yields the rather surprising result that lead sulphide cells, and especially the lead telluride cells developed by Simpson, are already within a factor of about two of the limit for room temperature. Therefore greatly increased sensitivities can only be obtained by using detectors in refrigerated enclosures, for which the limit is more favorable. Recent reports show that even present day cells can be considerably improved by using them in a cooled enclosure. It remains to exploit these observations practically.

P.B.F.

On the Ultimate Sensitivity and Practical Performance of Radiation Detectors. By P. B. Fellgett. *J. Opt. Soc. Am. 39: 970, Noevmber, 1949.*

### High Sensitivity

Wartime developments in radar have made available equipment for producing and detecting short radio waves of a few millimeters to centimeters in length so that it is now convenient and easy to study the absorption of various substances, particularly gases, in this region of the electromagnetic spectrum. This paper describes a modification of the standard microwave spectrograph with which it is easier to attain the high sensitivities necessary for studying many molecules. The principle is to use the Stark effect to modulate the absorption of the gas at an audio or radio frequency.

An electric field, applied in the wave guide to split or displace the spectral lines, is turned on and off at an audio or radio frequency. The microwave energy is, therefore, either transmitted freely or partially absorbed by the gas, and the detected output of the apparatus is modulated at the frequency of the applied electric field. This is amplified by a sharply tuned radio receiver or special amplifier. In the present apparatus the amplifier is very sharply tuned and the signal recorded on a pen-and-ink recorder. In this way the noise due to the crystal detector is very greatly reduced, enabling absorption coefficients as low as $10^{-9}$ centimeter to be detected in a ten-foot length of absorption cell. E.B.W.

A Stark-Effect Microwave Spectrograph of High Sensitivity. By K. B. McAfee, Jr., R. H. Hughes, and E. Bright Wilson, Jr. *Rev. Sci. Inst. 20: 821, November, 1949.*

### Flame Propagation

There is considerable interest at the present time in the behavior of flames and the various factors which control their propagation. This has been motivated by the development of jet engines in which the fuels and operating conditions are not even a second cousin to the conventional internal combustion engines with which engineers have had considerable experience.

We know so little about the mechanism of flame propagation that we cannot tell whether the rate of flame propagation is controlled by hydrodynamics (in the form of diffusion of hydrogen atoms or free radicals) or whether the problem is essentially chemical (the kinetics of the individual chemical reactions being rate controlling). The actual design of combustion chambers and the suitability of particular fuels depend on which one of these factors is predominant. Violent feuds are taking place between exponents of the two viewpoints. We believe there is a critical pressure above which the hydrodynamics is of more importance and below which the chemistry becomes important.

In order to settle the argument, we have set up the honest hydrodynamical equations in which the chemical kinetics is plugged into the equations of continuity, and a staff of able computers is tediously integrating the equations point by point. As soon as the bugs are eliminated from our method of solution, we will place these equations on high speed computing devices and expect in this manner to bridge the gulf between the practical jet combustion problems and the basic chemical kinetics. When this work is completed, it will be possible to tailor-make a fuel and combustion system for any given operating condition. J.O.H.

The Theory of Flame Propagation. By J. O. Hirschfelder and C. F. Curtiss. *J. of Chem. Phys. 17: 1076, November, 1949.*

### Quieting Ram Jets

In 1945 the Applied Physics Laboratory of Johns Hopkins University, in a project for the U. S. Navy Bureau of Ordnance, established a testing laboratory for ram jet motors at Forest Grove, Maryland in relatively open country where high noise levels could be tolerated. After the war, new housing developments close to the laboratory rendered extensive quieting necessary, if operations were to continue. The Kellex Corporation conducted the required acoustical surveys and prepared plans for necessary modifications.

The noise levels inside the test cells reached 155 decibels—one hundred to one thousand times more intense than the noise from a large airplane engine. Some operating spaces in the laboratory suffered the uncomfortably high level of 120 decibels while levels in the street behind the laboratory reached 100 decibels, comparable to those in a noisy subway train. It was necessary to eliminate the noise without interfering with the entrance and exit of large quantities of air and hot gases.

New test cells with double concrete walls, double doors with rubber seals, and observation windows with four panes of thick glass were provided. All joints and openings were carefully sealed. An elaborate system of sound absorbing panels was installed in the exhaust and intake stacks. The modified test cells have been operating steadily for over a year without annoyance to the occupants of apartment houses which now line the street opposite the laboratory.

The project demonstrates that proper application of known acoustical engineering principles will provide quiet test laboratories which need not be at remote locations.

W.B.S.

Method for Quieting Ram Jet Motor Test Stations. By W. B. Snow and C. J. T. Young. *J. Acous. Soc. Am. 21: 626, November, 1949.*

### - - - - - - - - - oscopes

An increasing number of scientists and engineers are finding need for instruments to observe events from remote stations. Borescopes, for example, are needed for viewing the inside of rifle barrels, while gastroscopes are used for observing the stomach. Probably the best example of this type of instrument is the submarine periscope. All of these instruments are called image relay systems because they consist of lenses which reimage the scene several times in the course of the length of the tube.

Many of the present day optical problems are special tasks, and only one instrument of its kind is needed. For this reason, need for such an instrument is often met by attempts to make up a system with readily available lenses. Satisfactory systems can usually be put together in this way if the relaying is done properly.

We have described a few of the standard ways of relaying images optically and have shown that the main problem is to reduce the secondary color and field curvature. Secondary color, sometimes called residual color, refers to the color which cannot be completely eliminated in the usual achromatic lens. Since an optical relay consists of several such lenses, the residual color tends to accumulate rapidly.

The rules to remember when laying out a relay system can be briefly stated as follows: The relaying should be done in as large a tube as practical; all the intermediate images should be made as large as the tube will permit; the scene should be reimaged as few times as possible; and the working distance of the lens nearest to the object should be kept short. R.E.H.

Secondary Color in Optical Relay Systems. By Robert E. Hopkins. *J. Opt. Soc. Am. 39: 919, November, 1949.*

### Humidity and Piano Tuning

It is common practice to tune a piano just before an artist performs on it. One reason is that humidity in the air causes the wood structure to swell, thus altering the tension on the strings with changes in humidity. This is true even though most of the string tension is sustained by the metal plate. The rise and fall in the tuning of a six-foot grand piano has been observed over a period of nearly two years, and quantitative observations indicate that, within the three central octaves, the tuning rose 0.3% in frequency (0.05 semitone) on the average when the relative humidity increased 10%. The tuning was accordingly higher in the summer than in winter, and while the total change is not great in a climate as equable as that of San Diego where the experiment was performed, a tuning at each change of season is likely to be desirable in regions where (indoors) there are marked changes in humidity.

The equilibrium moisture content of wood is known to be a function of the relative humidity. A working hypothesis has been developed to relate this fact to the physics of the string supports. Two parameters thus appear by which may be described the piano's response to changes of humidity: the tuning-humidity coefficient and the time constant. The latter is the time required for the change of tuning to follow a steadily changing humidity. For this particular piano the time constant was of the order of fifteen days.

Information of the kind obtained in this experiment can be helpful in keeping the instruments of an orchestra in