



# Design Analysis and Evaluation of Air Permeability Testing Machine for Foundry Sand

<Adekiigbe, A.><sup>1</sup>, <Igbalaye, M. T.><sup>2</sup>, <Adetoro, K. A.><sup>3</sup>

<sup>1,2,3</sup>Department of Mechanical Engineering Technology, Faculty of Engineering  
Osun State Polytechnic, Iree, Nigeria

**Abstract:** Permeability is the property by which we can know the ability of foundry sand to transmit gases. Rapid and reliable analysis of sand control trends is fundamentally important to the production of quality castings. A permeability-testing machine was designed, fabricated from locally sourced materials and its performance tested and found satisfactory for usage. The systematic design analysis of basic theories were considered in designing major components like air drum, water tank, bracket, manometer, base plate, center post, collar, orifice, valve and the dial to make it functional. The machine was designed to help foundry industries in Nigeria in order to improve castings quality.

**Keywords:** Permeability, systematic design, foundry industries, casting quality.

## 1. Introduction

Foundry sand, also known as moulding sand is sand that when moistened or oiled, it tends to pack well and hold its shape. It consists primarily of clean, uniformly sized, high-quality silica sand or lake sand that is bonded to form moulds for ferrous (iron and steel) and non ferrous (copper, aluminium, brass) metal castings (Ramana Rao, 2003). The moulding sand after it is prepared should be properly tested to see that required properties are achieved (Beeley, 2001).

Industrial and production trials required to make a lot of testing in laboratories, these testing s to allow evaluation of new materials (Sarek, Trytek & Nawrocki, 2009). Sand testing controls the moulding sand properties through the control of its composition. Control of mould materials parameters in production casting process provides repeatability of moulds and decreases quantity of casting defects (both kinds of defects, metallurgical and visual) (Doelman, 1966).

Air permeability of the moulding sand is the ability of the sand mould to allow the passage of gaseous product from the mould cavity to the atmosphere (Abolorin, Lawal & Salawu, 2010). This is important because during the pouring process many gases are produced, such as hydrogen, nitrogen, carbon dioxide, and steam, which must leave the mould otherwise casting defects, such as blow holes and gas holes, occur in the casting (Rao, 2001).

The urgent need to develop the foundry industries in Nigeria in order to meet the technological development of the country imposes new problems on the sand preparation equipment. Hence, there is a need to provide the foundry industry with locally sand testing machine that would satisfy the needs of the national economy and have the best technical and operational characteristics.

In the view of this, the design analysis and performance evaluation of gas permeability testing machine for foundry sand is considered in order to improve the casting product in

our foundry industries. This machine will absolutely show whether to increase or reduce grain size or bonding material, etc. It therefore meets the need of foundry industries to analyze the sand mould to be used.

## 2. Design of Machine Components

The machine composed of water tank, air drum, test piece tube, a three-way valve, manometer, and bracket.

**Air drum:** the air drum is cylindrical in shape, the volume  $V_p$  as given by Sharma & Aggarwal (2006)

$$V_p = \frac{\pi D_p^2 H_p}{4} \quad - \quad - \quad - \quad 1$$

Where  $D_p$  = diameter of air drum (m);

$$H_p = \text{height of air drum (m).}$$

Since, the air drum is to contain air; the volume of the air is also given by:

$$V_a = \pi D^2 h \quad - \quad - \quad - \quad 2$$

**Water tank:** The air drum is cylindrical in shape; the volume  $V_p$  is given by Sharma & Aggarwal (2006)

$$V_p = \frac{\pi D_p^2 H_p}{4} \quad - \quad - \quad - \quad 3$$

Where  $D_p$  = diameter of water tank (m);

$$H_p = \text{height of water tank (m).}$$

the volume of the water is also given by:

$$V_a = \pi D^2 h \quad - \quad - \quad - \quad 4$$

**Test piece tube:** All the parameters are same as design of air drum and water tank, the volume  $V_p$  is given by:

$$V_p = \frac{\pi D_p^2 H_p}{4} \quad - \quad - \quad - \quad 5$$

**Manometer:** A plastic material and cylindrical in shape, the volume  $V_p$  is given by Hall, Holowenko & Laughin (1998).

$$V_p = \frac{\pi d^2 l}{4} \quad - \quad - \quad - \quad 6$$

Where  $\frac{\pi d^2}{4}$  = area of manometer (m);

l = height of manometer (m).

**Centre post:** is cylindrical in shape, the volume  $V_p$  is given

by: 
$$V = \frac{\pi(D-d)^2}{4} \quad - \quad - \quad - \quad 7$$

**Collar:** All the parameters are same as design of the volume

$V_p$  is given by: 
$$V = \frac{\pi(D-d)^2}{4} \quad - \quad - \quad - \quad 8$$

The other parts are standard materials which are readily available in local markets.

**Table 1:** Calculated parameter of permeability test machine

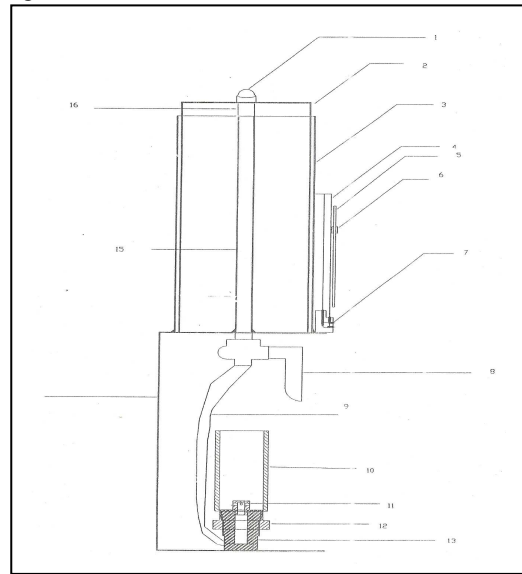
S/No	Calculated Parameter		
	Symbol	Value	Unit
1	$H_{air}$	118	mm
2	Water Volume, $V_w$	2728208	$mm^3$
3	Air drum Breath, $b_a$	462	mm
4	Water tank Breath, $b^w$	484	mm
5	Air drum cylinder,	246015	$mm^3$
6	Air drum cylinder cover,	25467.7	$mm^3$
7	Air drum pipe Volume,	4462.86	$mm^3$
8	Air drum Volume	275946	$mm^3$
9	Air drum Weight	21.25	N
10	Water Weight	28	N
11	Brackett Volume, $B_w$	44800	$mm^3$
12	Bracket Weight, $B_w$	0.34	N
13	Base support Weight	125400	$mm^3$
14	Base plate Weight	40.47	N
15	Water tank Volume	232650	$mm^3$
16	Water Tank Weight	17.92	N
17	Collar Weight	1.6	N
18	Manometer Volume	5657.14	$mm^3$
19	Center post Weight	222.75	N
20	Bracket Weight	3.5	N

### 3. Fabrication of Components

The permeability-testing machine was fabricated at Welding & Fabrication shop of Osun State Polytechnic, Iree, Nigeria using the calculated values shown in Table 1. It consists of air drum, base stand, center post, knurled collar, orifice, dial, manometer, manometer grain, bracket, an inverted bell jar, which floats in a water. The fabrication of air drum is done with mild steel rolled to form a cylindrical shape of diameter 147mm and length 335mm, electric arc welding is used for welding purpose. The fabrication of water tank have been done with 118mm diameter and 315mm length and welded to the base stand using the already drill base at the datum point. The base stand is made of mild steel of 3mm thick plate, cut into 680x100x3mm thick and folded into a U-shape of (190x300x190) mm, a triangular plate of 190x100x3mm thick was welded at four edges to support the weight.

The manometer is fitted in a hole which is link to the air passage. The centre post is made of carbon steel was cut with power hack saw, face centre drill to accommodate the test tube to allow the passage of the air from valve through the orifice to test sand, also threaded M24 to accommodate the knurled collar. The collar is made of medium carbon steel of diameter 70mm and 32mm length, face, centre drill step turning, bored threefold with M42 to fit in the centre post and knurled with diamond knurling tool. The orifice is made of brass and cut to diameter 25mm and 27mm length, faced, center drill step turning to the required dimension. The dial is plastic material, transparent in nature. It was calibrated for measuring the level of water in the manometer tube as well as to determine the permeability of the moulding sand. The bracket is made of mild steel bar, cut into (90x50x30) mm, faced, and marked out, step mill, centre punched, drilled and taped M6.

Inside water tank floats a balanced air drum carefully weighed and designed to maintain constant pressure of 10cm during its fall. The outlet from the air drum is connected to a centre post, the centre post incorporates a pipe for measuring pressure, which is connected to the water manometer and an expandable "O" ring for sealing the specimen tube. It also accommodates the orifices. The Figure 1 shows the assembly drawing of machine.



**Figure 1:** Assembly drawing of permeability-testing machine  
Key: 1-Archor, 2- air drum, 3- water tank, 4- manometer, 5- dial, 7- bracket, 8- air valve, 9- copper tube, 10- test piece tube, 11- orifice, 12- knurl collar, 13- centre post



**Figure 2:** Permeability-testing machine

After assembly the air permeability-testing machine is as shown in Figure 2

#### 4. Working Principle, Testing and Discussion

Permeability is determined by measuring the time required for air at standard volume and pressure to pass through the sand specimen. The permeability meter determines how easily air can pass through the moulding sand. The working principle is as follows:

- i. Check that open orifice is in the position in the centre.
- ii. Prepare an AF.S standard specimen of sand, before stripping from tube place in position on the centre post and seal by rotating the knurled ring anti-clockwise.
- iii. Check water level in the tank, turn air valve to VENT and slowly raise drum until it is out of water.
- iv. Allow the air drum to descend by turning the air valve to a position midway between closed and vent.
- v. Time the descend of the air drum between zero and 2000ml mark with a stop watch and record the pressure indicated on the manometer during the descend of the drum.
- vi. Calculate the permeability by applying the given formula

The permeability number was computed by the formula:

$$P = \frac{(v \times h)}{(p \times a \times t)}$$

Where, P - Permeability number (N); v - Volume of air passing through the specimen (cm<sup>3</sup>); h - Height of the specimen (cm); a - Cross-sectional area of the specimen (cm<sup>2</sup>); p - Pressure difference between upper and lower surface of test specimen (in cm of water column); t - Time taken by the air to pass through the sand (min.).

The fabricated machine was used to carry out permeability test on different types of moulding sand with additions at Foundry workshop of Osun State Polytechnic, Iree, Nigeria. The results are presented in Table 2

**Table 2:** The results obtained from the experiment

Mass (kg)	Permeability (kg/N)					
	Sand	Addition (s)	1 <sup>st</sup> readg	2 <sup>nd</sup> readg	Avg val	Std. Val
200	New	15kg Bentonite + 12kg coal dust + 10 L Water	4.1	4.1	4.1	19.5
200	New	17kg Bentonite + 12kg coal dust + 10 L Water	4.1	4.3	4.2	19
200	Back'g	4.3L Water	4.8	5.0	4.9	15.2
200	Old	4.25L Water	5.0	5.2	5.1	14.3
200	Old	5L Water	4.4	4.6	4.5	17.3

From this experiment, we determined the value of permeability of foundry sand for different quantity of mass and conditions in order to evaluate the performance of the machine. The readings were done two times to observe any changes that might present while experiment is performed. The readings obtained are presented in Table 2. The

theoretical value of permeability for the mass 200kg with 15kg bentonite coal dust water is 19.5mm, 200kg with 17kg bentonite coal dust water is 19mm, 200kg of backing sand is 15mm, 200kg of old sand with 4.3L water is 14.3mm, 200kg of old sand with 5L water is 17.3mm while experimental value determined from the experiment is for the mass 200kg with 15kg bentonite coal dust water is 4.1mm, 200kg with 17kg bentonite coal dust water is 4.2mm, 200kg of backing sand is 4.9mm, 200kg of old sand with 4.3L water is 5.1mm, 200kg of old sand with 5L water is 4.5mm.

There is significant increase in values because sand composition dries more and more after each test. It was discovered that the more bentonite and the water content, the more the permeability. Though, the environmental condition still affect the permeability, it varies with moisture contact of the environment. An increase in permeability usually indicates a more open structure in the rammed sand, and if the increase continues, it will lead to penetration-type defects and rough castings. A decrease in permeability indicates tighter packing and could lead to blows and pinholes (Granlund 1999).

#### 5. Conclusions

From the above discussion, we can conclude that the gas permeability-testing machine presented in this work was successfully designed and fabricated using locally available materials. It was confirmed to be effective in shaping metal-casting sand property by providing accurate information on casting conditions of foundry sand. The machine was to enhance indigenous development of Nigeria foundry industries by providing test equipment at minimum cost as well as enhance metal-casting sand at higher efficiency.

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