DESIGN

of a

MACHINE SHOP LABORATORY

for the

AMERICAN UNIVERSITY OF BEIRUT

By

Nazih Shaykh

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"This thesis submitted to the Civil Engineering Faculty in partial fulfillment of the requirements for the degree of Bachelor of Science in Civil Engineering:" A.U.B.

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INTRODUCTION

A "Machine Shop Laboratory" forms part of the recognised equipment of every up-to-date school and many schools have spent large sums on elaborate buildings and ready-made apparatus, yet it is quite rare to find any of these laboratories with a suitably equipped workshop for the repair and construction of apparatus.

It is also common to find in the cupboards of our laboratories a dusty collection of broken balances, galvanometers and such-like that are no longer in use owing to the lack of some small screw or essential part. The old apparatus can be packed and sent back to the makers for repairs, but this involves trouble, time and money.

A small workshop enables repairs to be done at negligible expense without delay and, what is even more important, the teacher of science with a knowledge of the use of tools is able to try experiments that are not found in school text-books and to introduce into his teaching a freshness and originality that is often sadly lacking in these present days.

The modern science student at the university receives little training in manual dexterity. The lecture experiments are set up by skilled assistants and the laboratory work seldom calls for much manipulative skill, with the result that few science masters have an opportunity of learning the use of tools and the construction and adjustment of apparatus.

Following the suggestions of Professor J.R. Osborn, the candidate has attempted to remedy this deficiency in his University by designing a "Machine Shop Laboratory". This became a necessity at the time when the American University of Beirut thought of building a new Engineering School which included in its program Civil, Electrical and Mechanical Engineering.

Although the "Machine Shop Laboratory" is of prime importance for students taking Mechanical Engineering courses, it is easy to realize that it is necessary for all science students. What is really beneficial to the students is not the completion of a certain model, but the manual dexterity gained while working on that model.

To sum up, the "Machine Shop Laboratory" will have two main functions: First, it will enable repairs, designs and constructions of different apparatus to be done relatively at negligible expenses at the University; and second it will be a vital laboratory for those students majoring in Engineering and Sciences. Moreover the laboratory will provide for them an escape from the stagnation of examination Science and something of the spirit of a research laboratory is introduced into school studies.

It is to be noted that an elaborate, expensive equipment is not necessary, but it does include the necessary machines for the performance of the different operations either on wood or metal. The details will be studied in the subsequent chapters.

CHAPTER I

LOCATION and GENERAL PLAN

Location:

The selection of a place to be used as a Machine Shop Laboratory is subject to various considerations.

1. The Machine Shop should be situated near the Engineering-Physics Building, since one of its main functions is to serve Engineering and Science students. It also forms part of their laboratory and easy access from the main building should be provided.

2. The Machine Shop is a centre of repair for the whole University and for that reason it should be reached by a road which will permit any material to be handled easily.

3. On the other hand, the noise created by the running machines should not be a cause of disturbance for the other buildings, especially when lectures are being given. For that, elaborate studies should be made as to adequate distance to be given and noise control. (see chapter VII)

4. Other factors should be considered as for example avoiding the proximity of the Machine Shop from a chemical laboratory. The fumes of a chemical laboratory can cause steel tools to rust over-night.

5. The available land is probably one of the deciding factors. Although this is an economical problem, it plays an important part in the location of the Machine Shop. In the present case, the available land is bounded by the New Engineering Building to the south, by the property line to the north and east, and by a residence to the west.

Taking all these facts into consideration, the "Machine Shop Laboratory" will be located to the north and at a distance of 16 meters from the New Engineering Building. Although it could be placed nearer, the Machine Shop is placed at that distance from the Engineering building so that the noise created by the running machines will not be a cause of disturbance. Also, the prevailing winds in Beirut have a South-West direction and the fumes of the Chemical laboratory are carried away from the Machine Shop.

The location plan shows the position of the "Machine Shop Laboratory" with respect to the surrounding buildings.

General Plan:

The building covers a total area of approximately 715 square meters and is divided into four distinct parts:

1. The forge shop
2. The foundry
3. The metal working shop
4. The wood working shop

The equipment and the general position of the machines in these different parts will be studied in detail in the following chapters. The divisions of the Machine Shop Building will be dealt with now.

The forge shop and the foundry occupy the north part of the building, and are separated by a movable partition. This movable partition consists of a masonry wall which can be easily removed in emergency cases. The forge shop and the foundry are each 12 meters long by 7 meters wide. Each one is provided with a door 2 meters wide to permit the handling of equipment and material. Two small rooms are located near the forge shop and can be reached through it. One contains the forge coal necessary for the functioning of hearth, and the second is used as a store place.

Similarly, two other small rooms are located near the foundry. One of them contains the moulding sand necessary in the moulding operations, and the other the foundry coal used in the core oven or brass furnace. These two rooms can be reached from the foundry itself. The pig iron, scrap and coke are placed in an elevated store outside the building and near the cupola to avoid the use of a vertical lift and save labour (see chapter III). The core oven, the cupola and the adjoining store are located outside the building. The necessary space is provided.

The metal-working shop and the wood-working shop form the front part of the building. Each one has a length of 15 meters and a width of 8.2 meters. They are also served by a two-meter door which can be reached from the outside for the handling of material and equipment. The welding equipment is placed in a separate room which can be reached through the metal shop. In this case, the arc produced during welding operation is not a source of trouble.

The metal shop and the wood shop can be reached from the main entrance thru a sliding door.

Adjacent to metal shop is the office. The dividing wall is made 30 cm. in thickness for the two following reasons:

1. To reduce vibration and noise
2. To provide enough space for the sliding door

Similarly, the drawing room is located near the wood shop and is separated from it by a 30 cm. wall. Also the pattern storage room is placed near the wood shop so as to make the handling of patterns easier.

This arrangement leaves an open space in the middle of the building, with the advantage that daylight reaches all the parts of the Machine Shop.

The toilet room is equipped with wash-up fountains. These can be used by more than one person at a time as shown in the accompanying picture.

A store room and a closet room are also shown on the plan.

Picture showing wash-up fountains

Figure 1

CHAPTER II

Forge Shop

It is undoubtedly true that since the new developments in machine construction and the introduction of lathes and the large variety of similar machines now in use in almost every machine shop, the Forge Shop has lost considerably of its importance as one of the indispensable departments upon which the machinist formerly depended for much of his work. The introduction of steel castings, malleable iron castings and other similar materials superseding in many cases the forgings, has also been an important factor in the same direction.

Yet, while the Forge Shop may have decreased in importance in the making of forgings, there will always remain the demand of the machine shop for a certain amount of strictly machine forgings of iron and steel which cannot be met by any other material. And although great and important improvements have been made in forging by the use of improved hammers and the process of drop forging, there is still a large demand for hand forging.

According to "Kent's Mechanical Engineers' Handbook", the desirable features in a drop forge shop production line are specified in figure 2, which diagrams the principal processes involved[1].

Figure 2

1. The chart is abstracted from a diagram by R.E.W.Harrison (Developments in Modern Drop Forging, and their Relation to Current Machine Shop Practice, Trans. A.S.M.E., 1936)

Of course this diagram shows a complete detailed process and in the actual forge shop, some processes can be combined, others omitted. The plan showing the forge shop lay-out gives probably the most convenient arrangement. The hearths are two in number and in case they are to be increased, they are placed in pairs, so that the total number becomes four. They are 60 cm. from the side walls to allow room for the main blast pipe, tuyere cooling tank, etc... The distance center to center of hearth is made 6.0 meters. The Smith works with his back to the fire, the beak of the anvil being always on his left. The position of the anvils is as shown. A clear zone of 2.5 meters wide must be left from the anvil outwards to allow for the swing of the striker's sledge hammer. A 1.0 meter way is made down the center of the shop for traffic. Benches are placed between the forges, and fitted with a standing vice. Windows light the bench, but are at the back of the smith when not working at the bench; he will, however, get enough light in this case from the side windows. Each Smith has a tool rack above the benches, on the wall. This arrangement gives a shop with a span of 7 meters.

A power-hammer, a grinder, a tool-hardening furnace and a case-hardening furnace are shown. The bending rolls and block are normally kept outside the shop, in the store room.

Now some of the important tool or equipment which have an influence on the plan lay out will be considered in detail.

<u>1. Hearth</u>

For convenience, and where output rather than portability is aimed at, it is desirable to provide fixed forges, constructed of metal or brickwork, in shops designed for permanent use.

The accompanying figure[2] (fig.3) shows a full-sized metal hearth, which can be built up in a machine shop.

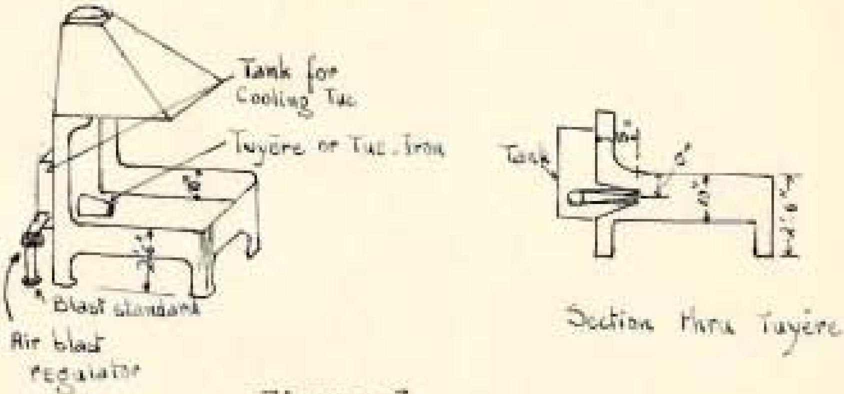

Figure 3

The top of the hearth is about 75 cm. above floor level, and the floor of the hearth is flat and from 22 to 30 cm. below the top edge. The air-blast, which is provided by a centrifugal blower, is conveyed through the tue-iron which projects about 25 cm. through the back of the hearth. The tue-iron, or tuyere, is conical in shape, and water-cooled, to prevent it from burning away, owing to contact with the flame, and is erected at such a level that the hole for exit of air is about 10 to 15 cms. below the top edge of the hearth.

The amount of air entering the tuyere, can be regulated by a slide valve, in the pipe connecting the shop air-main and the tue-iron.

The accessories of the hearth are :

1. A water tank, conveniently placed near the forge, for quenching.

2. A coal box

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2. The data shown on this figure are taken from "Duckworth & Harris; The Laboratory Workshop"

3. A water tank, at the back for cooling the tue-iron
4. A poker (metal rod used in stirring the fire)
5. A coal slice (poker with a flat end)

A sheet iron cowl is placed above the top of the hearth, and should be fitted with a sheet-iron chimney of sufficient length to clear the smoke properly.

The hearth can be built up of bricks if this will prove to be more economical. However, in small shops, the metal hearth will be more satisfactory.

II. The Power Hammer

The power hammer is a very useful machine where heavy material has to be worked. It may be either steam or pneumatic. The latter has a distinct advantage in that it can be electric-motor driven, and is made in various sizes complete with motors in self-contained sets.

"Kent's Handbook" specifies a 3-cwt hammer as a handy size for a normal forge shop. In this hammer, the weight of moving parts is 3 cwts.

III. The Air Blast

Another feature which must be given careful considerations is the air-blast. If not properly designed, it may become a source of trouble.

A small smith's fire requires[3] about 1.30 m^3 of air a minute and a large one about 2.60 m^3, both against a pressure of 6.25 cm. to 25 cm. of water. Small fires with the blower close to

3. Data taken from Duckworth & Harris: "The Laboratory Workshop"

them work well with a pressure of 6.25 cm. of water; large fires will require a pressure of 12 cm. of water. Allowing for pipe friction, 2.9 m^3 per minute should be taken as the basis for the normal fire having a 1 1/4 inch tuyere pipe.

The main blast pipe is taken in a trench or in the open at the back of the hearths; it is of the same diameter as the outlet of the blower. The connection to each forge is usually by 1 1/4 inch pipe, tapped straight into the blast main; in the connecting pipe, the regulating slide is placed.

It should be noted that bends in the blast main should as far as possible, be avoided, especially where a centrifugal fan blower is used. The blast main should invariably be carried from 1.25 to 1.85 meters past the last fire.

IV. Smith's Tools

In the following article, some of the indispensable tools are listed. Part of this equipment is not shown on the plan merely because they are placed in the tool rack.

The anvil, is made of wrought iron or steel, with a double-shear steel top welded on and hardened. It is placed on a metal or timber anvil block, of such a height that the top of the anvil is about 60 cm. above floor level.

The small tools include : hammers, blacksmith's tongs, cold set, anvil cutter or hardie, hot set, fullers, flatter, set hammer, swages, swage block, collar swage, punches, drifts, smith's mandrel, and an adjustable support. Before starting the next chapter, the following suggestions given in Kent's Handbook are listed :

" A forge shop should be well lighted and ventilated. Smoke will normally be discharged by the cowls over the hearths, through separate sheet-iron chimneys, to the outside of the shop, in addition the roof should be provided with louvres or ventilating skylights to lead off the smoke. The floor should be of rammed earth mixed with ashes. The spaces between the forges and at the back of them may be in concrete on which to stand tools, surface plates, vices, etc..."

CHAPTER III

The Foundry

It is necessary to point out in connection with this chapter that patterns and patternmaking will be dealt with in the chapter on wood working. It is also helpful to expose some facts about moulder's work, because this is an important operation in foundry practice.

Iron moulding comprises four distinct branches:

1. Green sand, in which metal is cast in a damp mould. This is the normal practice with iron and for that it will be studied in detail.

2. Dry sand moulding implies that the mould is dried thoroughly before metal is run into it, and is employed where a fine surface is required and also for heavy jobs.

3. Loam moulding does not require a pattern in the ordinary sense, strickles and sweep boards are used with wet loam or straw. It is confined to symmetrical articles.

4. Chill casting is the process of casting metal in a metal mould; the quick-cooling action causes an intensely hard surface to be formed on the casting.

In green-sand moulding, the sand of which the moulds are made must be fine-grained, free from lumps, and of such a consistency that it holds together when damp. It must be infusible when in contact with molten metal, and the mould must be sufficiently porous to allow the gases formed by the metal in the mold to escape.

Sea sand is not suitable. A casting can be produced in almost any type of yellow-coloured sand which will hold together when damp and retain the shape of the pattern. If such sand cannot be found, the addition of a little clay will improve the adhesive properties of the sands which may be available.

The foundry floor is covered with sand to a depth of from 60 to 100 cm. It is used repeatedly for filling moulds. Floor sand constitutes the body of the mould, but the actual surfaces which come in contact with molten metal are made of "facing sand", which is the true moulding material.

The mixture of facing sand should be of the right consistency. A rough recipe for general small work in iron is given by Fred H. Colvin in his book: "Starting a small Machine Shop", and consists of six parts floor sand, four parts new sand, and one part coal dust. The ingredients are ground up and mixed together.

The foundry will consist of the following equipments:

1. A Cupola [1]: Figure 4 shows the design of the cupola. It is constructed of 10 mm (or 3/8") steel sheet, lined with 12 cm. fire-brick set in fireclay and mounted on a steel pedestal, the legs of which are set in concrete. The drop bottom is 10 mm steel sheet (3/8"). The tuveres, slag hole, tapping hole, running spout (let through the foundry wall) and coloured sight glasses are all indicated in the figure. The air blast for the cupola is provided by a blower which is generally of the centrifugal type.

The firebricks are laid in a good quality of fireclay which should be thoroughly mixed with water and thin enough to ensure close joints. The layer of bricks are bedded upon the clay grouting as quickly as possible, and as each brick is laid, it is

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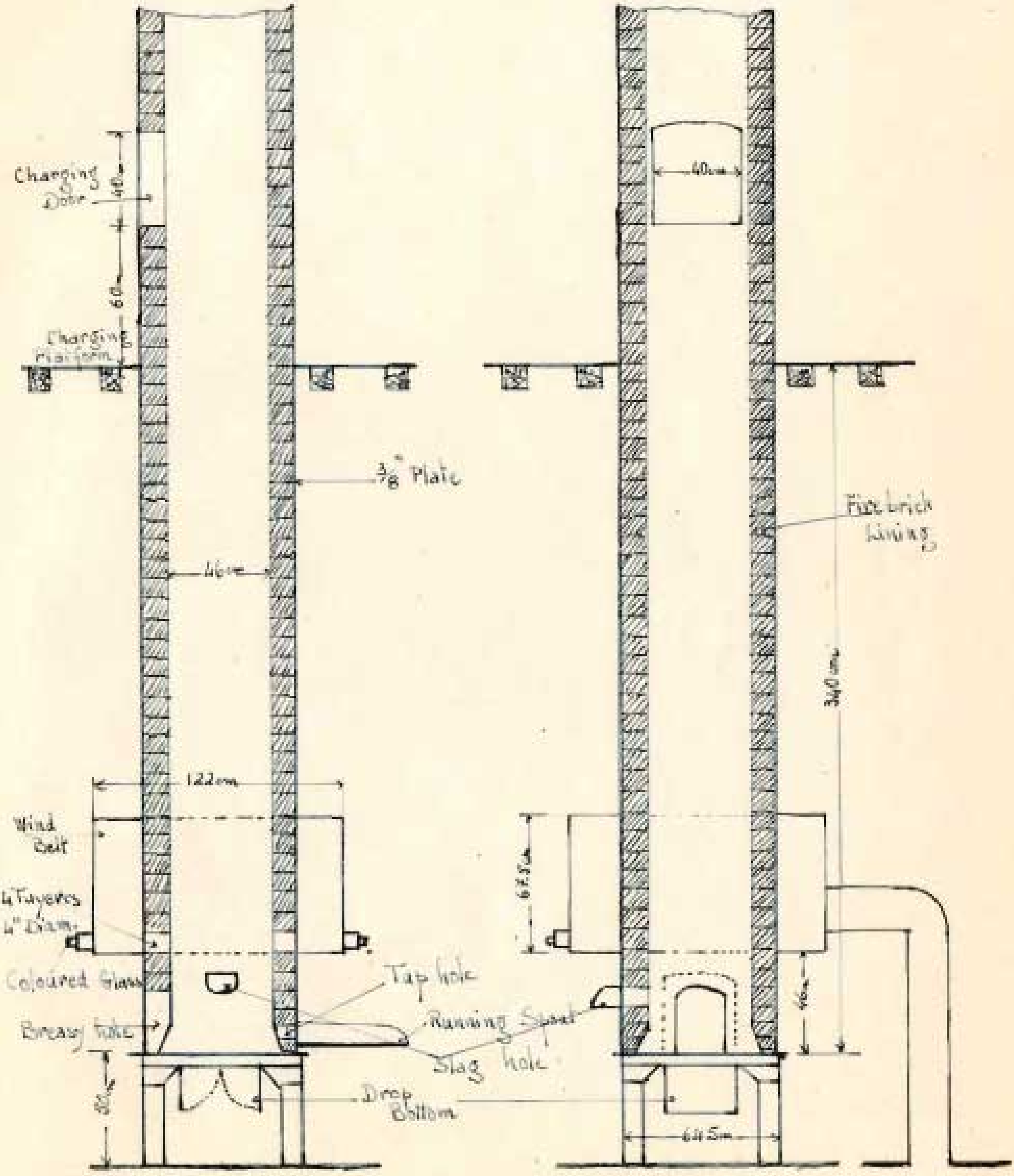
1. Data taken from "Textbook of Mechanical Engineering", official copy.

Figure 4

Cupola

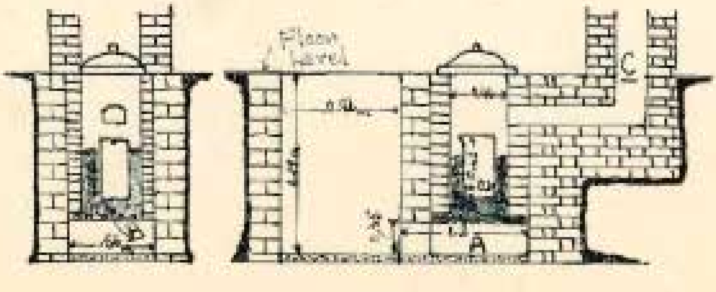


lightly tapped down with a hammer to ensure a solid bearing. A clearance of 1.25 cm to 1.80 cm is left between the bricks and the shell of the cupola. This space is filled with grouting made of about equal parts of fireclay and old firebricks ground together.

After the cupola has been lined, it is dried as slowly and completely as possible, otherwise the lining will be burnt much more by the first blow than need be the case. To carry out the drying, the drop doors are closed and covered with sand to a depth of 5 to 8 cm to prevent the heat from warping them. Wood is placed on the sand and a charge of coke or coal is added and the fire left to burn out.

After the drying out, the surface of the lining is given a thin coating of cement grouting made with fireclay. A handful of salt is placed in the pail of water used to wet the clay. This treatment will put a glaze on the face of the lining, which is very effective in resisting the burning effects of the first blow, which is always harder on the lining than subsequent blows. The shorter the first blow can be made the better, and care should be taken to keep the blast as mild as possible.

The cupola is placed outside the building, but is capable of being tapped from the inside. A labour-saving arrangement for handling pig-iron, scrap and coke, which should be stored near the cupola is shown in figure 6.



Crucible Furnace

Figure 5

In this case, vertical lift for charging is avoided.

2. A Brass Furnace:[2] The methods of using green sand are practically the same as in iron moulding. The green-sand method is the one usually adopted, and any yellow loamy sand, not too close in texture, is suitable, but no coal dust should be added. When a fine surface is required, about one-eighth of flour is sometimes mixed with the sand.

The fumes of molten brass are poisonous, and good ventilation is therefore essential.

Figure 5 shows a crucible furnace and is self-explanatory. The bricks are lined with fire-clay and preferably are fire-bricks. A is the ashpit, B the firebars, C a natural-draught flue.

Figure 6

Crucibles for brass work are very brittle, especially when damp. New crucibles should be heated up very gradually, near a furnace for 24 hours before use, to avoid cracking.

It is to be noted that portable oil-fired crucible furnaces can be obtained. The crucible furnace shown in the figure is, however, so easy to build that the heavy and expensive type is

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2. Specifications taken from "Textbook of Mechanical Engineering" Official copy.

not of much use to the foundry.

3. A drying-oven for moulds and cores: This is an essential part in the foundry. In making cores, the material is rammed up damp, clay-water being used to give the required cohesion. The cores are then baked in the core oven.

A design of a core oven is shown in figure 7. The drying-oven doors are flush with the wall, and the drying-oven built out as an annexe.

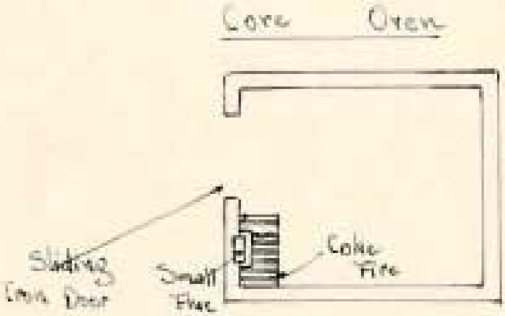

Figure 7

4. A core-maker's bench: Cores are used in a mould to prevent molten metal from flowing into places required to be hollow in the finished casting. They may be of any required shape. For this, a core-maker's bench is provided, and the necessary tools should be supplied.

5. A fettler's bench: Fettling consists of the removal of fins, runners, risers, and sand from the casting, and generally cleaning it up. The runners are sometimes hit off with a hammer, but when this is done care should be taken to see that the adjoining portions of the casting are not damaged. In the case of brass castings and thin iron castings the runners must be sawn off. The

burnt sand is removed by a wire brush or scaling tool, but a sand blast is preferable and is provided.

6. Emery wheel: The irregularities are chipped off or ground off on the emery wheel.

7. Sand mixer : To obtain a good composition of moulding sand, a sand-mixer is used and will prove to be of great help.

Castings should be delivered to the machine shop free from sand.When sand is embeded slightly in the surface, machining is extremely difficult.

CHAPTER IV

Metal Working Shop

Machine tools for working on metal are designed to perform the same operations as hand fitting. Strictly speaking, fitting is the operation of reducing accurately by manual work a rough casting, forging, or other piece of metal to the required shape and dimensions by the removal of the surplus metal, but the term covers various other operations such as assembling parts and adjustments to engines and machinery.

Machine tools fall into three main categories :-

1. Those employing tools with one cutting edge only. Examples are lathes,boring machines, planers, shapers, and slotters.

2. Those employing a series of cutting edges. These include all types of milling machines, broaches, drills, and reamers.

3. Grinding machines, using wheels of emery, carborundum,etc..

The practice followed in machine shops as for example the speed of metal removing or depth of cut, will not be studied in this chapter, because these facts have no influence on the lay-out itself and require a long discussion which is beyond the scope of this study.

In selecting the equipments of a machine shop, two facts are considered. First, the necessary tools are selected, and second, the machines using these different tools for the different operations on metal are considered.

The standard tools must include :[1]

1. A complete set of tools for mild steel
2. A complete set of tools for cast iron and tool steels
3. A complete set of tools for brass

The suggested equipment for a machine shop given by Fred H. Colvin in his book "Starting a small Machine Shop" includes:

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1. Taken from "Textbook on Mechanical Engineering", official copy

1. Drilling Machines: Bench - 1 high-speed (10,000 to 20,000 r.p.m.) for drills up to 1/8 or 3/16 in. One slower speed for drills up to 1/4 or 3/8 in.

Floor machine - capacity up to 1 or 1 1/2 in. holes

Portable motor drive - to carry 1/4 in. drills

2. Lathes : 8 to 12 in. swing. If two lathes, one 8 and one 16 in. One should have taper attachment. Motor driven tool post grinder (or tool block grinder) to be used on lathe, shaper, or milling machines.

3. Milling Machine : N: 1 or N: 2 universal, if possible, on account of variety of work it can handle, such as emergency gear cutting.

A Van Norman type machine with universal head is very useful. A bench-type miller is good for small work.

4. Shaper: An 18 or 24 in. stroke machine will handle a wide variety of work.

5. Planers: Open-side types as they can handle a much wider variety of work than the double housing type.

6. Slotters: Crank or hydraulic-driven. Some kinds of work can be done on either slotter or vertical miller.

7. Welding and cutting equipment: Should include both oxyacetylene and arc machines.

However, some of the machines listed above, will not be needed in a school shop equipment. For instance, slotters are mainly used for locomotive frame or similar work. Other operations requiring planers can be performed on an engine lathe. For that reason, the equipment as shown on the plan will consist of the following :

1. Bench lathe : The lathe should never face windows. For that reason it is placed at 45^{o} angle to windows. A clearance of 2 meters is allowed as shown on plan for feeding work through the head stock.

2. Engine lathe: The engine lathe is also placed at 45^{o} to windows. A clearance of 2 meters is also allowed for feeding work through the head stock.

The lathe is a machine tool designed originally for turning cylindrical work. A standard sliding, surfacing, and screw-cutting lathe can be used without any special attachments for:

a. Turning cylindrical work
b. Turning taper work
c. Boring cylindrical and taper work
d. Drilling, reaming, and tapping holes.
e. Formed work that can be cut with a formed tool.
f. Facing work that can be held on a face-plate or angle-plate.
g. Cutting screws internal and external of any desired form and pitch

Also with some special attachment, the lathe can be made to perform a wide variety of work.

3. Milling machine: This is one of the most important machines in the shop. It is placed at 45^{o} angle to windows. Chip guards are needed for safety.

Milling cutters operate upon the principle of the fly-cutter. A simple milling cutter is a cylinder having, upon its circumference a number of teeth, or cutting edges, upon one end of the cylinder. In operation, the cutter is made to revolve at a uniform speed. This motion produces the cutting action, so that the cutting speed is the product of the revolutions per minute and the circumference of the cutter.

Each edge of a circumferentially toothed cutter is in action during only a small portion of a revolution, and then completes the revolution freely, while the other teeth in succession are operating upon the work. In nearly all milling operations the work, i.e. the object which is being worked upon, is fed slowly and continuously towards the cutter, and in a direction opposite to that of the cutting movement of the teeth.

4. Tool Grinder: In fixing the position of the grinder, one important fact must be kept in mind. The grinder should never be located near finishing or polishing operations. On the other hand, it should have a good artificial light and for safety precautions, the grinder wheels must have guard.

Every grinding machine can be considered as a milling machine in which an abrasive wheel takes the place of a milling cutter. An abrasive wheel may be considered as a milling cutter in which, instead of a few steel cutting edges, many thousands of small cutting edges have been substituted, each consisting of the point of an exceedingly hard crystal, each crystal being embedded in a matrix, formed into the shape of the wheel.

In consequence of the small size of the cutting points, and, therefore, the small cut made by each one, very high cutting speeds are possible. The extreme hardness of the cutting points enables work to be carried out upon material which no steel tool could cut. Grinding is the only method of machining hardened steel.

5. The shaper: The machine is placed at 45^{o} angle to windows.

No other precautions need be considered. The ram on some shapers extends beyond the base of the machine on the back stroke.

Shapers are straight-line cutting machines in which the tool is moved to produce the cut, carried by a ram, which is driven by a rack and pinion or with reversing gear, giving a suitable forward speed for the cut and a quick return.

6. Drill Press: As shown on the plan, a clearance of 2 meters radius, 180°, for handling sheets and rods or ships is allowed for, around the drill press. On the other side of the machine, a clearance of 2.5 meters is left for the belt and motor adjustments.

In this machine, the drill is normally carried in a vertical revolving spindle, while the work rests on a horizontal table. There are two principal types:

a. Pillar drilling machines, in which the spindle is carried by a fixed arm, and can move vertically to feed the drill into the work, but has no lateral traverse.

b. Radial drilling machines, in which the spindle is carried by a saddle, which slides along a radial arm.

For light work, the first type is to be preferred because the radial type is heavy and expensive.

7. Power cut off saw: The distance from the wall is made 3.5 meters to allow enough clearance for stock feed. Plenty of work area is left for the operator. The machine itself is placed at 45° angle to windows.

8. Press brake or power shear: The power shear machine is allowed a clearance of 2 meters for handling sheets stock and is placed at 45° angle to windows.

9. The welding equipment consists of oxyacetylene and arc machines and is placed in a seperate room easily accessible from the metal working shop. In this case, the arc produced will not be a source of trouble in the main shop.

Having selected the machinery for the machine shop, the power to drive this machinery will be studied now.

The power required to drive any machine can be obtained from its maker, or failing that, an examination of the driving arrangements will usually afford sufficient guide. A rough rule given by Kent's Handbook is 1 H.P. per in. width of belt, for single leather belts up to 3 in. wide.

The power required for a given machine will depend on whether carbon steel or high-speed steel tools are to be used, and in the latter case also on whether the design of the machine will permit the tools to be used at their maximum cuts and speeds.

Small machines frequently do not allow for the maximum cuts with high-speed tools, the reason being that the work dealt with in these machines is usually too light to stand the strain.

The following table taken from the "Textbook of Mechanical Engineering" (official copy), gives suitable powers for various machines, the minima being for old-fashioned light machines using carbon steel tools, and the maxima for modern heavy duty machines with high-speed tools.

Lathes, 6-in centre	1 - 5	B.H.P.
Lathe, 12-in centre	2 -12	"
Planer, 2 feet X 2 feet	3 - 5	"
Planer, 5 feet X 5 feet	15 -20	"
Shaper, 12 in stroke	3 - 5	"

Sensitive drill, taking 1 in.diam.	1 - 2 BHP
Radial drill, taking 2 in.diam.	4 - 6 "
Cylindrical grinding machine, 8 in.swing	2 - 5 "
" " " 15 in.swing	5 -15 "
Surface grinding machine, 12 in.wheel	15 "

Although this table does not include the necessary information for all the machines selected, it is a fact that from it and from other considerations, the total maximum horse-power for all the metal working machines in the shop can be estimated.

CHAPTER V

Wood-working Shop

The woodworking shop has two important functions. In this shop are carried, first, the different operations on wood; and second the construction of patterns to be used in another part of the "Machine Shop Laboratory".

These two operations require the same equipment, but the presence of patterns makes it obvious that a pattern storage room is needed with some other accessories.

In the following paragraph, the different machines used in the woodworking shop will be considered and a brief description of their way of working will be given:

1. Circular Saw: The circular saw is located near the lumber rack. Lengthwise an allowance is made for cross-cutting long boards. Perpendicular to that direction, an allowance is made for ripping long boards.

The circular saw is secured to the revolving spindle of the saw bench by means of a nut. A steady-pin is provided to prevent the saw from revolving on the spindle. The saw has a central hole for the spindle to pass through, and a steady-pin hole. The spindle and steady-pin must be a good fit in their respective holes in the saw.

2. Band Saw : As shown on the plan, an allowance of 2 meters is made on one side and perpendicular to that, the path is kept clear to allow for big work.

Band saws have the advantage over circular saws in that they remove less wood; their relative thinness, however, leads to more frequent damage to their comparatively weak teeth. This machine can work with bands from 1/4 in. to 2 in. wide. The saw pulleys are faced with rubber tyres cemented to the rim. The top pulley can be adjusted by a screw, so that the saw can be made to run on any portion of the rim. The tension on the saw is obtained by a spiral spring. A handle varies the distance between centers, and enables saws of slightly different lengths to be used; this allows for breakages. A roller guide, adjustable for height, takes the thrust of the saw while cutting. The saw is guided through a wooden mouthpiece, but no packing is used. The table can be tilted for skew cutting. A brush, clears away chips from the rim. It is desirable also to fit wire guards over the top and bottom pulleys.

3. Scroll Saw: The wall should not be behind or to the left of the operator. No other allowances need be considered.

The scroll saw is used chiefly for cut-outs that cannot be made on band saws, and is much less costly than band saws. It is specially helpful for curved outline.

4. Wood Lathe: This machine is placed at 45^{o} angle to windows, and at a distance of 30 cm from the wall as shown on the plan. The light should come over the operator. The shop will contain two of these machines, due to the variety of work they can handle.

The lathe is an exceedingly versatile machine, turning rounds and polygonal sections in almost every conceivable combination. Cutter knives are mounted on a cutter spindle or arbor in the rear, and revolve at high speed. All knives are mounted on the arbor whether for square, round or hexagon cuts.

5. Grinder: No precautions need be taken in locating the grinder. Other machines may be close to it on either side.

The wood grinder is similar to the metal grinder in its way of construction. But here, the abrasive wheel need not be made of as hard a material as for metal work. Wheel guards are a safety precaution and should be used if possible.

6. Shaper: It is one of the oldest types of machines. It is still important in woodworking although many of its functions have been absorbed by more specialized machines. As shown on the plan, the path running from left to right of the operator, across the machine, is kept clear. An allowance of 2 meters is made beyond, to the left and right of the operator.

The shaper consists essentially of a large flat metal table with a vertical spindle, driven from below, extending up through the center of the table. Revolving cutter heads, mounted on the end of the spindle, accomodate a variety of knives for a wide range of cuts. Solid heads may be mounted for long runs. The shaper is especially useful in re-entrant curves, octagons and other odd contours not suited to machines designed for rectilinear or circular cutting. Small moulding, flutings, both straight and curved, and many edge and end cuts can be made on a shaper.

7. Jointer: The jointer should be located near the circular saw. Lengthwise an allowance is made for long work. The machine is placed at a distance of 1 meter,at least, from the wall.

The cutting mechanism of a jointer consists of a cutting head which revolves at a high-speed. Edged jointing is the predominant function of the jointer. The jointer is provided with a high fence to permit it both to square and true the edge.

8. Drill Press: In locating the drill press, care is taken to allow a clearance of 1 meter on both sides of the machine for long work

The lamp is placed over the machine and to the left of the operator.

The drill press is similar to that used for metalworking. It consists of a drill which is carried in a vertical revolving spindle, while the work rests on a horizontal table.

9. Belt Sander: An allowance of 2 meters in both directions is made for long work. The daylight should come from beyond the operator and to his left.

10. Disc Sander: Here also the light comes from beyond and to the left of the operator. An allowance of 1 meter is made at the right and at front, supposing that the sander runs clockwise.

The sanders are used in finishing operations. They give to the wood a smooth surface. The belt sander has a 6 to 8 in. endless sandpaper belt running clockwise on two 18-in. pulleys. In the overhead type the work table, moving on ways toward and away from the operator, is below the lower belt, and the smooth side of the paper is against the pulley. The work is held on the table by stops at the left and an edge clamp at the right.

The machines listed above form the equipment of the woodworking shop. Small tools which were not described and which are indispensable in the shop will be placed on racks or shelves.

In connection with this chapter, some paragraphs will be devoted to wood preservation.

Preservatives that lengthen the life of wood exposed to decay or attack by insects or marine borers are:

1. Preservatives of an oily nature, relatively insoluble in water

2. Salts injected into wood in water solutions.

3. Toxic constituents in a volatile solution other than water
4. Fire retardent wood treatments

An intelligent selection for a particular service greatly prolongs usefulness of wood, with excellent ultimate economy.

When natural or mechanical seasoning is impracticable, green timber is pre-conditioned. This consists in placing the wood in ovens for a certain time. In this case, the drying oven of the foundry can be used satisfactorily.

CHAPTER VI

Machine Foundations

Generally, foundations are used to distribute the weight of a structure on a larger area and thus prevent the ground from yielding.

It is of course true that no ground can be found so absolutely solid as not to yield somewhat when the weight of the structure is put upon it, and, therefore, we must not expect to wholly prevent a certain amount of settling, but we should use all possible care to have this settling as equal as possible over the whole of the foundation.

In the case of the foundations for machinery, the question is quite different. Here not only the weight must be sustained but the question is complicated by the jars, strains, and shocks due to the operation of the machines; and this must also be considered. These vary largely in different cases, as for instance, the steady revolutions of an engine lathe, the reciprocating motion of an engine and the vertical concussions of the steam hammer.

In other words, all machines when at work, have unbalanced forces which tend to give them either vertical or horizontal movements. Foundations are required in order to restrain this movement. Usually the size of the foundation is determined by the manufacturers of the machines from their knowledge of the unbalanced forces and, to a certain extent, by experience. Consequently, the maker's foundation plans should be required and carefully worked to.

The fact that the unbalanced forces within the horizontal machine are usually greater in the horizontal direction makes it obvious that great care has to be taken to get a good solid foundation block, but although the vertical machine produces less strain on the foundations, it is equally important to have the same solidity and homogeneity.

An insufficient foundation is usually a continual source of trouble, which, if not remedied, eventually results in costly repairs to the machine. Also, in addition to the risk of unequal settlement and fracture of the foundation block, there is always the danger of excessive vibration being set up in the surrounding soil, which may cause damage or annoyance, and which constitutes a public nuisance.

As to the choice of material, a reinforced concrete block is best for foundations and is preferable to ordinary building bricks which were used very often before. The best quality concrete should be used. Also before deciding on the dimensions of the foundations, the nature of the soil should always be considered.

The method of constructing the machine foundations which is generally followed will be described now.[1] The necessary excavation having been made, the position of the holding-down bolts is located by means of square wooden boxes, large enough to enable the holding-down bolts and plates to be put into position after the concrete has set and the boxes removed.

The boxes should be attached to a template to prevent any movement while ramming in the concrete. Depth of bolt holes should be sufficient to allow bolt to drop in, to clear the top of the bed. Thin wires are attached to the threaded portions of the bolts and then

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1. Description taken from "Textbook of Mechanical Engineering", official copy

passed through the holes in the machine bed. The bolts may then be pulled through when bed is in position. All bolts must hang vertically.

For machines not liable to severe vibrations in a vertical direction, it is satisfactory to use boxes with parallel sides. Provided the concrete is cleaned and roughened after removing the boxes, the parallel sided plug of cement formed by grouting in the bolts will hold firmly.

As an additional safeguard in the case of machines subject to severe vertical vibration, the boxes may be tapered, the larger end being downwards. The construction of the tapered boxes is shown in figure 8. Provided the width at the bottom is not greater than the diagonal of the top opening, with due allowance for the thickness of the boards, the sides can be knocked inwards, twisted to the diagonal position and withdrawn. The proportions shown provide the necessary clearance.

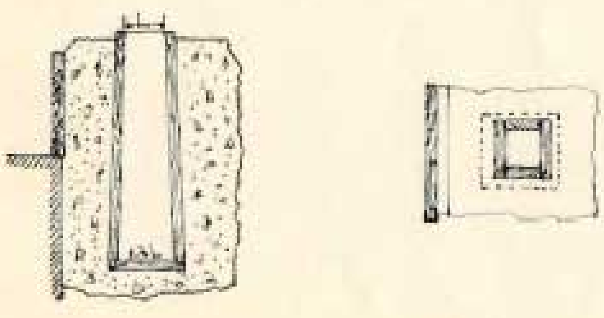


Fig. 8- Foundation Block
Showing both bolt & boxes

The boxes should be greased or soaped on the outside to prevent them from sticking to the concrete. They should rest on a block of wood (which can be left in the foundation) to prevent the concrete rising up in the box.

The concrete can now be put in and well rammed in the usual way. When the foundation is completed, several days or weeks should elapse before placing any heavy weight on it, so that it may be set uniformly. The bolt boxes, however, should be removed immediately; the concrete has set sufficiently to stand.

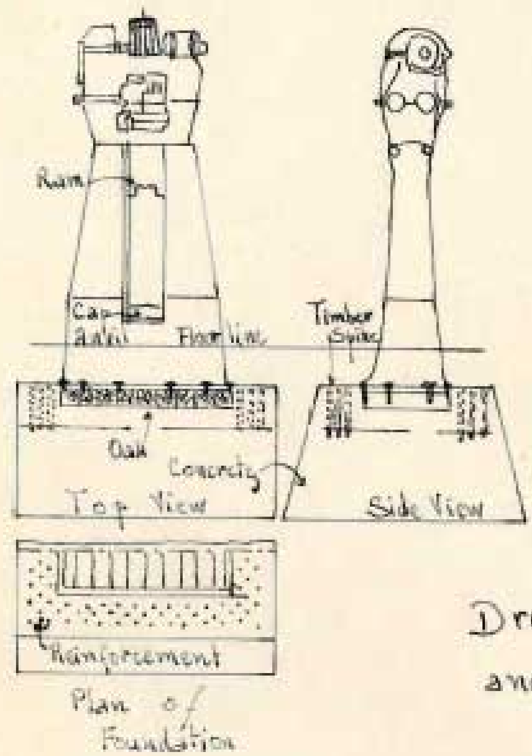
Then the holding-down bolts and plates can be placed in position, and the machine put on its foundation. The machine must then be carefully levelled up by inserting thin iron wedges under the bed, using a spirit level. The nusts can be screwed on the bolts, and the bolt-holes should then be filled with a grouting of one part cement and two parts sand, being made thin so that it flows easily.

Foundations for machines subject to considerable vertical shocks, such as steam hammers, and the like, must be treated in an entirely different manner. Such a foundation, unless properly made, would soon be spoiled by cracks and disintigration from the shocks, and serious consequences to the machine might ensue.

Typical drop-hammer foundation(2) is shown in Figure 9

2.Given in Kent's "Mechanical Engineer's Handbook

Figure 9



Drop hammer and Foundation

CHAPTER VII

Vibration & Noise Control

With this chapter, it is important to state that the methods of reducing vibration and noise are given the prime importance. The measurements and the experiments accomplished on vibration and noise are beyond the scope of this study. Nevertheless, the necessary definitions for the understanding of the remaining part will be given.

I. Vibration Prevention :

Of the several methods of attack in vibration reduction, the particular method or methods adopted depend on the individual problem. Briefly these methods are:

1. Removal of exciting cause- This, when possible, is most satisfactory. Unbalance in rotating machinery is a common source of trouble. In rigid rotors it can be almost completely eliminated by balance weights. Gear tooth frequency noise is best avoided by precision in manufacture.

2. Tuning is applicable only when vibration is distinctly of resonant type. Resonant vibrations usually are excited by a relatively small stimulus, which happens to be in step with a natural vibration frequency. The tuning of steam turbine wheels is an example, also the avoidance of shaft critical speeds through selection of proper diameter at the operating speed.

3. Elastic suspension: The function of elastic suspension is to isolate a powerful forced vibration so that it cannot be transmitted beyond the vibrating piece of apparatus. This is not a friction damping process. Springs do not absorb vibrations through damping, but are often a very effective means of preventing transmission.

Elastic suspension methods are much used to suspend noisy machinery, etc.., but there is still much guesswork in thier application. An incorrectly designed elastic suspension may do more harm than good. The design of a good suspension is not always an easy matter and often requires knowledge of vibration principles as well as experience.

4. Damping, or reduction of vibration amplitude through action of friction, is a cure for resonant vibrations only. Forced vibrations are apt to result from powerful exciting forces which are not much reduced by application of friction devices. Shock absorbers used in vehicle suspension are typical friction dampers which limit the amplitude of resonant vibrations excited by road irregularities.

In general some machinery can be isolated by mounting on a comparatively flexible floor frame, elastically supported on the solid floor below. This prevents the transmission of rumbles, grinding noises and hums through the building, to radiate sound from panels. Springs or rubber pad suspensions used at intervals of about 30 cm., depending on the floor load, will perform well, steel being more permanent. The flooring should yield perceptibly, say 0.25 cm. under machinery load.

Machinery requiring exact alignment, as an accurate lathe, cannot be placed directly on a flexible floor, but must be set on a rigid, spring-supported platform.

II. Noise Control:

Noise control is meaningful only in its relation to people. Sound together with heat and light, is one of the basic physical phenomena that determines the environment in which we live.

Human being has remarkable properties of adaptation and the question is not how much noise can we stand, but rather how much should we be expected to tolerate or find normally acceptable under a particular circumstance. Given adequate motivation, we can tolerate almost anything, within very wide limits. But beyond some reasonable limit we must exert excessive compensatory effort.

Before proceeding with this discussion it is necessary to define here some terms used in that article.

Decibel: a logarithmic unit expressing the ratio of two quantities, or the magnitude of one quantity with respect to a specified reference magnitude. The decibel by itself is not an absolute measure of anything unless associated with a particular quantity and a particular reference.

Intensity: the amount of sound energy falling on a unit area per unit time, represented by I

Intensity level: is given by $IL = 10 \log I/10^{-16}$

Transmission coefficient: (τ): the fraction of incident energy that is transmitted through a barrier (wall, floor, window, etc..)

Transmission loss: (TL) in decibels : $TL = 10 \log (1/\tau)$

Noise reduction: (N.R.) in decibels $NR = 10 \log (I_1/I_2)$

$= IL_1 - IL_2$

is the difference in sound level between two spaces or conditions.

Briefly, the effects of noise on people can be divided into three general classes: (a) Physiological effects, (b) damage, and (c) psychological effects. Even these three are not completely independent of each other.

When we increase the noise levels about 130 db., damage to our hearing mechanism occurs. Prolonged high levels bring on permanent deafness. Noise from machinery varies with power, speed, type of mechanism, mounting and even the state of repair.

Noise control in buildings is achieved by means of (1) proper planning, to segregate sounds, (2) proper design and detailing of structures, to block effectively the passage of sounds, and (3) proper utilization of finishes and furnishings to absorb sound. Segregation reduces noise by putting the source farther away; insulation reduces noise by presenting a barrier against its passage, and absorption reduces noise by draining off sound energy. These three techniques are based on distinctly different physical principles.

Sound is transmitted through a wall by air pressure oscillations produced on its farther side by leakage, or more commonly, by oscillations produced by vibrations of the wall itself. This latter phenomenon usually occurs regardless of the presence of the former.

In general the transmission loss (TL) increases as the barrier becomes heavier and more complex, as shown in figure 10.

Unfortunately the cost also generally increases, so that economic compromises often become necessary.

The conclusion is that we need for the "Machine Shop Laboratory" walls of low transmissibility. A double wall is more desirable than a single wall, being cheaper and less massive for the same transmission loss. A comparatively rigid skeleton of ordinary 5 X 10 cm. studding should be used, with inner and outer walls hung from it by spring connections. These walls are generally made of celotex or similar material. A thin layer of plaster-like reinforcement

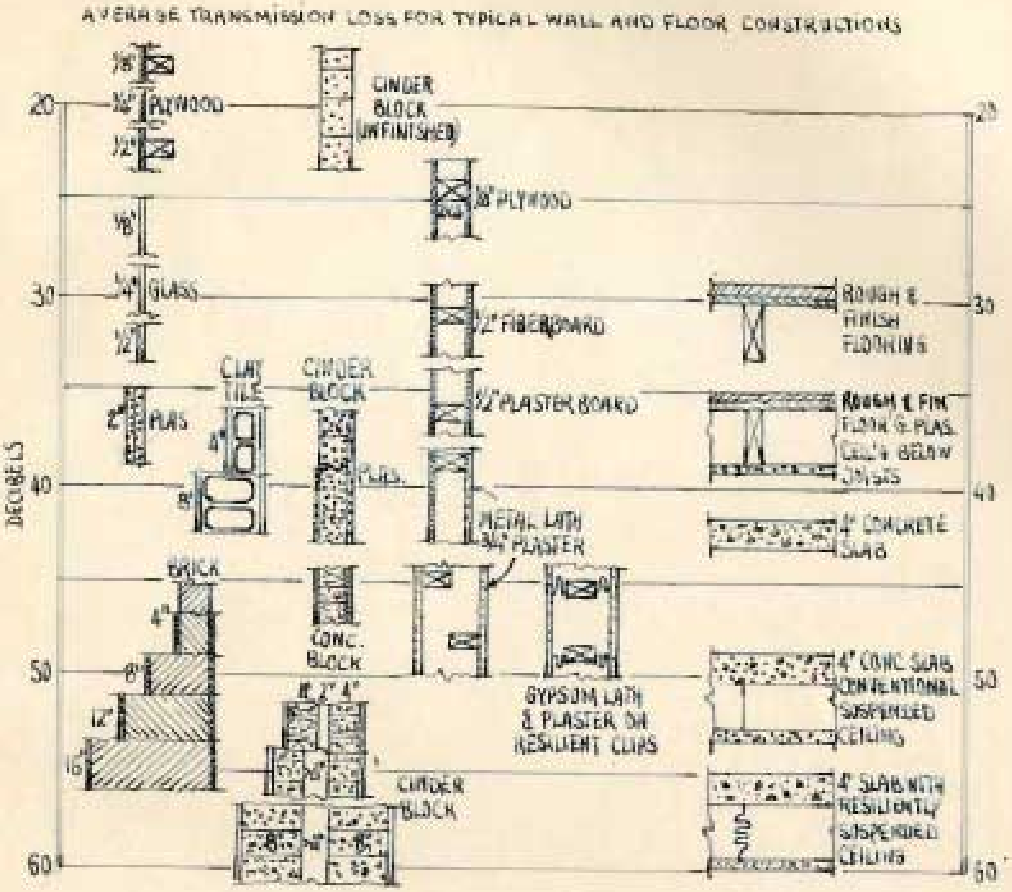
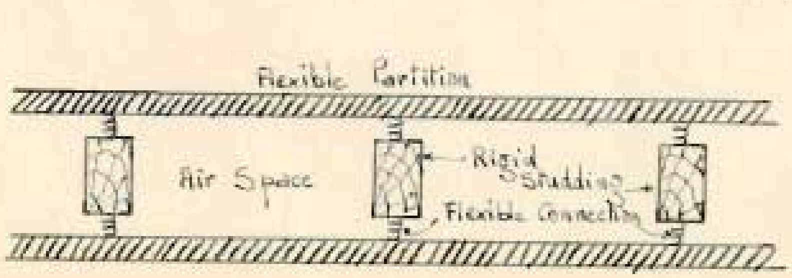


Figure 10

is helpful. Besides adding mass, it decreases porosity, which is an advantage. The celotex may be reinforced by thin sheet iron. Sheet iron must not be used without celotex, as it is subject to resonances.

Spring connectors eliminate the bridging effect of studding, which results when the walls are directly nailed to it.



Wall construction of low Transmissibility

Figure 11

Such a wall has an air space of about 12.5 cm., which is fair spacing.

This kind of wall is less expensive than a heavy masonry wall and has an advantage over it, in that it has a greater effect on resonances.

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