of the pyrochlore type rather than of the perovskite or ilmenite types in which earlier double-oxide ferroelectrics were found.[3,4] The importance of cadmium niobate as the possible fore-runner of a new class of ferroelectrics led us to investigate the dielectric properties of this compound at temperatures down to 1.2°K. Figure 1 shows the temperature variation of dielectric constant (uncorrected for porosity) for two ceramic specimens fired in cadmium oxide vapor at 1180°C (*A*, density=4.77) and at 1260°C (*B*, density=5.72), respectively.

Although the difference between the dielectric constants for the two specimens in Fig. 1 is mainly due to the difference in densities, the two curves do not coincide exactly when a suitable porosity correction is applied. The striking maximum at the upper Curie point shifts from 187°K to 183°K as the firing temperature is changed from 1180°C to 1260°C, perhaps owing to slight deviations from the stoichiometric formula $Cd_2Nb_2O_7$. In addition to the main peak, a small, previously unreported, dielectric constant peak is clearly visible at about 80°K for both specimens in Fig. 1, the temperature of the peak again depending slightly upon the specimen firing temperature. Since with an alternating field of about 10 kilovolts per cm, hysteresis loops were observed over the whole range from the upper Curie point down to 1.2°K, it seems possible that the small peak at 80°K marks a phase change similar to the minor transitions occurring at about 180°K and 270°K in barium titanate,[5] where a symmetry change is associated with a discrete jump in the direction and magnitude of the spontaneous electric moment without, however, the disappearance of ferroelectricity. Such transitions are obviously favored in ferroelectrics of the perovskite and pyrochlore types which are cubic in the paraelectric range and may lose several degrees of symmetry with decreasing temperature.

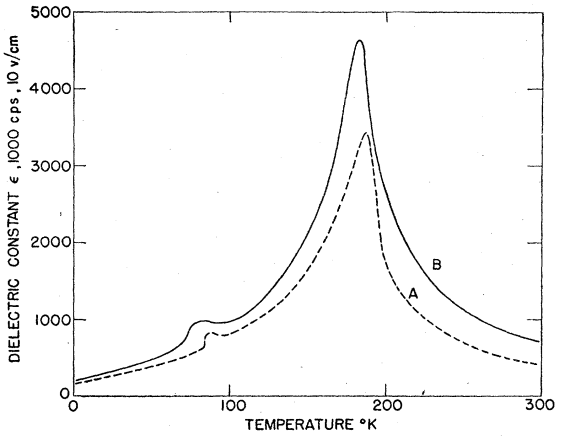

FIG. 1. Temperature variation of dielectric constant for specimens of cadmium niobate fired at 1180°C (A) and at 1260°C (B).

From dielectric observations above liquid nitrogen temperatures, Cook and Jaffe[2] suggested that lead niobate, $Pb_2Nb_2O_7$, which has an orthorhombic structure of a distorted pyrochlore type, should have a Curie point at very low temperatures. We have extended dielectric measurements on ceramic specimens of this compound down to 1.2°K, with the results shown in Fig. 2 for a specimen of density 6.53.

The dielectric constant of lead niobate rises steeply with decreasing temperature, obeying the Curie-Weiss law $\epsilon=C/(T-\theta)$, with $C=6.26\times10^4$ and $\theta=-166$°K, down to 75°K. Below this temperature the curve flattens out, passing through a maximum at 15.4°K and dropping gradually down to 1.2°K, as shown in the enlarged inset of Fig. 2. Although the behavior of the dielectric constant is rather similar to that of potassium tantalate,[6] the polarization-field curve of lead niobate was found to be strictly linear at field strengths up to 15 kilovolts per cm and at temperatures down to 1.2°K, implying that lead niobate is not a ferroelectric crystal. While the dielectric constant peak may be associated with an antiferroelectric phase transition, it is difficult to reconcile either ferroelectric or antiferroelectric behavior with the negative Curie-Weiss temperature of lead niobate, which suggests paraelectric behavior down to absolute zero. Theory[7] indicates, however, that the dielectric constant of such a paraelectric should increase monotonically with decreasing temperature, as has been observed for strontium titanate.[8] Further work is thus required to establish the nature of the dielectric constant peak in lead niobate.

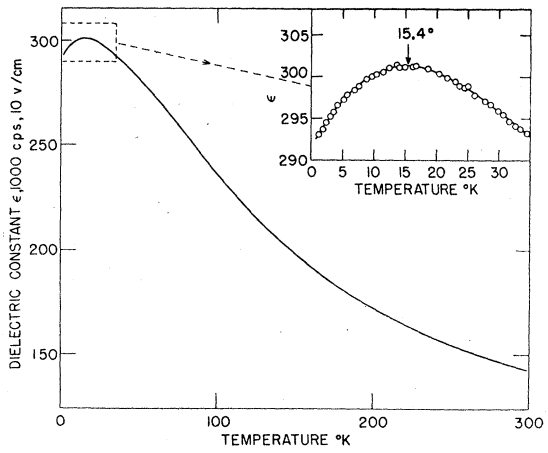

FIG. 2. Temperature variation of dielectric constant for specimen of lead niobate fired at 1180°C.

In conclusion it will be noted that no unusual dielectric properties were observed in $Cd_2Ta_2O_7$, $Pb_2Ta_2O_7$, $In_2Ti_2O_7$, $In_2Zr_2O_7$, $In_2Nb_2O_8$, $Y_2Nb_2O_8$, and $In_2Ta_2O_8$ between room temperature and liquid air temperature. The absence of ferroelectricity in the last three compounds is perhaps to be expected in view of the probable absence of NbO_6 or TaO_6 octahedra, which play such a vital role in the ferroelectricity of niobates and tantalates.[9]

I am grateful to Drs. Gen Shirane and Ray Pepinsky of Pennsylvania State College for kindly informing me of their unpublished data on cadmium and lead niobates,[10] which are in good agreement with the above results.

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Helium II Film Transport Rates over Machined Metal Surfaces*

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ONE widespread interpretation of previous transport measurements over metals maintains that ordinary, unpolished metal surfaces always show very high film transport rates (i.e., compared with glass).[1–3] The supposition is that, in contrast to glass, machined metal surfaces are characterized by a high degree of surface roughness which acts either to present a microperimeter many times larger than the measured macroperimeter,[3] or else to produce surface cracks which enhance the flow of bulk liquid.[1,2]

According to this view, "there may be only one transfer rate (that exhibited by the glass surfaces) and any higher rate would be due to the microstructure of the substrate."[2] Furthermore, it is maintained that "glass appears to be the only surface over which simple and reproducible phenomena of film flow have been observed."[4] The recent finding of Chandrasekhar and Mendelssohn[2] that highly polished stainless steel yielded a rate identical with that obtained for baked glass by Mendelssohn and White[1] is frequently cited in support of this interpretation.

In a previous note we have submitted evidence which does not support the assignment of this special role to glass. We wish now to report some new measurements which are at variance with the above view of transport over metals.

The method used to determine the rates listed in Table I was similar to that previously described.[5,6] The transport vessel-

TABLE I. Transport rate in $cm^3/sec\text{-}cm \times 10^5$.

	1.2°	1.4°	1.6°	1.8°	2.0°
Stainless steel[a]	9.8	9.7	9.1	7.5	4.9
Aluminum[b]	9.8	9.8	9.3	7.1	3.8
Aluminum[c]	9.3	9.0	8.5	6.8	4.0
Nickel silver[d]	11.4	11.3	10.6	8.8	5.5
Nickel silver[e]	···	9.0	8.3	6.8	4.5
Nickel silver[f]	10.3	10.1	9.4	8.0	5.2
Silver[g]	8.6	8.3	7.9	7.0	5.2
Copper[h]	10.2	10.1	9.5	7.4	4.2

[a] (Type 303, 18 percent Cr, 8 percent Ni, 2 percent Mn, 1 percent Si): Six runs in a two month period.
[b] (Alcoa Alloy 11*S*—5.5 percent Cu, 0.5 percent Pb, 0.5 percent Bi) Sample 1: two runs six weeks apart.
[c] (Alcoa Alloy 11*S*) Sample 2: one run.
[d] (46.5 percent Cu, 40.75 percent Zn, 2.75 percent Pb, 10 percent Ni) Sample 1: three runs in a five week period.
[e] (same as d)—Sample 2: one run.
[f] (same as d)—Sample 2: two runs three weeks apart.
[g] (Fine, 99.9 percent pure): one run.
[h] (Oxygen free, high conductivity): one run.

capacitors were turned from solid cylindrical rods and no abrasives or polishes were used to modify the microfinish resulting from the turning process. The choice of metals was dictated by their suitability for various surface treatments in preparation for measurements to follow the initial work on turned surfaces.

The rather narrow range of flow rates obtained for these "rough" metallic surfaces appears noteworthy in view of the wide range of values which have been reported for metals on other occasions. The results for stainless steel are in good agreement with previous, but completely independent measurements made in this laboratory.[7,8] Furthermore, the results of Chandrasekhar and Mendelssohn for highly polished stainless steel[2] (in the absence of a prepolishing control measurement) do not seem sufficiently different to justify definitive conclusions concerning the effect of surface polish.

In view of these considerations, we therefore conclude that:

I. Machined metals do not always yield rates much higher than glass.

II. Transport rates over machined metals are capable of demonstrating a simplicity and reproducibility at least matching that of glass.

III. The effect of a highly polished metal subtrate on transport rates needs further clarification.

A series of control experiments on the role of polishing is now in progress in this laboratory.

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Expectations from a Unified Field Theory

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IN classical field theories we have the following, completely independent, descriptions: (1) the electromagnetic field; (2) the gravitational field; (3) a prescribed distribution of charge in an elementary particle; (4) the equations of motion of a particle under the influence of fields.

A unification of (1) and (2) must, *inter alia*, also contain the statements (3) and (4); that is, a correct unified field theory must provide us with an acceptable distribution of charges and the law of motion for its carrier. A theory with the above characteristics is a field theory in an absolute sense; i.e., apart from the well-known features of a classical field it does not contain the constants e and m explicitly, but these constants are to be obtained as parameters in the solutions of the field equations with certain boundary conditions. This kind of field is very different from a mechanical theory since the latter contain in its equations the constants e and m. In this sense, classical electrodynamics also is not a pure field theory. The situation is the same in quantum mechanics, in which the Schrödinger and Dirac equations contain e and m. The passage to quantum field theory or to many-particle theory is achieved by the usual methods of second quantization but with the same mechanical equations that contain e and m explicitly. A quantized field in the above sense still bears the seeds of a mechanical concept even though it is called field theory.

We know from quantum electrodynamics that if the interaction between the radiation field and particles is considered to be small and the solution is worked out only to the first non-vanishing approximation in this interaction, the theory always gives correct results which agree with experiment up to the highest energies known. Thus the constants e and m appearing in the quantized equations fit in only for the first order perturbation theory; for higher order terms these constants have to be renormalized. Since the agreement of the first order calculations with experiment is satisfactory, one may regard the equations containing e and m, explicitly, as very good approximations to a future field theory from which e and m can be derived. The renormalization process is ample proof of the need for a field theory from whose equations the constants e and m are eliminated, so that there will be nothing left for renormalization.

The relativistic theory of gravitation is the only field theory in theoretical physics which has the above-mentioned desirable features of an absolute field theory. Its non-symmetric generalization, i.e., the unified field theory,[1] is a second example of an absolute field theory. Despite the great symmetry and beauty of its equations, it has not yet been possible to show its superiority over all other classical field theories. A much more difficult step is to discover a quantum version of the theory which, within the present realm of field quantization knowledge, may be regarded as Utopian. However, for the sake of argument, let us suppose that we have found a new method of quantization, which would mean a transition from a pure field theory to a mechanical theory having the properties of a quantized field; from this point of view it should be regarded as a unification of field and mechanics in an opposite sense to that of the usual quantized field, which is a unification of wave and particle concepts. Since, according to the above view, every physically measurable quantity is described by a field, then from its quantized version mass, and charge must result as quantum effects. In this fashion the so-called mass spectrum of elementary particles would be a natural consequence of the theory and all the divergent aspects of the present field theories might not arise. We are quite aware of the very ambitious form of the above statements, but it is conceivable that a complete field theory without the constants e and m may be reached in two big steps as described above. It also seems to us that trying to get agreement with all the experimental facts merely on the basis of the present form of the quantum field theories, is no less ambitious than the program outlined above.