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SUMMARY REPORT

STUDY OF OVERHEATING OF ALUMINUM-WIRED
ELECTRICAL RECEPTACLES IN SCARBOROUGH,
TORONTO, HOMES.

ABSTRACT:

Temperatures of aluminum-wired receptacles in three Scarborough homes have been measured at 11.5 amp current, well within the expected normal usage and within the circuit rating. The receptacles measured were as originally installed by the electrical contractor.

Seventeen (63%) of the receptacles measured reached temperatures in excess of the insulation rating of the attached conductors, with many going substantially higher. The high temperatures reached indicate that an abnormal fire hazard exists in these homes and in other homes similarly wired.

Two of the homes had recently been inspected by Ontario Hydro. The Ontario Hydro inspection is seen to be inadequate with respect to identifying the hazard and, consequently, with respect to providing the homeowners with responsible fire-preventative advice.

Issued: January 11, 1982

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This report has been prepared at the request of
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1. Number of Homes Studied: Three
2. Age of Homes: 13 years (approximate)
3. Builder (Developer): Alcan
4. Electrical Contractor: Ainsworth Electric
5. Type of Receptacles: Leviton, Canada, Catalog 1297-I.
The receptacles are connected to the aluminum wire as shown in Figure 1. This type of receptacle, and the method of connection, were approved for use with aluminum wire at the time of installation. The type of contact established between the terminal screw and the aluminum wire is a "straight-in, sidewired" connection in which the wire is tightened under one side of the binding head screw. (The manufacturer considers this a "back-wiring" method, because of the guide through which the wire is inserted, but this has no relevance to the type of termination.)
6. Owners: Original
7. Previous Experience of Overheating Receptacle Connections:
 - Home "A" - Two receptacles "burned out" prior to 1975, at aluminum-wire connections. Hydro inspection found heat-damaged insulation, due to connection overheating, on aluminum conductor attached to receptacle above kitchen counter.
 - Home "B" - Arcing, "sparks", at receptacle above kitchen counter, due to insulation failure caused by overheating aluminum-wire connections to receptacle.
 - Home "C" - Overheating connection damage at receptacle above kitchen counter.
8. Previous Corrective Work:
 - Home "A" - Two receptacles damaged by overheating aluminum wire connections were replaced by owner.
 - Home "B" - Receptacle with overheating (insulation failure) damage was replaced with a CO/ALR receptacle, by electrician.
 - Home "C" - Receptacle with overheating connection damage was replaced with a standard receptacle, by owner.

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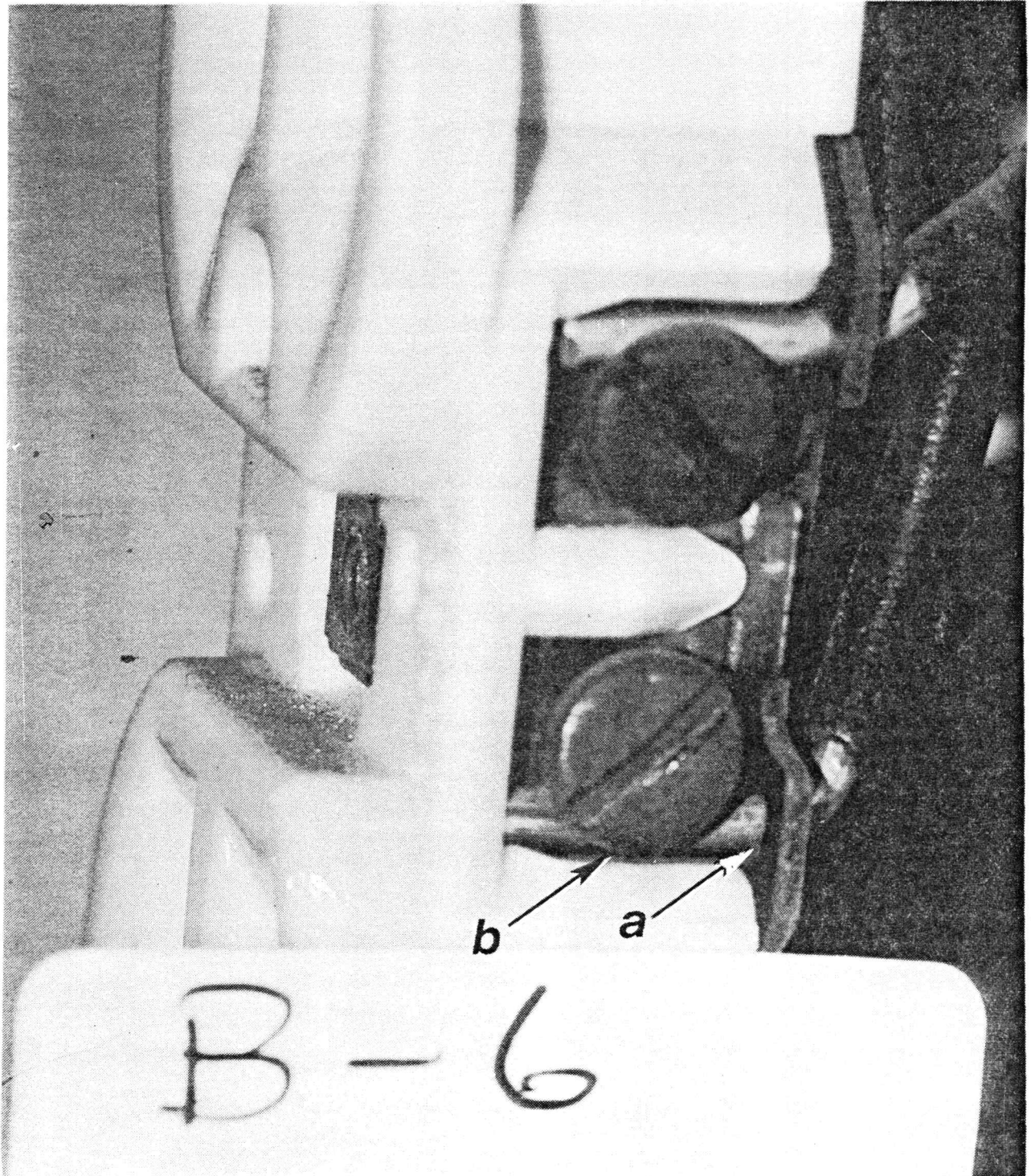


FIGURE 1 - Receptacle With Straight-in Sidewiring.
Conductor is inserted through wire guide, "a",
and tightened under screw, "b".

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9. Measurements Made:

Temperature in receptacle plug slots was measured using electrically-isolated thermocouples in attachment plug prongs. Readout via Doric (Omega) #400A digital temperature indicator.

Load; portable plug-in heater, 11.5 amp (measured).

Receptacles measured were randomly chosen from those accessible. Included, in all homes, were samples in each of the following areas; kitchen/dinette, living/dining/family rooms, and bedrooms.

All measurements were made in place, without disturbance of the receptacles.

Determination of the receptacle wiring, to identify which receptacles are passing current through their wire connections when the load is plugged in, was accomplished by measuring the potential drop between the upper and lower receptacle slots on the same side of the line. These potential drop measurements were made using a Fluke #8020A digital multimeter connected by plugging into the receptacle blade slots with standard prongs.

10. Results:

Following is a statistical summary of the measurement results on all receptacles which were as originally installed by electricians. Twenty seven of the original type of receptacles were measured.

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SUMMARY OF RESULTS

a. Number of aluminum-wired receptacles measured, as originally installed by electricians.....	27
b. Number overheating.....	22 (81%)
c. Number exceeding temperature rating of the conductor insulation (60 C).....	17 (63%)
d. Number with readings in excess of 75 C....	10 (37%)
e. Number with readings in excess of 100 C...	5 (18%)
f. Number with readings in excess of 125 C...	3 (11%)
g. Number with readings in excess of 150 C...	1 (4%)

Table 1, following, is a complete tabulation of the measured temperatures of the aluminum-wired receptacles at 11.5 Amp load current. In most cases, the time of the measurement is that at which significant change was no longer evident. In the case of receptacle C-15, the test was discontinued after 20 minutes for safety reasons, even though the temperature was still increasing.

Most of the measurements involve all four slots of the receptacle. In these cases, the load was plugged into a receptacle elsewhere in the circuit. For receptacles which did not feed other receptacles downstream in the circuit, the load was plugged into one socket of the receptacle and temperature measurements were made in the two remaining slots of the unused socket.

Classification of the receptacles with respect to hazard level is based on laboratory and field experience with aluminum and copper wired receptacle measurements. Normal receptacles of the screw terminal type are expected to have very little temperature rise at 11.5 Amp current, generally less than 5 Deg. C above the ambient or starting value.

Receptacles which measure 40 Deg. C or more (starting from a 23 to 25 Deg. C initial reading) are generating abnormal heat at the terminal screw connections. Above 60 Deg. C, there is a definite hazard, since the terminals are operating above the safe rating of the adjacent insulation on the conductor (type "A" hazard in

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Table 1). Receptacles which measure above 100 Deg. C are considered to be at a hazard level greater than those which are only somewhat above the insulation rating temperature. The receptacles in the higher fire hazard category are listed as type B hazards in Table 1.

RECEPTACLE	TIME (min.)	TEMPERATURE READINGS (four prong slots, Deg. C)				CLASSIFICATION			
						NORMAL	ABNORMAL	HAZARDOUS	
							A	B	
A-1	10	27	28	28	28	X			
A-2	20	77	115	63	95				X
A-4	10	37	31	33	30	X			
A-5	10	42	28	33	28		X		
A-6	10	45	31	33	29		X		
A-7	10	42	62	53	43			X	
A-8	10	49	31	64	31			X	
B-1*	5	26	26	-	-	X			
B-2	5	31	25	-	-	X			
B-3	18	31	29	36	28	X			
B-4	20	82	40	54	37			X	
B-5	15	113	43	66	39				X
B-6	8	101	34	79	33				X
B-8	15	52	59	67	78			X	
B-9	10	55	34	88	34			X	
B-10	20	74	44	80	42			X	
B-11	23	42	68	41	49			X	
C-1	30	53	47	-	-		X		
C-2	30	134	69	-	-				X
C-4	30	40	37	40	66			X	
C-5	30	66	49	-	-			X	
C-11	30	-	-	77	42			X	
C-12	30	57	42	73	43			X	
C-13	10	38	61	37	44			X	
C-14	10	33	37	32	40		X		
C-15	20	153	104	128	83				X
C-16	5	38	32	42	32		X		
C-17	6	31	31	32	30	X			

TABLE 1 - TEMPERATURES IN ALUMINUM-WIRED RECEPTACLES MEASURED IN SCARBOROUGH HOMES.

* Recent Replacement of original,
not included in summary on previous page,
but included here for comparison.

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11. Additional Observations: In home "A", one additional overheating device, a combination switch-outlet, was discovered in an upstairs bathroom. The insulation on one conductor had flowed and discolored adjacent to the terminal, indicating prior overheating. This device had conventional binding-head screw terminals, with the wires attached as is today considered proper for aluminum wire connections.

A small sample inspection was made of aluminum-wired twist-on connections. Of 15 such connections inspected, insulation damage, due to overheating, was found on one. The major troublesome area with respect to aluminum-wired twist-on connections, those between solid aluminum and stranded copper conductors in baseboard heaters, is not present in these homes because the baseboard heating circuits are copper-wired.

12. Previous Inspection By Ontario Hydro: According to the owners, homes "A" and "C" had been inspected by Ontario Hydro as part of the free inspection program in response to the aluminum wiring problems and concerns. One outlet which had overheated in home "A" (see section 7, page 1) was found by that inspector, apparently by the visual appearance of the conductor insulation. The homeowner was advised to have that receptacle replaced.

Neither homeowner was given any advice with respect to repair or replacement of the other receptacles in the homes, in spite of the fact that the particular wiring technique employed is known to be failure-prone when used with aluminum wire.

In one case, the homeowner's impression was that the inspector, rather than giving advice on solving the problem, tried to be reassuring regarding the safety of the aluminum wired connections in the home. This was hardly justified, since he had just found evidence of another (the third) instance of hazardous overheating in that same home.

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13. Discussion:

A high percentage of the aluminum-wired receptacle connections in these homes studied are in hazardous condition. When electrical current passes through these connections, abnormal heating occurs, and the temperature can increase to dangerous levels.

This is, very specifically, a fire hazard. There is an abnormal risk of fire in these homes which can result from overheating receptacle connections when the electrical circuits are used in their normal and intended manner. (Reference 1)

The risk of fire is twofold. First, at relatively low levels of connection overheating, the insulation of the attached conductors deteriorates, leading to the possibility of short-circuit arcing. When this occurs, even though the circuit breaker or fuse opens the circuit, there can be a significant shower of "sparks", consisting of red-hot and white-hot materials (including molten metal). Some of these hot materials can escape from the junction or outlet boxes, through various openings, into the wall or room space. Ignition of fire occurs if a hot enough particle lands on a sufficiently flammable material.

The second category of ignition mechanisms is due to direct heating effects when connections overheat to temperatures beyond the ignition point of adjacent or nearby flammable materials. Wallpaper, draperies, bedding, and books were among the flammable materials found to be adjacent to overheating receptacles in the homes studied. Wallpaper, tested to be flammable, was sometimes found to be touching the receptacle terminal screws inside the box behind the coverplate.

Both types of ignition mechanisms have been confirmed by laboratory investigation and field experience. For instance, Mr. W. L. Bates (Mississauga) experienced a fire in a spare bedroom where a receptacle overheated and the bedding caught fire. (Reference 2) In classifying the overheating receptacles as hazardous, this report is not in conflict with the Wilson Commission. Although the subjects of fire hazard and ignition mechanisms are not seriously discussed in the body of the Commission's report, the Commission defines "temperature, abnormal" as:

in functioning electric-wiring devices, an increase in temperature sufficient to cause charring of combustible materials, short circuits, or harmful deterioration of conductor insulation. An abnormal temperature increase may be considered as a sign of a fire hazard. (Reference 3)

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The fire hazard is not limited to the receptacles which have loads plugged into them. Most branch circuits have several receptacles wired in a "daisy-chain" fashion. Current flowing to a load plugged into a receptacle flows through the wire connections of the other receptacles in the chain which are in the path from the circuit breaker (or fuse). Any of the connections in the chain can overheat, and the overheating receptacle can be located far from the receptacle with the load plugged into it. In home "C", for example, a load plugged into a living room receptacle resulted in the overheating of a receptacle behind the drapes in the dining room. Upstairs, a load plugged into a bedroom receptacle resulted in overheating of a receptacle (C-15, to 153 deg. C) in the hallway. In home "B", plugging a load into a receptacle in one bedroom resulted in overheating of another receptacle in the same bedroom plus overheating of four additional receptacles in two other bedrooms.

All three of the homes studied had experienced previous incidents of overheating aluminum wire connections at receptacles. That more had not been noted is due to the fact that most of the circuits are very lightly loaded most of the time. Additionally, overheating connections in homes can go undetected by the occupants, as, for example, the two receptacles found to have insulation damage on the attached conductors (due to connection overheating) in home "A". One was noted by the Ontario Hydro inspector, and one was found in this present study.

The Ontario Hydro inspector, in one of the cases studied, had advised the homeowner to "feel the outlet faces" to detect overheating. This is ineffective, and potentially dangerously misleading, because the homeowner cannot be expected to know how much current, if any, a receptacle's connections have been passing, and for how long, prior to being tested in that manner. For instance, consider the case of receptacle C-15, the most hazardous receptacle measured in this study. The homeowner might feel the outlet face during the day and find it to be cool. Yet at night, with everybody asleep, circuit loads plugged into receptacles in the adjacent bedroom (electric blanket, vaporizer, heating pad) would result in hazardous overheating of receptacle C-15, possibly leading to fire.

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The measurements presented here demonstrate the hazardous nature of the aluminum wire in combination with the particular receptacles as installed in these homes. There is a very high degree of certainty that other aluminum-wired homes with the same connection type would show similar results. To determine the extent of hazardous conditions in aluminum-wired homes with other types of receptacle and twist-on connections, additional in-home measurements must be made. Without direct measurements and observations, any attempt to assess the safety of the aluminum-wired homes cannot be taken seriously.

No other in-home measurements are known to have been made in Canada. None were presented to the Wilson Commission, and the Commission did not initiate any. Therefore, the only comparative data comes from the United States. Table 2, below, compares the results found in the US national controlled study (by the Franklin Research Institute for the US Consumer Product Safety Commission) with the results of these measurements in Scarborough, Canada. (Reference 4)

	<u>United States*</u>		<u>Canada</u> (Scarborough, This Study)
	Copper- Wired	Aluminum- Wired	Aluminum- Wired
Number of Receptacles Measured	1,089	1,013	27
Number reaching 75 Deg. C	1 (0.1%)	65 (6.4%)	10 (37%)
Number reaching 100 Deg. C	0	21 (2.1%)	5 (19%)

TABLE 2 - COMPARISON OF UNITED STATES NATIONAL SURVEY
IN-HOME MEASUREMENTS WITH THOSE OBTAINED IN
SCARBOROUGH, CANADA.

* US data on copper-wired receptacles includes both backwired (push-in) and binding-head screw terminals, while the data on aluminum-wired receptacles is for binding-head screw terminals only.

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14. Conclusions:

- a. An abnormal fire hazard exists in aluminum-wired homes with receptacle terminations similar to those found in the surveyed homes. The fire hazard is due to the overheating of the aluminum-wired receptacle connections when passing electrical current well within the expected range of normal usage and within the circuit ratings.
- b. Considering the hazardous condition of the aluminum-wired receptacle connections in these homes, the Ontario Hydro inspections were clearly inadequate. The advice given to the homeowners was also inadequate. Neither the inspection methods nor the advice given reflect the responsible application of Ontario Hydro's knowledge of the subject, as evidenced by their own research reports, toward the interest of electrical safety in existing aluminum-wired homes.

15. Recommendations

- a. Ontario Hydro should prescribe specific fire-preventative measures, with respect to the receptacle connections and the twist-on connectors, for the surveyed homes and like-wired homes in their region of jurisdiction.
- b. A broader survey should be undertaken to determine, with a measure of certainty, the following:
 - 1) What various types of connections are actually installed in the aluminum-wired homes?
 - 2) What is the probability of hazardous overheating for the various types and brands of connections, as they presently exist in the homes?
 - 3) To what extent has each type of failure-prone aluminum-wire connection been used in the existing homes?
- c. Specific fire-preventative measures should be prescribed for homes with aluminum-wired connection types which are determined to be prone to overheating.

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16. References

1. J. Aronstein, "Fire Due to Overheating Aluminum Wired Branch Circuit Connections", Electrical Safety Conference; Electrical Fires, Cause, Prevention, Investigation. University of Wisconsin, Extension, Madison, Wisconsin, April 7, 1981.
2. J. Tuzo Wilson, Commissioner, Report of the Commission of Inquiry on Aluminum Wiring, Queen's Printer for Ontario, 1979, (Part 2) Section 2.7.3 b (xii), p. 138
3. Wilson, Part 3, p. 38
4. Franklin Research Center, Philadelphia, PA, Report #F-C4812-01, April 20, 1979. Tables 1.3.2.1 and 1.7.4.