THESIS,

DESIGN OF STEAM ENGINE

AND

BOILER WORKS,

FOR DEGREE OF B. S. SCHOOL OF M. E.

BY

A. G. Goldschmidt,

1888.
Design of Steam Engine and Boiler Works.

The main object kept in view in the design of these works, is the convenient location of the different shops and machines. They are intended for the building of portable and traction engines and small stationary engines and boilers. They are intended to be placed in some medium sized town, where ground for building is plenty and cheap. They would naturally be placed in some town which has good farming country surrounding it and also has good railroad communication. The grounds are assumed to be in possession of the company intending to build the shops and would therefore not be included in the estimate of the cost of the works. They are of the following dimensions: 200 feet long fronting the west and 150 feet deep fronting the south. The portion covered by buildings is 160 feet long and 115 feet deep. The several buildings contain the fol-
lowing shops and rooms: the main building contains the principal machine shop, with erecting and wood working shops, the offices, a draughting room and a tool room. In the annex to the main building are the engine room, boiler room, a wash-and dressing-room, water-closet and a coal-house. To the east of the main building and near its north end is the foundry, while at the south end is a building containing the boiler-shop and the blacksmith shop. The foundry and the boiler- and blacksmith shops are separated from the main building by 10 foot passages. The smoke-stack for conveying away the smoke and gases from the boilers and from the blacksmith's forges, is located immediately behind the boiler-house. The shops are all to be built of the best hard burned brick, all one-storied, stories to be 20 ft. high in the clear. The east and west walls of the main building
will each be 22" thick, the north and south walls 18". The partition wall between the offices and main shops will be 13½", all other partitions 8½". The walls for the blacksmith and boiler-shops will be 13½", those for the foundry the same. The north wall of the boiler and engine-room will be 13½", all others in the annex 8½". The dimensions of the shops and rooms will be as follows: the main shops, D, 137 ft. long and 56 ft. 4 in. wide; the offices, A, 18 ft. 6 in. by 18 ft. 2 in.; draughting room, B, 18 ft. 6 in. by 17 ft. 4 in.; F, vault for the safe-keeping of books, valuable papers etc., 5 ft. 7 in. by 5 ft. B, a room for depositing drawings and for blue-printing. This room has a single large window, with the walls at the side of the window cut away at an angle of 45° so as to cast no shadow. In this room can be fitted up, a small dark-closet for the preparation of paper for blue-printing. This room also receives the
sun-light from the south during the greater part
of the day, so that it can be used as a printing room.
It is 13 ft. 3 in. by 5 ft. 7 in.; a tool room, C, 18 ft. 6 in.
by 13 ft. 2 in.; blacksmith-shop, E, 42 ft. 9 in. by 23 ft. 7 in.
boiler-shop, F, 42 ft. 9 in. by 23 ft. 4 in.; wash- and
by 9 ft. 6 in.; engine room, I, 25 ft. by 18 ft. 6 in.;
boiler-room, J, 27 ft. 9 in. by 22 ft. 4 in.; a coal-house
K, 27 ft. 9 in. by 15 ft.; foundry, O, 42 ft. 9 in. by 32 ft.
9 in.; shed for storing patterns and flasks, P, 25 ft. by 10 ft.

The power is supplied by a Corliss engine,
developing 75 horse-power, when cutting off at
.3 stroke and running at 80 revolutions per minute.
This will be in excess of that actually needed. What
is actually necessary is found by estimating the
power required to run the several machines and then
Summing up in the following Table:

<table>
<thead>
<tr>
<th>Machines</th>
<th>HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 plate planer</td>
<td>3</td>
</tr>
<tr>
<td>2 pulley-turning machines</td>
<td>3</td>
</tr>
<tr>
<td>2 gear cutters</td>
<td>2.5</td>
</tr>
<tr>
<td>2 shapers</td>
<td>2.5</td>
</tr>
<tr>
<td>2 horizontal boring machines</td>
<td>3</td>
</tr>
<tr>
<td>2 milling machines</td>
<td>4</td>
</tr>
<tr>
<td>2 drill presses</td>
<td>2</td>
</tr>
<tr>
<td>3 16&quot; lathes</td>
<td>2.25</td>
</tr>
<tr>
<td>3 12&quot; lathes</td>
<td>2</td>
</tr>
<tr>
<td>12&quot; fox lathe</td>
<td>.5</td>
</tr>
<tr>
<td>10&quot; screw machine</td>
<td>.4</td>
</tr>
<tr>
<td>24&quot; lathe</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Machines</th>
<th>HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending rolls</td>
<td>3</td>
</tr>
<tr>
<td>Punch and shear</td>
<td>6</td>
</tr>
<tr>
<td>Grindstone</td>
<td>4.3</td>
</tr>
<tr>
<td>28&quot; planer</td>
<td>1.75</td>
</tr>
<tr>
<td>Bolt cutter</td>
<td>.8</td>
</tr>
<tr>
<td>Speed lathes</td>
<td>2</td>
</tr>
<tr>
<td>Circular saws and other</td>
<td></td>
</tr>
<tr>
<td>Wood-working machines</td>
<td>10</td>
</tr>
<tr>
<td>Friction of engine and shafting at 15%</td>
<td>9</td>
</tr>
<tr>
<td>Total power req.</td>
<td></td>
</tr>
<tr>
<td>Mixed on this assumption</td>
<td>69.5</td>
</tr>
</tbody>
</table>

Blowers and exhaust fans: 3.5
Centering machine: .5
Cutter and tool grinders: 1.5
The engine has a cylinder 14 in. in diameter by 30 in. stroke. The diameter of the band-wheel is 120 inches, its width of face 16 inches. The weight of the wheel is about 8000 lbs. Length over all of engine about 19 ft. The working speed is 80 revolutions per minute.

Dry steam for the engine is furnished by Babcock and Wilcox water-tube boilers, rated at 45 HP. each. During summer but two of these boilers are in constant use, while a third is supplied in case of accident and also to supply the steam-heating apparatus in cold weather. Their dimensions are as follows: length over all, 19 ft.; width, 5 ft. 6 in.; height, 13 ft. 9 in.; tubes are 14 ft. long and 3 inches in diameter. There is one steam drum on each boiler, 30 in. in diameter and 14 ft. 5 1/2 in. long. The steam opening is 3 1/2 inches, with 3 in. safety valve. The grate surface is 16 square feet, the grate being 6 ft. long and
32 inches wide. The amount of coal consumed is found by first assuming an evaporative power per lb. of coal per hour, of 7 lbs. of water. Then knowing that one commercial HP. is 30 lbs. of water converted into steam at 100° and 60 lbs. pressure, and having two 45 HP. boilers in constant use, we get $2 \times 45 \times 30 = 2700$ lbs. water evaporated per hour. To accomplish this $\frac{2700}{\frac{1}{2}} = 300$ lbs. coal per hour must be burned. Assuming a working day of 12 hours, it would require 3600 lbs. per day, or 108,000 lbs. or 54 tons per month. One ton of bituminous coal requiring 45 cubic feet of storage room and the dimensions of the coal house being 27.75' by 15 ft. by 8 ft. = 3330 cu. ft., we can store about 81 tons of coal, a supply lasting about one and one-half months. For convenience in receiving coal a rail-road siding, Q, is run into the grounds, so that coal can be transferred directly from the cars.
The boilers are fed by a Deane steam pump, capable of furnishing 700 gallons of water per hour, when running at a speed of 150 strokes per minute. The capacity of the pump is determined from the horse power of the boilers. A one-horse-power boiler should evaporate 30 lbs. of water per hour. We have two 45 horse power boilers, which at that rate would evaporate 90 x 30 = 2700 lbs. of water. The weight of one gallon of water is about 8 lbs., then 2700 lbs. would be equal to \( \frac{2700}{8} \approx 337.5 \) gallons per hour, so the actually required amount. Taking a pump of double the capacity we would get 674 gallons and one of 700 gallons would be still safer.

The power delivered by the engine is transferred to the main shaft, N N, by a belt 12 in. wide running over a 42 in. wrought iron pulley. The ratio of the speed of the driver and the driven, being in
inverse ratio to their diameters, we find the main shaft to run at 228 revolutions per minute. The diameter of the shaft was found from the following formula for mill shafting, given by Brünwirth; the ratio of the torsional stress to the stress of flexure being equal to 1. $d = 4.414 \sqrt[3]{\frac{H \cdot P}{2E}} = 4.414 \times 97.85 = 4.31$ inches. The shaft is made of cold rolled wrought iron and runs in bearings formed by hangers, supported from the tie-beams of the roof trusses. On the plans these beams are marked z. A shaft, similar to the main shaft extends along the west side of the shops. The power is brought to this by a single belt running over the pulleys t and t'. This belt is prevented from swaying by running it over two idlers, placed midway between the shafts.

The machines necessary to perform the required work are given in the following list. A statement
of the weight, approximate price and speed of counter-shaft, is also given. The placing of the
machines can be seen by referring to the plans.

a and a₁ are two universal automatic gear-cutters,
weight, each, 2000 lbs.; price, each, $800; speed of counter-
shaft, 150 revs. per minute.

b and b₁ are two horizontal boring and drilling machi-
nes, svt. each, 4000 lbs.; price, each, $1150; speed of counter-
shaft, 150 revolutions.

c₁, Browne & Sharpe, No. 1, universal milling machine,
with gear cutting attachment; weight, 1750 lbs.; price,
$700; speed of counter, 110 revolutions.

c₁, vertical milling machine; weight, 1200; price,
$550; speed of counter, 140 revs.

d and d₁, Gould and Eberhardt patent shapers; (c₁)
a 15 in.; weight, 1500 lbs.; price, $350; speed of counter, 250 revs.
d₁, a 20 inch with concave attachment, weight, 2100 lbs.
price $500; speed of counter, 250 revo.

L, a slotting and drilling machine, weight, 3800 lbs.; price, $850; speed of counter, 250 revo.

L, a 42" drill press, weight, $250 lbs.; price, $400; speed of counter, 250 revo.

L, is a 16" lathe, with 7 ft. bed; weight, 1850 lbs.; price, $500; speed of counter, 110 revo.

L, a 16" lathe with 10 ft. bed; weight, 2400 lbs.; price, $625; speed of counter, 125 revo.

L and L, are two 12" screw-cutting engine lathes, weight, each, 800 lbs.; price, each, $280; speed of counter, 150 revolutions.

L is a 10" screw machine, weight, 575 lbs.; price, $325; speed of counter, 200 revo.

L, is a 12" fox lathe for brass work; weight, 900 lbs.; price, $325; speed of counter, 200 revo.

L, is a centering machine; weight, 300 lbs.; price, $100.
speed of counter shaft, 250 revs.
At $w$ is a 48" grindstone with 5" face; weight, 900 lb.; price, with iron frame, $70.
At $j$ and $j'$ are two pulley turning machines, weight, 2500 lb.; price, $600; speed of counter, 150 revs.
At $k$ is a 28" planer, with quick return motion, weight about 7000 lb.; price, $1000; speed of counter, 240 revs.
$l$ is a bolt cutter, weight, 900 lb.; price, $300; speed of counter, 150 revs.
$ll$, is a valve milling machine, weight, 900 lb.; price, $325; speed of counter, 375 revs.
$q$ is a 24" lathe, with 12 ft. bed; weight, 6200 lb.; price, with screw gear, $1000; speed of counter, 125 revs.
r, is a 16" engine lathe; weight, 1850 lb.; price, $500; speed of counter, 110 revs.
r', is a 12" hand lathe; weight, 500 lb.; price, $90; speed of counter, 350 revs.
at 0 is an emery grinder; weight, 290 lb.; price, $150; speed of counter, 375 revs.

p, is a cutter and reamer grinder; weight 650 lb.; price, —; speed of counter, 375 revs.

q, is a plain milling machine; weight, 850 lb.; price, —; speed of counter, 300 revs.

In the boiler shop, w is a plate planer; weight, 10000 lb.; price, $1100.

s, is a set of bending rolls, 10 ft. 6 in. between housings; weight, 19250 lb.; price, $1000.

v, is a boiler maker's combined punch and shear; weight, 12000 lb.; price, $1150.

In the foundry is placed a blower x, to furnish blast for the cupola x. In the foundry is also a crane with a radius of 15 ft. for convenience in handling heavy work. Another 10 foot crane is placed in the boiler shop. In the black-smith shop will be
placed a blower, to furnish blast for the forges and an exhaust fan, to remove the smoke from the shop.
In the pattern- and wood-working shop, N, will be placed the necessary machines, such as lathes, circular saws etc., while in the erecting shop, N, will be placed an hydraulic press, for forcing crank pins into the crank-discs. The shop will be supplied with all the necessary bench-tools, vises etc. for a vice bench, 30" wide, extending along the west wall of the shop. A light rail-road track, x' x" x'' x", runs from the boiler shop to the erecting shop to facilitate the handling of completed boilers and other heavy work. x" and x'" are turn tables. This track is also run into the foundry for convenience in handling heavy castings. In the wash-room, g", is a wash-stand for the employees and g'g', are cases in which they may keep their street clothes. The water-closet, H, is supplied from
A tank on the roof of the building. The buildings are lighted by windows, 3 ft. wide and 10 ft. high, also by a skylight running along the gable of the roof. They are heated by steam-pipes running under the vise bench and by radiators distributed throughout the building.