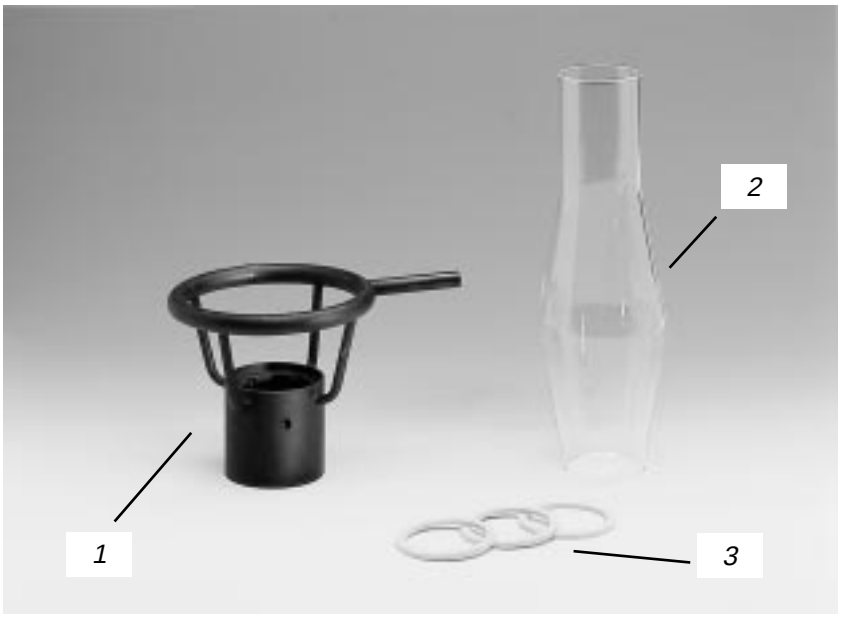
Support with closed-circuit pipeline

36688.01

Operating instructions



1 PURPOSE AND CHARACTERISTIC FEATURES

The „Blast furnace, working model“ enables an impressive and realistic simulation of the reduction of iron ore to crude iron (pig iron) in a blast furnace to be carried out. The model itself, the starting materials, the charging and the functioning are very true to the original, but some simplifications have been made to suit the model for use as a teaching tool, and to allow a better observation of the processes which occur.

The glass stack and hearth (glass stack), for example, allow a direct observation of the increasing temperature (glowing intensity) down to the height of the tuyeres (see Fig. 3) and the sinking down of the ore-charcoal layers during the reaction. The blast-furnace gas exiting from the top of the stack can be set alight to flare it off.

Because of the size of the model and the simplifications made, it cannot completely reproduce the processes which occur in an actual blast furnace. The melt which trickles through the charcoal (representing coke) and collects in the support cannot be tapped off. The molten iron tap hole and the slag tap hole are each bore-marked in the model blast furnace support. The product which results from the model experiment does not have the quality of that produced by an actual blast furnace. At the end of the experiment, a metallic looking lump which consists of slag, partly reduced iron ore and pig iron is to be found in the support

2 DESCRIPTION

The blast furnace working model (see Fig. 1) consists of a metal „support“ *1* which has a circular air pipeline (bustle pipe) and air inlets (tuyeres), and the „stack“ *2* which is made of heat resistant glass. A glass fibre sealing ring *3* must be positioned between the support and the stack.

The following components are supplied under the order no.: 36688.88 „Blast furnace, working model“:

Blast furnace stack, DURAN	36688.09
Support with closed-circuit pipeline	36688.01
Rings, ceramic fibre, pack of 5	36688.08

The following accessories are additionally required:

Iron ore, 500 g		36688.05
Activated charcoal, granular, 500 g		30011.50
Hot air blower with adapter		36688.93
Safety base plate		39180.10
Rubber tubing, i.d. =8 mm		39283.00
Pinchcock, width 15 mm		43631.15
Retort stand, *h* = 55 mm	(2 x)	37692.00
Right angle clamp	(2 x)	37697.00
Universal clamp	(2 x)	37715.00
Crucible tongs, 200 mm, st. steel		33600.00
Glass rod		
Gas burner (2 x)		

The current of air (blast of air) which is needed to operate the model can be generated with a cold/hot air blower. The blast furnace is set up on a retort stand which is placed on a safety underlay, as shown in Fig. 2. The blower is fixed to

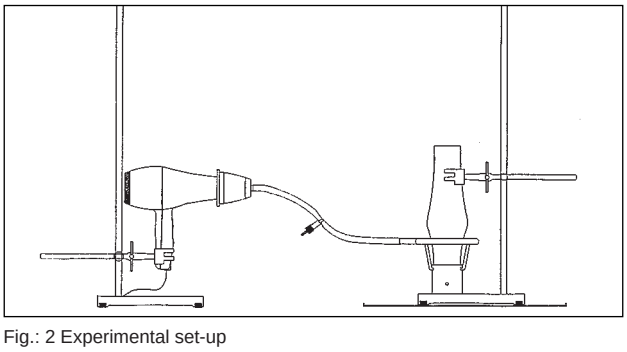


Fig.: 2 Experimental set-up

a second stand and connected by means of an adapter and rubber tubing to the connecting piece on the air pipeline of the support. A pinchcock fitted onto the rubber tubing makes it possible to regulate the air flow to some extent as required.

3 USAGE

Place a ceramic fibre ring in the groove inside the support and press on it with your fingertips to fit it in evenly. Fit one end of an approximately 50 cm long piece of rubber tubing onto the connecting piece on the air pipeline of the support, and the other end onto the blower adapter. Place the glass stack on the ceramic fibre ring (see Fig. 1). Fasten the upper end of it to a retort stand by means of a universal clamp and a right angle clamp. When doing this, take care that the glass stack is seated firmly and evenly on the ceramic fibre ring. Fit a pinchcock onto the rubber tubing. This serves to regulate the amount of air which the blower blows into the air piping. Fasten the blower to a second retort stand by means of a universal clamp and a right angle clamp. To protect the benchtop, position a safety underlay underneath the stand holding the model blast furnace. Ensure the readiness of two gas burners (preferably Teclu burners), iron ore, activated charcoal, a glass rod and a pair of crucible tongs.

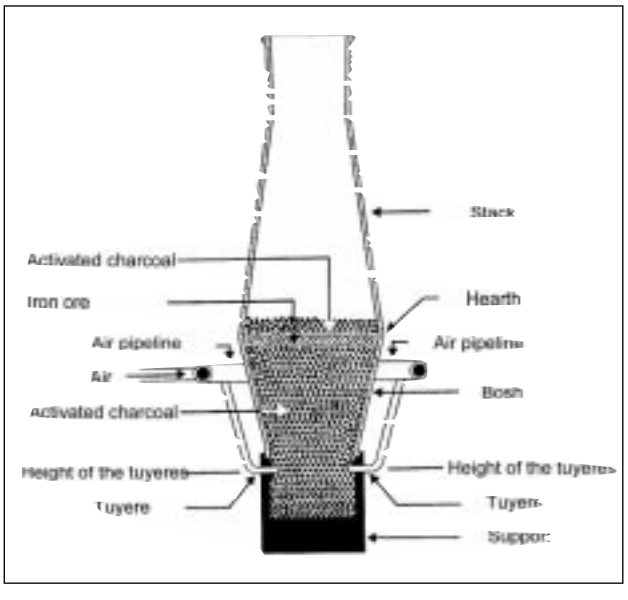


Fig. 3: Cross-section of the blast furnace model

The reaction in the „Blast furnace, working model“ can be started in two different ways:

1. Remove the glass stack (stack and hearth) and fill the support up to just below the height of the tuyeres (air inlets) with activated charcoal. Replace the glass stack on the sealing ring and fasten it to the retort stand as previously explained (see Fig. 2).
Use crucible tongs to hold a small piece of activated charcoal in the flame of a burner until it begins to glow. Switch on the blower (cold air) and fully open the pinchcock. Throw the glowing piece of charcoal onto the activated charcoal layer directly in front of an air inlet, so that it continues to glow. Carefully add a little more charcoal onto it, taking care not to completely cover it, as it would then cease to glow. When the added charcoal which contacts the glowing piece also starts to glow, and the glowing area spreads out, fill in more charcoal up to the bosh (the widest part of the stack). Put 20 to 25 g of iron ore on top of the charcoal, and distribute it evenly over the charcoal surface using a glass rod. Cover the iron ore layer with an approximately 1 cm height of charcoal. The experiment now continues by itself.

2. First fill the three layers (activated charcoal, iron ore, activated charcoal) into the „Blast furnace, working model“. Switch on the blower (cold air) and fully open the pinchcock. Now carefully heat up the hearth of the glass stack, particularly the part which is directly above the support, by fanning it evenly for about 1 minute with two strong burner flames. Now direct the burner flames onto the tuyeres, so that they are opposite to each other and each heats up neighbouring tuyeres (see Fig. 4).

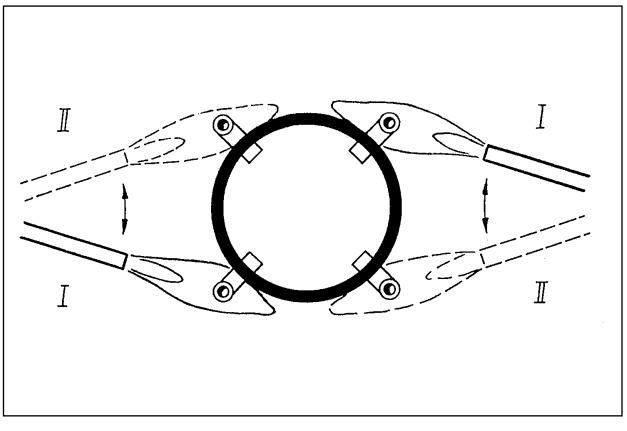


Fig. 4: Position of the burner flames when heating the tuyeres

Change the flame position between I to II more quickly at the start of heating, and at continually larger time intervals after about 1 minute (there is a danger that the bottom part of the glass stack will crack if the heating is not carried out uniformly). Heat the tuyeres until the charcoal which is in the direct vicinity of the air inlet begins to glow, which normally takes about 2 to 4 minutes. Flaming can be stopped when there is a clearly visible glow in the vicinity of at least three, but better all four, tuyeres. The experiment now continues by itself.

When, at the start of the experiment, the charcoal layer glows all around the lower glass periphery, then sufficient carbon monoxide is already being generated for it to be ignited at the mouth of the stack with the burner flame. Throttle the air input as soon as the gas burns at the mouth of the stack, as otherwise the hearth glow would increase and become too hot for the glass part. Screw the pinchcock in until the gas flame at the mouth of the stack is not higher than 20 cm.

The gas at the top of the blast furnace model normally burns continuously. When the reduction of the iron ore sets in strongly, the flame becomes smaller and sometimes even goes out, i.e. when the carbon monoxide content drops below the combustibility limit. Should the flame go out prematurely, re-light it with the flame of the burner (pay attention to the poisonousness of carbon monoxide).
Several observations which are very important for the technique of the blast furnace process can be made during the operation of the blast furnace. The process runs by itself when the charcoal-iron ore layers continually sink. It can however happen in the model - as in actual blast furnaces -

that parts of ore stick to each other and that then, because of the pressure of the upwards gas flow, the charge above them, or some of it, cannot sink down („scaffolding“). The voids which result light up intensively and can so be easily recognized. The cause is the baking together and sticking of the upper layers as a result of thermal expansion. To counteract this, the blast furnace has been given the typical double cone shape. This allows the layers in the stack to expand with the increase in temperature as they sink down, without too much baking together and therefore also without too much pressure on the walls of the blast furnace.

In the area of the hearth (the part of the blast furnace which constricts downwards) the charcoal burns down to a small residual volume, and this passes into the slag and collects in the support together with the molten iron. This construction therefore enables the coke and ore layers in an actual blast furnace to sink down continually.

This construction is naturally not effective in the small blast furnace model, as the charging in this is practically only in the hearth, so that slight baking together can occur. Here you can easily cause the hanging layers to drop down, however, by pinching the tubing so that the flow of air is briefly interrupted.
When, in the course of the experiment, the charcoal-ore layers have sunk down somewhat, the pressure of the air which is blown in can cause glowing charcoal particles to be whirled out of the glass stack (*Be careful* - danger of fire!). This can be avoided by correspondingly throttling the air flow by means of the pinchcock. A type of boiling movement of the upper charcoal layer towards the end of the experiment is of no concern and need not be stopped.

After 20 to 30 minutes - the charge should have sunk down about 2 to 3 cm - end the experiment by stopping the air flow (switch off the blower).
Slag, pig iron and reduced iron ore have already trickled through the remaining charcoal layer and collected in the support.
Wait until there is no glow more to be seen (about 2 to 4 minutes), then open the model blast furnace by carefully sliding up the glass stack held on the stand (protect sensitive benchtop surfaces, e.g. plastic surfaces, against very hot products which can fall out by suitably covering them!).
Use crucible tongs to move the remaining charcoal to one side and remove the reaction product from the support.
Among the residues you will find metallic looking lumps as well as ash and charcoal remains. These lumps consist of slag, partly reduced ore (magnetite) and a small amount of pure iron.

The following reactions have therefore taken place in the blast furnace:

in the lower layer	$C + O_2$	—> CO_2
above this:	$CO_2 + C$	—> $2\ CO$
in the ore:	$Fe_2O_3 + 3\ CO$	—> $2\ Fe + 3\ CO_2$

The model can naturally not reach the high temperature prevailing in an actual blast furnace, so that the iron is not molten and cannot be tapped from the support.
If the experiment is broken off too early, then insufficient melt will have trickled through into the support. You will then find ore-iron-slag products which were baked-together in the doughy stage in the charcoal layer above the height of the tuyeres.
The charcoal which has not been burnt in the experiment can be used in the next charging of the blast furnace.
The reaction product produced in the blast furnace model has, from its appearance, the homogeneity of a rigid melt. This shows that the solid pieces of ore which were used must have gone through the liquid phase before they reached the support and solidified to a solid lump. This is also shown by the fact that the charge only sank down about 2 to 3 cm, while the iron ore travelled the much longer distance to the support. This was only possible when it flowed through the charcoal layer.

The product obtained clearly shows other properties to those of the ore used. It has a different colour, has a metallic appearance (shine) and is attracted by a magnet. The ore which was started with has no magnetic properties. The magnet test proves in any case that a reduction of the iron ore has occurred. Whether the reduction is to pig iron or simply to a type of magnetite precursor is still open, and can be determined by a test of the electrical conductivity.
To test for electrical conductivity, the product is checked for conducting areas by touching it all over with the tips of two electrodes which are held close together (approximately 2 mm apart). The conductivity value can be read off from an ammeter (see Fig. 5). A small light bulb can possibly be substituted for the ammeter.
The composition and quantity of the matrix, and the iron

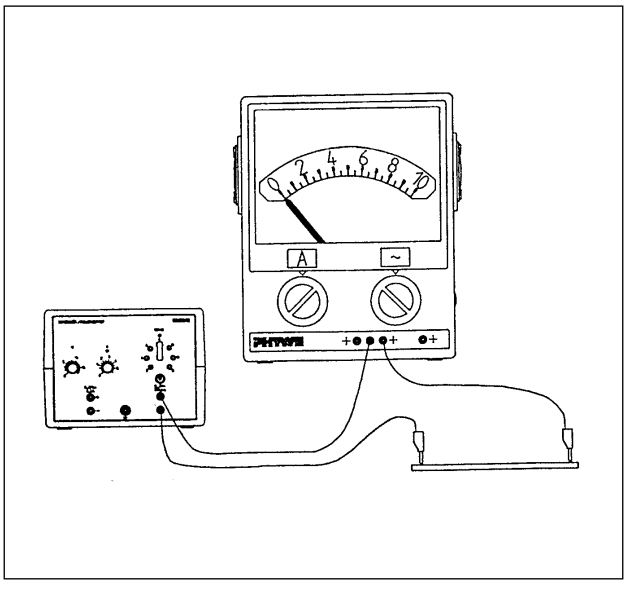


Fig. 5: Testing the electrical conductivity

oxide content, can differ greatly because of the small amount of starting material. As a result of this, the conductivities which are determined also differ from experiment to experiment. Conducting areas are always found, however. The conductivity measurement shows that the oxide ore has been partly reduced to crude iron, and, in addition, that a partial separation of iron and slag has occurred.
The test also shows that the reduction process in the blast furnace does not go directly from the iron(III) oxide in the ore to iron, but that there is an intermediate oxide stage (such as magnetite). Iron can be detected not only by the conductivity test but also by the hydrochloric acid test. As the iron is embedded in the slag, this detection only gives good results when the sample has an elevated crude iron content (approx. 40 to 50%).
The differences in the product which is produced in the model blast furnace to that which is produced in an actual blast furnace (incomplete reduction of the iron oxides and only partial separation of the iron from the slag), can be ex-

plained by the simplifications made in the model, and the difference in size. The major causes of the differences are the too short carburizing distance, the lack of additives which are specially matched to the composition of the ore and the too low temperature in the support.
Because of the lower temperature than that in an actual blast furnace, the experiment can only be satisfactorily carried out with a low melting iron ore, such as Nimba ore or bog iron ore. Ensure also that the activated charcoal used is not too finely granulated (average of at least 2.5 mm grain size).
The individual chemical reactions which take place in a blast furnace are described in detail in the pertinent school and high-school books, and so are not included here.

4 NOTES ON THE HANDLING AND MAINTENANCE OF THE EXPERIMENTAL EQUIPMENT

The most sensitive part of the „Blast furnace, working model“ is the DURAN® glass stack. The softening point of DURAN® glass is at approximately 815°C, so that a slight bulging of the short cylindrical glass end seated on the ceramic fibre ring can occur. This has no effect on the course of the experiment, and such a stack is fully usable for further experiments.
DURAN® glass holds up well to changes in temperature, but tension can build up in the glass as a result of the strong heat and the large temperature differences which it is exposed to during the experiment. It is therefore possible, that cracks occur in the lower part of the glass stack. There is also the fundamental possibility, that high built-up tension can cause the glass stack to break during the experiment or on cooling down after the experiment. This is also the case when a new glass stack is first used. The probability of cracking occurring increases with the height of the temperature to which the reaction is allowed to go. Cracking can result in a piece of glass breaking out of the stack. Such a glass stack cannot be re-used. When there is only a crack in the glass, however, then the stack can be used for a further experiment, but great care should be taken, as such a glass stack could burst during the experiment and allow red-hot charcoal and ore-slag mixture to fall out.

Cracking of the glass stack can be extensively avoided, when

1. the glass stack is heated as uniformly as possible, and
2. the glass stack is allowed to cool down slowly after the experiment. To do this, leave the stack above the metal support for some time after removing the reaction product. The hot air which flows up from the metal support then slows down the cooling of the stack.

Should the glass stack have been slightly damaged during the experiment, be particularly careful when washing and re-using it.
Use water, a normal washing-up liquid for glass and a brush to clean the stack after it has completely cooled down.
Contaminants which have been sintered into the glass by the high temperature cause the lower part of the stack to become increasingly opaque until it is no longer usable.
The metal part of the model should simply be freed of residues of substances and wiped with a damp cloth after use.
When, after a number of experiments, the ceramic fibre ring is so damaged that the glass stack can no longer be firmly seated on it, it must be discarded and replaced by a new ring.

5 SAFETY PRECAUTIONS

In this experiment, there is a danger of flying sparks. It should therefore be carried out in a closed fume cupboard or outdoors at a sufficient safety distance. It is absolutely necessary to ensure that appropriate fire prevention measures are taken, and that no observers can be hurt by the hot sparks. In addition, carbon monoxide is generated during the reaction and can be burnt off at the mouth of the glass stack.
Carbon monoxide is a colourless, odourless gas, which has no taste, is poisonous and highly inflammable. Mixtures of it with air are dangerous as they can explode (lower ignition limit 12.5%, upper limit 74%). It is a blood toxin and causes an oxygen deficiency in organisms. In severe cases of poisoning, long-term damage can result from the lack of oxygen. Experiments with carbon monoxide must therefore be carried out in a fume cupboard with a good draught of air.
First aid when carbon monoxide poisoning occurs: Immediately call a doctor when an accident occurs or somebody feels very unwell. In the case of difficulty in breathing, immediately let in fresh air and when necessary, provide respiratory assistance. Keep the respiratory tract free. Hold the patient warm and comfortable. When there is a danger of unconsciousness, keep the patient lying on his side in a stable position, also during transport.