daylight ground temperatures are below freezing in the Martian winter. (Air temperature on the surface of Mars is thought to be below freezing at all times.)

Whatever water exists on Mars should thus be frozen most of the time, making the existence of any familiar biological forms extremely difficult. Nevertheless, William Pickering, director of Caltech's Jet Propulsion Laboratory, did not rule out the possibility of life on Mars. He remarked that the probe did not give evidence either way. Furthermore, the pictures could not have shown any works of intelligent life, past or present. He pointed out that the Mariner pictures have a resolution of two miles, and therefore artificial surface features would be unlikely to show up.

Microwaves from a tin sandwich

Three years ago, in England, a young graduate student quietly advanced the theory that supercurrents can be expected to flow across a sandwich consisting of two superconductors separated by an insulating barrier. Since then, a growing ripple of excitement has been stirring the solid-state physics community as the predictions contained in his theory have been verified one by one.

The theory had its origins in the fact that Brian Josephson, an experimentalist and a student of A. B. Pippard at Cambridge University, had become interested in the boundary effects of superconductivity. Suspecting that there would be important coherence and phase effects across a junction of superconductor, normal substance, and superconductor, Josephson made some calculations and then published the results. These appeared in *Physics Letters* in 1962, and later in the thesis he wrote to become a fellow of Trinity College at Cambridge. He is still there working on an experiment for his PhD thesis.

Josephson predicted that pairs of electrons could tunnel from one superconductor to another through a sufficiently thin insulator, and he showed that the tunneling current could have two forms. In its first form, a dc supercurrent could flow without any voltage across the junction. P. W. Anderson of Bell Telephone Laboratories, while visiting Cambridge, became interested in Josephson's work and applied his own theoretical talents to the subject. Shortly afterward, Anderson and J. M. Rowell reported the first observation of the dc Josephson effect.

Josephson also predicted that putting a biasing voltage, V, across the sample would cause pairs of electrons to tunnel from one superconductor to the other. Although this is a virtual process, such a system has oscillating currents of frequency $\Delta E/h = 2eV/h$. These currents interact with the electromagnetic field, causing real processes to occur in which a photon is emitted. These photons have recently been observed in experiments carried out independently in the United States and in the Soviet Union.

Josephson expected that if the ac supercurrent were modulated by an applied rf field, a dc supercurrent would be produced. This would show up as regions of zero slope in the current-voltage characteristic (using dc or low frequency) at bias voltages given by $nhf/2e$ (f is the radio frequency and n takes on integral values). This inverse effect was found and reported by S. Shapiro of Arthur D. Little, Inc., in July 1964.

Since the Josephson predictions, many physicists have been trying to detect the radiation associated with the ac supercurrent produced when a dc voltage is applied across a tunnel junction. The difficulty was in getting the fields out of the junction and into a conventional detector. Late in May of this year I. Giaever of General Electric reported the indirect observation of the ac supercurrent. He used two superimposed junctions, with the second junction acting as detector of the radiation being produced in the first junction. He was able to detect about 10^{-7} W of ac power from the first junction, but did not get the power out of the system of junctions.

Late in June, a group from the University of Pennsylvania (B. N. Taylor, D. N. Langenberg, D. J. Scalapino, and R. E. Eck) gave a post-deadline paper at the New York American Physical Society meeting, and followed this with a paper in the August 16th issue of *Physical Review Letters*. They reported the direct observation of radiation emitted by a Josephson junction, and detected 10^{-12} W outside the junction. Meanwhile, it was learned that a Soviet group (I. K. Yanson, V. M. Svistunov, and I. M. Dmitrenko of the Ukrainian Academy of Sciences) had reported a very similar experiment in the March issue of *Zhurnal Eksperimental' noi Teoreticheskoi Fisiki*, and detected 10^{-14} W outside the junction.

In both experiments a film of tin was deposited on a glass substrate, then a layer of oxide was formed on top, and finally a second layer of tin was deposited on top, forming a right angle. The Penn group used tin strips about 1 mm wide and an oxide layer of about 10 Å. The sample was placed in a rectangular waveguide, equipped with a short-circuiting plunger, and the whole system was placed inside a cryostat with liquid helium. A small magnetic field (about one gauss) was applied in the plane of the junction, perpendicular to the axis of the waveguide. This field produces a spatial variation in the phase difference beween the two superconductors and thereby turns the junction effectively into a driven microwave cavity.

To show how the magnetic field does this, the following explanation has been offered. Figure 1 shows an imaginary circuit through the junction. Let φ be the phase difference between the two superconductors at a particular point, z. The difference between φ at z_1 and z_2 is proportional to the flux enclosed in the circuit; one flux quantum $hc/2e$ corresponds to a phase difference of 2π. Thus grad $\varphi = (2e/\hbar c)\ d\ (\mathbf{H}\times\mathbf{n})$, where d is the effective penetration

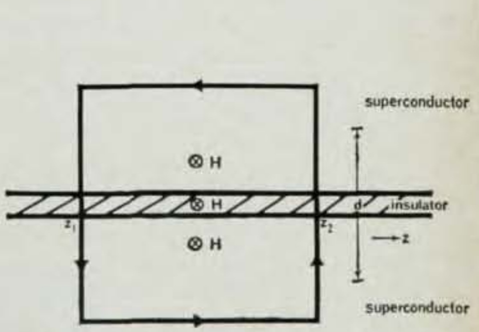

Fig. 1. Imaginary circuit through a Josephson junction.

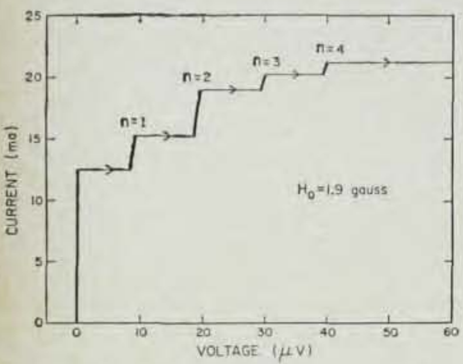

Fig. 2. A characteristic curve for the tin-tin oxide-tin junction used to detect Josephson radiation. Each step corresponds to a frequency separation of about 4600 Mc/sec.

thickness of the flux sheet through the junction, and **n** is a unit vector normal to the junction. The current density is given by a constant times sin φ (**r**, t), and one is interested in what φ will be for a fixed dc bias voltage V_0 and a constant field H_0 in the plane of the junction and aimed in the y direction. Since $\partial\varphi/\partial t = 2eV/\hbar$, the equation obtained is $\varphi = \omega t - kz$, where $\omega = 2eV_0/\hbar$ and $k = 2edH_0/\hbar c$. The first term shows that the current density varies with time; the second term shows that it varies with position. A third term also has to be considered; it is caused by the induced ac voltage. This introduces a dc component in the current density and gives the I-V characteristic of the junction.

The spatially modulated Josephson current now excites TM (transverse magnetic) waves which propagate in the insulating barrier in the z direction with a phase velocity $\bar{c}$. A Josephson junction of length L will have characteristic frequencies, ν_n, given by $nc/2L$, where n has integral values. The excitation of these modes shows up as steps in the I-V characteristic at bias voltages equal to $h\nu_n/2e$. Figure 2 is one of the characteristic curves obtained by the Penn group.

The group found that the magnitude of the signal received depended on the distance between the junction and the short, and became maximum when this distance was half the guide wavelength. Operating in the $n=2$ mode, a frequency of 9200 Mc was detected, with a spectral purity better than one part in 10^4. The highest power reported in the published letter was 10^{-12} W. Subsequently, the group has achieved 10^{-11} W.

Now that detectable power has been found, experimenters are trying to get usable power out. The problem is that the effective impedance of the Penn junction, for example, was only about 10^{-5} of the waveguide's impedance. Attempts to improve impedance matching include: (1) shaping the oxide layer like a horn, spreading out from 10 Å to 0.1 mm, (2) hanging an antenna on the junction, and (3) putting the junction in a high Q cavity.

Many solid staters are forecasting a useful future for Josephson junctions. They could serve as a generator or detector of microwave or infrared radiation, as an extremely sensitive dc detector (since frequency can now be measured to one part in 10^{12} and is proportional to applied voltage), and as a sensitive detector of magnetic fields. The effect can be used for a precise determination of h/e, and also of h/m (m being the electronic mass). Macroscopic quanta have already been used as a uniquely sensitive ammeter—the current was measured by simply counting the number of flux quanta.

AGS modification

The Atomic Energy Commission has requested funds to modify the Brookhaven Alternating Gradient Synchrotron. The alterations are expected to take five years and will raise the AGS intensity to about 10^{13} protons per pulse. Until the Soviet Union's 70-BeV machine at Serpukhov is finished in 1967 or 1968, the AGS will continue to produce higher-energy particles than any other machine on earth. The proposed 200-BeV proton accelerator will not be in operation in the United States until 1975 at the earliest.

When the AGS was originally proposed, its designers promised 10^{10} protons per pulse, although they actually hoped for 10^{11} protons per pulse. With experience and improvements, the AGS now yields 1.5×10^{12} protons per pulse, but further intensification is limited by space-charge effects to 2×10^{12} protons per pulse. (If there are too many protons in a region, they start to interact with each other.) Since the space-charge limit is roughly proportional to the injection energy, this energy will be increased. Brookhaven's original plans for modification called for a thousand-foot linac to produce 500-MeV protons. (At present, protons are injected from a 50-MeV linac.) In order to keep costs down, only a 200-MeV linac will be built at this time. However, there is a provision for an addition, to be built sometime later, that will provide 300 MeV more energy.

While the linac is being built, the power supply (now 35 000 kV-amperes) will be doubled. This modification will make it possible to pulse the AGS every second at full energy, instead of once every two and a half seconds. Even more rapid cycling is possible at lower energies. According to John Blewett, director of BNL's Advanced Accelerator Development Division, the combination of increased injection energy and more frequent pulsing should give at least 10^{13} protons per second. At 30 BeV and the new pulse rate the proton current will have a time average of 1.6 microamperes. It will also be possible to pulse more slowly to allow a longer-lasting beam for counter and spark-chamber experiments.

The number of straight sections used for rf acceleration will be reduced from twelve to eight, in order to provide more space for experimental targets, beam-extraction equipment, and so forth. Further, the electronic components of the accelerating system will be moved outside the ring so they can be serviced during operation.

The modified AGS is expected to produce 400 R/hour in target areas. Even now, radiation damage to equipment has become a problem. It was recently necessary to replace the particular AGS magnet which had been getting the largest dose. The insulation of the copper coils had changed from a healthy grayish brown, to a bright green, and finally a bilious yellow. At this color, in the last stages of radiation sickness, it became conducting.

In order to prevent similarly induced ailments in physicists and other essential equipment, the more intense AGS will require about ten extra feet