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NATIONAL BUREAU OF STANDARDS REPORT

10263

REPORT ON THE INVESTIGATION OF CERTAIN DEFECTS AND DEFICIENCIES IN TRAILER-TYPE HOUSES ON KWAJALEIN ATOLL MANUFACTURED BY NORTHLAND CAMPS, INC.

Report to

Department of the Army
Honolulu District, Corps of Engineers
Fort Armstrong
Honolulu, Hawaii

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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> Office of Standard Reference Data—Clearinghouse for Federal Scientific and Technical Information [3]—Office of Technical Information and Publications—Library—Office of Public Information—Office of International Relations.

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Located at Boulder, Colorado 80302.
[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
4214445	July 1, 1970	10 263

REPORT ON THE INVESTIGATION OF CERTAIN DEFECTS AND DEFICIENCIES IN TRAILER-TYPE HOUSES ON KWAJALEIN ATOLL MANUFACTURED BY NORTHLAND CAMPS, INC.

Clinton W. Phillips, Thomas K. Faison and Thomas H. Boone
Building Research Division
Institute for Applied Technology

Report to

Department of the Army
Honolulu District, Corps of Engineers
Fort Armstrong
Honolulu, Hawaii

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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1. Introduction

The Building Research Division of the National Bureau of Standards (NBS) was requested by the U. S. Army Engineer District Honolulu (HED) through Agreement No. HED-70-8 and change order No. 1, dated January 29, 1970 to perform an investigation on design, installation, and/or material defects and deficiencies in trailer-type housing located at Kwajalein Atoll. This report covers the findings of the field inspection at Kwajalein, and the results of a limited laboratory investigation. Documents including specifications, procurement details and chronology of events leading to this investigation were supplied to the NBS team for review and study in preparation for the field inspection.

2. Background

Of concern were 191 trailer-type houses supplied under U. S. Army Corps of Engineers Contract No. DACA83-68-C-0012 and manufactured by Northland Camps, Inc. of 1205 Northland Drive, Nampa, Idaho, shipped to Kwajalein and placed on location at the north tip of the Atoll and shown at the right of figure 1. Sixty-three units arrived on July 25, 1968, 64 on September 14, 1968, and 64 on November 13, 1968. The units are used for family living quarters. Figures 2 and 3 respectively show a typical family living unit and placement of the units in the housing area.

3. Scope

The investigation was principally related to the following problem areas as requested by HED and stated in NBS agreement letter dated September 12, 1969. For the purpose of this report they have been grouped as follows:

1. Warpage of exterior doors
2. Water leakage of exterior doors
3. Water leakage of windows
4. Water leakage of air conditioner cabinets
5. Air conditioner condenser fan motors
6. Tiled floor construction
7. Corrosion of exterior main electrical service risers
8. Exterior door hardware

4. Approach

A research team, consisting of two mechanical engineers and a building materials technologist, performed the following tasks:

1. Reviewed an assembly of documents pertaining to the procurement of the 191 trailer-type houses which consisted of the Army's specifications and request for proposals, the supplier's technical proposals with amendments, the shop drawings and miscellaneous correspondence and transcripts.

2. Attended the following briefing conferences:

   a. Background and trip arrangement meeting with Mr. Harold I. Rosen, counsel, HED, on October 3, 1969, at the National Bureau of Standards.

   b. Briefing, on design, procurement and shipment, by the design and legal staff at the U. S. Army District Headquarters, Fort Armstrong, Honolulu on October 20, 1969.

   c. Conference on documented failures, repairs and replacement and remedial steps taken with regard to the housing units. The staff of the Kwajalein Area Engineer's Office, the representative of Global Associates*, Division and District counsels, and the NBS representatives were in attendance at this meeting held in the Office of the Area Engineer on October 21, 1969. At this meeting, areas of concern beyond the eight items listed under scope above were also considered, such as capacity of air conditioning units, compressor motor failures, toilet bowl cracking, paint thickness on supporting beams, and electrical fixture and wiring damage caused by water leakage. The scope of this investigation was not enlarged to consider these items.

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* The contractor responsible for providing the logistic and community support for Kwajalein.

3. On-site team inspection was made of the windows, doors, floors, risers, and air conditioning units from October 20 through October 25, 1969, on the trailer-type houses of concern in this investigation. At the time of the field inspection 29 trailer-type houses were unoccupied and were made available for detailed inspection of the interior and exterior items. In addition, selected air conditioning units, main electrical service risers and doors were examined on some occupied houses. Assistance in disassembling and removing of units for inspection and sampling was provided by the staff of Mr. A. J. Moseley, Project Engineer, KMR*, and Mr. Frank Granich, of Global Associates.

4. Short term laboratory investigations of exterior doors, floor system cut-outs, floor tile adhesives, air conditioner condenser fan motors with capacitor, and main electrical service risers, taken at the time of the field investigation and shipped to the National Bureau of Standards were also made.

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* Kwajalein Missile Range

5. Results of Investigation

5.1 Warpage of Exterior Doors

a. Field Investigation

Doors were measured on thirty of the housing units. The units chosen for inspection represented each of the three shipments. Both exterior doors were examined and measured for warpage. In the units examined, 22 of the 60 doors had been replaced. The composition of the original exterior doors was, from exterior to interior; .032-inch sheet aluminum, 1/4 inch hardboard, 1 3/16 inch particle board, and 1/4 inch hardboard with interior surface matching the adjoining wall panels. Adjacent materials were bonded by resorcinol glue. A cross section of the door composition is shown in figure 4. The replacement doors were similar in construction to the original but had plywood in place of hardboard components. Measurements of all doors were made along the diagonal from the lower hinged corner to the outer-top corner and along the vertical face at the outer edge. The procedure used in measuring the warpage was to draw a string tautly across 3/4 inch spacing blocks positioned at the diagonal corners and at the outer edge corners. Measurements were made at the midpoint along the diagonal and at midheight. The deviation from the spacing block thickness was the magnitude of warpage. Along the diagonal the warpage of the original doors ranged from 1/8 inch to 7/16 inch. The warpage at the outer edge was of similar magnitude ranging from 1/8 inch to 5/16 inch. In all of the doors observed, the warpage caused the upper and lower edges of the door to move away from the door jamb (warp outward at top and bottom).

The replacement doors were also measured for warpage and the warpage ranged from negligible to 5/16 inch but for most of the replacement doors only negligible warpage had occurred. A tabulation of the observed warpage is given in Table 1 (see page 8 & 9).

The doors were examined for delamination (see Table 1). In cases where delamination was evident, the cause appeared to be the field application of the screwed-on weather stripping flange added subsequent to original installation. The screws were just long enough to penetrate through the 1/4 inch hardboard to which the aluminum skin was bonded. It appeared that the screws caused the cracks between the hardboard and the solid wooden frame member.

b. Laboratory Investigation

Two sample doors, one shown in figure 5, were selected during the field investigation to be returned to NBS for laboratory study. Sample #1 was taken from house 911 and was a door having the least amount of warpage for the original type doors observed, 1/8 inch at both points of measurement. Sample #2, taken from house 894 was the most warped, 7/16 inch along the diagonal.

In the laboratory the two samples were mounted horizontally on metal pads and were supported at four points. This test set-up is illustrated in figure 6. Deflection gages sensitive to 0.001 inch were mounted to indicate the relative changes in deflection caused by warpage. The doors were subjected to temperature gradients encountered in normal conditions and were exposed to moist conditions to determine the warpage reaction.

Under these conditions, Sample #1 although erratic at the start of the test settled down to a rate of change of approximately 0.003 inch per day deflection along the diagonal. The other sample, #2, was more responsive at 0.007 inch per day. The warpage in both cases was in the same direction as was observed in the field, convex with respect to the interior surface. These short term tests were conducted in a three week period. Over an extended time (90 days or more), changes at the indicated rate could produce significant dimensional changes (.5 inch).

Based on these test results and on discussions with personnel of the Forest Products Laboratory, USDA, and on review of information [1, 2]* furnished by them, it is evident that composite structures such as these wood-core exterior doors with one bonded aluminum surface (exterior) would warp because of change in moisture content of wood members of the door. The wetting of doors caused by rain in service at Kwajalein may have contributed to the rate of warpage, but differences in humidity between the time of manufacture and subsequent utilization would have caused warpage with or without the effects of rain. The bonding of an aluminum skin to one side only of a wood-core door, making the construction of the composite non-symmetrical from interior to exterior was a major factor in the warpage of the doors observed at Kwajalein.

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* Numbers in brackets refer to references given in Section 7.

Table 1

Field Observation of Exterior Doors

House Building Number	Ship-ment	Living Room Door	Hall Door	Original	Replacement	Warpage		Delamination
						Diag. (in.)	Outer Edge (in.)	
897	3	√			√	1/16	1/16	---
897	3		√	√		1/4	3/16	---
899	3	√			√	1/8	1/8	---
899	3		√		√	1/8	1/8	---
894	3	√		√		7/16	5/16	---
894	3		√		√	0	0	---
896	3	√		√		3/8	3/8	---
896	3		√		√	1/8	3/16	---
892	3	√		√		1/4	1/4	Aluminum Skin Top Corner
892	3		√		√	0	0	---
887	3	√		√		5/16	1/4	---
887	3		√	√		3/16	3/16	---
881	3	√			√	0	0	---
881	3		√	√		1/4	3/16	---
883	3	√			√	5/16	1/4	---
883	3		√	√		1/8	3/16	At Screws of Stripping
879	3	√			√	0	0	---
879	3		√	√		1/8	1/8	At Screws
873	3	√		√		1/4	1/8	---
873	3		√	√		3/16	3/16	---
868	3	√		√		1/4	3/16	Top Corner
868	3		√		√	1/8	1/8	---
865	3	√			√	0	0	---
865	3		√		√	0	0	At Screws
867	3	√			√	0	0	At Screws
867	3		√	√		1/4	1/4	---
861	3	√			√	0	0	---
861	3		√	√		1/4	1/4	---
864	3	√		√		5/16	1/4	---
864	3		√		√	0	0	---
863	3	√			√	0	0	---
863	3		√		√	0	0	---
857	3	√			√	0	0	---
857	3		√		√	0	0	---
859	3	√			√	0	0	---
859	3		√	√		1/8	3/16	---
811	1	√		√		3/16	1/8	---
811	1		√	√		1/4	3/16	---
807	1	√		√		1/4	1/4	---
807	1		√	√		1/4	3/16	---
831	1	√		√		1/8	1/16	Interior Surface

House Building Number	Ship-ment	Living Room Door	Hall Door	Original	Replacement	Warpage Diag. (in.)	Warpage Outer Edge (in.)	Delamination
831	1		√	√		3/16	1/8	---
830	1	√		√		1/4	3/16	---
830	1		√	√		3/16	3/16	---
911	2	√		√		3/16	3/16	---
911	2		√	√		1/8	1/8	---
942	3	√		√		3/16	3/16	---
942	3		√	√		3/16	1/8	---
940	3	√		√		5/16	1/4	---
940	3		√	√		3/16	3/16	---
948	3	√		√		1/8	3/16	At Screws
948	3		√		√	0	0	---
950	3	√		√		1/4	3/16	At Screws
950	3		√		√	0	0	---
992	1	√		√		3/16	3/16	---
992	1		√	√		1/8	1/16	---
954	2	√		√		5/16	5/16	---
954	2		√	√		1/4	1/4	---
998	1	√		√		5/16	5/16	---

5.2 Water Leakage of Exterior Doors

a. Field Investigation

The exterior doors and jambs were manufactured with tongue-and-groove metal weather stripping members around the inside perimeter of the door. Wind-driven rain could penetrate to the weather stripping thus allowing the door edges to be wetted at the joint between the door and jamb. In some cases, because of door warpage, which was accelerated by the edge wetting, the weather stripping did not adequately perform its intended function. As the warpage became increasingly large, the mating of the weather stripping members was not accomplished and water leakage into the house interior resulted. The location of the weather stripping with respect to the threshold also contributed to water leakage. The vertical weather stripping was positioned near the center of the ends of the threshold plate which, as designed, allowed water to drain to the interior of the house rather than providing positive direction to the outside. Figure 7 shows construction of the weather stripping at house 811 and its position in relation to the threshold plate. Water which ran down the weather stripping could also leak to the interior through the uncaulked end joint between the threshold and jamb. Lack of caulking under the threshold plate also contributed to leakage of rain water to the interior of the house. Construction of the threshold plate from house 887 is shown in figure 8.

5.3 Water Leakage of Windows

a. Field Investigation

In each of the twenty-nine unoccupied houses inspected, the windows were examined for evidence of damage from leakage. Eight of these houses had some deficiency with respect to window leakage. In most cases where leakage was observed it had not caused damage to the interior and the only evidence was a white deposit on the sill remaining after evaporation of the water.

In two cases there was damage to the window sill material. Severe leakage was observed in house 899. The window above the kitchen sink was streaked and the sill material discolored. This window was selected for removal and inspection. After loosening the retaining screws and prying the window frame away from the aluminum house surface, the path of leakage was very evident. A white deposit could be traced from a crack in the caulking material through the butyl rubber type gasket of the window in house 899. The crack in the caulking and the path through the gasket material is evident in figures 9 and 10. The gasket was very tacky as shown in figure 11 and resisted the removal of the frame. The gasketing of the joint between the aluminum skin and the window frame appeared to be of adequate design but there was, as evidenced by leakage, inadequate bonding at one point. It was observed in all houses inspected that the spacing of the screws around the frame perimeter was irregular. With thin framing material and excessive spacing between screws, the gasket material might not be compressed sufficiently for gasket bonding between the aluminum skin and window frame. Placement of the gasket over improperly prepared surfaces could also be a cause for leakage, such as occurred in house 899.

5.4 Air Conditioner Cabinet Water Leakage

a. Field Investigation

No actual leakage of water through the air conditioner cabinets was observed during the field investigation. From examination of the cabinet construction it was evident that leakage would occur if vertical joints were not taped, caulked, or otherwise sealed. In some of the installations water stains within the supply and return ducts were evidence of previous leakage. It is not known whether vertical joints were sealed at the time of original installation. The major source of leakage appeared to be the vertical joints. The vertical joints between the plenum and air conditioner cabinets, which were simple flange joint connections, were the worst of the joints observed. At places the flanges were separated 1/2 inch. A 2 1/2 inch wide covering plate was placed over the top joint between the air conditioning unit and plenum and caulking was applied along the edges to prevent leakage. The other vertical joints of access panels which were normally removed for servicing also contributed to the leakage problem. Views of a) the overall air conditioner assembly, b) the cover plate and the top joint between the two cabinets, c) the vertical joint between the two cabinets, and d) a view of the interior of the plenum are shown in figure 12 through 15 respectively.

The vertical joints for the access panels were slip type with the male flange being on the access panel. This poor design feature allowed any water which might enter the joint to drain to the interior of the plenum. The lower left corner of figure 15 shows the construction of the vertical joints of the access panels.

A terminal switch box as shown in figure 14, was mounted on the exterior of each of the air conditioner cabinets and could have contributed to the leakage problem. The power lines, prewired at the factory and placed in the air conditioning duct work, were run from either the supply or return opening through the side of the plenum cabinet to the switch box. A flexible conduit (vinyl) was used to make the connection between the plenum and the switch box. The connection between the conduit and the cabinet may have provided a path for water to enter the plenum.

The joint between the house roof and the plenum appeared to be holding up quite well and there was no evidence of leakage at this point.

5.5 Air Conditioner Condenser Fan Motors

a. Field Investigation

Each of the 191 trailer-type houses was supplied with a roof-mounted air conditioner, manufactured by the Bard Manufacturing Company, Bryan, Ohio. The units were shipped to Kwajalein inside the houses and were erected and installed by Martin-Zachry Constructors after each house was set in place. Each air conditioner was self-contained (compressors, coils, blowers, motors, etc., in one cabinet). Installation consisted of cutting the roof to provide access to the supply and return ducts, assembling the plenum section to the air conditioner cabinet, mounting on bases, flashing and sealing the plenum to the roof surface, and connecting electrical service. All air conditioners were of similar type and style. A typical nameplate read as follows:

"P36A Ser. No. _______
Comp. 208V 13A 72LRA 3Ph
Outdoor fan 208V 3.8A 1/2 HP 1Ph
Indoor fan 208V 3.8A 1/2 HP 1Ph
Fuse 25A min. 35A max.
Test Press, psig 475 Highside 150 Lowside
Refr. F22 charge 72 oz
Bard Manufacturing Company
Bryan, Ohio"

Figures 16 and 17 show typical installations. Figure 18 shows arrangement of the major elements of the air conditioner at house 915.

Thirty-two air conditioners were inspected and/or operationally checked with regard to voltage, compressor motor current, condenser fan motor current and evaporator blower motor current. Table 2 lists these units, by house number. House 892 was equipped with a Fedders air conditioner which had been installed as a replacement for the original BARD unit and no further comments apply to this unit.

Each of the 31 BARD Mod. P36A air conditioners inspected contained a 5-blade, 20 inch diameter propeller-type condenser fan shaft-mounted on a 1/2 HP GE PSC (permanent split capacitor) motor, Model No. 5KCP39MG7626S. See figure 19. These motors were positively identified by the motor nameplate, if legible, and by the model number stamped on the rear bearing end cap. Figure 20 is a facsimile of a nameplate from one of these motors. Figure 21 shows the condenser fan and motor from house 915. The motor model number can be seen on the rear bearing end cup.

The evaporator centrifugal blowers also were powered by direct shaft mounting on the same model 1/2 HP GE motors, based on similar identification in a sampling of approximately 15 of the 31 inspected units. Figure 22 shows the evaporator blower and motor assembly removed from house 915.

Table 2

Houses Inspected for Air Conditioner Performance/Data. Except as Noted All Air Conditioners are BARD Mod. P36A

House Number	Shipment No.	House (NCI)* Serial Number	Air Conditioner (BARD) Serial Number
807	1	255-61090	21484 FH
808	1	" -61044	21483 FH
811	1	" -61082	21527 FH
830	1	" -61042	21510 FH
831	1	" -61092	21496 FH
853	2	" -61115	21612 FH
857	3	" -61223	21565 FH
859	3	" -61225	21628 FH
861	3	" -61224	21593 FH
863	3	" -61222	21558 FH
864	3	" -61187	21600 FH
865	3	" -61221	21564 FH
867	3	" -61227	21561 FH
868	3	" -61200	21637 FH
873	3	" -61219	21583 FH
879	3	" -61218	21652 FH
881	3	" -61213	21651 FH
883	3	" -61211	21632 FH
887	3	" -61229	21566 FH
892	3	" -61205	(Replacement Unit) - Fedders Mod. CAC 036A8 Ser. HC980520 Rev. A
894	3	" -61203	21638 FH
896	3	" -61204	21570 FH
897	3	" -61210	21624 FH
899	3	" -61209	21647 FH
911	2	" -61124	21610 FH
915	2	" -61104	21585 FH
940	3	" -61189	21586 FH
942	3	" -61194	21661 FH
948	3	" -61198	21566 FH
950	3	" -61021	21569 FH
954	2	" -61159	21619 FH
992	1	" -61048	21517 FH

* Northland Camps Inc.

It was not possible to determine in every case whether the motors inspected were original or replacement. In some cases replacement motors could be identified by the length of the shaft. The original shaft length was 3 inches. To facilitate subsequent fan removal the shafts of the replacements, according to Global Associates maintenance personnel, were cut off so as not to extend beyond the fan hub. Figure 23 shows the original shaft length and where the shaft was cut for replacement motors.

For record purposes, it was decided to remove and mark the original condenser fan motor and evaporator blower motor from at least one house in each of the three shipments to Kwajalein. Five houses in each shipment which, according to available service records, still contained original motors, were examined and motors were removed from the following three houses:

House 808	1st shipment
House 853	2nd shipment (incorrectly identified as 3rd shipment)
House 915	2nd shipment

On October 24, Mr. L. Olson, a serviceman for Global Associates, identified a 1/3 HP Delco condenser fan motor, model (or part) number C644M1. The serviceman stated that the motor had just been removed from the air conditioner at house 838, an occupied house not on our schedule and that the motor was a replacement, and not an original type. It was the only condenser fan motor to come to our attention different from the 1/2 HP GE motors previously described.

Table 3

Inspection/Observations - 31 BARD Air Conditioners

October 21-24, 1969

House	Motor Amperes			Volts	Hi-Press. Switch Shunted	Cond. Fan Motor on Line Term.	Cond. Fan Motor G.E. 5KCP39MG7626S	Remarks
	Cond. Fan	Evap. Blower	Comp.					
807	3.2 to 3.6	2.3	-	-	Yes	Yes	Yes *0	-No insulation under top of unit or plenum.
808	-	-	-	-	-	-	Yes	-Insulation from plenum cover had fallen into supply duct. Cond. fan and evap. blower motor marked and removed to NBS.
811	2.9	2.2	12.7 13.2 13.8	204 203 205	No	No	Yes	
830	3.3	2.3	14.5 14.3 13.9	201 198 200	Yes	Yes	Yes	
831	7.2	2.4	16.0 14.0 15.5	-	No	-	Yes	-Cond. fan cycling on internal temp. limit switch. Compressor runs briefly until hi-press switch trips.
853	3.1	2.0	12.4 11.8 12.2	204 203 203	No	No	Yes	-Cond. fan & evap. blower motors marked and moved to NBS.
857	3.6	2.4	13.5 13.0 14.0	204 204 203	Yes	Yes	Yes *0	

2

Table 3 (Continued)

House	Motor Amperes Cond. Fan	Motor Amperes Evap. Blower	Motor Amperes Comp.	Volts	Hi-Press Switch Shunted	Cond. Fan Motor on Line Term.	Cond. Fan Motor G.E. 5KCP39MG7626S	Remarks
859	-	-	-	-	-	-	Yes[*0]	-Cond. fan motor cycling on internal temp. limit switch. Compressor cycling on internal temp. limit switch. Not pumping properly. Con. fan motor ok after replacement capacitor. Defective capacitor marked and removed to NBS.
861	$3.6^{(3.6)}$	$2.5^{(2.6)}$	14.3(14.0) 14.0(13.3) 13.4(13.8)	205(210) 205(211) 205(210)	Yes	Yes	Yes	
863 } 864 }	No power - risers removed				No No	No No	Yes[*0] Yes[*0]	
865	-	-	-		-	-	Yes[*0]	-Cond. fan blade loose and jammed against compressor. Fan and motor marked and removed to NBS.
867	2.8 $3.3^{(2.6)}$	$2.3^{(2.9)}$	13.0(11.5) 13.5(14.5) 13.5(12.0)	202 202 200	Yes	No	Yes[0]	
868	3.6	2.4	13.3 12.8 14.0	205 204 205	Yes	Yes	Yes[*0]	

3

Table 3 (Continued)

House	Motor Amperes Cond. Fan	Evap. Blower	Comp.	Volts	Hi-Press Switch Shunted	Cond. Fan Motor on Line Term.	Cond. Fan Motor G.E. 5KCP39MG7626S	Remarks
873	4.0$^{(3.2)}$	2.6$^{(2.4)}$	13.4(12.7) 12.0(11.5) 12.5(12.0)	204 204 204	No	No	Yes^{0}	
879	-	-	-	-	Yes	Yes	Yes^{*0}	-Cond. fan motor stuck--freed readily-runs backward. Marked and removed to NBS. Unit circuit breaker was tripped.
881	7.2	-	6.3 to 10.2**	203 204 203	Yes	-	Yes^{*0}	-Cond. fan motor cycling on internal temp. limit switch.
883	3.6$^{(3.6)}$	2.2$^{(2.2)}$	14.7(13.2) 15.5(13.9) 14.0(13.4)	204(200) 204(200) 204(200)	Yes	Yes	Yes^{0}	
887	-	-	-	-	-	-	Yes^{0}	
894	-	-	-	-	-	-	Yes^{0}	
896	3.6	2.0	14.8 15.0 15.0	200 200 200	Yes	Yes	Yes^{*0}	
897	3.0	2.2	14.0 14.6 14.6	202 202 202	Yes	Yes	Yes^{0}	
899	-	-	-	-	-	-	Yes	
911	3.3	1.3	14.0 14.0 14.0	202 202 202	Yes	Yes	Yes^{*0}	

Table 3 (Continued

House	Motor Amperes: Cond. Fan	Motor Amperes: Evap. Blower	Motor Amperes: Comp.	Volts	Hi-Press Switch Shunted	Cond. Fan Motor on Line Term.	Cond. Fan Motor G.E. 5KCP39MG7626S	Remarks
915	-	-	-	-	No	No	Yes[0]	-Cond. fan & evap. blower motors marked & removed to NBS
940	3.4 to 3.8	2.0	11.5 11.5 12.0	-	Yes	No	Yes[*0]	
942	3.4	2.3	11.0 10.6 10.8	203 201 202	No	No	Yes	
948	3.0	2.4	Comp. off on thermostat		Yes	Yes	Yes	
950	3.5	2.2	14.3 13.4 14.3	202 202 202	-	-	Yes[*0]	
954	3.2 to 3.6	2.1	8.2[**] 8.2 8.6	205 203 204	No	No	Yes[0]	
992	2.6 to 3.6	1.2	12.4 13.0 12.5	207 207 207	Yes	Yes	Yes[0]	

( ) Indicates 2nd data set

* Service records show motor had been replaced since original installation

** Probable compressor malfunction

0 Service records show capacitor had been replaced since original installation.

Table 3 shows the observations made during our inspection of BARD air conditioners on 31 houses. In Table 3 the measurements of motor currents and voltages were made with a field-type service instrument. Motor currents can be considered accurate within 10 percent, voltages within 5 percent, based on checks of the instrument before and after the inspection trip.

The major purpose of this inspection of the air conditioners was to attempt to determine reasons for excessive failure rates for the condenser fan motors. Of the 31 units inspected, three condenser fan motors, at houses 831 (original), 859 and 881 (both replacements) were cycling on internal temperature limit switches, drawing about 7.2 amperes (compared to 3.9 amperes nameplate rating) for approximately two-minute on-cycles. In each case this was caused by shorted capacitors. The condenser fan motor at house 879 was running backward at reduced speed. This was caused by a grounded capacitor. The condenser fan motor at house 808 (original) was also running backward at normal speed. This was a function of internal motor wiring. At house 865 (replacement) the condenser fan blade had worked loose from the motor shaft and jammed between the condenser fan shroud and the compressor, resulting in damage to the motor shaft. The motor was apparently a replacement because the shaft had been cut. In two houses (863 and 864) operational checks of the units were not possible because electrical risers had been removed. In the remainder, condenser fan motor operation was satisfactory.

In at least 12 of the 31 houses the condenser fan motors, which normally run only when the compressor is operating, had been wired (subsequent to original installation) to two line terminals of the compressor motor contactor, which resulted in continuous condenser fan operation. It was explained that this was done to prevent reverse "windmilling" of the condenser fan during normal fan off-cycles. It was an attempt to prevent motor damage possibly caused by excessive starting loads or, if reverse windmilling was fast enough at time of motor cut-on, reverse operation of fan during normal on-cycles.

It was noted that, subsequent to original installation, shields had been fabricated and installed (in place of original grilles) over the condenser air inlet openings on each side of each air conditioner. See figure 24. The stated purpose for this addition was to reduce windmilling of the condenser fans.

Winds were moderate, probably less than 20 mph, during most of the inspection. Some windmilling was observed. Where the wind entered directly into the condenser face (normal fan motion forces air out) the windmilling was about the same whether the shields were in position or removed. This was observed during the inspection at house 896. The wind direction was SE, gusty and estimated between 20 and 25 mph. Reverse windmilling, estimated at about 100 rpm, was overcome by the normal starting torque of the fan motor with longer-than-normal high current starting time. Performance of a condenser fan and motor under various starting conditions is discussed under the laboratory test part of this section. At other houses during our inspection, only occasional slight windmilling (not always reverse) caused by wind entering either side was observed and was eliminated by the shields. An examination of the house layout plan, figure 1, shows that the prevailing wind (approximately ENE) would approach 66 air conditioners directly from the side, and the remainder generally from the side. It should be noted that rate of windmilling would be directly related to wind direction and speed and that maximum speeds do not necessarily occur in the prevailing wind direction. For example, the maximum wind speed for the period August 1968 through September 1969 according to Kwajalein Island airport station weather data was 55 mph at a SW direction. During this same period winds (one minute readings) with speeds at 30 mph or higher were recorded on 15 days as follows:

	MPH	Direction (degrees)
Aug. 1968	32	320
Sept. 1968	30	70
	30	180
Oct. 1968	40	200
Nov. 1968	-	-
Dec. 1968	31	90
Jan. 1969	30	50
	30	60
	30	60
	55	220
Feb. 1969	30	60
Mar. 1969	35	60
Apr. 1969	31	80
	31	70
May 1969	-	-
June 1969	30	80
	32	100
July 1969	-	-
Aug. 1969	-	-
Sept. 1969	-	-

Including these 15 days, for the same 14-month period there were 258 days for which one-minute speeds of 20 mph or higher were recorded. The average wind speed for each month was:

	MPH
Aug. 1968	10.2
Sept. 1968	10.1
Oct. 1968	9.6
Nov. 1968	11.2
Dec. 1968	13.4
Jan. 1969	19.5
Feb. 1969	15.8
Mar. 1969	18.2
Apr. 1969	18.5
May 1969	18.0
June 1969	15.3
July 1969	12.3
Aug. 1969	9.5
Sept. 1969	8.8

Another effect of wind on condenser fan motor performance was observed during measurement of fan motor amperage. Because of the reaction of propeller fans to differential pressure, a wind direction opposing the normal fan discharge direction causes a noticeable increase in the resulting fan power. A sustained wind in a specific direction of more than 20 mph could raise the amperage of the condenser fan to a level above the nameplate recommended value of 3.9 amperes.

Centrifugal blowers, as required in Military Specification MIL-A-21261, would have minimized, if not eliminated, both the windmilling and excess power effects of winds. An example of a blower used for condenser air cooling is shown in figure 25 which is a replacement unit installed on house 892.

As shown in Table 3 it was observed in at least 15 of the 31 houses that the compressor high pressure limit switch was shunted by attaching both wires to the same terminal. The shunting is illustrated in figure 26 which shows the control panel of house 883. The limit switch is at the top center of the panel. It was assumed that this shunting was done to minimize service calls to reset the high-pressure control which would trip when erratic condenser fan operation occurred. The practice of shunting the high pressure switch is not recommended because of deleterious effects on motor components. Shunting causes the compressor to cycle on its internal thermal overload mechanism in the event of high discharge pressures and is accompanied by undesirable high motor winding temperatures and accelerated wear of the internal switch.

It became evident during our inspection that failure of the starting capacitor for the condenser fan motor was a major, and probably the principal, factor in the subsequent damage to the motor. It was observed that, as originally assembled, the capacitor for the condenser fan motor was mounted in such a way that the capacitor leads were held against the end of the capacitor. Abrasion rapidly wore holes into the capacitor and in the wire insulation, with resultant shorting of the capacitor, and grounding of the wire against the capacitor. Figure 27 shows this problem on the motor removed from house 853. Figure 21 shows how replacement capacitors have been positioned to avoid this problem.

With a shorted capacitor, it was observed that the motor would run in the proper direction but at reduced speed, had higher-than-normal starting torque, and much higher current (7.2 amps) than the motor could tolerate for more than a minute or so. Under this condition, even though the internal temperature limit switch would open the circuit in about 2 minutes, the case temperature would continue to rise for a period of time after the switch would open. Off-time before the switch would reset was observed to be five or more minutes.

Corrosion of the metal parts of the air conditioners was evident. Condenser fan motors and shafts and mounting frames and fan hubs had corroded sufficiently to make fan replacement quite difficult but did not appear to be a major factor in motor failure. Servicemen reported a few bearing failures. Capacitors for the condenser fan motors generally showed evidence of rapid and extreme corrosion in addition to the abrasion problem mentioned above. Failure of the capacitors occurs in three principal ways; open circuiting, internal shorting, and grounding, any of which subjects the motor to unusual stress. The rapid corrosion of the capacitors would tend to promote the latter two types of failure; shorting and grounding. Subsequent examination of Global Associates service records from December 1968 through September 1969 bears out the observed evidence of excessive condenser fan motor capacitor failure - 163 replacements. The same records show 64 condenser fan motor replacements.

No strong pattern of failure of either condenser fan motors or capacitors was evident with regard to location or orientation of the air conditioners.

The service records mentioned above show 3 evaporator blower motor replacements, 1 evaporator blower motor capacitor replacement, and 20 compressor replacements. The service records referred to are in addition to any prior to December 14, 1968.

Because no condenser fan motor failures actually occurring during our inspection were brought to our attention and because no recently failed motors were on hand, it was requested that the next six (or more) motors removed for failure be marked and retained for more detailed study as to the actual mechanism of failure. The NBS team has not been advised whether or not this has been done. Three condenser fan motors which had failed and had been replaced at houses 878, 880, and 888, during June, 1969, were made available to us and were shipped to NBS laboratories in Gaithersburg, Maryland for further study. Also shipped to NBS were the three condenser fan motors and three evaporator blower motors, removed from houses 808, 853 and 915 which were selected as samples of original installation. Condenser fan motors from houses 865 and 879, removed for fan and shaft damage and reverse rotation, respectively, during our inspection, were also sent to NBS.

Other observations of the air conditioners during our inspection, not directly related to the condenser fan motor, include:

Corrosion of the screws used to assemble the cabinet parts. This was very severe.

Severe corrosion of compressor shells.

Placement of filters. In several units, the filters were still in place in the return air section of the plenum even though the filter was supposed to be mounted in the return air grille in the house. Figure 28, showing the unit being disassembled at house 808 for removal of motors, shows the filter in the return air plenum. Note the screen below the far end of the filter. This screen shows the location of the outdoor or make-up air inlets (one on each side). Removal of the factory-installed filter as shown permits the make-up air to enter the coil unfiltered.

Inadequate bonding of the insulation on the underside of the top surface of the unit and plenum. In at least three (only a few of the units were disassembled) the insulation had separated from the underside of the metal tops. Figure 29 shows the insulation which has dropped and been turned back by air flow in the supply plenum of house 899. Figure 30 shows insulation which has dropped into the supply plenum of house 808. Figure 31 of the unit portion of the supply plenum of house 807 shows the absence of sufficient adhesive used to attach the insulation. Surface condensation was observed on the top of this plenum.

Condensate drain lines. These were not installed as a part of original installation. Prior to installation, corrosion damage and staining of the house roof and front wall occurred. Figure 32 shows drain line installation. Note corrosion of roof surface.

b. Laboratory Investigation

Eight condenser fan motors and three evaporator blower motors removed from air conditioners at Kwajalein were examined at NBS laboratories in Gaithersburg, Maryland. All were GE 1/2 HP Model 5KCP39MG7626S. They are listed by house number, with short descriptive commentary:

808(C) Condenser fan motor removed from house 808 on 10/23/69. Operating satisfactorily, but runs backward. Shaft full length. Lightly rusted in spots. No worn spots on leads--slight wear of capacitor case where leads touch. GE capacitor 72F5057FB.

808(E) Evaporator blower motor removed from house 808 on 10/23/69. Operating satisfactorily. Shaft full length. Lightly corroded. GE capacitor 72F5057FB.

853(C) Condenser fan motor removed from house 853 on 10/24/69. Operating satisfactorily. Shaft full length. Shell, shaft and fan hub rusted. Worn spots in both capacitor leads where they had touched the capacitor. Capacitor mount had been bent to avoid further contact--leads now touch other side. Capacitor GE 72F5057FB.

853(E) Evaporator blower motor removed from house 853 on 10/24/69. Operating satisfactorily. Shaft full length. Lightly rusted only in spots. Sprague Clorinol capacitor 200P1905P6-1S.

915(C) Condenser fan motor removed from house 915 on 10/23/69. Operating satisfactorily. Shaft full length. Shell, shaft and fan hub rusted. Has replacement capacitor (Vanguard RAC-6-370-OV) taped to frame arm. Original capacitor with shorted terminals still frame-mounted. One line lead and one capacitor lead worn through to wire apparently where they touched end of original capacitor. Hole burned in original capacitor case. Original capacitor Sprague 200P1905P6-1S.

915(E) Evaporator blower motor removed from house 915 on 10/23/69. Operating satisfactorily. Shaft full length. Lightly corroded. Sprague capacitor 200P1905P6-1S.

865 Condenser fan motor removed from house 865 on 10/22/69. Shaft cut to 1 1/2 inch. Moderately corroded. Motor operates satisfactorily--was removed because fan had come loose, damaging shaft, and finally jammed between condenser shroud and compressor. Original capacitor in mount GE 72F5057FB electrically operative. Replacement capacitor taped to arm GE 45F521FB electrically operative.

878 Condenser fan motor reportedly removed from house 878 about 6/5/69. Full length shaft. Shaft will not turn. (Note: bearings may have rusted in storage). Electrical measurements indicate no motor winding failure. Rusted shell and shaft. Capacitor GE 72F5057FB internally shorted.

879 Condenser fan motor removed from house 879 on 10/25/69. Running backward at lower than normal speed. Generally rusted. Shaft has been cut. Capacitor GE45F521FB shorted to ground.

880 Condenser fan motor reportedly removed from house 880 about 6/5/69. Not operative--start winding has excessive resistance (3000 ohms compared to normal of 50 ohms). Full length shaft. Leads worn where apparently rubbed against capacitor. Unattached capacitor (marked 880) GE72F5057FB shows wear due to lead wires--electrically operative.

888 Condenser fan motor reportedly removed from house 888 about 6/5/69. Full length shaft. Heavily rusted. Not operative, one capacitor lead burned through and both windings open circuited internally. Internal temperature limit switch not open circuit. Shaft will not turn. (Note: bearings may have rusted in storage). No capacitor.

Figures 19 and 22 show respectively the condenser fan and motor from house 853, and the evaporator blower motor from house 915. All of the motors are identical.

Electrical resistance measurements were made of the windings of the 11 motors described above. Motors numbered 808C, 808E, 853C, 853E, 915C, 915E, 865, and 879, were all operational when removed, and measured similarly. Main winding resistance was about 7.5 ohms, start winding about 50 ohms, and both windings were of high resistance to ground. Motors numbered 878 and 888 had capacitor leads burned through where they had shorted against the capacitor case. Each of these motors was open-circuited internally, possibly caused by the grounding short at the capacitor lead. Motor number 880 was found to have a higher-than-normal start winding resistance, possibly caused by high winding temperature.

Operational tests were made of all motors except those numbered 878, 880 and 888 to determine starting ability and direction of rotation. Motor number 808C started and ran backwards (clockwise facing motor shaft). All others started and ran in the proper direction, including motor number 879, which was removed for running backward. The reversed operation was caused by shorting to ground of the start winding capacitor terminal--the motor operated satisfactorily when a good capacitor was used.

Motors numbered 853C and 915C were further tested operationally to determine effects of reverse windmilling on starting and running characteristics. Figure 33 shows how a pedestal-type fan was used to produce reverse windmilling at various speeds. It should be noted that the test setup did not duplicate the actual case in that no coil or housing of the actual unit was employed. It was intended only to produce reverse rotation rates. Depending on fan bearing drag, wind angle, etc., air speeds from 10 to 19 miles per hour were required to produce 200 rpm reverse windmilling in the test specimens. Motors were tested with good capacitors, shorted capacitors, and open-circuited capacitors. Normal locked rotor currents (shaft not able to turn) were:

Good capacitor	7.8 amperes
Shorted capacitor	10.4 amperes
Open capacitor	8.1 amperes

Running currents, free delivery, were:

Good capacitor	3.5 to 3.7 amperes
Shorted capacitor	7 to 7.5 amperes (Note: runs less than 3 1/2 minutes from a cold start at this condition.)

Starting currents, free delivery, were:

	Amperes		
	Total	Run Winding	Start Winding
Good capacitor	9.5	8.8-9.3	0.7
Shorted capacitor	9.5	8.8-9.3	2.3

Starting time, free delivery, was about 2 seconds with good capacitor.

Starting time in proper direction, with reverse windmilling at time of start was:

Reverse rate, rpm	
190 to 215	Good capacitor $\approx$ 3 sec. Shorted capacitor $\approx$ 2 sec.
215 to 250	Good capacitor - would not start in proper direction--ran in reverse direction Shorted capacitor $\approx$ 2 sec.
285	Good capacitor - would not start in proper direction Shorted capacitor 2-3 sec.

When motor current was applied with reverse rotation at about 215 rpm, with a good capacitor, the motor continued and ran in the reverse direction, with slightly increased current (about 0.2 amperes above normal) but at lower-than-normal speed (about 840 rpm instead of normal speed of about 1075 rpm). At this condition the motor overheated and tripped the internal temperature limit switch in about 30 minutes.

With an open-circuited capacitor the motors did not start by themselves but ran satisfactorily in either direction when started manually. If not started manually, the motors passed locked rotor current through the running winding and tripped the internal temperature limit switch in 3 to 5 minutes.

Fifteen condenser fan motor capacitors and three evaporator blower motor capacitors removed from Kwajalein were examined. All showed corrosion (rusting) of the capacitor case to some degree, ranging from incipient to severe. Six showed abrasion wear from capacitor leads. Ten were electrically operative, including eight in use at the time of the inspection with operating motors numbered 808(C), 808(E), 853(C), 853(E), 865 (2 capacitors), 915(C), and 915(E). Eight defective capacitors, previously removed from service or with inoperative motors at the time of our inspection, had failed as follows: three had shorted to ground only, two had shorted internally and to ground, and three had shorted internally only. Types of capacitors in the sample included GE72F5057FB, GE45F521FB, Sprague 200P1905P6-1S, KKL37P605Q (make unknown--reported to have been original type used with condenser fan motors--not verified), Mallory (no further identification), Vanguard RAC-6-370-OV, and one more completely unidentifiable because of rust.

5.6 Tiled Floor Construction

a. Field Investigation

According to information furnished to the NBS Team all flooring was installed at the point of manufacture and the floors were protected for shipment by covering with polyethylene sheeting. At the time of arrival of the houses at Kwajalein it was reported that some had loose floor tiles. Many of the 64 units received with the third shipment in November 1968 were reported to have had standing water on the floor. Repair on the floors, which had taken place before the visit, reportedly included some replacement of plywood subfloor. In some cases existing tiles were relaid, and in some cases new tiles were laid.

Between October 20 and 24, 1969, floors of 29 houses were closely inspected by the NBS Team. Included in the investigation were 5 houses delivered in July 1968, 2 houses in September 1968 and 22 houses in November 1968. The investigation included inspection of the overall appearance of the floor and plywood subfloor and evaluation of the performance of the adhesive. Evaluation of the identifiable replacement areas was limited to determination that the replacement adhesive was performing adequately. The findings are listed in Table 4 (see page 38).

The general observations were:

Plywood Subfloor - With the exception of houses 897 and 867, the plywood subfloors in the 29 houses were sound and showed no signs of warpage or delamination. It was reported that large sections of warped and delaminated plywood had been replaced at Kwajalein. The records of replacement are available from the Area Engineering Office, Kwajalein.

Tile Adhesive - With the exception of those areas where additional adhesive had been applied at Kwajalein, the tiles could easily be removed from the subfloor. The procedure used was to insert a knife at the edge of the tile and exert a slight prying action. The adhesive was oily and had no tack or body. Its appearance was similar to thin, black oil. The black, oily substance could be transferred to the finger with slight rubbing as shown in figure 34. There was little evidence on the subfloor of notched trowel marks (the tool usually used to apply floor adhesive). The adhesive used appeared to have leached or soaked into the subfloor. On the under side of the tile striation marks could be seen as evidence that adhesive had been applied using the trowelling technique.

Tiles - Except as noted in Table 4 all tiles were flat, showed no sign of shrinkage and were placed tightly against adjacent tiles. The floor tile did not really fail appreciably.

Table 4

House Number	Condition Of: Plywood[1/]	Adhesive[2/]	Tile[3/]	Remarks
897	Delaminated in master bedroom	Poor	Good	
899	Good	"	"	
894	"	"	"	
869	"	"	"	Water droplets noted on adhesive
892	"	"	"	
887	"	"	"	
881	"	"	"	
883	"	Fair	"	
879	"	Poor	"	
873	"	Good	"	
868	"	Poor	"	
865	"	Good	"	
867	Delaminated in master bedroom	Poor	Curled in center bedroom	
861	Good	"	Good	Salt crystals on joints of tiles in Master BR and hall (see figure 35)
864	"	"	Curled in bathroom	(See figures 36 and 37)
863	"	Fair	Good	Evidence of water floodin
857	"	"	"	
859	"	"	"	
811	"	Poor	"	
954	"	"	"	
807	"	"	"	
831	"	"	"	
830	"	"	"	
911	"	"	"	
942	"	"	"	
940	"	Fair	"	
948	"	Good	"	
950	"	"	"	
992	"	Poor	"	

1/ "Good" indicates sound subfloor throughout the unit.

2/ "Poor" indicates tile easily removed.
"Fair" " tile removed with slight effort.
"Good" " tile could not be removed without considerable effort.

3/ "Good" indicates flat tile with tight joints.

b. Laboratory Investigation

Sections of flooring (tile and subfloor) were removed on October 23 from houses 811, 954 and 896 as shown in figure 38 and shipped to the National Bureau of Standards for analysis. Results of this analysis are:

<u>Tile</u> - The tile was 1/8 inch vinyl asbestos meeting the requirements of Federal Specification SS-T-312, Type IV.

<u>Subflooring</u> - Measurements of moisture content were made of the subflooring from units 811, 954 and 896, and their moisture content levels were 16.9, 14.3 and 17.9% respectively. These units were also respective parts of the first, second and third shipments.

<u>Adhesive</u> - Infrared spectrophotometer analysis of adhesive removed from the plywood subfloor on each cut-out indicated the adhesive was a water emulsion asphalt type.

For comparison, a commercially-available adhesive meeting Federal Specification MMM-A-115a, Adhesive, Asphalt, Water Emulsion Type (For Asphalt and Vinyl Asbestos Tile) was obtained. This adhesive was spread on plywood and vinyl asbestos tiles laid in normal fashion. After conditions listed below, the tiles could not be removed without damaging them.

Test #1 - made 3 hours after setting of tile
Test #2 - made after 48 hours at 90% RH and 100°F
Test #3 - made after 5 days in water at 73°F

5.7 Corrosion of Exterior Main Electrical Service Risers

a. Field Investigation

The investigation was limited to the exterior 1 1/2 inch conduits between the connection at ground level and the connection at the main electrical service box fastened to exterior rear side of each house. The conduit served as a raceway for the electric wiring into each house. It was stated that the risers were shipped to Kwajalein within each house and installed to the side of the house after placement at location.

Between October 20 and 24, 1969, 45 risers were visually examined at Kwajalein. This includes risers on houses located along the east shore line of the Pacific Ocean, the north shore line of North Bay, the west shore line of the Kwajalein Lagoon as well as on houses located more centrally in the housing areas. See figure 1 for general layout of housing area (North tip). Some risers were within 80 feet of the shore line.

Because of the different angle and directional orientation of the houses, the risers were in three general positions in relation to the east-northeast prevailing winds; direct, indirect, or protected (by other structures).

Nearly all risers showed signs of corrosion. The corrosion was most severe on the leading edge toward the prevailing wind. Figure 39 illustrates the effect of corrosion on the windward side of the riser on house 883. The distance from the Pacific Ocean shore line, the relation to the prevailing winds, the time of exposure and the degree of corrosion of the 45 risers observed, are listed in Table 5.

Table 5

Corrosion of Exterior Main Electrical Service Risers

House Number	Approx. Distance From Pacific Ocean Shore Line (feet)	Approx. Relation to Prevailing Wind [1/]	Exposure Time (months) [2/]	Observed Corrosion [3/]
897	230	Direct	11	B
899	150	"	11	B
894	230	"	11	B
896	150	"	11	B
893	220	"	11	B
895	140	"	11	B
883	130	"	11	A
880	130	Indirect	11	B
879	120	"	11	A
873	200	Direct	11	B
876	130	Indirect	11	B
875	120	Direct	11	A
870	200	Indirect	11	B
869	200	Direct	11	A
871	120	"	11	A
872	130	Indirect	11	B
866	220	"	11	B
865	200	Direct	11	A
868	130	Indirect	11	B
867	120	Direct	11	A
862	190	Indirect	11	B
861	180	Direct	11	A
864	100	Indirect	11	B
863	90	Direct	11	A
858	190	Indirect	11	B
857	200	"	11	B
860	70	"	11	B
859	70	Direct	11	A
910	350	Indirect	11	B
940	330	"	11	B
948	330	"	11	B
950	440	"	11	C
855	170	"	13	B
853	300	"	13	B
911	350	"	13	C
941	330	"	13	C
949	330	"	13	D
951	440	"	13	C
807	900	"	15	B
808	900	"	15	C
831	1000	"	15	C
832	1000	"	15	D
829	890	"	15	C
830	890	"	15	D
992	1125	Protected	15	E

1/ Prevailing winds from ENE

2/ Based on time the trailer-type house was placed at its location in Kwajalein.

3/ A - brown iron oxide with heavy scaling; B - brown iron oxide with light scaling; C - slight brown iron oxide with white zinc oxide; D - white zinc oxide; E - no visual sign of corrosion.

With the exception of two risers, no maintenance or replacement at time of investigation was reported by the Area Engineering Office at Kwajalein. One riser had been coated with an aluminum paint and one riser had been replaced with a PVC conduit.

b. Laboratory Investigation

Three risers removed from houses 863, 864 and 992 on October 24, 1969, were shipped to the National Bureau of Standards for analysis. The risers selected represented three degrees of corrosion found at the time of visit and are listed in Table 6. The three risers as marked for shipment are shown in figure 40. The laboratory results are listed in Table 7.

Table 6

House Number	Degree of Corrosion
863	Brown iron oxide with heavy scaling (A)
864	Brown iron oxide with light scaling (B)
992	No visual signs of corrosion (E)

Based on analysis of these samples, the risers were steel with an exterior zinc coating and an interior coating of enamel meeting requirements of Federal Specification WW-C-563, Conduit, Metal, Rigid and Bend and Elbow, Electrical Conduit: Thin-Wall Type (EMT) and American Standard Association, Inc. Standard (now American National Standard Institute, Inc.) C80.3 - Standard for Electrical Metallic Tubing except that the wall thickness was slightly below the .065 inch required. The analysis of wall thickness, zinc coating and extent of corrosion is listed in Table 7.

Table 7

	House Number		
	863	864	992
Length of riser, nominal, feet	4	4	4
Inside diameter, nominal, inch	1-1/2	1-1/2	1-1/2
Wall thickness, inch	0.059	0.059	0.059
Zinc coating thickness, inches	0.0009	0.0009	0.0009
Loss of thickness, average inches 1/	0.005	-	0.000
Pit depth, maximum, inches 2/	0.007	-	0.000
Scale thickness, maximum, inches	0.090	-	0.000

1/ Along leading edge, facing prevailing wind

2/ Below corroded surface

5.8 Exterior Door Hardware

a. Field Investigation

During the field investigation none of the houses examined had a serious problem with respect to inoperative lock sets. Each of the houses had to be unlocked before examination and in no case was there difficulty in unlocking the doors. In a couple of cases the doors were hard to close because door warpage had caused a misalignment of the latch and keeper.

b. Laboratory Investigation

Two sample doors were sent to NBS for additional laboratory tests and each contained lock sets. One of the samples, from house 911, had a replacement lock set according to Global Associates maintenance records and the other from house 894, was assumed to be an original lock set since no replacement was indicated in the available maintenance records. The lock set from house 894 had some rust marks downward from the key hole. This lock set was dismantled at NBS and found to have a rusted cylinder assembly. The rust streak appeared to have come from the housing around the cylinder and from a linkage member attached to the rear of the cylinder. The rust deposit could be carried by rain water through the cylinder and in time retard the tumbler action. Figure 41 is a view of the cylinder and housing assembly.

6. Conclusions

Within the scope of the field and limited laboratory investigation of the Northland Camps, Inc., trailer-type houses at Kwajalein, several deficiencies were noted. They are listed in the following summary, grouped in the same order of topics as used to present the field and laboratory investigation results in the previous section of this report.

6.1 Warpage of Exterior Doors

The bonding of the aluminum skin to the exterior face of the door provided an asymmetric composition from interior to exterior. For the application at Kwajalein this is considered to be a design deficiency. The aluminum skin as applied to the door composite restrained the natural response (expansion) that occurred in the humid environment, thus producing warpage with one side restrained and the other unrestrained. The warpage of the exterior doors could have been lessened if 1) the composition of the door had been symmetric, i.e., if the aluminum skin had been applied and bonded equally to both sides or 2) had the existing aluminum skin been attached mechanically with provision for relative movement. In either case, symmetric construction or mechanical attachment, edge protection from rain and weathering should have been provided. Failure to provide such weather protection is considered to be a design deficiency.

6.2 Water Leakage of Exterior Doors

For the type of weather stripping supplied, the edges of the door and jamb were not adequately protected from water penetration and positive drainage to the exterior was not provided for water which could enter the joints. The type weather stripping provided was inadequate and is considered to be a design deficiency. Failure to caulk the end joints between the threshold plate and the door jamb and failure to caulk under the threshold plate were considered to be installation deficiencies. Weather stripping and its proper placement could have been provided to protect the joint between the door and jamb from wind-driven rain.

6.3 Water Leakage of Windows

Although there was considerable leakage around the windows reported by the Kwajalein personnel, there was little evidence of leakage during the NBS field investigation. No design deficiency was noted with regard to the window assembly. The majority of the windows had been caulked along the two vertical joints and across the top. The joints seemed for the most part to be adequately caulked at the time of the investigation but it was reported by Kwajalein personnel that the caulking was applied after arrival at Kwajalein and the leakage problem had developed. This indicates an installation deficiency. Irregular spacing of the screws attaching the window frame to the siding was an installation deficiency, as was failure to properly prepare the surfaces to provide good bonding of the butyl tape between the window frame and the siding. Failure to caulk or otherwise seal the joint of the vertical seam in the aluminum siding at the top of the window frame was also an installation deficiency.

The weep holes in the bottom tracks could contribute to leakage under very severe conditions of wind driven rain but under most circumstances should perform satisfactorily.

6.4 Air Conditioner Cabinet Water Leakage

1. Use of exposed vertical simple flange joints between the air conditioner cabinet and its companion plenum was poor design for a roof top installation exposed to wind driven rain.
2. Vertical joints in access panels of both the air conditioner and plenum cabinets were of poor design in that they drained into the air duct portions of the interior of the cabinets, unless caulked or otherwise sealed each time each panel was removed and replaced for service operations.
3. As designed and furnished, the air conditioner and plenum cabinets required field caulking to prevent rain water entry into the air duct parts of these cabinets. Considering this, failure of the supplier to make specific provisions for a means of sealing the joints mentioned in 1 and 2 above and the top joint between the two cabinets at the time of installation, would be an installation deficiency.

6.5 Air Conditioner Condenser Fan Motors

a. The condenser fan motors lacked acceptable reliability for the application as evidenced by the high number requiring replacement (64 from December 1968 to October 1969). In contrast, the same type motors and capacitors used to power the evaporator blowers required only 3 replacements during the same period. While corrosion of the condenser fan motors was evident, this did not appear to be the major factor with regard to motor failure. The field and laboratory investigations indicated that electrical failure of the motors was caused principally by operation at excessive temperature resulting from deficiencies noted in following items b and c.

b. Use of a propeller-type condenser fan for roof mounting with air discharging horizontally out of a vertical faced coil was a poor selection for this environment because predictable wind loads caused reverse windmilling of the condenser fan, and excessive motor loads. Excess starting loads and excess operating loads produced overloading of motors and capacitors. Other available fan arrangements such as vertical discharge or use of a centrifugal blower (as required in Military Specification MIL-A-21261) would have minimized or eliminated the wind problem.

c. The capacitors selected for use with the condenser fan motors were not sufficiently corrosion resistant for the environment and lacked electrical reliability as applied. The large number requiring replacement (163 from December 1968 through September, 1969) is evidence of inadequate reliability. As shown by our investigation the capacitors failed primarily by shorting either internally, or to ground, or both. In any of these cases, the motor is subjected to overheating to the point of cycling on its internal temperature limit switch until turned off manually, repaired, or shut down by other control mechanisms in the system.

d. As originally installed the capacitor leads (and line leads, in some cases) rubbed against the capacitor case with resultant abrasion and penetration of the capacitor case and electrical shorting of the leads to the case.

e. Condenser motor shafts and fan hubs were not sufficiently corrosion resistent to facilitate the necessary replacement of motors or fans. Use of stainless steel is common practice in intermodal refrigeration systems which may see service in atmospheres such as at Kwajalein.

Deficiencies in the air conditioners not directly related to condenser fan motors, but noted during inspection of the fan motor problem, include:

f. Insufficient corrosion protection for the compressor casings.

g. Use of screws having poor corrosion resistance in unit access panels.

h. Inadequate bonding of the insulation on the underside of the top surface of the air conditioning unit and plenum.

6.6 Tiled Floor Construction

The adhesive used did not perform satisfactorily, and this is considered to be a material deficiency. Opinions expressed by recognized manufacturers of floor tile and adhesives indicate that adhesive systems and techniques are commercially available and commonly used which would have adequately adhered the 1/8 inch thick vinyl asbestos tile to the treated plywood deck of the trailer-type houses provided under this contract.

6.7 Corrosion of Exterior Main Electrical Service Risers

According to K. S. Frazier, Technical Director of the American Hot Dip Galvanizers Association, Inc., in his portion of a monograph on zinc[3/], zinc protective coatings of 0.8 mil (0.0008 inch) gives a service life of 10 years under a tropical marine environment. This estimate, in the form of a service chart, is distributed by the American Hot Dip Galvanizers' Association and the American Zinc Institute.

The specifications under which the trailer-type houses were built permitted the use of electric service risers having a minimum thickness of zinc coating of 0.8 mil (0.0008 inch).

Despite these considerations, the galvanized electrical service risers, installed in Kwajalein Atoll, with an average zinc coating thickness of 0.9 mil, exhibited considerable corrosion after about one year's exposure, when subjected either directly or indirectly to the coastal wind in that climate. It is concluded that the Kwajalein coastal climate is not a good application for galvanized steel conduit of the type used, and that the climate conditions on Kwajalein are more severe from a corrosion viewpoint, then were contemplated in the monograph of the American Hot Dip Galvanizers Association.

Other materials more suitable for this environment were available.

6.8 Exterior Door Hardware

For the severity of corrosion experienced at Kwajalein, the internal parts of the lock sets, which were found to be corroded, are considered material deficiencies.

7. References

1. Importance of Balanced Construction in Plastic-Faced Wood Panels, B. G. Heebink, FPL-021, 1963, Forest Products Laboratory, Forest Service, U. S. Department of Agriculture.
2. Reaction of Unbalanced Panel Construction to Slow and Rapid Changes in Relative Humidity, B. G. Heebink, FPL-0116, 1966, Forest Products Laboratory, Forest Service, U. S. Department of Agriculture.
3. Zinc--The Science and Technology of the Metal, Its Alloys and Compounds, edited by C. H. Mathewson, ACS Monograph #142, Reinhold Publishing Corporation, New York, 1959.

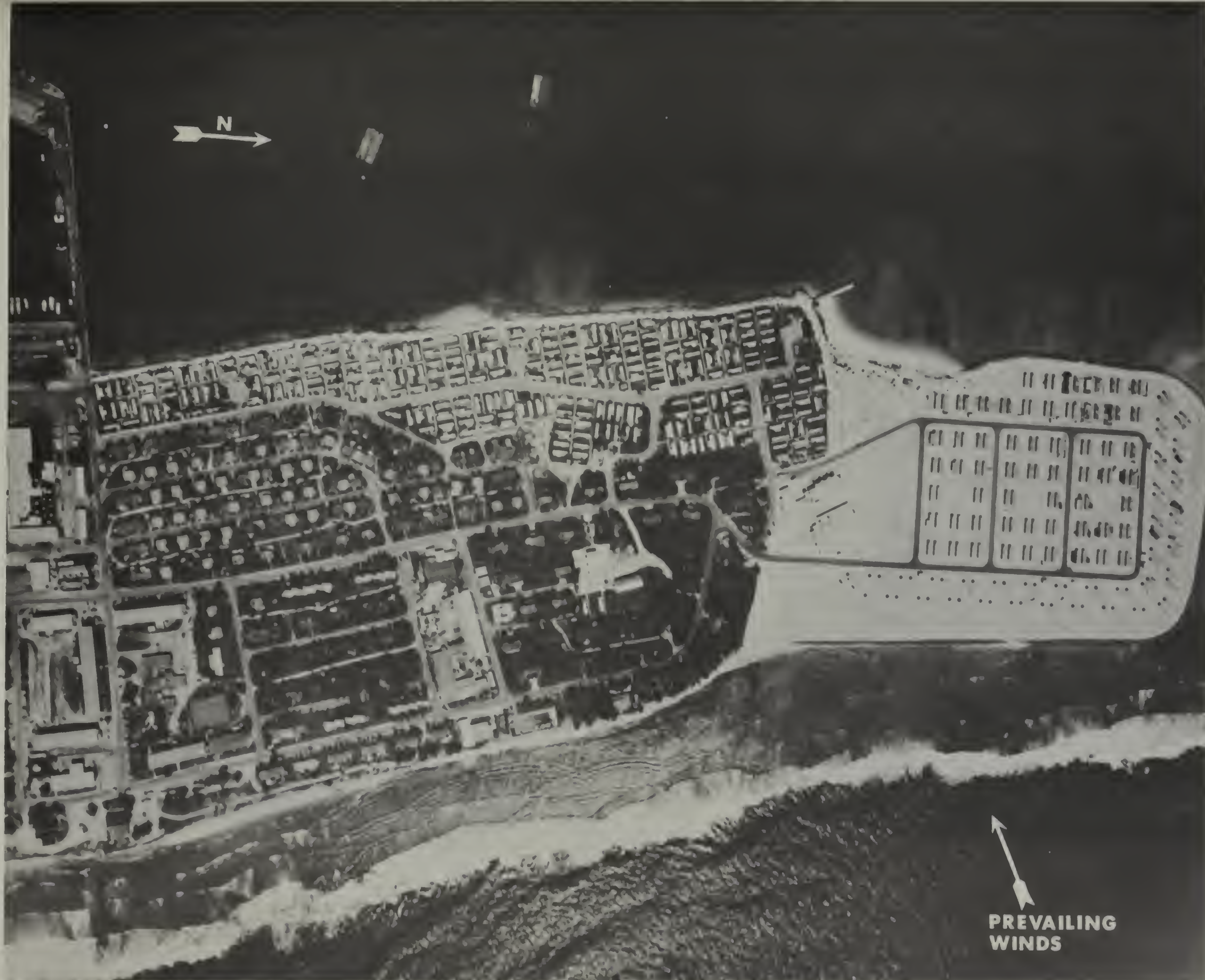

Figure 1. Location of trailer-type houses at the north tip of the Kwajalein Atoll. The prevailing winds are approximately ENE.

Figure 2. Exterior of typical housing unit.

Figure 3 . Placement of units in the housing area.

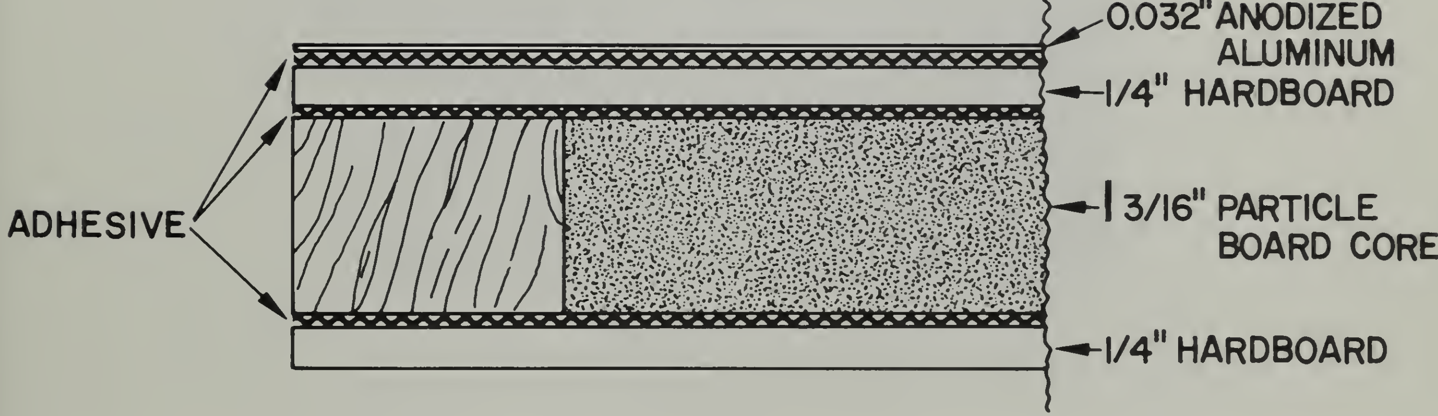

Figure 4 . Composition of exterior door.

Figure 5 . Exterior door taken as sample. Note weatherstripping added after installation at door perimeter.

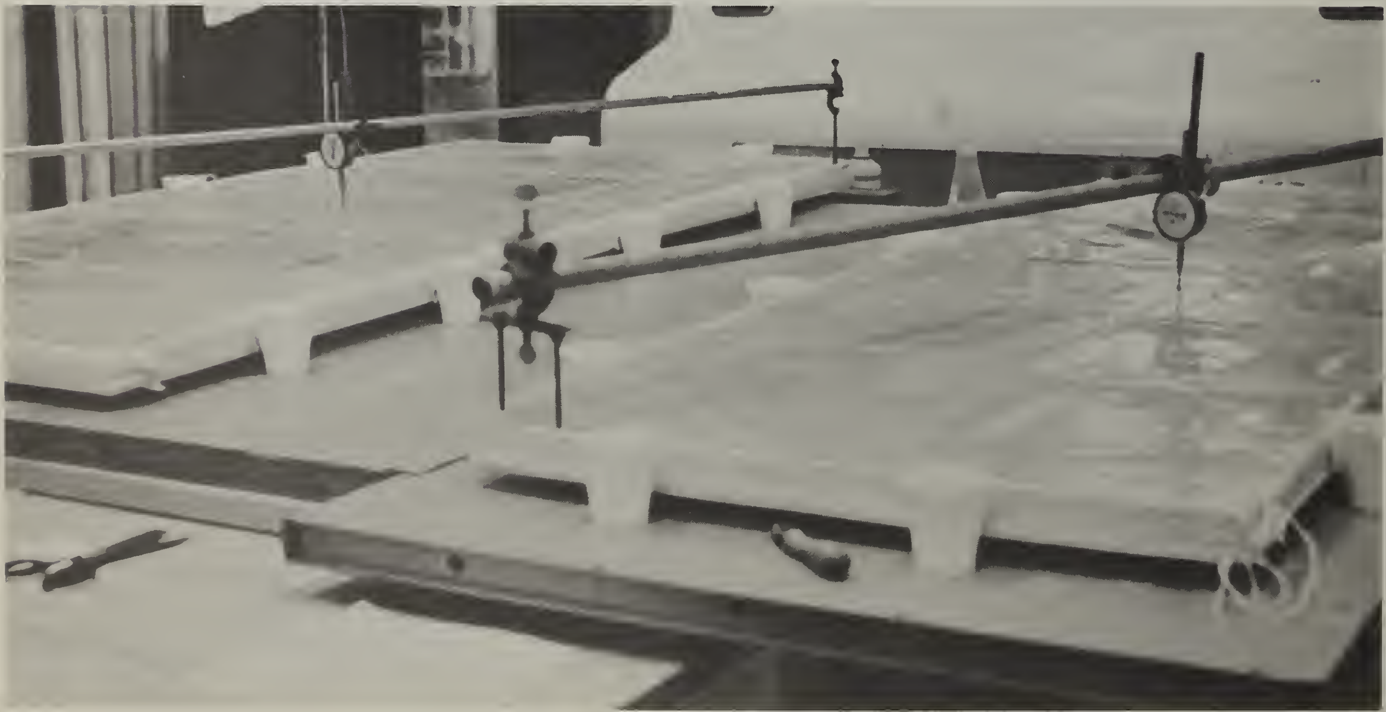

Figure 6 . Laboratory tests for warpage of doors.

Figure 7. Weatherstripping on the hinged side of the door jamb showing the placement of the weatherstripping at midwidth of the threshold.

Figure 8. Components of the threshold assembly.

Figure 9. Cracks in the caulking above the window frame.

Figure 10. Window assembly pulled away from the opening.

Figure 11. View of the window assembly and gasket material from inside the housing unit.

Figure 12. Exterior view of the roof mounted plenum and air conditioner cabinets.

Figure 13. Joint cover and caulking of the top joints between the air conditioner and plenum cabinets.

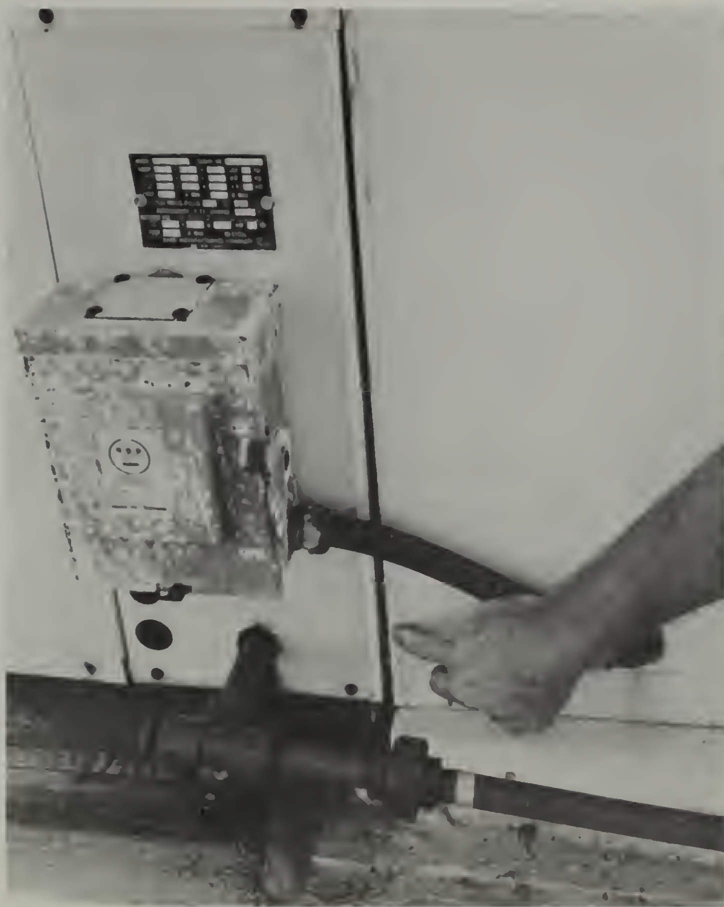

Figure 14. Vertical joint between plenum and air conditioner cabinets showing joint width.

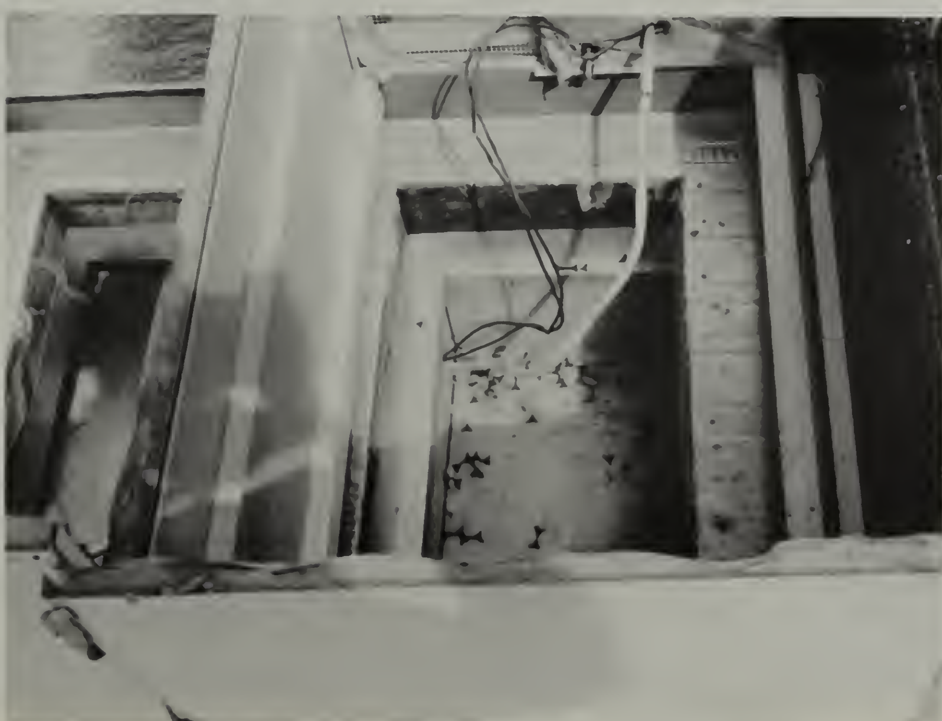

Figure 15 . The supply and return openings and assembly of the plenum cabinet.

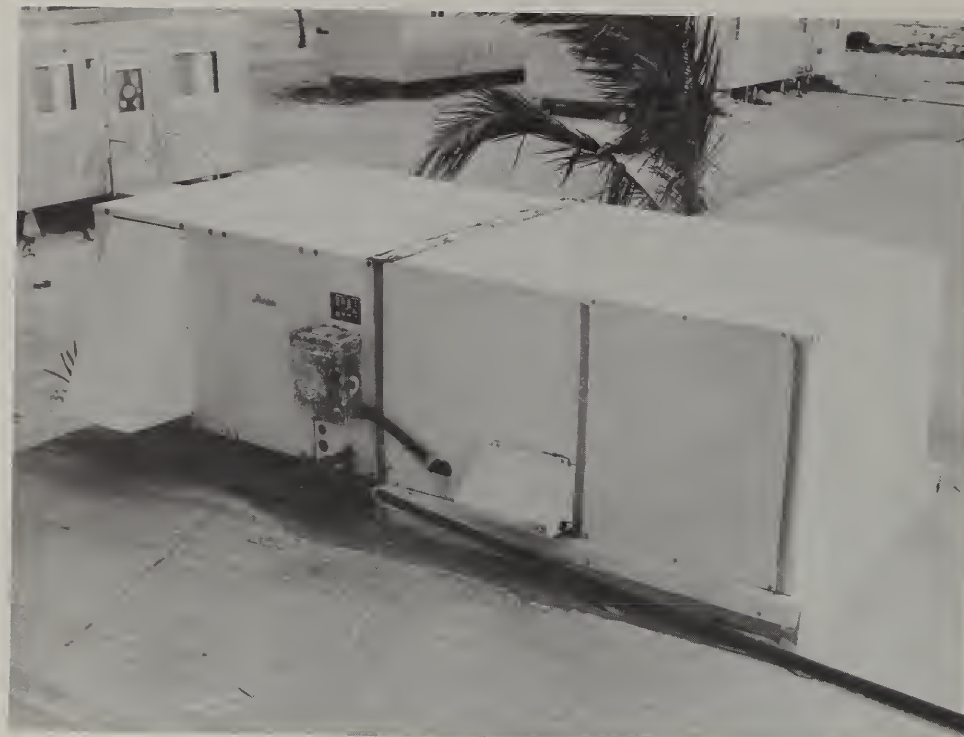

Figure 16. Typical air conditioner installation, right side.

Figure 17. Typical air conditioner installation, left side.

Figure 18. Interior of air conditioning unit showing left to right - return air opening, evaporator coil, evaporator blower and portions of the compressor and condenser fan.

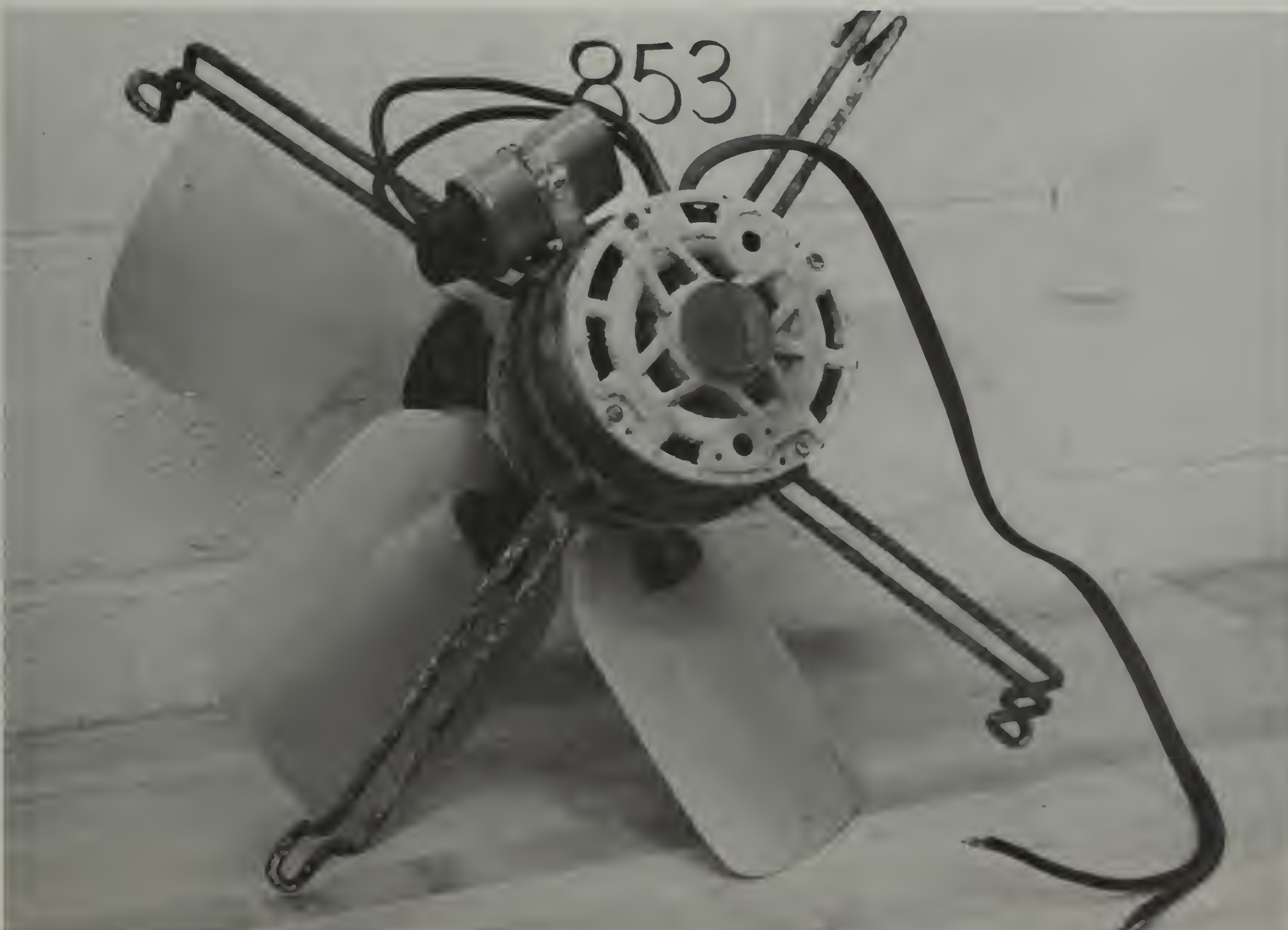

Figure 19. Condenser fan, motor, capacitor, and mounting frame, removed from house number 853.

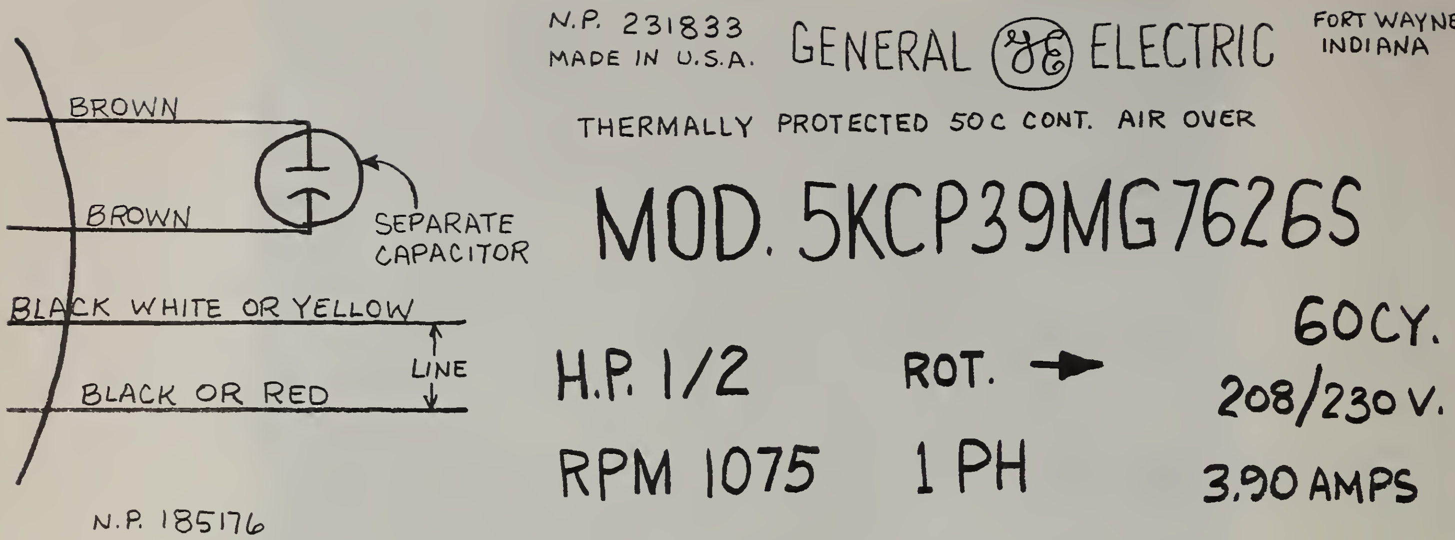

Figure 20. Facsimile of nameplate of condenser fan and evaporator blower motors from Bard P36A air conditioners.

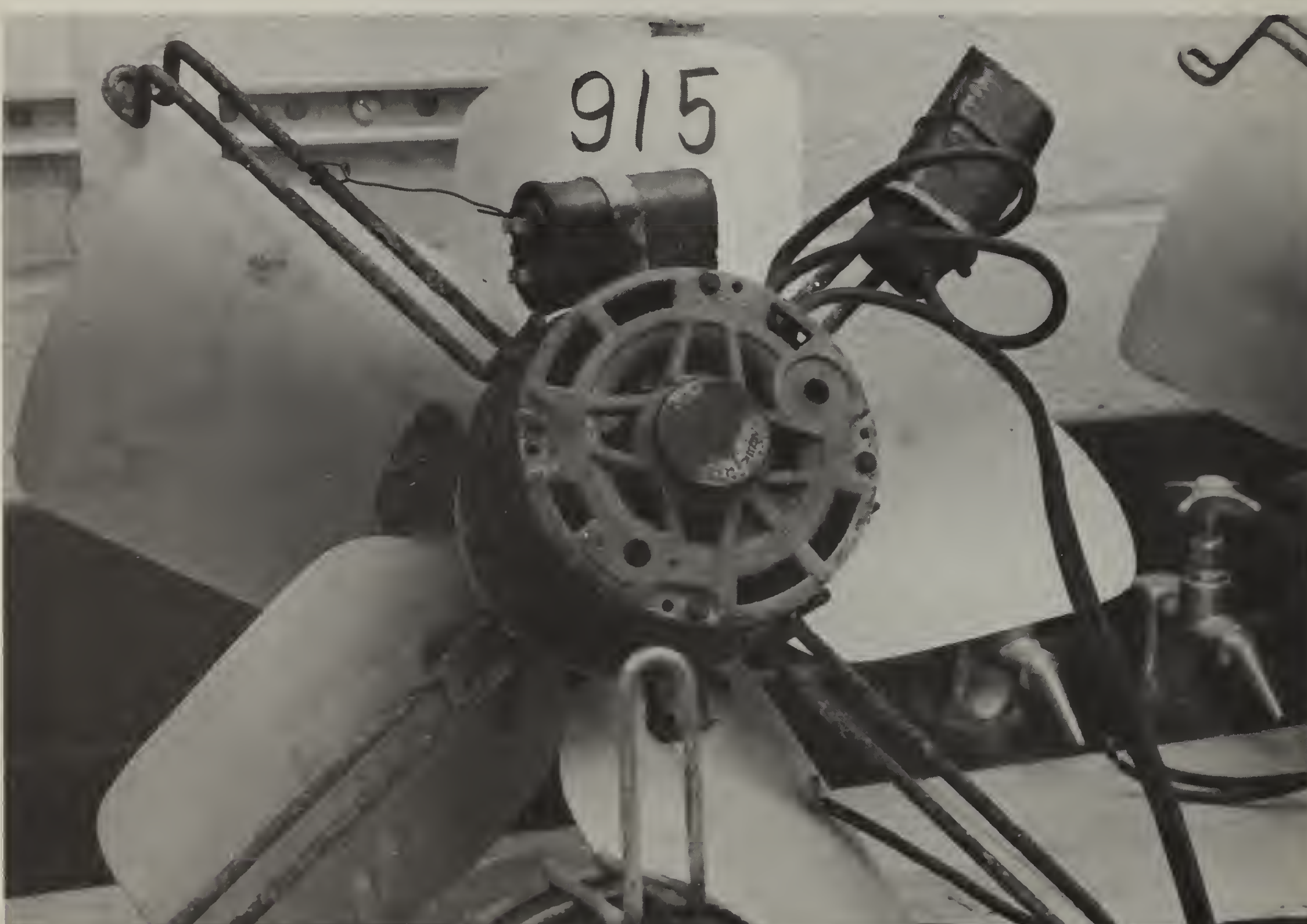

Figure 21. Condenser fan and motor removed from house number 915. Note motor bearing end cap on which model number was stamped and placement of original (left) and replacement capacitors.

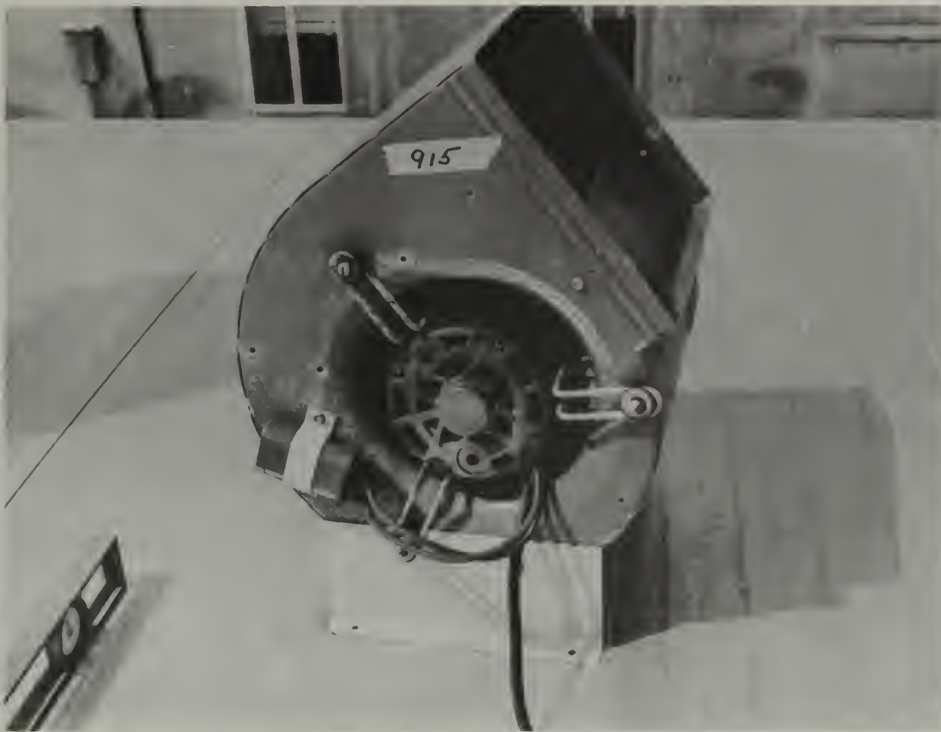

Figure 22. Evaporator blower and motor assembly from house 915.

Figure 23. Condenser fan motor showing original length of shaft.

Figure 24. Modification of the air conditioner unit by the addition of wind shields for the condenser fan section.

Figure 25. Replacement air conditioning unit on house 892 showing a blower type condenser assembly.

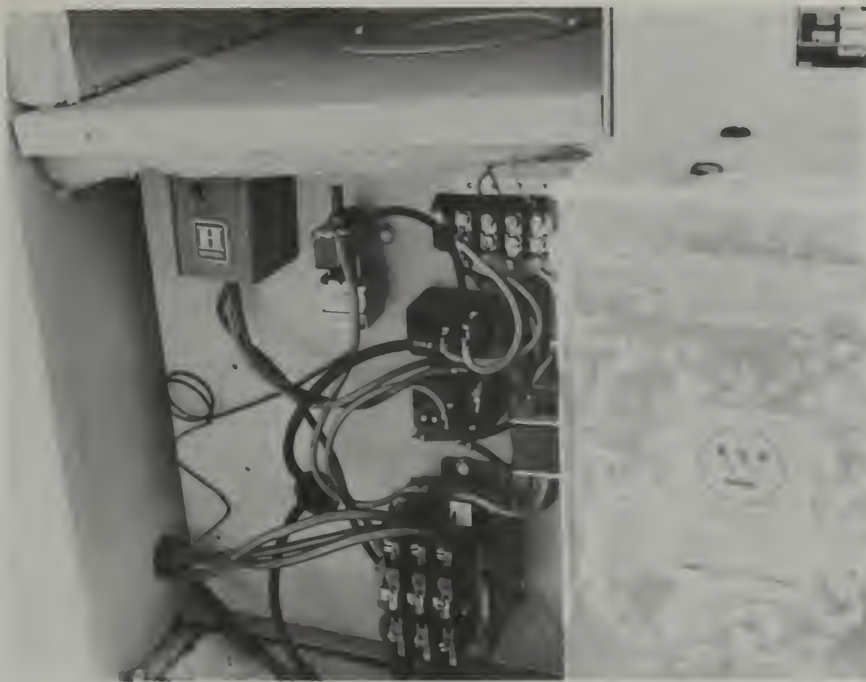

Figure 26. Air conditioner control panel showing shunted pressure switch at top center on house 883.

Figure 27. Air conditioner condenser fan motor showing capacitor lead wires resting against tne case of the capacitor. Arc pits shown at the end where the case and wires have shorted.

Figure 28. Factory installed filter in return air section of plenum in house 808.

Figure 29. Detachment of insulation in supply duct of plenum on house 899.

Figure 30. Detachment of insulation in supply duct of plenum on house 808.

Figure 31. Photograph showing the unit portion of the supply plenum. Note that insulation is missing.

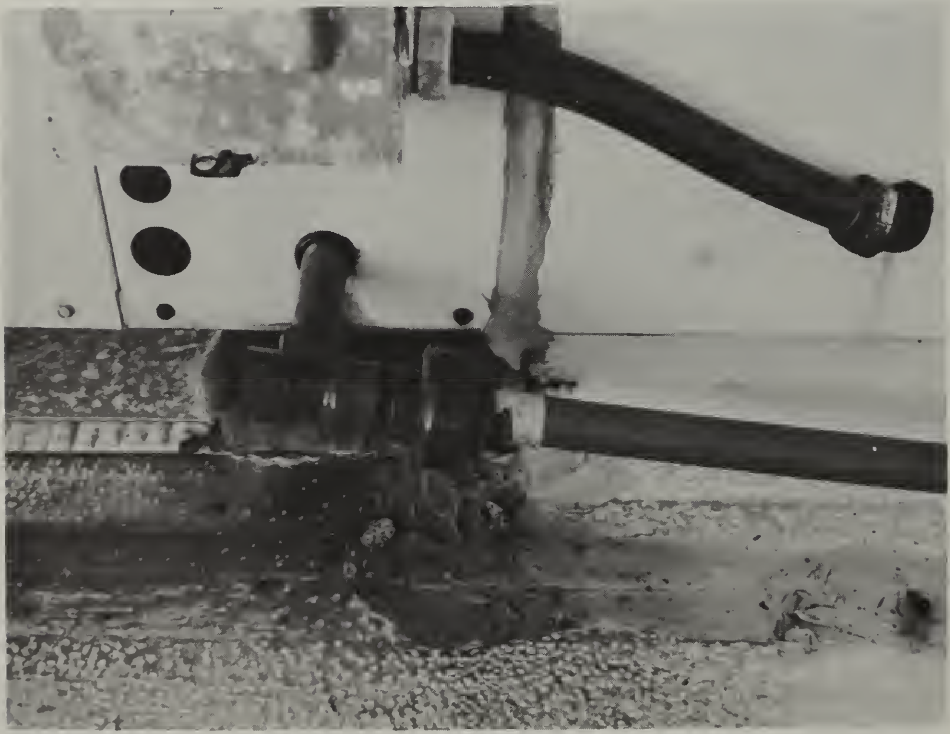

Figure 32. Condensate drain line leading from the condensate pan to ground level.

Figure 33. Laboratory setup for measuring effect of reverse windmilling on starting and running capability of condenser fan motor.

Figure 34. Typical oily characteristic of floor tile adhesive, which was easily transferred to finger with slight rubbing.

Figure 35. Mineral deposits at the tile joints in the master bedroom of house 861.

Figure 36. Buckling of the tile in the bathroom of house 864.

Figure 37. Water beneath the tile near the tile joints in the bathroom of house 864.

Figure 38. Floor sample removed from bathroom of house 811.

Figure 39. Corrosion on windward side of the main electrical service riser.

Figure 40. Comparative conditions of three sample service risers examined at NBS.

Figure 41. Lock-set cylinder assembly showing rusted components.

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