# MAXIMIZING PENETRATION DEPTH OF CONSERVING AGENTS

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## 1 INTRODUCTION

Many items of cultural significance are built of sandstone. Sandstone is quartz grains held together by a binding matrix of clay or siliceous minerals. It is the reactions of the binding matrix with components of the atmosphere, rain or by-products of microbiological life that causes decay of the stone. These reactions can occur in a reaction zone up to 40mm deep into the stone. Any treatments to stabilize the binding matrix must penetrate the stone deeper than the reation zone. In some cases - special the application of stabilizing fluids - problems have been caused by insufficent fluid penetration. Whilst various fluids have been developed to reduce the reactivity of the binding matrix there is no fluid application method suitable for use on a building site that can apply a fluid to the required depth. There is no way of telling what amount of the fluid caused the problem because prevailing site fluid application methods are not suited to controlling or monitoring the amount of fluid.

There are many fluid application methods used in the construction and conservation industries but only one method, bathing, applies the fluid to an adequate depth, allows the amount to be controlled and does not waste fluid. Bathing requires the immersion of the heritage item in the fluid. This is practical for statues but not for entire building facades. However we can use use the bathing method as a yardstick to measure other application methods against.

An application method should aim to:

- achieve the required fluid peneteration depth by using capillarity,
- avoid loss of fluid through overspray,
- control amount of absorbed fluid.

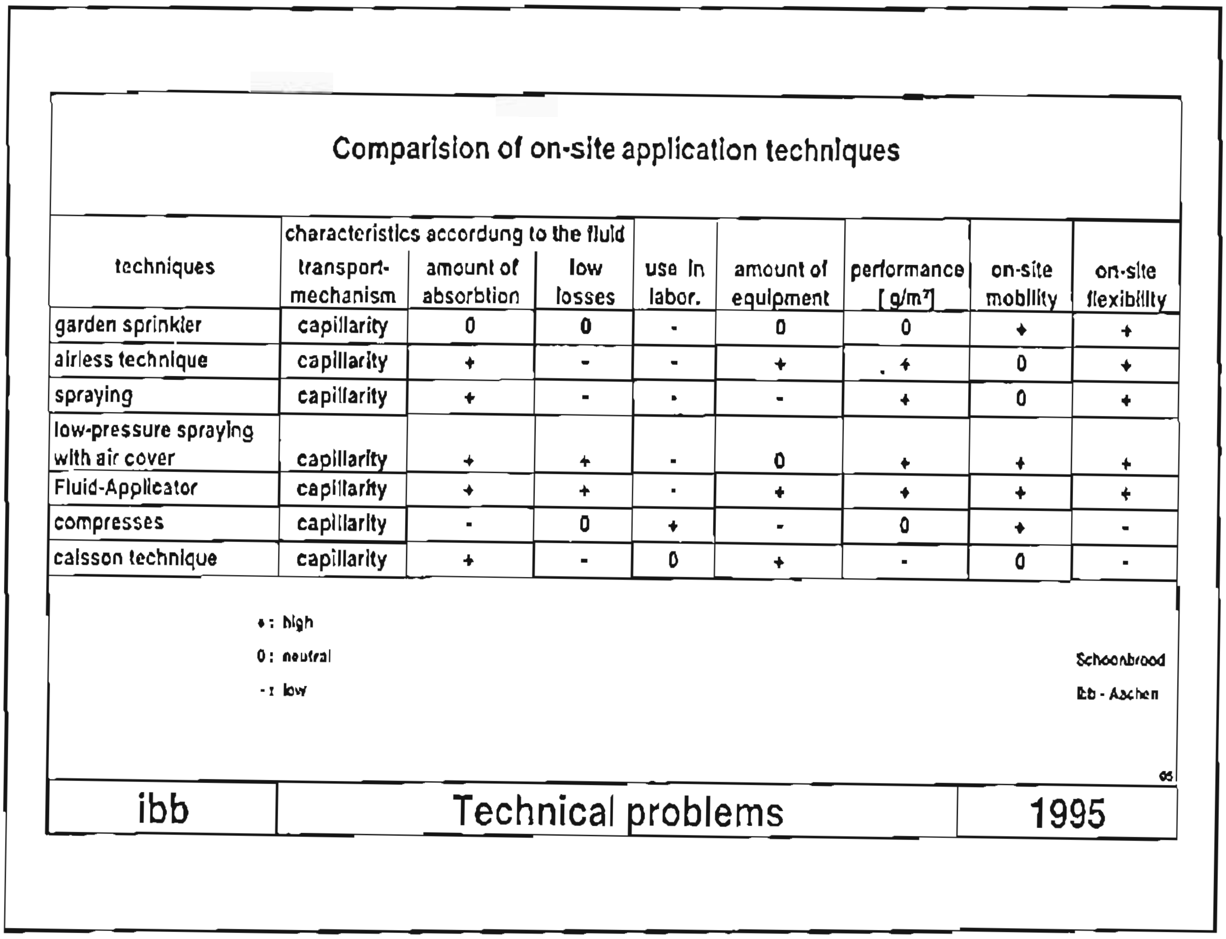
This paper outlines the experiments that led to using capilliary action to give maximum pentration depth and control of the amount of absorbed fluid. It illustrates how this led to the refinement of the ibb's Fluid Applicator to fulfill the above requirements with the addition of guidance apparatus.

# 2 PROBLEMS WITH CURRENT APPLICATION TECHNIQUES

Until the development of the ibb's Fluid Applicator there was no fluid application technique suitable for insitu masonry that fulfilled all of the aims. For detailled technical information about the Fluid Applicator we refere to literature.

Table 1 shows the results of comparized current application techniques. Obviously the Fluid Applicator fullfilles the formulated requirements in most cases.

TABLE 1 Comparission of current application techniques



Comparision of on-site application techniques

| techniques | characteristics accordung to the fluid | | | use in labor. | amount of equipment | performance [ g/m²] | on-site mobility | on-site flexibility |
|---|---|---|---|---|---|---|---|---|
| | transport-mechanism | amount of absorbtion | low losses | | | | | |
| garden sprinkler | capillarity | 0 | 0 | - | 0 | 0 | + | + |
| airless technique | capillarity | + | - | - | + | + | 0 | + |
| spraying | capillarity | + | - | - | - | + | 0 | + |
| low-pressure spraying with air cover | capillarity | + | + | - | 0 | + | + | + |
| Fluid-Applicator | capillarity | + | + | - | + | + | + | + |
| compresses | capillarity | - | 0 | + | - | 0 | + | - |
| caisson technique | capillarity | + | - | 0 | + | - | 0 | - |

+: high
0: neutral
-: low

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# 3 CURRENT APPLICATION TECHNIQUE FOR INSITE MASONRY

The current application method is known as 'wet in wet'. An area of the facade is flooded for ten or fifteen minutes with fluid applied with for example a garden sprinkler. The flooding session is repeated one, two or three times. Fluid lost through overspray and overflow removes the opportunity to record the amount of fluid applied. The penetration depth is insufficient.

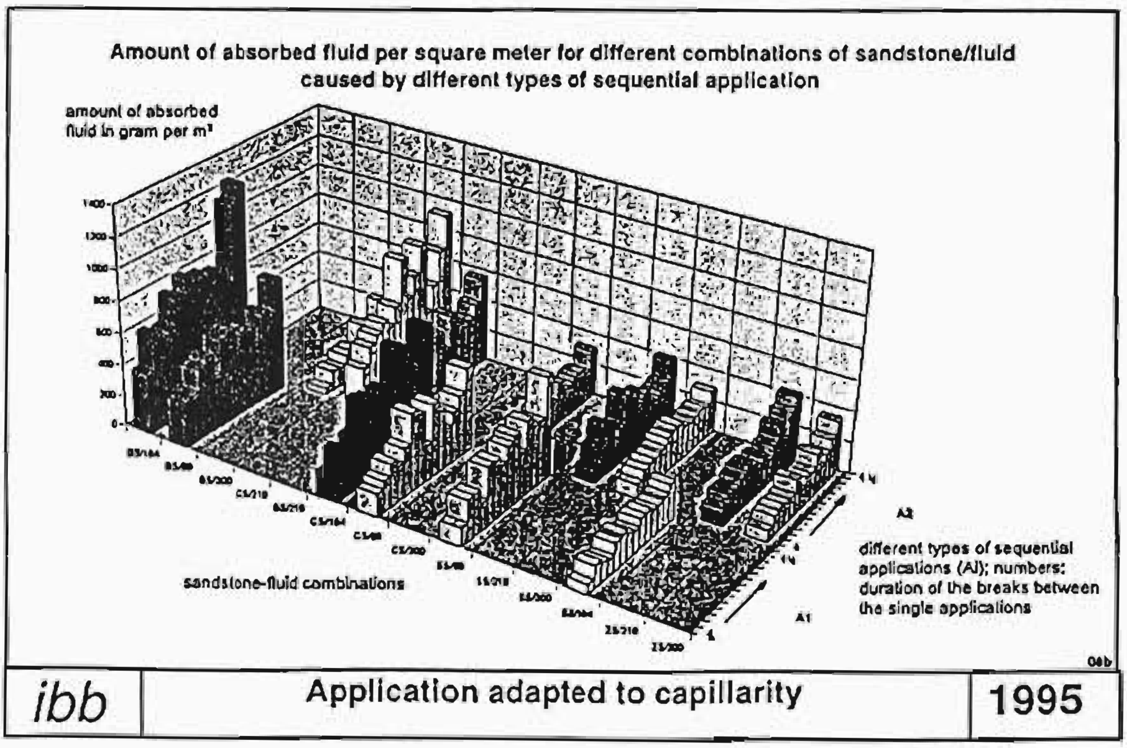
In order to improve penetration depth, we started investigations by looking for the optimum number of flooding sessions for the wet in wet application method.

We performed two series of tests, A1 and A2. In the first step of A1 three samples of different kinds of sandstone were flooded with conserving fluids once. In the second step samples were flooded twice with a gap of ten miniutes between flooding. Then three samples were flooded three times with a gap of ten mintues and so on to a maximum of ten flooding sessions. This was repeated for various combinations of stone and fluid. A2 is a slightly different series of tests for different combinations of stone and fluid, according to the gap between the single flooding sessions.

Figure 1 shows the results from te two different sequences of tests. A1 and A2 in the Z axis. The X axis is the combination of different fluids applied to different kinds of sandstone with the Y axis showing the average penetration depth of the fluid over threesamples.

The results illustrate that ten single applications give the best penetration depth. However more than ten applications does not lead to further improvement in the penetration depth.

FIGURE 1 The optimum number of flooding sessions for the wet in wet application method

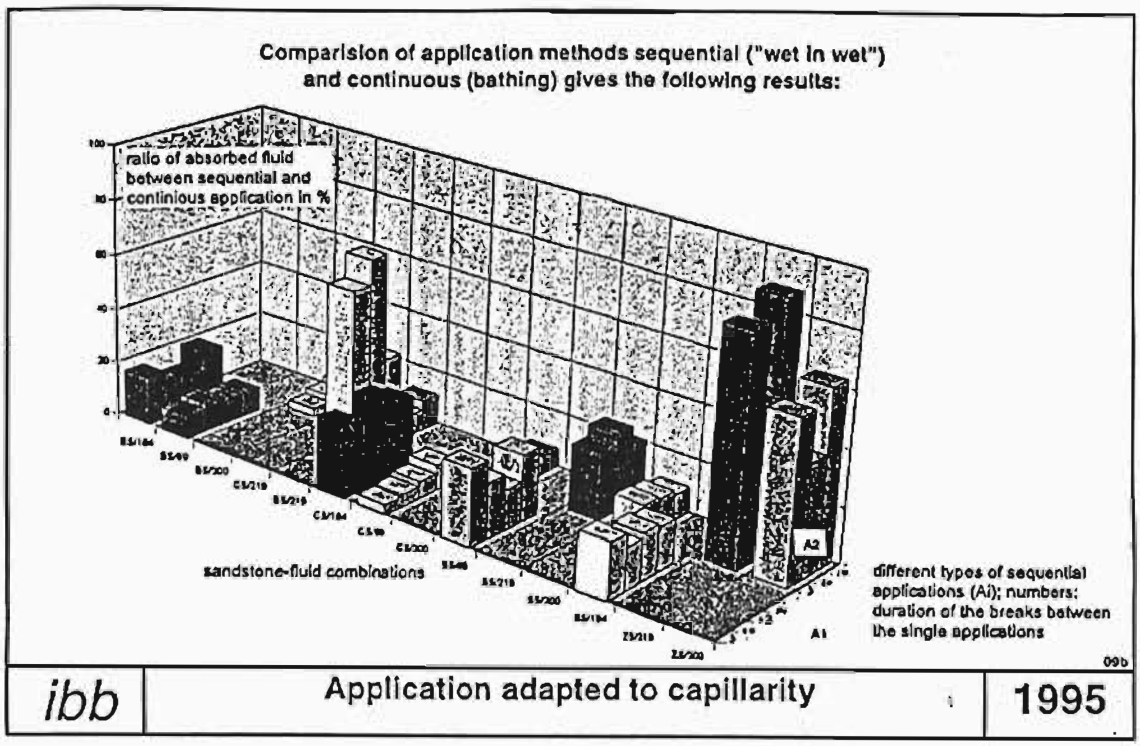


# 4 COMPARING APPLICATION METHODS

Even with ten flooding sessions of the 'wet in wet' method the penetration depth remains inadequate. So we compared the results for the different combinations of stone and fluid from the preceeding table (where we looked at results for wet in wet) with the same combinations but with the fluid applied with the bathing method (figure 2). The bathing method being the optimum method but that which is impractical for use on site.

Again the X axis is the combinations of different fluids applied to different sandstones but this time the Y axis is the ratio between the penetration depth achieved by the bathing technique and the sequential spraying expressed as a percentage. The two different series of tests, A1 and A2, are again shown in the Z axis.

FIGURE 2 Ratio between the penetration depth achieved by the bathing technique and the sequential spraying



Comparision of application methods sequential ("wet in wet") and continuous (bathing) gives the following results:

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This table leads to the conclusion that for fluid to attain the greatest penetration depth it must be applied continuously. So we abandoned the idea of flooding sessions and turned to developing additional equipment to use the Fluid Applicator continuously.

## 5 INVESTIGATING ABSORBED FLUID & PARAMETERS

We investigated the relation between the amount of absorbed fluid and application time and the amount of absorbed fluid and penetration depth. The fluid was applied with the Fluid Applicator continuously in very small amounts to a maximum application time of twenty four hours. The amount of fluid and rate of application was controlled by a computer and the pistol was guided by a rail; thus, both apparatus ensuring a consistent application.

With the results for Sander Sandstone we can see that the amount of fluid absorbed and penetration depth increases over twenty four hours (figure 3). With the Cottaer Sandstone we can observe that after four hours penetration depth achieves the back side of the samples, penetration depth and amount of fluid do not further increase (figure 4).

FIGURE 3 Relation between the amount of absorbed fluid and application time and the amount of absorbed fluid and penetration depth for Sander Sandstone

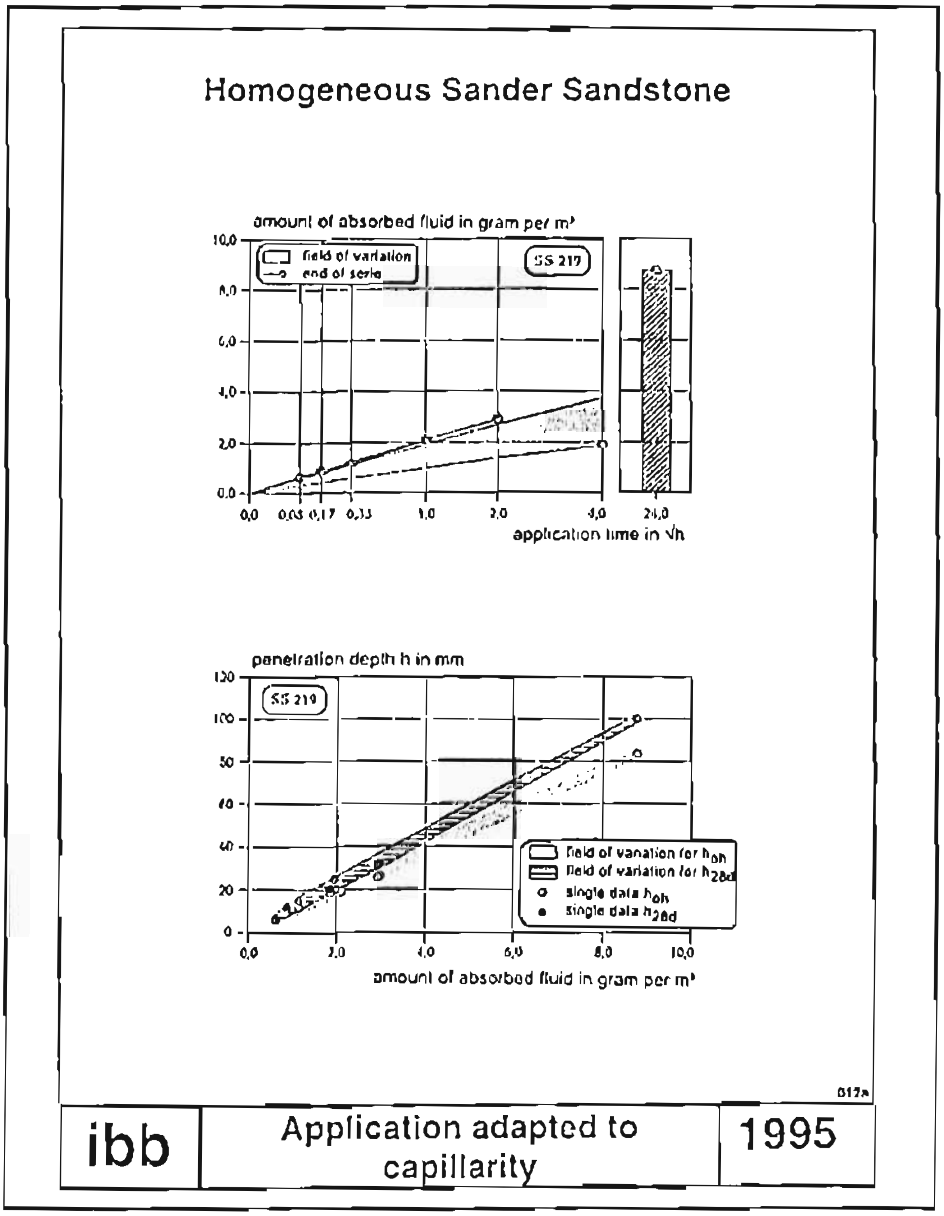
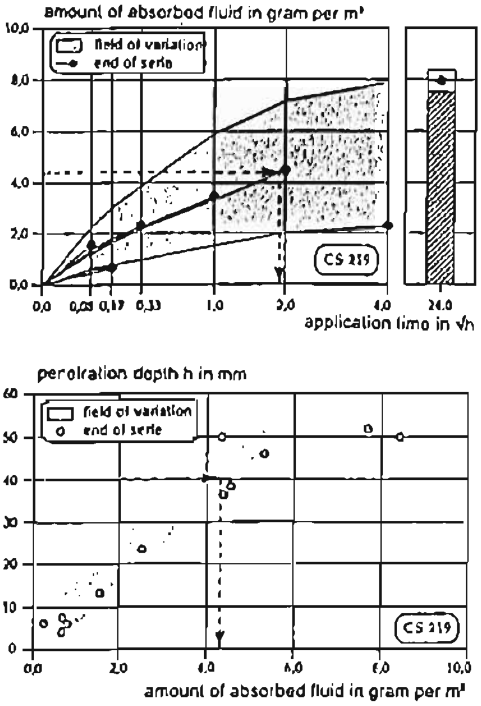


Figure 4 Relation between the amount of absorbed fluid and application time and the amount of absorbed fluid and penetration depth for Cottaer Sandstone

## Inhomogeneous Cottaer Sandstone



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This type of testing also enables us to predict the amount of fluid and application time to achieve a required penetration depth for any kind of sandstone. From these tests we can begin to form a model of fluid penetration for different kinds of sandstone.

# 6 TECHNICAL SOLUTIONS

Prevailing application techniques flood the stone for ten to fifteen minutes leave it for half an hour then flood the stone again one or two times. If sections of a large area are flooded in rotation the operator can work quickly over vast areas of a facade. However it has been proven in the above experiments that periodic flooding does not achieve a great penetration depth and it wastes fluid.

To use capillarity to give the maximum penetration depth with minimum of fluid, a small amount of fluid must be applied over one to four hours.

The fluid applicator gave the best results with periodic flooding so we started development of equipment to guide and control it to fit to the capillarity of the sandstone. The equipment controls the pistols movement across the facade.

## 6.1 TRANSPORTING THE FLUID FROM THE PISTOL TO THE FACADE

Since 1994 the pistol has been modified to reduce the overspray. The optimum drop size is achieved by delivering the fluid to the pistol almost without pressure and by fully opening the nozzle to reduce blockage of the fluid. Around the nozzle a cone of air is released to form a cone of air to direct the fluid drops to the facade. For further information we refere to literature.

## 6.2 TWO GUIDANCE AND CONTROL SYSTEMS

Refered to the requirements speed and direction of the pistol must be regulated in relation to the amount of the fluid. Furthermore the amount of fluid has to be controlled by a dosage regulator (figure 5). Even coverage of the wall can be achieved by variation of $V_x$ to $V_y$ at the edges of the field. The distance between the facade should also be varied. All the parameters could be controlled with a joystick or with a computer.

There are two possibilities of guidance equipment. Both can be mounted on a standard scaffold section.

1 The first is attached directly to the scafold and is based on the guidance system of the Fugomat - developed for the removal of mortar joints - where $V_x$ and $V_y$ are separately governed by a horizontal and a vertical guide rail (figure 6).

2 The second option is mounted on a beam fixed to the scaffold. A telescopic arm governs $V_x$ and $V_y$ (figure 7).

FIGURE 5 Transport of the fluid from the pistol to the facade

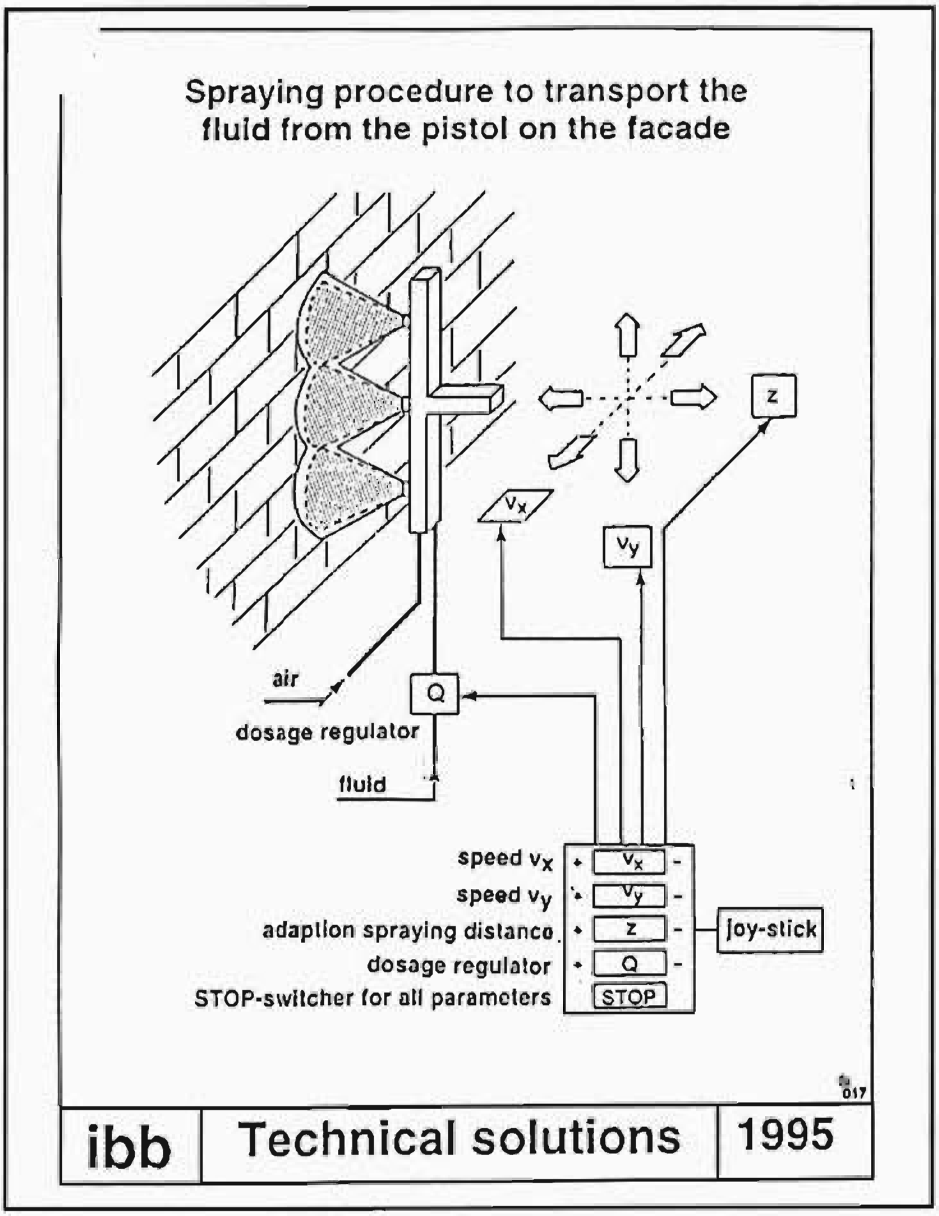
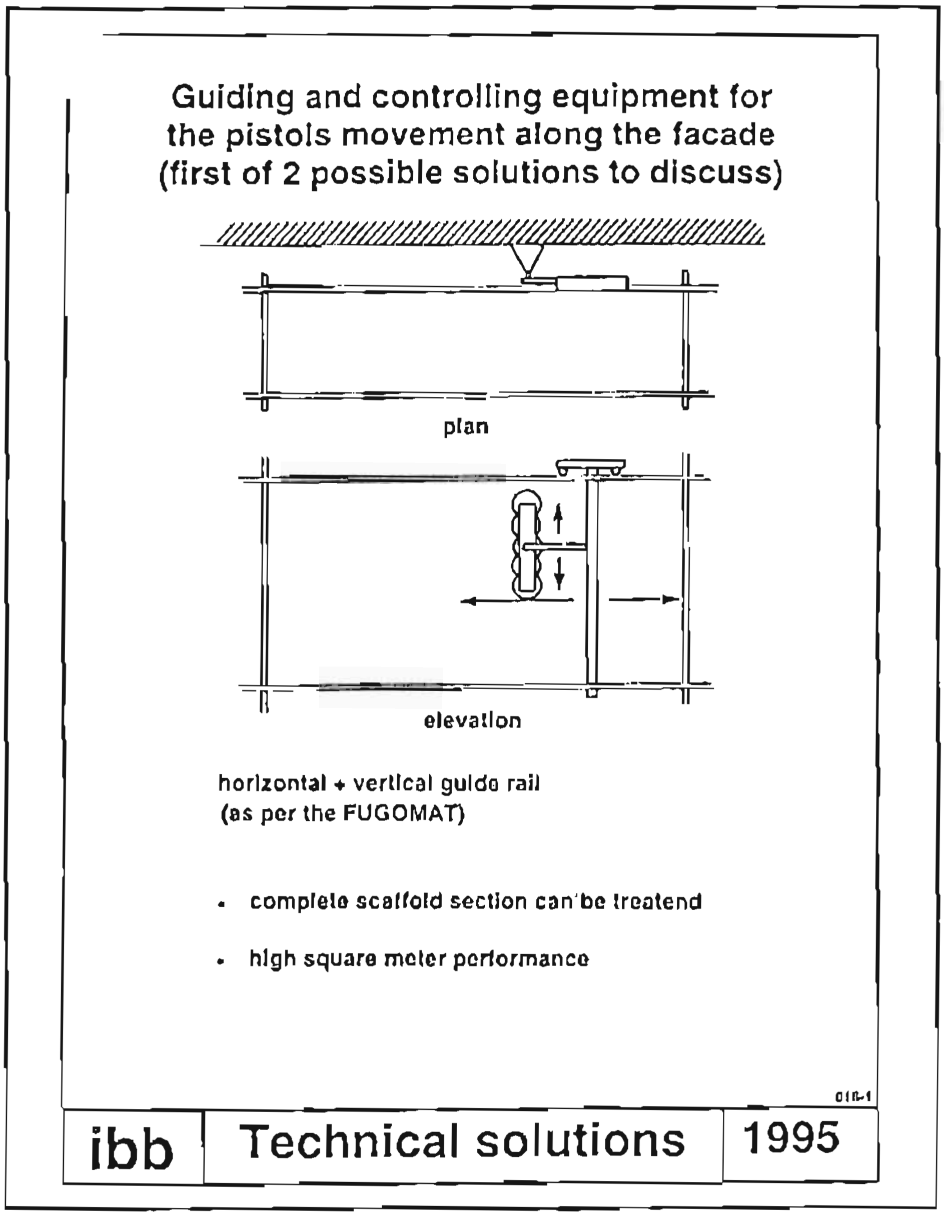


FIGURE 6 First of two possibilities of guidance equipment



Guiding and controlling equipment for the pistols movement along the facade (first of 2 possible solutions to discuss)

plan

elevation

horizontal + vertical guide rail
(as per the FUGOMAT)

- complete scaffold section can be treatend
- high square meter performance

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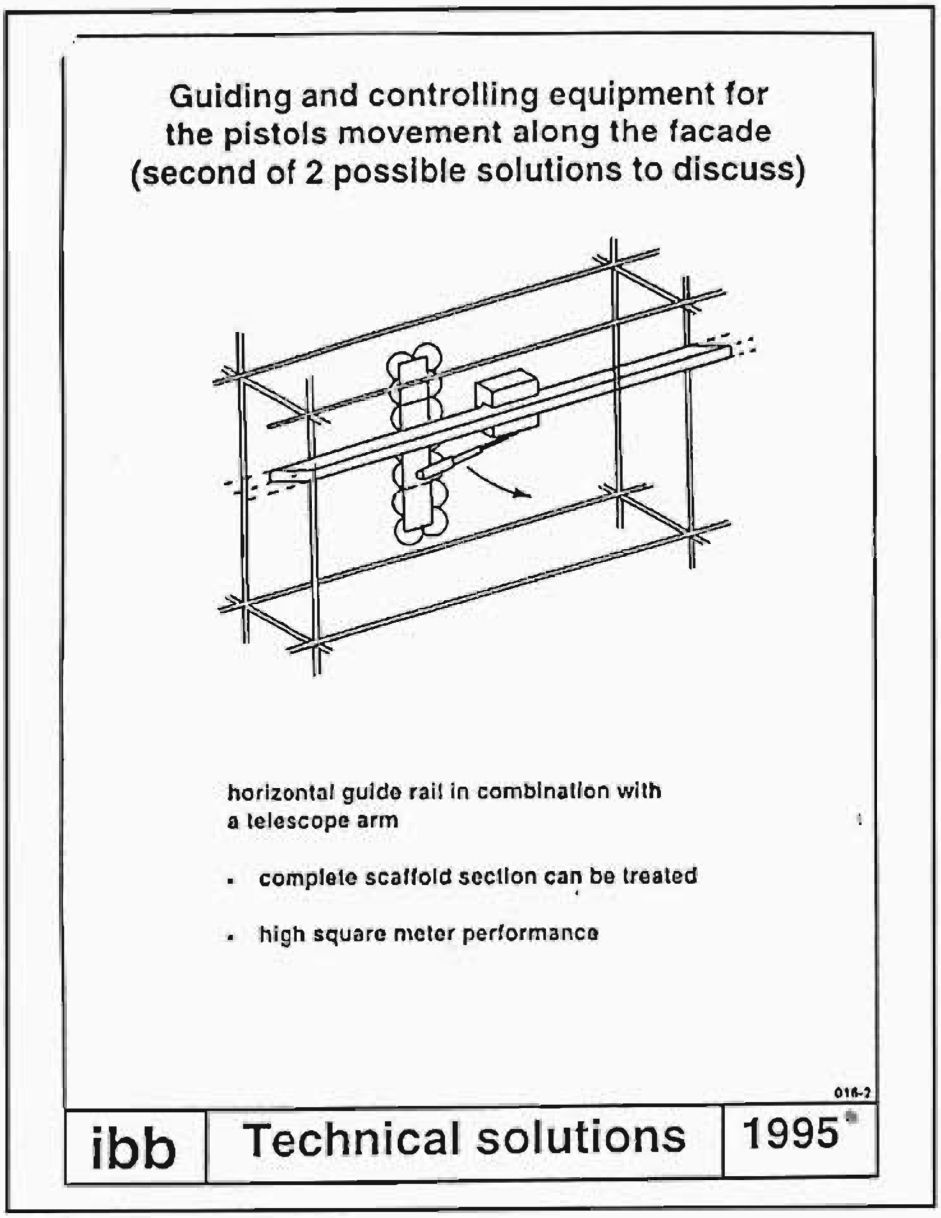
FIGURE 7 Second of two possibilities of guidance equipment



## Guiding and controlling equipment for the pistols movement along the facade (second of 2 possible solutions to discuss)

horizontal guide rail in combination with
a telescope arm

- complete scaffold section can be treated
- high square meter performance

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# 7 SUMMARY

To achieve a deep penetration the fluid has to be applied over a longer time period of up to 4 hours.

The Fluid-Applicator was developed to apply a small amount of fluid with a minimum of overspray however it requires additional equipment to control and monitor the amount of applied fluid.

Two options of guiding the Fluid Applicator pistol, and therefore controlling the amount of fluid, have been explored.

Further experimental research of the relation between the amount of absorbed fluid, application time and penetration depth, with various sandstones, will lead to a model for predicting penetration depth as influenced by conditions on the building site.

# 8 LITERATURE

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