Monitor, and a large number of volumes dealing with the South African war of 1899–1902. The catalogue also includes more than sixty oil paintings by James Baines, who had a wide experience of southern tropical Africa, and was with Livingstone on his Zambezi expedition. The only other known collections of Baines's pictures are in the possession of the Royal Geographical Society and the museum at Kew Gardens. The catalogue is exclusive of Mediterranean Africa and the Red Sea border.

OUR ASTRONOMICAL COLUMN.

SUN-SPOTS AND PRESSURE.—A paper dealing with pressure data has been received from Dr. Gilbert S. Walker, who is engaged on a comprehensive statistical investigation in world meteorology with the object of laying the foundation of a secure system of seasonal weather forecasting. The data are treated as in the case of rainfall and temperature in preceding papers. For pressure the Indian area is characterised by negative correlation coefficients, whilst in the western hemisphere and boreal regions the opposite sign prevails. A general tendency is observable for the pressure coefficients to be opposite in sign to those for rainfall, indicating that their variations are dominated by a common cause, and temperature would seem to have little influence on either. Humidity, especially in the upper air, appears to control the relationship between sun-spots and temperature (Mem. Indian Met. Dept., vol. xxi., part xii., No. vi.).

HARMONIC ANALYSIS OF THE MOTIONS OF THE HELIUM STARS.—The dynamics of our stellar system are engaging an increasing degree of attention, and although Alcyone, and, recently, Canopus have been the suggested super-suns, it is still a question of establishing the existence of the general orbital movement. Prof. von S. Oppenheim adopts the working hypothesis that such movement exists, and some results of his work in this field were recently noted in this column (October 21). In an earlier investigation Prof. Oppenheim employed harmonic analysis to answer cognate questions. This is now recalled because these investigations have lately been carried a stage further (*Astronomische Nachrichten,* 4822). Pursuing the analogy drawn from the swarm of minor planets, he observes that a precise parallelism probably exists if instead of dealing with the totality of the stars the movements of the galaxy-grouping helium stars (type B) are alone taken into account. Employing the methods of the earlier papers to deal with the Lick results for the radial velocities of 233 stars of this type, taking proper motions from the Boss Catalogue, and making an approximation in regard to parallax, he finally obtains as developments of expressions involving respectively proper motions and radial velocities two Fourier series the terms of which are in good agreement regarding an orbital position angle of the sun, a result considered to establish the reality of the original hypothesis (*i.e.* that the stars, including the sun, move in circular orbits about one ideal centre). The numerical results which may be specially mentioned concern the position of this centre. Taking $\Omega = 234^\circ\ 40'$ as the ascending node of the plane of the sun's way, with inclination $i = 53^\circ$, then the sun viewed from the centre of the system appears in R.A. $203^\circ\ 55'$, declination $-34^\circ\ 9'$. The corresponding apex of the solar motion is R.A. 266°, and declination $+34^\circ\ 37'$.

THE ASTRONOMICAL AND ASTROPHYSICAL SOCIETY OF AMERICA.—We have received a copy of the second volume of the publications of this peripatetic society. The meetings reported range from the eleventh, 1910—attended by a number of important English astronomers—to the fifteenth, 1913. Abstracts are given of the papers. A most important feature of the volume is an appendix devoted to Halley's comet. The special committee of the Astronomical Society made suggestions that led to Mr. Ferdinand Ellerman taking an expedition to Honolulu to secure a record of the appearances presented by the comet during the spring of 1910. Two cameras were employed, a 6-in. Brashear, f.l. 31·8 in., and a Bausch and Lomb Tessar lens of 57 mm. aperture, and 251 mm. f.l. The greatest length of tail photographed with the latter was 50° on May 14. The photographs obtained are described by Prof. E. E. Barnard, and no fewer than forty-seven are reproduced. The dates range from April 26–June 6. The Comet Committee also publish a very extensive index catalogue of photographs of the comet, giving date, time of exposure, optical constants, place, and an indication of the technical quality of the photograph.

PROBLEMS OF EFFICIENT METHODS OF DOMESTIC HEATING.

THE determination of the efficiencies of different methods of heating is a problem very difficult to solve on a purely scientific basis. It is, indeed, difficult to attach a precise meaning to the expression "efficiency" in connection with heating apparatus. The word as commonly understood in connection with devices for the utilisation of energy in any form means the ratio of the total amount of energy utilised to that consumed. In a heating apparatus it is difficult to say what fraction of the energy is to be regarded as "utilised." If we regard that heat only as utilised which is delivered into *the air* of a room, in one sense every apparatus which when suitably disposed delivers almost the whole of its heat into the air of a room may be regarded as having nearly the maximum possible efficiency—100 per cent. Such, for example, is the electric low-temperature stove (not taking into account the generating mechanism or boilers from which the heat is ultimately derived), or the oil stove, or the gas radiator, which deliver the products of combustion into the air of the room.

But heat is delivered into a room not only by convection currents of heated air, but also by the conversion of radiant energy into heat. The proportion of the radiant energy which may be converted into heat is essentially uncertain. It depends on the position of the radiant body relatively to the windows, walls, furniture, etc., and on other circumstances. If therefore the "efficiency" of the apparatus depends on such extraneous considerations, it is evidently out of place to use, in connection with this matter, such a word as "efficiency," which has a precisely defined significance. Alternatively we are debarred from regarding the air heat as the only "utilised" energy.

Functionally, a heating apparatus is one by which a certain amount of heat energy is passed through a room to the outer air. As a consequence of its passage, certain thermal and other conditions in the room are maintained. If the resistance interposed between the room and the outer air is relatively high, the same flow of heat will maintain a higher temperature than if the resistance is low. In the limit if the resistance were supposed infinitely great, the thermal conditions might be conceived to be maintained without any expenditure of heat whatever. It will thus be evident that the word "efficiency" in connection with heating apparatus can have only a relative and not an absolute significance. At the best we can only compare the efficiency of different methods of heating relatively. But even in this the difficulties are at least equally great.

The only possible experimental means would be to maintain the same room in the same conditions in the same circumstances by each of the two methods, and to compare the amounts of energy expended in the two cases. But different methods of heating produce in the room widely different and varying thermal results which are very difficult either to compare, control, detect, or even to define. In a practical experiment on an existing room, it is impossible to exercise any control over the out-of-door conditions, such as the temperature, the humidity, and the air movement, otherwise than by enclosing the test building in another outer shell. This at once makes the experiment unreal and artificial, and could only be applied to a very few specially constructed rooms.

As regards the indoor conditions, we have simultaneously and independently to control and to measure the interchange, the humidity, and the movement, as well as certain obscure electrical conditions of the air, the air temperature, and what may be called the radiant temperature, which is an entirely independent function. All these factors are extremely difficult, either to control with accuracy or to measure. They all vary in different parts of the same room; the variation of any one of them would be sufficient to vitiate the scientific accuracy of any exact experiment. The loss of heat from a room depends to a notable degree on variations in all such factors, especially on the uncontrollable exterior conditions. Even so apparently simple a function as the internal temperature cannot be obtained even approximately by that of a simple thermometer. This latter reading depends on the shape, the nature of the surface, the mass, and material, of the thermometer itself. The radiant temperature especially varies from point to point over the whole area of a room heated by a hot body within it. A scientific comparison would therefore be of so unwieldy a nature that it would be almost useless as a practical guide.

A practical comparison can only be made with the reservation that such a comparison would not bear the brunt of scientific criticism. It would be impossible without some pedantry to leave out of count the practical object of all systems of heating, namely, to render the room heated comfortable to inhabit. A system which did not produce this result would be valueless, however theoretically "efficient" it might be. This introduces variations of individual idiosyncrasy. What is comfortable for one person is not so regarded by another. The physiologist and hygienist have also to be heard on the question. Conditions which are often regarded as comfortable may be notoriously unhealthy. Amid this diversity of considerations, it is difficult to establish a basis even of relative heating efficiency without laying down arbitrary conditions which may have little or no relation to the real problems involved. It is evident that the conditions to be produced must be specified in terms of physics and chemistry, so as to take the matter out of the subjective region.

The temperature condition of a room is very uncertain and difficult to ascertain, as the naked thermometer is a very untrustworthy criterion of the temperature of the air; it is equally so of the feeling of warmth in a room. Indeed its reading in a heated room indicates nothing but its own temperature. It is possible to obtain from different kinds of correct thermometers at the same point in a heated room indications which vary by as much as 10° or 12°. The true air temperature at the same point may be far different from either of the two. It is impossible to say which of these is the "correct temperature" without laying down arbitrary conditions. Thus it is absurd to take the identity of the reading of ordinary thermometers on two separate occasions as an indication that the room is in the same temperature condition on the two occasions. If it could be proved that the identity of the thermometer reading produced a similar sensation of warmth the practical significance of this objection might vanish, but this is notoriously untrue. The feeling of warmth is an exceedingly complex matter, and can only be measured by a different instrument altogether—a kind of electrical calorimeter, which has to be proved by physiological experiments of the most difficult character to give a true criterion of the feeling of warmth.

It would be futile even to make any comparison without taking account of the interchange of air. To estimate or control this is as difficult an experimental problem as any previously alluded to. It can only be done by introducing into and thoroughly mixing with the air of the room known quantities of an easily recognised gas, and afterwards making periodic analyses of the air at intervals. Mathematical calculations based on the results of these observations will then give the actual interchange. This complicated determination must be made, otherwise any possible kind of test would be altogether untrustworthy. The interchange of air generally accounts for half the total loss of heat.

As a rough practical basis of comparison between different systems of heating, we may take the relative amounts of energy necessary to be employed in a room in order to produce the same feeling of warmth as measured by a suitably calibrated instrument (not a thermometer), while maintaining approximately the same interchange of air.

The subjoined table is based on direct experiment in this sense, and refers to the cost of continuous uniform heating in certain natural or normal conditions, the full description of which would occupy much space. An alteration of the conditions would undoubtedly alter the percentages given. These values cannot, however, in any event be taken as the *practical* relative costs, because of the manner in which the respective methods of heating are commonly employed in practice. A hot-water heater or anthracite stove is generally burning all the day and frequently at night. A gas fire or electrical stove is usually turned off when the occupant leaves the room. When these latter agents are so employed, the function of the heater is not to maintain a continuous constant temperature throughout the room, but to provide rapidly and temporarily such radiant conditions, that the region near the heater is in a thermal condition (including the radiant condition), tolerable for persons to sit there. There is a wide difference between this and the maintenance of a continuous temperature throughout the room, and a set comparison between the "cost efficiency" is therefore misleading. Indeed, a comparison of cost cannot be reasonably made without a good deal of definition of requirements. It is probable, for instance, that in certain circumstances a good gas stove is a cheaper method of heating an occasionally used room than is an anthracite stove, although the cost efficiency of the latter is far below (*i.e.* more economical than) the former.

In order to enable the running cost to be calculated at different prices of the fuel (including in that term electrical power), it will be desirable to quote the relative equivalents of different agents, as compared with 1000 Board of Trade units of electrical energy.

TABLE OF EFFICIENCIES FOR CONTINUOUS HEATING.

The rates given are those current in London previous to the war and at present:—

Approximate equivalents.		Nominal relative Thermal efficiency.	Rates per unit.	Gross cost £	Relative cost
Electric Radiator.					
1,000	Board of Trade Units of Electrical energy utilised in best radiant stove of 69% radiant efficiency disposed in the best manner .	Per cent. 100	1½*d.* 3*d.* 5*d.* 6*d.*	6·25 12·5 20·8 25	100 200 335 400
Open Fire.					
1·38 tons of best house coal, 14,000 B.T.U. per lb.	Burnt in bad grate unsuitably disposed.	8	26/- 35/-	1·8 2·42	29 39
0·520 ton best house coal, 14,000 B.T.U. per lb.	Burnt in best open modern grate sunk in wall	21	26/- 35/-	0·675 0·91	10·8 14·6
Closed Anthracite Stove.					
0·235 ton best anthracite, 14,500 B.T.U. per lb.	Burnt in best modern slow combustion, closed anthracite stove ...	45	40/- 50/-	0·47 0·59	7·54 9·42
Gas Stove.					
18,300 cub. ft. gas, at 520 B.T.U. per cub. ft. ...	Burnt in medium old-fashioned gas fire (not worst type) ...	36	2/6 3/-	2·29 2·75	36·6 44
10,700 cub. ft. gas, 520 B.T.U. per cub. ft. ..	Burnt in best modern ventilating gas stove	62	2/6 3/-	1·34 1·60	21·3 25·6
Water Radiators.					
0·198 ton of coke, 12,500 B.T.U. per lb.	Burnt in best provided modern water boiler with well-clothed circulation to radiators or pipes .	62	20/- 30/-	0·198 0·297	3·17 4·75
0·306 ton of coke, 12,500 B.T.U. per lb.	In usual small house hot water installation as generally installed	40	20/- 30/-	0·306 0·459	4·9 7·36
Oil Stove.					
19·5 gallons petroleum 0·87 gravity, 20,240 B.T.U. per lb.	Completely burnt in any kind of stove discharging products into air of room .	100	8*d.* 10*d.*	0·650 0·810	10·4 13·0

ARTHUR H. BARKER.

THE PHYSIOLOGY OF INDUSTRIAL FATIGUE.[1]

THE gradual recognition of the prevalence among industrial workers of severe physical or mental fatigue has led during the last few years to a closer study of its harmful effects and to various suggestions as to its prevention. Although moderate fatigue is a healthy and natural event, there is little doubt that unduly prolonged hours of work, particularly if the work is carried on under unfavourable hygienic conditions, may lead to such a degree of fatigue that the efficiency and health of the worker are seriously impaired. The decline in efficiency manifests itself not only in a smaller output of work, but also in many occupations by an increased liability to accidents.

The prevention of extreme fatigue is, therefore, a matter of great importance, both to the employer and to the worker; but hitherto one of the most serious difficulties in the consideration of the problem has been the lack of any simple and certain test for the presence of fatigue. The question of finding a suitable index of fatigue has recently been taken up by Prof. Stanley Kent, and the preliminary results of his investigation are recorded in a report on industrial fatigue, which has been issued by the Home Office. Prof. Kent examined the influence of fatigue upon certain physiological phenomena, namely, the arterial blood-pressure, the reaction time in response to a simple stimulus, the acuity of hearing and of vision. The acuity of hearing was determined by noting the distance from the ear at which the ticking of a watch could be heard, and the acuity of vision was ascertained by noting the distance at which certain letters (test types) could be recognised.

The main experiments were carried out on three groups of workers—one group of six colliers, one group of six workmen in a chemical works, and one of six workers in the printing trade. The tests were applied twice daily, once before and once after the day's work, over a period of a week or more.

The experiments on the arterial blood-pressure and the reaction time yielded irregular and discordant results, but it was found that there was a striking diminution in the acuity of both vision and hearing at the end of the day's work, and that in many cases there was a progressive decline during the course of the week. The latter effect might be regarded as evidence of cumulative fatigue towards the end of the week. The decline in visual or auditory acuity was observed in all three groups of workers; in some members of each group the diminution amounted to 50 per cent. or more, whereas in others the change was so slight as probably to fall within the limits of normal daily variation apart from fatigue. The large variations in visual or auditory acuity in the same person on successive mornings, or on successive Monday mornings, when the subject was presumably not fatigued, are a prominent feature in Prof. Kent's results. These variations rather suggest that the subjective factor (as distinct from fatigue) is an important element in the test; and the fact that the test is purely "subjective," and that there is no means of checking the worker's statement as to the distance at which he hears a watch or sees a standard letter, is a distinct drawback to these tests.

Prof. Kent's observations also make it clear that, in some individuals, a day's work or a week's work leads to impairment of hearing but not of vision, or, on the contrary, to impairment of vision but not of hearing. This was noticed in each group of workers. It might be expected that, if the decline in visual or auditory acuity is a manifestation of general fatigue,

[1] Report on an Investigation of Industrial Fatigue by Physiological Methods. By Prof. A. F. S. Kent. (Home Office.)