tron at Daresbury. The project will cost $6,250,000 to build, and the projected operating budget is $2 million per year for the first 5 years. Completion is scheduled in mid-1979.

When finished, the storage ring, dubbed NINA II, will have up to ten beam ports with two or three experimental stations each. The current in the storage ring is designed to be 1 ampere. The NINA II ring may also be the first synchrotron radiation source in which superconducting wiggler magnets are used. These magnets, located in the straight sections of the ring, will force the beam to follow a meandering path that is, on the average, straight. The locally increased curvature of the beam path means that high intensities of short wavelength x-rays can be produced without the expense of building a very high energy storage ring.

At Orsay, in France, the 4-year-old ACO storage ring will be converted next spring into a dedicated facility. But the 550-Mev energy will only permit experiments into the soft x-ray region. A larger 1.8-Gev storage ring (DCI) is just now being tested at Orsay. It will have approximately the same spectral range as NINA II (without wiggler magnets), but less intensity. The DCI ring will not be a dedicated facility, but one port with five experimental stations will be available to synchrotron radiation users.

Researchers in other countries are also pursuing synchrotron radiation. The most ambitious plan appears to be the Japanese proposal to build a $57 million "photon factory." The $57 million, however, is to be divided between three facilities that would have a common electron source: a storage ring for synchrotron radiation, a pulsed neutron source, and a high energy physics laboratory. The 2.5-Gev project is still awaiting funding. In Italy, the ADONE storage ring has no beam ports for synchrotron radiation at present, but a design study for synchrotron radiation is under way. Scientists in the U.S.S.R. have access to several high energy physics machines for synchrotron radiation studies, and two proposals are now under consideration for dedicated storage rings capable of producing x-rays.

What effect will the development of still bigger storage rings, which seem to be so attractive for high energy physics research, have for synchrotron radiation users? Although the larger machines, such as the 15-Gev PEP planned at Stanford and the 19-Gev PETRA planned at DESY, can produce harder x-rays, they have enough disadvantages that they will probably only be attractive for a few selected experiments, according to Christof Kunz at DESY. Apparently dedicated machines are needed much more than bigger machines, and an international panel concluded in 1974 that 2 Gev was the optimum energy.

In the United States, interest in a national synchrotron radiation center is at a high pitch, but the difficult process of unifying the scientific support and obtaining government approval has barely begun.

This month, however, the National Science Foundation (NSF) (which supports the Stanford and Wisconsin projects) and the Energy Research and Development Administration (ERDA) (which would like to have a national facility at one of its laboratories) are issuing a joint call for information, according to William Oosterhuis of NSF and Mark Wittles of ERDA. They emphasize, however, that they are only seeking preliminary information for the purpose of defining the scope and format of a synchrotron radiation facility, not proposals.

Nonetheless, Brookhaven National Laboratory has already sent ERDA a proposal for a $20-million facility that would be based on a 2-Gev storage ring with a more progressive design than the British project at Daresbury. The Brookhaven design would maximize the radiation intensity obtainable and be flexible enough to meet most experimental requirements. Stanford scientists are talking up the idea of converting SPEAR into a dedicated synchrotron source that could have a source intensity comparable to that of DORIS in the event that PEP is approved, and researchers at Stoughton feel that a case can be made for establishing a high energy source there.—WILLIAM D. METZ and ARTHUR L. ROBINSON

Conservation of Stone Artworks: Barely a Role for Science

Last summer in Bologna, about 150 scientists and craftsmen met to discuss the complicated subject of preserving stone objects and buildings. The Third International Symposium on the Conservation of Stone was not a dramatic occasion, in the sense that no breakthroughs were reported. But the difficult dialogue between the craftsmen who do the restoration and the scientists who evaluate the problems inched forward.

The conservation of stone is really a sequence of independent procedures. First, the causes and mechanism of the decay are (it is hoped) elucidated. Then the stone is, in turn, cleaned, consolidated (strengthened by binding together the individual grains), and protected against future chemical or physical attack.

In most cases of stone deterioration, water has been the saboteur. The porosity of sedimentary rocks makes it very easy for salt solutions to circulate through them. And although granites and igneous rocks are not so porous by nature, when eroded by weathering and temperature changes they are also susceptible to attack by water.

On stone that has been heavily weathered by water, alternating deposition and dissolution of soluble salts over a long period of time creates a flux in the structure of the decayed stone's crust, which shows up in microscope scans of cross sections and surface patinas. Using an optical interference technique, Seymour Z. Lewin of New York University and E. J. Rock of Wellesley College, Massachusetts, found orientation patterns of the gypsum crystals in the layers of decay of marble that had been exposed to the New York City atmosphere for years. This indicates that the corrosion crust of decaying marble is not static, but heterogenous and dynamic. Acids formed by the dissolution of air pollutants (oxides of sulfur and nitrogen) in rainwater or condensed moisture penetrate the stone, leach out calcium salts, and deposit these salts on the surface of the stone, producing the patina. Thus, a patina on weathered stone may appear to be firm and nonporous, yet the stone beneath may be soft and ready to crumble. Similar effects are caused by the capillary rise of underground water into the stone and its evaporation from exposed surfaces. (Usually water from the ground reacts with stone as a dilute solution of carbonic acid.)

Whereas water has always been a nemesis to conservators, air pollution, which accelerates the rate of stone decay, has become increasingly important in many urban environments. Thus, if the main source of air pollution is automobile traffic and home or factory heating plants, its effects should be most severe closest to the emission sources. However, the correlation between the actual SO_2 concentration to which the stone is exposed and other factors, such as altitude, has only recently begun to be understood. A new device called the Immission Rate Measuring Apparatus (IRMA) developed by S. Luckat from Landesanstalt für Immissions und Bodennutzungsschutz, West Germany, may help to solve this problem. Based on the principle of the Soxhlet extractor, IRMA can be used to measure SO_2 and other pollutants by circulating the test atmosphere through an alkaline carrier substance.

The need for an instrument like IRMA at all goes back to two fundamentals in conservation: first, the stone in an object or building does not behave exactly like its quarry or laboratory sample counterpart, and second, the climatic conditions that stone objects are subjected to (the so-called microclimate) may be different from the macroscopic environmental conditions. Both of these factors have hindered the design of reliable controlled experiments.

Typical of attempts to impose order on the study of weathering effects is the laboratory procedure for accelerated aging. Cubes of stone, taken from the same quarry as stone in selected sculptures and monuments, are soaked in various concentrations of ammonium hydrogen sulfate to simulate the effects of a range of acidities in rainwater. Later the samples are exposed to freezing and thawing cycles and then tested for changes in porosity. However, the discussions at Bologna revealed general skepticism about correlations between accelerated weathering tests and field experience.

The presence of sulfur on stone was discussed at the conference as a clue to another kind of stone decay. When sulfur in stone was analyzed, the results were in some cases surprising. Although calcium sulfite was expected on the surface of the stone (from the reaction of sulfurous acid and calcium carbonate), it was completely absent in some stone, even heavily polluted atmospheres. Instead the sulfur was found only as sulfate. Some investigators consider this a clear sign of the activities of sulfating bacteria, and this has led to the proposal that if stone could be sterilized, and kept sterile, the deterioration would largely cease. However, it was also argued that sulfite is catalytically oxidized to sulfate on moist stone surfaces, and that bacterial activity, although undoubtedly present, is an after-the-fact phenomenon, rather than a primary cause of the observed deterioration.

Methods of controlling biological decay due to moss, lichen, and algae on stone were reported by B. A. Richardson, director of the Penarth Research Centre in England. He suggested that quaternary ammonium and organotin treatments are the most effective for removing and inhibiting biological growth. The positive reception his research received indicates the real dilemma of the working conservators. In many cases, the available conservation techniques do not satisfy art historians and critics, since they often alter surface appearances. But if nothing is done, an irreplaceable object may be lost.

Kenneth Hempel of the Victoria and Albert Museum in London and Ottorino Nonfarmale of the Center for Conservation of Sculpture in Bologna are respected artisans, whose successes at stone conservation were well received at the conference (Fig. 1). Their plea was for more and better input to the craftsman from the scientist, with respect to testing and evaluation of commercial products as well as analysis of exposed stone structures.

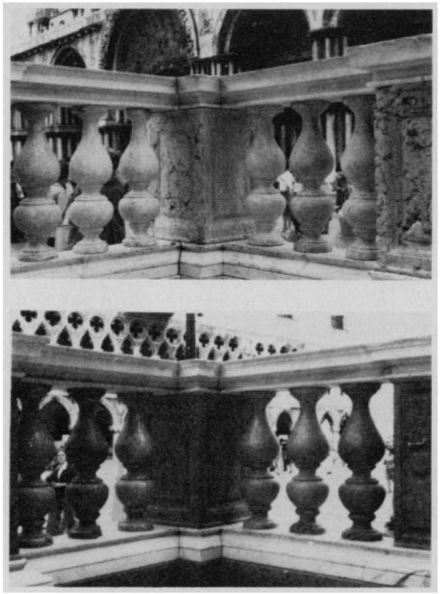

Fig. 1. Two different stone balustrades, one (top) restored by Giulia Musumeci, of the Victoria and Albert Museum in London, and the other (bottom) unrestored. They are part of the Loggia Del Sansovia opposite San Marco in Venice. In this instance, the task of consolidating the stone was complicated, because the balustrade is made of two different kinds of marble with different porosities.

With one major exception, the pivotal step in successful conservation—cleaning the stone—was barely discussed at the conference. The exception was that Lewin and Rock described their work on removing iron corrosion from marble and limestone. The trick here is avoiding damage to the highly reactive calcium carbonate. Ammonium oxalate, ammonium phosphate, and ammonium fluoride are considered the most effective agents for removing iron stains. But experiments on a model system—an artificial stone consisting of sintered glass beads of known physical properties, which is impregnated with iron, treated, cross-sectioned, and analyzed—showed that the common treatments could only remove surface stains.

Most of the discussion centered on consolidation—the step needed after cleaning to strengthen the stone when its internal structure and cohesion have been substantially weakened by decay. Successful consolidation is crucial, according to Giorgio Torraca of the International Center for Conservation in Rome, because "the main factor in weather resistance of stone is . . . its ability to withstand mechanical stresses arising from weathering processes—salt crystallization, frost, temperature fluctuations, and expansion."

Consolidation may be achieved by the use of inorganic or organic impregnants. Which are preferable is one of the key open questions in this field. Inorganic consolidants, such as barium hydroxide, seem to work well for calcareous stone, and calcareous cement seems suitable for sandstone. But other inorganic consolidants, such as the alkali silicates and fluosilicates, can hydrolyze, resulting in the formation of soluble salts; their deposition produces efflorescences that work against the consolidant's purpose as a waterproofing and strengthening agent.

Organic consolidants may be polymerized in situ by catalysis or gamma radiation so that they adhere to the stone's grains. But they have the disadvantage that they undergo surface deterioration caused by oxygen and ultraviolet radiation, with the result that the color, texture, and integrity of the stone surface change with time. Polyesters, acrylics, and epoxies seem to be the most frequently tried organic consolidants, but they leave open the possibility that an impervious crust may form over a porous core, preventing the evaporation of trapped moisture.

The failure rate of consolidation techniques is remarkably high, in spite of numerous claims about wonder-working methods. Torraca suggested several reasons for failures in consolidation, including insufficient diagnosis, cleaning, and penetration. But a perhaps more enlightening rationale was his suggestion that many conservators are still making the incorrect assumption that a single process should be adequate for all types of stone and all kinds of microclimates. The one-step conservation assumption may also discourage continuing care for stone objects. Control, maintenance, and evaluation, the consensus seemed to be, are all too sparingly practiced. Often the results of conservation efforts are not suitably or objectively measured. In short, Torraca concludes, "rather than a conservation *process*, we need a conservation *policy*."

Sources of support are few, and usually one object is conserved rather than another simply because of the personal preference of the donor, rather than any assessment of historical or esthetic value. But scientific activity has definitely accelerated in the past several years. The breadth and depth of the concerns of this year's conference suggest that there is now a much stronger case for the serious study of stone conservation.—DEBRA S. KNOPMAN

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