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Organ, §II: Construction

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II. Construction

There are three main parts to the construction of an organ: the wind-raising device, the chest with its pipes, and the (keyboard and valve) mechanism admitting wind to the pipes. These three parts are common to any pipe organ; it is in their precise nature that essential differences lie – from the small hydraulic organ of the 3rd century BCE; to the monster electric organ of the 1920s. At different points in history builders have tended to develop different parts of the instrument, while at other times (*c*1400 and *c*1850) all parts saw intense development.

1. Hydraulic organ.

Said to have been invented by the Alexandrian engineer Ctesibius, this most primitive form of organ, which was known from Greco-Roman times through numerous descriptions and iconography, differed from later versions in that the wind supply to the pipes was regulated by water-pressure rather than by weighted bellows. The number of pipes and compass of keys were small, and it was frequently used outdoors, and in various secular ceremonial functions. For a full discussion and illustrations of its construction, *see* **HYDRAULIS** and see also §IV, 1 below. It is not to be confused with the later **WATER ORGAN**, a normal pneumatic organ in which the bellows were operated by water power.

2. A medieval chest.

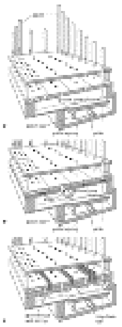
Fig.1 [not available online] shows how in Theophilus's organ (11th century) the wind, raised by two or more bellows operated by the blowers' body-weight, is admitted to the several ranks of pipes when a perforated hand-slider is pulled out until its hole is aligned with the vertical channel between the wind-chest and the pipe-foot; to obtain a 'clean' sound, the slider must be operated as quickly as possible. To stop the sound, the slider is pushed back. The whole chest could be made of wood or moulded metal.

Other medieval chests differed significantly. According to the description in the Berne Codex (11th century), the wind did not pass to the two ranks of pipes from one duct but each pipe had its own duct from the wind-chamber below; thus the hand-slider required as many holes to be aligned as there were ranks. Also the 'key' was (like that of the hydraulis) a pivoted square which, when depressed, would push the slider into sounding position, while a spring pulled it back afterwards to its blocking position. Early medieval positives and portatives probably worked by one or other of such systems, which do not of themselves presuppose any particular size.

3. A positive (or chamber) organ action.

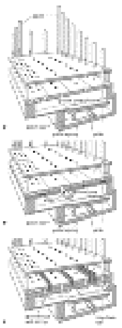
In the ‘pin action’ portrayed in fig.2 [not available online], wind accumulated in the lower chamber or pallet box is admitted to each upper chamber or groove when the corresponding key depresses the hinged pallet. The new, crucial device in this system is the pallet and its groove or channel, both of unknown origin, although well established by the 14th century. The effectiveness and versatility of the resulting chest construction promoted the development of the Renaissance organ. In theory and (many organists and builders believe) in practice, the grooved or ‘barred’ chest facilitates tonal blend between the several pipes belonging to each key. Later medieval positives probably had a similar action, in most cases to fewer (and often sliderless) ranks of pipes; later medieval portatives also probably worked from a similar (though simpler and more compact) pin action, whatever the shape and size of the keys.

4. Details of medieval and Renaissance chests.



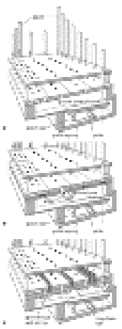
Medieval and Renaissance chests: (a) medieval block-chest; (b) ?late 15th-century…

Fig.3*a* shows a medieval block-chest (or **BLOCKWERK**): the opened pallet admits wind to all the pipes on one groove or channel (i.e. all those belonging to one key) and the player is unable to separate the ranks of pipes. To obtain variety of sound some organs had grooves divided into two parts, each with its own pallet; each resulting ‘half-chest’ could have its wind blocked off with a valve somewhere between bellows and pallet box, though in practice the front half-chest (whose pipes were those of the case front or Open and perhaps Stopped Diapasons) played all the time. Each key in such a double chest operated two pallets. The reliability and wind-saving virtues of this system gave it some popularity in the Netherlands during the 15th century.



Medieval and Renaissance chests: (a) medieval block-chest; (b) ?late 15th-century…

In the slider-chest (? late 15th century) shown in **fig.3*b***, the opened pallet admits wind to each single or multi-rank ‘stop’ by means of a perforated slip of wood (‘slider’) running longitudinally in the board between the pipe-foot and the groove on the upper level of the chest. The slider can be aligned either to allow wind to pass through (‘stop drawn’) or to prevent it passing through (‘stop pushed in’). By means of rods, trundles and levers, the sliders can also be operated by a ‘stop-knob’ near the player (below and in front of the chest itself). Sliders were known first in small organs, perhaps as early as 1400, but were not much used in larger ones (or the larger departments of two-manual organs) until the 16th century.



Medieval and Renaissance chests: (a) medieval block-chest; (b) ?late 15th-century…

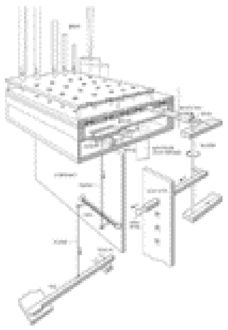
Fig.3*c* shows a spring-chest (early 16th century) in which the opened pallet admits wind to each single or multi-rank stop by means of a secondary pallet or ‘groove-valve’ for each, which is operated by the stop-lever bar. The spring acting on the secondary pallet also causes the bar to spring back to the ‘off’ position unless prevented (i.e. unless the player notches the stop-lever at the keyboard into the ‘on’ position).

Other spring-chests differed significantly. Many Italian ones from the late 15th century onwards had their secondary pallets placed vertically rather than horizontally, with the result that the bar moved horizontally. Because brass springs lose their flexibility in time, some builders in 16th-century Italy and 17th-century Germany designed the chest so that all the secondary pallets belonging to one groove could on occasion be pulled out in one strip (looking like a long, narrow drawer) and the faulty spring replaced without dismantling the pallet box.

The spring-chest is troublesome to make, as 17th-century theorists such as Mersenne and Werckmeister noted; it also takes up more room than a slider-chest. But it is said that spring-chests last longer, and (although no results of controlled experiments have been published) cause the pipes to speak better. Since there could be no loss of wind through shrinking or warping of sliders, spring-chests probably contributed to greater stability of tuning, although their complexity would be likely to make them more sensitive to the extremes of humidity and dryness found in modern, centrally heated churches. While the spaciousness of the chests dictated by the spatial requirements of the 'groove-valves' makes pipes and action more accessible for tuning and repair, it also requires that the main key pallets be made larger, making the touch heavier and less sensitive than that of slider-chest organs. This may be why the spring-chest was abandoned in the north, where higher wind pressures complicated this situation.

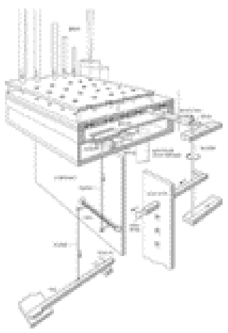
5. Mechanical action.

Fig.4 [not available online] depicts the side and front elevation of a single-manual organ with suspended action. Organs of this simple construction have been built since at least the 15th century; larger and more sophisticated instruments of this type were being built in Spain, Italy and Central America as late as the 19th century, and there was a revival in the use of this action during the late 20th century.


Key- and stop-mechanism of a single-manual organ with suspended action

In this action, shown in exploded detail in fig.5, all motion is in the same (downward) direction. A tracker attached to the centre of a key which is hinged at the back end descends when the key is depressed. As the width of the chest is greater than that of the keyboard, the action is intercepted by a roller, which transfers the motion horizontally to another tracker, which in turn pulls down the pallet in the chest, admitting wind to the groove under the pipe. Very small or very primitive organs can be found in which the rollerboard is eliminated and the trackers simply fanned or splayed to correct the discrepancy between key-scale and chest-scale.

Fig.6 [not available online] depicts the so-called balanced action which originated in north-western Europe in the 17th century, was adopted in England shortly before the beginning of the 18th century and was widely used in the 19th century. This action, which allows for more flexibility in the location and number of chests, involves a transfer of motion direction. Fig.6*a* [not available online] illustrates how the key, when depressed, pushes up one end of the balanced backfall, causing the opposite end to descend, pulling down the tracker attached to the pallet; in this simple arrangement the backfalls must be splayed to compensate for the difference between key-scale and chest-scale, but it is also possible for them to remain key-scale and communicate with a rollerboard, as shown in fig.6*b* [not available online]. Fig.6*c* [not available online] shows another variant (illustrated here in the pedal department, although the mechanism may also be applied to the manuals) in which motion is transferred by means of a rocking square.


Key- and stop-mechanism of a single-manual organ with suspended action

Regardless of the type of key action (suspended or balanced), the stop action usually operates in the manner depicted in fig.5. The stop-knob is attached to a rod which is attached either to a rotating trundle (as shown), or, by means of squares, to a rocking arm, which in turn draws or retires the slider associated with a particular rank of pipes on the chest.

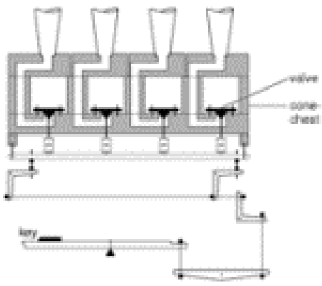
6. A north European organ.

Fig.7 shows a four-manual instrument in cross-section; only a selection of pipe-ranks is indicated. In this design, the pedal-chests may be to the left and right of the main case or (with less immediacy of sound) behind it. The space between bench and Chair Organ was often enlarged in Roman Catholic countries to accommodate a choir and orchestra; special stops (cornet), chests (echo chests), and toy stops could be conducted off the main wind-trunks; one or more departments could be enclosed in a Swell box; Tremulants could be fixed in the main trunk, a subsidiary department trunk, or the trunk of an isolated stop (*see* **TREMULANT**).

7. Barker-lever action.

Fig.8 illustrates the principles of a mechanism invented in the mid-19th century by **CHARLES SPACKMAN BARKER** and constantly redesigned and patented by countless other builders. When a key is depressed, air under pressure from the main bellows is admitted through a pallet-like valve to inflate small bellows (one for each key) which, in moving, travel sufficiently to pull a tracker connected with the pipe-chest pallet. On release the exhaust valve at the top allows the small bellows to deflate immediately. In this way, average light finger pressure on the key brings into play a wind-power sufficient to operate pallets at some distance from the player, especially those of large-scale pipes and on chests working under high wind pressure (e.g. Solo organ). The pneumatic unit, or 'Barker lever', is placed inside the organ, near the keyboard, at a point where the tracker rises vertically from the keys and merely intercepts an otherwise traditional mechanical action. Perhaps one of its most important applications is to inter-manual couplers, allowing additional manuals to be coupled to the main manual without significantly increasing key resistance. This type of assisted action was used extensively in France during the second half of the 19th century, and generally used for larger organs in the USA and Britain during the same period.

8. Cone-chest



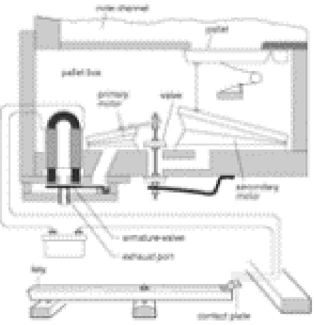
Cone-chest, mid-19th century

(*Kegellade*). The cone-chest, or ventil-chest with cone-shaped valves, is found particularly in 19th-century German organs (fig.9 [not available online] shows a mid-century example) and was one of several chests developed between 1775 and 1875 in the interests of mechanical reliability. Though bulky, the cone-chest avoided some of the faults to which a working slider-chest was subject, but was more inclined to be affected by extremes of humidity. In the cone-chest all the pipes belonging to a rank are mounted on one channel running the length of the chest; to the whole of this channel wind is admitted when the stop-knob is drawn. There are no lateral key-channels or grooves in such 'barless chests'. Each key activates a series of cone-shaped valves, one for each pipe; thus although only one stop may be required by the organist, all the other valves move. The valves need not be cone-shaped; they may even be replaced by little discs operated by small bellows-like pneumatic motors.

9. Tubular-pneumatic action.

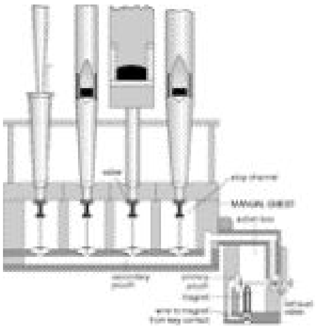
This type of action, shown in fig.10 [not available online], was developed in the late 19th century, and could be applied either to slider-chests or to the newer individual pipe-valve chests. Two forms of tubular-pneumatic action are illustrated here: in fig.10*a* [not available online], when a key is depressed, air under pressure in the touch-box above the key is admitted along the lead or copper tubing to the bellows-like 'primary' pneumatic motor which opens, forcing a valve to rise (hence the name 'pressure-pneumatic action'). This in turn releases air from the pallet box that was held under a secondary motor. The secondary motor collapses under pressure from the wind in the pallet box, pulling open the pallet. 'Exhaust-pneumatic action' (shown in fig.10*b* [not available online]) is that in which the air under pressure is contained in a box underneath the pipe-chest pallet box, pushing the pallet shut via the secondary motor when at rest; when depressed, the key opens a valve that allows this wind to escape along the lead tubing away from the pallet, collapsing the primary and secondary motors, thus pulling open the pallet. Pressure-pneumatic action never became popular in France, and in England and North America many builders preferred exhaust-pneumatic, believing it to be more prompt, silent and durable. Tubular-pneumatic action continued to be extensively used by builders in Australia and New Zealand until the 1940s.

10. Electric actions.



Electro-pneumatic action as applied to a slider-chest

From the final years of the 19th century to the middle of the 20th century, electricity was used in a variety of ways by different organ builders and in different countries. The basic premise is that the key (or stop control) closes a switch which sends a low-voltage impulse to a mechanism in the chest. One of the simplest forms, utilizing the traditional slider-chest, is shown in fig.11 [not available online]. An electro-magnet is activated when the key is depressed and its circuit completed. The armature acts as a valve, rising to the magnet and thus allowing the wind to escape from the primary pneumatic motor (previously filled with wind from the pallet box) which in turn collapses, opening the port below the secondary pneumatic motor and thus allowing its wind to escape. On collapsing, the secondary motor pulls down the pallet. On the release of the key, the circuit is broken, the magnet drops the armature valve and wind is restored to the small pneumatic motor, while the external spring closes the port under the main pneumatic motor which inflates and, assisted by the pallet spring, pushes up the pallet.



Simple type of ventil chest, with individual pipe-valves

Electric action is most commonly used in conjunction with various types of 'individual pipe-valve' chests, in which there is a separate valve for each pipe. An early type, also used in conjunction with tubular-pneumatic action, is the ventil chest (fig.12). In this chest, also called a 'membrane chest', channels isolate the stops, and a stop is activated by releasing wind into its channel. Felt and leather discs attched to thin leather pneumatic pouches replace the larger wedge-shaped pneumatic motors, since less effort is required to open a small pipe-valve. The electro-magnet is activated by an impulse from the key, exhausting a small channel to the primary pouch. This is pushed in by pressure in the action-box, pulling open a larger exhaust port; this in turn causes the valves under the pipes for a given note to be pulled open, admitting wind from the stop-channels into the pipes.

More complex but very efficient is the so-called 'pitman' chest, particularly popular in America, which uses a similar principle to open the pipe-valves. Other kinds of electric action include the Austin type, in which a trace attached to a single pneumatic motor opens all pipe-valves of a given note that have not been disengaged by the stop mechanism, and the 'direct electric' or 'electro-mechanical' type, in which each pipe-valve has its own magnet, directly energized by the key contact, and stop-control is by means of switching mechanisms. For detailed diagrams and descriptions of various chest actions and other electrical mechanisms, see Audsley (B1905), W. and T. Lewis (B1911), Whitworth (B1930) or W.H. Barnes (D(xxxv)1930). Electric actions allow divisions of the organ to be separated and the console to be placed at a distance from the pipes if required. Since electricity takes the place of a direct mechanical connection, however, control over pipe-speech is sacrificed.

11. Wind supply.

(i) A medieval bellows.

In fig.13, derived from Theophilus's organ (see §II, 2 above), air is fed in turn by three 'feeder bellows' through channels meeting inside the *conflatorium* to make one central duct (the inner construction is shown with dotted lines); before the channels meet, the wind passes through a copper valve which flaps open as the bellows send out air and flaps closed as soon as they are emptied. The collected wind is then directed along a trunk curving up to the pipe-chest. There may be more than one *conflatorium*, and the bellows can be in pairs or larger sets.

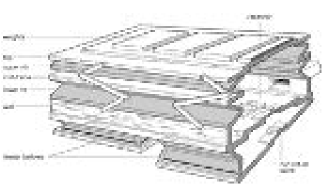
(ii) Wedge-bellows.

The late medieval bellows (Ger. *Spanbalg*) was wedge-shaped, consisting of upper (movable) and lower (fixed) boards hinged at one end, and wooden ribs hinged with leather. They could be of any size, depending on the size of the organ. They could be single-fold (fig.14*a* [not available online]) or multifold (14*b* [not available online]); during the 17th and 18th centuries the former was favoured in northern European countries, and the latter in France and southern European countries. The number of bellows in an organ varied with the size, from the small single-bellows portative to large cathedral organs with eight or more; the average church organ usually had two to four. Methods of operation varied, but all were based on the principle of mechanically raising the weighted upper board of the bellows and then allowing it to 'rest on the wind'; by the time one bellows had been exhausted, another would have been filled, thus assuring a continuous supply. A system of one-way check-valves allowed only the filled bellows to deliver wind to the wind-chests of the organ.

The commonest means of filling the bellows were either by treading (hence the German term *Balgetreter*) on one end of a lever which pushed up the upper board (fig.14*a* [not available online]), or by pulling down on a lever which pulled up the upper board (fig.14*b* [not available online]). In some instances, especially if the bellows were located above the organ, a system of ropes and pulleys was employed, but in all cases the motive power was the organ-blower's body weight and muscle. Small or medium-sized instruments could be blown by a single person, but larger ones often required several.

(iii) Reservoir and feeder-bellows.

The wedge-bellows system was universally in use until the 18th century. Although effective, it was bulky, because a minimum of two bellows was needed to provide an uninterrupted supply of wind to the chests of the organ, and even in quite small organs a separate person was required to operate them. Early in 18th-century England a more compact arrangement appeared, perhaps orginally devised for chamber organs, in which a single wedge-bellows affixed to the underside of a board fed wind into a second, weighted wedge-bellows above, which in turn delivered it to the wind-chest. Continuous operation of the lower (feeder) bellows assured that the upper (reservoir) bellows would always contain sufficient wind. In chamber organs, this allowed the player to provide the wind by operating a foot-lever connected to the feeder-bellows; when applied to larger organs, the feeder would still have to be operated by a second person.



Reservoir and feeder-bellows

An improvement on this system was the replacement, in the late 18th century, of the upper wedge (reservoir) with a horizontal reservoir having usually two sets of ribs with a floating-frame between, expandable on all four sides, which afforded greater capacity within the same space and allowed the entire wind-supply system to be located in the base of the organ-case (fig.15 [not available online]). This reservoir is continuously supplied with wind by two wedge-feeders below it, operated by a rocking lever which opened one while it closed the other. By this means a single person could supply adequate wind to a fairly large instrument, although as larger organs were built in the early 19th century, more than one reservoir (and thus more than one organ-blower) was required.

By the 19th century this system was in universal use in England and America, and was soon adopted in France and elsewhere. Early in the 19th century the English builder Benjamin Flight, noting that a slight pressure-rise occurred as the typical double-fold reservoir collapsed, reversed the fold of the upper set of ribs to help equalize the pressure (fig.15). This system was widely used in England thereafter, although not adopted in America until the 1880s and rarely employed on the Continent save by the French who, following Cavaillé-Coll, devised complex wind systems involving multiple reservoirs of this type, often supplying differing wind pressures. In the 20th century, with the advent of the electric fan-blower, builders elsewhere often adopted this kind of multiple-reservoir, multiple wind-pressure system.

In the mid-20th century, some builders replaced the smaller regulating reservoirs with a spring-loaded 'floating' plate, attached by a rubber-cloth membrane to the bottom of the wind-box of the soundboard. While useful in saving space in small organs, these devices (called ‘Schwimmer’ by the German builders, a term also adopted by many English-speaking builders) often produced undesirable wind characteristics such as oscillation and pressure-drop unless carefully designed and adjusted.

(iv) Other types of bellows.

During the 17th century a type of square, multifold bellows appeared in France, called *soufflets à lanterne* because of their resemblance to multifold paper or parchment (‘Chinese’) lanterns. The weighted top board was raised by a rope and pulley and allowed to collapse, sending wind to the organ; as with the wedge-bellows, more than one was needed for a continuous supply. In 19th-century Germany, the box-bellows (*Kastenbalg*) appeared. It operated on the same principle as a gasometer, in that a weighted smaller box, fitting snugly into a larger one, was raised by a pulley and allowed to drop, forcing wind into the organ. Neither became widely accepted, probably because the former was more fragile than its wedge-shaped counterpart, and the latter, being made of wood, was liable to get out of order owing to atmospheric changes.

(v) Organ blowing.

Until the middle of the 19th century, manpower was the only means of operating the feeders, even in large organs, although in these one sometimes found alternative systems such as a crank-and-flywheel operating three feeders from a camshaft. During the second half of the 19th century, while manpower still sufficed for most smaller church organs, advancing technology offered alternatives for the larger ones. English builders such as Hill and Willis favoured steam power, by which steam-driven pistons supplied the wind in place of the feeders; such a system was employed in the Royal Albert Hall, London, from 1871 to 1920. In America, water power from the mains was preferred, especially by city churches, which were exempt from water taxes. These water motors were quite simple, the principle being a reciprocating piston which was attached to the lever operating the feeders. At the turn of the century, the electrically operated centrifugal fan blower came into use, eliminating the necessity of feeders, and is now almost universally employed.

With the advent of the unlimited mechanical wind supply brought by the fan blower and by the use of multiple small reservoirs, a fashion for ‘rock-steady’ wind supply emerged, particularly in connection with the ‘monster’ organs of the early 20th century. Study of the wind characteristics of pre-20th-century organs during the 1970s and 80s began to cast doubt on the musical efficacy of an inflexible wind system. Although this inevitably caused some controversy among both players and builders, by the end of the 20th century many had accepted that a wind system with a carefully calculated amount of natural ‘give’ is of musical value, especially in organs designed to emulate historical tonal principles. Many of these eschew modern wind systems for reproductions of older types, sometimes with both electric and manual blowing options.

Barbara Owen, Peter Williams