TABLE 1.—*Solor radiation intensities during September, 1917*—Contd.

Santa Fe, N. Mex.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Sept. 3	......	......	......	1.18	1.11	1.06	1.00	......	......	......
4	......	......	1.21	......	1.13	1.09	1.02	0.96	0.91	......
5	......	1.37	1.24	1.17	1.10	1.04	0.98	0.92	0.87	0.82
6	1.45	1.32	......	......	......	......	......	......	......	......
7	......	......	......	1.13	1.06	1.01	0.93	0.86	0.79	......
12	......	1.39	1.34	1.30	1.08	1.00	......	......	......	......
13	......	1.37	1.28	......	......	......	......	......	0.95	0.91
15	......	......	......	......	1.21	1.18	1.14	1.10	1.03	0.91
19	......	......	......	......	1.17	1.06	0.97	0.86	......	......
22	......	1.44	1.32	1.26	1.20	1.14	1.08	1.02	0.97	0.93
Monthly means	(1.45)	1.38	1.88	1.21	1.13	1.07	1.02	0.95	0.92	0.89
Departure from 5-year normal	−0.06	−0.03	−0.03	−0.04	−0.03	−0.04	−0.03	−0.06	−0.04	−0.03
P. M.										
Sept. 28	......	1.52	1.48	1.36	1.29	1.21	1.15	......	......	......
Monthly means	......	(1.52)	(1.48)	(1.36)	(1.29)	(1.21)	(1.15)	......	......	......
Departure from 5-year normal	......	+0.02	+0.07	+0.05	+0.09	+0.07	+0.07	......	......	......

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Dates.	8 a.m.	8 p.m.	Dates.	8 a.m.	8 p.m.	Dates.	8 a.m.	8 p.m.	Dates.	8 a.m.	8 p.m.
1917.	*mm.*	*mm.*	1917.	*mm.*	*mm.*	1917.	*mm.*	*mm.*	1917.	*mm.*	*mm.*
Sept. 4	9.14	10.21	Sept. 10	4.75	4.75	Sept. 5	15.11	11.81	Sept. 3	7.04	5.79
7	9.47	9.14	11	5.36	6.27	7	14.60	14.10	4	6.50	6.50
11	5.16	7.04	21	7.29	8.48	8	10.59	13.61	5	7.57	6.76
12	7.57	7.29	22	8.18	10.21	11	7.87	9.47	6	6.76	6.76
13	7.87	9.14	24	8.48	10.59	13	11.81	13.61	7	6.02	8.81
17	9.83	8.47	28	7.04	7.29	17	11.38	11.81	12	9.83	9.83
18	8.48	11.38	29	5.79	6.02	18	9.47	12.24	13	8.48	10.59
19	10.59	12.24	......	......	......	21	9.83	9.47	15	4.75	5.56
22	10.97	7.87	......	......	......	22	9.47	10.21	19	7.32	6.50
26	9.83	11.38	......	......	......	23	7.87	9.14	22	7.32	6.76
						24	9.47	13.61	28	3.81	3.81
						27	5.79	6.50	......	......	......
						28	5.16	7.29	......	......	......
						29	6.27	5.16	......	......	......

TABLE 3.—*Daily totals and departures of solar and sky radiation during September, 1917.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.		Departures from normal.		Excess or deficiency since first of month.	
	Washington.	Madison.	Washington.	Madison.	Washington.	Madison.
1917.	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*
Sept. 1	195	330	−217	−64	−217	−64
2	362	452	−47	61	−264	−3
3	352	267	−55	−121	−319	−124
4	505	471	100	86	−219	−38
5	380	233	−23	−150	−242	−188
6	113	477	−288	98	−530	−90
7	319	53	−80	−321	−610	−411
8	50	429	−348	60	−958	−351
9	117	92	−279	−274	−1,237	−625
10	400	549	5	187	−1,232	−438
11	569	554	176	196	−1,056	−242
12	526	383	135	29	−921	−213
13	456	197	67	−152	−854	−365
14	238	403	−150	58	−1,004	−307
15	101	349	−285	7	−1,289	−300
16	273	413	−111	74	−1,400	−226
17	506	394	124	58	−1,276	−168
18	454	417	75	84	−1,201	−84
19	436	258	59	−71	−1,142	−155
20	337	99	−37	−226	−1,179	−381
Decade departure			......	......	53	57
21	316	436	−56	114	−1,235	−267
22	432	429	63	111	−1,172	−156
23	303	422	−64	107	−1,236	−49
24	216	414	−148	103	−1,384	54
25	243	394	−118	86	−1,502	140
26	429	94	71	−210	−1,431	−70
27	409	412	54	112	−1,397	42
28	208	419	−143	123	−1,520	165
29	336	412	−12	120	−1,532	285
30	435	310	91	22	−1,441	307
31	......	......	......	......	......	......
Decade departure			......	......	−262	688
Excess or deficiency since first of year. calories			......	......	−5,981	1,680
Excess or deficiency since first of year. per cent			......	......	−5.6	1.6

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DÖPPLER'S PRINCIPLE FOR A WINDY ATMOSPHERE.

By HARRY BATEMAN, Ph. D.

[Dated: 730 South Lake Avenue, Pasadena, Cal., Oct. 15, 1917.]

In view of the interest which is being taken in the effect of wind on the propagation of sound it may be worth while to recall the form which Döppler's principle assumes when a wind is blowing.

If the observer is moving with velocity u, the source of sound with velocity v, and the wind with velocity V, all measured in the same direction, then in the case of sound waves moving in the opposite direction and originating at the source with frequency ν the observed frequency is

$$\nu_o = \nu \frac{c - V + u}{c - V + v} \tag{1}$$

where c is the velocity of sound in still air.

This result may be obtained with the ordinary form of Döppler's principle either by reducing the air to rest by substracting the wind velocity V from u and v, or by regarding the velocity of sound in the moving air as $c - V$.

To prove the formula analytically let us neglect the variation of air-density and wind-velocity with altitude and assume that the wind is blowing steadily in a direction parallel to the axis of x with velocity V, then the velocity potential ϕ of sound waves propagated through the air satisfies the partial differential equation.[1]

$$\left(\frac{\partial}{\partial t} + V\frac{\partial}{\partial x}\right)^2 \phi = c^2 \nabla^2 \phi.$$

This equation may be transformed into the ordinary wave-equation for still air by writing x' in place of $x - Vt$. The solution corresponding to sound from a moving source which is at the point $\xi(\tau)$, $\eta(\tau)$, $\zeta(\tau)$ at time τ is

$$\phi = \frac{1}{\gamma} f(\tau)$$

where τ is defined by the equation

$$[x - \xi(\tau) - V(t-\tau)]^2 + [y - \eta(\tau)]^2 + [z - \zeta(\tau)]^2 = c^2 (t-\tau)^2,$$

and γ is the partial derivative of the left-hand side with respect to τ.

Putting

$$x = a + ut, \ y = 0, \ z = 0, \ \xi(\tau) = \alpha + v\tau, \ \eta(\tau) = 0, \ \zeta(\tau) = 0,$$

where a, α, u, v, are constants so as to have the case of a source and observer moving along the same straight line with different constant velocities, we find that

$$\tau = \frac{t(u - v \pm c) + a - \alpha}{v - V \pm c}$$

For sound of frequency ν we may write $f(\tau) = A \sin(\nu\tau + \epsilon)$ and the observed frequency is seen to be given by formula (1). The wave-length is also

$$\lambda_o = \frac{2\pi}{\nu}(\pm c - V + v)$$

It should be noticed that if $u = v$ the observed frequency is the same as the natural frequency whatever be the velocity of the wind. If $v = V$ the observed wave-length is the same as the natural wave-length. In actual practice the horizontal wind velocity may be different at the locations of the source and observer owing to vertical motion of the air, eddy motion, and friction. An exact mathematical treatment of the general problem is difficult

[1] See, for instance, S. *Fujiwhara*, in Bull., Central meteorol. obs'y, Japan, Tokyo, (1912), 2, no. 1.

but if U is the wind velocity near the observer and V the wind velocity near the source of sound, the empirical formula

$$\nu_0 = \nu \frac{c - U + u}{c - V + v}$$

may be fairly accurate. It may be worth while to test this formula experimentally.

In the case of an overhead source of sound the theory is naturally complicated and is much more so when the variation of air density and wind velocity are taken into account. Experiments with sound produced in a moving aeroplane may indicate whether the above variations of atmospheric conditions with altitude have any appreciable effect on the observed frequency.

PROPAGATION TO GREAT DISTANCES OF THE SOUND OF CANNONADE AT THE FRONT.[1]

By G. BIGOURDAN.

[*Reprinted from* Science Abstracts, Sect. A, July 30, 1917, §657.]

A cannonade produces various noises from the mouths of the guns and from the explosions of the shells. Some of these noises can reach great distances, 200 to 300 kilometers, but it is not agreed how they reach them.

It is thus thought desirable to cite the case of an engineer, aged 52, totally deaf since the age of 6 through cerebrospinal meningitis. Placed at the side of a locomotive whistling, he perceived only a sudden pain of the drum skin, which ceased immediately in spite of the continuation of the whistling. For the last 20 years if within 1,000 to 1,500 meters of gunfire, he perceives two successive shocks—one transmitted by the earth, one by the air. The last affects the thorax particularly. At the commencement of the Somme offensive, from the outskirts of Paris, when attending [attentive?], he was conscious of vibration during the cannonade; sometimes he would perceive only dull blows, at others he would perceive something at the same instant as an ordinary hearer. The distance to the Somme front (120 kilometers) excluded entirely the route through the air, so it must be by the earth; and so also for the normal hearer, since both perceive it at the same time (see Science Abstracts, 1916, §1056).—*E. H. B[arton]*.

551.575 : 534 (048)

ACCOUSTIC EFFICIENCY OF FOG-SIGNAL MACHINERY.[2]

By L. V. KING.

[*Reprinted from* Science Abstracts, Sect. A, July 30, 1917, §655.]

The first section of this paper sketches the history of fog-signal experiments, dwelling specially on the work of Tyndall published in 1874 in a Trinity House report.

At about the same time experiments by Duane and by Joseph Henry were conducted, and were published in 1874. The result of fog-signal tests carried out in the United States to the year 1894 were published in Livermore's Report to the Lighthouse Board of that date.

In 1901 a committee of the Trinity House carried out, at the Isle of Wight, a series of tests under the scientific direction of Rayleigh and T. Matthews. For calm weather a low note (about 180 per second) was considered most suitable; when the wind was contrary and the sea rough, it was found that a higher note penetrated farther than a low one. The physical significance of this was discussed by Rayleigh at that time.[3] It appears surprising that while a blast is being sounded from a siren which can be heard about 8 miles away on a good day, energy is being expended at the rate of about 100 horsepower. The high note of a Scottish signal required 600 horsepower. Rayleigh raised the question as to whether these enormous powers are really utilized for the production of sound or whether from some cause, possibly avoidable, a large proportion may not be wasted.

The experience of French fog-signal engineers was summed up by C. Ribbière in 1908. This emphasized the desirability of obtaining further knowledge as to the efficiency of the fog-signal apparatus.

The second section deals with the production of sound by a special siren called the "diaphone," due in its present form to J. P. Northey. The essential feature of this apparatus is a hollow cylindrical piston, which is oscillated longitudinally by the "driving air," and so opens and closes ports which allow a series of puffs from the "sounding air." These puffs give a nearly pure tone of about 180 per second. This sound passes through a suitable horn.

The third section is occupied with the numerical relations between sound waves and their audibility as fog-signals.

The fourth section deals with the "phonometer" due to S. G. Webster. This consists of a Helmholtz hollow cylindrical resonating chamber, one end of which is pierced by a smooth hole communicating freely with the atmosphere, while the other has a very uniform plate of the best mica obtainable (such as is used in phonographs). The resonator is tuned to the pitch for which it is to be used as a detector, and the vibrations of the mica diaphragm are detected and measured as follows: The mica disk carries a sharp steel point firmly clamped at its center. A narrow steel strip is suitably held taut at both extremities in a fork capable of adjustment, and the strip has its center in contact with the steel point, so that a slight movement of the disk and point gives the strip a corresponding twist. This twist is detected by the movement of a beam of light reflected from a small concave mirror carried by the strip.

The diaphone may be worked backward and is then called the "phone" or standard generator. When its diaphragm is made to oscillate through a known amplitude it is possible to calculate the numerical characteristics of the spherical sound waves emitted. By the use of the "phone" and the "phonometer" the acoustic output of any sound generator of the same pitch (such as violin, cornet, or human voice) may be calculated.

Section five is on aerial sound waves of large amplitude and the discontinuity that may be expected to occur in their propagation. In the sixth section the thermodynamic estimate of acoustic efficiency is treated. By the use of resistance thermometers of iron wire one one-thousandth inch in diameter the temperature fall of the air, due to the conversion of the compressed air energy into sound, was measured in the diaphone.

Section seven deals with the actual fog-signal experiments carried out near Quebec in 1913. The acoustic efficiency of the diaphone in one case was found to be nearly 6 per cent, in another a little over 8 per cent. Using his phonometer A. G. Webster had previously found the violin, the cornet, and the human voice to have acoustic efficiencies of about 0.05 per cent, 0.1 per cent, and 1 per cent, respectively.

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[1] Comptes Rendus, Paris, Oct. 2, 1916, 163: 323-324.
[2] Jour., Franklin Inst., Philadelphia, Mar., 1917, 183: 259-286.
[3] Phil. Mag., 1903, 6: 289-305.