INSIDE A PIPE ORGAN

Centuries old engineering with wood, wire and leather

We are very grateful to the National Lottery Heritage Fund for a grant of £32,400 towards the organ restoration, and to Empingham villagers for £4000.

The total project cost is estimated at £36,400 when the community involvement takes place.

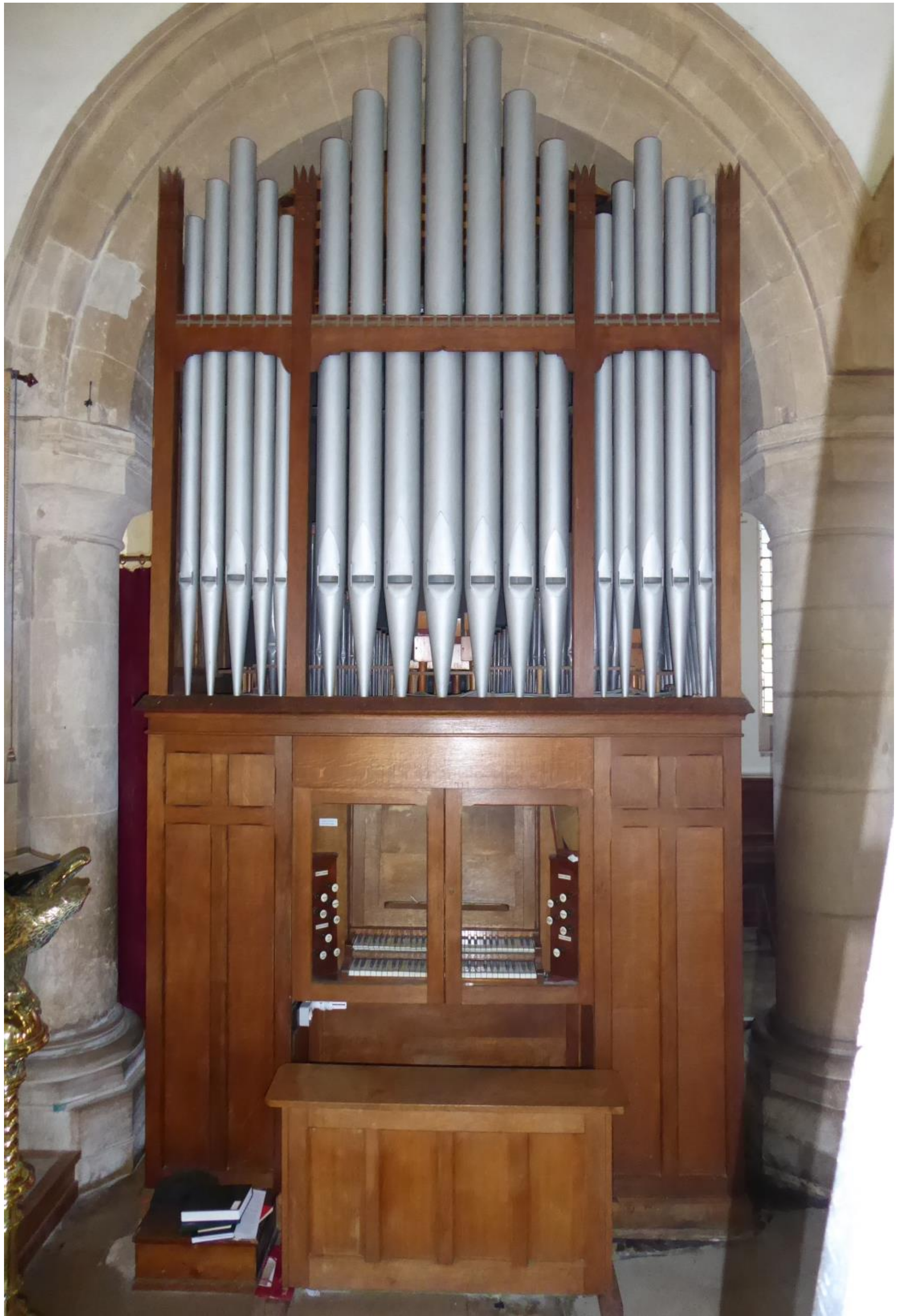
INTRODUCTION

The organ in St Peter's Church, Empingham was thoroughly renovated by Malcolm Spink Ltd of Leeds.

While the work went on photographs were taken of various parts that are concealed in enclosures or by other parts.

These are included in this album with descriptions and sketches of all the main parts, and how they work.

Compiled by John Haward
October 2020



THE PARTS OF THE ORGAN AND HOW IT WORKS

The upper keyboard controls the pipes in the centre of the organ. The lower keyboard controls the group of pipes in the front of the organ, including the metal ones on the exterior.

On each side are handles called “stops”. When pulled out they select the rank of pipes which give that particular sound – e.g an oboe.

The cover behind the keyboard has been removed in this photograph, revealing the Coupling Action, the most complex part of the organ.

The pedal board, worked by the feet, controls the pipes at the back of the casing. A cover has also been removed here to reveal the “roller board”. The pedal on the right controls the swell action.

The supply of air to the pipes

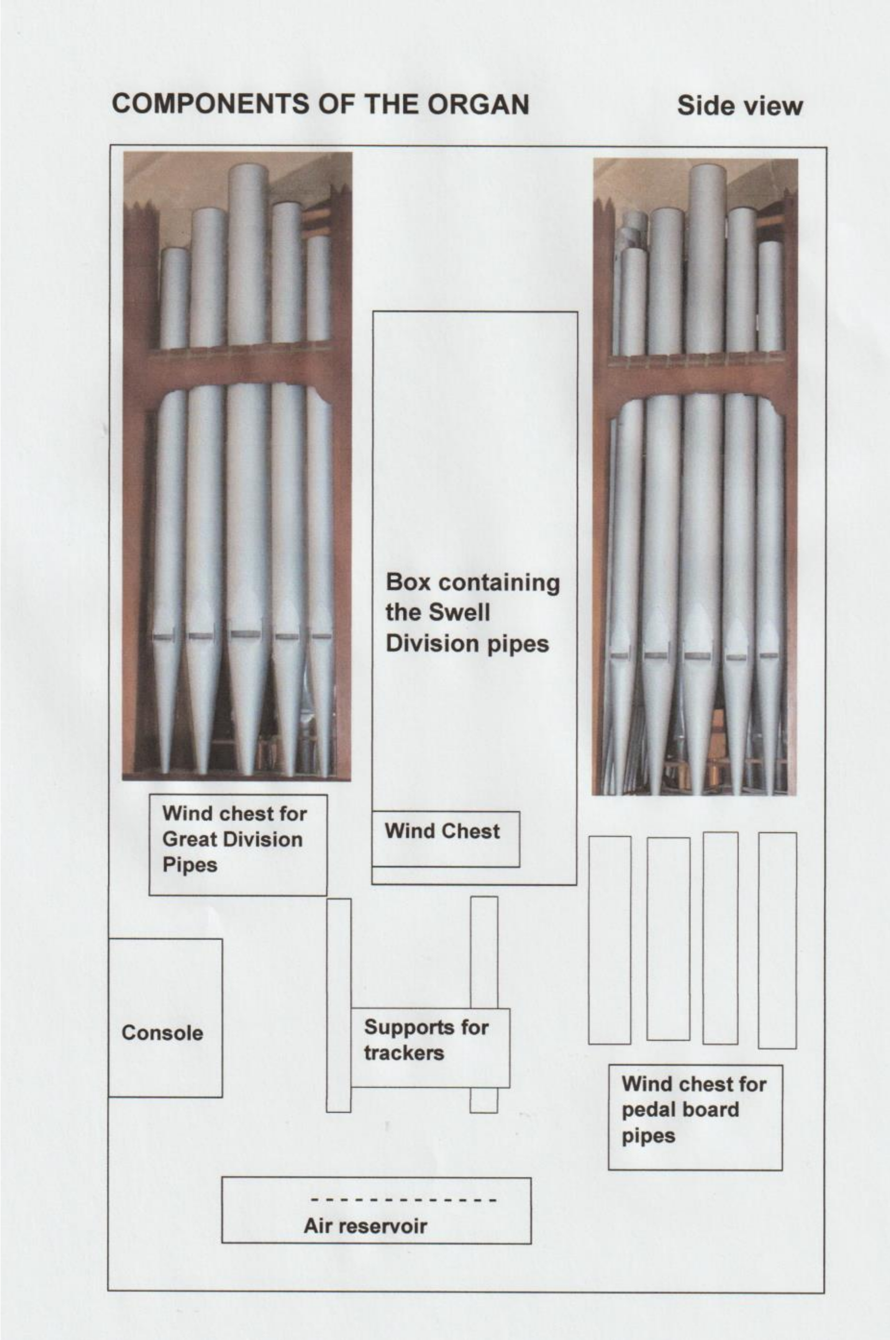
An electric motor powers a blower to supply air to a large reservoir. This has flexible sides like a bellows and a top board with heavy weights on it. When the blower is switched on the top rises up and this keeps the air inside at a constant pressure as the pipes are played. From here the air is led via a number of wooden ducts, painted blue, to boxes called wind chests on which the pipes sit. There are three wind chests in the organ, one for each division of pipes.

How the air pressure is controlled.

Weights on the top control the pressure to 0.12 psi which is measured on a manometer as 3 3/8” water.

As the top of the reservoir rises, when the blower is switched on, a cord moves up over a pulley and down to the inlet from the blower. There it is attached to a plate which partly cuts off the flow of air. This keeps the volume of air in the reservoir constant.

The blower and motor are in a sound insulated box.



The “Swell Control”.

The pipes of the Swell Division are enclosed in a large box in the centre of the organ. One side of this has louvres which can be opened like a venetian blind. When the player wants to make the sound from these pipes louder he operates a pedal which opens these louvres.

Connections from keys and pedals to the pipes.

The keys of the upper and lower keyboards are connected by wooden rods and wires to the valves at the bottom of the pipes inside the wind chests.

Malcolm Spink is connecting the wires to the "Square" unit which has levers which change the horizontal motion of the wooden rods into a vertical motion of the wires extending up to the pipes..

The pedals operate valves which move air inside small lead tubes to open the valves for the pipes at the back of the organ.

The Stops.

These photographs show the stops, each with a label showing its particular sound. When they are pulled out they select one rank of pipes.

There are 5 stops in each division of the two keyboards with 58 keys each.

So there are 290 pipes for each division - 580 in both.

The pedal board has 30 pipes, making a total of 610 pipes.

The pipes

The note made by the pipe is entirely determined by the length of the pipe. So the lowest base note comes from the longest pipe, 32 feet (9.75m) long in some large organs but approximately 8ft (2.4m) in this instrument. The shortest pipes are less than one inch (2.5cms) long.

LIST OF PIPES IN THE EMPINGHAM ORGAN

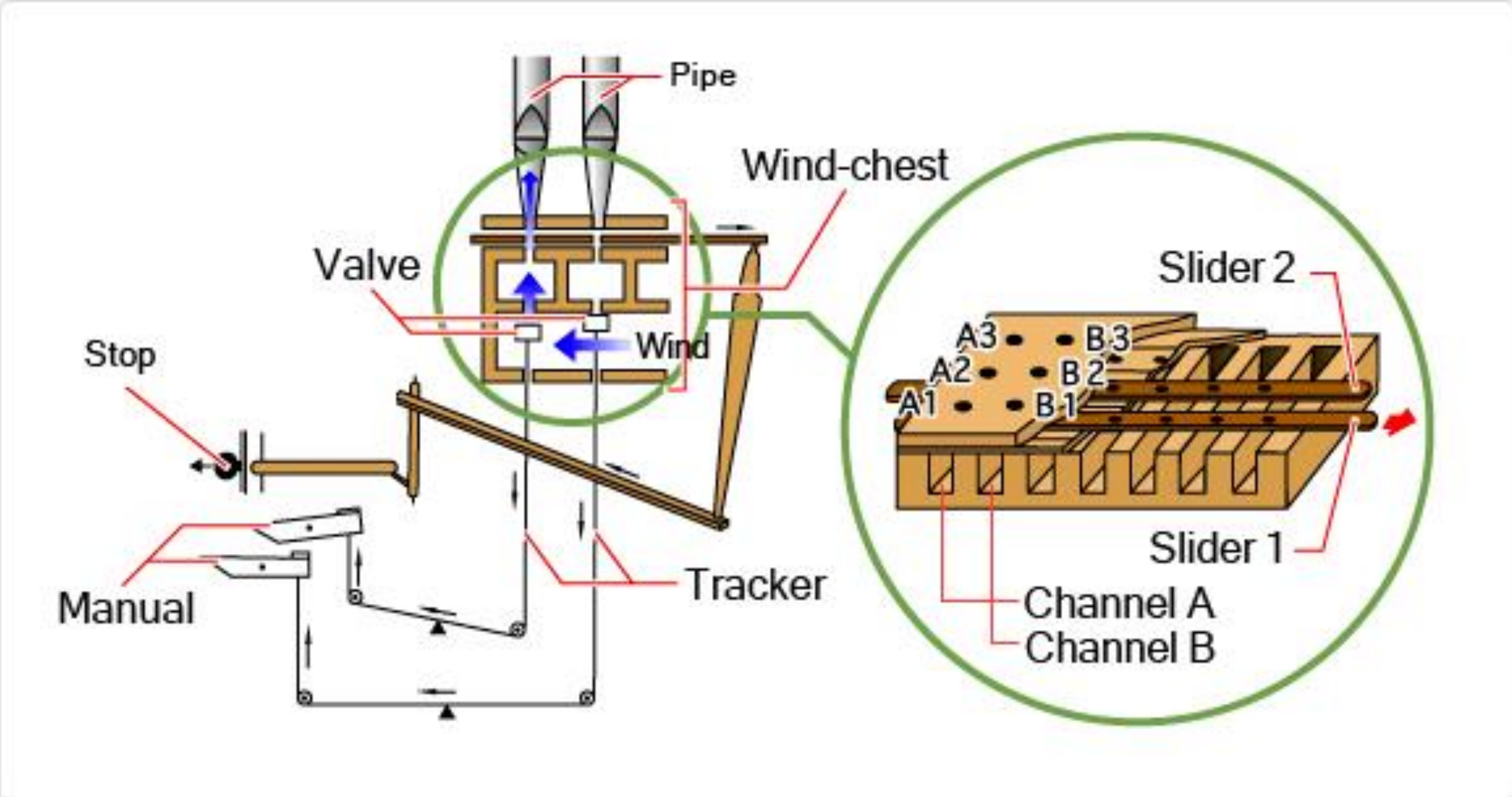
Listed in order from the front of the organ to the back:

In the Great Division:	**Length, ft**	**Open or stopped**	**Material**	**Other comments**
Open Diapason	8	Open	Zinc/lead	All the pipes on the front are zinc and those behind are lead.
Dulciana	8	Open	Lead/zinc	One octave of pipes in the centre of the display pipes at the side are zinc.
Stopped Diapason and Claribel	8	Diapason stopped, Claribel open.	Lead	
Principal	4	Open	Lead	
Wald Flute	4	Open	Wood	
In the Swell Division:				Enclosed in the swell box.
Oboe	8	Open	Lead	Reed pipes
Piccolo	2	Open	Lead	Producing the highest notes.
Gemshorn	4	Open	Lead	
Leiblich Gedacht	8	Stopped	Lead	
Violin Diapason	8	Open	Wood/lead	Bottom 12 only wood.
Pedal Board Division				
Bourdon	8	Stopped	Wood	At the back of the organ.

On the left of the keyboards are three Couplers:

a. Swell pipes to be played on the Great keyboard.
b. Swell pipes to be played on the pedals.
c. Great pipes to be played on the pedals

THE ACTIONS CONTROLLED BY THE STOPS AND THE KEYS



Explanation of the actions of the stops.

The stops on the console operate sliders which open a connection to the row of pipes A1 B1 C1 etc, corresponding to the 58 keys.

When a key, (the “manual” shown here), is depressed it operates a valve through wire linkages called “trackers”. Air is fed by the valve to the appropriate channel relating to that note (A, B, C, etc). The stop selected (1, 2, 3 etc) will determine which pipe is played and consequently the type of sound you hear (Oboe, Flute etc)

In this organ the valve is a hinged flap, the “pallet”, not as in this diagram.

With two stops selected two pipes “speak”.

The photograph shows some of the connecting levers and rods between the stop and the sliders.

To summarise:

The organist first selects a stop which allows a connection from the wind chest to the bottom of the row of pipes. When he depresses a key this opens the valve to allow air to the particular pipe required.

The pipes.

Most of the pipes in this organ are “Flue” pipes, either open or with closed ends. There is one row of “Reed” pipes which have a vibrating reed in the base.

HOW THE PIPES PRODUCE DIFFERENT SOUNDS

Metal Pipes. Before being formed into a tube the metal is beaten making fine patterns on the surface. The particular sound depends on how the surface has been treated and the composition of the alloy. The metal used in this organ is an alloy of tin 12%, lead 77% and antimony 1%.

The ratios are sometimes changed; for example more tin, the brighter the sound, more lead produces a more mellow sound.

The timbre of sound produced also depends on many things which can be chosen when a lead pipe is made. Its diameter, the metal thickness, whether it is tapered and the exact shape of the mouth.

Sometimes this has very small “teeth” on it, (known as “nicking”).

The length of a pipe halves (or doubles) after every 12 pipes. All other dimensions are halved (or doubled) after every 17 pipes.

Wooden Pipes. These are made of four pieces of spruce wood glued together.

Below is the rank of Wald Flute pipes

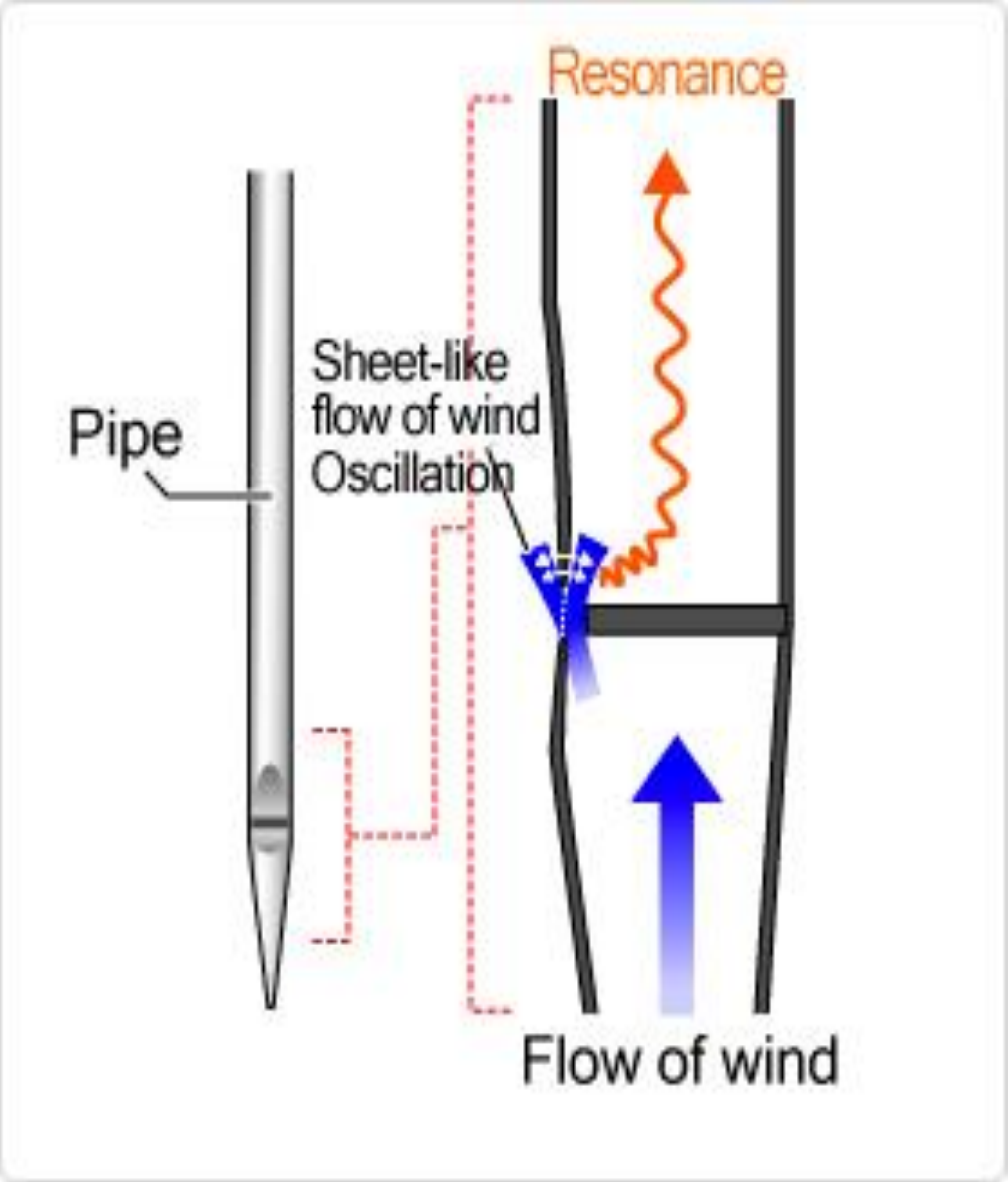
When a stop is pulled a long piece of wood called a slider opens up the holes for air into the pipes. The slider lies across the board shown above, called the “sound board”. The grooves prevent air leakage from one pipe to the next.

Below is the complete rank of Gemshorn pipes.

FLUE AND REED PIPES

Flue pipes have a structure that is similar to a recorder. Wind that has entered from below passes through a slit and forms a sheet-like flow. On hitting the upper part of the mouthpiece the air alternates between flowing into and out of the pipe.

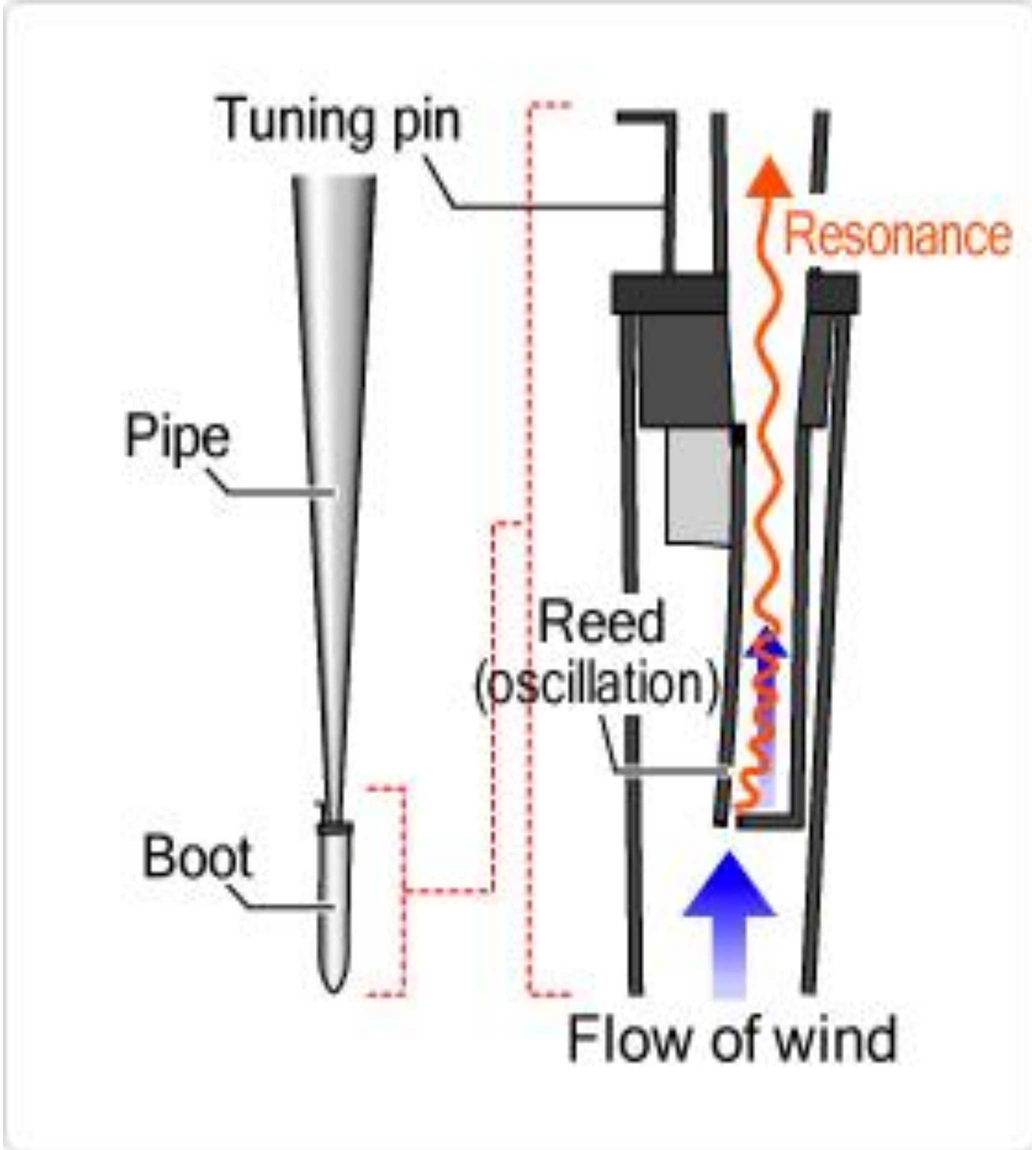
The periodic motion of the air causes the whole pipe to resonate, and sound is produced. A thick pipe produces a flute timbre, while a thin pipe produces a timbre close to that of a stringed instrument.



Reed pipes

This diagram shows the bottom of a reed pipe. Reed pipes are structures in which the flow of wind causes a reed to vibrate, causing the whole pipe to resonate and produce sound. The reed is made from springy brass and slightly curved.

By varying the thickness and shape of the reed and the form of the pipe, the timbre can be transformed from the brilliant sound of a brass instrument to the subdued, gentle sound of a bassoon



TUNING THE PIPES

Reed pipes are tuned by adjusting the
position of the reed with a tuning spring.

Some wooden pipes are tuned by moving the wooden
bung in the end which has felt around it so it wedges in the
pipe.
Metal pipes can be tuned by means of a tuning slide which
adjusts the length of the pipe

Some of the Oboe reed pipes are bent around to fit into the
Swell box.

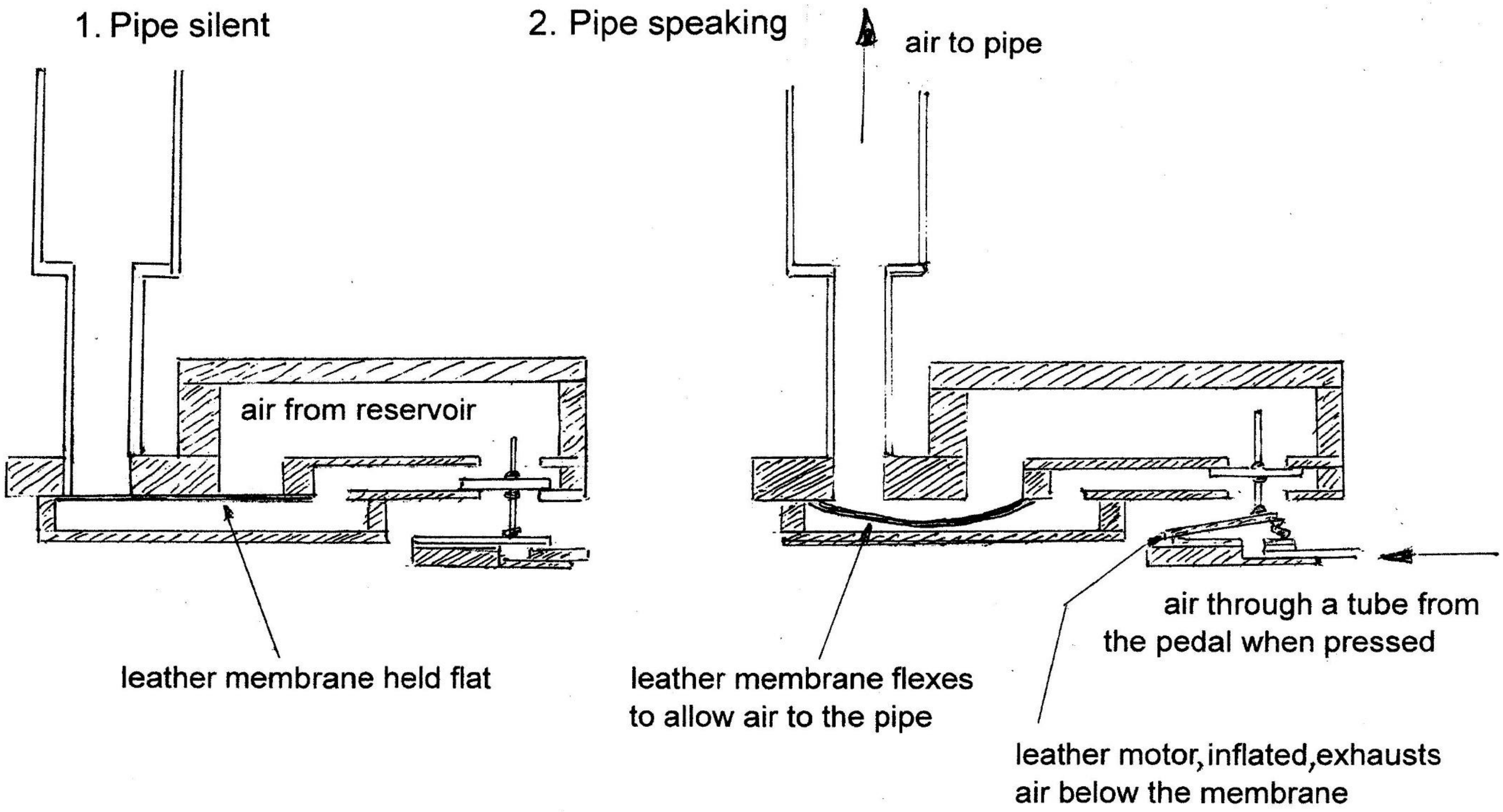
THE TRADITIONAL NAMES FOR PARTS OF THE ORGAN

Manual	The keyboard or key
Stop	Control knob which selects the type of sound or timbre.
Rank	Row of pipes selected by a stop.
Division	Group of pipes; e.g Swell division.
Great Division	Pipes operated by the lower keyboard
Swell Division	Pipes operated by the upper keyboard
Trackers	Wires connecting the keys to the valves.
Roller Boards	Devices that spread the trackers wider.
Wind	The air from the blower.
Wind Chest	The box under the pipes which feeds air to the valves.
Pallett	The valve allowing air to a pipe.
Pipe speaking	The pipe making a sound.
Bellows	The reservoir with flexible sides containing the supply of air at a steady pressure.

THE BOURDON PIPE VALVES

A pneumatic system is used to control the valves at the back of the organ. A key part of this is a flexible leather membrane. When a pedal is depressed it sends air through a lead tube to operate a leather motor seen white in the photographs.

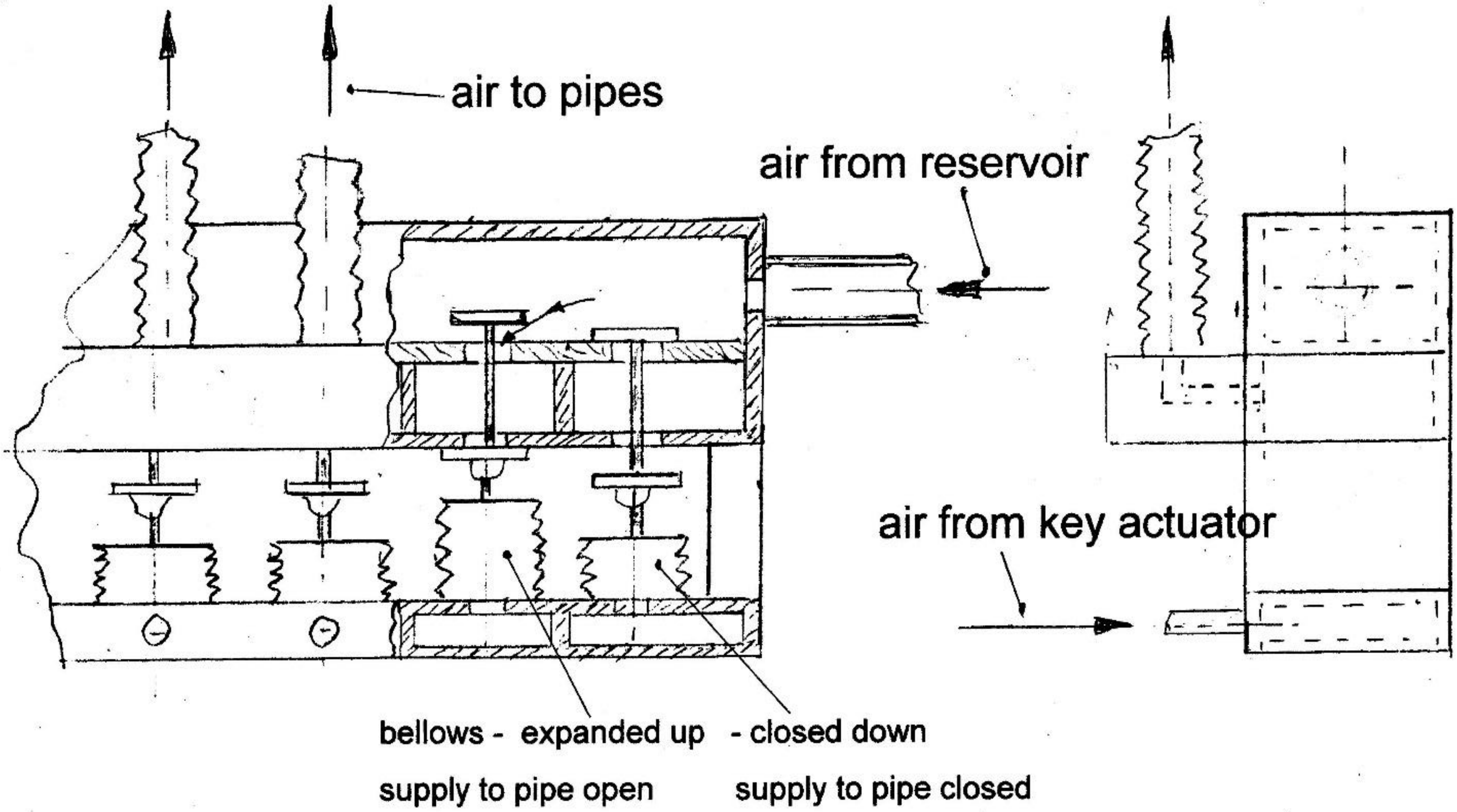
This moves a disc valve to open the bottom of the membrane to the atmosphere. Then air from the pressurised reservoir can pass into the pipe through the blue duct and the wind chest. This is the long wooden box below the pipes.

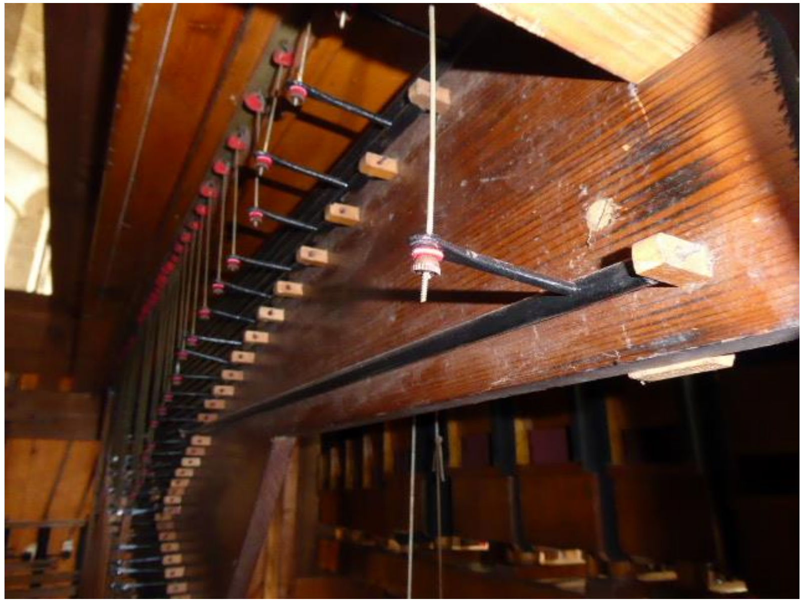


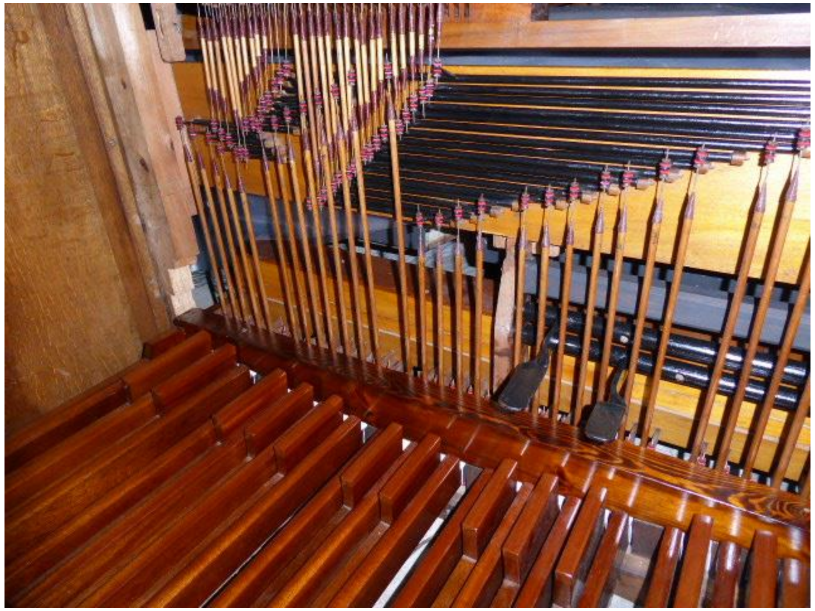
THIS DEVICE CONTROLS THE AIR TO THE BOURDON PIPES

THE DULCIANA PIPE VALVES

The lowest octave of the Dulciana pies are operated by a pneumatic system. With a key depressed air expands the white leather bellows. This raises a valve to allow pressurised air through to the pipe. The photograph shows the lead pipes that come from the keys.


air to pipes
air from reservoir
air from key actuator
bellows - expanded up
- closed down
supply to pipe open
supply to pipe closed





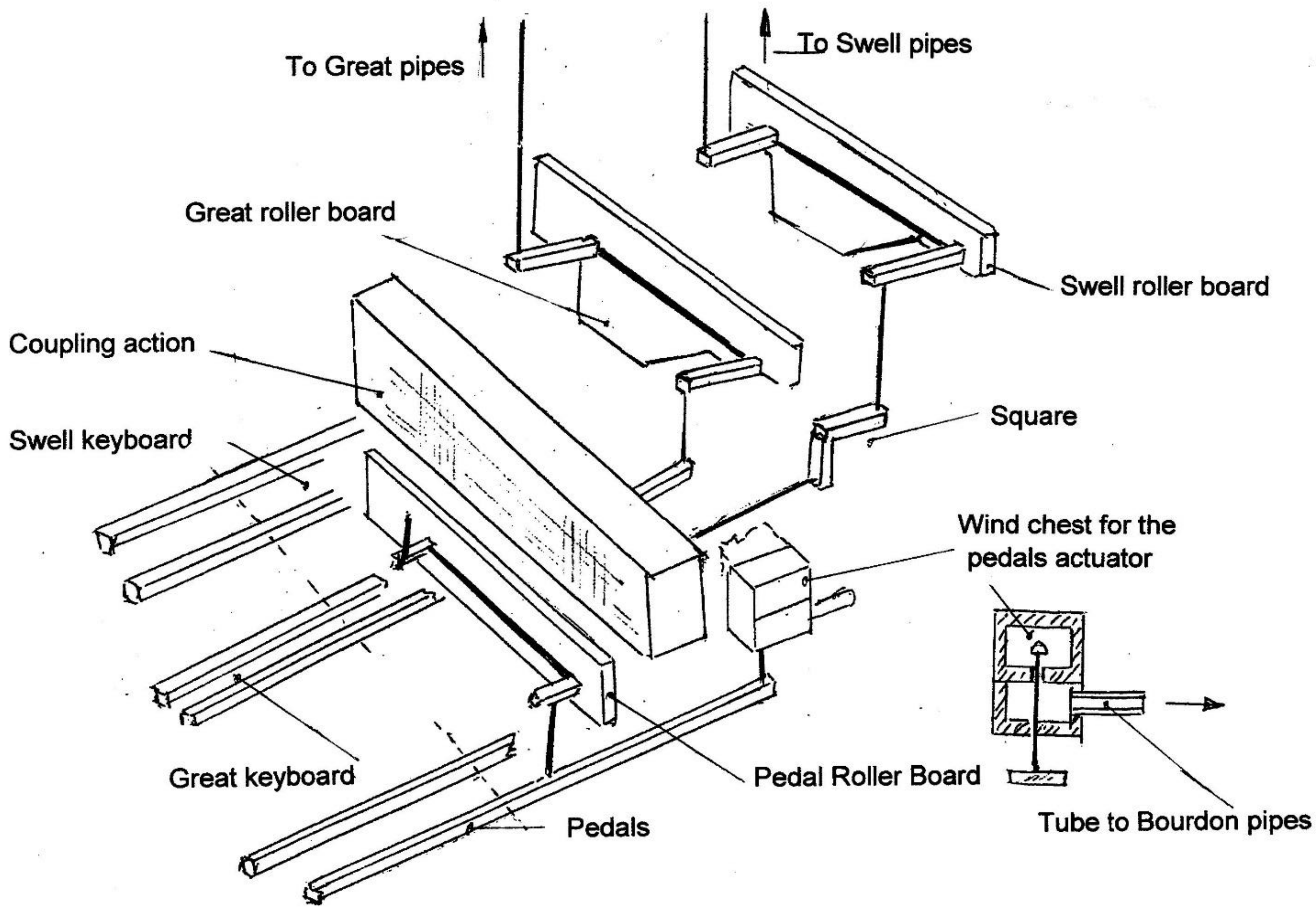
USING A ROLLERBOARD TO SPREAD THE CONNECTIONS TO THE PIPES.

The keyboard is 30” wide and the dimension over the row of pipes is 73”. The upper photograph shows the assembly of rods on a roller board. This increases the spacing of the wires to the wider spacing of the pipes. A rod with a particular length is rotated by a lever and then moves the wire to the pipe with a second lever placed along it.

You can see the long black rods which pivot in the white blocks on the roller board. Levers extend out from the rods and are attached to the wires by the red washers and “buttons”. They act as nuts on the rods which are threaded.

At the other end of the rod is another lever connected to the wire operating the pipe valve.

The lower photograph shows the pedal roller board with connecting rods extending upwards from the ends of the pedals. These consist of wires encased in wood so they can pull and push. In other parts of the organ wires alone are used because a spring in the pipe valve returns the action.


To Great pipes
To Swell pipes
Great roller board
Swell roller board
Coupling action
Swell keyboard
Square
Wind chest for the pedals actuator
Great keyboard
Pedal Roller Board
Pedals
Tube to Bourdon pipes

This is the swell roller board with the Bourdon pipe valves on the right
and stop connections to the left.

The Frequency of Notes Produced

The Middle C pipe, operated by a key in the centre of the keyboard, produces a frequency of 265 Hz for the 8 ft open pipes. (It is 523 Hz on a piano).

12 keys span an octave of frequency. As you move up or down the keyboard the 12th key always produces a frequency double, or half, that of the first key of the octave. So the 12th key up from Middle C produces a frequency of 530 Hz.

This organ has 58 keys, not quite 5 full octaves.

The first key at the left end of the keyboard controls an 8ft pipe giving the lowest note, a C, with frequency of 65.4 Hz.

The lowest frequency heard by an adult is 20 Hz.

The pipe giving the highest note, an A with Picollo stop, has a frequency of 7040 Hz. It is two quadrants higher than the others.

Pipe Length and Frequency

When a pipe is tuned correctly the air resonates in the pipe producing a note. Its frequency is entirely governed by the length of the pipe.

The length can be calculated from the frequency of the sound. For an open ended pipe the formula is: L = v/2F, where v is the velocity of sound, 346 m/sec or 1124 feet/sec.

(The formula for a closed end pipe L = v/4F).

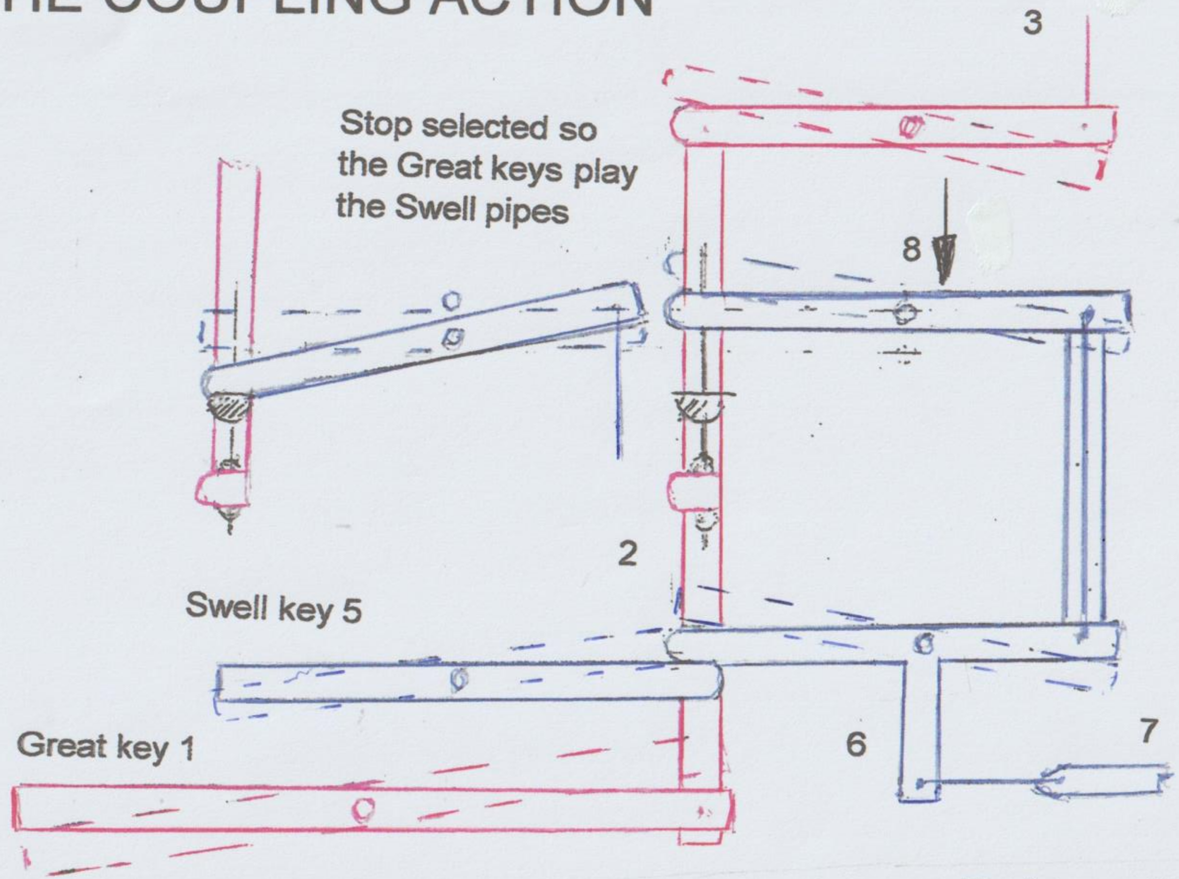
The length of the pipe giving the lowest note, a C, in this organ is 1124/2x65.4 = 8 ft 7 inches.

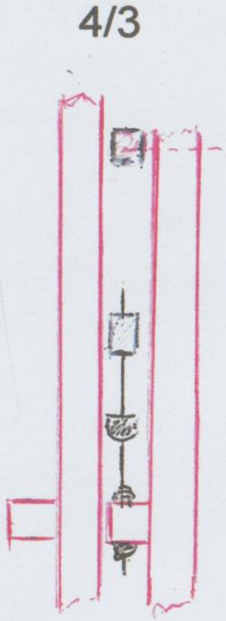
This simple formula does not calculate the exact length because of end effects caused by the particular shape of the end and the window.

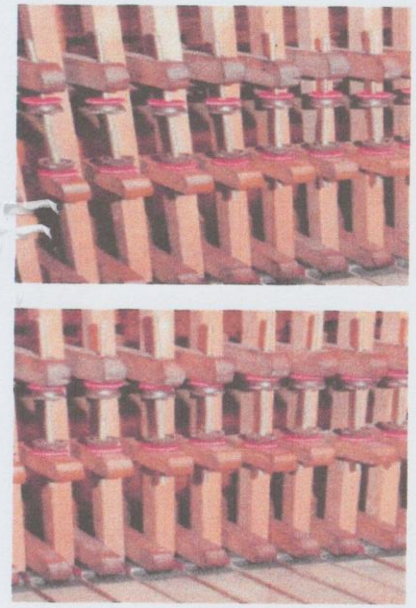
The pipe for middle C at 265 Hz would have a length of 1124/ 2x265 = 2 ft 2inch long.

The smallest Picollo A pipe has a length of 1124/2x7040 = 0.08 ft (1”)1124/2x7040 = 0.08ft (1”).

THE COUPLING ACTION







These photographs show the wires of the Swell action that fit between the rods of the Great action. Above is the normal position of the buttons. Below is the position with the stop selected.

The linkage which actuates the Swell pipes is shown in blue.

When a Swell key 5 is depressed it moves the levers which rotate a quadrant 6. This pulls a wire 7 leading to the Swell pipe.

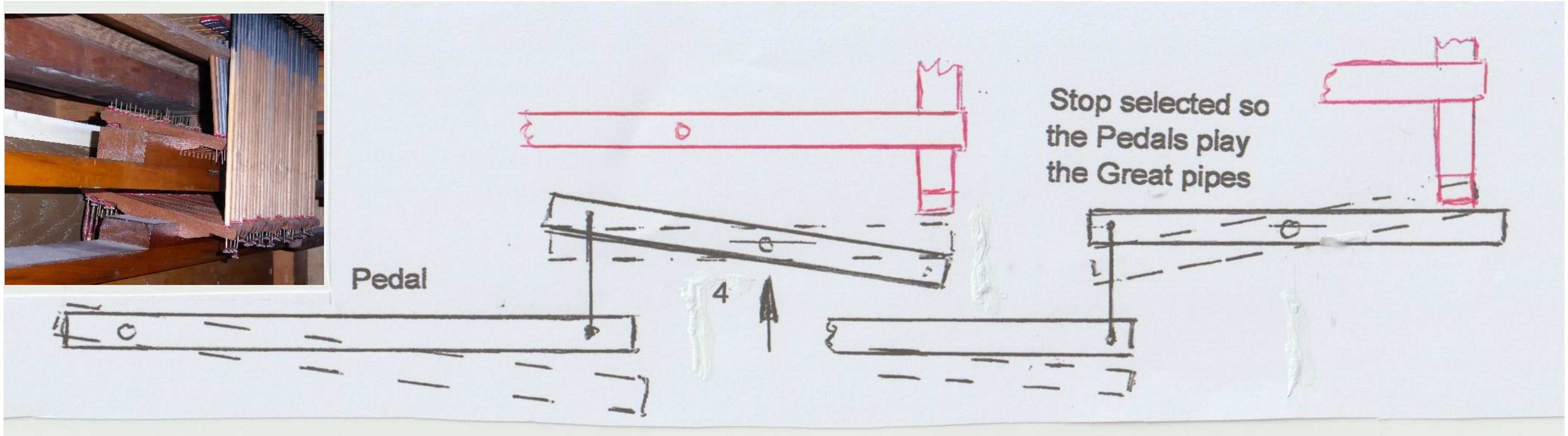
When the stop is operated it moves the pivot 8 downwards. A button on the wire is now contacting the lever so that the Great action can now rotate the quadrant and operate the Swell pipe.

The linkage which actuates the pipes in the Great Division is shown in red.

When the key1 is depressed it moves the wooden rod 2 upwards and through the lever at the top pulls a wire down. This wire 3 actuates the pipe valve.

The stop moves the pivot 4 upwards so that the end of the lever is in contact with the rod. As a pedal is depressed it moves the rod upwards.

Similarly a stop labelled “Swell to Pedals” allows the organist to play 30 of the Swell pipes with the pedals.



A stop labelled "Swell to Great" allows the organist to play all the Swell pipes with the Great keys as well as all the Great pipes.

A stop labelled "Great to Pedals" allows the organist to play 30 of the Great pipes with the pedals, at the same time as the pedal pipes

On the right: The back of the Coupling Unit.

This shows the red wires,3, that operate the Great Division pipes. The white rods below actuate the Swell Division pipes.

On the left: the front of the Coupling Unit above the Swell keyboard. Behind it are the connections to the Great pipes.

SOME SURPRISING FACTS

1.Obtaining the correct thickness of each pipe.

The lead sheet used in making each pipe has to have a carefully controlled thickness. If the largest pipe is number 1 then pipe number 17 will have its metal thickness half that of pipe number 1, half its diameter, half its mouth width and half its mouth height. This continues through the rank of pipes so pipe number 51 has half the dimensions of number 34.

The smallest pipe in a rank might have a thickness 1/32" (.030") or 0.8mm. So the adjacent pipe would only be approximately .001" thicker than the first. The correct thickness is obtained by planing the lead sheet. This is a very skilled process.

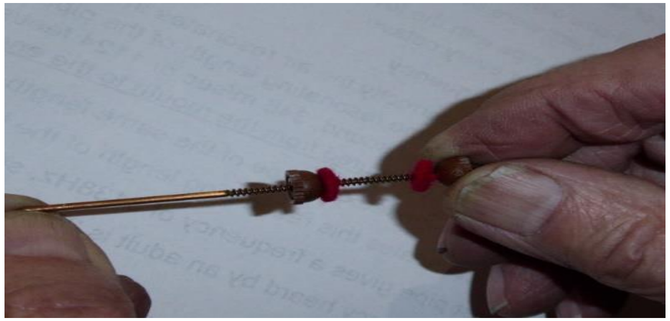
2. Altering the end of a pipe.

To obtain the correct volume of sound throughout the rank of pipes the size of air inlet has to be adjusted. Lead can be easily opened out or closed in. This is not possible on the display pipes on the exterior of the organ which are made of zinc. So a small piece of lead is joined onto the end to make the inlet.

3. Fabricating the pipes and tubes. The lead sheet is rolled into shape and the joint along its length is soldered in one continuous operation. The lead tubes which carry air from the pedals are made by extruding a thick tube and then rolling it down to the small diameter, in the same way as Blackpool rock is made.

4. Combinations of stops

This organ has 10 stops on the manuals giving a possibility of 1023 different sounds using the formula to calculate that number
i.e (2 to the power of n) – 1. Peterborough Cathedral has 65 stops giving the number of different sounds as 36,893,488,147,419,103,231.



5. Making the threads on the tracker wires. These are phosphor bronze 16 gauge wire = 1.3 mm diameter. Threads are rolled onto parts of these rods by a forming tool passed diagonally over them. Metal is not cut but is formed into a thread which will take a leather button screwed onto it.

THE SPINK FAMILY

HERITAGE FUND

Malcom Spink with his son Antony and grandson Tom carried out all the work on the renovation of the organ.

We are very grateful to them for a job well done, and to the National

COMMUNITY INVOLVEMENT

The Lottery Fund grant that we received also funds presentations to community groups, particularly school children.

The organ is adapted to make it possible to see all the internal parts. The side panels can be unlocked and opened, and internal lights switched on.

This will be done when an authorised person can explain the various parts and how they operate