Heat Production by Ultrasonic Equipment

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Abstract □ Temperature profiles were developed for several ultrasonic instruments over varying time intervals with two volumes of water. A wide range of temperatures at different power levels was noted.

Keyphrases □ Ultrasonic instruments—temperature profiles of heat production during insonation □ Insonation—temperature profiles of heat production for six ultrasonic instruments □ Heat production—temperature profiles for six ultrasonic instruments during insonation

It is well known to many users of ultrasonic equipment that heat is developed in an irradiated liquid due to mechanical energy emission. Literature indicating the extent of heat development by standard equipment in liquid systems is not readily available. In theory, if the energy output of the ultrasonic probe is known, calculations can be made to determine heat loss to the environment. In practice, this is difficult for the ordinary user because of the unreliability of the data available for most equipment.

This study was conducted to determine temperature profiles of various equipment found in biological laboratories. It is hoped that the results will afford the scientist adequate data for selection of optimal instrument parameters to avoid thermal problems.

EXPERIMENTAL

Equipment—Six instruments[1] (Instruments A–F) were studied.

Method—Distilled water (25 and 100 ml) was placed into 50- and 120-ml polyethylene containers. The ultrasonic probes were immersed to a depth of 1.27 cm into the liquid, the power levels were set, and the water was irradiated for intervals of 30, 60, 120, 180, 240, and 300 sec. The temperature after insonation was recorded at each time interval. All experiments were run in duplicate.

In the case of Instrument F, the probe was immersed to within 0.6 cm of the bottom of the plastic container prior to activation rather than at a depth of 1.27 cm from the top of the liquid since it operates on a different principle from the other instruments.

RESULTS AND DISCUSSION

The temperature profiles for the instruments studied are shown in Tables I–VII. Wherever possible, three power levels (low, medium, and high) were selected.

The probe immersion depth of 1.27 cm was selected on the basis of a previous report (1) and was verified using Instrument E at a power setting of 10 (Fig. 1). Maximum cavitational intensity values were obtained when the probe was immersed to a depth of no more than 1.27 cm.

Instrument F was studied because it is widely used as a cell disrupter and because the trade literature implies that it is an ultrasonic instrument. When used by most individuals, the probe is immersed to the greatest extent possible to expose the sample to maximum shear forces. For this reason, the probe was immersed to within 0.6 cm of the bottom in this study.

Instrument C—Conditions of operation were 20 kc/sec, 1.27-cm probe, and 75 w.

At the highest power of 8, the maximum temperature recorded during 300 sec was 74.8° in a volume of 25 ml while 59.3° was obtained in 100 ml (Table I). The temperatures at the two lower powers, 3 and 5, were considerably less, with a maximum of 37.8° attained in a 25-ml volume at a power of 5.

Instrument D—Conditions of operation were 20 kc/sec, 1.27-cm probe, and 125 w.

At high and medium power and at 25-ml volume, the curves are almost superimposed and are at about the same levels as for Instrument C. The high and low power values for 100-ml volumes are also about the same as those recorded for Instrument C with the intermediate power level much higher (Table II).

Instrument E—Conditions of operation were 20 kc/sec, 1.27-cm probe, and 185 w.

At the high power of 10 and a volume of 25 ml, the temperature reached a maximum of 95° after 240 sec and appeared to level off thereafter. By contrast with Instrument C where the intermediate and low level powers produced small temperature changes, Instrument E showed significant temperature changes at both lower powers. A similar result occurred in the 100-ml volume, the maximum temperature reaching 60° at high power (Table III).

Instrument A—Conditions of operation were 20 kc/sec, 0.95-cm probe, and 300 w.

The maximum temperatures reached with this 0.95-cm probe in 25 and 100 ml of water were 66 and only 38.3°, respectively,

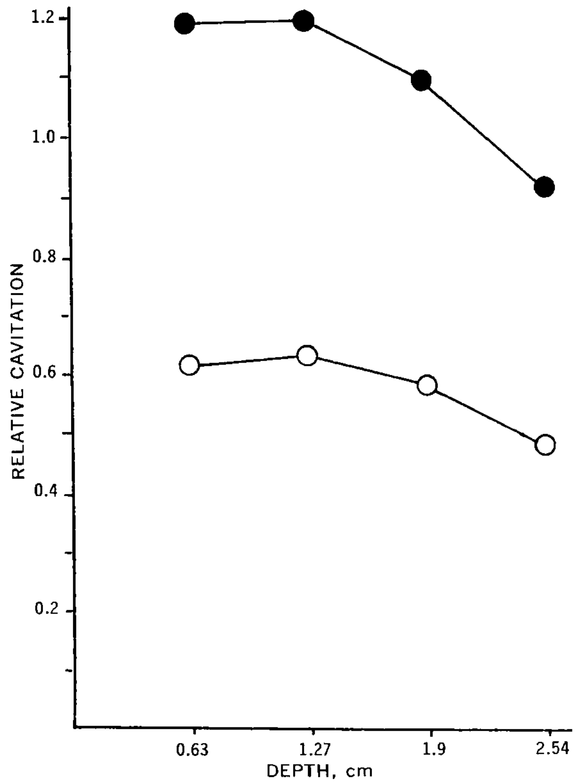

Figure 1—*Effect of depth of immersion upon cavitational intensity (Instrument E). Key:* ○, *30 sec; and* ●, *60 sec.*

[1] Instrument A, Biosonik III, Bronwill Scientific Co., Rochester, N.Y.; Instrument B, Biosonik IV, Bronwill Scientific Co., Rochester, N.Y.; Instrument C, Sonifier S-75, Branson Sonic Power Co., Danbury, Conn.; Instrument D, Sonifier S-125, Branson Sonic Power Co., Danbury, Conn.; Instrument E, Sonifier W-185, Branson Sonic Power Co., Danbury, Conn.; and Instrument F, Polytron, Bronwill Scientific Co., Rochester, N.Y.

Table I—Increase in Temperature during Insonation of Water Using Instrument C with a 1.27-cm Diameter Probe

	25 ml Power Level			100 ml Power Level		
Seconds	3	5	8	3	5	8
0	25°	25°	25°	25°	25°	25°
30	25.8°	26°	34°	25°	25°	28.5°
60	26.8°	27°	41°	25.5°	25.5°	32°
120	28.5°	29°	53.5°	26°	26°	40.3°
180	29.8°	31°	64.5°	26°	27°	47°
240	31.3°	33.8°	71.3°	26°	28°	53.3°
300	34.8°	37.8°	74.8°	26.5°	29°	59.3°
Average difference[a]	±1.3°	±0.8°	±1.6°	0°	0°	±0.3°

[a] The average temperature difference between duplicate runs.

Table II—Increase in Temperature during Insonation of Water Using Instrument D with a 1.27-cm Diameter Probe

	25 ml Power Level			100 ml Power Level		
Seconds	3	5	8	3	5	8
0	25°	25°	25°	25°	25°	25°
30	26.5°	34.2°	36°	26°	28°	30°
60	28.3°	43°	43°	27°	32°	34°
120	29.5°	54°	54°	29.5°	38°	42°
180	31.3°	63°	62.3°	32°	44°	49°
240	33.8°	69.5°	69°	34°	50°	56°
300	35°	73.5°	72.5°	37°	56°	62°
Average difference[a]	±1.6°	±3.6°	±1.6°	0°	±0.7°	±0.1°

[a] The average temperature difference between duplicate runs.

Table III—Increase in Temperature during Insonation of Water Using Instrument E with a 1.27-cm. Probe

	25 ml Power Level			100 ml Power Level		
Seconds	3	7	10	3	7	10
0	25°	25°	25°	25°	25°	25°
30	30°	35°	42°	26.5°	27.5°	29.3°
60	34°	45°	55.6°	27.5°	30.3°	33.5°
120	42°	61°	78°	30°	35°	41.3°
180	48.5°	74°	90°	32°	39.3°	48°
240	54.5°	82.5°	95°	34°	44°	54.5°
300	60°	88°	95°	36°	48°	60°
Average difference[a]	±0.7°	±0.4°	±0.4°	±0°	±0.2°	±1.6°

[a] The average temperature difference between duplicate runs.

Table IV—Increase in Temperature during Insonation of Water Using Instrument A with a 0.95-cm Probe

	25 ml Power Level			100 ml Power Level		
Seconds	20	40	60	20	40	60
0	25°	25°	25°	25°	25°	25°
30	28.5°	27.5°	30.3°	26°	25.8°	26.5°
60	31.3°	30.8°	35.3°	26.8°	27°	28.3°
120	36.0°	36.5°	44.5°	28.5°	28.8°	30.5°
180	41.2°	41.5°	52.8°	30.3°	30.5°	33.3°
240	46.5°	46.3°	60°	31.5°	32.5°	35.5°
300	49.3°	50.8°	66°	33.5°	34°	38.3°
Average difference[a]	±1.2°	±1.1°	±1.2°	±0.5°	±0.1°	±0.8°

[a] The average temperature difference between duplicate runs.

Table V—Increase in Temperature during Insonation of Water Using Instrument B with a 0.95-cm Probe

Seconds	25 ml Power Level—Hi			100 ml Power Level—Hi		
	20	40	60	20	40	60
0	25°	25°	25°	25°	25°	25°
30	27°	29°	28°	27°	27°	26°
60	29°	33°	32°	28°	28°	27°
120	33°	40°	37°	29°	29°	28°
180	38°	45°	44°	31°	31°	31°
240	42°	50°	49°	32°	33°	32°
300	47°	53°	53°	34°	35°	34°
Average difference[a]	±1.1°	±1.2°	±1.1°	0°	±0.2°	±0.5°

[a] The average temperature difference between duplicate runs.

Table VI—Increase in Temperature during Treatment of Water Using Instrument F

Seconds	25 ml Power Level			100 ml Power Level		
	3	7	10	3	7	10
0	25°	25°	25°	25°	25°	25°
30	27°	29°	30°	26°	27°	28°
60	28°	31°	31°	27°	28°	28.5°
120	30°	34°	34°	28.5°	30°	31°
180	32°	35°	35°	29.5°	31°	32.5°
240	33°	36°	36°	30°	32°	34°
300	33.5°	36°	37°	31°	33°	35°
Average difference[a]	±1.5°	±0.3°	±0.4°	0°	±0.3°	±0.9°

[a] The average temperature difference between duplicate runs.

Table VII—Increase in Temperature during Insonation of Water Using Instrument A with a 0.4-cm Diameter Probe

Seconds	10 ml Power Setting		25 ml Power Setting	
	20	30	20	30
0	25°	25°	25°	25°
30	35.5°	25.5°	26°	25.5°
60	26.5°	26.5°	26.5°	26°
120	28°	28°	27°	27°
180	29.5°	29.5°	27.5°	27.5°
240	31°	31°	28°	28°
300	32.5°	32°	29°	29°
Average difference[a]	±0.2°	±0.8°	0°	±0.8°

[a] The average temperature difference between duplicate runs.

after 5 min irradiation and full power. At lower power settings, the temperature increases were linear but less than at full power (Table IV).

Instrument B—Conditions of operation were 20 kc/sec, 0.95-cm probe, and 300 w.

Maximum temperatures were obtained at power settings of 40 and 60 using the 0.95-cm probe in 25 ml of water. Temperature increases with 100-ml volumes were minimal at all three power levels, with the highest temperature reaching 35° (Table V). These experiments were carried out at the instrument panel setting of Hi.

Instrument F—Temperature profiles for 25- and 100-ml volumes of water treated by Instrument F are shown in Table VI. Maxima are not as high as those attained by some other instruments. The maximum of 37° obtained in the 25-ml volume was only slightly higher than that obtained with the 100-ml volume.

Microprobes—The only available instrument with a microprobe was Instrument A with a 0.4-cm probe. Since microprobes are widely used, temperature profiles for power levels of 20 and 30 in 10 and 25 ml of water were prepared. As shown in Table VII, the temperature increases are minor with the highest at 32.5°.

Cavitation is responsible for much of the heat produced during the ultrasonic irradiation of a liquid with a step-horn transducer. If the equipment is well designed, little if any heat is contributed by the horn itself. Since many users of step-horn probes are interested in the disruptive effects of cavitation which is accompanied by heat, any additional heat contributed by the probe should be avoided.

The results indicate that where modest increases in temperature can be tolerated and where agitation rather than power is important, the irradiations of up to 5 min can be conducted at the low power settings of Instruments C, D, A (100 ml), E at lowest power (100 ml), B at all power levels (100 ml), A with the microprobe, and F at all power levels.

If power is significant and the system is thermolabile, then cooling will be necessary at all high power settings of all of the instruments studied except Instruments F, A with the microprobe, and B (100 ml).

REFERENCE

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