ESTIMATED COSTS OF PLOTS

Kind	*Number of Plots*	*Cost per plot Dollars*	*Total cost Dollars*
Ground plots	149	40.00	5,960.00
Photo plots	2,871	.20	574.20
Photo points	4,676	.02	93.52
Total			6,627.72

DISCUSSION

ADVANTAGES OF THIS PLAN:

1. Stand photo volume-tables are not required before the photo interpretation.
2. Photo interpretation work is clear-cut and straightforward.
3. This plan is believed more efficient than present survey techniques.
4. No serious changes are made in the over-all compilation procedures.
5. Plan will fit in with continuous inventory designs now under study.
6. This plan should be very useful in unexplored areas.

DISADVANTAGES OF THIS PLAN:

1. The variable or photo measurement used may not be the best for the area, although present experience shows that it is the most promising in the spruce-fir-hardwood forests in question.
2. Extra work in compilation is required for the construction of the regression formula. But this replaces the work required for the photo volume-table construction.

RECOMMENDATIONS

It is recommended that this plan be tried for forest survey purposes to test the application, soundness, and stated advantages.

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*Precision Measurements of Bubble Chamber Film**

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ABSTRACT: *The accuracy and speed of measurement of the motions and interactions of fundamental particles during the study of high energy nuclear physics is of increasing importance. The use of the bubble chamber has increased the amount of data available. Faster and more accurate methods of 3-dimensional measurement of data are being developed.*

IN THIS paper will be described the solution to a recent problem in reconstructing three dimensional images from two or more stereoscopic photographs. In high-energy nuclear physics we are concerned with the interactions between fundamental particles. We must study the scatters, the fragments, and the new particles which are produced when a high-energy particle collides with an atomic nucleus. When the incident particle has an energy of hundreds of MEV or greater, it no longer can be counted on to bounce off of the nucleus like a billard ball. Instead, it frequently creates new particles such as π-mesons, K-mesons, and at the very high energies, anti-protons. One of the most satisfactory ways for many years of studying these interactions has been by means of the Wilson

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cloud chamber: when a charged particle passes through a gas containing a supersaturated vapor, small droplets can be made to condense along the trajectory of the charged particle. The actual trajectory of the particles can be recorded and reconstructed by means of stereoscopic flash photographs.

Conventional ways of carrying out this reconstruction were:

1) By reprojection through an optical system identical with the chamber and photographing camera. A screen was then adjusted until a small sector of the track from both images was superimposed. Measurements of the space angles and positions of the screen then defined the coordinates of the track to approximately one millimeter accuracy. Templates laid along the screen permitted the radius of curvature and hence the momentum to be defined to within about ± 5 per cent.
2) The two separate stereo-views were projected onto a table; the tracks of interest were traced with a pencil; and the required parameters were obtained by graphical reconstruction.
3) Occasionally, a microscope was used to measure the coordinates of several bubbles along a track in order to define the radius of curvature. (A strong magnetic field of about 15,000 gauss causes the tracks to bend with a radius proportional to their momentum.)
4) Various optical systems have been used to distort the track either by straightening it or by increasing its curvature in an attempt to improve the accuracy above that attainable by templates.

There is a difference of opinion regarding whether these techniques really did represent a gain. Careful measurements of an event by any of the above techniques required from half-a-day to one and one-half days.

When cloud chambers were first used for Physics experiments at the Brookhaven Cosmotron, approximately five years ago, it quickly became apparent that none of these analyzing techniques were rapid enough. In some experiments the data were obtained ten times as fast as they could be analyzed.

During that same year a new detector, the bubble chamber, was invented. In this device, liquid is maintained under pressure and temperature conditions which causes the liquid to boil along the trajectory of charged particles. The flash photographs which are obtained are quite similar to cloud chamber photographs. But the liquid is one thousand times as dense as gas at atmospheric pressure, and therefore, interactions occur 1,000 times as frequently. Big accelerators like the Cosmotron or the Bevatron cost about 10 dollars per minute to operate. Hence, it is very important that we attempt to obtain as much physics as possible from every pulse of the machine. At the Lawrence Radiation Laboratory in Berkeley, we have conducted physics experiments with liquid hydrogen chambers of 4 inch, 10 inch, and 15 inch size. By the time that this article is published, we expect to be operating a liquid hydrogen chamber the size of a bathtub. We have not been able to devise a technique for analyzing every interaction which occurs in a bubble chamber, but we have achieved great increase in speed and some increase in accuracy over the methods which were previously used with cloud chambers.

In the foregoing section we have indicated the necessity for carrying out the analysis as rapidly as possible. It is also necessary that the measurements be made very accurately, in order to determine unambiguously what reaction has occurred. In a recent experiment, for example, we were unable to decide in 8 per cent of the events whether one neutron or one π°-meson had been emitted.

The ultimate limit in attainable accuracy of curvature measurements and range measurements is set by the statistical nature of the coulomb interactions between the incident particle and the atomic electrons in the liquid. For fast particles in liquid hydrogen this multiple coulomb scattering gives us an uncertainty in curvature of $1.45/\beta H\sqrt{L}$ where β is the ratio of particle velocity to the velocity of light, H is the magnetic field in kilogauss, and L is the length of the track measured in cm. in the liquid hydrogen. Thus, the uncertainty in momentum of a 10 cm. long track in a 15 kilogauss field is about 3 per cent. There is no point in trying to make measurements to higher accuracy than this.

Although multiple coulomb scattering sets an ultimate limit on the attainable accuracy of analysis, there are many other factors such as turbulence and optical distortion which may be more severely limiting in a particular experimental arrangement. For purposes of comparing the various factors, let us consider a standard "track" of momentum 1 Bev/c and length 25 cm. in a 10 kilogauss field. The sagitta would be 0.23 cm. in the absence of multiple coulomb scattering, but m.c.s. will make the sagitta unreliable to ± 3 per cent, i.e., ± 70 microns in space. If the image is demagnified in photography by a factor of 15, this corresponds to an uncertainty of ±5.7 microns on the film. Bubbles are characteristically about 0.3 mm. diameter at the moment of photography. Diffraction and depth-of-field effects enlarge the image by a factor approximately two from the geometrical image, so that the bubbles on the film appear to be circles of approximately 40 microns in diameter. It is necessary, therefore, to find the center of a row of bubbles to an accuracy of approximately 0.1 bubble diameter in the case of our "standard track" in order to match the coulomb scattering limit. We have found that it is possible to make measurements reproducibly to ±1 micron when film with resolution of 90 lines per mm. is used.

All measurements of our bubble chamber events are made with respect to fine fiducial marks of known separations engraved on the glass of the bubble chamber. Hence, the absolute scale of optical demagnification or of measuring engine calibrations are of little importance. The measuring engine calibration must, however, be uniform to within approximately ±2 microns in one centimeter of travel, if the engine errors are to be small compared with coulomb scattering.

Distortion of film may set a broader limit on the reliability of measurements than the coulomb scattering. We expect to use Cronar base film as soon as available. We do not plan to use photographic plates since we take nearly 1,000,000 pictures per year. We have made some measurements of distortions on Panatomic film by making a grid of lines with one cm. separation. Measurements of these line spacings showed normal variations of ±3 microns. I understand that photometric data attest that this amount of non-linear distortion is to be expected in normally processed acetate base commercial films, and that distortions as high as 15 microns may occasionally be observed.

Non-linear thermal expansion of film could produce errors as large as the coulomb scattering if for example the temperature change of acetate base film were 15 degrees centigrade, and non-linear distortion were as large as three per cent of thermal expansion. The temperature rise of the film in our projection apparatus is less than 6 degrees centigrade; expansions are more nearly characteristic of glass expansion coefficients than of acetate, because we hold the film to a glass backing by vacuum during the measurement.

The magnetic fields in our bubble chambers are not uniform. The maximum variation across the 15″ chamber, for example, is approximately 30 per cent. This introduces variations in the curvature of tracks passing through the chamber, but it does not represent an uncertainty provided we make appropriate corrections in the computation. The accuracy of magnetic field measurement does not present a problem because curvature measurements on tracks are inherently limited to an accuracy of a few per cent, whereas magnetic field calibrations are normally made to an accuracy of a fraction of a per cent.

Tracks in some parts of the chambers also show non-uniformity of curvature, because of aberrations and distortion in the optical system of the photographic equipment, and of the measuring equipment. These aberrations and distortions can be measured and corrected to the necessary accuracy by reference to a precise grid inside the bubble chamber.

Although it may be possible to achieve measurements that are limited only by the multiple coulomb scattering effects, our experience indicates that the gross movements of the liquid in the hydrogen bubble chamber often introduce momentum errors on high energy tracks which can exceed the coulomb scattering limit. A track image may be displaced from the true track position because of liquid motion subsequent to the bubble formation, or because of aberrations introduced by mixing liquids of different index of refraction. (Hydrogen of different temperatures.) The severity of these effects depends critically upon the delay of the photographic flash, the chamber recompression time, the frequency of chamber expansion, temperature gradients in the chamber, and other physical and operational characteristics of the chamber.

MEASURING AND COMPUTING PROCEDURE ADOPTED

Considerations of measurement speed, optical distortions, and camera aberrations led Dr. L. W. Alvarez to propose analysis by servo-controlled coordinate measurements on the film, followed by calculation on a high-speed digital computer. The Cartesian coordinates of a set of points on a track (roughly uniformly spaced) are measured on a projection microscope and automatically recorded on punched cards. Such measurements are made on all tracks of an event in two or more stereoscopic views; in addition, several reference marks are measured in each view. Such a complete event undergoes two principal stages of computation, a "geometrical" and a "kinematical" one.

Geometrical stage: From the points of the track in the two views a representative set of points in space is calculated. This calculation is quite simple in "first-order optics," that is, in the approximation that the sine of the angle of a ray with respect to the optic axis is equal to the tangent. For H_2 bubble chambers, this approximation is adequate only in case all the ray angles are less than about 10 degrees. In order to describe the orbit of a track in space, the representative points are projected onto a horizontal and a vertical plane. A parabolic fit is made to the horizontal projection and a linear one to the vertical projection. (The magnetic field is vertical.) This is an adequate representation of a high-momentum track. Some corrections are necessary for low momentum tracks. The digital computer uses the magnetic field and the parameters of the best-fit curves to calculate and print out the momentum, direction, position, and length of each track, as well as some auxillary information.

Kinematical stage: The equations of energy balance and momentum balance usually impose some constraints on the interrelations between the momentum components of the observed tracks. The computer calculates those constrained momentum components which most closely approximate the measured values (according to the criterion of "least squares"). If the event can be interpreted in several different ways, the computer is made to calculate the best fit on the basis of each hypothesis. The relative goodness of fit may then allow one to choose among the various hypotheses.

The computations described are currently carried out for our 10″ chamber and our 15″ chamber, on an IBM type 650 magnetic drum data-processing machine with a memory capacity of 2,000 ten-digit words and a speed of about 100 multiplications per second. The analysis of events in the 72″ hydrogen bubble chamber, now nearing completion at Berkeley, will be sufficiently more complex to require the use of an IBM 704 electronic data-processing machine (8,192 memory locations, 4,000 multiplications per second).

PRESENT LIMITS ON ANALYSIS SPEED

Measuring the coordinates along tracks of an event by means of ordinary microscopes can require more than an hour; the measurements are particularly subject to operator error when they are made on a routine basis for many hours. J. V. Franck's group has developed a projector for making rapid error-free measurements of the coordinates along track images. The machine is basically a projection measuring engine with servo-motor control of the engine stage position, to provide automatic centering of the image while the stage is being translated at speeds up to 2.5 mm. per sec., and coordinates are being recorded in IBM punched cards. The precision of the machine depends upon the use of carefully designed servo loops, and of accurate lead screws. These accurate X and Y lead screws, each with a correction bar, can move the stage 12 cm. in the X direction and 7 cm. in the Y direction. Coordinate measurements are made by determining the angular positions of the 1 mm. pitch lead screws, by means of rotary encoders. The accuracy of tracking can be continuously monitored by observation of a cathode-ray tube mounted at the lower edge of the viewing screen. The film being measured is projected at 30 diameters magnification on a transmission-type viewing screen. Illuminated cross hairs on the screen give visual indication of the region of the track being measured. The film is rigidly held to the moving stage by a vacuum platen, so that measurements are made with respect to a fixed optical axis.

With this "Franckenstein" measuring projector, a good operator can record all the data from a normal event in 5 minutes, and will average ten events on a routine 2-hour shift.

Computation of an event from IBM punched-card coordinate data requires 2 to 5 minutes.

Study of the output result from the IBM computation averages 10 to 30 minutes per event, depending on the experiment. This individual scrutiny and re-measurement or recalculation of questionable events is now the most time-consuming part of the data reduction.

We have recently examined the possibility of making our measurements by means of a stereoplanigraph or a similar instrument. We were stimulated by the reports of experimental apparatus which would automatically follow contoured tracks in three dimensions. Various photogrammetric experts have assured us that the accuracy obtainable by stereo measurement is twice as high as the accuracy obtained by making measurements independently on separate views. Stereoscopic measurement will only be of interest to us, however, if it also offers the possibility of increased speed and cheaper apparatus. Since the index of refraction of liquid hydrogen is not unity, and since the magnetic field is non-uniform and since we have large optical distortion, it will certainly be necessary to subject any measurements obtained by stereo to extensive IBM computation.

The technique which we have adopted for measuring bubble chamber film has sufficient accuracy. Its speed is more than an order of magnitude greater than the conventional methods of cloud chamber data analysis, but we are still far short of being able to analyze all of the interesting physics which exist in the bubble chamber film. We are currently working on the development of a type of mechanical flying spot scanner which promises to provide considerably higher speed.

*Length Measurement of Migrating Salmon by Paired Underwater Cameras**†

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ABSTRACT: *To provide accurate information for the management of commercial salmon fisheries, certain basic data on the habits and numbers of the fish must be obtained. Because of the large numbers of fish involved, visual methods of counting are not of sufficient accuracy. Cameras mounted on towers had inherent problems. This paper discusses use of an underwater camera system to produce stereo pairs of photographs to obtain data.*

THE purpose of management of the red salmon fisheries in Bristol Bay, is to allow a sufficient number of fish to escape the fishery, to spawn and to maintain the catch at its highest possible permanent level. To determine what this number should be, there is but one available method, the use of historical records. To be usable, these must be accurate statistics of the year-by-year runs and their escapements, with sufficient biological data to interpret the record thus obtained. The equipment described in this paper is designed to provide such data.

These red salmon are anadromous, feeding in the open sea, breeding far up the river systems of our Pacific Coast, laying their eggs in the gravel of lake shores, or in the bed of streams from which the emerging young can reach lakes in which to feed and grow for a period before going to sea. The adults return when four to six years old, to spawn once and die.

If the returning adults were all of the same age, it would be easy to compare the number of spawners of the parent generation with the new generation which returns and contributes to catch and escapement in a later year. For these fish return to their own streams, in fact to the particular gravels in which they were born. But to secure these basic statistics has been a difficult task, in the multitude of streams, for the five species of salmon. And to make the task far more difficult, the returning generation comes back in successive installments, over three years of overlapping generations. The different species move together, and the sexes differ in size and appearance. Counts of migrants must be supplemented by biological sampling to determine species, age and sex.

Counts of fish taken are secured from records of the commercial catch. There is no major difficulty in so doing.

Counts of the remainder of each run—the

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