Air Photography Apparatus.

Paper read by Mr F S Barton, M A , F Inst P , before the Institution in the Lecture Room of the Junior Institution of Engineers, 39, Victoria Street, London, S W 1, on 30th November, 1926 Mr H B Molesworth in the Chair

THE use of a camera in the air dates back many years, and some attempts were actually made as early as 1858, when Mons Nadar successfully took photographs of Paris from a balloon From these initial attempts the taking of air photographs has always made an appeal to the Services both from a Military point of view and from the map making aspect

The development of air photography in the British Air Service dates from the formation of the Royal Flying Corps in 1912 Very little progress was made until the outbreak of war in August, 1914 At this time the British Air Service was equipped with a few press type cameras and some simple portable developing equipment From these small beginnings, however, grew the Photographic organisation of the Royal Air Force which towards the end of the War was producing thousands of negatives and prints every day The equipment in use was necessarily designed under War conditions, and the personnel handling this equipment had often to forsake the camera for the machine-gun Thus as a natural consequence the equipment, excellent though it was, had not all the refinement and accuracy which is desirable or demanded for survey purposes

Since the cessation of war, attention has been turned to improving the photographic equipment in use by the Royal Air Force In this paper, it is intended to describe the latest design of camera and the associated equipment now in use The equipment required for air photography consists of a camera, a camera mounting, a sight and the additional apparatus used on the ground for developing, fixing, washing and printing Attention will be devoted mainly to the actual equipment carried on the aircraft, *i e* , the camera, its mounting, and the sight

A camera for use in the air has to fulfil very stringent requirements, and is in consequence, rather more complicated than might at first sight appear necessary

The requirements for the ideal air camera were clearly stated by Squadron-Leader F C V Laws, O B E , R A F , in an article in " Photography as a Scientific Implement," published by Messrs Blackie & Sons, Ltd , in 1923 As these requirements are important for the purpose of the present paper they are, with slight additions and modifications, set out as follows —

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(*a*) Light in weight
(*b*) Small in bulk
(*c*) Automatic in operation both in plate or film changing and shutter setting, also automatic in making continuous exposures at fixed intervals for overlapping purposes
(*d*) The centre of gravity should not be displaced during operation due to the movement of weight of the film or plates
(*e*) The camera should be adapted to take lenses of any focal length
(*f*) The sensitive material, *i e*, plates or films, should be held stationary and flat in the focal plane at the moment of exposure
(*g*) The shutter should be of an efficient between-lens type
(*g*) The size of the picture, which to a great extent is controlled by the work in hand, should be about 7 × 7 ins with sufficient margin on the sensitive material for items described at (*i*) to be recorded on each exposure
(*i*) Provision should be made for recording automatically upon every exposure —
    (1) The compass bearing
    (2) The angle and direction of tilt of the optical axis from the vertical
    (3) The date and time
    (4) The number of the exposure
    (5) The optical centre of the photograph
    (6) Altitude
(*j*) The focal length of the lens should be accurately measured and engraved on the mount
(*k*) The camera should be stabilised by some means, such as a gyroscope
(*l*) It should be simple in operation and reloading
(*m*) Means should be provided for making either single exposures, or an automatic succession of exposures ranging from 1 to 12 per minute

While certain of the requirements called for are self-evident, others may perhaps need some explanation

The need for automatic operation is very important as it is only by this means that regular overlaps can be assured A further important gain is that by the use of remote automatic operation, the camera may be installed in a position inaccessible to pilot or observer without any detriment to its operation

The requirement (*f*) that the sensitive material should at the moment of exposure be held stationary and flat in the focal plane is of prime importance It has been found that the curvature of commercial plates is quite a noticeable source of error This curvature would seem to be due to the practice of cutting photographic plates from a "sausage" and also to some extent to the pull of the emulsion in drying

In the case of film cameras the best means of securing the required flatness and exact positioning of the sensitive material is to have the emulsion side of the film pressed against a flat surface accurately located in the focal plane

With regard to (*g*) although the between-lens shutter is ideal, it is obviously impracticable for any lens much over 2-inches aperture, owing to the large

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unsupported span of the shutter leaves, which sooner or later, will lead to jamming Consequently the focal plane shutter is usually employed In this case, however, in addition to mechanical troubles there is an error owing to different parts of the same negative being exposed at slightly different times This error has been found to have a mean value of about one-fifth of a millimetre in a particular case A new type of shutter has been evolved which it is thought meets many of the objections to the other two types This will be dealt with at greater length at the end of the paper

It is, as may be realised, of extreme importance both for Service use and general survey purposes that the data called for in paragraph (*i*) should actually be recorded on the film or plate

It is of the highest importance that the camera calibration constants should be invariable This necessitates amongst other things, the focal plane and marks to indicate the Principal Point being fixed by reference to a surface rigidly attached to the lens In a plate camera the plate can be pressed against this surface whilst similar means can be adopted in the case of film cameras In some cameras the film is held against a perforated plate located in the focal plane by means of a suction device In other types the film is held against the surface of a glass plate by means of a pressure pad

In the case of the F 8 camera, as described in detail later on, the film is held with the emulsion side in contact with a sheet of plate glass The surface of this plate glass is accurately located in the focal plane The glass itself is held in the camera body and this is definitely fixed in relation to the lens

The stabilisation of the camera is obviously very desirable and in this connection there are two courses open —

(*a*) The camera may be carried on a mounting in the aircraft, the mounting being stabilised in space by suitable gyroscopes

(*b*) The aircraft itself may be stabilised by gyroscopic means, though this is obviously a much more difficult problem

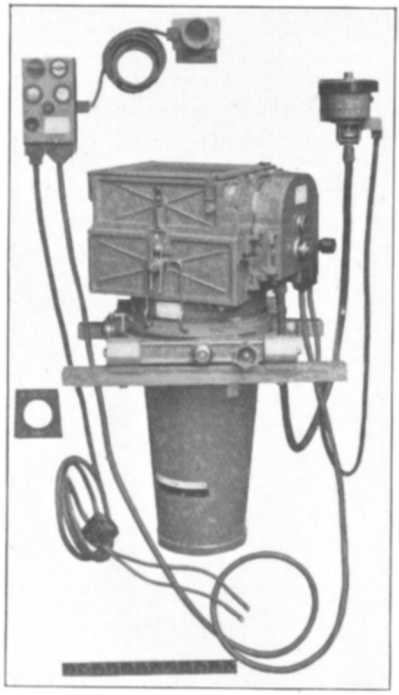
There are cameras of foreign manufacture which have been designed for Air Survey Work, and as might be expected they incorporate many of the features set out above and have in the hands of air photographers done exceedingly good work There is not, however, a single one of these cameras which, so far as is known, incorporates all the points called for in the above schedule

The following account of the air camera Type F 8 shows the principles underlying the construction and the method of operating

The principal use of this camera is for taking photographs for the construction of photographic mosaics of large areas, but, in its evolution the needs of the Service have received first consideration and the camera may be used with equal facility for all military purposes

The camera may be controlled in the air either by electrical or mechanical means

With electrical control, the exposures are automatically made in regular succession at any pre-determined time interval and in addition, single photographs may be taken by operating a Push Button between the successive overlaps Although the possibility of augmenting the timed overlaps with " extras " is



EXTERIOR VIEW OF THE F8 CAMERA

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provided for, it has been found by experience that it is seldom necessary Single photographs may also be obtained by means of this button with the automatic device switched out of action

With mechanical control the exposures are made by hand and the film changed and the camera " set " by either an electric motor or a windmill which is fitted outside the aircraft in the slipstream of the airscrew

The system of controlling the exposure is by means of an adjustable lens aperture, the slit and tension of the shutter remaining fixed The width of the shutter slit is sufficiently small to preclude any posssibility of the effects of vibration and sufficiently large to enable adequate exposure to be obtained on the film on a dull day with the lens aperture opened to its widest extent

The camera is built up on the interchangeable unit system which greatly facilitates the question of repairs, a breakdown due to a broken or damaged part being instantly rectified by replacing the complete unit in which the faulty part is contained The unserviceable unit can then be returned to a base where it can receive expert attention

The design of each of the units has been the subject of considerable research, and all the parts subjected to searching endurance tests It may be mentioned that one of the finished models withstood a continuous bench test of 100,000 exposures, passing through approximately 60,000 feet of film In addition to, and following the bench test, this camera did approximately sixty hours in the air, exposing some 2,000 feet of film Both these tests were completed without failure

The comparatively small weight of the type F 8 camera is shown by the following table The small extra weight required, and the ability to take 100 exposures at one loading, should be particularly noted in comparison with the plate type of camera

Comparative Weights of Air Cameras with 10-*inch lens and plates or films for* 100 *exposures*

	Size of Picture	Weight	Each additional 100 exposures	No of magazines per 100 exposures
P 5	18 cms × 24 cms	193 lbs	128 lbs	8
P 7	5 ins × 4 ins	72 lbs	24 lbs	6
F 8	7 ins × 7 ins	69 lbs	14 lbs	1

The Type 8 mounting is designed to enable the camera to be finally levelled in two directions (*i e* , port and starboard, and fore and aft) in the air The camera is isolated from machine vibration by a felt packing incorporated in the casting It is provided with a movement enabling the camera to be rotated about the optical axis for drift correction , safety links hold the camera securely in position Provision is also made for swinging and locking the camera in an oblique position , photographs can then be taken through the side of the aircraft at an angle of 15° from the horizontal

A mounting is also provided to hold the camera on a Scarf Gun Ring This fitting allows a depression of 60° from the horizontal, and a traversing movement by swinging the complete gun ring A sight is provided for use with the camera when taking oblique photographs

It must not be thought for one moment that the present camera is regarded as indicating finality There are many possible ways in which improvements could be effected and one or two of the more outstanding features will now be discussed

As stated earlier in the paper the provision of a suitable shutter is a matter of very considerable difficulty The between-lens shutter is impracticable for large apertures and the focal plane shutter as previously explained suffers from other faults This has led to the development of an entirely new type of camera shutter known as the Louvre shutter

It comprises a number of narrow metal strips or plates mounted so as to be rotatable about axes in their own planes to effect the exposure, somewhat in the manner of the opening and closing of a Venetian blind During the rotatory movement of the strips the axes are moved transversely, so that if the shutter is arranged immediately in front of the photographic plate or film no part of the plate is masked during the exposure To obtain the movement of the strips just referred to, at each end of the axis of each strip is mounted a pinion which meshes with a long fixed rack and a long movable rack By reciprocating the movable rack not only are the strips rotated but they are also moved transversely The shutter is constructed wholly of metal thereby providing a robust construction and also reliability in operation

For purposes of air survey work, a supplementary camera designed to take one vertical and two oblique views at the same time is being developed It is to be essentially an instrument of the highest precision It is hoped that such an instrument will be of use for contouring and the extension of control points

The slides and camera were loaned for the purpose of this paper by the courtesy of the Air Ministry

DISCUSSION

SQUADRON LEADER LAWS In the first place I should like to say that I had the pleasure of working with the President of your Institution, Lieut -Colonel J T C Moore-Brabazon, during the war, but previous to that I had struggled with almost every type of air camera since 1912 under various difficult conditions The paper which we have heard to-night reveals a steady rate of progress from 1912 to date, and I think that the accomplishments of the Air Ministry and the Royal Aircraft Establishment in working in close co-operation together have resulted in what is acknowledged to be one of the finest cameras in the world

A camera in the ordinary sense is a thing that we pick up in a shop, press a button, and it works That is what we want in the air, but it is difficult to obtain Also the small film which is used in a Kodak curls up in the hand, and is often difficult to handle during development In the air camera this small film is replaced by a film 65 feet in length, and 9 inches wide, which presents a very difficult problem in development

The pilot and observer on a service aeroplane are both called upon to do very many jobs, and this must be borne in mind when setting out the requirements for an ideal air camera, but above all, it must be automatic

We struggled through the late war with plate cameras chiefly because of the very early difficulties in using films Since the war tremendous strides have been made on the mechanical side, also on the chemical side, that is, in the production

of a panchromatic film which is capable of being used in the camera described to-night A great deal of credit is due to the British photographic industry for providing such a film One of the requirements stated by Mr Barton is that the camera should be light If you look at the camera demonstrated here to-night, it appears to be very bulky, the saving however, is not so much in the apparatus as in adoption of film as the sensitive material If 100 exposures are made on plates 100 pieces of glass are used, which soon mount up in weight, and each of these pieces must be mounted in a metal sheath, and of these metal sheaths and not more than twelve can be carried in each magazine Whereas using film a spool containing 100 exposures complete in magazine does not exceed the weight of one magazine of twelve plates

CAPTAIN MCCAW I congratulate Mr Barton on his most interesting lecture, and I do think we are all grateful to the designers of this camera I speak as a surveyor, for folk who are always wanting something more—some further improvements That is understandable, as I shall explain

It must be remembered that the detail is there on the plate, but to determine measures of precision from it is quite a different matter A tenth of a millimetre is the equivalent of say a metre on the ground , to measure to a metre, therefore, we expect a great deal from the designer Moreover, it must be remembered that the conditions under which the machine works are very severe indeed The camera has to function in all conditions of temperature—in the Tropics and the Arctic zones—and you see from the picture on the screen that the mechanism is necessarily involved I think therefore, that the R A E and its designers are very much to be congratulated on what they have done If we want them to do anything more it must be understood that we are simply taking it as granted that what they have done in the past is an earnest of what they will do in the future

LIEUT HOTINE I am afraid I can only speak of the application of aerial photographic apparatus to the somewhat specialised work of producing maps

I cannot agree with everything Mr Barton has said in his modest claims as regards mosaics We have actually produced a complete topographical map of Sussex three inches to the mile The methods were not like those of survey photography altogether, but the result was as good as could have been obtained on the ground, and five times as fast To execute that survey we needed on the ground about ten shillings' worth of control fixed by ground methods

I am aware of the quite ideal refinements of Mr Barton's camera, but the same problem remains—to reduce that ten shillings' worth of control

As Mr Barton and Squadron Leader Laws have pointed out, we have not saved much money, but in most countries it is necessary to provide most of your control from the air as well

I have had an opportunity of examining the foreign makes, particularly during last week at Berlin, and I think I can substantiate Squadron Leader Laws's statement that this is practically the best aerial photography camera in the world for its particular purpose

CAPTAIN TYMMS In the presence of so many experts I will not take up your time, or more than a few minutes, but I should like to add my congratulations to the lecturer on his very interesting talk, and I would also congratulate the Institution on having included a lecture on Air Photography in its programme The study of air survey and therefore of air photography is of vital importance to the future of aviation, and as a sort of official advocate of commercial air survey I am very glad to see that the Institution has arranged such a lecture

With regard to the Eagle camera, General Caddell recently told me he had demonstrated this camera to Mr Fairchild, who remarked " You have there a camera which is as good if not better than mine, and at half the price " I think this is rather a striking statement to get from a rival camera designer

Is it possible to design a plate magazine to be interchangeable with the film magazine ? It is sometimes necessary to use plates for more accurate work, and from a commercial point of view interchangeability may be of some importance , the commercial survey companies are not over rich, and anything that tends to reduce their capital outlay is all to the good

MR BRAMSON I am a complete novice on this subject, which renders it not less, but rather more, fascinating than otherwise

It comes rather as a surprise to someone who has not had the good fortune to come in touch with the practice of aerial photography, to discover how immensely complex the science is , although one ntaurally has not the presumption to criticise, even favourably, because one cannot compare, it does seem that every detail in that apparatus has been thought out as thoroughly as can be imagined

Mr Barton has referred to the making of mosaics It would be interesting to know what is the order of the inaccuracies met with between a mosaic and a map, and what is the procedure to eliminate them

It would also be interetsing to hear his experience as regards the actual errors met with in practice due to deviation from the vertical axis of the camera owing to gusts or other incidental causes, and whether it has been found worth while to study the question of gyroscopic suspension as a solution of the problem

MR BARTON'S REPLY TO THE DISCUSSION

I should like to thank the various speakers for their praise and criticisms of the camera about which I have been speaking

So far no difficulty has been experienced due to the camera axis being out of the vertical when the exposure is made The warning lamp gives the pilot a signal immediately prior to the taking of the photograph and so enables him to hold the aircraft on an even keel while the exposure is being made

As regards the question of suspension or stabilisation of the camera, this is called for in the requirements I rather think, however, that it would be almost as easy to gyroscopically stabilise the aircraft as to fit the camera with a gyro-stabilised mounting

The camera cannot as it stands be used with a plate magazine, though there

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would probably be no difficulty in making a suitable adapter should there be any call for it

In conclusion I should like to mention that we have with us here this evening Mr Stringer, one of the designers of the camera, and he has very kindly offered to demonstrate the camera in detail to those of you who are more especially interested

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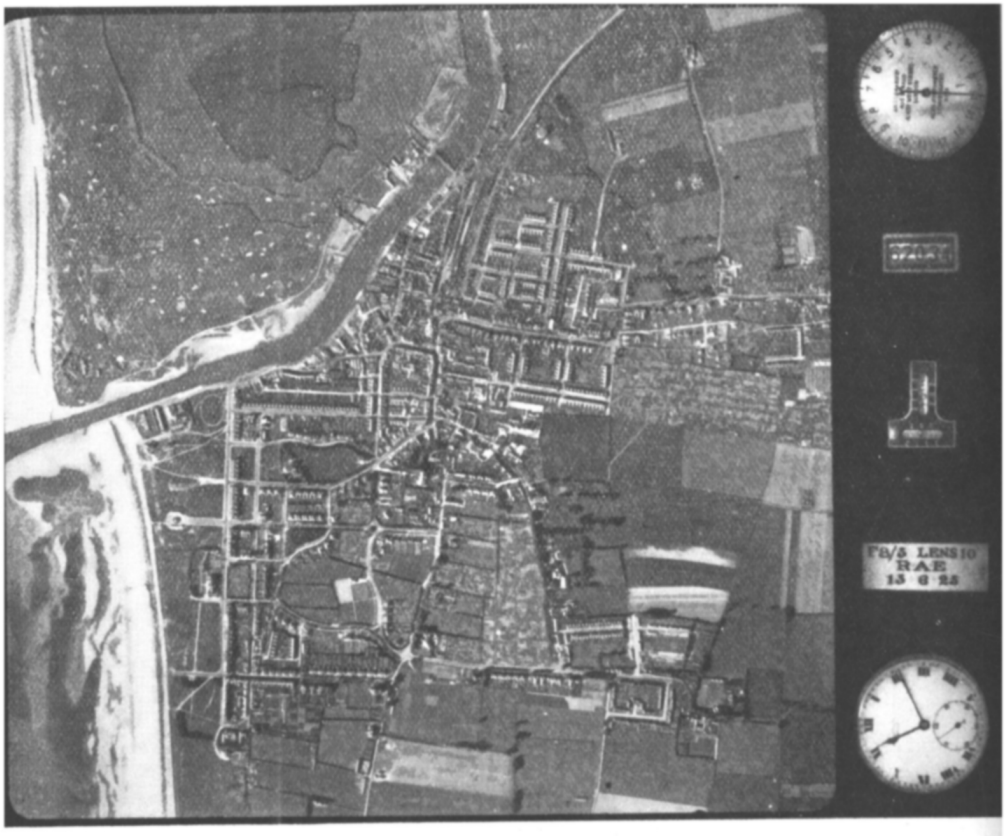
The meeting concluded with a very hearty vote of thanks to Mr Barton for his interesting paper, and the camera and other apparatus which he had kindly brought with him were then examined by the audience



AIR PHOTOGRAPH OF LITTLEHAMPTON

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