The anterior body-cavity is now small and lies near the oral end in the body-wall. Into it opens the water-tube or stone-canal, which runs from the water-vascular ring in the oral longitudinal mesentery, and is distinguishable from the anterior body-cavity by its higher epithelium. It is not, therefore, in direct continuity with the water-pore. The anus opens externally in the same interradius as the water-pore.

The Skeleton remains to be described. Shortly after the orals and basals have appeared, three small plates are developed at the posterior end of the stem, which resemble the basals in form but are not derived from them. They are so arranged that the most dorsal, which is smaller than the other two, lies on the right side opposite the interradius of the water-pore. These three plates are the undoubted homologues of the under-basals of the dicyclic Crinoids (*Poteriocrinus*, *Encrinus*, *&c.*). Shortly after the fixation of the larva they fuse with one another and with the top stem-joint, so as to form a large plate which has hitherto been mistaken for a simple centrodorsal. The five radial angles of this plate belong to the under-basals, and it is only at a much later period that these angles are hidden by the growth of the true centrodorsal (= top stem-joint), the angles of which become interradial when its cirri appear.

IV. "Heat Dilatation of Metals from low Temperatures." By THOMAS ANDREWS, F.R.S.E. Communicated by Professor G. G. STOKES, P.R.S. Received November 30, 1887.

It is understood that the coefficients of heat dilatation increase with rise of temperature; but Professor P. G. Tait, in his recent work on 'Heat,' p. 87, remarks that "we are not aware of any experiments made with a view of deciding whether, as is probable, these coefficients become gradually less as the temperature is lowered below zero" (0° C.).

The following experiments were made to investigate the subject in relation to metals of the iron and steel series. The varieties of modern steels manufactured by recent processes manifest properties sufficiently diverse as almost to constitute them distinct groups of metals, although for practical purposes they are conveniently grouped under the generic name of steel. Some of these modern metals have recently been so largely used for constructive purposes that the author considered it desirable to obtain an approximate quantitative estimation of their dilatation by heat through varied ranges of temperature. The rolled metals under observation in the experiments consisted of round polished bars, 3 inches diameter, and 13 inches long, planed perfectly square at each end; they were care-

Table I.

Analyses of Wrought Iron, Steels, and Cast Metals employed.

Rolled Bars.

Description.	Graphitic carbon.	Combined carbon.	Silicon.	Sulphur.	Phos-phorus.	Manganese.	Iron (by difference).	Total.	Specific gravity.
Wrought iron (Wortley best scrap) .	..	None.	0·392	0·034	0·270	0·194	99·110	100	7·590
Bessemer steel, "soft"	..	0·150	0·009	0·112	0·088	0·468	99·173	100	7·853
" "hard"	..	0·480	0·121	0·096	0·089	0·684	98·530	100	7·838
Siemens-Martin steel, "soft"	..	0·230	0·014	0·100	0·075	0·698	98·883	100	7·856
" "hard"	..	0·460	0·107	0·023	0·075	0·972	98·363	100	7·845
Cast steel, "soft"	..	0·450	0·016	0·027	0·048	0·086	99·373	100	7·863
" "hard"	0·259	1·190*	0·175	0·063	0·019	0·396	97·898	100	7·805
Cast metal "best"	2·780	0·390*	2·340	0·090	0·580	0·450	93·370	100	7·206
" "common"	2·620	0·670*	1·940	0·090	0·950	0·520	93·210	100	7·134
Hammered Forgings.									
Wrought iron (Wortley best scrap).	..	0·038	0·117	0·019	0·246	0·112	99·468	100	

* Combined carbon in these samples was determined by combustion, and in the other samples by the colour test.

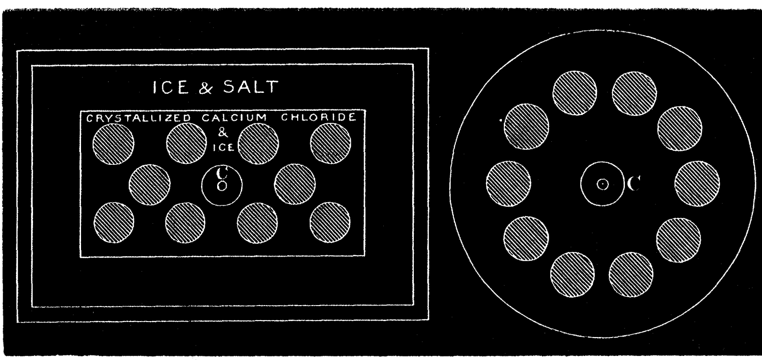
The terms "soft" and "hard" relate only to difference of percentage of combined carbon, and not to any annealing or hardening processes. The metals were so prepared as to obtain a wide difference in the percentage of combined carbon between the "soft" and "hard" varieties.

fully manipulated during manufacture, and were selected from the author's standard samples, having the chemical composition given in Table I.

The range of temperature chosen for the observations was from —45° C. to 300° C.

The experiments were conducted as follows :—For the measurements commencing at the low temperature of —45° C., the bars (having previously been slowly reduced to the temperature of 0°C., and then gradually cooled to —18° C.) were placed upright in the bath A (see fig.), and immersed in a freezing-mixture of three parts of calcium chloride and two parts of snow, each of these ingredients previous to mixing being maintained in separate jacketed freezing

Bath A for Temperature of —45° C. Bath B for Temperature of —18° C.



Ground Plan. Ground Plan.

Scale, $\frac{3}{4}$ inch = 1 foot.

tanks at a temperature of —18° C. The vessel A, containing the bars and the calcium chloride freezing-mixture, was further surrounded by another compartment holding a quantity of a freezing-mixture of snow and salt at a temperature of —20° C. By this means and by constantly renewing the calcium chloride and snow mixture during the experiments, an uniform temperature of —45° C., as registered by an alcohol thermometer, was maintained for the experiments in the cold bath A.

Much larger cooling tanks of a snow capacity for each charge of 8 cwts. were used for the large forgings, and a large cast metal oil-bath having a capacity of about 70 gallons of oil was used for the highest temperature.

The bars remained thus immersed in the freezing bath whilst their internal temperature was regularly ascertained by another alcohol thermometer placed in a hole in the centre of the test bar C,

wherein was also placed a little alcohol. When the bars had reached and remained for some time at the registered temperature of $-45°$ C., each was in turn removed and placed on a suitable wooden frame, and its length instantly and carefully measured by telescopic readings from a delicate micro-vernier gauge (deviations of $\frac{1}{2000}$ of an inch were perceptible) also supported on a suitable rigid stand. The bars were then replaced for a short time in the freezing-mixture and again removed and their diameter then carefully measured. No perceptible alteration in the temperature of the bars occurred during the very short time occupied in taking the observations, and frequent tests were made to ascertain this. The average of about thirty measurements in each case, both longitudinal and transverse, was regarded as fairly accurate. The dimensions of the bars were taken in a similar manner for the temperature from $-18°$ C., substituting in another cold bath, B, a freezing-mixture of snow and salt to obtain this temperature, and using powdered ice and snow for the observations at 0° C. The higher temperature observations were obtained by heating the whole of the bars in a large hot-water bath for the period necessary to insure that their temperature throughout was as required, and the oil bath was used for the temperature of 300° C. Liability to temperature errors was, as far as possible, carefully guarded against by constant reference and comparison between the bath thermometers and that in the centre of the test bar, and by keeping the bars immersed during sufficiently long periods.

The hammered metals under observation were large forgings of the different metals 7 feet 3 inches long, and 5 inches diameter, planed perfectly square at the ends and turned and polished bright. The measurements were taken on the total length of the forgings, as in the case of the rolled metals, to ensure greater accuracy, the experiments being conducted in somewhat similar manner: but owing to the greater length of the forgings, a modification of the method was made. One end of the forging was rigidly secured and the expansion ascertained by measuring the diminishing space between the other end of the forging and a fixed point situated a distance from it. The results are recorded on Table II.

General Remarks.

It is interesting to notice that the coefficients of dilatation were greater in the case of the "soft" than the "hard" steels, a circumstance which may be accounted for by a reference to Table I of the analyses, from which it will be seen that the percentage of combined carbon was much lower in the "soft" than in the "hard" steels, the percentage of pure iron was consequently also greater in the "soft" steels, this caused them to be of a greater specific gravity. The

Table II.

Rolled Bars.

Description.	Coefficients of linear dilatation for 1° C. between			1000 parts at −45° C. became at 300° C.	
	−45° and 100° C.	−18° and 100° C.	100° and 300° C.	Longitudinal.	Across the diameter.
Wrought iron (Wortley best scrap)	0·0000086	0·0000114	0·0000133	1003·638	1003·588
Bessemer steel, "soft"	0·0000093	0·0000117	0·0000159	1004·133	1003·944
,, "hard"	0·0000085	0·0000101	0·0000133	1003·746	1004·322
Siemens-Martin steel, "soft"	0·0000088	0·0000116	0·0000144	1003·807	1003·946
,, "hard"	0·0000079	0·0000100	0·0000139	1003·731	1003·570
Cast steel, "soft"	0·0000086	0·0000112	0·0000150	1003·755	1003·502
,, "hard"	0·0000084	0·0000101	0·0000130	1003·577	1003·411
Cast metal "best"	0·0000088	..	0·0000137	1003·637	1003·621
,, "common"	0·0000088	0·0000090	0·0000152	1003·784	1003·579

Large hammered Forgings.

Description.	−45° and 100° C.	−18° and 100° C.	100° and 300° C.	1000 parts at 0° C. became at 300° C. Longitudinal.	1000 parts at 0° C. became at 300° C. Across the diameter.
Wrought iron (Wortley best scrap)	0·0000096	0·0000117	0·0000131	1003·944	1003·537
Do. do.*	0·0000081	0·0000104	0·0000157	1003·790	1003·330
Bessemer steel	0·0000099	0·0000107	0·0000137	1003·829	1003·601
Siemens-Martin steel	0·0000093	0·0000113	0·0000142	1003·953	1003·641

* This was a smaller forging, only 3 inches diameter and 13 inches long.

results on Table II appear also to indicate another circumstance of metallurgical interest, viz., that the dilatation was generally rather more in the direction of the length of the metallic cylinders than when measured across the diameter, numerous repeated experiments confirmed this. The result appears more marked in the large round forgings of hammered steels and wrought iron than in the case of the rolled bars. It would therefore seem probable that the crystalline particles of the metals suffer slight permanent alteration of form in the direction of their length during the process of rolling or drawing out, sufficient to very slightly affect their relative longitudinal and transverse dilatations.

Furthermore, the observations of this memoir, conducted at these very low temperatures, experimentally confirm the suggestion of Professor Tait, inasmuch as the coefficients of dilatation were found generally to decrease with the reduced temperature below 0°C. The author also found such to be the case in his observations on the "Heat Dilatation of pure Ice from very low Temperatures." (See 'Roy. Soc. Proc.,' June, 1886, No. 245, p. 544.)

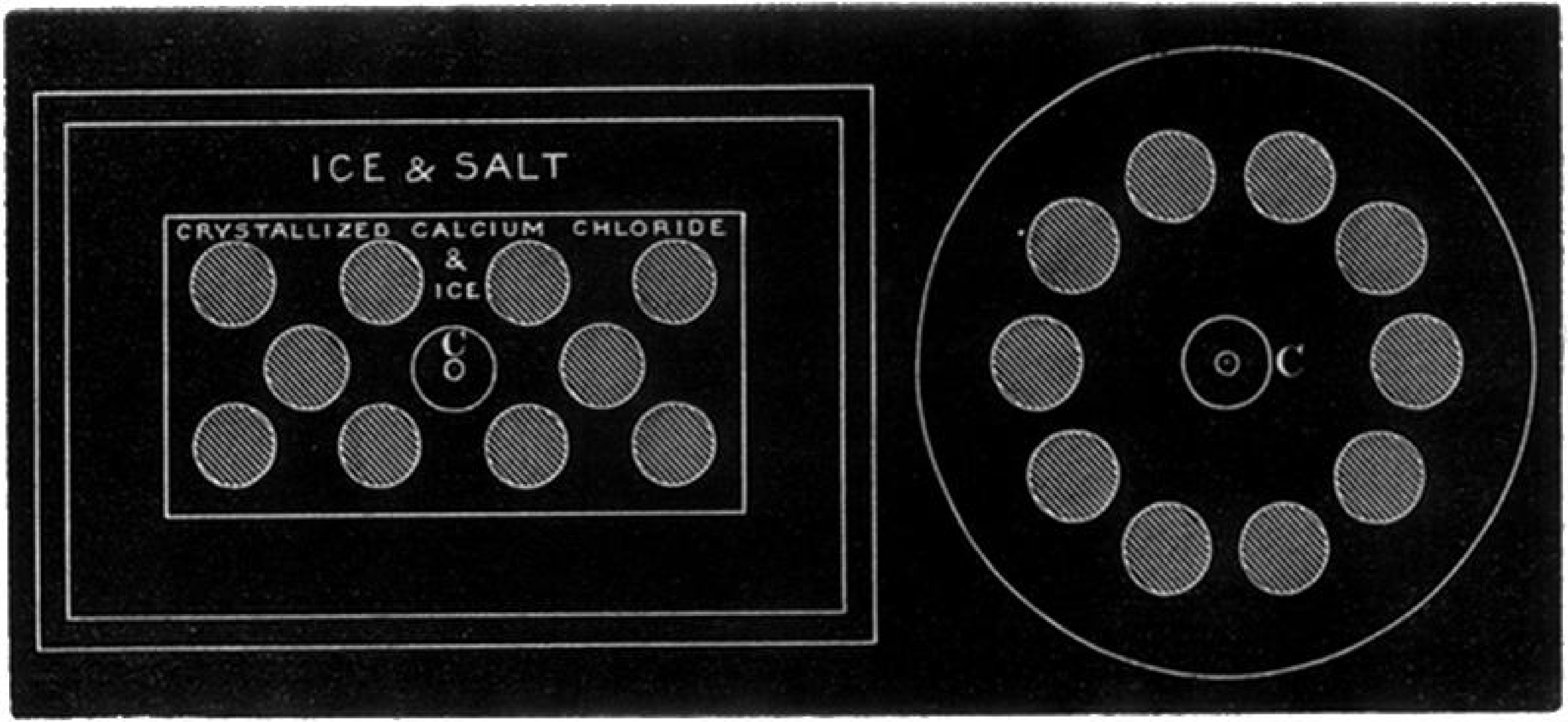
It may be remarked that many tons of the various freezing mixtures, snow, &c., were required for the experiments.

Appendix.—Received January 12, 1888.

I think it would be misleading to use the figures, given in the second column (Table II), of the dilatation from −18° C. to 100° C. for purposes of exact comparison with the other results. The coefficients for dilatation between the small margin of −45° C. and −18° C. could not be accurately inferred from the results recorded in Table B, because the series of experiments from −18° C. to 100° C. were not made consecutively with the other observations. The molecular condition of the metals in that series (−18° C. to 100° C.) I consider was probably somewhat different. Judging from the whole of the results over the wider ranges of temperature, I do not think that the coefficients for the temperature between −45° C. and −18° C., whenever specially determined, will be found to be of a comparative negative character, or vitiate the general conclusions arrived at in this paper. The whole series of observations I believe coincide in establishing the reduction of the coefficients of heat dilatation with reduced temperature. I hope to make further investigations at these low temperatures.

The Society adjourned over the Christmas Recess to Thursday, January 12th, 1888.

Bath A for Temperature of $-45°$ C. Bath B for Temperature of $-18°$ C.



Ground Plan. Ground Plan.

Scale, $\frac{3}{4}$ inch = 1 foot.