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FULLY-DEVELOPED FIRES WITH FURNITURE IN A COMPARTMENT

by

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#### SUMMARY

This note describes three experimental furniture fires and compares their behaviour after flashover with earlier fires in the same compartment in which wood cribs formed the fuel.

The burning rates and hence the duration of the furniture fires were close to those of the wood crib fires, but the temperatures were somewhat lower. This is probably the result of circumstances peculiar to these tests, not to any special difference between crib fires and furniture fires.

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MINISTRY OF TECHNOLOGY AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

#### FULLY-DEVELOPED FIRES WITH FURNITURE IN A COMPARTMENT

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#### 1. INTRODUCTION

An extensive programme of experimental fires has recently been carried out at the Fire Research Station in which the duration, temperature and other variables of fully developed fires have been related to various parameters of the fuel and compartment 1,2,3.

For most of these tests the fuel consisted of standardised wooden cribs, which provided the reproducibility essential to comparative tests of this kind. However to confirm experimentally that the results obtained would apply to fires in a domestic occupancy, three further tests with furniture fuel have been carried out in the same compartment. The results of these further tests are reported and compared with the earlier tests.

#### 2. COMPARTMENT

The test compartment was one of those used in the previous series<sup>1</sup>, measuring internally 7.7 m wide, 3.7 m deep and 3.0 m high (Fig. 1). The walls were constructed of Fletton brickwork or lightweight concrete blocks rendered with vermiculite/gypsum plaster. To reduce deformation the ceiling was specially constructed of refractory concrete slabs suspended on steel beams. The two ventilation openings, in the long wall, were each reduced by asbestos steel panels to an opening 1.8 m high and either 1.5 m or 0.71 m wide, corresponding to  $\frac{1}{4}$  or about  $\frac{1}{8}$  of the area of the wall respectively.

The steel columns and beams present in the earlier tests had not been removed. In Test 28 almost all the steelwork was insulated; in Tests 29 and 30 almost all the steelwork was unprotected.

<u>Key words</u>: Burning rate; Compartment; Duration; Fuel, solid; Furniture; Temperature.

#### 3. FUELS

In one test (Test 28) a mixed collection of various types of furniture formed the fire load. Furniture for the next two tests was sorted into two groups of 'heavy' and 'medium' items; the heavy group (Test 29) consisted of heavy, bulky, upholstered chairs and articles made from wood more than 1 in thick. The medium group (Test 30) consisted of lighter upholstered chairs and furniture of average thickness less than 1 in., some of which was made of plywood. Details of the tests are given in Table 1. The ratio of fire load to ventilation area was 130-160 kg/m<sup>2</sup>, well within the range of the previous experiments (20-670 kg/m<sup>2</sup>).

Table 1

Fuel and ventilation area

Test reference number	Fuel description	Total combustible weight of fuel kg	Fire load density kg/m <sup>2</sup>	Surface area of fuel m <sup>2</sup>	Ventilation opening area m <sup>2</sup>
28	'Mixed' furniture	720	25	95*	5.6 ( <del>1</del> )
29	'Heavy' furni ture	424	15	52	2.6 (1/8)
30	'Medium' furniture	424	15	60	2.6 ( <del>1</del> 8)

#### \*Estimated

The arrangement of the furniture is shown in Plates 1 to 3. The items of furniture were positioned in a reasonably realistic manner to provide equal amounts of fuel in each half of the compartment. The largest and bulkiest single items were placed in the same positions as the cribs in the earlier tests and small pieces including kitchen chairs occupied the spaces in between. The furniture was stored under cover until it was placed in the compartment just before the test when its moisture content was measured, (Table 2a). In all the tests the fuel was ignited by pieces of fibre insulation board soaked in kerosine and placed beneath the largest items of furniture. Metal fixings, springs and other incombustible parts were taken into account in determining the total combustible weight of furniture in each test. A piano was included

in the heavy fuel test and most of the iron frame, strings and bolts were removed prior to the weighing which preceded the fire.

#### 4. MEASUREMENTS

The quantities measured were generally similar to those in the previous series 1. Thermocouples were positioned along the centre line of the compartment at heights of 75 cm above the floor and 75 cm below the ceiling in three places corresponding to a quarter, one-half and three-quarters of the length of the compartment (Fig. 3 of reference 1). Thermocouples were also fixed to the surface of the ceiling, and wall and partition wall; Two radiometers were mounted so as to receive radiation from the window openings: one was shielded by a flat plate which cut off radiation from any flames above the window and thus registered radiation from the interior of the compartment only. None of the fuel was weighed during burning to give a direct measurement of rate of burning. It was not practicable to weigh the whole of the fuel and with such a mixed fire load it would be very difficult to relate the rate of burning of the whole of the fuel to that of a few weighed items.

# 5. RESULTS

#### 5.1. Visual observations

All the fires burned up quickly after ignition and fire spread was rapid. Flames soon reached the ceiling and flashover usually occurred within about 5 minutes. At about this time, the flames in the compartment appeared starved and the compartment was filled with dense smoke; flames were only visible near the windows. In the  $\frac{1}{8}$  ventilation tests the fire proceeded to burn mainly in one end only of the compartment and then spread through the centre to the opposite end.

This effect was most marked with test 30 (medium fuel); soon after ignition the wind freshened, blowing across the compartment from west to east. The east window acted as an inlet and strong flaming was observed in the east end of the compartment only, while the combustion products were blown into the west end of the compartment where the gases appeared too rich to burn and passed out through the west window. As the fire in the east end burned out, the burning zone progressed into the west part of the compartment.

Generally, flames were contained within the compartment although some flames extended out of and above one window for short periods.

Usually the dense smoke issuing from the windows appeared too rich to burn. The fuel in all the tests burned out completely.

#### 5.2. Rate of burning

In fire tests where weight is measured directly mean rates of burning are usually taken over the period when the weight of fuel is falling from 80 to 30 per cent of its initial value, which is mainly the period of steady flaming combustion. This period was determined for the present tests where no such measurement was made by comparing the variation with time of the mean compartment gas temperature and the intensity of radiation emitted from the compartment for the furniture tests with those for the crib tests.

The time when burning had decreased to the stage where only half the fuel area was still burning with flames more than 15 cm high ( $t_{\rm NF}$ ) was noted. For the crib tests the ratios of typ and the times at which the weight had fallen to 80 and 30 per cent of its initial value were known from weight measurements and  $t_{80}$  and  $t_{30}$  times for the furniture tests were then calculated assuming that the ratios  $t_{80}/t_{\rm NF}$  and  $t_{30}/t_{\rm NF}$  were the same in the furniture and crib tests.

#### 5.3. Temperature and radiation intensity

The averages of the temperatures given by the six thermocouples suspended within the compartment are given in Tables 2a and 2b. In Test 30, four thermocouples were put out of action by a wiring failure and there was a cross wind which tended to deflect flames and hot gases away from the two remaining thermocouples, so that the temperature measurements for this test are of doubtful accuracy, temperature values almost certainly being too low. Also given in Table 2 are average values of the wall and ceiling temperatures and the intensity of radiation from the ventilation opening for the 80/30 period.

#### 6. DISCUSSION

# 6.1. Development times

The times for flames to touch the ceiling and to emerge from the window and the time to flashover were similar to those of the wood crib fires although as might be expected there was more variation.

#### 6.2. Rate of burning

The estimated rates of burning are used to define an effective duration. In Fig. 2 the reciprocal of this, i.e. the rate of burning divided by fire

load is plotted against the ventilation area also divided by fire load as has been customary for previous experiments where the rate of burning was directly measured. The results are in excellent agreement with the wood crib data and lie in the critical region<sup>2</sup> between ventilation control (defined by the dotted line through the origin) and fuel bed control (horizontal line at 0.05 min<sup>-1</sup>).

# 6.3. Effective fire duration

The data are replotted in Fig. 3 where the effective fire duration is shown. When fire load/ventilation area is less than about 150 kg/m<sup>2</sup>, the rate of burning is independent of ventilation and the fire duration is characteristic of the type of fuel<sup>3</sup>. Thus, 20 minutes is a fire duration characteristic of the crib tests with 4 cm thick timber. The three furniture tests are of similar duration to the previous tests.

# 6.4. Temperature of gases in compartment

Temperatures of thermocouples suspended within the compartment are shown as averages for the 80/30 period against rate of burning per unit ventilation area in Fig. 4. The temperature in the mixed furniture test (Test 28 with  $\frac{1}{4}$  ventilation), though slightly low, was not significantly different from that of wood crib fires having the same rate of burning/ventilation area.

The temperature in Test 29 was however substantially lower than that of the wood crib fires and there are two reasons for this.

Firstly, except for one column, none of the steelwork was insulated in this test so that a much larger proportion of the heat released in the compartment would have been taken up by the steel. From a heat balance of this fire and relations established between the heat losses—and compartment gas temperature it has been estimated that had most of the steel been insulated with mineral fibre slab, the material employed for the wood crib fires, temperatures would have been some 130 deg C higher.

Secondly, the low temperatures may also be attributed in part to the low ventilation opening  $(\frac{1}{8})$  employed, lower than that of most of the wood crib fires. The heat loss to the walls, though only some 15 per cent of the heat release at large ventilation openings, becomes relatively more important as the size of the ventilation opening is decreased. It has been estimated that for the same ratio of burning rate to ventilation area as in this fire, temperatures would be about 100 deg C higher if the ventilation area had been increased to  $\frac{1}{4}$ .

The sum of these two temperature differences, viz. 230 deg C, is of the order of the amount by which the gas temperature in Test 29 is lower than that of wood crib fires of the same burning rate/ventilation opening and with  $\frac{1}{4}$  ventilation.

The effect of ventilation area is also to be seen in the data for the radiation emitted from the ventilation opening. Thus in Fig. 5 the radiation intensity per unit window area in the crib experiments is seen to increase with ventilation area.

### 6.5. Surface temperatures

For tests 29 and 30 there are larger differences between the temperatures of the surface of the ceiling and walls than in the wood crib tests. This is probably due to the localised flaming and the effects of cross winds noted in Section 5.1.

# 6.6. Radiation from ventilation opening

The intensities of radiation in the plane of the ventilation opening are shown in Fig. 5 plotted against rate of burning/ventilation area, together with data for the wood crib fires. As would be expected from the gas temperature measurements, the intensities in the furniture fires are lower than those of the wood crib fires, but it can also be seen that the data fall in line with the systematic variation of intensity with area of ventilation opening.

#### 7. CONCLUSIONS

- (i) The rates of burning of the furniture fires were close to those of wood crib fires having the same fire load/ventilation area.
- (ii) The gas temperatures and the intensity of radiation emitted from the <sup>1</sup>/<sub>4</sub> ventilation furniture test were not significantly different from those of comparable wood crib fires.
- (iii) The temperature and intensity of radiation measurements for Test 29 are lower than those in correlations established previously for wood cribs, but it is shown that if corrections for the size of the ventilation opening and for the heat loss into the unprotected steel are made, the temperature obtained is in agreement with the data for wood cribs.
- (iv) The temperature and intensity of radiation measurements of Test 30 should be discounted because of a cross wind.

- (v) Fires with cribs made of 4 cm thick sticks are therefore reasonably representative of the fires which the type of furniture tested can produce.
- (vi) The tests produced no evidence to indicate any difference in behaviour during a fire between the heavy and the medium furniture fuels,

#### 8. ACKNOWLEDGEMENT

The authors wish to thank Mr. N. Darrington for assisting with these experimental fires.

#### 9. REFERENCES

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Table 2a
Test results

	Weather conditions					Development of fire					
Test ref. No.	Air temp.	Relative humidity	Wind speed m/s	Wind direction	Mean moisture content of fuel	Time for flames to touch ceiling (min)	Time for flames to emerge from window (min)	Time for flashover	Time (min) for fuel weight to fall to following percentages of initial weight:-		
		<i>J</i> o	щз		ν	(штп)	(1111)	( 1111 )		,,,,,	
28	_	_	3	NW	-	3•45	8.20	4.30	7.1	17.4	
29	14.5	70	1.2	SW	13	2,00	4.20	3.00	7.6	16.8	
30	23	69	3 <sup>+</sup>	s	15	3.15	6,00	6.00	11.2	21.5	

 $<sup>^{</sup> ext{+}}$ Wind strengthened during test.

i C

Table 2b

Test results (cont'd.)

! I COVI !	Mean	I HEATT TO LANT I	Temperature rise deg C (Mean over 80/30 period)			Intensity of radiation cal cm 2s (Mean over 80/30 period)			Configuration		
ref.	rate 80/30	duration of flaming	fire duration	Compt. gas temp.	Thermocouples on surfaces		At radiometer		At	factor Ø	
	(kg/min) (min)	(min)		(mean over several thermo- couples)	Ceiling	Rear wall	Side wall	Unshielded rad.	Shielded rad.	ventilation opening	
28	35	28	.21	865	825		-	0.108	0.070	1.75	0,040
29	.23	30	18	775	715	700	465	_	0.:041	2,1	0.020
30**	20	40	21	_	. 170	550	365	-	0.0105**	0.53	0,020

<sup>\*</sup>Fire load/mean burning rate over 80/30 period.

<sup>\*\*</sup>Flames deflected by cross wind.

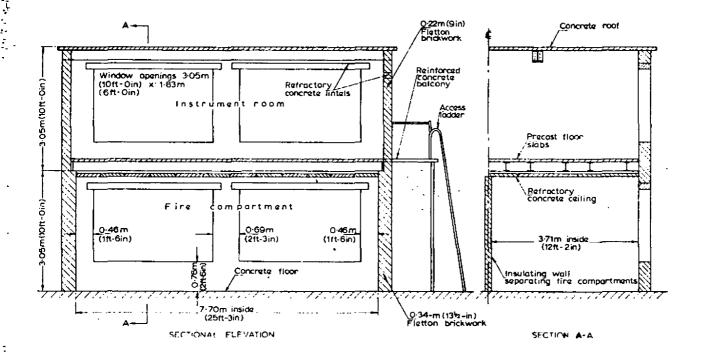
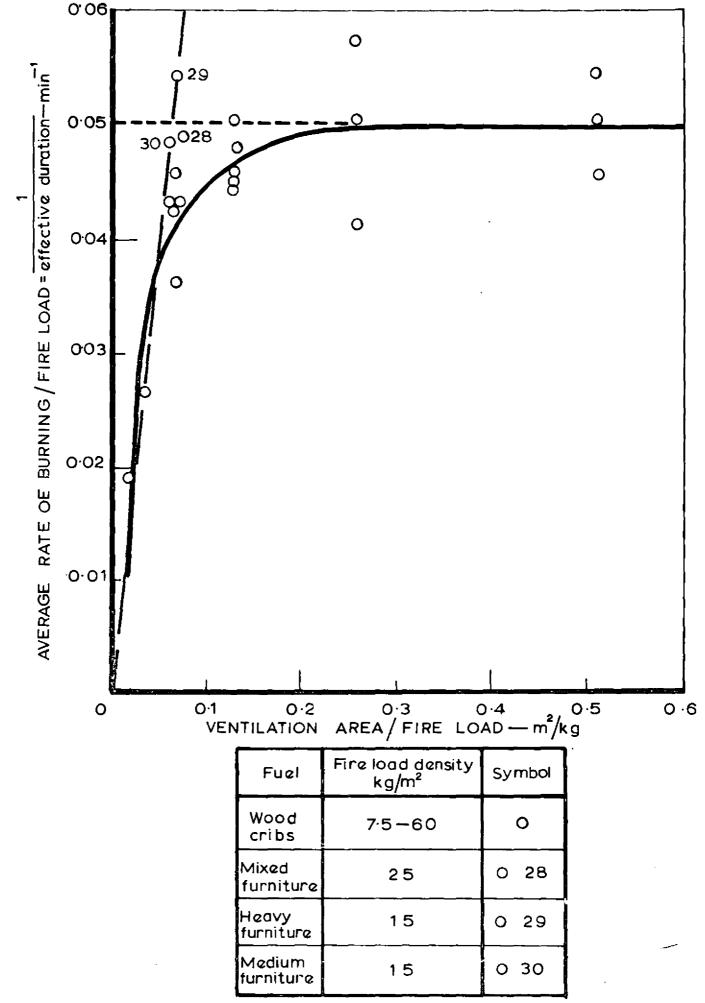
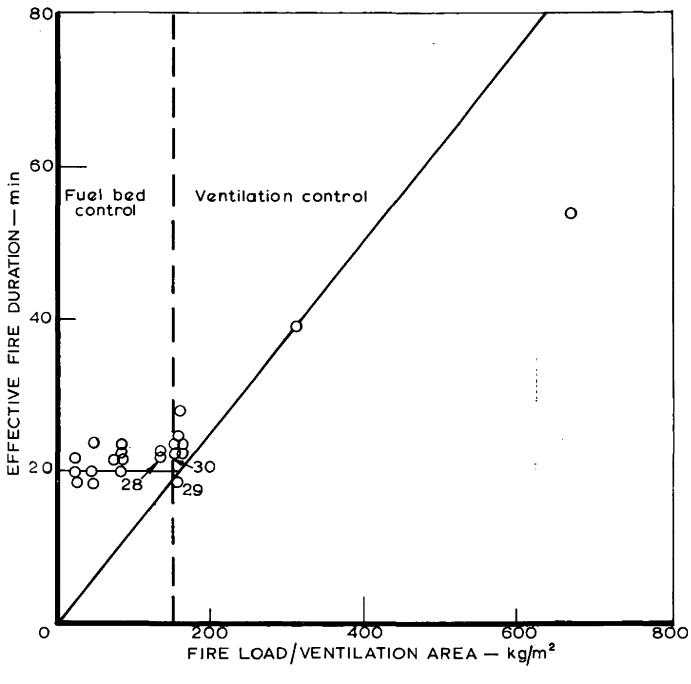


FIG.1. BUILDING USED FOR EXPERIMENTAL FIRES





Fuel	Fuel Fire load density kg/m²				
Wood cribs	7-5-60	0			
Mixed furniture	25	O 28			
Heavy furniture	15	O 29			
Medium furniture	1 5	O 30			

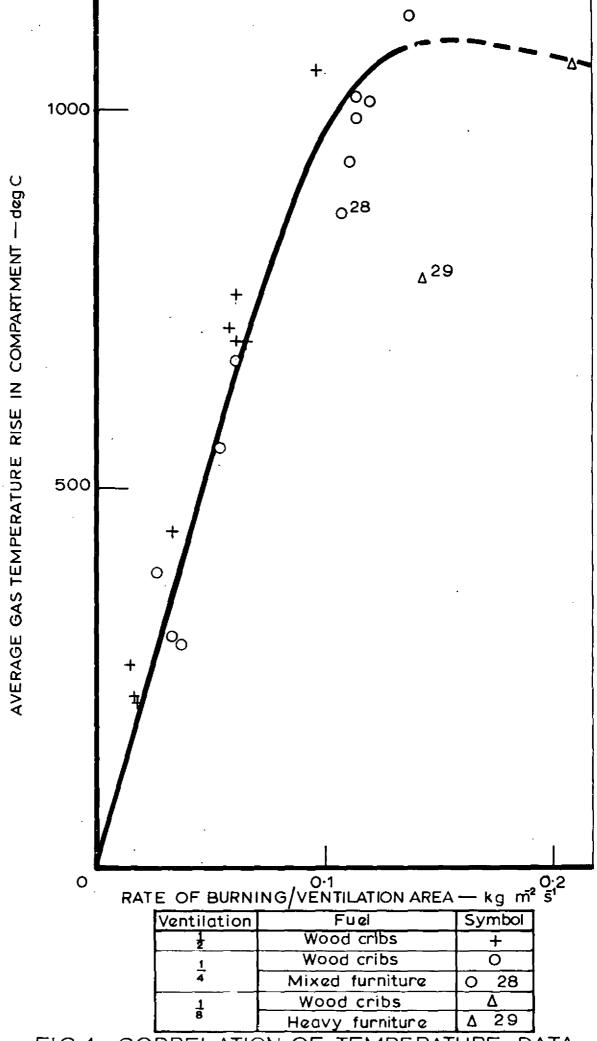
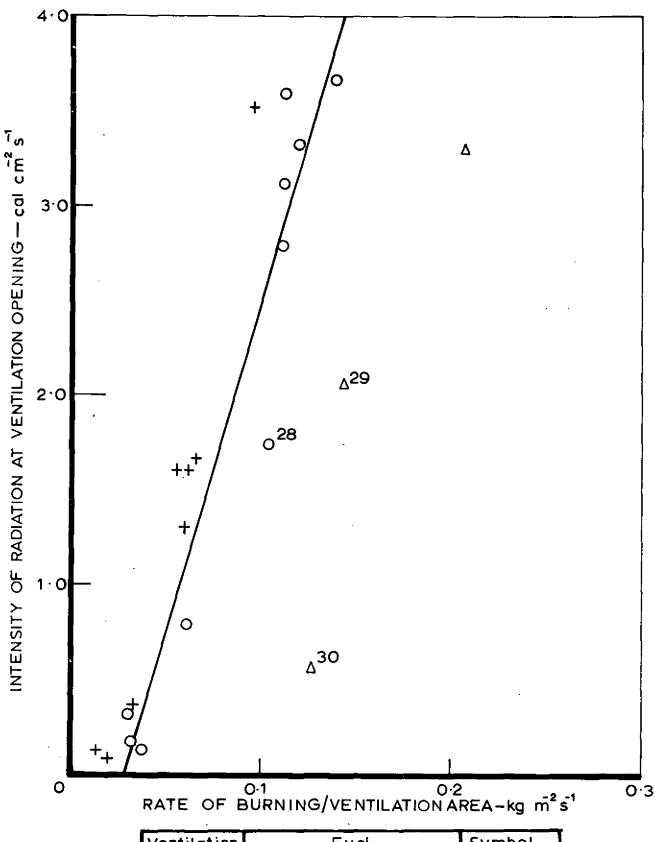
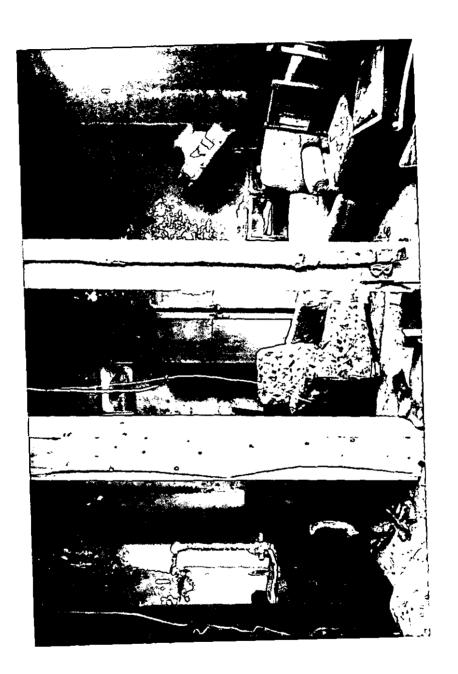


FIG.4. CORRELATION OF TEMPERATURE DATA

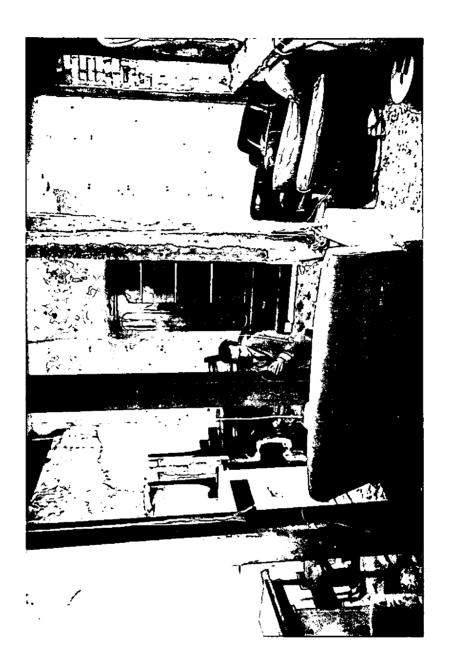


Ventilation	Fuel	Symbol
1/2	Wood cribs	+
1	Wood cribs	0
	Mixed furniture	0 28
	Wood cribs	Δ
8	Heavy furniture	Δ 29
	Medium furniture	Δ 30

FIG.5. INTENSITY OF RADIATION IN THE PLANE OF THE VENTILATION OPENING



MIXED FURNITURE TEST (28) LOOKING EAST. PLATE 1.



HEAVY FURNITURE TEST (29) LOOKING EAST. PLATE 2.



MEDIUM FURNITURE TEST (30) LOOKING EAST. PLATE 3.

