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INVESTIGATION OF THE STRESSES AND DEFLECTIONS INDUCED IN THE ARM SUPPORT OF A MEDICAL THERAPY UNIT

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Stresses induced by the weight of the head, counter-weight, and arm, at various areas of the supporting frame, and dynamic stresses and deflections due to starting, stopping, and reversing arm rotation, were determined from electrical resistance strain gauge readings. Maximum static stresses were 3,000 psi tension and 5,000 psi compression, with about 300 psi maximum change due to rotation. Dynamic stresses were all less than 2,000 psi, and were not altered significantly by the installation of a reinforcing plate on the support. Maximum measured dynamic deflection was $\pm$ 0.030 in. with no significant reduction due to the re-inforcing plate.

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INTRODUCTION

In a letter dated 3rd October 1963, File No. DD93-D63-10-DOL958, Mr. A. Shewchenko, Design Engineer of the Commercial Products Division, Atomic Energy of Canada Ltd., Ottawa, Ontario, requested a partial experimental stress analysis of the front bearing support for the arm of a Medical Therapy Unit. Static and dynamic stresses, and dynamic deflections, were to be measured at areas designated by the Design Engineer. These areas are indicated in Figure 1.

METHOD OF TEST

Areas chosen for measurement of stresses were lightly ground by hand, to remove paint and scale, thoroughly cleaned, degreased, etched lightly, and neutralized. Foil strain gauges, Type 181E, were mounted at positions 9, 10, 12, 14 and 17 (see Figure 1), and Type 181 gauges were mounted at all other positions. Eastman Type 910 cement, and "Gaugecote" Type 1 were used for all gauges. Temperature compensating gauges were mounted on suitable areas of an adjacent therapy unit which was not in use.

Readings were taken on all gauges, using a Type N Strain Indicator, with the head of the unit at 0°, 90°, 180°, and 270°.

A deflectometer was constructed, using a thin steel cantilever, on which were mounted two foil strain gauges, connected to a Kelvin and Hughes Bridge Amplifier and Recorder. The deflectometer was calibrated statically with a standard micrometer.

Dynamic strains were recorded, with the aid of the Kelvin and Hughes equipment, for all gauges, when the arm rotation was started and stopped at angular positions 0°, 90°, 180° and 270°. Deflections, under the same conditions, were recorded for positions A to H, shown on Figure 1.

The head, and then the entire arm and counterweight were removed from the unit, and static strain readings were obtained for all gauges after each operation. Readings were again taken when the arm, counterweight and head were replaced.

Dynamic readings were then recorded for all gauges as the direction of arm rotation was automatically reversed ("arc" mode of operation) at the above noted angular positions. Deflections were recorded for positions A to H under these conditions.

A heavy steel plate was bolted to the bearing support, in an attempt to reduce deflections. The operation caused the destruction of gauges Nos. 2, 4, 5, 6, 8, and 14. A Type 181 gauge was mounted at position 20, and dynamic readings were taken in the "arc" mode as before, for all serviceable gauges. Deflections were measured at positions A, C, E, K.

Maximum speed of rotation (1 rpm) was used in all dynamic tests, and peak readings only are given in this report. Figure 2 is a typical dynamic recording.

RESULTS OF TEST

The material of the bearing support was stated to be Class 30 grey iron, with a value of 16×10^6 psi for Young's modulus in tension, and a fatigue limit of 14,000 psi in reversed bending. Measured strains, and therefore calculated stresses, were in the directions of the gauges, shown in Figure 1, and were averaged over the areas of the gauges, which all had a nominal gauge length of 1/2 in., the grid widths being 0.500 in. for the Type 181 gauges, and 0.180 in. for Type 181E. For all but three gauges, "zero" readings taken statically varied by well under 10 micro-in./in. Table 1 shows stress variations for the various angular positions of the head, and stresses induced by the weight of the head, arm and counterweight.

Dynamic stresses were generally found to be highest on starting rotation of the arm, rather than on stopping rotation, or on reversing, in the "arc" mode. Peak stresses were, in general, of equal amplitude either side of "zero", and in most cases were highly damped, dropping to zero in a few seconds. The frequency of stress variation was in most cases about 3 cps. Maximum peak dynamic stresses (from zero to maximum in either direction) are given in Table 2.

TABLE 1

Static Stresses in psi
(Tension +ve)

Gauge No.	Stress Induced By: Head Only	Stress Induced By: Head, Arm and Counterweight	Stress Variation at Position 90°	Stress Variation at Position 180°	Stress Variation at Position 270°	Maximum "zero" Variation
1	+ 500	+1600	+ 70	+ 70	+150	500
2	+ 350	+1400	-160	+ 20	-160	80
3	+ 800	+2600	0	+ 50	0	0
4	- 500	-1000	+ 40	+ 40	-100	20
5	-1600	-4000	0	0	0	0
6	-1800	-4200	- 50	- 50	+ 80	0
7	+ 500	+1100	0	0	0	0
8	+ 650	+1600	+ 40	+ 40	0	50
9	+ 500	+1600	+160	+250	0	0
10	+ 650	+1600	0	0	0	100
11	- 900	-3000	- 70	- 70	-130	0
12	-2100	-5000	- 40	- 40	+130	40
13	-2500	-5000	0	-130	-300	0
14	+ 800	+3000	0	+160	-160	200
15	- 800	-1600	- 80	0	+160	70
16	-1600	-4000	- 80	- 80	0	0
17	- 250	- 500	0	0	0	400
18	- 250	- 400	0	0	- 20	50
19	0	+ 600	0	0	0	150

TABLE 2

Maximum Peak Dynamic Stresses in psi, ±

Gauge No.	Start-Stop Mode Before Reinforcing				Arc Mode Before Reinforcing				Arc Mode After Reinforcing			
	0°	90°	180°	270°	0°	90°	180°	270°	0°	90°	180°	270°
1	980	250	190	190	750	190	190	190	350	200	250	200
2	800	350	500	400	420	280	280	240	-	-	-	-
3	190	250	250	190	60	250	250	190	1000	400	400	300
4	350	300	350	400	190	280	280	240	-	-	-	-
5	340	340	340	340	130	390	260	260	--	-	-	-
6	400	550	500	550	100	500	450	350	-	-	-	-
7	0	135	0	135	65	130	65	65	360	90	90	90
8	100	150	200	200	100	200	200	150	-	-	-	-
9	600	670	740	600	120	730	610	490	1120	660	800	530
10	940	1090	1280	1140	330	1160	1120	750	1130	270	350	175
11	200	270	270	270	190	190	190	190	170	170	170	170
12	600	690	890	790	150	840	740	550	220	130	130	130
13	1350	950	950	900	900	700	830	510	340	290	230	170
14	50	100	50	100	100	100	100	100	-	-	-	-
15	340	400	400	340	260	390	390	190	90	90	90	50
16	300	350	300	300	50	350	300	200	230	290	230	230
17	70	70	70	70	0	65	0	65	50	50	50	50
18	50	100	100	50	0	100	100	100	90	50	50	50
19	100	100	200	200	0	200	200	200	200	100	100	100
20	-	-	-	-	-	-	-	-	1400	1000	1000	1000

Deflections, measured during the "arc" mode of operation for the four angular positions of the head, are given in Table 3. Deflections were generally symmetrical about the "zero" position, at about 2-1/2 to 4-1/2 cps, and maximum amplitudes only are shown in the table.

TABLE 3

Deflections in inches x 10^3, Frequencies in cps

Position	Before Reinforcing		After Reinforcing	
	Deflection	Frequency	Deflection	Frequency
A	± 25	3	± 15	4
B	± 10	3	-	-
C	± 30	3	± 25	3-1/2
D	± 15	3	-	-
E	± 10	4	± 25	4-1/2
F	± 3	2-1/2	-	-
G	± 3	3	-	-
H	± 3	4	-	-
K	-	-	± 5	4-1/2

DISCUSSION OF RESULTS

From Table 1, it is seen at once that stresses induced by the weight of the arm and head, at the areas under observation, are very low, and, that the variations in stresses with arm rotation are insignificant. Tensile stresses, due to the weight of the head and arm, would be expected at positions 1, 2, 14, 3, 4, 7, 8, 9, and 10. The compressive stress at position 4, and the difference in tensile stress magnitudes at positions 1, 2, and 7, 8, however, suggest that there is a certain amount of twisting in the frame. The signs and relative magnitudes of stresses at all other positions are as one would predict.

Table 2 indicates that dynamic stresses, induced at the areas observed by starting, stopping, or reversing arm rotation, are insignificantly low, the highest peak stresses being less than 2,000 psi. While the addition of a reinforcing plate affected stress distribution slightly, stress magnitudes were not significantly altered.

Dynamic deflections measured at various positions on the support, were all relatively low, as seen in Table 3, and the reinforcing plate had little effect on either amplitudes or frequencies.

CONCLUSION

Measurement of static and dynamic strains at selected areas of the supporting frame for a Medical Therapy Unit indicated that operational stresses were very low, at the maximum angular velocity of 1 rpm. Some parts of the frame deflected by up to $\pm$0.030 in. with respect to the rest position, during operation. A reinforcing plate, bolted to the support, did not significantly alter stresses or deflections. Since the mass of the rotating components is extremely large compared with that of the stationary components, it would appear that a significant reduction in deflection of the support would be difficult to attain.

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FWM:KAR:vb

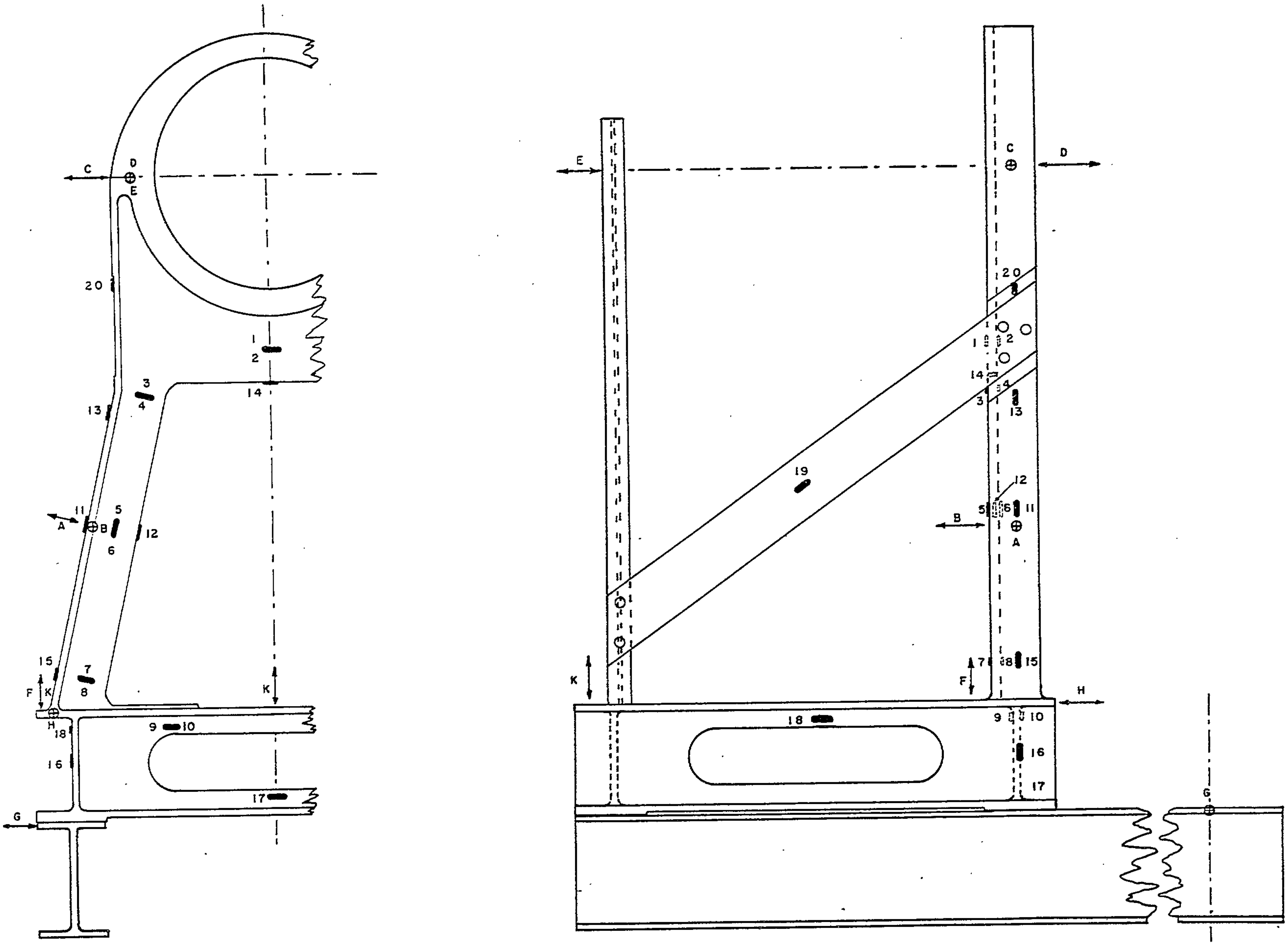

Figure 1. Location of Strain Gauges (Numbers) and Deflection Measurements (Letters).

Figure 2. Typical Recording of Strains for "Start-Stop" Mode, Gauge No. 9 (bottom) Gauge No. 10 (top). 1 cm (horiz.) = approx. 10 seconds
1 cm (vertical) = approx. 2,500 psi.