Colt and the Ghent Fire Tests

An International research programme
on the interaction between sprinklers and smoke ventilation

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The Ghent Fire Tests

Summary

A series of full-scale experiments to investigate the interaction of vents and sprinklers were carried out in the purpose built multifunctional fire test building in Ghent.

These experiments involved steady state and growing fires with a variety of conditions of venting and sprinklers.

A vast amount of data has been collected and this now has to be analysed in great detail.

Preliminary indications show that the ventilation system had little effect on the opening times of the first sprinkler, and that the mathematical model predictions are quantitively similar.

Peter Hinkley worked for the Fire Research Station for 35 years. Notable amongst his many accomplishments are that he carried out the initial research into smoke control in single storey buildings, with Dr Philip Thomas, in the early 1960's, and is co-author of Fire Research Technical Papers 7 and 10. Mr. Hinkley is now employed as a consultant by Colt International.

Acknowledgements

The experiments were carried out at the Multifunctioneel Trainingcentrum by courtesy of the governor of the Province of East Flanders, Dhr. H. Balthazar; and the Director of the Fire School, D. de Muynck.

We would also like to express our grateful thanks for the co-operation and assistance of the BRE Fire Research Station who provided instrumentation and research technicians, and the Ghent Fire Service who provided workshop facilities, fire and safety cover during the experiments, and a video camera and operator.

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The experiments

The specific objectives of the experiments were:

(a) to validate the model of the effects of ventilation on the time of operation of sprinklers, and the number of sprinklers operating;

(b) to determine the possible significance of any local effects of open ventilators on the ceiling jet;

(c) to determine whether a sprinkler system is likely to cause serious loss of stratification of the layer of hot gases when ventilation is carried out in good time;

(d) to determine the possible reduction in efficiency of ventilators within the zone of operating sprinklers.

A combined team from Colt and the Building Research Establishment carried out a total of over 30 experiments during the course of the programme. Colt undertook the main experimental work, while the team from the Fire Research Station were responsible for measurements of temperature, velocity and CO_2 content of the fire gases in the building, and in conjunction with Peter Hinkley, for preliminary analysis of the results.

▲*A vast amount of data was collected during the course of the experiments, much of which was recorded on computer disc to allow detailed analysis.*

▲*Recordings were obtained during the experiments to help monitor progress.*

The experimental facility

The building incorporates a sprinkler system and Colt roof-mounted ventilators and inlet ventilators.

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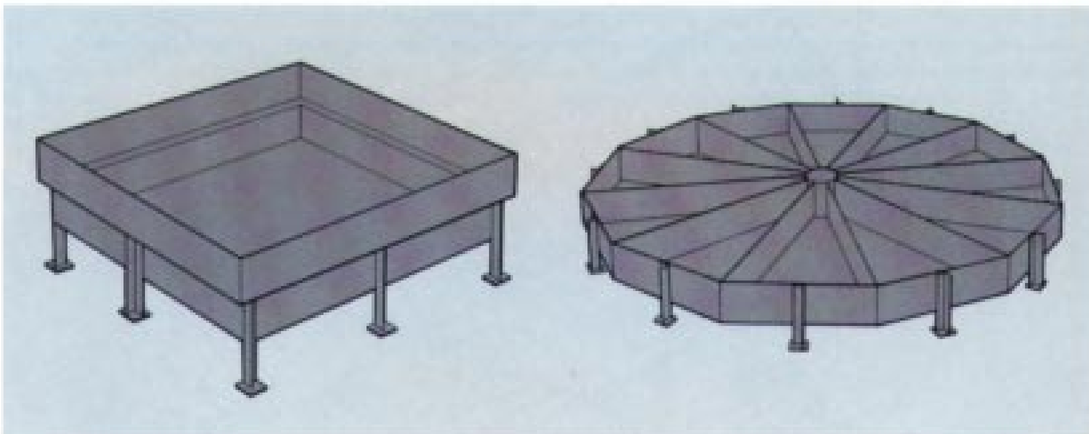
A data logger recorded most of the measurements on disc, and a computer provided graphs of the results between experiments.

Hexane was chosen to fuel the fires for the majority of the experiments. Hexane burns relatively smokelessly so that the sampling equipment was not contaminated. In particular there was no blockage of probes or CO_2 sampling tubes.

The heat output of the fire was determined by the rate of supply of fuel, injected beneath the surface of water contained in metal trays.



The weather throughout the experimental programme was moderately settled with little rain. Although wind speeds of 10m/s were recorded above the roof of the building during experiments, they were generally in the range of 2 – 7m/s and predominantly from a southerly direction.

Tests were conducted with two main types of fire: steady fires of a maintained size; and growing fires. Additional tests were conducted on fires fuelled by plastic.

▲ *The 10,000m³ Multifunctioneel Trainingcentrum*

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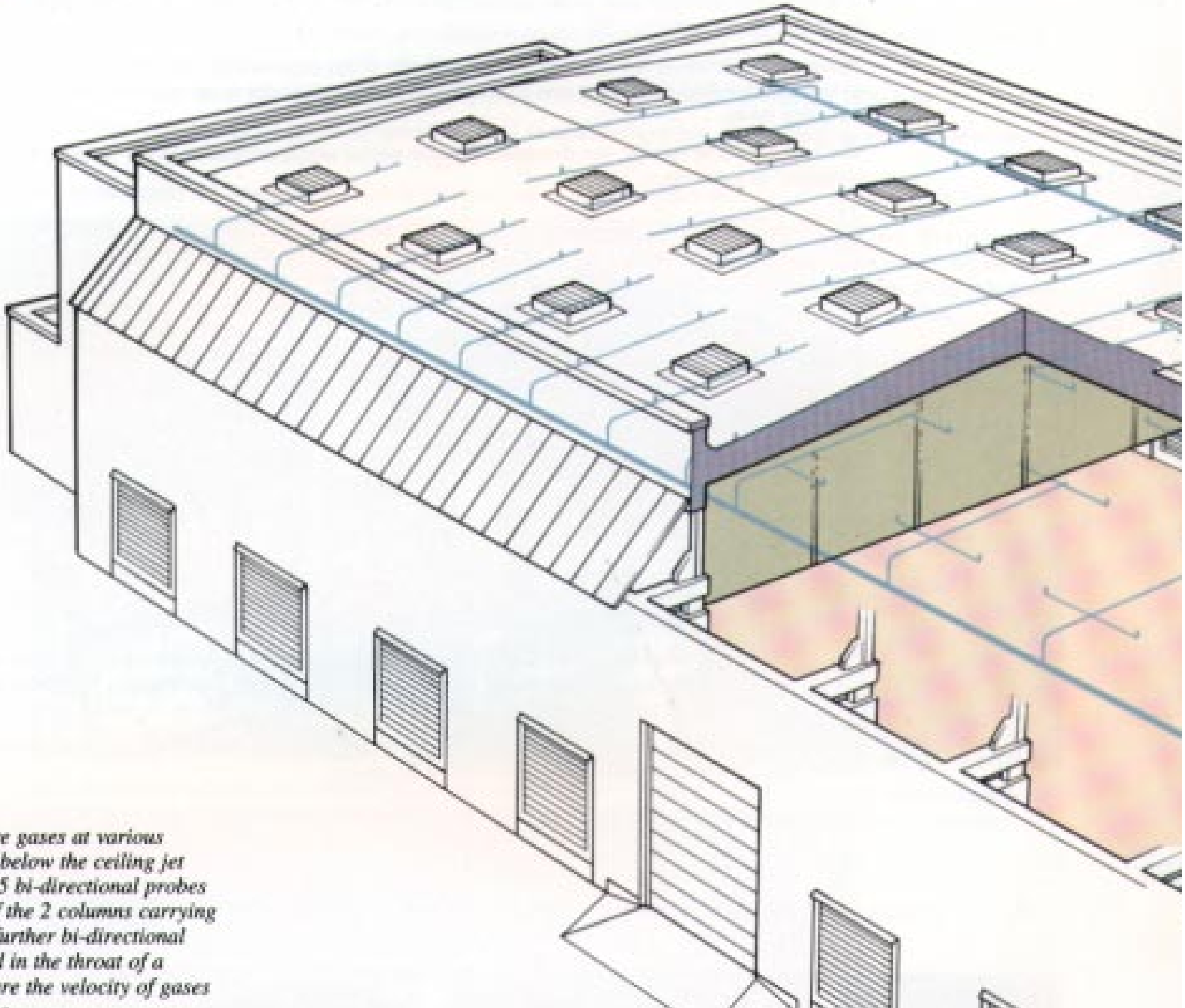

Velocities of the fire gases at various heights in and just below the ceiling jet were measured by 5 bi-directional probes attached to each of the 2 columns carrying thermocouples. A further bi-directional probe was installed in the throat of a ventilator to measure the velocity of gases through the opening.

While there was generally sufficient light smoke to enable visual estimates of smoke layer depth, a smoke generator was provided to assist observations. The height of the outlet could be positioned at the required distance from the ceiling.

The sequence shows the rapid build up of smoke during an unvented experiment.

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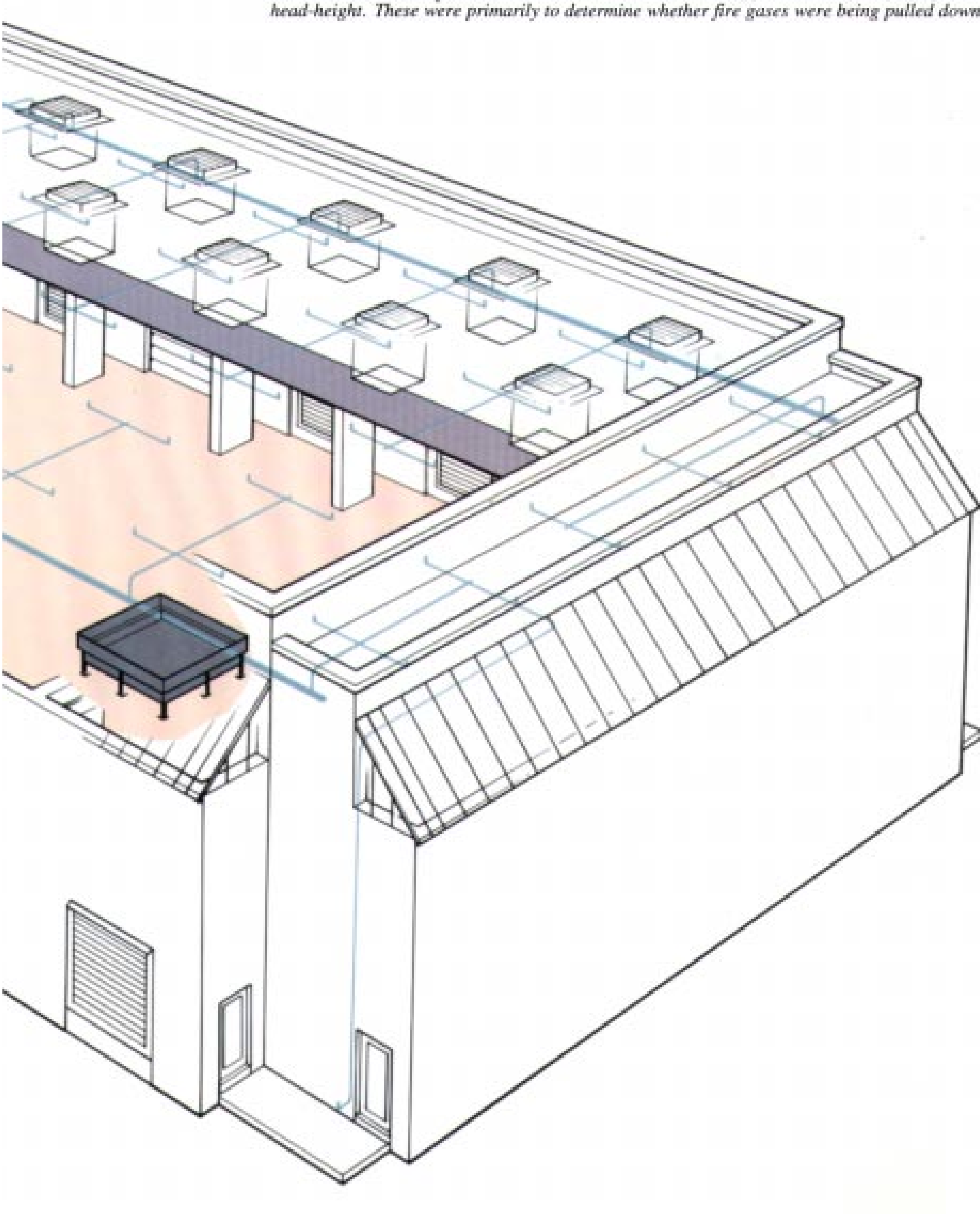
Temperatures 150mm beneath the ceiling were measured by some 30 thermocouples. Vertical temperature distributions were measured by 2 columns, each carrying 21 thermocouples, and positioned 6m and 8m from the axis of the fire. Other thermocouples were provided to measure ambient temperatures and the temperatures in the apertures of 4 ventilators. A further 55 thermocouples were added in the second series of experiments primarily to determine the opening times of sprinklers.

Measurements of CO_2 concentration were made in the ceiling jet, in the layer of hot gases beneath, and at head-height. These were primarily to determine whether fire gases were being pulled downwards.



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Experiments with steady fires

The fires were in 2m sq trays and had a heat output of 5MW. It was found that a 10 minute duration was adequate and provided at least 5 minutes of relatively steady temperatures.

The main block of 18 experiments was carried out with combinations of 0, 1 and 5 open sprinklers and 0, 10, and 20 open vents.

There was no evidence of the fire gases being pulled down by the sprinkler spray in any of these experiments.

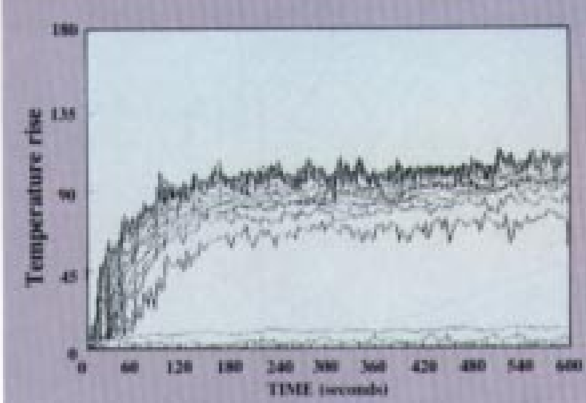

Fig. 1 All ventilators closed

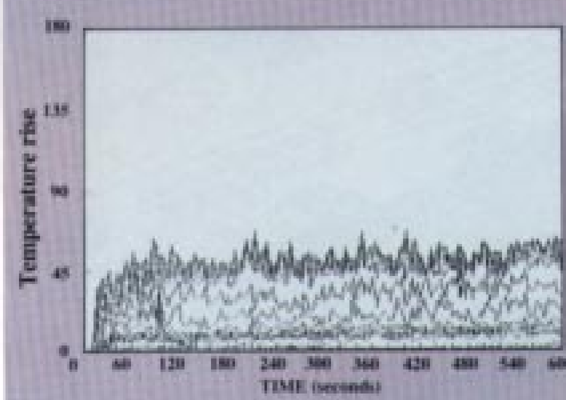

Fig. 2 20 ventilators open

Figures 1 and 2 each show the records of temperature against time for all the thermocouples on one of the vertical columns plotted on the same graph.

In both examples, the ceiling jet can be distinguished because the small temperature variations are in phase. As expected, the ceiling jet is about 1m deep, and the temperature is much lower in the vented fire than in the unvented fire.

The layer of hot gases is distinguishable beneath the ceiling jet, at approximately 1.9m deep in the vented experiment and 4.3m deep without ventilation.

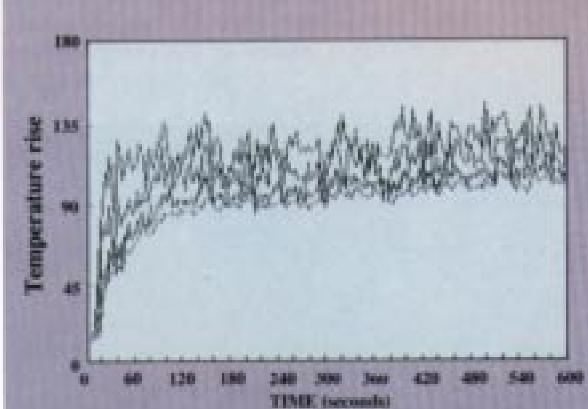

Fig. 3 All ventilators closed

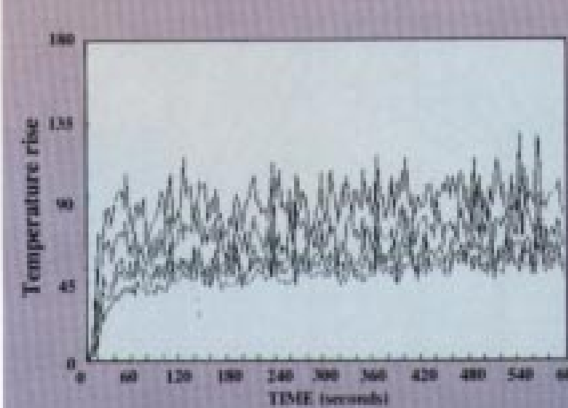

Fig. 4 20 ventilators open

Figures 3 and 4 each show records of temperature against time for a line of thermocouples 150mm beneath the ceiling and extending from the axis of the fire to a wall. The temperature decreases with distance from the axis of the fire, and the temperature variations are much greater near the fire than near the wall, indicating that the gases are more stagnant near the wall.

Temperatures are lower and decrease more rapidly with distance in the vented test than in the unvented test.

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Experiments with growing fires

13 Experiments were carried out to investigate the effects of ventilators on the operation of sprinklers with growing fires.

Hinkley's model predicted that water flow would be of prime importance in determining the number of sprinklers opening after 'control' of the fire. Lower water pressure causes the sprinkler head to produce larger water droplets, reducing the cooling effect. The subsequent temperature build-up will cause other sprinklers to operate remote from the fire.

The mains water supply was found to be insufficient to maintain adequate pressure to the sprinkler system, resulting in a large number of sprinklers operating. After the first five experiments the main riser was modified to enable a fire pump to be used to provide adequate pressure.

The rate of supply to the segments of the tray was increased every 10 seconds to produce a heat output growing exponentially from 0.83MW to a potential maximum of 14MW.

As soon as the first sprinkler opened, the rate of fuel supply was held constant to simulate the fire being controlled by the sprinklers. The number of sprinklers subsequently opening depended both on water pressure and venting. In those experiments where the sprinkler system was fed only by the mains supply, water pressure at the end of the system fell to a fraction of a bar (too small to measure) and only 20 open ventilators prevented all 55 sprinklers from opening.

Even when a pressure of 5 bar was maintained at the pump (effectively at the base of the rising main) all 55 sprinklers opened during the unvented experiment. 41 sprinklers opened when the heat output of the fire was reduced by 20% a further 30 seconds after the operation of the first sprinkler.

In general, ventilation caused only a negligable delay to the opening of the first sprinkler.

All of the ventilation arrangements tried resulted in a reasonable number of sprinklers opening (between 6 and 14).

SUMMARY OF RESULTS OF EXPERIMENTS WITH GROWING FIRES

Expt No.	Vents	Pumped supply	Fire after 1st Spr	First spr open		No. of sprs open
				Time s	fire MW	
21	20	no	A	c155	10.2	26
22	20	no	A	169	13.0	40
23	10	no	A	157	10.6	55
24	10	no	A	152	10.2	55
25	0	yes	A	146	9.2	55
26	0	yes	B	151	10.2	41
27	9 C	yes	B	168	13.0	11
28	9 C*	yes	B	148	10.0	9
29	16 D*	yes	B	158	11.6	12
30	16 D	yes	B	172	14.2	14
31	20	yes	B	157	11.6	7
32	10	yes	B	155	10.2	6
33	10	yes	A	154	10.2	11

A: Heat output constant after first sprinkler opens
B: Heat output constant for 30s after first sprinkler opens, then reduced by 20%
C: Block of 3 x 3 vents, fire beneath central vent
D: Vents open round perimeter of reservoir
***: Vents 30% open**
spr = sprinkler

▲ *Table 1 shows the time of operation of the first sprinkler, the heat output of the fire at that time, and the total number of sprinklers opening in each experiment.*

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Preliminary results

The series of experiments were successfully completed, and although a full analysis of the results has yet to be completed, some tentative conclusions can be drawn from observations of the tests.

1. The smoke ventilation system and the sprinkler system appeared to work well in combination.
2. The effect of venting on the operation of the first sprinkler is qualitatively similar to that predicted by the model but more careful quantitative comparisons are to be made.
3. During the experiments with steady fires there was no evidence of smoke being pulled down to low level by the sprinkler spray.
4. During both vented and unvented experiments with growing fires there was some tendency for the fire gases to be pulled down when the sprinklers were operating at high pressure. Although the effects appeared to be only local, this was most evident when the fuel supply to the fire was turned off (therefore heat was no longer being generated) and the sprinklers were still in operation.
5. The depth of the ceiling jet was approximately 1m as expected.
6. Sprinkler 'skipping' occurred in most of the experiments, including the unvented ones, and was most evident in the experiments with high water pressure. The results will be analysed with the objective of determining whether ventilation bears any relationship to this.

The results are also pertinent to the design of sprinkler systems. Other aspects may become apparent during analysis.

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