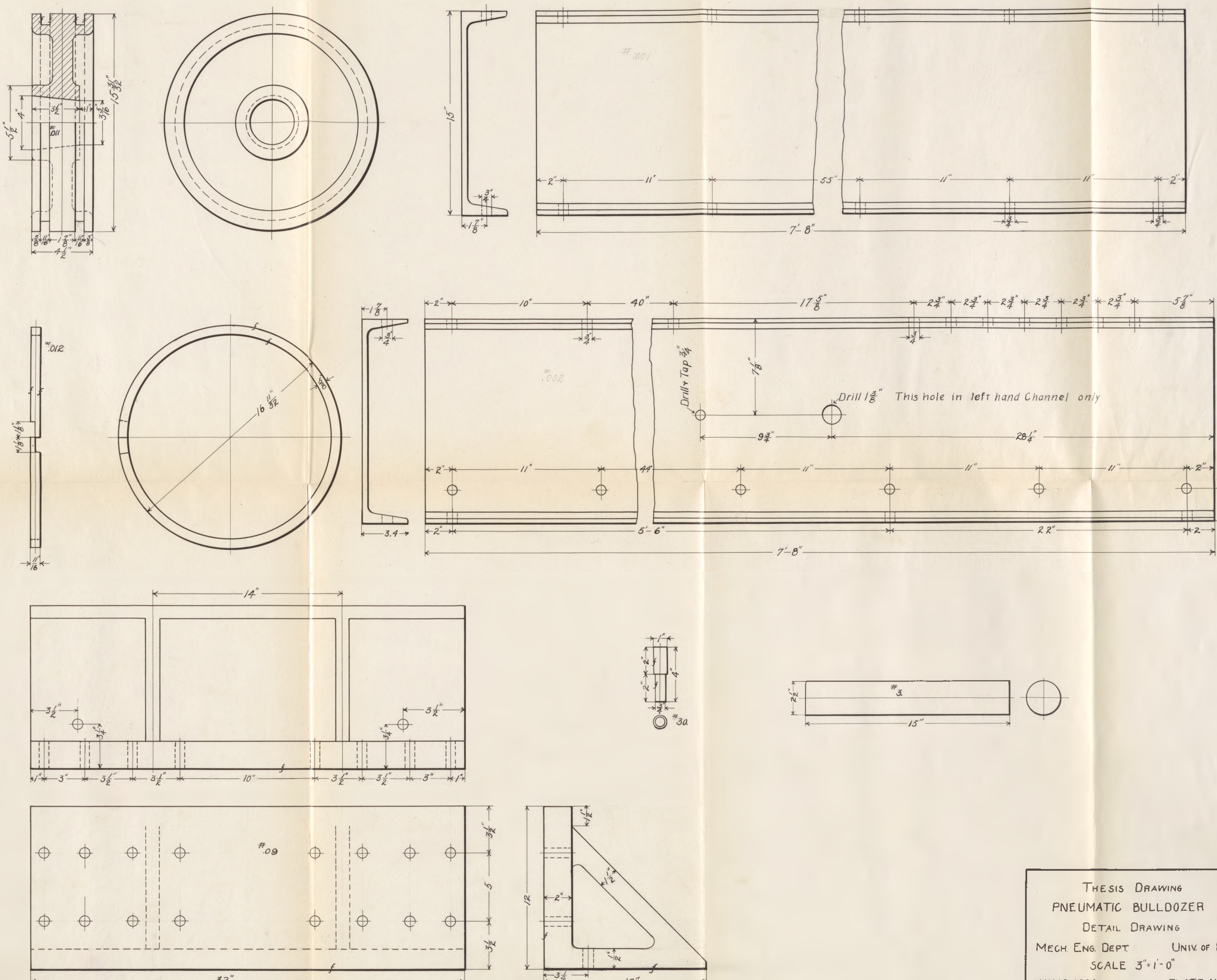
DETAIL DRAWING

MECH. ENG. DEPT. UNIV. OF ILL.

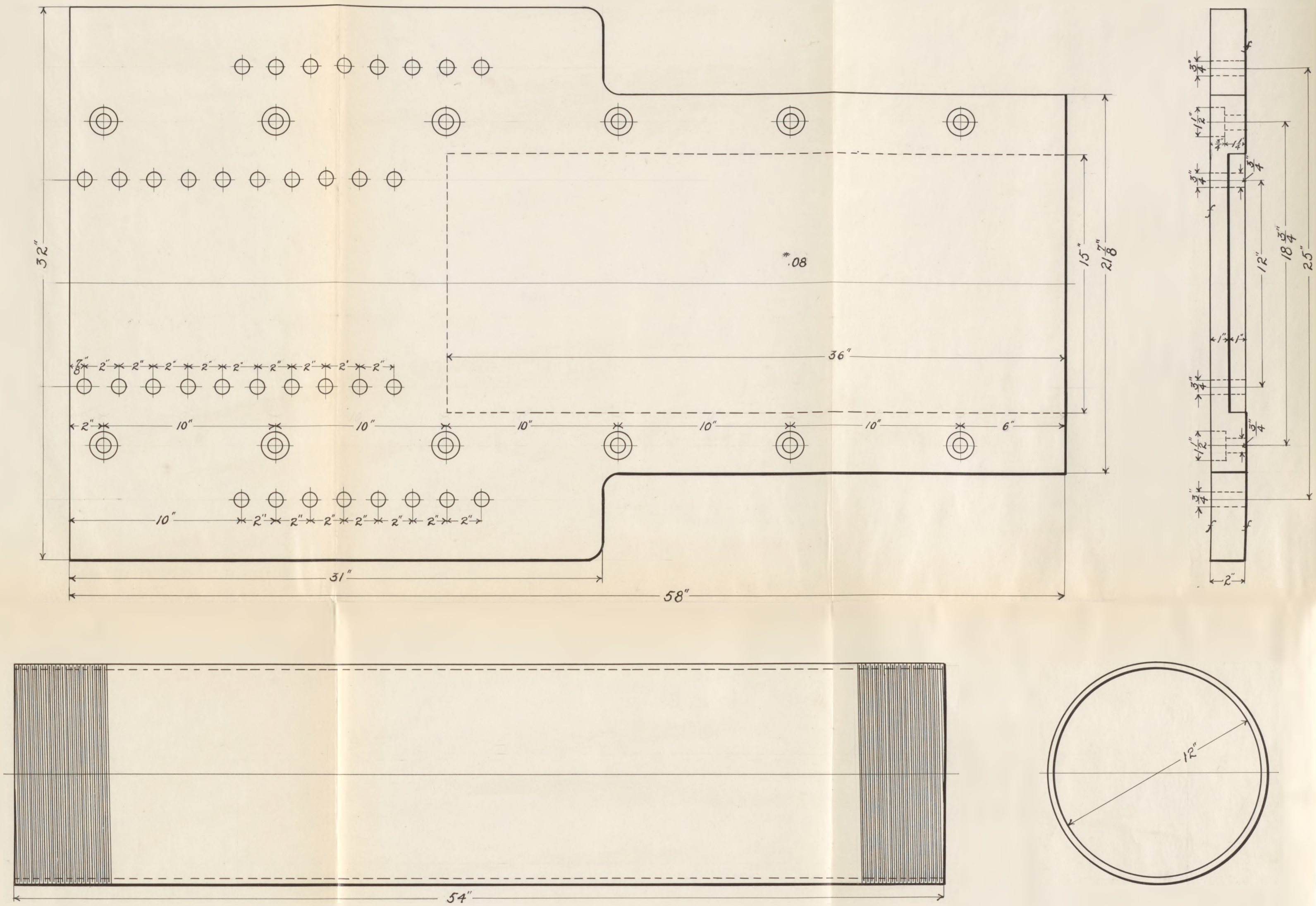
SCALE 3" = 1'-0"

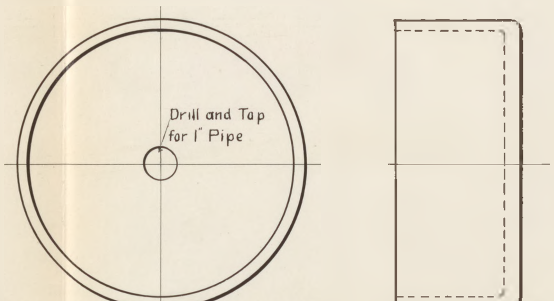
MAY 17, 1904 PLATE No. III

W. K. Wiley '04.




THESIS DRAWING
PNEUMATIC BULLDOZER
DETAIL DRAWING
MECH. ENG. DEPT. UNIV. OF ILL.
SCALE 3" = 1'-0"
MAY 19, 1904 PLATE No. IV
W. K. Wiley '04




THESIS DRAWING

PNEUMATIC BULLDOZER

DETAIL DRAWING

MECH. ENG. DEPT. UNIV. OF ILL.

SCALE 3" = 1'-0"

MAY 20, 1904 PLATE No. V

W. R. Wiley. 04.