Magnetic Susceptibilities of Coals

Abstract. *Magnetic susceptibilities are reported for seven American coals of different rank. The susceptibilities were measured in magnetic fields parallel and perpendicular to the bedding planes. The coals have diamagnetic susceptibilities approximating -0.5×10^{-6} centimeter-gram-second unit. Only anthracite shows significant magnetic anisotropy.*

Air pollution has recently come under public scrutiny. Oxides of sulfur produced by combustion of coal are receiving special attention as a health hazard. Since the major portion of sulfur in coals rich in sulfur (more than 3 percent S) is in the form of sulfides of iron, mainly pyrite, removal of iron sulfides by magnetic separation is being studied by the U.S. Bureau of Mines. During these studies we measured the magnetic susceptibilities of several coals. Very few studies have been made of the magnetic susceptibilities of coals (*1, 2*), and none have been reported of American coals in particular. We now report the results of our studies of seven selected American coals ranging in rank from high-volatile C-bituminous to anthracite.

It is well known that many physical properties of high-rank coals [for example, refractive index, extinction coefficient (*3*), x-ray and electron-scattering intensities (*4*)] differ according to whether they are measured along the bedding plane or perpendicular to it. For this reason samples of vitrains (anthraxylons) were carefully cut, the direction normal to the bedding being noted; cubes measuring 5 ± 0.5 mm were obtained. The vitrain samples were selected from relatively wide uniform bands, and were examined microscopically to make sure that they were free from visible mineral matter. Final shaping was done by grinding with sandpaper to avoid ferromagnetic contamination.

The magnetic balance used was a Faraday-type null instrument constructed at the Bureau of Mines for measurements of diamagnetic and low paramagnetic susceptibility. For diamagnetic measurements it was calibrated with water occupying the same volume as the coal specimens; measurements were made at room temperature under a field of 6000 gauss. The cubes were oriented so that the field was either parallel or perpendicular to the bedding plane. In the cases of anthracite and semianthracite, measurements were made along the third axis of the cube. The results appear in Table 1. No corrections were made for paramagnetic contributions. The data correspond to averages of at least two measurements on the same sample, the second measurement being made after measurements were made on at least one other sample. The average deviation of all repeated measurements was $\pm$ 0.02; root-mean-square deviation was $\pm$ 0.03 in the units specified.

Table 1. Magnetic susceptibilities of some American coals. Measurements: parallel (PAR) or perpendicular (PERP) to the bedding plane, or along another axis in the bedding plane (TA).

Coal	Magnetic susceptibility (10^{-6} cgs unit)		
	PAR	PERP	TA
Anthracite, Luzerne County, Pa.	−0.56	−0.77	−0.53
Semianthracite, Northumberland County, Pa.	− .42	− .44	− .43
Low-volatile bituminous, Wyoming County, W.Va.	− .49	− .52	
Medium-volatile bituminous, Wyoming County, W.Va.	− .56	− .58	
High-volatile A-bituminous, Allegheny County, Pa.	− .54	− .55	
High-volatile B-bituminous, Saline County, Ill.	− .57	− .61	
High-volatile C-bituminous, St. Clair County, Ill.	− .45	− .50	

Table 1 shows that coals are diamagnetic. Susceptibilities with the field parallel to the bedding plane indicate no special trend with rank. The perpendicular susceptibility of anthracite is significantly higher than its parallel susceptibility; that is, anthracite shows significant magnetic anisotropy, Measurements along two axes in the bedding plane, with anthracite and semianthracite, indicate no anisotropy. In every instance the perpendicular susceptibility is slightly higher than the parallel susceptibility, the difference being very small except for anthracite.

These results are in good agreement with others (*1*) from British coals.

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Radioactive Wastes from Fusion Reactors

Abstract. *Calculation of the amount of tritium released from a hypothetical fusion reactor shows that it is 2×10^4 the amount released by generation of an equivalent amount of electricity by a fission reactor. Release of the tritium generated by a power economy, if the nuclear power were all fusion, would result in unacceptable worldwide dosages by the year 2000.*

Although fusion reactors are still far from being operational, the long-term future for power generation is in breeder-fission or fusion reactors, and "the prospects for economic fusion power seem brighter today than in recent years" (*1*). In addition to the limitless supply of fuel and the low cost of the energy produced, one of the most attractive features of fusion reactors is the promise that they "would be free of radioactive waste" (*2*). When one recognizes that the usual spectrum of fission products will not be present, and that induced activity in the structural components of the reactor will be minor compared with the fission-product activity produced in a fission reactor, the most important aspects with respect to wastes are those dealing with the neutron economy and the tritium inventory and losses in a D-T-type reactor.

The debate over the feasibility of generating sufficient tritium and neutrons internally seems to have been resolved with publication of the Massachusetts Institute of Technology studies (*3, 4*). For the configuration investigated, it is stated that "It is evident that tritium breeding with sufficient margin to allow for all anticipated losses can be achieved in physically practical blanket configurations by using present available materials and techniques. Thus the basic question of the feasibility of D-T fusion reactors from the point of view of tritium regeneration appears to be favorably re-

solved" (*3*, p. 111). The removal of tritium from the blanket for injection into the plasma seems to be relatively easy. The cost of such a system at 1000 Mw_e at this early date appears to be low; estimated capital costs are \$150/kw_e—equivalent to about 2.6 mill/kw · hour (*1*, p. 27). The cost per kilowatt-hour (electrical) for thermonuclear power may be substantially less than that for: advanced converters, about 4 mill/kw · hour (*5*); breeders, less than 4 mill/kw · hour (*6*). Since a long confinement time of high-temperature plasma has not yet been experimentally demonstrated, these estimates for thermonuclear power are only first approximations and can be expected to change as knowledge of the system grows.

For the fusion reactor, the fission products and induced activity wastes from the alpha particles and neutrons generally will be negligible; the major problem will be loss of tritium. If Rose's estimate is correct (*7*)—that 1.15 tritons (T) must be generated for each triton burned, because of losses and adsorption—10^6 c of tritium must be disposed of daily per 1000 Mw_e of power produced daily.

The conceptual design of Homeyer states that the fusion of 228 g of tritium daily is required for 300-Mw_e production of power (*4*, p. 69):

$$\frac{228\ \text{g T}}{300\ Mw_e \cdot \text{day}} \times 9.78 \times 10^5 \frac{\text{cT}}{\text{gT}} \times 0.15 \text{ loss} \times 1000\ Mw_e = 1.1 \times 10^6\ \text{c T/day}$$

For a fusion reactor, then, tritium would be released at 1.1×10^6 c/day per 1000 Mw of electrical power. This is a significantly higher release of tritium than that to be expected from a fission reactor. The work of Albenesius (*8*) shows that tritium is a fission product, although produced in very low yield (1.15 tritons per 10^4 fissions).

Recent studies (*9*) of the siting of fuel-reprocessing plants indicate that fission-product gases will impose the most severe limitations on siting. One can compare the total amount of tritium produced in fission reactors with that lost from fusion reactors. However, I must emphasize that the major amounts of tritium are released not at the reactor site but during reprocessing of the irradiated fuel elements. In this case, looking at a global average, we should compare the total products per 1000 Mw_e from fission reactors with the losses from a 1000-Mw_e fusion reactor. Only the losses need be considered in a fusion reactor, because the major portion of the tritium is used as fuel. If one assumes the usual factors of 200 Mev per fission, 1.15 tritons per 10^4 fissions, and thermal efficiency of 30 percent for 1000 Mw_e,

$$\frac{1.15\ \text{T}}{10^4\ \text{fissions}} \times \frac{1\ \text{fission}}{200\ \text{Mev}} \times \frac{6.24 \times 10^{18}\ \text{Mev/sec}}{Mw_t} \times \frac{1000\ Mw_e}{0.3\ Mw_e/Mw_t} \times 8.64 \times 10^4\ \text{sec/day} = 1 \times 10^{21}\ \text{T/day}$$

$$\frac{1 \times 10^{21}\ \text{T/day}}{\frac{6.02 \times 10^{23}\ (\text{T/g mol. wt})}{3\ (\text{g/g mol. wt})}} \times 9.78 \times 10^3 \frac{\text{c T}}{\text{g T}} = 50\ \text{c T/day for 1000}\ Mw_e$$

Thus a fission reactor would generate 50 curies of tritium daily per 1000 Mw of electrical power. It appears that the problem of radioactive waste, in terms of production and losses of tritium, will be 2×10^4 times greater with fusion reactors than with fission reactors.

It has already been calculated that the overall increase by the year 2000 in dose rate for the population, due to plants reprocessing nuclear fuel, will be about 2×10^{-3} mrem/year (*10*). If the releases were to be increased by a factor of 2×10^4, the resultant increase in annual dose would not be acceptable; thus methods for removing tritium must be improved in order to make fusion power safe.

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Cell Lysis: Another Function of the Coat Protein of the Bacteriophage f2

Abstract. *Evidence is presented that the coat protein of bacteriophage f2 causes the lysis of infected* Escherichia coli. *To lyse bacteria, the coat protein produced must be of the quality to produce phage particles, although it need not be produced in amounts sufficient to give a large yield of particles. Mutants that are blocked in coat-protein synthesis, or that direct the synthesis of an imperfect coat protein, do not lyse their host bacteria. In addition to its obvious structural role and its postulated regulatory role, another, perhaps enzymatic, role has been found for the coat protein of the phage f2.*

In order to be released from their host bacteria, many bacteriophages cause the production of a lysozyme-like endolysin that dissolves the bacterial cell wall (*1*). However, certain phage mutants, presumably those mutated in the lysozyme gene, result in a normal yield of phage which is not released from the cell and must await artificial rupture (*2*). The small RNA bacteriophages such as f2 also are released by cellular lysis (*3*), but the mechanism of this release is not known. Of the three known genes in f2 (*4*), none is directly related to cell lysis. Gene 1 specifies the viral RNA polymerase; gene 2, a particle assembly protein; and gene 3, the major coat protein. We now have evidence that the coat protein of the phage is responsible for cell lysis.

In an early study of *amber* mutants of bacteriophage f2, when little was known about them, their suppression, or of the genes of f2, Zinder and Cooper (*5*) found that all of their mutants could be classified on the basis of the mode of growth of nonpermissive cells infected with the various mutants. One class of mutants caused the cells to lyse at the normal time, resulting in the release of a full yield of defective phage particles. These mutations are in the assembly gene and allow normal production of coat protein, but produce only defective particles. Another class of mutants allows the infected cells to grow as if uninfected; these are either mutants of the polymerase gene or polar mutants (see below) of the coat-protein gene. After infection with a third class of mutants, the cells increase in mass at a normal rate for a period equivalent to that prior to normal lysis;