CRYSTALS AND PHOTONS

IN his presidential address to the Indian Academy of Science, Sir C. V. Raman surveyed recent progress in the investigation of those phenomena which are observed when radiation is scattered in a crystal (*Current Science*, January 1941. Supplement). The subject is a natural extension of the well-known Raman effect usually observed in liquids, which has proved such a fruitful source of knowledge concerning molecular vibrations.

The analogous effects observed in crystals are, according to Raman and his collaborators, the result of interaction between the incident radiation and the material particles of the crystal. As a result of the absorption of energy from the incident beam, the regular geometrical array of atoms or molecules in the crystal is set into vibration. The lattice waves in the crystal can then be regarded as stratifications of density which may reflect the energy preferentially in certain directions. Owing to the interchange of energy between radiation and matter, the reflected ray suffers a change of wave-length. Thus when a diamond is illuminated by monochromatic radiation, the scattered ray contains two components with wave numbers differing by $\pm$ 1332 cm.$^{-1}$ from the wave number of the incident ray. This change of frequency appears on the quantum theory as the result of an exchange of energy between a photon and the crystal, a diminution occurring if the photon is the donor and the crystal the acceptor, an increase if the reverse is the case.

In the experiment just described, the radiation is scattered in all directions from the crystal; but Sir C. V. Raman also envisages circumstances in which the incident radiation is regularly reflected in certain directions. He states that infra-red radiation, within a certain range characteristic of the material, is strongly reflected backwards by the crystal because the optical vibrations of the lattice are powerfully excited by the incident waves. Recently, the observation of similar phenomena has been extended to the range of X-ray frequencies. According to Raman, the optical vibrations of the lattice, excited by the incident X-rays, create dynamic stratifications of the electron density, and these give regular reflexion of X-rays with a change of frequency in much the same way that the static planes of atoms give the classical Bragg reflexions without change of frequency.

These ideas are obviously of great interest, especially with regard to the reflexion of X-rays. This part of the subject has received considerable attention in both Europe and the United States. Reference to the correspondence columns of NATURE in the last year or two shows that the X-ray phenomena which Raman describes have been ascribed by other investigators to reflexion from the thermal waves in the lattice. The difference in point of view seems to be that Raman considers the lattice waves to be a result of excitation by the incident energy, and he also postulates a frequency change in the scattered energy. His case would be greatly strengthened by direct observation of this frequency change, which is, unfortunately, too small to be detected at present. The other approach to the problem regards the lattice waves as being already present in the crystal as a result of the thermal vibrations of the atoms, and the observed effects do, in fact, appear to be explicable on these lines. Whether a quantum mechanism is necessary for an accurate description of the phenomenon would seem to be a matter for still further investigation (see also p. 467 of this issue).

DAMS AND THE PROBLEM OF MIGRATORY FISHES

THE special symposium issue, with the above title, of the *Stanford Ichthyological Bulletin*, published through the co-operation of the Fish Commission of the State of Oregon and the Natural History Museum of Stanford University, comprises a number of papers read by leading fishery authorities in the United States on the problem presented by the construction of dams for generating electric power and for irrigation of agricultural land in certain States on the Pacific seaboard of North America.

The dams in question—already constructed or to be constructed—are in the basins of the Columbia and Sacramento Rivers. The fish mainly affected are the anadromous Pacific salmon (Oncorrhyncus)—chinook, blue back and cohoe—and the steel-head trout; fish which are of great importance in connexion with the world-famed commercial fisheries of the North American Pacific coast. Consideration has had to be given to the question of the effect these dams will have not only on the ascent of the breeding fish to their customary spawning grounds (and on the spawning grounds themselves) but also on the descent of the fry (and spent adults).

Fundamentally, a proposition of this nature resolves itself into the formulation of two questions, namely, (*a*) are such industrial developments on a river compatible with the continued maintenance of the fisheries in that river, and (*b*) if the answer is in the negative, are the fisheries to be regarded as of secondary importance and therefore inevitably to be sacrificed—the issue being the relative merits of each *quâ* progress? A subsidiary question will be the cost of the necessary measures involved under (*a*) to safeguard the fishery interests. If the cost is high it may be urged that the proposition really comes under heading (*b*).

At the outset neither of these questions seems to have even suggested itself to the industrial interests bent on exploiting these rivers as power generators. Nor does it appear that the central authorities vested with the power of supervisory administration (and whose consent had to be obtained in the first instance) were any more alive to the situation and to its implications. It devolved upon the fishery interests, through the American Bureau of Fisheries, to direct attention to the probable effect on the fisheries and to the very considerable monetary value to the community at large of those fisheries. Incidentally, these schemes were apparently initiated in connexion with the relief of unemployment

In the Columbia River system four of the dams are either already constructed or in process of being constructed; and there are nineteen others contemplated. In the Sacramento River two are constructed, or nearing completion, and the erection of fourteen others is under contemplation. The heights of two of these are mentioned, namely, at Grand Coulee on the Columbia River, 350 ft., and at Shasta on the Upper Sacramento River, 560 ft. The United States fishery experts are therefore obviously confronted with a problem of exceptional magnitude. How they are proposing to tackle it is set out in the symposium.

As regards the Grand Coulee Dam alone, which is going to eliminate some 600 miles of main river and 530 miles of tributaries as breeding ground, it is estimated that the runs of fish involved represent an annual value of an investment amounting to a capital outlay of 11,000,000 dollars yielding 4 per cent (or approximately £88,000 per annum), this area representing apparently about one third of the total catchment area of the Columbia River.

Grand Coulee Dam is 350 ft. in height; and the fishery experts have reached the conclusion that any measures devised to facilitate the ascent of fish to the waters above would cost at least 2,000,000 dollars "with a very good chance that they would not work". These measures, moreover, would be irrespective of what would have to be done—if practicable—to safeguard the downward migrating fry and spent fish (in this case the spent fish would be only among the steel-head trout, as all the so-called salmon of the Pacific die after spawning once).

The only alternative presenting itself was to divert the fish that would normally spawn above the site of the dam to tributaries entering the river below, where they would be held until ready to spawn, the intention being to let the fish spawn in the natural way in the spawning grounds previously investigated and regarded as probably suitable and adequate. The means adopted to secure this diversion, the difficulties and expense involved, are described.

The diversion had to be effected by actually transporting the fish from a dam (of surmountable dimensions) lower down. The fish were deposited at the mouth of the stream draining the tributary system selected (which was racked to prevent them dropping down stream), but unfortunately the fish failed to proceed upstream to the appointed place. Accordingly they had to be transported to where it had been intended they should go, and where they were retained until ripe eventually for stripping, the ova being fertilized and hatched artificially and the fry distributed over the selected rearing grounds.

It is, as yet, by no means certain that success will attend these efforts. Whether the available rearing ground will prove adequate for the quantity of fry released, and if so whether the returning adults resulting therefrom will be disposed to find the same streams where they were reared as fry, or whether they also will have to be diverted by actual transportation as were their progenitors, remains to be seen.

In the Sacramento River system the problem seems to be an even harder one. Here the embankment of the dam being constructed will be 560 ft. in height. It will impound the waters not only of the upper third of the Sacramento River itself but of the whole of the McCloud and Pit Rivers, permanently cutting off some 112 miles of previously available spawning and rearing ground.

In view of its cost and its problematical practical value when constructed—having regard to the height to be surmounted and to the seasonal fluctuations of the surface water-level (amounting to upwards of 200 ft.)—the idea of a fish pass had to be abandoned. There remain the alternatives of either diverting the fish to other still available spawning grounds in tributaries entering the main river below the dam or, after collecting the spawners, hand stripping the fish and sowing the fry in waters where they would have a chance of developing and from which they could migrate downstream without danger to themselves. From previous counts that have been made of the runs of fish going up past the site of the Shasta Dam it is estimated that in the case of the second alternative a total of approximately 100 million ova would have to be handled, "a number greater than that which is now produced by all the federal salmon hatcheries".

Schemes of this magnitude are not (and are never likely to be) encountered in Great Britain. There are, however, a number of impounding dams in England and Wales and (as yet not so many) in Scotland for the storage of water required by townships for domestic and industrial purposes. These are mainly in the headwaters of rivers, and though considerably less in height and dimensions than those which are the subject of discussion in the symposium under consideration, the problem they have presented has points in common.

The dams themselves are, of course, quite insurmountable by ascending fish and, because until recently the technique of dealing with the fluctuating surface-level of the reservoirs created by the dam had not been grasped, the notion of a fish pass to enable the fish to get up had been more or less dismissed. In any event the consequent extensive flooding of country above the dam so reduces the available area of spawning and rearing ground that the cost of a fish pass was deemed to be scarcely worth while. Moreover, the question of the descending fry and spent fish remained unsolved owing to the fluctuating top-water level of the reservoir and consequently to the uncertainty as to where, when and how egress could be found for them.

The difficulties presented as regards the ascent of the breeding fish and the subsequent descent of the fry and kelts have now to some extent been met by the idea of a fish pass with an adjustable feed from the reservoir, as has been adopted at Tongland (where the range of fluctuation in the top-water level does not exceed 41 ft.) and at the other impounding reservoirs on the same river system (the Kirkcudbright Dee) which are comprised in the Galloway Power Scheme.

At Tongland a large proportion of the fry pass through the turbines apparently without serious harm. The remainder, together with the spent fish, eventually find their way to the fish pass intake. The Tongland dam is 72 ft. in height and is the lowest situated of the series of dams, being immediately above the tidal water. It was, therefore, of vital importance to make it surmountable if the salmon of the Dee were not to be exterminated. That the measures taken to that end have been successful is apparently the case, and it can be assumed that the similar measures at the other dams above have been equally successful.

Though Tongland and its associated dams store water for power and not for distribution, the principle involved is the same as that applying to large imdounding dams generally. In each case there is the problem of assisting the fish (descending as well as ascending) over or round the dam, complicated by the fact that the top-water level of the reservoir varies according to meteorological and seasonal conditions.

An additional problem presented by, and peculiar to, the impounding of water for generating power, as distinct from supply, is the draw through the turbines. If there is adequate clearance between the blades, and the revolutions per minute do not exceed a certain—as yet not fully determined—maximum, small fish, such as smolts, can pass through, as they do at Tongland (and elsewhere) without hurt. It is probably better to let these small fish avail themselves of a quick exit from the reservoir by this, usually more readily found, route rather than compel them, by the interposition of closely interspaced gratings at the turbine intake, to seek it after probable delay through the fish pass intake. Screened, but by a grating with relatively wide interspaces, the turbine intake must be, however, to prevent the larger adults, spent and dropping downstream as kelts, from getting involved in the turbines, with certainly fatal results—to the fish.

It might be supposed that what has been possible on the Dee at Tongland would be equally possible on the Columbia and Sacramento Rivers. The magnitude of the proposition on the latter rivers, however, removes it to a somewhat different category. On no single river system in Britain has it been nor is it likely to be, necessary to contemplate an overflow at any dam amounting to as much as 650,000 cu. ft. (as at the Grand Coulee on the Columbia River), or an annual catch of salmon exceeding 1,500,000 lb. (as is the case in regard to one commercial fishery alone at the mouth of the Sacramento River).

It requires no exceptionally acute imaginative faculty to realize that the problem in these Pacific coast rivers is on a scale which introduces a somewhat different standard of outlook and demands a special mode of treatment.

The fight of the fishery interests to prevent the extermination of these important and valuable fisheries will be watched with sympathetic interest.

THE INTERNAL COMBUSTION ENGINE

THE full text of the series of three Cantor Lectures of the Royal Society of Arts delivered by Prof. S. J. Davies under the title "Recent Developments in Internal Combustion Engines", is now available (*J. Roy. Soc. Arts*, Feb. 1941).

In his opening remarks Prof. Davies quoted the prophecy made by Sir Frederick Bramwell at the jubilee meeting of the British Association in 1881 with respect to the steam engine: "I very much doubt whether those who meet here fifty years hence will then speak of that motor except in the character of a curiosity to be found in a museum"; such was the overwhelming opinion he had formed regarding the internal combustion engine. While the steam engine, including the steam turbine, has found success in certain definite fields of application, as has its rival in others, it cannot be denied that the internal combustion engine has, due to its special advantages, opened up fields of application, not closed to but only remotely accessible by the steam engine. Of these the highest is that of aeronautics, in which the present-day performance of the engines in use is such as Bramwell could not have imagined.

The first of these three lectures was in the nature of a general survey, outlining the development of the various types of engine as regards combustion, materials and manufacture. It is only in the last twenty years or thereabouts that the processes of combustion in petrol engines have been elucidated. Such well-recognized phenomena as 'pinking' and 'knocking' were known to be of importance in practice, but only the vaguest ideas were prevalent regarding the conditions which give rise to them. Although finality has by no means been reached, the systematic investigations of Ricardo and others have given the engine designer a sound basis on which to work.

In the compression-ignition type of engine, the development of 'airless' injection has been the most important improvement in combustion processes, as the resulting simplification of the engine has extended its field of application and given an impetus to its further improvement. Striking developments have also taken place in the materials used in their construction and in methods of manufacture, with great advantages in the reduction of weight relative to power.

The steadily increasing speeds at which internal combustion engines are now designed to operate has led to a virtual modification of the working cycle from the constant-pressure combustion proposed by Diesel to one approximating more closely to the constant-volume combustion of the petrol engine. In the petrol engine the direct injection of the fuel avoids the loss which otherwise occurs during the scavenging process in the two-stroke cycle and has opened up a wider field for this type. Prof. Davies expressed the view that the development of two-stroke petrol engines for aircraft appears to be within the range of practical possibility, and that, given success in this field, the extension of two-stroke working to all forms of petrol engines used in transport may be only a matter of time. Discussing the relative merits of carburation and fuel injection for aircraft engines, he gave it as his opinion that, if the two systems had started together forty years ago, fuel injection would have been in universal use to-day. The secret development work done by the Germans to make fuel injection satisfactory has enabled them to use it in all their fighter and bomber aircraft. Given a satisfactory arrangement of the controls, it offers the advantages of elimination of freezing, better distribution, low consumption at reduced brake mean pressures, lower hydraulic resistance in induction by the absence of choke and the possibility of two-stroke working.

An interesting comparison was made between the Rolls-Royce Merlin and a captured Daimler-Benz engine. Both develop practically the same power at take-off, but as the former is 27 litres against 33·9 of the German and their respective speeds are 3,000 and 2,400 r.p.m., the specific rating of the British engine is much higher. The Rolls-Royce has a two-