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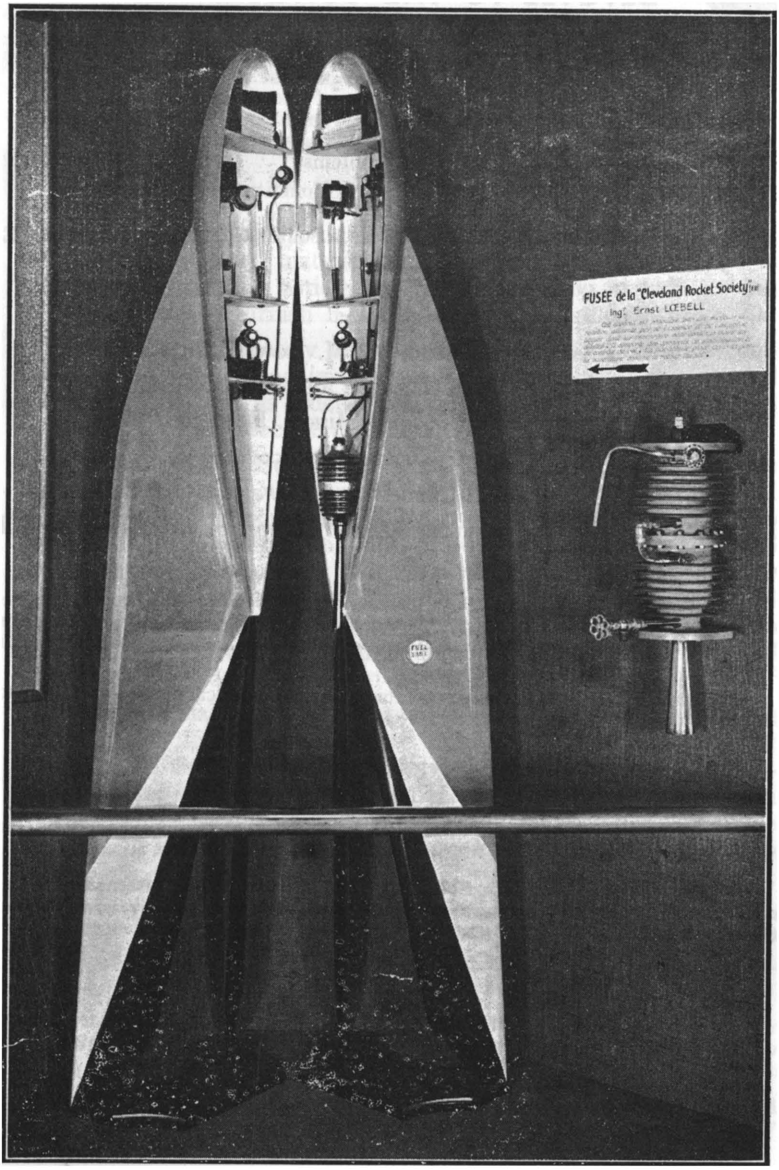

Space Ship Model displayed at the Paris Exhibition. *See article*

THE BRITISH INTERPLANETARY SOCIETY

DEVOTED TO THE CONQUEST OF SPACE

> "Founded for the stimulation of public interest in the possibility of interplanetary travel, the dissemination of knowledge concerning the problems which the epock-making achievement of an extra-terrestrial voyage involves, and the conducting of practical research in connection with such problems."
>
> Constitution of the Society.

Headquarter's Address: 92 Larkswood Road, South Chingford, London, E.4

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The annual subscription for three classes of membership are: Active Membership, 10/6 : Associate Membership, 7/6 : Associateship, 2/6. Quarterly subscriptions for the former two are taken at 3/- and 2/- respectively. All subscriptions date from time of election to the Society.

All members receive free copies of the Society's publications, as well as such available literature obtainable from other Rocket Societies.

THE RESEARCH FUND

The Research Fund has been established for the purpose of financing rocket and other astronautical research in the British Isles. All contributions should be sent to the Treasurer, and requests for further particulars from the Hon. Secretary at HQ.

Neither the Society as a body nor the Editor hold themselves responsible for the statements made or the opinions expressed by contributors to the Journal.

ON THE COVER OF THIS ISSUE

is shown a photograph of the half-scale model rocket of the Cleveland Rocket Society, which was on view at the "Palais de la Decouverte" in the Paris International Exhibition, 1937, and mentioned by Robert Lencement in this issue.

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JOURNAL

OF THE

BRITISH INTERPLANETARY SOCIETY

Edited by EDWARD J. CARNELL

No. X. December 1937 Vol. 4. No.2

EDITORIAL

Here, at last, is the much-heralded first London issue of the " Journal." As my predecessor did in the last one, so also must I apologise for the delay, due to an enforced change of copy after most of the proposed material had been edited. I had hoped to include an interesting article by Willy Ley, now in U.S.A., but he was unable to furnish it within the period given.

You will immediately observe the difference in contents comprising this issue, as against previous " Journal's "; the Council wishing to give you as much technical information as is available. I hope that you appreciate the change.

Regarding the issue being dated " December, 1937," this is because two issues were scheduled for last year—and dare I prophesy it ?—it is hoped to publish two for this year as well. To be assured of accomplishing this, however, it is sincerely hoped that each one of you will endeavour to obtain at least one new member during the next few months. By doing this, you will enable us to extend our present activities considerably, and also guarantee those two promised issues of the " Journal." Will you do this small thing as part of your work for the Society ?

Astronautical activities seemed to have ceased round the world lately, nothing having been done in U.S.A., Germany, or Austria. In Calcutta, India, however, after his successful Coronation rocket experiments, Stephen H. Smith built and launched a rocket train of three compartments, which travelled a considerable distance. Meanwhile, in Britain, apart from our own work, the Paisley Rocketeers' Society (now an affiliated B.I.S. group), successfully fired Experimental Rockets 45, 46 and 47 in Scotland, the latter being of the three-step principle.

Here, however, is the place to give you the President's message, which is upon

PIONEERING.

By Professor A. M. Low, D.Sc.

I never like New Year messages because they seem to imply that one period of time is necessarily more important than another. But I think that appreciation is often useful, and I am hoping that this " commodity " will arrive in a large share amongst the members of the Interplanetary Society during 1938.

We are pioneers, and a pioneer might be defined as someone who helps everyone but himself. In this respect the Society has yet to receive its proper measure of public support, for it is doing work which can be of vital importance to the whole community. I am thankful to say that the international aspect of space travel has helped to destroy much of the ignorant criticism under which we have suffered for so long.

In nearly all great scientific ventures, those who bore the brunt of early research and early experiment have been called ignorant. They were ignorant, perhaps, of limitation. They knew that nothing in the world is impossible that can be conceived by the mind of man.

Space travel will ultimately become an accomplished fact and I cannot put too much enthusiasm into my request that more and more members will be sought for by each one of you. It is necessary to influence public opinion. We must explain that we are not peculiar people who desire to go to the Moon like children who cry for a new toy.

To me there is one useful analogy . . . . Many years ago the temperature at which hydrogen could be liquified was unknown, but it was calculated with complete accuracy and long afterwards these figures were checked in detail by the aid of apparatus which could at last be constructed and put to practical use. It is much the same with the Interplanetary Society. We know perfectly well that space ships are a matter of time and patient research.

Research of all kinds needs encouragement, not only monetary, but by the thought and good wishes of other people. I regard it as our duty to " tell the world " as the expression has it, that we are not content to say glibly " we want to be shot by a rocket to the Moon." No detail has been too small for our members to consider. Problems of temperature, gravity, food, atmosphere, how to get back to earth, the utility value of this great venture, all have been planned in detail.

That these plans are romantic as well as scientific remains to be fully realised. They are plans based on skilled experiments, and based upon research with which every country of the world is vitally concerned. I find that an evening spent in the company of the Society is enthralling, and I would like others to know how practical, cautious and entertaining are our views. Vulgarly speaking, I want to say to everyone " Come and see for yourself," for observation is science by another name.

POLICY OF THE B.I.S.

R. A. Smith.

When the Liverpool members decided to transfer the Society to London, they made it possible to approach more nearly the description implied in the title " British Interplanetary Society." By moving the headquarters of the Society to the centre of greatest density of membership geographically, a wider choice of personnel was made available ; the Society ceased to be a provincial organisation in the eyes of the public, and it became possible to form an effective and competent Technical Committee.

The fact that the membership consists on the one hand of those who believe Space should be crossed if we can find the means to do so whilst others believe it should be done because we can do it, leads to greater difficulties in the formation of an acceptable policy than are immediately apparent. The discussions which have taken place at the monthly meetings, and in the Technical Committee, have however, gone so far in the reconciliation of these two points of view as to make it possible at last to reach agreement as to the best course to pursue.

We have decided to concentrate our attention on the task of meriting a reputation for sound scientific work, by undertaking a survey of the whole problem, such as will attract the interest of the scientific world and command the respect of the layman.

Any attempt to remodel our Society on the lines of any existing Societies is foredoomed to failure, because of one of its fundamental peculiarities.

Our Society has to promote an entirely new industry and is not in the position to offer its members any immediate return, financially, for their support and interest.

It would be difficult to persuade anybody that the holding of a diploma, or degree, granted by us, would automatically entitle the holder to lucrative employment. I regret to say, that with the average industrialist, it would seem more in the nature of a substitute for Certification. In due course—and shortly—I hope they will be disillusioned. The time when the activities of our Society will have a very considerable effect on human affairs is a great deal closer than many have been led to suppose. How near, depends upon the effectiveness of our present policy, and the enthusiasm with which it is pursued.

The fundamental of our policy is the demonstration of the fact that only a comparatively small amount of research and development will be required to make it possible to undertake a voyage to our Satellite, with a reasonable assurance of a successful outcome, and yet within the realms of financial probability.

We are convinced of this ourselves because we have studied the subject and are certain that others will be convinced if they can only be persuaded to do the same.

The fact that the progress made to date is not very convincing is easily explicable. This task is the most complex problem yet presented to Man's ingenuity. A close knowledge of a diversity of subjects is needed for its solution. So wide a diversity in fact, as to render it improbable that any one individual, no matter how talented, can hope to bring the problem appreciably nearer solution. It can only be done by the whole-hearted co-operation of many.

The results obtained by the Technical Committee go far to show how successful a methodical co-operation can be made. A preliminary survey has revealed that the suggestions as to the cost of this enterprise which have been previously made, are gross exaggerations. New methods of approach to this problem have already been examined, and show every indication of leading to a successful conclusion. The sums of money needed to complete our research are large, but not beyond the means of many existing public benefactors. If we can succeed in attracting the support this project merits in the right quarters, we can definitely promise that the first voyage into Space will be undertaken within fifteen years from now, allowing for all foreseeable contingencies.

Here, then, is the outline of our policy.

We shall endeavour to maintain the popular interest in the Society by providing in addition to the Journal, a monthly Bulletin, which will carry the immediate news items of the Society's activities, thus leaving the Journal free for more permanently valuable contributions. We are concluding arrangements whereby a technical supplement to the Bulletin will become available. Details of this supplement must be left until the arrangements have been completed. We have succeeded in arranging for articles of interest to the membership to receive publication in certain well known periodicals, and will arrange for members to be informed when they are due to appear.

The membership and scope of the Technical Committee will be progressively enlarged, until all those who have the aptitude, and opportunity, are included. The monthly meeting will be continued, and in addition to the lectures and debates such as we have been having, a new feature will be introduced.

Members wishing to join the Technical Committee will be asked to submit papers on certain subjects, upon the merits of which their ability to assist will be judged. Where the papers submitted justify it, the author may be called on to read them before the meeting of the Society, or to nominate someone to do so in his stead.

Those who have been serving on the Technical Committee have found their interest in the Society enhanced, because they have been kept in closer contact with the work as it proceeded. This, of course, must inevitably result from the fact that they have participated in the work itself. The fact that attendance at these meetings have been practically one hundred per cent., in spite of the fact that it has meant that those participating have had to devote four evenings a month to the Society's business, explains, at once, the progress made, and, at the same time, seems to offer proof that its members find the work sufficiently interesting to repay them for their attendance.

Their feeling that they are doing work of paramount importance would seem to be justified by consideration of the programme mapped out for the Technical Committee.

Apart from the experiments it is hoped we will be able to conduct, there is the enormous amount of work required to enable the various necessary reports, and surveys, to be completed. The Committee will first complete the survey already begun. This takes the form of a detailed examination of the feasibility of a specific case. It has been our feeling that further constructive effort can only be effective if focussed. Generalisations are useless and cannot be an effective guide to the fundamental usefulness of any particular investigation.

The case under consideration is to show how a vessel may be constructed to carry a crew of two safely to the Moon ; permit of their landing for a stay of fourteen days ; provide for their safe return with a payload of half a ton.

It is proposed to give an indication of the nature and cost of the research necessary to be undertaken ; to prepare a programme of experiments, designed to ascertain the information required, bearing in mind the possible development of information commercially applicable to other spheres. The preliminary framework of a report on this matter has been completed, and the detail work involved in the report itself has been begun. When this has been completed, it is intended to take each salient aspect of our case, and reduce it to terms of a treatise, limited to the exposition of this particular item. These treatises will be developed in such a way as to make it possible to submit each, independently, to such authorities as may command respect for their views on this particular matter. They will be asked to consider them and proffer their views on them. They will be revised, and/or re-submitted until acceptance has been obtained.

The experiments indicated in the survey will be analysed in detail. Those immediately practicable within the scope of the Society's resources will be undertaken forthwith. Those we cannot cope with will be brought to the notice of suitable sources of financial support, and, where possible, a case made out for their usefulness in obtaining information valuable in other connections.

When these matters are suitably concluded the whole subject will be reviewed ; a final report prepared, embodying the scientifically endorsed details and the experimental data, and a case prepared for the immediate commencement of the work.

Armed with this document we will approach every available source of financial support.

In the mean time, there are matters which we believe can be made the subject of the immediate experiment referred to in the special notice circulated to members. These experiments will produce evidence which will be useful in itself, and, at the same time, prove that we are a body which may be entrusted with a scientific task.

As this is an obvious prelude to the wider acceptance of our work, we ask you to realise that your prompt response to the appeal already circulated will constitute the most convincing evidence of your willingness to co-operate with our efforts. We would ask you not to overlook this opportunity to do your part.

I would like to conclude by thanking those members who have already offered their support so generously. If others live up to this level, we shall be in a position to congratulate ourselves on a New Year well begun.

TECHNICALITIES.

(Being the report of the Technical Committee up to October, 1937. Compiled by R. A. Smith, A. Janser, E. Ross, H. Bramhill, and A. C. Clarke, under the direction of J. H. Edwards.)

Prior to the passing of the new constitution in February, 1937, a group of the technical members of the London branch of the Society formed the habit of holding meetings at which the technical aspects of the subjects of the Society were discussed. These matters were gone into very thoroughly and some of the earliest ideas and principles were revised to make sure that the later developments had not been made at the expense of the abandonment of more potentially fruitful lines of approach. In particular, the abandonment of the Opel rocket car as a consequence of a disastrous accident was a point of this nature. The result of this investigation led to the invention of the cellular construction for spaceships, of which full details are given later, and which was designed as an attempt to incorporate the advantage of the rocket car type of design in conjunction with methods of avoiding its greatest disadvantages and, later, in conjunction also with the principles of step construction.

It was also noted at about this period, that it was a common fault of experimenters in this field to try to go so far in one experiment that a multitude of variable factors obliterated any specific knowledge that might have been obtained. In particular, this was the case with the firing of free rockets, where the tests, owing to scale factor and lack of manual control, were under conditions so different from those of the jet propelled vessel as to make them useless from the point of view of comparison ; while at the same time the unknown factors of high velocity air resistance, co-efficient of the form (particularly when jet propelled) percentage combustion and chamber pressure made it quite impossible to make any reasonable calculation of the efficiency of the motor. To a lesser degree this also applied to proving stand tests, although a greater number of tests with more care in arranging them to a definite schematic would perhaps obviate it in this case. Owing to the lack of funds for any serious research work it was decided that the best policy was to concentrate on devising the best method of sorting out useful information from the data already available.

As a consequence of the preliminary work of this unofficial group, when the new constitution was passed and the technical committee was organised on an official basis its programme was clearly indicated.

The Research Fund remains at microscopic proportions, consequently the Society itself has not been able to carry out any experiments, but individual members have co-operated to enable a certain amount of useful work to be done. We would like, at this point, to mention to those who think the £5 Research Fund to be adequate to enable us to start serious experimentation, even to the extent of firing rockets, that of the fuels that have been tested the cost of two of these tests alone amounted to £2 10s. 0d. and that although, of course, one or even several rockets could be make and fired for the cost of £5 the result would only be to add yet another redundant case to the number of free rocket tests that have already been made. It is the purpose of the technical committee to confine itself to serious experimentation with a definite object in view of producing jet propelled vessels capable of travelling in a vacuum. Random experiments cannot possibly lead to this result and to complete the series of experiments that have already been made will undoubtedly cost a very considerable amount. The technical committee would therefore like to emphasise to all members the importance of augmenting the research fund to the point at which it can effectively be used.

FUELS. Rough tests have been made of over eighty suggested fuels (the majority of them eliminated as useless). A number of both liquid and solid fuels have been found with energy values higher than any yet used. None are perfect but several have been put forward for trial in actual propulsion tubes as soon as we can afford the tests. As a consequence of the hope of using cellular construction, a fresh consideration has been given to solid fuels, as no method has yet been devised for using liquid fuels with this construction. The fuels that have been suggested or used in the past have mostly comprised liquid oxygen with liquid hydrogen or hydrocarbons. Preliminary tests with these substances immediately showed that the energy rendered available by the combustion of the pure substance was always considerably lower than that theoretically obtained by calculations from other, and more accurate, methods of testing the total calorific value. At first this was thought to be due to the rise in specific heat at high temperatures being greater than that which had previously been estimated. Text books differed considerably on this point. Temperature and volume curves however showed that although the specific heat itself did not actually rise even to the lowest figures stated in the text books, a very considerable excess of heat was required to raise the temperatures, not owing to rising specific heat but owing to disassociation.

It was found that carbon dioxide almost completely decomposed in the presence of excess oxygen at a temperature of less than 3,000 degrees. In the absence of excess oxygen the decomposition occurred at not much more than 1,000 degrees. Water vapour did not decompose quite so readily but in this case the result was more serious as the carbon dioxide only decomposes to carbon monoxide, thereby leaving some of the energy still available, whereas there was none left when the water vapour decomposed. Against this the higher specific heat of the oxygen compounds tended to keep the temperature down and thereby minimise the decomposition. Following this, fuels were concentrated upon in which the organic content was considerably reduced or eliminated entirely. It was found, for instance, that aluminium oxide and magnesium oxide did not decompose to any detectable extent at the highest temperature it was possible to obtain (of course, this does not actually mean that these substances will not disassociate at all in practice, as the flame temperatures run higher than any temperatures otherwise obtainable, in fact, so high that we have not yet been able to devise a method of measuring them).

Some idea of the significance of the above can be gathered from the following. The theoretical calorific value of hydrogen-oxygen is 3.2Kcals/g and of carbon-oxygen 2.2.Kcals/g. In practice, however, the heat available is only 1.8Kcals/g for hydrogen and 1.0Kcals/g for carbon. These are of course an absolute maximum. In practice, owing to various sources of loss of energy, nothing like these values have been obtained. Against these, the values are 3.5Kcals/g for magnesium and 3.7Kcals/g for aluminium and these oxides do not, as far as we know, decompose. Against this, it is of course useless to devise a satisfactory combustable and at the same time have the difficulties of liquid oxygen with which to contend. Various mixtures of aluminium and magnesium with oxydising solids have therefore been tried and mixtures have been obtained giving up to as high as 2.0Kcals/g. These mixtures, however, tend to be very explosive and the only mixtures which have been found sufficiently safe for rocket experiments are mixtures with ammonium nitrate or sodium perchlorate which give calorific values of 1.2Kcals/g. This is, of course, a great deal better than that of the black powders previously used which run about .3Kcals/g for the English and .4Kcals/g for the American mixture. At the same time the value given is not sufficiently high for spaceship use, consequently a considerable amount of work has been done to devise means of stabilising the more energetic mixtures. A certain amount of organic admixture is found necessary to obtain a certain desired structural nature in the fuel substance and by a suitable choice of organic material this can be made to act as a stabiliser. In addition to the above, several fuels have been devised which, though having higher calorific values, have so far been held in obeyance as no satisfactory method of stabilising them has yet been found.

MOTOR DESIGN. In motor design, progress has necessarily been small, as with our latest fuels nichrome nozzles would be quite useless owing to the high temperatures obtained ; whereas proper ceranic nozzles would cost an amount quite beyond our present resources. On one point, however, definite advance has been made. The actual tests of the German and American experimenters have never given results in accordance with theory. Careful investigation has revealed, however, that there are several theories of jet propulsion besides the one usually accepted, and that one of these theories, that of Herr Sänger, with slight modification, actually corresponds with practical results. The following approximations, which have been devised partly from the theoretical formulæ and partly from data of experimental tests, enable the information obtained from experiments to be readily sorted out so as to segregate the loss due to incomplete combustion from the mechanical losses.

H =heat energy available per gram of fuel.
C =combustion efficiency.
S max.=spec. heat at max. temperature and constant pressure.
S mean=spec. heat at cons. press. between normal and max. temp.
S vol.=spec. heat at max. temperature and constant volume.
E =CHS max./S mean. S =S max./S vol.

E and S can be caluculated theoretically from text book data, but this is frequently inaccurate, and more reliable values can be obtained by firing samples of the fuel mixtures in a closed cylinder and measuring the resultant pressure and volume.
Firing under constant volume conditions $P=DE\ (S—1)/S$.
Firing under constant pressure conditions $P=DE\ (S—1)$
Where P and D are the resultant pressure and density respectively.

If the chamber pressure and rate of combustion are determined by a prooving stand test, the percentage combustion can be determined by comparing the theoretical value of E with the working value by the formula $E=1.2(PAS)^2/(S^2—1)m^2$ where P is the chamber pressure, A is the minimum cross section and m is the mass of fuel per second.

The reaction of a motor can be expressed as mv where v, the effective discharge velocity, is theoretically $(2H)^{\frac{1}{2}}$ which has to be corrected for incomplete combustion, etc., to $(2E)^{\frac{1}{2}}$. This has to be corrected by being multiplied by the efficiency of the jet for which a reasonable approximation is $.3(1—a^{\frac{1}{2}}) + (S^2—1)^{\frac{1}{2}}/S$ where a is the expansion ratio of the outlet.

The results of applying these formulæ to such test data as is available show that in all cases the greater part of the loss is due to incomplete combustion, the orifice loss being somewhere between 5% and 10%. This agrees extraordinarily well with text books data on steam turbines where the orifice loss is about 7% for a very wide variety of conditions. It is significant that Herr Sänger, working with correct formulæ and using high chamber pressures which his formulæ indicate as necessary, has obtained results markedly better than those obtained by any other experimenter. The principal errors in the other formulæ consisted in ignoring the residual exhaust gas pressure at the lip and also the external air pressure over the corresponding section of the front of the chamber. In practice Herr Sänger's formulæ hold good for under expansion, correct, and slight under expansion, at which point a burble condition sets in beyond which (i.e., for considerable over expansion) Mr. Shesta's formulæ are correct. Correct expansion is indicated by the lip pressure being equal to the external pressure, thus in a vacuum the condition will always be one of under expansion.

Besides giving more efficient operation of the motor proper, the higher chamber pressure used by Herr Sänger would of course lead to an improved combustion condition as the main difficulty in obtaining complete combustion is that liquid fuels do not have time to mix adequately and the higher pressure, by reducing the gas velocity in the chamber, gives more time for the combustion to occur. This difficulty does not, of course, arise when mixed fuels are used. Tests have been made to confirm this point with crude miniature nozzles from which gases under various conditions have been expelled. As no (internal) combustion was involved in these tests incomplete combustion could not confuse the results. Tests were made with nitrogen, hydrogen, carbon dioxide and steam (unluckily tests were limited to these gases which one of our members was able to obtain for nothing). A striking point was noted from these, that with cold hydrogen flowing into air and also with high pressure steam flowing into a partial vacuum (produced by condensation), velocities of about 2.5Km/s were obtained, which is as high as the best rocket motors yet produced (i.e., Sänger—oil liquid oxygen, and Goddard—powder fuel). This would seem to indicate that the mean temperature of the gases flowing from the rockets was not a great deal higher than that of high pressure steam, and a striking confirmation of this is given in Mr. Goddard's report by the fact that frequent flashes are observed in the tail, due to gasolene, which has not ignited in the rocket, but ignited after it comes in contact with the air.

SPACESHIP DESIGN. In this field considerable progress has been made. During the past twelve months cellular construction has been thought of and worked out to a basis of practical design. Just as step construction can be said to have made interplanetary travel an engineering possibility, so cellular construction can be said to have made it a commercial possibility. The value of this advance can best be judged from the following figures of the cost of a voyage to the moon. The case is taken from P. E. Cleator's book " Rockets through Space " as also are the values of the stepped ship. The figures are for comparison purposes only, being based upon the assumption that hydrogen oxygen are used for fuel at 100% efficiency. It is, of course, neither a likely fuel nor a possible efficiency, but it is most suitable for use for the purpose of comparison owing to the high degree of accuracy with which its energy is known. The value for the one way voyage with the stepped ship is Herr Oberth's.

	Step Construction	Cellular Construction
One way trip ...	£50,000	£20,000
Return trip ...	£200,000,000	£200,000

In the actual form of the design in its present stage of development, the ship is divided laterally into steps, the higher ones being smaller than the lower ones. Each step is then divided longitudinally into cellules, the larger steps at the bottom containing fewer cellules than the smaller steps at the top (i.e., the cellules are. so far as possible, arranged all to have the same proportions and to comprise a small number of different sizes, with the object of enabling them to be made by mass production and so substantially reducing the cost). Each cellule is a complete unit comprising a motor with its load of fuel. The firing is electrically controlled but no attempt is made to control the output of a cellule once it has been fired (except in its initial design). Owing to the large number of cellules there is quite a reasonable accuracy of control available by adjusting the moment of ignition of the various cellules, thus obviating the difficulty which would otherwise arise in controlling these vast quantities of fuel. It should be noted that the systems which have been experimented with for the control of free rockets would be quite useless for a spaceship as it would obviously be impracticable to force the controlling vanes into a stream of gas comprising several tons per second travelling at a velocity of 3Km/s and having a temperature exceeding 5,000 degrees Centigrade. Furthermore, the rate of firing could not be controlled by varying the speed of feed pumps as such pumps would weigh many tons and would be quite impracticable as they would require 20,000 horse power to drive them.

The main danger of the Opel car design is that of the heat from a tube which is burnt penetrating to a tube that has not yet been fired and thereby initiating ignition from within. This difficulty is surmounted in cellular design by detaching each cellule as soon as it has finished firing. Owing to the short period of firing of each cellule the heat has not sufficient time to penetrate the lagging before the cellule is detached. Of course, owing to the fact that the thickness of the lagging for this purpose is independent of the size of the tube there is a minimum size below which this system could not be used. This limit corresponds to a ship of about 20 to 30 tons gross weight, though smaller sizes might be used with lower grade fuels. In addition to the main control obtained by controlling the ignition of the cellules, auxillary tubes are used for fine control, burning a lower grade fuel of a separated nature.

NAVIGATION. In this connection a considerable amount of work has been done on computing the orbits of space ships under various conditions, and as a consequence it has been found that several of the preconceived ideas about such orbits are erroneous. In particular there is no kink in the orbit of a space ship travelling between the Earth and the Moon. Owing to the disproportionally large mass of the Earth's satellite and its considerable distance from the Earth, perturbations are involved which render this first voyage of immense complexity as compared to any other voyages that are likely subsequently to be undertaken in the Solar system. As a consequence, it is felt that these calculations must be detailed much more fully than they previously have been, before we can feel confident that there is no error in the estimation of the performance which is required of the vessel.

RESUME. The Committee has made a study of the conditions for a successful journey to the moon, based upon the data already available from a rough but comprehensive analysis of the problem. They have come to the conclusion that such a voyage would be possible with the knowledge at present at our disposal but that the costs would be very considerable. Bearing in mind, however, that we have developed fuels of considerably higher effective calorific values than have previously been used and the fact that careful anaylsis of other people's work should enable us to avoid their mistakes in motor design, it could reasonably be anticipated that when we are in the position to manufacture motors of a suitable type for the consumption of our high grade fuels, we should not be unduly optimistic in anticipating an increase of 50% on the reaction velocities hitherto obtained. This increase in velocity would, of course, enormously reduce the necessary expenditure.

FUTURE PROGRAMME. It has been decided that until funds permit the construction of the above mentioned motors, the Committee should concentrate on studying, in full detail, the design and performance of a vessel of the type demonstrated as desirable by the past work, and shall conduct such experiments as are found essential to make the examination of the problem complete. It is emphasised, however, that in order to obtain the maximum result from a minimum of outlay, no experiment should be conducted without a very careful preliminary examination of the problem with which it deals. In particular, it should first be ascertained (1) That there is no possible method of obtaining the information required other than going to the expense of an experiment ourselves. (2) That the proposed experiment will definitely decide the particular point at which it aims.

It may be a matter of some general interest in connection with the vessel under consideration, that the high cost is not so much the enormous amount of fuel required, but the high price of fuels which are comprised of pure chemicals, costing over a £100 a tonne to refine whereas terrestrial voyages are made with such fuels as petrol at about £8 a tonne or coal at about £1.

The vessel under consideration is of 1,000 tonnes gross and it may come as a surprise to those who think of a spaceship as the size of an Atlantic liner or an airship, that its dimensions are 6mts. by 30mts. (about the size of a large barge). The reason is, of course, that the liner and airship are mostly hollow, whereas the spaceship is almost solid.

The programme as outlined may seem to some as looking too far ahead, but it will be realised that there is no greater source of abortive effort than starting a job without a plan of action and it is felt that we shall get further in the long run by making quite sure of all our facts before trying to translate them into action.

A Contribution To The Fuel Problem.

By Arthur Janser.

The possibility of overcoming the gravitational attraction of earth and freely navigating through space has been proved and demonstrated by quite a number of investigators in the course of the last fifteen years, notably by Goddard, Oberth, Esnault-Pelterie and many others. This is rendered possible by the principle of reaction as demonstrated in a rocket and it has been shown that by means of a suitable arrangement—such as the well-known step rocket system—the available chemical energy of known exothermic reactions would be sufficient to impart the velocity of escape (11.3km/sec) to a suitable body (space ship). But even when the most powerful reaction mixture is used as a fuel and we manage to convert the bulk of its chemical energy into thrust, without incuring the losses, the problem remains formidable enough, involving the combustion of hundreds of tons of fuels within the space of a few minutes and the ejection of immense masses of hot exhaust gas to produce the thrust. If we would be forced by technical reasons to use low powered fuels or if we would sustain substantial losses when using a powerful one, this problem would assume phantastic dimensions and become unpracticable. The following example shows this clearly : Assuming we impart escape velocity to our craft, accelerating with 2g, the exhaust-velocity of the fuel being 2km/sec ; the load ratio M_0/M_t would be then 1600 ; if the exhaust velocity be raised to 4km/sec, the load ratio comes down to 40. While the first rate is utterly beyond practical realization, the second offers a serious chance. It is noteworthy, that while there are quite a number of compounds known, whose reaction heat at their formation would produce exhaust velocities exceeding 4km/sec (calculated on the mechanical heat equivalent), practical tests carried out so far yielded exhaust velocities but little exceeding 2km/sec. It appears therefore, to be the key problem of astronautics, to determine all conditions which influence these exothermic reactions and based on this knowledge, to devise practical means, which permit a close approach to the theoretical value of v.

Firstly : The more powerful a fuel is, and the more we try to utilize its power, the higher t and p will be in the combustion chamber ; with increasing t the loss caused by the specific heat of the combustion gases becomes appreciable. The combustion heat at a given temperature t, L_t will be given by $L_t = L_0 + \int_0^t (s - S) dt$, whereby s is the specific heat of the substances in combustion and S the specific heat of the combustion products, both at the temperature t. Thus, for instance, when t rises from 1800°c to 2600°C, the thermic yield of the combustion of one gram mol. of H_2 drops from 55 to 48 calories, and with CO even from 6.0 to 1.9 cal.

High temperatures produce another adverse effect, that of thermic dissociation, which also increases with the temperature ; it has been suggested, that it may reach such a value with the H_2+O reaction, that the theoretical value of its exhaust velocity of 5.2 km/sec might be halved. A remedy in this particular case is offered by using a surplus H_2 over the stoichiometric amount : by the presence of free, uncombined H_2 the equilibrium of reaction will be shifted towards lesser dissociation ; besides, free Hydrogen, at the t of reaction of around 4000°C will assume a v of its own exceeding 4.5 km/sec. In this way a mixture of $3\ H_2+2\ O$ will have a theoretical v of 5km/sec and an efficient v (v^1) exceeding in practice by far that of H_2 and O. The same objection applies in an increased measure to C, or C containing fuels (hydrocarbons); in this case the dissociation will reach considerable values at t over 2500°C and here the given remedy would be either to increase the amount of oxygen over the amount necessary for quantative combustion to CO_2, or cut it down to the amount just sufficient for the formation of CO. Again, the theoretical value of v will drop from 4.3 to 2.9 but v^1 will be appreciably higher. If we use for instance a liquified fuel consisting of 6 H_2 and 3CH we would cut down the oxygen from the theoretically required $5O_2$ by one third.

Increased pressure in the combustion chamber increases of course v^1, chiefly owing to decreased dissociation. Esnault-Pelterie shows in an example v^1 (of H_2+O) to be 4.15km/sec at 10atm. pressure, to rise to 4.45km/sec, when the pressure is raised to 100atm. (These figures make allowance for inevitable losses in the expansion chamber, a practically adiabatic expansion being assumed). The increase of pressure on the other hand entails such difficulties regarding weight of the jet motor, fuel supply and so forth, that we will have to reckon with pressures not exceeding 40atm. as our practical limit.

The supply of the fuel into the combustion chamber overcoming the constant pressure of combustion in it, is a problem, which is by no means settled yet, especially, when the huge amount of fuel to be burnt in the short space of a few minutes, is to be considered. Oberth has made a big advance towards its solution, by discovering the principle of "self-disruption," by means of which it becomes possible to inject liquid fuel and oxygen into the chamber without the previous use of a carburettor. But even so, we are faced with loses due to insufficient contact and activation and consequently the fast removal of hot, partly unburnt gas from the chamber. Unburnt fuel leaves the chamber and some energy is lost ; part of it is recovered by continued combustion in the expansion chamber the rest burns away in the open, producing the fiercely burning tail, so often observed on experimental rockets.

An intimate knowledge of the physico-chemical mechanism of the combustion in each individual case will help to avoid these losses and provide conditions approaching optimum. A typical example of this is the so often quoted case of the reaction between hydrogen and oxygen ; this is not a simple combination of the two elements after the formula $H_2+O=H_2O$, but a very complicated chain reaction and it has been found, that its rate increases, up to a point, with the square of the diameter of the combustion chamber and also in the presence of an inert gas such as Nitrogen.

In this way optimum size and shape of the combustion chamber, etc., for each fuel will have to be developed individually, providing the necessary " inner streamlining " of furnace, throat and jet which the gas stream moving at high (over sound) velocities requires. Thus a jet engine for hydrogen may be constructed along somewhat different lines to a benzol rocket, very much the same way, as petrol and diesel engines are differentiated.

We come now to consider which type of fuel might be the most promising on account of the general principles outlined above. Surveying the available literature, the remarkable fact is revealed, that all fuels hitherto considered are either explosives, or usual motor fuels (including hydrogen, which is used in gas engines). Furthermore the opinion appears unanimously in favour of liquids, rejecting solid explosives entirely. This state of affairs is truly astounding. In the first place, the jet motor is neither a gun, nor a petrol engine, but in certain respects something in between. Consequently, neither gun cotton, nor gasoline would be the ideal fuel, but an energy carrier which takes up an intermediate position between the two. In fact, certain colloidal suspensions of high caloric value, containing oxygen carriers, considerably less brisant and erratic than an explosive, appear to be an ideal approach to this condition. A few tests, carried out recently, seem to bear great promise. It is not possible, to say much more on this matter at this early stage, except, that the energy carrier is a light metal in colloidial dispersion and that the obtained values of efficiency approach the theoretical value closer than any of the previously tested fuels.

There are a number of metals and metalloids which produce very high energy values on oxydation (some even exceeding that of hydrogen) which are still awaiting investigation. In the following table the caloric values and relative exhaust velocities are given of the tested fuels, as well as of the ones which are here suggested, for easy comparison.

FUEL	Caloric	v	FUEL	Caloric	v
C to CO_2	2,220	4,3	Gun-Cotton	1,240	3,2
C to CO	1,050	2,9	Metal-Sol	2,300	4,4
H_2......O	3,240	5,2	Mg......O	3,590	5,6
CH_4.....O	2'400	4,5	Al......O	3,850	5,7
C_2H_2...O	2,880	4,9	P.........O	2,580	4,6
C_2H_4...O	2,580	4,6	Ca......O	2,720	4,7
C_6H_6...O	2,430	4,5	Si.......O	3,000	5,1
C_2H_5OH...O	1,970	4,0	B.........O	3,980	5,8
H_2S.....O	1,380	3,4	$C_{14}H_{10}$...O	2,500	4,6

Notwithstanding these new and promising lines of progress the solid and liquid fuels in the usual sense still remain in the picture and are well worth our serious consideration. Some of them, suitably applied, even if not good enough for crossing space may lead up to interesting side lines, such as mail rockets, meteorological sounding rockets, take-off rockets for fully loaded planes, and other similar purposes. In this context it is worth noting that the solid fuels have an even chance with the liquids in producing practical results. This statement is made in spite of the generally accepted opinion to the contrary. Without wishing to refute any of the arguments for the liquid and against the solid fuels, which are fully accepted, it is necessary to point out, that the liquid fuel motor has still to overcome a number of difficulties, as has the combustion turbine (with which it has much in common). These are mainly of constructional nature, to which may be added the problem of adequate cooling and fuel supply. Against this the solid fuel rocket offers simplicity and cheapness of design, a more advantageous progagation of the reaction and less strain on the lining of the chamber. These advantages are sufficient to warrant further investigation of the solidly fuelled rocket.

Finally, mention should be made of two theoretically possible fuel components, which have the only drawback, that they cannot be produced in a sufficiently stable and safe form—yet. These substances are mono atomic hydrogen on the one, and tri atomic oxygen (ozone) on the other hand. To burn them together to water would give a theoretical v of near 30km/sec which may sound utterly phantastic. With this fuel at hand the conquest of the solar system would become the task of tomorrow. As things stand, the chances for this fuel are very small and the serious investigators will do better to concentrate his efforts to available fuels, which offer all the same an undoubted chance to produce practicable results.

Astronautics at the " Palais de la Decouverte,"

Paris International Exhibition, 1937.

By Robert Lencement, Ing.E.T.P.

With an introduction by A. C. Clarke.

One of the attractions of the great Paris Exhibition in 1937 was the Palais de la Decouverte, which contained demonstrations and exhibits of modern scientific discoveries, arranged in a form to interest and impress the general public. All branches of science were represented, the Astronomical section being organised by Monsieur Lencement of the Paris Observatory. M. Lencement, unlike most of our official English astronomers, is keenly interested in interplanetary travel and has done a great deal to spread the idea in France by articles in popular scientific journals and by similar means. He is a member of the B.I.S. and has been able to influence many prominent French scientists in favour of Astronautics. As might be expected, M. Lencement did not miss the unique opportunity presented by the exhibition. Besides the main astronomical section, he set aside a room to deal with astronautics and collected exhibits from all countries to show the public what had been done and what might be done in the near future.

This far sighted move aroused great interest among the crowds visiting the exhibition and no doubt has done much to popularise the notion of space travel. The B.I.S. and its officers are glad to have been of some assistance to M. Lencement, who has kindly sent us the accompanying article and photograph. All B.I.S. members will join with us in wishing him every success in his further attempts to influence public opinion in France.

A.C.C.

Professor Jean Perrin desired that the " Palais de la Decouverte " should be a living exhibition of science, showing its importance in everyday life, with, where possible, indications of future progress. So the opportunity was taken of adding a room on Astronautics to the section dealing with Astronomy in the Discovery Palace.

France is the country of Cyrano de Bergerac, Jules Verne and Robert Esnault-Pelterie, but nevertheless the science of interplanetary travel is quite unknown to the general public and to men of science here. No experiment, or attempt to send mail by rocket, has ever been made in France and no Rocket or Interplanetary society exists in the country. Papers and lectures on the subject are very rare. The French literature consists of only one book, " L'Astronautique " by Esnault-Pelterie. It is true that this work is one of the two or three in the world which constitute the main theoretical basis of the question. I must also say that the name " Astronautics " was born here, its father being the well-known writer J. H. Rosny.

This being the case, it was necessary to arouse people's interest and curiosity, and to show them that astronautics is a real new activity of science, that it is no longer a fiction and that renowned scientists of other countries are working on every aspect of the problem.

Documents on astronautics are rare and for good reasons. We would like to have shown, as of astronautical interest, all improvements in each branch far and wide connected with the subject, such as combustion and the rocket motor, rockets of every kind and their uses, the mechanical and mathematical aspects of spacial navigation, biological questions, planetary atmospheres, etc. . . . . But showing all this was quite impossible and the space available was small. Moreover we had to avoid too technical matter and exhibit only the more spectacular documents. Finally, I could not get all the material I had expected. For all these reasons, I made a choice (perhaps open to criticism) nearly sufficient for a first glance at astronautics though not of very great interest to those accustomed to the idea of space travel.

The display room was arranged as follows :—

(1) Experimental work in the field from Oberth and Tilling in Germany and Pendray, Loebell and Goddard in America. These photographs are not all new, some of them having been published here and there before. Then, the main item (see photograph), a half-scale model of the upper atmosphere research rocket sent by the Cleveland Rocket Society. The rocket is opened and apparatus can be seen inside from the motor at the rear to the parachute in the nose. By the side of the model, one of the motors used in Loebell's experiments for the Cleveland Rocket Society is shown.

(2) Mail by rockets. This shows samples of letters and stamps flown by rockets everywhere in the world. Many of Schmiedl's performances are shown here. Postal rocketry can be considered as the first step towards rocket transportation.

(3) The Future, and Space Travel. Anticipation is only represented by three documents. Two are diagrams : the journey around the moon in a hundred hours, as it has been proposed by Esnault-Pelterie, and the journey to Venus and Mars according to the calculations of Baron von Pirquet. The third item is a photograph of the space ship from the model built under H. Oberth's direction for the film " The Girl in the Moon." In addition, a general note on astronautics, its aims and means and the present state of the problem was shown, together with a photograph of the French Committee on Astronautics when constituted

in 1928.

Some books in the English and German languages were available at the Library for examination. I also gave some lectures illustrated from the technical part of the film " The Girl in the Moon " and with a short one of the Cleveland Rocket Society's experiments.

It is very difficult now to collect recent documentation on the subject. In some countries, experiments are performed for war purposes which is not quite the same as astronautics. In others, workers keep their secrets. Despite these difficulties, I received interesting material from everywhere, though different in kind and value. I must apologise for not having exhibited all the papers, diagrams, photographs, bulletins and books which I received, for the above reasons. I am glad of the opportunity given here to express my thanks to all the persons who assisted me in the matter, and especially :

In England : The B.I.S., and Messrs. C. Bein, E. J. Carnell, Arthur C. Clarke, P. E. Cleator, J. H. Edwards, Francis J. Field, L. J. Johnson, Professor A. M. Low, R. Morris, and Chas. G. Philp.

In the U.S. : Professor Robert H. Goddard, the Cleveland Rocket Society, and Chief Research Engineer Ernst Loebell, and Willy Ley.

In Germany : Herr Werne Brügel, Dr. Steinitz, and the U.F.A.

In Roumania : Professor Oberth.

In Austria : Professor Kobes, Dr. Kuba, Baron Guido von Pirquet, Friedrich Schmiedl.

In the U.S.S.R. : Professor Nikolai A. Rynin.

The Exhibition is now over, but the " Palais de la Decouverte " will most probably re-open and everyone expects that it will remain as a permanent Science Palace. As elementary astronautics has been represented at the exhibition, I hope some day to make a more complete and interesting display of its technical aspects and future possibilities. There all the documents received will have their proper places together with quite new material—including, we hope, results of the B.I.S's awaited experiments.

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SPACESHIPS, AIRCRAFT AND ROCKETS.

Some definitions and comparisons given by

J. H. Edwards.

During recent meetings it has become increasingly obvious that misunderstandings were occuring owing to members drawing no clear distinctions between spaceships and aircraft or spaceships and rockets. There are some who think that if a rocket is made large enough and given a container to hold a man it becomes a spaceship. There is another, and usually opposing group who consider that if a jet propelled aeroplane is provided with suitable jets to make it independent of its wings for lift, it becomes a spaceship. There are, however, clear lines of demarcation, the principal of which is the method of control.

A **rocket** is adjusted beforehand to be controlled by air reaction. Its power is distributed between inertia and air resistance, and it is kept to its initial direction of motion by an effect of air resistance which turns it towards its line of motion if it tends to deflect. It will be noted that since a considerable portion of its power is expended against inertia, its direction of motion may be considerably different to the direction in which it points. The larger a rocket is made the more uncontrollable it becomes, because the air resistance becomes less in proportion to the inertia. Special methods may be devised to make larger rockets controllable but these are limited in their scope. A rocket might be made to carry a man, but he would most likely be in considerable danger. This system might be used for altitude records but it would be of little use for point to point transport. A rocket might be made to reach a higher altitude by being made cellular, but this would be limited by the fact that only a comparatively low power fuel could be used. A larger size, provided it can be stablised, can reach a higher altitude than a small size owing to the lower relative air resistance.

An **aeroplane** is controlled by steering. It uses its power almost entirely against air resistance, and any inertial motion it may have in a particular direction is quickly deflected if its nose is pointed in another direction, thus it is still under control even when the power is not applied. These conditions still apply if it is jet propelled and also if it is jet supported but retains its wings. If, however, the wings are removed the air resistance becomes much less and consequently the vessel is much less controllable. A jet propelled air vessel is much faster than an ordinary aeroplane, but its range is much less. Owing to the steerability of an air vessel it can be used with advantage for point to point travel about the Earth's surface, steering being effected by visual observation of the terrain. Astronomical observations are of limited value owing to shortage of time and lack of gravitational horizon. A jet supported air vessel could rise into space and thus improve its velocity and range, but would lose its steerability while in space and, as a consequence, the manoeuvre would mean considerable danger. Owing to the opacity of the troposphere as seen from above and to the flames of the supporting jets, the point of return to the atmosphere would be a matter of conjecture, and arrival at the correct destination would depend on the terrain being recognised after the return to the atmosphere.

A space ship is controlled by being driven in a different direction to that in which it is moving. Its power is expended entirely against inertia. Once it is moving in a given direction it will go on moving in that direction until power is applied to deflect it. If it is desired to alter the course by 10° it would be of no use to point its nose in that direction. The vessel would have to be turned through 90° and power applied in that direction until the desired change of 10° was attained. If it is desired to reduce the speed it is necessary to reverse the ship and apply power backwards. To make any substantial change in its speed or direction takes several minutes. It is almost impossible to keep the vessel stable while the power is on except by rotating it (gyros not being effective on a free body). As a consequence of this, the course must be largely determined beforehand, and such subsequent alterations as are required left till after the driving period. Owing to air friction it is necessary for the vessel to rise almost vertically, and at the end of the drive period it is too high to be controlled from observations of the terrain. Being a free body it has no gravitational horizon, and consequently its course must be plotted from a number of astronomical observations. This needs a considerable time and distance of travel, consequently spaceships are unsuitable for point to point travel on the earth's surface.

The difficulty could be overcome by placing the ship in an orbit round the earth and keeping it there long enough to make the necessary observations, perhaps going several times round the earth while this was being done. This would, of course, waste power, but the extra time taken would only be a matter of a few hours. Owing to the fact that a spaceship is almost completely consumed during a voyage, it must be constructed for the particular voyage it is to make and any particular type of design can only be used on the voyage for which that design is intended.