DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

AND

FIRE OFFICES' COMMITTEE

JOINT FIRE RESEARCH ORGANIZATION

FIRE RESEARCH NOTE

NO. 569

THE FIRE HAZARD OF ELECTRIC BLANKET ELEMENTS ON BREAKING

by

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October, 1964.

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SUMMARY

Experiments have been performed to compare the fire hazard of various types of electric blanket element on breaking. The elements, which were carrying current, were bent regularly until they broke, the number of cycles required to break them and their behaviour on breaking being noted.

The number of cycles has been related to the design of the element, except for a few unusually long-lasting types. Those elements constructed with a single heating wire appear to be less of a fire hazard than those with multiple wires.

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1. Introduction

The number of fires caused by electric blankets is increasing every year[1] and a large proportion of these fires is thought to be due to broken heating elements[2]. It has been suggested that the overheating caused by the arcing between the broken ends of the element is responsible and experiments have demonstrated that such an arc can ignite the element. It was therefore decided to build a machine that would bend the elements regularly so that after some time they would break and compare their behaviour. This machine was similar to that used in an investigation at the University of Canterbury, New Zealand[3]. However, in that investigation, only the number of bending cycles required to break the element was measured, the arcing behaviour of the element on breaking was not studied.

2. Experimental Procedure

The machine built to bend the elements is shown in Plate 1. Short lengths of element were mounted between a fixed and a movable clamp so that, when the clamps were at their maximum separation, the elements were just taut. Thus, as the clamp moved back and forth, the elements were subjected to a regular bending cycle. The maximum separation between the clamps was 4.1 cm and the minimum 1.8 cm and the mean rate of flexing was approximately 300 cycles per minute.

The British Standard on electric blankets[4] specifies 180 watts as the maximum input on any one circuit in a blanket and, where appropriate, the elements were tested in series with a 180 watt load. However, several of the elements tested, with resistances greater than 50 ohms per metre (Table 1), were designed to be used in a circuit dissipating much less than 180 watts and these were run at a load of 100 watts. Each sample was connected to an ammeter, so that arcing or breaking of the element could be detected.

In some of the tests the element was covered by a fabric sleeve, to resemble more closely a section of an electric blanket; in particular to raise its working temperature nearer to the actual operating level. Both winceyette and cotton wool were used as sleeving materials.

TABLE 1

Construction of Element Types Tested

Element type (a)	Resistance per metre (ohms)	Heating Wire				Core		Sheathing Material	$\frac{DP}{d}$ (cm^{-1})
		No. of strands	Material	Diameter [d] (cm.)	Turns per cm. [P]	Material	Diameter measured over wire [D] (cm.)		
D1	31	1	not specified	0.021	7.1	rayon	0.11	P.V.C.	40
B1	23	1	" "	0.013	5.9	cotton	0.13	"	59
B2	32	1	" "	0.015	5.9	cotton	0.12	"	50
B3	46	1	" "	0.017	9.1	cotton	0.12	"	67
B4	70	1	" "	0.012	7.1	cotton	0.11	"	69
A2	77	1	Nichrome	0.017	5.1	rayon	0.09	"	28
E2	43	2	not specified	0.012	5.5	not specified	0.13	"	60
E3	81	2	" "	0.012	9.1	" "	0.13	"	101
E4	90	2	" "	0.012	10.2	" "	0.14	"	118
A1	12	3	Copper, Nickel	0.017	4.7	rayon	0.10	"	29
E1	19	3	not specified	0.015	4.3	not specified	0.14	"	40
C1	24	3	" "	0.013	6.3	nylon	0.08	"	39
C2(b)	35	3	" "	0.013	3.5	glass fibre	0.09	"	24

(a) The figure denotes a type of wire from the particular supplier denoted by the letter.

(b) This type has a glass fibre braid between the heating wire and the insulation.

3. Results

Thirteen types of element, from five manufacturers, were tested; their constructional details are given in Table 1. The results are shown in Tables 2 and 3.

Types B1 and B2 did not break, although subjected to one million bending cycles.

TABLE 2

Fatigue Life of Element Types

Element Type	No. of strands	No. Tested	No. of cycles to fracture			
			Maximum	Minimum	Mean	Standard Deviation, σ
D1	1	24	4,530	1,270	2,220	730
B1	1	6	None broke			
B2	1	6	None broke			
B3	1	21	175,000	15,980	54,730	40,040
B4	1	20	(a)	21,450	-	-
A2	1	19	6,270	1,100	2,090	1,110
E2	2	23	9,200	2,230	5,050	1,740
E3	2	21	(b)	7,000	-	-
E4	2	20	(c)	15,200	-	-
A1	3	79	5,140	880	1,830	780
E1	3	24	8,000	1,420	3,210	1,590
C1	3	28	4,420	1,690	2,610	680
C2	3	24	9,950	3,490	5,870	1,400

(a) 13 specimens were still intact after 250,000 cycles.

(b) 1 specimen was still intact after 250,000 cycles.

(c) 5 specimens were still intact after 250,000 cycles.

TABLE 3

Fire Hazard of Element Types

Element Type	No. of strands	Unsleeved			Sleeved			Percentage of samples arcing
		No.	No. ignited	No. charred	*No.	No. ignited	No. charred	
D1	1	14	0	0	W 10	0	0	17
B1	1	6	Did not break after 1 million cycles					
B2	1	6	"	"	"	"	"	
B3	1	8	0	0	W 8 C 5	1? 0	1 4	24
B4	1	4	0	0	W 1 C 2	0 0	0 0	0
A2	1	8	0	1	W 6 C 5	0 0	0 0	5
E2	2	8	0	4	W 9 C 6	0 0	4 4	65
E3	2	7	0	0	W 6 C 7	0 0	2 1	20
E4	2	5	0	0	W 5 C 5	0 0	1 1	15
A1	3	42	0	30	W 25 C 12	0 0	16 10	85
E1	3	12	0	8	W 6 C 6	0 0	5 4	88
C1	3	10	0	2	W 10 C 8	0 0	0 0	29
C2	3	12	8	2	W 12	5	6	100

*W = winceyette sleeved, C = cotton wool sleeved

All the element types tested were self-extinguishing when an external flame was applied and then removed. Thus, to produce sustained flaming, the broken element must ignite the sleeve material or else cause heavy arcing over a long period. Although, with many elements, the arcing was protracted, the heat produced was often insufficient to char the sleeve and flaming was rare.

Element type C2 was experimental in construction and, so far as is known, it has not been used in commercial blankets; it was the most consistently poor element of those tested. This may be due, in part, to its mode of breaking which, in turn, is probably due to its unusual construction. Specimens tended to break completely in half but the broken ends came into contact at each cycle for some time after the break, thus producing very heavy arcing.

One specimen of type B3 has been recorded as having ignited, but the effect was so transient it may have been a large spark rather than a single, small flame.

4. Discussion

There was a wide variation in the number of cycles required to break the elements, not only between the different types of element but also between different specimens of the same type. The results were analysed to determine whether the latter variation was increased by sleeving the elements (Table 4) and it was found that, in most cases, this made no significant difference to the life of the element although it appeared to affect the variability of the results. For example, the value of σ^2 for the cotton wool sleeved elements (σ_2^2) is generally larger than σ_3^2 for the winceyette sleeved elements.

TABLE 4

Comparison of the mean life and variance ratio for sleeved and unsleeved elements

x_1 = unsleeved elements

x_2 = winceyette sleeved elements

x_3 = cotton wool sleeved elements

x_4 = x_2 + x_3 = sleeved elements

Element Type	Difference of Means - cycles				Variance Ratio			
	$\bar{x}_1-\bar{x}_2$	$\bar{x}_2-\bar{x}_3$	$\bar{x}_1-\bar{x}_3$	$\bar{x}_1-\bar{x}_4$	σ_1^2/σ_2^2	σ_2^2/σ_3^2	σ_1^2/σ_3^2	σ_1^2/σ_4^2
D1	-30	≠	≠	-30	2.13	≠	≠	2.12
B3	24,040	13,000	37,040	29,040	3.81	7.92	30.14**	5.61**
A2	-790	1,030	250	-320	0.10	22.11**	2.30	0.17
E2	70	1,400	1,470	630	1.22	0.51	0.62	0.81
A1	330	320	650	430	3.79****	4.64**	17.57****	4.55****
E1	-770	1,870****	1,110	170	1.98	6.75	13.38**	1.84
C1	320***	840*	520***	560*	1.04	2.50	2.57	1.23
C2	-648	≠	≠	-648	0.27	≠	≠	0.27

Significance level 5 per cent = *
2 " " = **
1 " " = ***
0.2 " " = ****
≠ = not available

The New Zealand workers found[3] that the group $\frac{DP}{d}$ - where D is the diameter of core (measured over the heating wire), P is the number of turns of heating wire per unit element length, and d is the diameter of heating wire - could be used, to a limited extent, to predict the number of cycles, n, required to break an element when subjected to fatigue tests. The values of this group for the element types tested are given in Table 1 and n is shown plotted against DP/d in Fig. 1.

The regression line for the present results, ignoring those where there was no fracture, is shown in Fig. 1 together with the 95 per cent confidence limits; the majority of the New Zealand mean results also fall within these limits. Both sleeved and unsleeved elements were included in the analysis, although Table 4 shows that, in some cases, these are not part of the same population. It was thought, however, that the differences were sufficiently small to be ignored for present purposes.

The equation of the regression line is:

$$\log_{10} n \simeq 1.9 \log_{10} \left(\frac{DP}{d}\right) + 0.5$$

This correlation was significant at the 0.01 per cent level.

The New Zealand workers also thought that a glass fibre braid around the element wire reduced the fatigue life of the element. Although no such effect was found in the present results, nevertheless the element type incorporating such a braid was the only one in which the chance of ignition was high. This confirms that this form of construction should not be used.

The life of an element in these tests did not appear to depend upon the number of strands in its heating wire. However, if the percentage of element specimens which arced and visibly charred their insulation (Table 3) is a reasonable measure of the fire hazard, then single-strand elements are, in general, less of a fire risk than multiple-strand wires. The heating wire of the single-strand elements tested was much more springy than those of the multiple-strand elements and it seems probable that, whereas the ends of the single-strand element wire would spring apart on breaking and hence not arc, the broken ends of the multiple-strand wire would remain quite close to one another in a suitable position for arcing to occur.

5. Conclusions

Electric blanket elements are likely to be fractured by continual bending and then they may arc and, hence, become a fire hazard. The life of an element can be increased by selecting its dimensions to give a high value to the group $\frac{DP}{d}$, though clearly other factors are also involved and, although the likelihood of ignition by an element does not appear to be related to its life, it would obviously be advisable to design elements to have as long a life as possible.

An element with a single-strand heating wire is less likely to arc on breaking than a multiple-strand one.

A glass fibre braid between the heating wire and the insulation makes the element more prone to ignition and should not be used.

References

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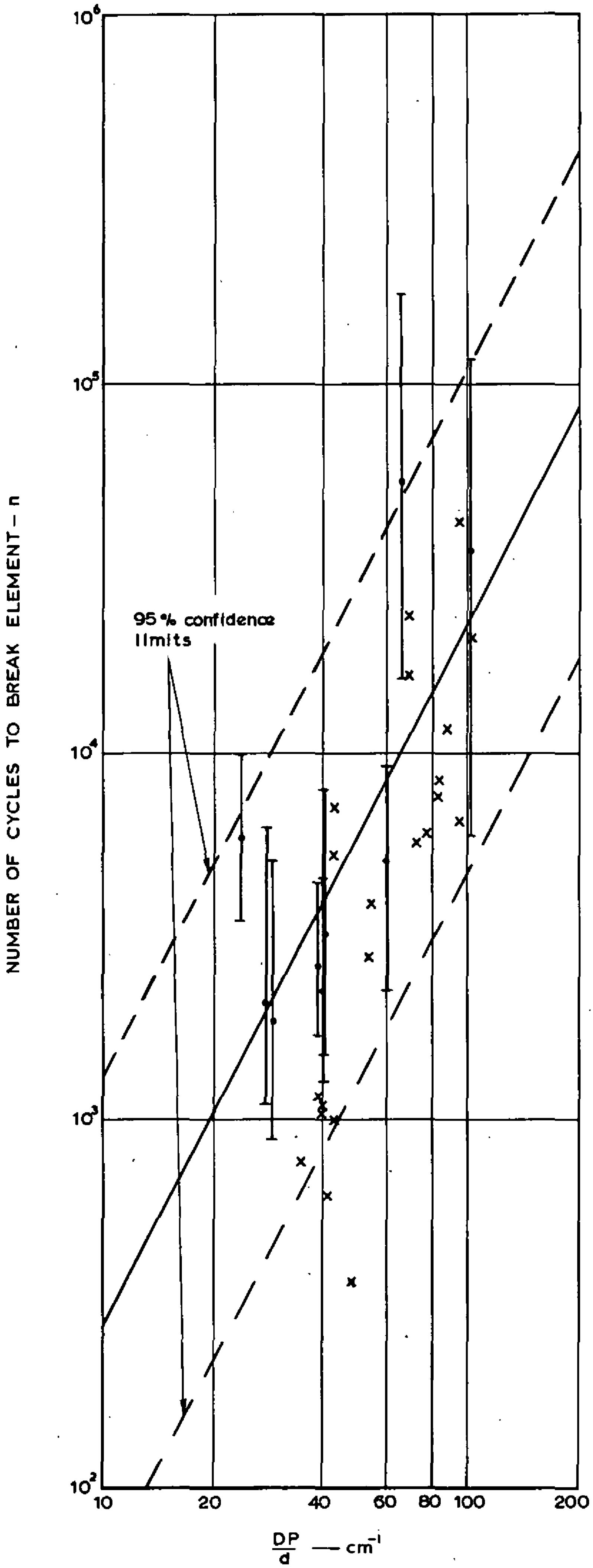

Range and mean of J.F.R.O. results

× New Zealand mean results

FIG.1. $\frac{DP}{d}$ AS A FUNCTION OF ELEMENT LIFE

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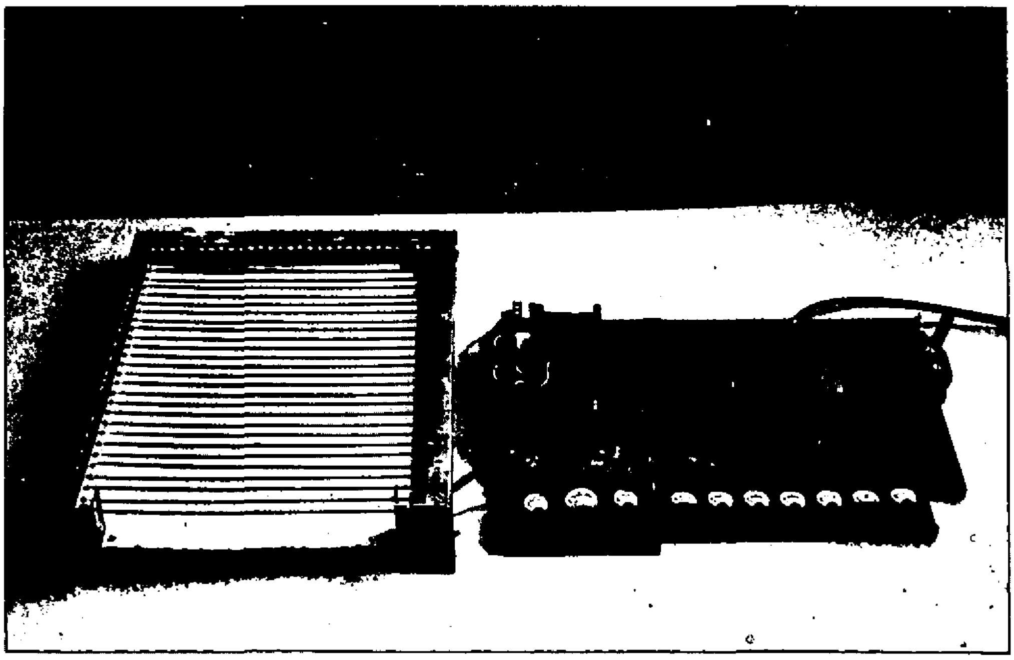

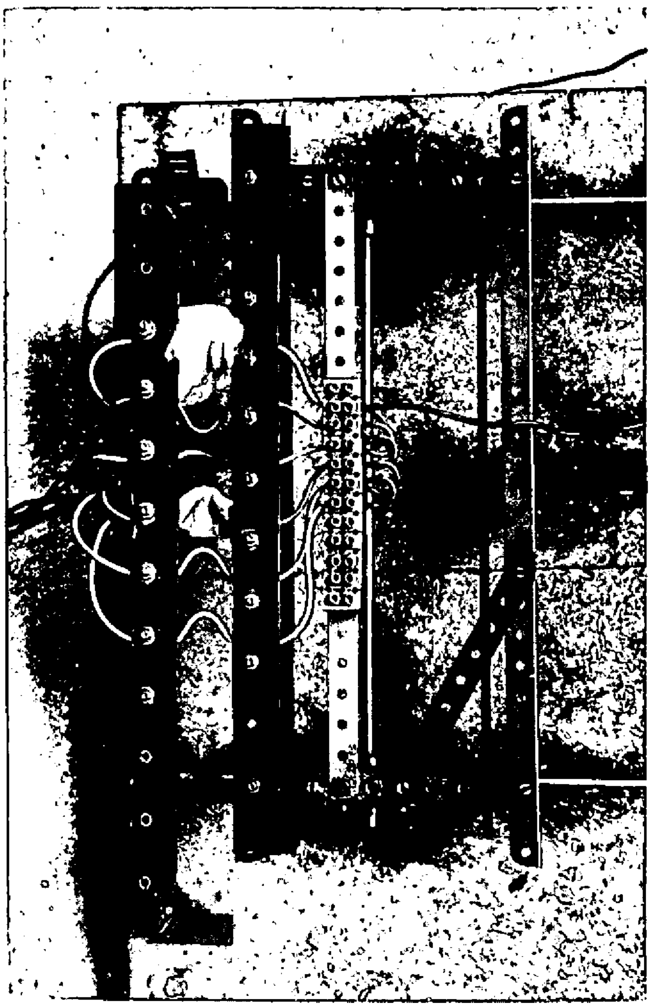

The Element Flexing Machine

One Element has a cotton wool sleeve, the other a winceyette sleeve

PLATE 1