division of technology for society

netherlands organization for
applied scientific research

STANDARD TEST METHOD
for
FROST RESISTANCE
OF
CLAY ROOFING TILES
Radiation Freezing Test

by

J.H. v.d. Velden

Intended for:

The Ceramic Industry.

TNO

p.o. box 342
7300 AH apeldoorn

address
laan van westenenk 501

telex 36395 tnoap
phone 055 - 77 33 44

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SUMMARY

Details are given of the equipment and the standard test procedure of MT-TNO at Apeldoorn, The Netherlands, for the determination of the frost resistance of clay roofing tiles by the radiation freezing test.
The procedure has been designed in narrow cooperation between the TNO-Division of Technology for Society (MT-TNO) and the TNO Institute for Building Materials and Building Constructions (IBBC-TNO) and has proved to produce results, relating to the behaviour of the relevant products under natural exposure conditions.

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Standard: MT-TNO 8501-E
1985

1. SCOPE

This method is designed to test the frost resistance of all types of clay roofing tiles, when subjected to natural conditions of wetting, freezing and thawing.
This method does not apply to clay roofing tiles, which have been made artificially water-repellent after firing (for instance by means of a silicone-treatment).

2. SUMMARY OF METHOD

A wet test unit of the product is subjected to a fixed number of controlled freeze/thaw cycles, after which it is inspected for any possible visible frost damage.
Uni-directional freezing effected by radiation and natural convection, is followed by a complete thawing out of the test pieces by immersion in water. This is to restore the initial level of saturation, related to the potential water absorption of the roofing tiles at issue under natural conditions.
Both initial saturation and alternative freezing and thawing are performed under standardized external conditions during standardized periods of time.

3. APPARATUS

Drying oven, capable of maintaining a constant temperature of 110 ± 5 °C.

Balance, used for weighing the test pieces, with a maximum tolerance of 0.1%.

Saturation basin, thermostat controlled, capable of maintaining a water-bath at a constant temperature of 80 ± 2 °C.

Frost-thaw simulator, as shown in the figures 1, 2 and 3, comprising:

- an exposure tray, which can be moved in and out the apparatus, with an exposure surface of at least 0.5 m^2, slightly inclined to ensure rapid run-off of thawing water;
- a freezing plate, serving as a heat extractor for the exposure surface, mounted in a cabinet;
- a refrigeration unit, capable of producing controlled constant freezing-plate temperatures down to -50 ± 1 °C within two hours after starting a freezing stage of an exposure tray filled with test pieces at a temperature of +15 ± 1 °C;
- equipment for the controlled supply of thawing water at a constant temperature of 15 ± 0,5 °C at an average flow of (100 ± 10)ml/s for each m^2 of available exposure surface, as well as appliances for a controlled discharge of thawing water. Thawing water should contain less than 400 g ($CaCO_3$ + $MgCO_3$) (or equivalent hard water salts) per m^3.
- a programmer for the freeze/thaw/periods.

4. SELECTION AND PREPARATION OF THE TEST UNIT

4.1 Selection of the test unit

The test unit is composed of four test pieces, selected from a laboratory sample of ten roofing tiles, which should to be representative for the sampled object. The selected test pieces are those, which on account of visual characteristics, sound, dimensions or ultrasonic testing are the least sintered ones of all.

4.2 Inspection and weighing of the test pieces

Carefully inspect the selected test pieces for possible damage. Mark each damage with waterproof ink. Dry the test pieces in a drying oven at a temperature of 110 ± 5 °C for at least a period of 24 hours. Thereafter allow to cool off to ambient temperature, weigh and note down the masses M_d of the test pieces.

4.3 Saturation of the test unit

Immerse the test pieces quickly in drinking water of 80 ± 2 °C in such a manner that they don't touch one another or indeed the walls of the saturating basin, and maintain them under these conditions for 72 ± 1 hours. Following this, allow the immersed test pieces to cool off to 20 ± 5 °C for a period of 24 ± 1 hours in the same water. After termination of this procedure, the test pieces have acquired the requisite high degree of saturation for the freeze/thaw test on roofing tiles.

4.4 Determination of water absorption and bulk density

Take the test pieces out of the water bath and first weigh them submerged in water of 15 ± 5 °C and after having wiped them off with a moist cloth, again weigh them in air.
Calculate the water absorption W in % by mass and the bulk density d in kg/m^3 from the formulae:

$$W = \frac{M_d - M_w}{M_d} \cdot 100$$

$$d = \frac{M_d}{M_w - M_a} \cdot 1000$$

M_d = weight of dry test pieces [g]

M_w = weight of wet test piece in air [g]

M_a = apparent weight of wet test piece in water [g].

5. CYCLIC FREEZE/THAW TEST

5.1 Method of exposure

Place the pre-processed saturated roofing tiles, next to and overlapping each other, with their face surfaces upward and embedded in fine gravel (2-4 mm) in the exposure tray. The highest parts of the roofing tiles are to be level with the upper peripheral edges of the tray or not more than 10 mm below. The layer of gravel should have a thickness of 25 ± 2 mm at the lowest parts of the roofing tiles.
The remaining space in the exposure tray has to be stuffed with coarse filtermats.
After having filled the tray, it should be slid into the simulator and pushed up against the freezing plate frame. In this position the upper parts of the test pieces will lie at a distance of 40 ± 10 mm from the freezing plate.

5.2 Testing procedure

Starting with the supply of water to the exposure tray, the frost-thaw simulator automatically subjects the exposed test unit to a cycle of freezing and thawing in accordance with the data given in tabel 1.
The test can be interrupted after the first 10 cycles to enable inspections.

The test is terminated after 25 freeze/thaw cycles, after which the test pieces are available for inspection for frost damage.

TABLE 1. The freeze/thaw program

total number of cycles		25	
testing stage		first 10 cycles	last 15 cycles
freezing conditions	units		
intensity of frost	-	hard	slight to moderate
heat flow density (from an exposed surface at 0 °C)	W/m^2	300±60	100±20
freezing plate temperature	°C	-50±1	-25±1
freezing period, refrigerating unit in operation*	h	8	8
thawing conditions	units		
supply temperature of thawing water	°C	+15±1	+15±1
flow of water supply per m^2 of the exposed surface	ml/s	100±10	100±10
thawing period, thawing system in operation*	h	4	4
duration of the cycle (variation < 1%)	h	12	12
total time of duration of test	days	12½	

* Waiting times of approximately 3 minutes are included in these periods.

6. CHECK ON VISIBLE FROST DAMAGE

Subject the test pieces to an inspection on all sides. Check whether the testing has led to visible frost damage in the form of cracking, splintering, peeling or breakage. This check should be carried out with normal eyesight, in clear day light and at a distance of 400 ± 100 mm.

Mark the positions of any possible damage and note the type and the degree of seriousness of the frost damage.

As a guideline in the determination of the degree of seriousness of the frost damage, take the extent to which, in the judgement of a qualified inspector, the quality of the product is affected from both the aesthetic and technical aspects. Differentiate between no, light, moderate, and heavy frost damage.

7. APPRAISAL OF THE TEST RESULTS

A sample of roofing tiles, tested in accordance with this standards is considered as being frost-resistant at the specified high level of saturation, if none of the test pieces from the test unit exhibits visible frost damage in the form of cracking, splintering, peeling or breakage after termination of the test.

8. TEST REPORT

In referring to this standard, the test report gives the following information:

a. Name and address of client supplying the laboratory sample.

b. Date of receipt of sample.

c. Identification data of the sample.

d. A short description of the test conditions.

e. The test results of each of the test pieces, namely:

- weight in dry condition;
- bulk density;
- water content on testing;
- nature and degree of seriousness of visible frost damage, stating the number of cycles.

f. Appraisal of the frost resistance.

9. REMARKS

This standard for clay-roofing tiles has been taken from the proposed general Dutch standard for the determination of the frost resistance of all types of stony building materials by single-sided freezing in a frost-thaw simulator, in which heat extraction during freezing occurs at choice either by forced convection or by radiation and natural convection.
Referring to this general standard the test units are to be tested with a Moderate, a High, or an Extreme degree of saturation, dependent on the area of application of the products in question. Clay-roofing tiles are to be tested with a High degree of saturation. This standard for the determination of the frost resistance of roofing tiles is subject to revision at any time by the responsible technical committee in the Dutch Organization for Applied Scientific Research TNO.

10. REFERENCES

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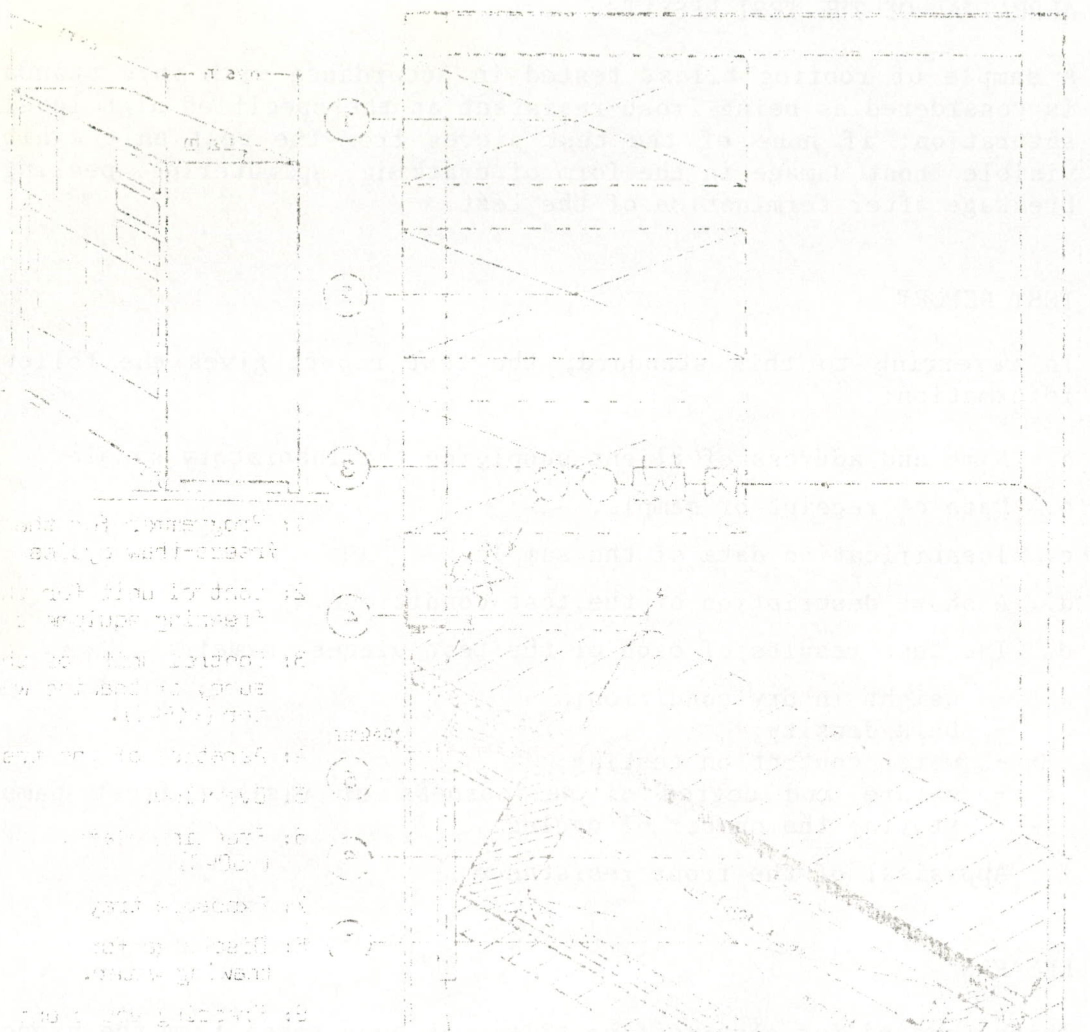
Van der Velden, J.H. "Weathering and Frost Testing of Structural Ceramics", Ziegelindustrie Int. 35(1983)1, p.18-26.


1: Programmer for the freeze-thaw cycles
2: Control unit for the freezing equipment
3: Control unit for the supply of heating water
4: Aeration of the tray
7: Receiving tray
8: Discharge for draining water
10: Water supply
11: Discharge to drainage

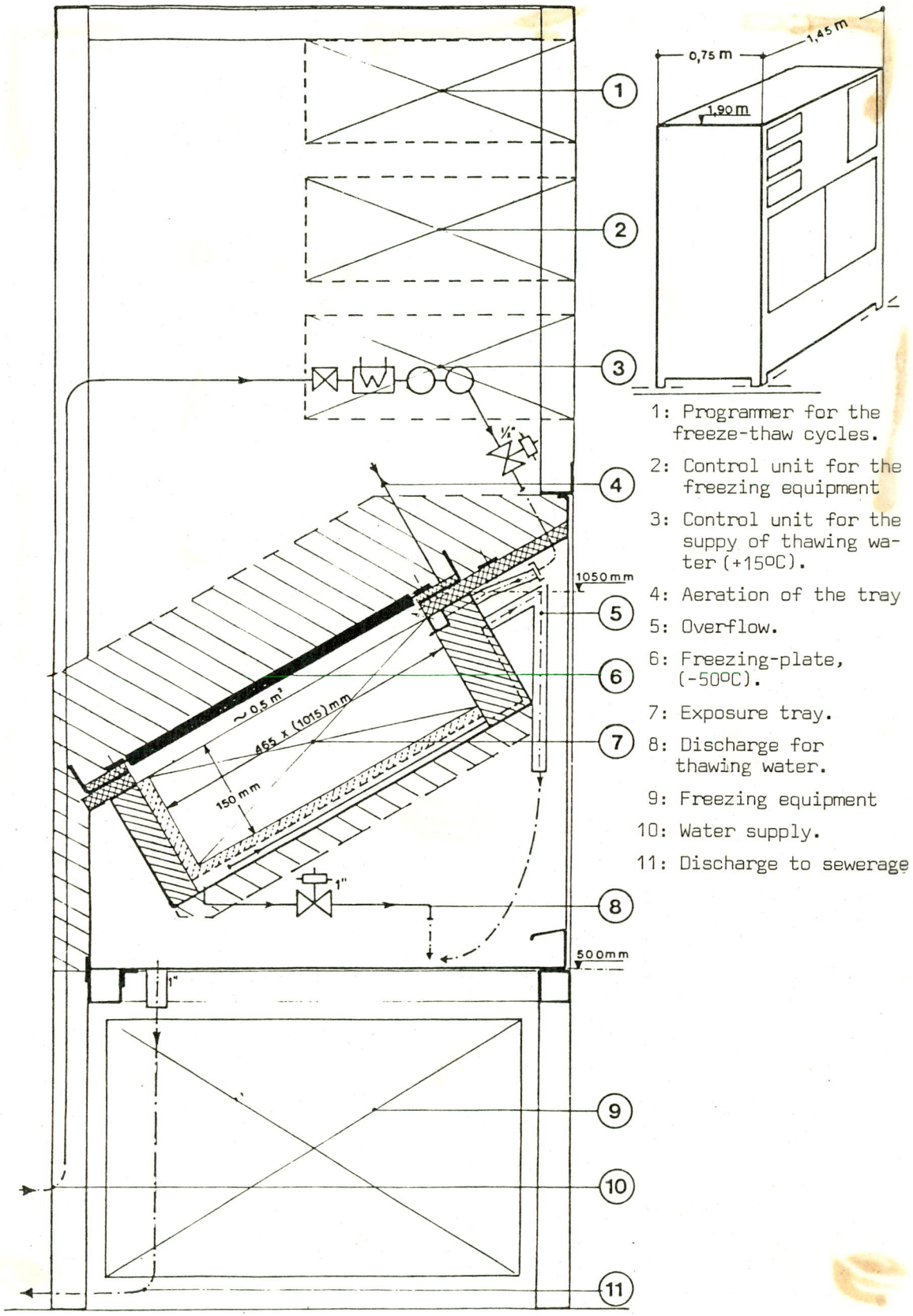


Figure 1. SKETCH OF FROST–THAW SIMULATOR.

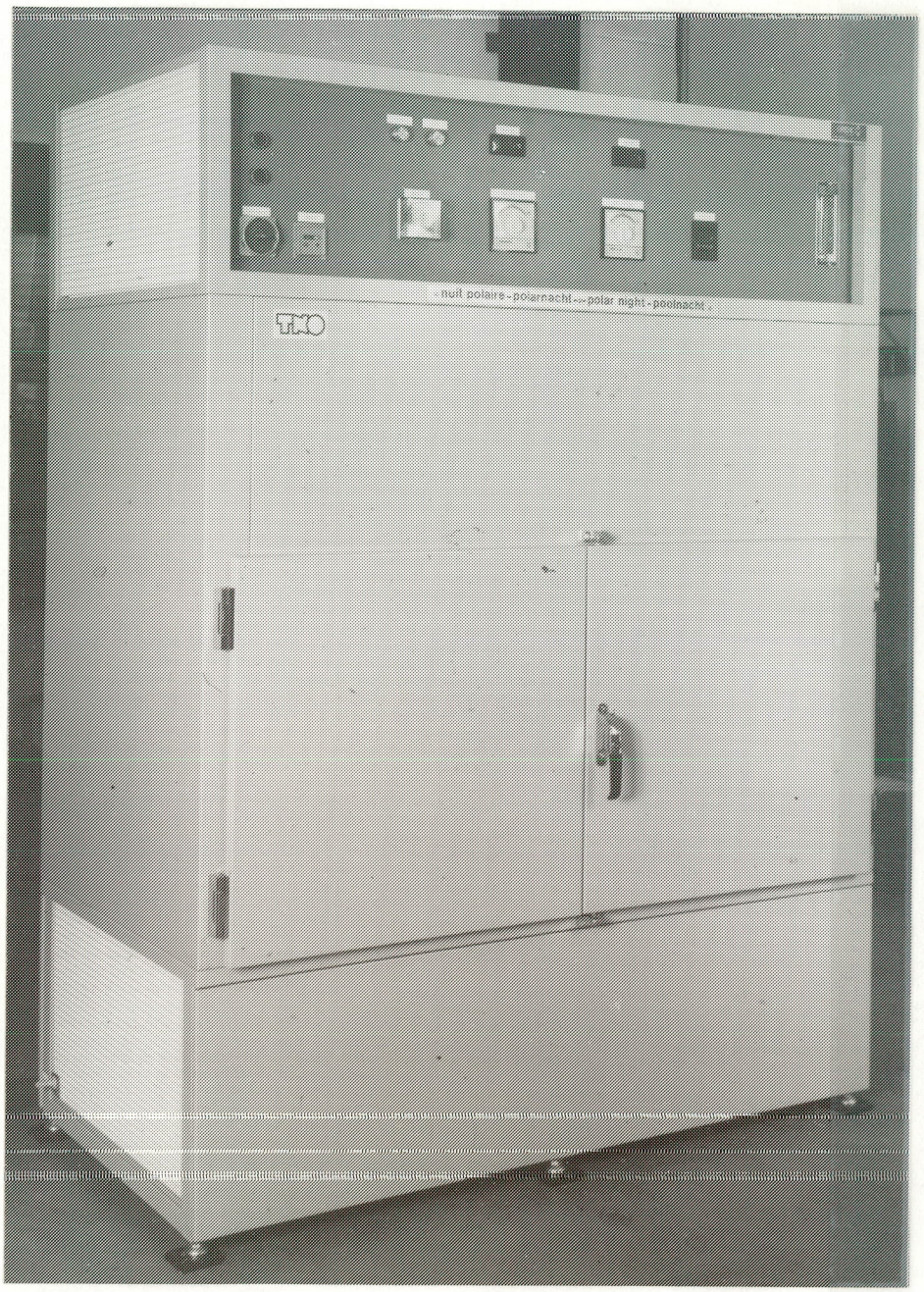


Figure 2. GENERAL VIEW OF APPARATUS.

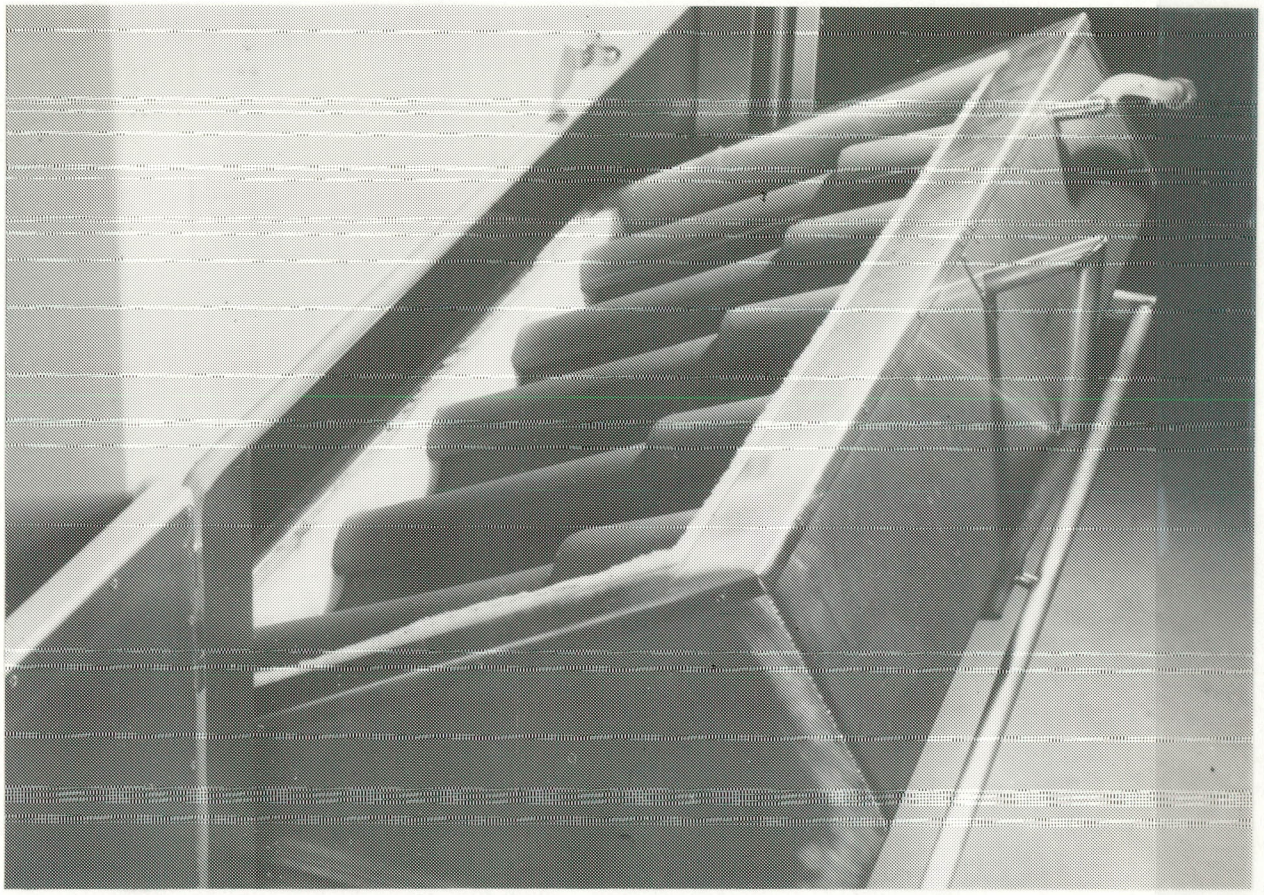


Figure 3. EXPOSURE TRAY WITH CLAY—ROOFING TILES