ABSTRACT

This survey describes how external walls and joints are constructed in practice. The paper gives you an opportunity to compare how successful the implementation of airtightness has been in Sweden in comparison with the results presented in the report D2:1983 "Air infiltration control ..." by A Elmroth and P Levin.

The survey covers the majority of all Swedish prefabricated single family houses constructed in 1984. All big prefabrication companies are included in the survey.

The following issues are presented:
- Wall sections
- Sealing systems
- Measured airtightness and method
- Number of houses measured
- Distribution between different heating and ventilation systems
- The demand from the customers to measure the value of airtightness

The conclusions are that:
- the majority of the houses has an airtightness of 2-2,7 ach/h
- the airtightness is easy to decrease to less than 1,0 ach/h
- it is recommended to control 5-10 % of the production of each housetype
- airtithtness is easy to control with the exhaust fan
- only the big customers carry out control

1. INTRODUCTION

In Sweden 1/3 of all dwellings are prefabricated houses. These are single-family dwellings built as detached houses and constructed of timber.

The companies have during the last 4 years developed well insulated and airtight houses with a low demand of heat power.

Three different types of element are used in house production: small elements (L < 2,5 m) 20 %; large elements (L 5-11 m) 60% and volume elements 20%.

The main part of the population in Sweden lives under the condition of 4 100 degree days.

2. METHOD

14 companies participated in the survey. They represent 2/3 of the total production (12 000 houses) of prefabricated houses in Sweden today. A questionnaire was sent to each company. The answers were collected by telephone and drawings were sent in to the author.

Test results were received from each company. The tests were carried out by consultants or official test institutes.

3. RESULTS

3.1 Thermal insulation

Prefabricated houses in Sweden have better insulation than required in the Swedish Building Code.

Table 1 House production and different k-values

Number of companies	Houses/ year	k-value wall	roof	window
1	200	0.23	0.20	1.9
2	1 000	0.23	0.15-0.16	1.9
2	1 200	0.24	0.14	1.9
3	1 100	0.21	0.13	1.9
1	400	0.21	0.20	1.9
1	1 200	0.15	0.13	1.5
1	450	0.20	0.15	1.9
1	600	0.19	0.12	1.9
2	1 300	0.17	0.11	1.9
1	100	0.13	0.09	1.5
Swedish Building Code		0.25-0.30	0.17-0.20	2.0
Swedish Building Code Electric resistance heating		0.17	0.12	2.0

The conclusion to be drawn from this is that the k-value and the insulation in the prefabricated houses are 15% better than required in the Building Code. The trend still shows a reduction of the k-value to very thick insulation.

3.2 Heating and ventilation systems

With very tight and well insulated houses the demand for a good designed ventilation system increases. With the introduction of thick insulation and heat recovery systems the power required for heating the house has decreased. To save oil for heating, Sweden has turned to electricity. In order to save both energy and electricity Sweden has developed systems with heat pumps connected to exhaust air producing hot tap water and heating the supply air or heating the water in a hydronic system.

Table 2 Heating systems in prefabricated single family houses in Sweden

Direct electric resistance heating	20 %
Air heated	60 %
Electric boiler, hydronic system	5 %
District heating, hydronic system	5 %
Wood boiler, hydronic system	5 %
Misc.	5 %

Table 3 Ventilation systems and heat recovery systems in prefabricated single family houses in Sweden

Mechanical exhaust ventilation	22 %
Mechanical exhaust ventilation - heat pump - hot tap water	9 %
Mechanical exhaust ventilation - heat pump - hot tap water - heating supply air	52 %
Mechanical exhaust ventilation - heat pump - hot tap water - preheating hydronic system	10 %
Mechanical supply and exhaust air-heat exchanger	7 %

This investigation showed that natural ventilation has totally vanished from the market. Not a single house was reported.

3.3 Airtightness

All companies included in the survey had carried out some kind of measuring with a view of convincing themselves that the end product (the house) and its detail solutions came up to standard.

One company considered that this result could be achieved by measuring a couple of exterior walls. Furthermore the detail solutions give the impression of being extremely good. Five companies have controlled that the various types of houses function with a satisfactory degree of tightness. Three companies control every year a selection of houses at various building sites in Sweden with a view of checking that the erecting is properly done. Four companies carry out routine test of various types of houses all over the country. Finally, there is one company that is measuring all their houses and guarantees the tightness of these houses.

Table 4 Measured houses. Value of airtightness

	Com-pany	Production houses/year	Measured since -82	Measured/ year	Value ach/h 50 Pa
Checked some housetypes and/ or elements	6	3 100	60		2
Checking sometimes	3	2 500	110	30	2.5
Good quality control	4	1 700	780	170	2.0-2.5
Guarantee	1	300	450	300	0.7
	14	7 600	1 400	500	
The Swedish Building Code					3.0

All houses were measured with the blower-door method except houses with provided guarantee. All these houses are measured by means of the exhaust fan. People from the company measure the air tightness and some of the results are then checked by the Swedish Testing Institute. All other measurements have been carried out by consultants.

Companies marked with "good quality control" usually have professional customers measuring 10-20 % of the houses. Sometimes also thermography tests are being carried out.

The differences in ach/h are not high between 1-storey houses and 1½ storey houses. Usually the airtightness is between 1/10-2/10 ach/h lower in 1-storey houses.

3.4 Sealing

The results from the 14 companies participating in the survey have been compared in order to discover if there is a solution that will give a significantly better airtightness.

The following tables and figures give an idea of how the Swedish houses are constructed.

Table 5 Wind barrier

Material	Number of companies	Houses/year %
Particleboard	1	3
Asphalt impregnated board	5	51
Gypsum board	1	8
Fibre board	1	4
Paper	4	34

Table 6 The place for vapour barrier

Vapour barrier	Number of companies	Houses/year %
Behind inner sheet. Wall	11	80
Behind inner sheet. Ceiling	13	96
50 mm in insulation. Wall	2	16
50 mm in insulation. Ceiling	-	-
Secret	1	4

Table 7 Ceiling joints

	Houses/year %	Airtightness ach/h
Vapour barrier clamped	38	no
Vapour barrier overlapping + tape	55	significant
No overlapping	3	differences
Secret	4	-

Table 8 Element joints

	Houses/year %	Airtightness ach/h
Glass fibre in plastic film	26	2-3
EPDM rubber strip	63	2-3
EPDM rubber strip + polyethylene film	5	2
EPDM rubber strip + mastic	2	-
Secret	4	0.7

Table 9 Window joints

	Houses/year %	Airtightness ach/h
Mineral wool	32	2.3-2.7
Mineral wool + mastic	18	
Mineral wool + EPDM-rubber	20	2.0-2.5
EPDM-rubber	18	2.2-3.0
Glass fibre in plastic film	5	2.0
Glued construction + foam strip	3	2.0
Secret	4	0.7

4. CONCLUSIONS

Most of the prefabricated single family houses in Sweden seem to have an airtightness of 2-2.7 ach/h. With good control and constructions it is easy to get less than 1.0 ach/h. With all the constructions presented in this paper it is possible that the companies can get an even better airtightness than shown above. It is very important that the houses are submitted to a control. It seems to be enough to control 5-10 % of the production. But then it is important to have a proper distribution between different house types and different locations in the country. The last depending on the construction workers skill.

Only one company used the fan in the house for measuring the airtightness. All the other used the blower-door method.

It is easier to get a wide-spread control if the fan in the house is used for measuring. This method is also possible because all the houses are equipped with at least one fan.

5. ACKNOWLEDGEMENTS

The author wishes to thank the following companies:

Anebyhus, Aneby; Begushus, Korsberga; Eksjöhus, Eksjö; Elementhus, Mockfjärd; Faluhus. Falun; Gullringshus, Gullringen; Götenehus, Götene; Hedlundshus, Furudal; Hjältevadshus, Hjältevad; LB-hus, Bromölla; Modulent, Hässleholm; Myresjöhus, Vetlanda; Nässjöhus, Nässjö; Ådalshus, Kramfors.

6. REFERENCES

ELMROTH, A. and LEVIN, P.
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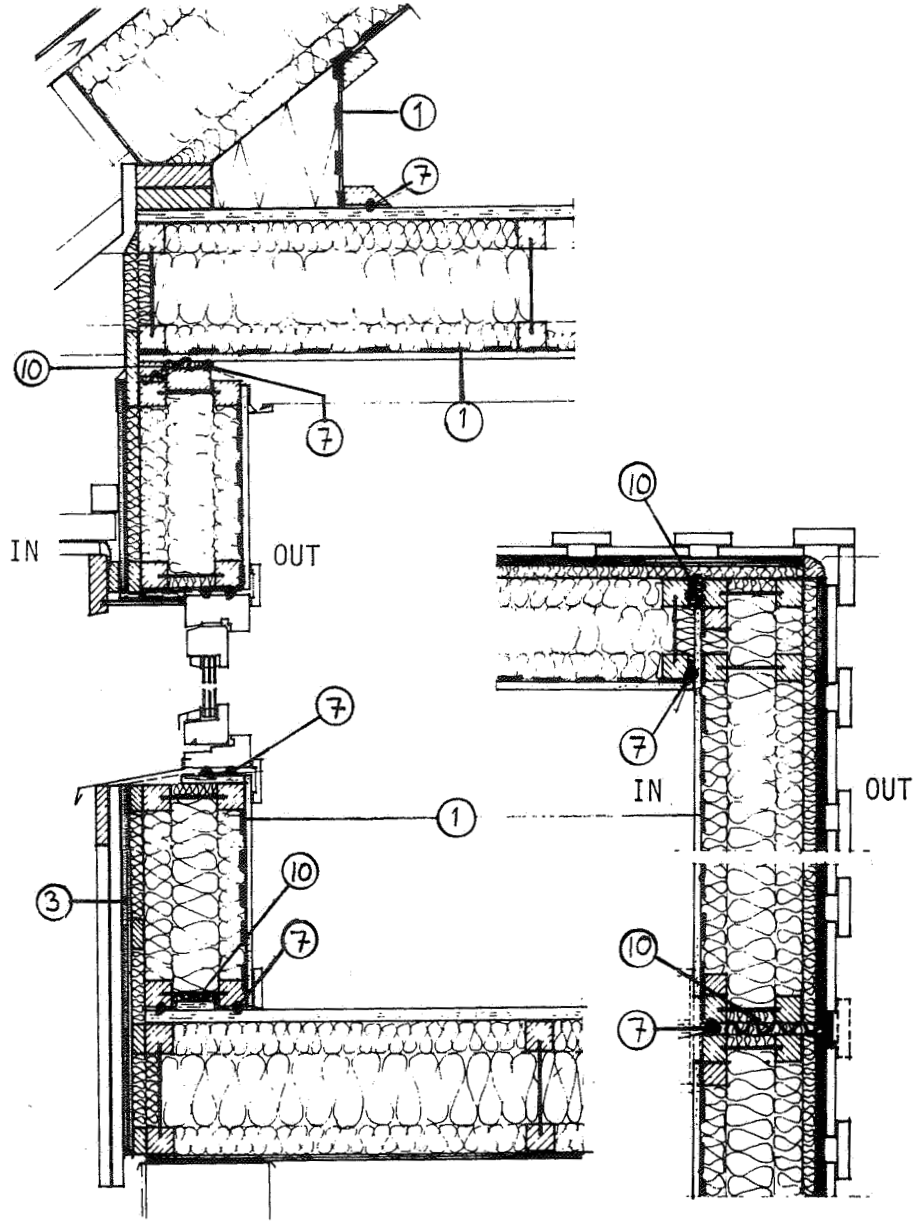


Figure 1. Volume element. Wall section and outer corner

1. Vapour barrier
2. Particle board, glued construction
3. Asphalt impregnated board
4. Gypsum board
5. Paper
6. Glassfibre in plastic film
7. EPDM rubber strip
8. Foam strip
9. Mastic
10. Mineral wool packing
11. Tape

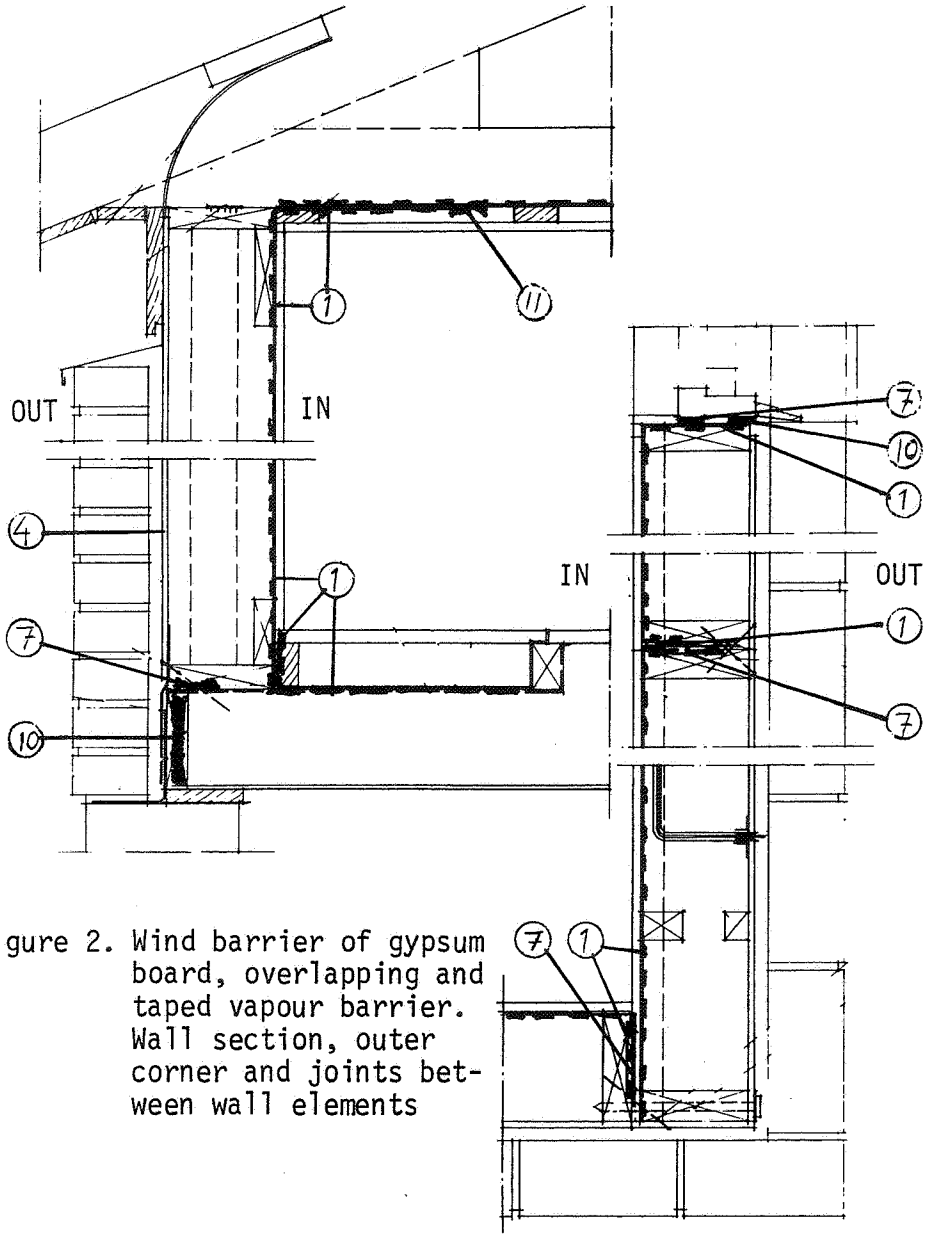


Figure 2. Wind barrier of gypsum board, overlapping and taped vapour barrier. Wall section, outer corner and joints between wall elements

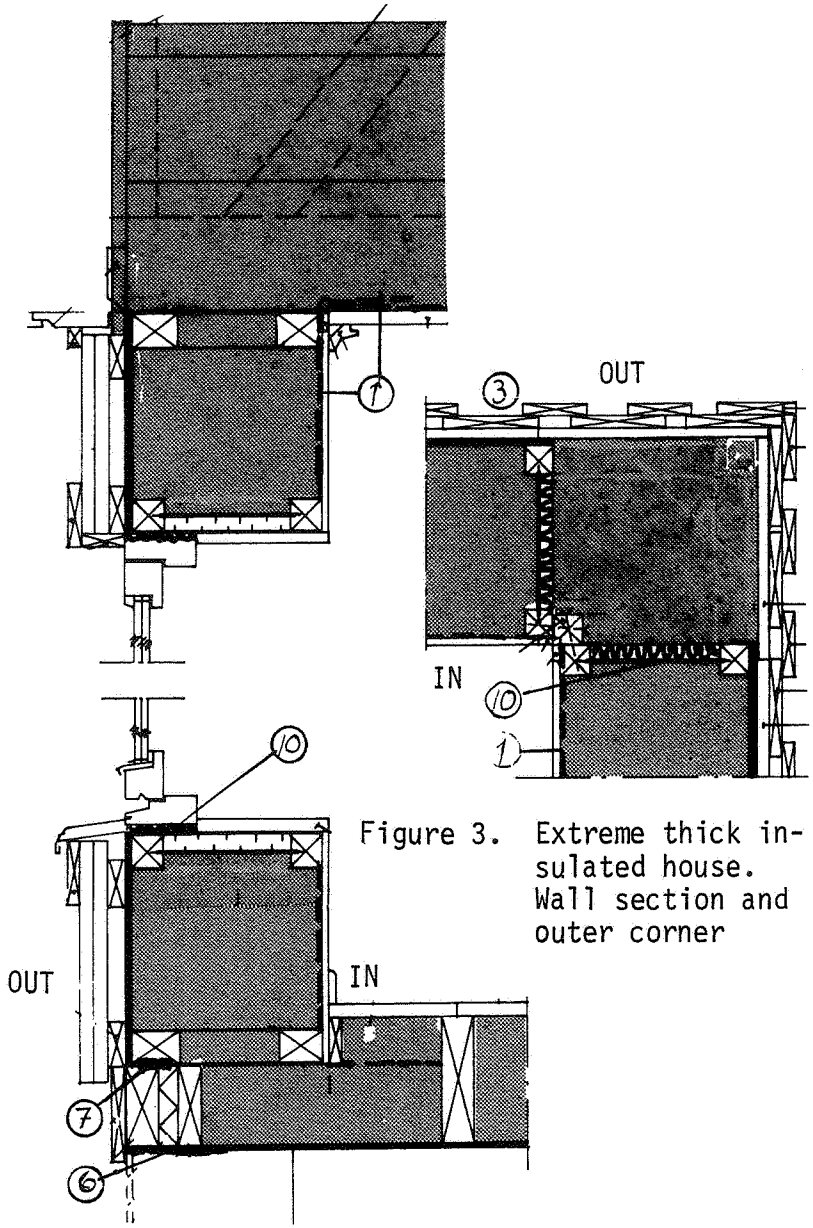


Figure 3. Extreme thick insulated house. Wall section and outer corner

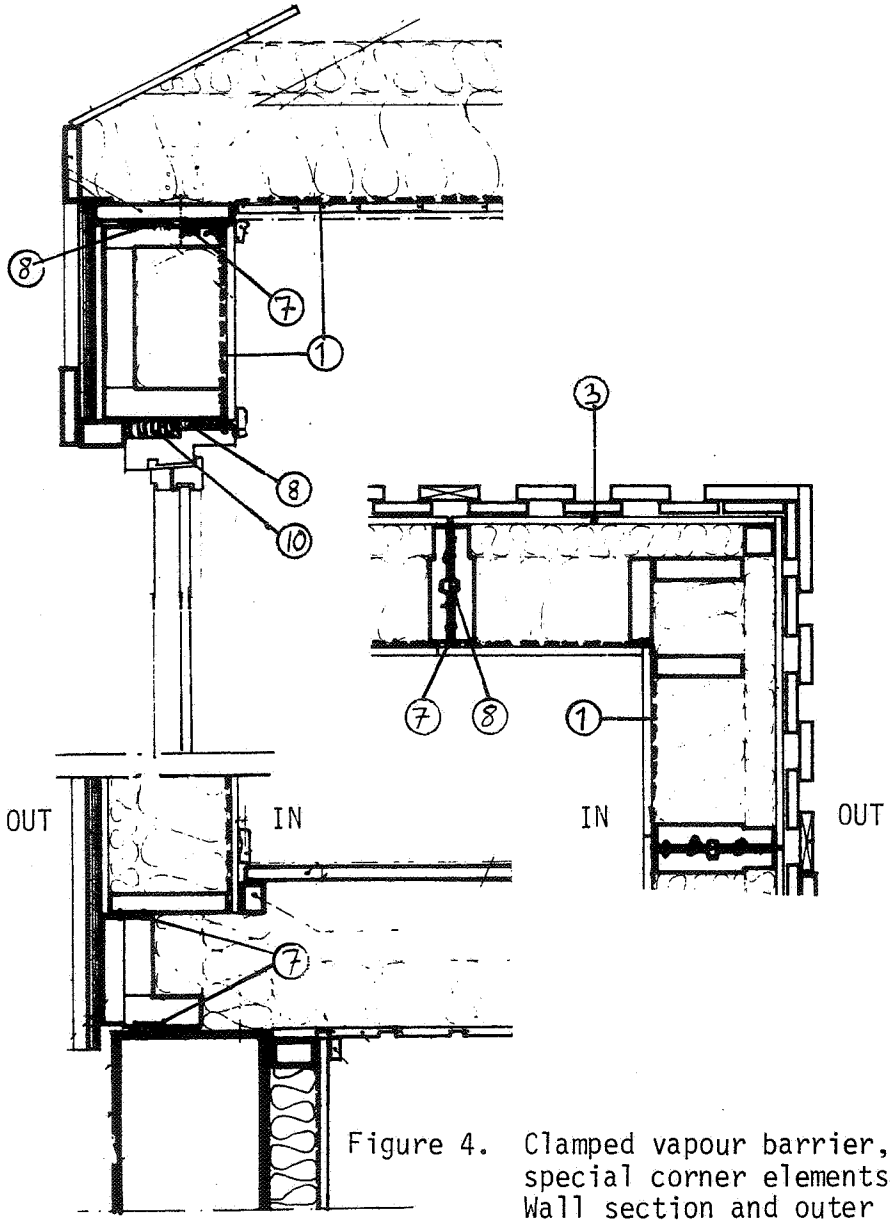


Figure 4. Clamped vapour barrier, special corner elements. Wall section and outer corner

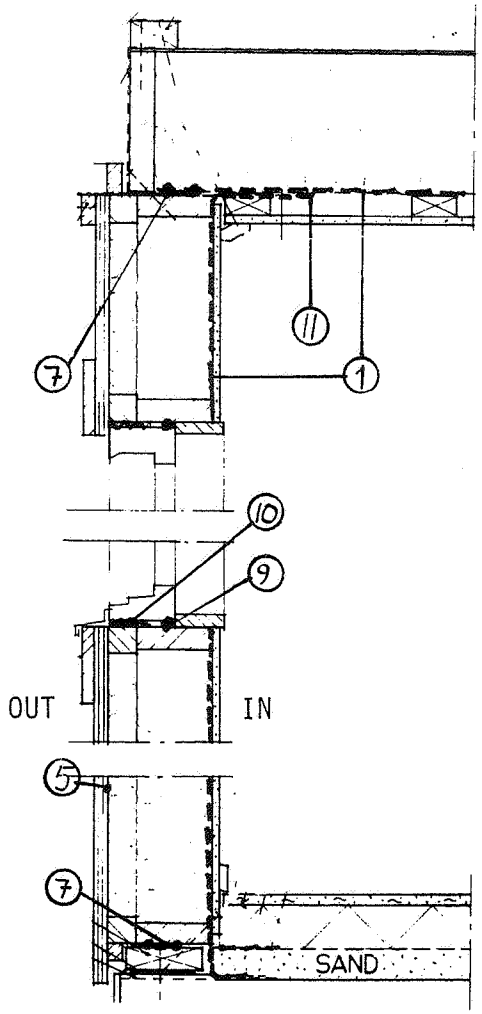


Figure 5. Wind barrier of paper, overlapping and taped vapour barrier. Wall section

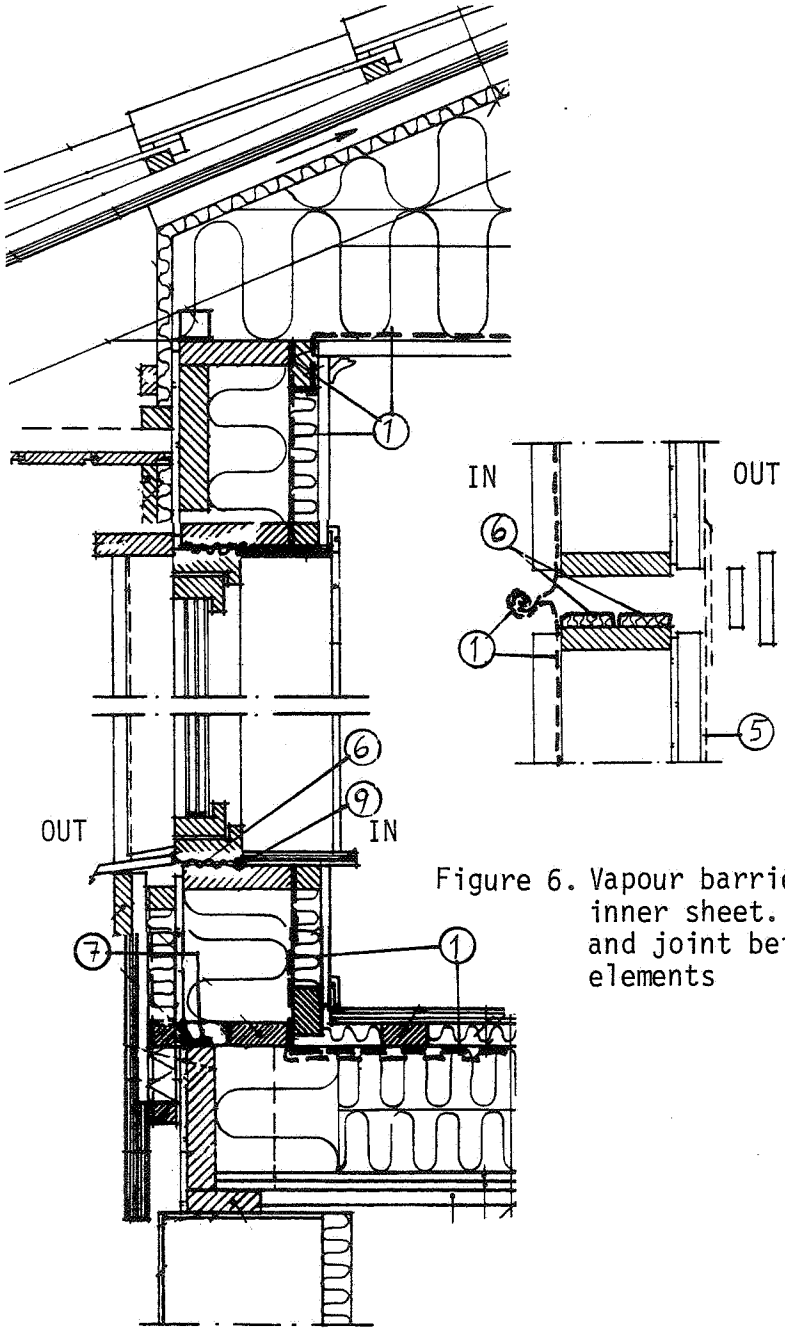


Figure 6. Vapour barrier 50 mm behind inner sheet. Wall section and joint between wall elements

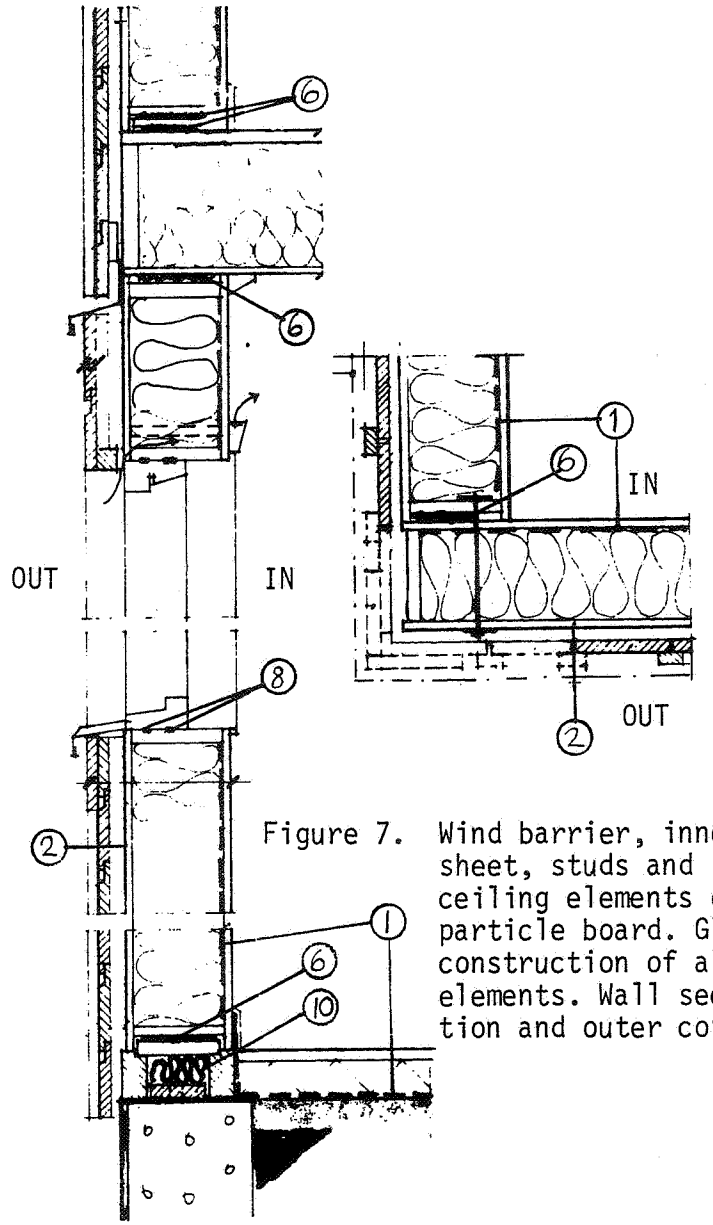
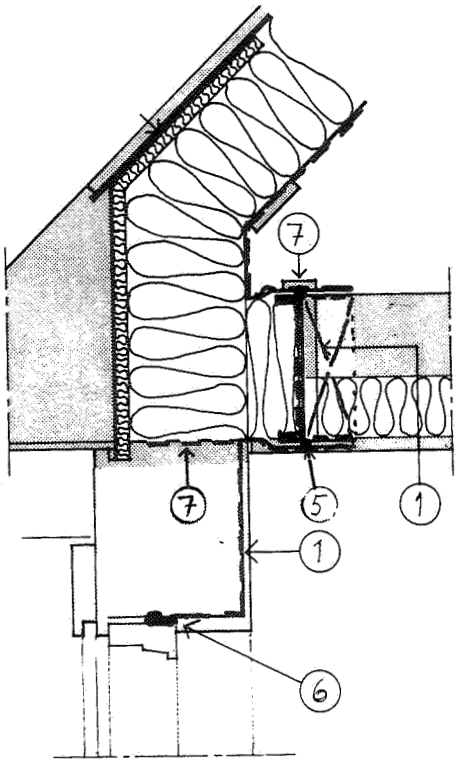
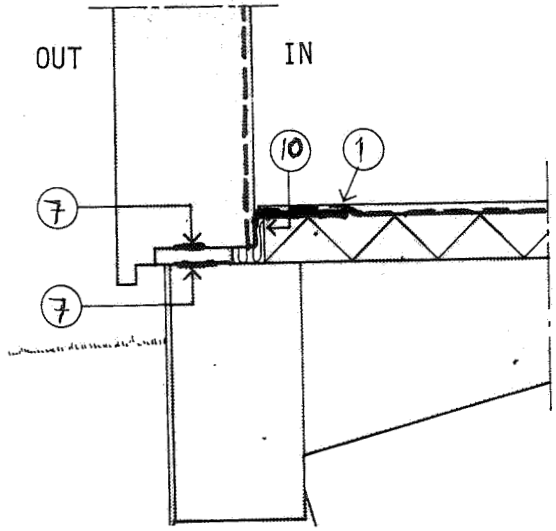


Figure 7. Wind barrier, inner sheet, studs and ceiling elements of particle board. Glued construction of all elements. Wall section and outer corner





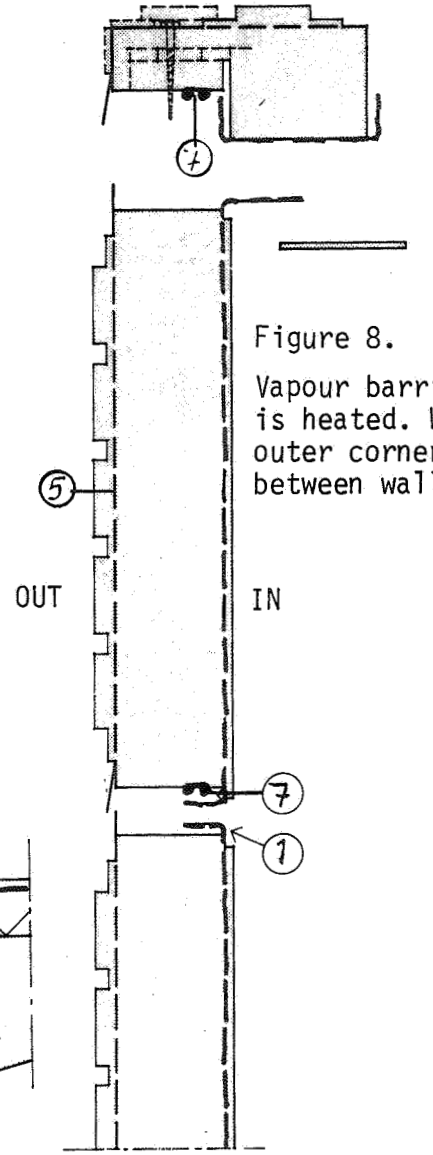


Figure 8.

Vapour barrier if attice is heated. Wall section, outer corner and joints between wall elements

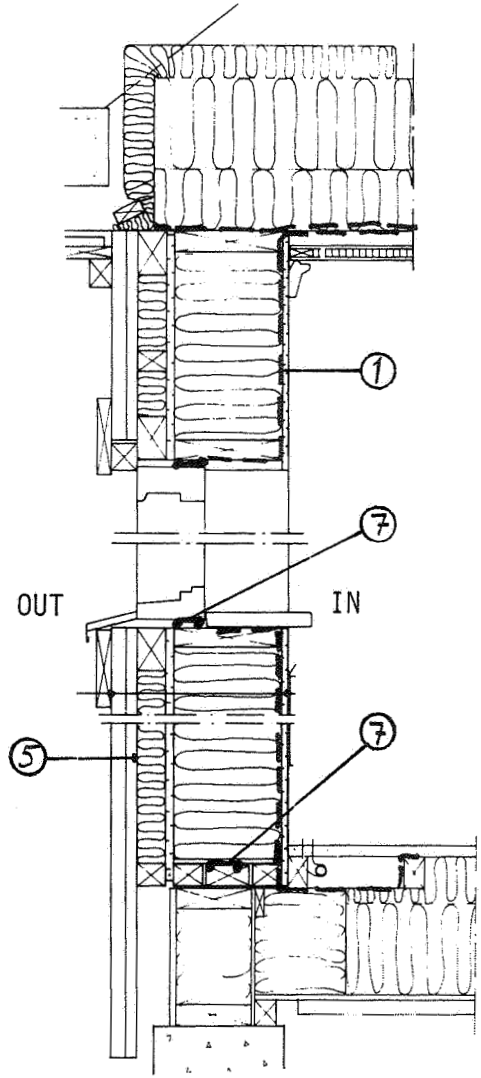


Figure 9. Floor element with installation zone. Wall section

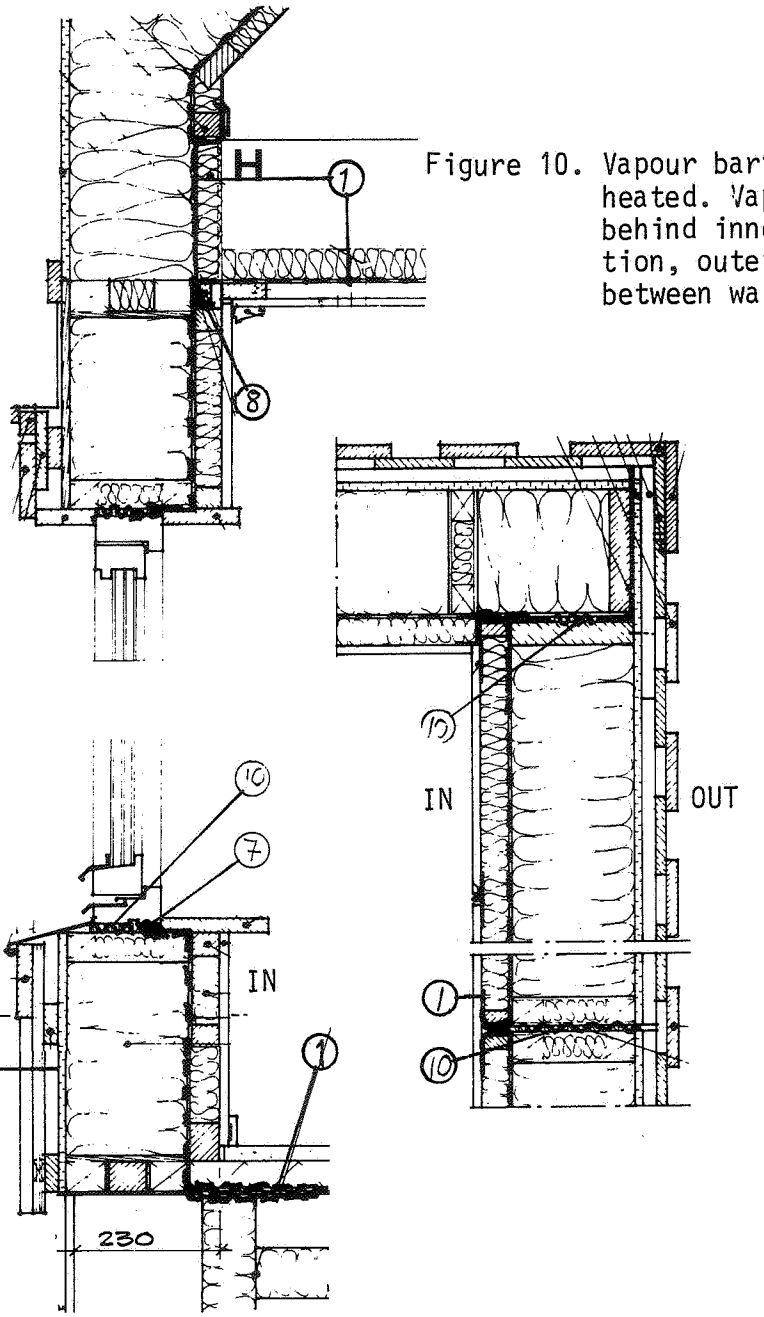


Figure 10. Vapour barrier if attice is heated. Vapour barrier 50 mm behind inner sheet. Wall section, outer corner and joint between walls

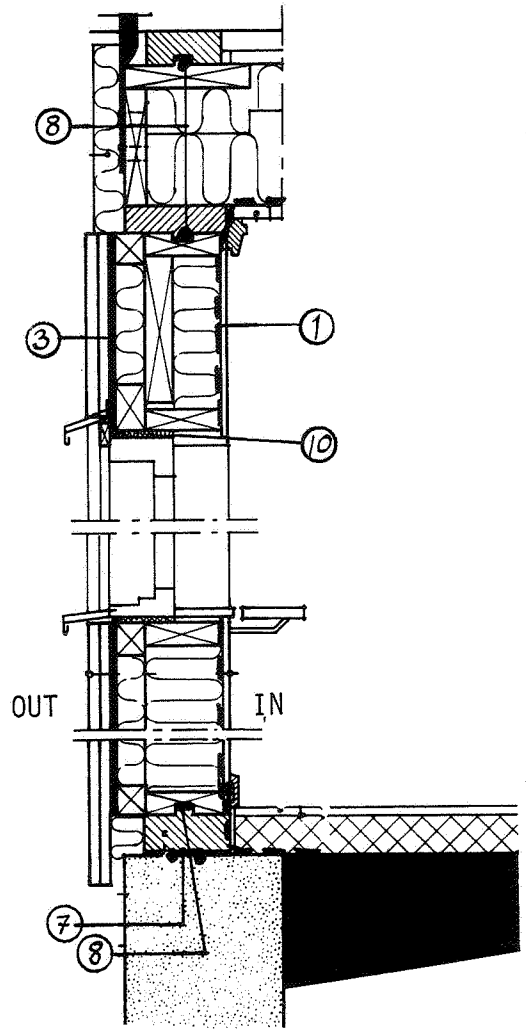


Figure 11. Vapour barrier clamped. Wall section