Table 1. Carbon-14 assays of organic extracts from streams.

Extract	Concn. (parts in 10^9)	Contemporary carbon (%)	Sample No.*
Raw water with industrial pollution, Nitro, W. Va.			
Chloroform	1673	5 ± 2	W-1014
Ethanol	297	42 ± 2	W-1081
Tap water with domestic and industrial pollution, Cincinnati, Ohio			
Chloroform	120	50 ± 2	W-1079
Ethanol	288	66 ± 2	W-1080
Raw water with natural, domestic, and petroleum pollution, Whiting, Ind.			
Chloroform	202	30 ± 2	W-1015
Ethanol	269	72 ± 2	W-1013

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and determining their carbon-14 activity, it is possible to estimate the relative contributions of both types of organic wastes. The method considers that domestic (or "municipal") wastes consist primarily of animal and vegetable matter in garbage and sewage. These are contemporary in their content of the radioactive isotope, carbon-14. Conversely, organic industrial wastes are discharged by industries that utilize nonradioactive fossil carbon materials—coal, petroleum, or natural gas. A similar determination has been made (*1*) of the sources of air pollution.

The sample of organic contaminants required for carbon-14 assay is recovered from the stream by use of an activated carbon filter sampling system (*2*). Adsorbed organics are recovered by successive extraction with chloroform and with 95-percent ethanol. Industrial wastes are usually concentrated in the chloroform extract, whereas the more polar compounds of domestic wastes are more abundant in the ethanol extract. The weight ratio of these two extracts is in itself an indication of the type of pollution source.

The described premise is, of course, a simplification. Domestic wastes may contain a portion of fossil compounds, such as detergents and antifreeze. Industries dealing with vegetable and animal matter, such as dairies and canneries, have been classified as "domestic" because of the nature of their wastes. Finally, to a limited and unknown degree, natural biological cycles of oxidation and photosynthesis may rearrange a portion of both the contemporary and fossil carbon (organic and inorganic) in the stream into new organic compounds resembling those of domestic waste. Nevertheless, experimental data appear to justify disregarding these factors in a first approximation, for the results of several isotope assays agreed with the actual pollution sources, where these were known.

Organic chemical contaminants were collected from surface waters representing three classes of pollutional situations. The contamination of the Kanawha River at Nitro, West Virginia, is almost entirely due to chemical industrial wastes. At Cincinnati, the Ohio River reaches a maximum loading of organic products of both industrial and domestic origin and the products have had opportunity for oxidative stabilization. Samples from Lake Michigan at Whiting, Indiana, represent water containing oxidized natural and sewage organics, together with the discharged wastes of many petroleum refineries.

For carbon-14 assay the tar-like samples were converted to acetylene for counting in the radiocarbon dating apparatus of the U.S. Geological Survey. Difficulty was encountered in burning the samples in the oxygen-flow atmosphere customarily used, so a double-tube method was employed. The samples, in combustion boats, were heated in flowing nitrogen which swept the combustible vapor to an orifice, where oxygen was introduced. There the gas burned, providing a slower and more complete oxidation. The carbon dioxide was collected and converted in steps to a carbonate, a carbide, and purified acetylene, as described by Suess (*3*). The radiometric determinations were made in proportional counters of 1-liter capacity at 1 atmosphere pressure, with counting times of 2 days for each sample. Results are reported in percentage of contemporary carbon, and the contemporary carbon is taken to be 95 percent of the radiocarbon oxalic acid standard, a convention agreed on by all carbon-14 laboratories.

The results of carbon-14 assays of the organic extracts, expressed as percentage of contemporary carbon, are shown in Table 1. Carbon-14 assay reveals proportions of fossil and contemporary carbon that are consistent with our knowledge of the pollution sources at the three sampling sites. The samples from Nitro show the preponderantly industrial origin; the samples from Cincinnati show that the major portion of the organics was of biological origin. The results with the samples from Whiting clearly show two classes of pollutants, with the petroleum materials effectively concentrated in the chloroform extract.

Further applications of the method will be made. A particular effort is being directed to the assay of single classes or isolated compounds among the organic contaminants, with the objective of discerning whether specific contaminants are of natural or industrial origin when both sources are possible.

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13 February 1964

Explosive Welding with Nitroguanidine

Abstract. *By using the explosive nitroguanidine, continuous welds can be made between similar and dissimilar metals. Since low detonation pressures are attainable, pressure transfer media are not required between the explosive and the metal surface. The need for either a space or an angle between the metals is eliminated, and very low atmospheric pressures are not required. Successful welds have been made between tantalum and 4140 steel, 3003H14 aluminum and 4140 steel, and 304 stainless steel and 3003H14 aluminum.*

The explosive nitroguanidine ($CH_4N_4O_2$) has been utilized extensively at this laboratory, since 1959, for research in explosive-metal working. The primary advantage of its use in this field is its detonability in practice at bulk densities from 0.11 to 1.7 g/cm^3, corresponding to computed detonation velocities from 1890 to 8270 m/sec and detonation pressures as low as 1 kilobar.

The relationship between detonation velocity and bulk density for nitroguanidine is (*1*)

$$D = 1445 + 4015\,\rho \qquad (1)$$

and that between detonation pressure and bulk density is

$$P = 77\,\rho^{1.94} \qquad (2)$$

where D is the detonation velocity in meters per second, P is the detonation pressure in kilobars, and ρ is the bulk density in grams per cubic centimeter. As these equations show, values of detonation velocity and pressure may be varied over a wide range.

The range of bulk densities used in these studies of direct-contact explosive welding was from 0.6 to 1.2 g/cm^3. This corresponds to a range of 28 to 109 kilobars in detonation pressure and 3850 to 6250 m/sec in detonation velocity.

A simple experimental arrangement was used. The explosive charge of nitroguanidine, which was in intimate contact with the exposed surface of the top layer of metal, was detonated at one end. The thickness of explosive used throughout the study was 13 mm. The weld specimens were approximately 25 mm in width and 75 mm in length. The thickness of the tantalum and of the 3003H14 aluminum was 0.5 mm; the thickness of the 304 stainless steel was 1.2 mm, and that of the 4140 steel was 6 mm. The interfacial surfaces were cleansed by emery paper to remove most of the surface oxides. The experiments were conducted under conditions of normal temperature and pressure (that is, no vacuum was created) and the two metals to be joined were in direct contact. Other workers (*2, 3*) have reported the use of a space and angle between the metals during explosive welding since satisfactory welds were not made when the two metals were in intimate contact.

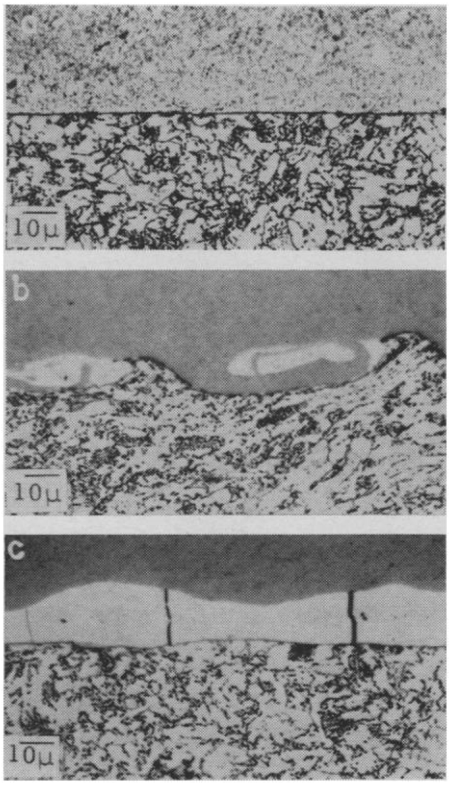

Fig. 1. Photomicrographs of the various types of weld formed in explosive welding with nitroguanidine. (*a*) Clean weld between 3003H14 aluminum (above) and 4140 steel (below); (*b*) tumbled weld between tantalum (above) and 4140 steel (below); (*c*) diffusion weld between tantalum (above) and 4140 steel (below).

Since the explosive charge was initiated at one end, the welded joint was formed at the same velocity as the detonation velocity of the nitroguanidine. In the range of detonation velocities used in this method of explosive welding, the weld velocities were varied so that they were either above, at, or below the sound velocity of the various metals. Satisfactory welds, as evaluated by peel tests, were made over the entire range of velocities; where failures did occur, these were usually in the weaker parent metal rather than at the weld interface.

The photomicrographs in Fig. 1 show the typical structure of the various types of welds that were observed. The three weld types are classified here as clean, tumbled, and diffusion welds. In the clean weld (*a*), there is a smooth interface between the two metals. The tumbled weld (*b*) consists of interlocking wavelets of the two metals with enclosed pockets of diffused material, and the diffusion weld (*c*) has a clearly defined zone of a brittle nature which is formed continuously along the interface between the two metals. Since only a limited number of experiments were performed for each system, correlations between weld types and the experimental parameters will not be attempted in this report.

Several investigators have observed zones similar in appearance in welds formed by other explosive techniques but have, on a theoretical basis, stated that diffusion of the metals could not take place during such brief explosive loadings (*3*). However, as a form of direct observation of this interfacial zone we have performed microprobe analyses (*4*) across these zones. For example, the typical microprobe profile of iron, in passing from tantalum through the interfacial zone to 4140 steel, shows very clearly that a diffusion zone has been produced (Fig. 2). Observation of the tantalum-iron equilibrium diagram (*5*) shows that an intermetallic compound $TaFe_2$ exists at room temperature, diffusion alloys being formed at higher temperatures. The diffusion zone is of a brittle nature as is indicated by the fissures (Fig. 1*c*) formed perpendicular to the weld interface. These failures also indicate that the diffusion zone was formed prior to the return to normal conditions of temperature and pressure, as tensile unloading phenomena (the probable cause of failure) occur only after passage of the shock wave-heat pulse from the detonating explosive.

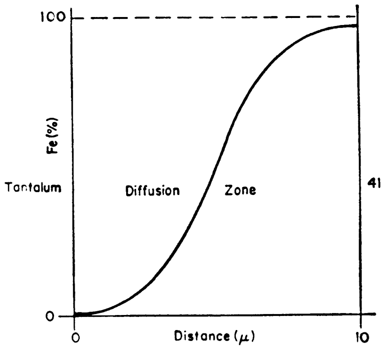

Fig. 2. Microprobe analysis of iron in the diffusion zone of a weld of the type shown in Fig. 1*c*, between tantalum and 4140 steel. The diffusion zones observed were in the range of 1 to 20 μ in thickness.

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