



# RESEARCH MEMORANDUM

MEASUREMENT OF DISTORTION IN SECOND EXPERIMENTAL CONTROL  
 ROD WITH TEMPERATURE PATTERNS SIMULATING SHIM ROD OUT  
 AND SHIM ROD 50 PERCENT INSERTED FOR ARGONNE

NAVAL REACTOR

By *A. F. Lietzke* and *T. F. Nagey*

Lewis Flight Propulsion Laboratory  
 Cleveland, Ohio

FOR REFERENCE

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NATIONAL ADVISORY COMMITTEE  
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 WASHINGTON

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## NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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MEASUREMENT OF DISTORTION IN SECOND EXPERIMENTAL CONTROL ROD

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## SUMMARY

Thermal distortion tests were made on a stainless-steel clad, cadmium-silver control rod furnished by the Argonne National Laboratory. Two temperature patterns supplied by the Argonne National Laboratory were simulated in these tests; one represented the shim-rod-out condition and the other the shim-rod-50-percent-inserted condition.

The greatest reduction in clearance affected by thermal distortion was 0.076 inch. No permanent set of the control rod was observed after repeated heating and cooling cycles.

## INTRODUCTION

Thermal distortion tests were made at the NACA Lewis laboratory on a stainless-steel clad, cadmium-silver core xenon control rod furnished by the Argonne National Laboratory. Distortion measurements on the first experimental control rod with temperatures intended to simulate 50-percent shim-rod insertion are presented in reference 1. Thermal-distortion measurements on a later model xenon rod with temperature patterns simulating operation with shim rods 50 percent inserted and with shim rods out are presented herein. The temperature patterns used as a basis for the tests were obtained from the Argonne laboratory.

## EQUIPMENT

Control rod. - The control rod core was made of an alloy of 75-percent silver and 25 percent cadmium and was clad with stainless steel. A cross section of the rod was in the shape of a cross having a span of 4 inches. The core alloy thickness was 1/8 inch with a cladding thickness

of  $3/64$  inch, resulting in a total arm thickness of  $7/32$  inch. The rod had an over-all length of 53.75 inches. The cladding joints for the tips of the arms and ends of the rod were welded. After fabricating, the rod was hot-rolled in order to form a bond between the core alloy and the stainless steel. The rod was stress relieved.

Several weld failures were found on the rod as received from the Argonne laboratory. Figure 1 shows the most severe failure found. The failures occurred at the welded juncture of the cladding at the tip of the cross at several locations along the length of the rod.

Method of supporting control rod. - The rod was supported essentially as in reference 1. The vise which holds the control rod, however, was bolted indirectly to the mounting plate through insulating material to reduce the heat flow to the mounting plate. Strain gages were located near the fixed end of the rod to insure freedom from stress during the clamping of the rod in the mounting vise.

Method of obtaining temperature distribution. - The control rod was heated by a 75 KVA induction heater. Axial temperature distributions were obtained by varying the axial spacing of the heater coil turns. Transverse temperature gradients were obtained by making the heating coil and the rod nonconcentric and by a series of air jets mounted along the rod and directed toward the center of the cross. The air jets were provided by 0.0135-inch diameter holes located  $3/8$  inch apart, and were controllable in groups of 14 by a valve.

Temperature patterns were measured by means of 104 thermocouples distributed between 8 stations located along the axis of the rod as indicated in tables I(a) and II(a) and (b). In addition, thermocouples were located at stations  $20\frac{1}{2}$ , 21,  $21\frac{1}{2}$ ,  $22\frac{1}{2}$ , 23, and  $23\frac{1}{2}$  inches from the free end of the rod (these positions are adjacent to specific coils of the induction heater) to note any local hot spots due to the proximity of the induction coils. No hot spots at these locations were indicated and the temperatures at these special locations are not reported.

Tables I(a) and II(a) and (b) list the required temperatures at each station as requested by the Argonne laboratory and the measured temperatures in the several runs.

Method of measuring distortion. - Distortion on the rod was measured as in reference 1 by means of dial indicators. Normally two indicators were located at each tip of the cross in positions along the length of rod as given in tables I(b) and II(c) and (d). The indicators were mounted on four vertical supports fastened to the same mounting plate as the control rod (see fig. 2). These supports were protected from conduction and radiation to eliminate thermal distortion in the supports themselves.

Dial indicators were also supplied to indicate any motion of these supports. Fused quartz rods, 12 inches in length, were used to transmit the motion of the control rod to the dial indicators. The use of fused quartz eliminated the need for a correction for thermal expansion of the indicator rods. The reproducibility of the indicator readings was within  $\pm 0.002$  inch. A vibrator was attached to the mounting plate and was operated before each set of readings was taken to reduce the effect of static friction of the gages.

## RESULTS AND DISCUSSION

Summary of data. - The desired temperature patterns for the tests reported herein were obtained from the Argonne laboratory. Distortion measurements were made with two different temperature patterns; one pattern was intended to simulate operation with the shim rods inserted 50 percent, and one pattern was with the shim rods out. The location of the thermocouples and the corresponding surface temperatures are listed in tables I and II, along with the corresponding distortion measurements. For each thermocouple location, the temperatures desired by the Argonne laboratory and the temperatures experimentally obtained in the present tests are listed. The distance of the thermocouple station from the free end of the rod is represented by  $Z$ . The thermocouple locations at each value of  $Z$  are designated by numbers from 1 to 16. As indicated in the tables, 16 thermocouples were not installed at each value of  $Z$  listed.

The displacement of the tips of the cross are indicated in tables I and II by the values of  $\Delta x$  and  $\Delta y$  with their proper signs. These values are given with reference to the unheated position of the control rod. The distortion measurements are those corresponding to the temperatures obtained in the tests, which differed slightly from the temperatures desired by the Argonne laboratory.

Distortion of control rod. - The motion of tips 1 and 9 in the  $y$ -direction and of tips 5 and 13 in the  $x$ -direction are plotted in figures 3 and 4. It would be expected that the sign of the  $y$  displacement would always be the same (negative in this case) at the free end, inasmuch as the desired temperatures at location 1 are equal to or higher than those at location 9 in both desired temperature patterns. Figure 3, however, shows  $\Delta y$  to be positive at the free end. Examination of the temperature patterns obtained in table I(a) indicates that near the fixed end of the control rod the temperatures obtained at location 1 were lower than those at location 9 which accounts for the change in direction of displacement. Figure 4 shows  $\Delta y$  to be negative at the free end and inspection of the data in table II(a) indicate that the test temperatures and the desired temperatures agree more closely than in table I. Figure 4(c) and (d) represent the distortion for a slightly different

temperature pattern than those in figures 4(a) and (b), the difference being that the fixed end temperatures more nearly matched the required values. The distortions as measured in either case are, however, nearly the same.

The maximum reduction in clearance cannot be determined from figures 3 and 4 alone, inasmuch as the motion of each point in one direction only is shown and hence reference must be made to the tables. It can be seen from the distortion data given in tables I and II that the values for reduction in clearance given in figures 3 and 4, are within 0.002 inch from the maximum. The greatest reduction in clearance obtained in the tests was 0.076 inch as indicated by the data in the tables.

#### SUMMARY OF RESULTS

The results of tests on a stainless-steel clad, silver-cadmium control rod under the influence of two temperature patterns which simulated the shim-rod-out condition and the shim-rod-50-percent-inserted condition can be summarized as follows:

1. The greatest reduction in clearance obtained in the tests was 0.076 inch.
2. No permanent set of the control rod was observed after repeated heating and cooling cycles.

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National Advisory Committee for Aeronautics,  
Cleveland, Ohio,

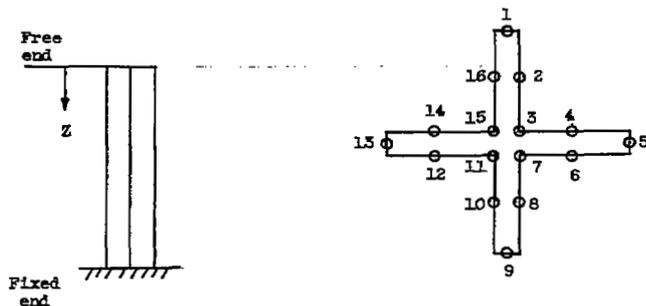
#### REFERENCES

1. Nagey, T. F., and Lietzke, A. F.: Measurement of Distortion in First Experimental Control Rod for Argonne Naval Reactor. NACA RM E51A30, 1951.

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TABLE I - SIMULATED SHIM RODS INSERTED 50 PERCENT.

(a) Temperatures.

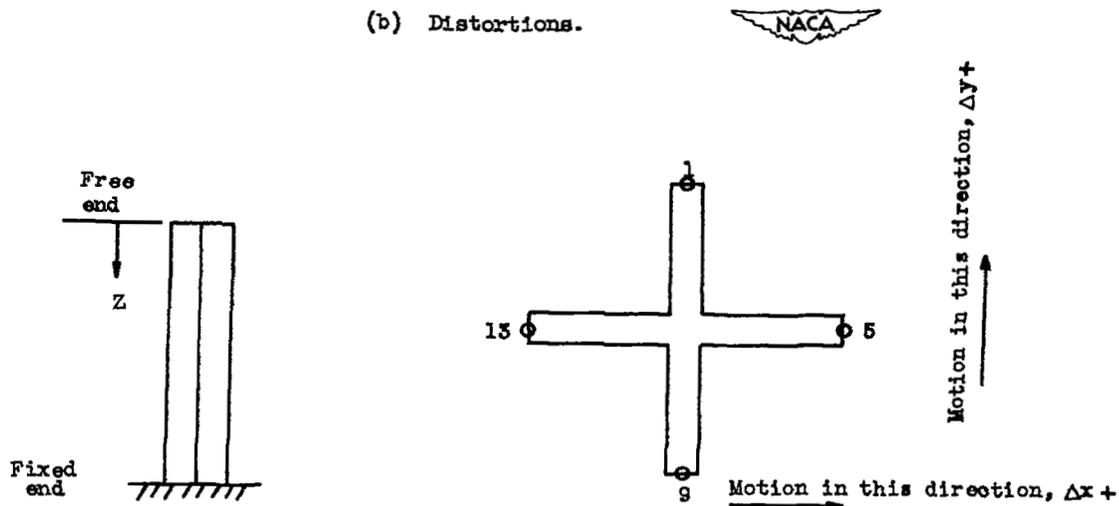


Z (in.)	Run	Thermocouple location															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	(a)	476	466	455	463	471	463	455	459	467	459	455	463	471	463	455	466
	1	479	484	484	484	480	480	484	483	479	481	482	476	476	458	485	484
8	(a)	525	500	476	492	513	492	476	484	502	484	476	492	513	492	476	500
	1	529				513	509	479	494	504				514	511	482	521
15	(a)	509	490	471	484	500	484	471	478	492	478	471	484	500	484	471	490
	1	490	487	470	492	497	494	478	495	504	491	470	478	479	479	461	487
22	(a)	458	455	452	454	456	454	452	453	455	453	452	454	456	454	452	455
	1	452				449	448	447	454	451	451			441	443	443	444
29	(a)	455	453	451	452	454	452	451	452	453	452	451	452	454	452	451	453
	1	441	446	452	451	449	449	453	455	451	453	455	447	444	445	448	441
36	(a)	453	451	450	451	452	451	450	450	451	450	450	451	452	451	450	451
	1	452				458	461	468	476	473	473	478	464	459	464	467	461
43	(a)	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448
	1	461	470	476	473	467	469	476	491	478	482	482	471	465	467	476	469
50	(a)	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448
	1	439				436	454	482	490	479	479	479	448	448	465	482	462
50	(a)	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448
	2	425				430	440	473	481	465				435	456	474	451

\*Requested by Argonne National Laboratory.

TABLE I - SIMULATED SHIM RODS INSERTED 50 PERCENT. Concluded.

(b) Distortions.

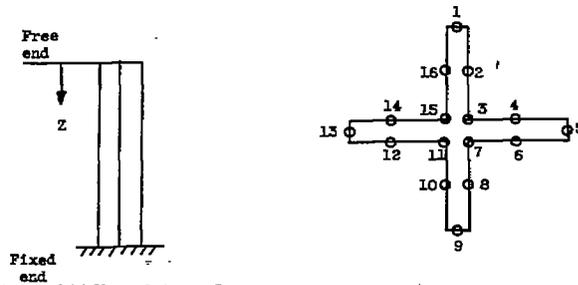


Z (in)	Run	Displacement (in)	Gage location			
			1	5	9	13
2	1	$\Delta x$	0.006	0.005	-	-0.027
		$\Delta y$	.067	.053	.047	.060
	2	$\Delta x$	.004	.007	-	-.027
		$\Delta y$	.065	.051	.047	.058
10	1	$\Delta x$	-.001	.013	.011	-.011
		$\Delta y$	.056	.058	.035	.049
	2	$\Delta x$	-.002	.016	.010	-.008
		$\Delta y$	.054	.047	.033	.048
20	1	$\Delta x$	-.003	.011	-.005	-.002
		$\Delta y$	.036	.005	.023	.031
	2	$\Delta x$	-.003	.011	-.003	-.001
		$\Delta y$	.034	.005	.022	.031
35	1	$\Delta x$	-.001	.010	.003	-.006
		$\Delta y$	.015	-	-	-
	2	$\Delta x$	-.001	.010	0	-.006
		$\Delta y$	.013	-	-	-
52	1	$\Delta x$	-	-	-	-.005
		$\Delta y$	.010	-	-.009	-
	2	$\Delta x$	-	-	-	-.004
		$\Delta y$	.008	-	-.008	-

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TABLE II - SIMULATED SHIM RODS OUT

(a) Temperatures, runs 1 and 2.

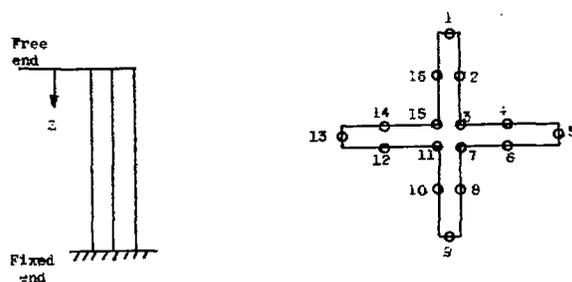


Z (in.)	Run	Thermocouple location															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	(a) 1	460	455	449	453	458	453	449	451	455	451	449	453	458	453	449	455
	2	459	461	461	461	458	458	459	454	451	449	450	449	437	417	456	460
8	(a) 1	476	466	455	462	470	462	455	459	466	459	455	462	470	462	455	466
	2	480				475	476	456	466	467			464	471	459	480	
15	(a) 1	490	476	461	470	482	470	461	466	476	466	461	470	482	470	461	476
	2	493	493	460	479	485	485	446	474	483	478	487	482	483	482	462	488
22	(a) 1	490	476	461	471	482	471	461	467	476	467	461	471	482	471	461	476
	2	500				487	487	448	470	473			480	480	469	435	
29	(a) 1	481	471	459	466	475	466	459	463	471	463	459	466	475	466	459	471
	2	483	485	477	477	473	473	465	474	474	474	469	479	479	480	477	484
36	(a) 1	467	461	454	459	464	459	454	457	461	457	454	459	464	458	454	461
	2	464				462	463	463	469	469				466	466	466	466
43	(a) 1	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448
	2	443	444	445	445	448	445	445	445	444	444	446	446	443	440	445	445
50	(a) 1	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448
	2	441				441	449	456	446	436				436	447	462	465
		449				453	459	469	456	445				445	458	472	478

<sup>a</sup>Requested by Argonne National Laboratory.

TABLE II - SIMULATED SHIM RODS OUT. Continued

(b) Temperatures; run 3.

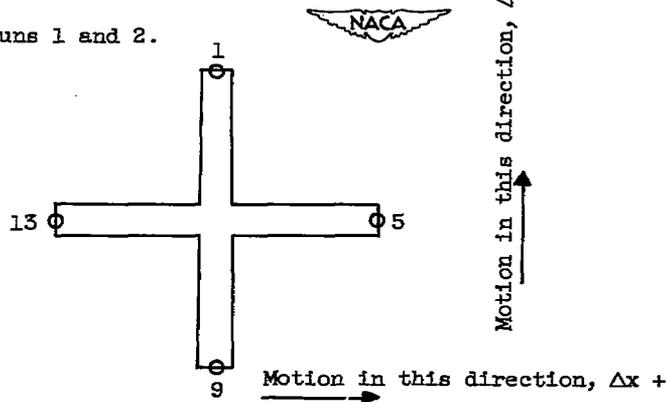
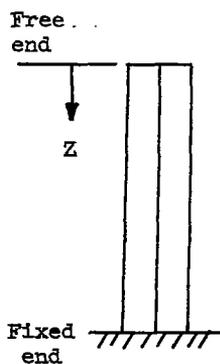


Z (in.)	Run	Thermocouple location															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	(a)	460	455	449	453	458	453	449	451	455	451	449	453	458	453	449	455
	3	449	452	450	449	449	451	452	449	444	442	445	444	432	422	448	453
8	(a)	476	466	455	462	470	462	455	459	466	459	455	462	470	462	455	466
	3	475				465	466	447	456	457					458	465	475
15	(a)	490	476	461	470	482	470	461	466	476	466	461	470	482	470	461	476
	3	487	487	460	472	478	478	441	467	474	472		472	472	471	461	473
22	(a)	490	476	461	471	482	471	461	467	476	467	461	471	482	471	461	476
	3	491				490	492	450	474	478			480	480	472	464	476
29	(a)	481	471	459	466	475	466	459	463	471	463	459	466	475	466	459	471
	3	489	490	482	481	479	479	469	479	479	478	475	485	485	484	485	490
36	(a)	467	461	454	459	464	459	454	457	461	457	454	459	464	458	454	461
	3	462				461	462	465	467	470			469	465	465	461	461
43	(a)	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448
	3	441	440	441	441	442	442	441	442	442	442	443	444	441	440	437	441
50	(a)	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448	448
	3	450				456	463	469	458	447			448	459	475	480	480

<sup>a</sup>Requested by Argonne National Laboratory.

TABLE II - SIMULATED SHIM RODS OUT. Continued

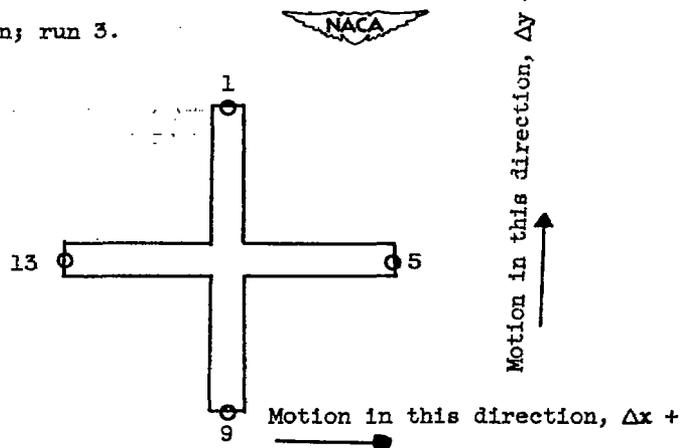
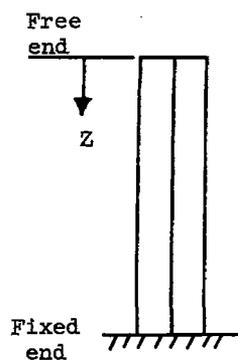
(c) Distortion; runs 1 and 2.



Z (in.)	Run	Displacement (in.)	Gage location			
			1	5	9	13
2	1	$\Delta x$	0.006	0.000	0.006	-0.017
		$\Delta y$	-.039	-.052	-.057	-.046
	2	$\Delta x$	.005	.002	.006	-.016
		$\Delta y$	-.040	-.053	-.058	-.047
10	1	$\Delta x$	.007	.005	.013	-.008
		$\Delta y$	-.029	-.033	-.043	-.029
	2	$\Delta x$	.006	.006	.012	-.007
		$\Delta y$	-.030	-.035	-.045	-.030
20	1	$\Delta x$	.000	.005	.006	-.008
		$\Delta y$	-.008	-.021	-.027	-.032
	2	$\Delta x$	-.001	.006	.006	-.008
		$\Delta y$	-.009	-.022	-.029	-.033
35	1	$\Delta x$	.002	.009	.005	-.007
		$\Delta y$	-.003	-.001	-----	-----
	2	$\Delta x$	.001	.010	.006	-.007
		$\Delta y$	-.004	-.012	-----	-----
52	1	$\Delta x$	-----	.007	-----	-.004
		$\Delta y$	.002	-----	-.007	-----
	2	$\Delta x$	-----	.006	-----	-.004
		$\Delta y$	.001	-----	-.007	-----

TABLE II - SIMULATED SHIM RODS OUT. Concluded

(d) Distortion; run 3.



Z (in.)	Run	Displacement (in.)	Gage location			
			1	5	9	13
2	3	$\Delta x$	0.002	0.005	0.004	-0.014
		$\Delta y$	-.029	-.048	-.054	-.043
10	3	$\Delta x$	.004	.007	.011	-.005
		$\Delta y$	-.027	-.031	-.041	-.027
20	3	$\Delta x$	-.002	.007	.013	-.006
		$\Delta y$	-.008	-.021	-.027	-.031
35	3	$\Delta x$	.001	.013	.012	-.006
		$\Delta y$	-.004	-.010	-----	-----
52	3	$\Delta x$	-----	.006	-----	-.003
		$\Delta y$	.004	-----	-.007	-----

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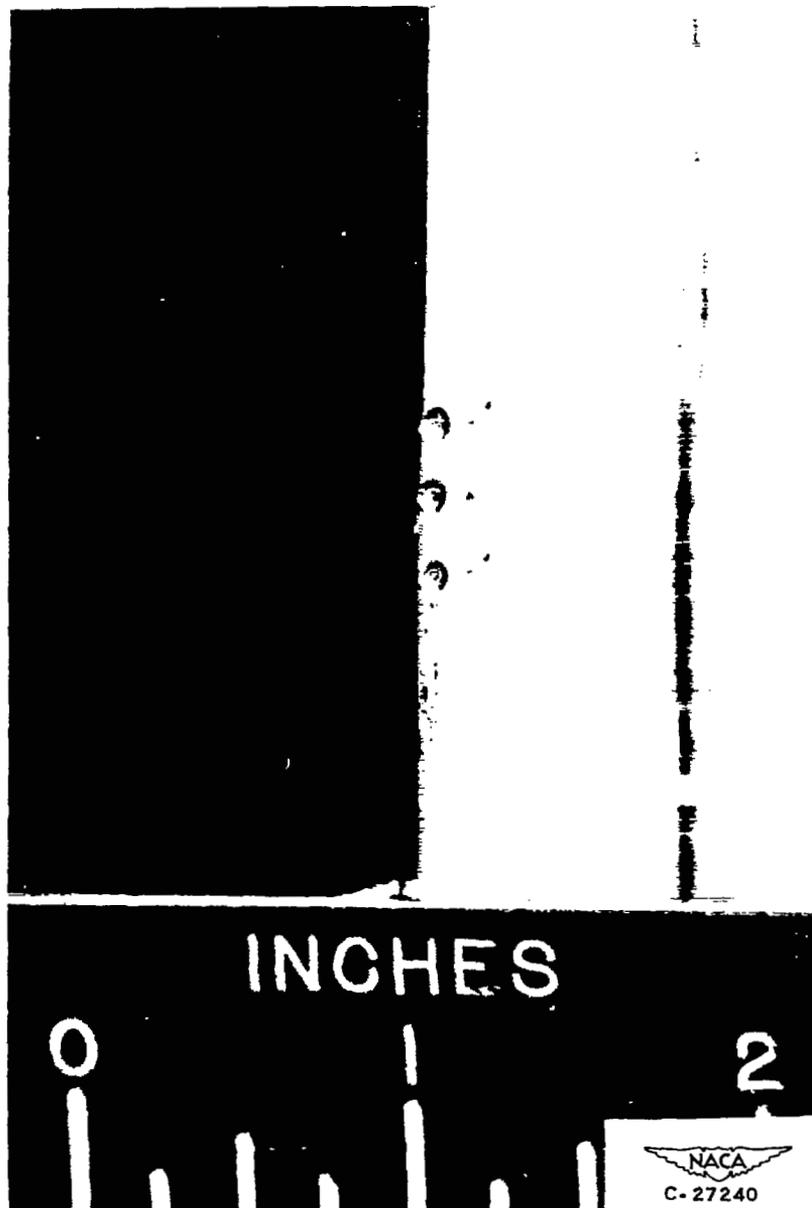


Figure 1. - Photograph of most serious weld failure.

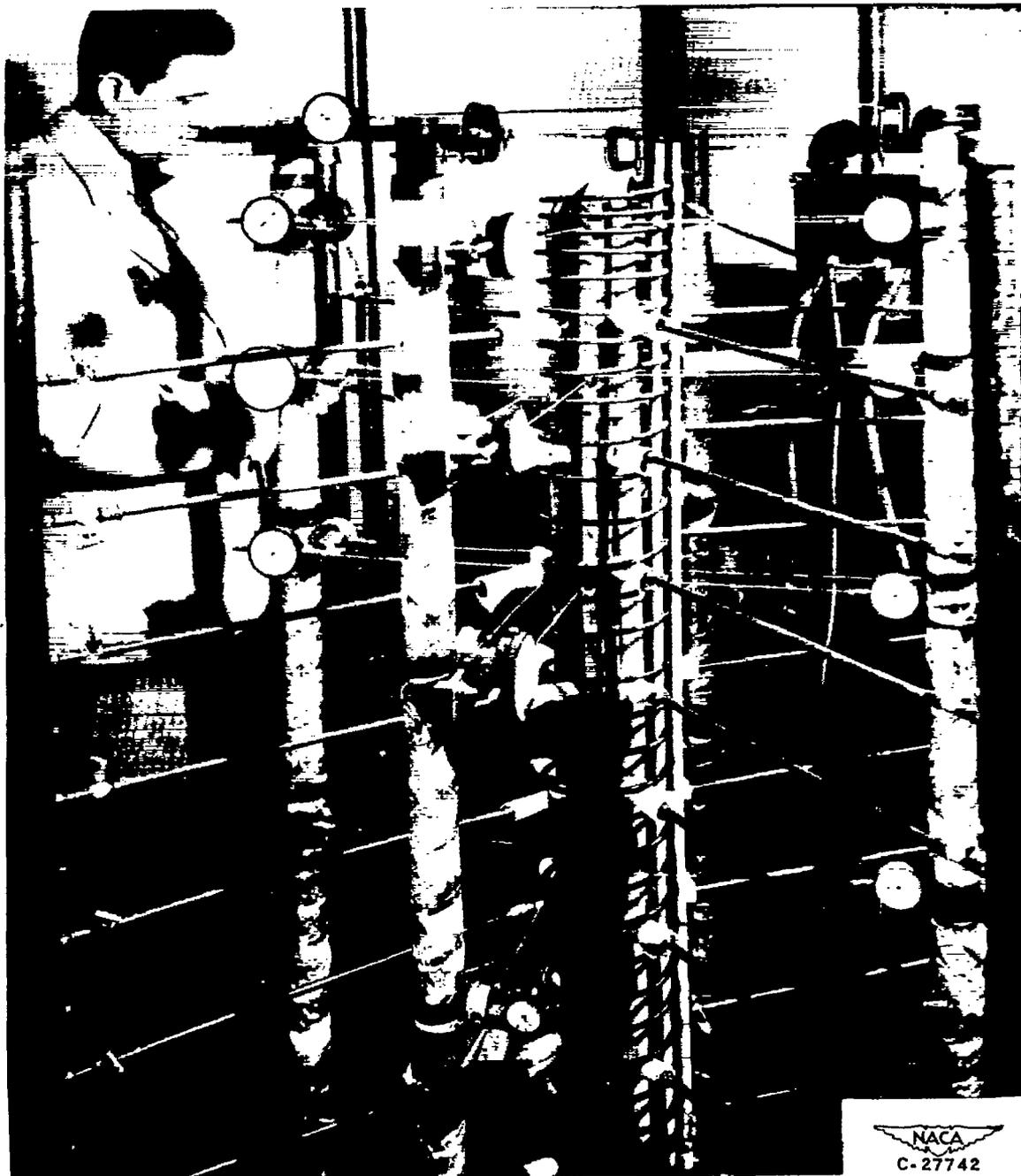
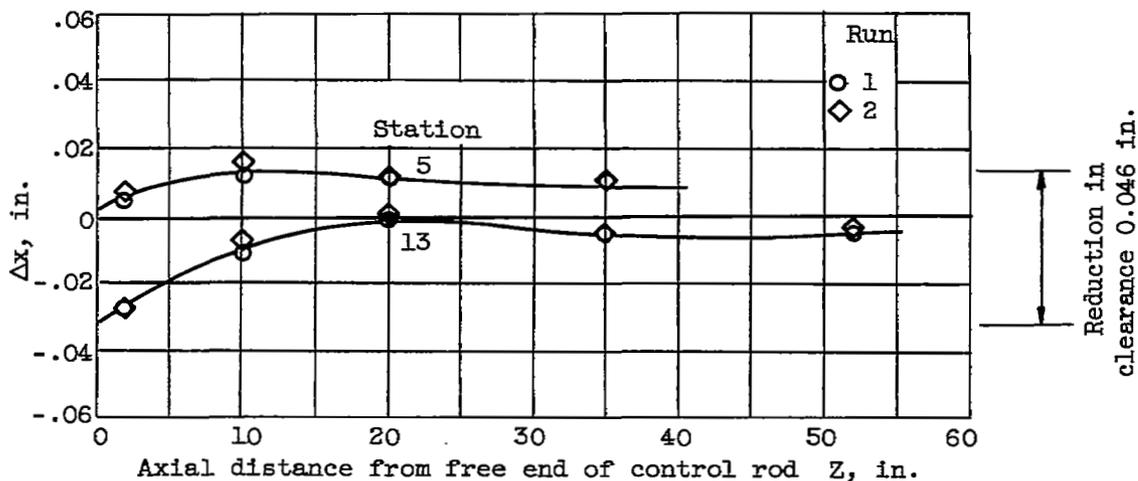
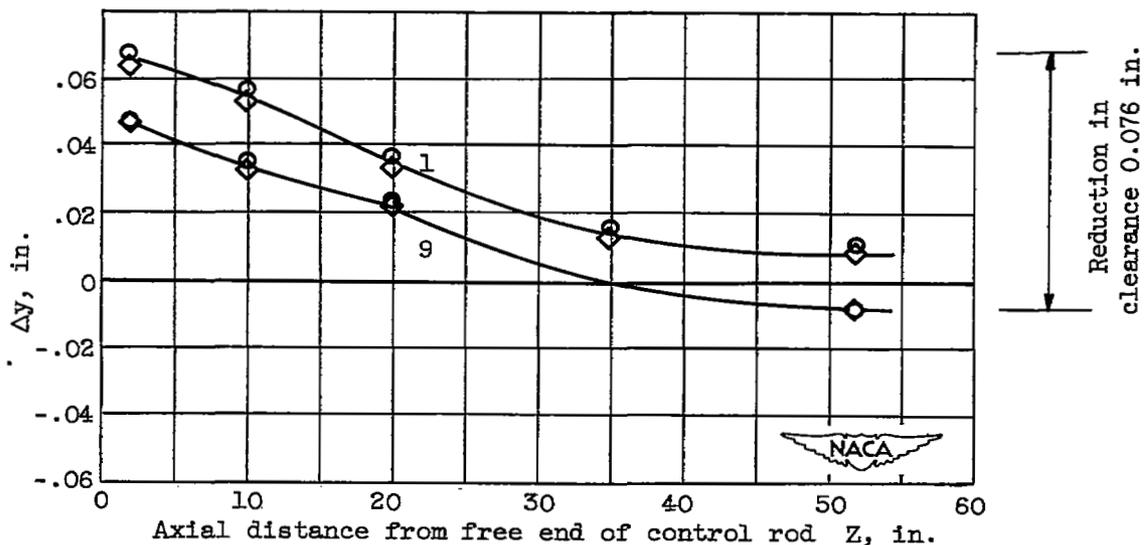


Figure 2. - Photograph of setup.

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(a) Variation of  $\Delta x$  with Z.



(b) Variation of  $\Delta y$  with Z.

Figure 3. - Distortion of control rod with temperature pattern intended to simulate shim rods inserted 50 percent; normal temperatures.

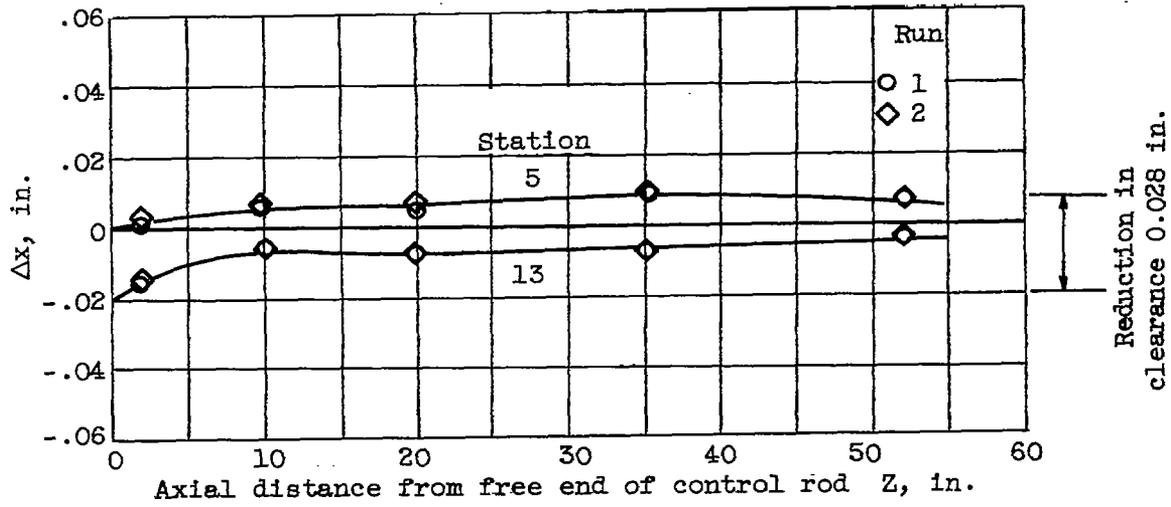
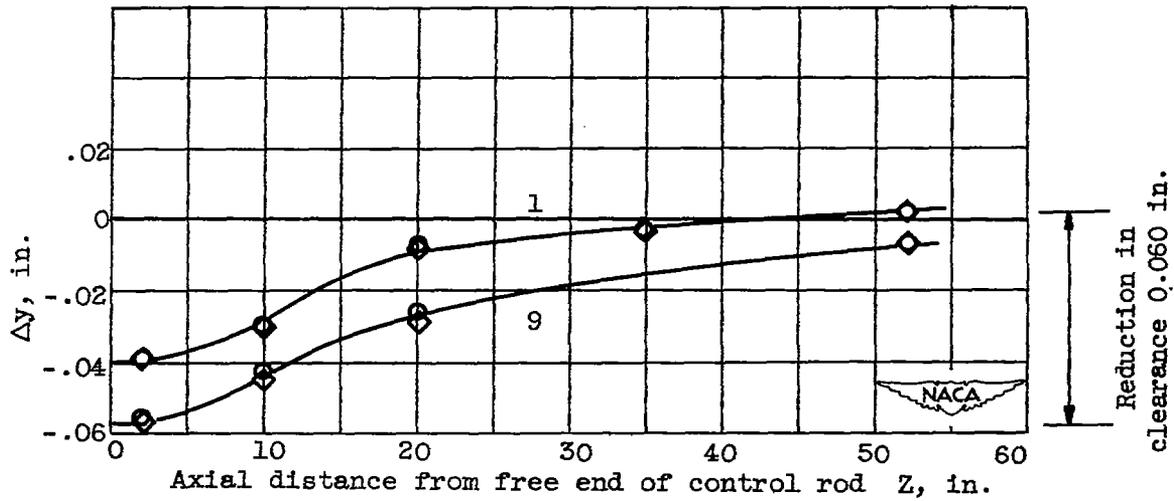
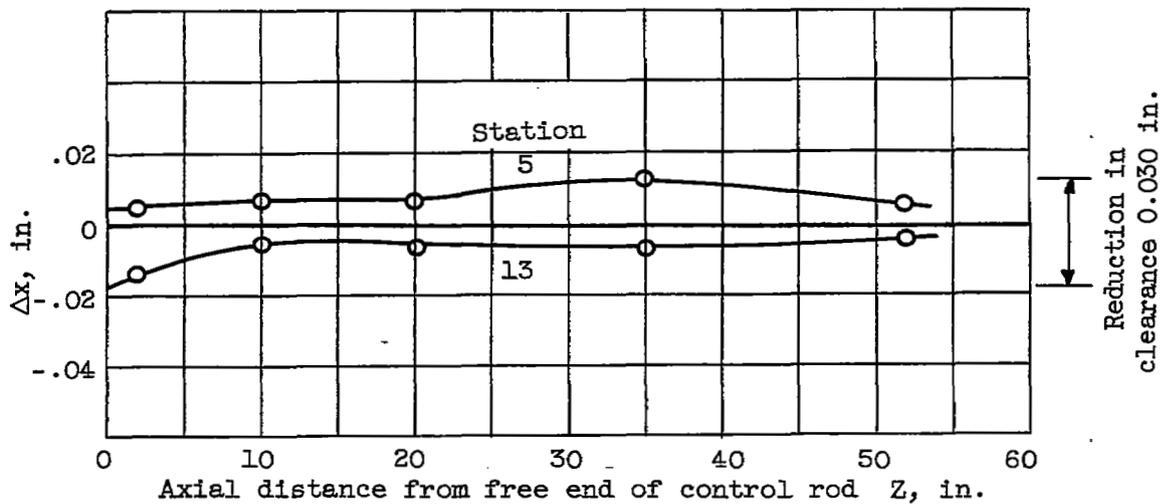
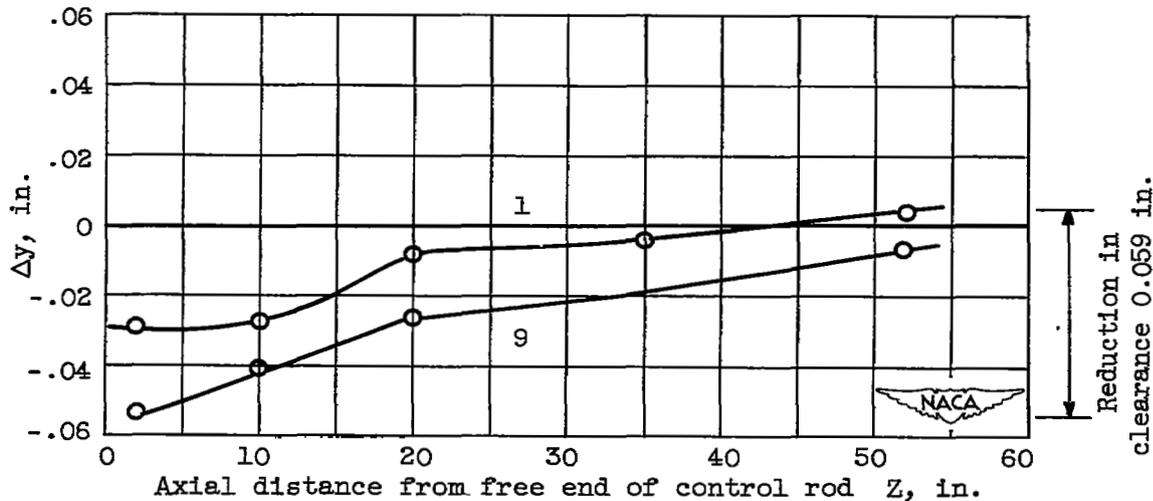
(a) Variation of  $\Delta x$  with  $Z$ ; runs 1 and 2.(b) Variation of  $\Delta y$  with  $Z$ ; runs 1 and 2.

Figure 4. - Distortion of control rod with temperature pattern intended to simulate shim rods out, normal temperatures.

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(c) Variation of  $\Delta x$  with Z; run 3.



(d) Variation of  $\Delta y$  with Z; run 3.

Figure 4. - Concluded. Distortion of control rod with temperature pattern intended to simulate shim rods out; normal temperatures.

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