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Advanced Light Source Life Sciences Center - Conceptual Design Report

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Conceptual Design Report

ALS Life Sciences Center

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1.

OVERVIEW

FUNDAMENTAL scientific advances and technological progress occur hand in hand, each leading to and dependent upon the other. We can trace this pattern throughout the history of science and technology: New knowledge of the character of the natural world leads to unexpected practical outcomes, which, in turn, permit new basic scientific investigations to be undertaken. Every technological tool of modern science is itself based on earlier science. This report is about just such a conjunction of technology and science.

The discovery of the x-ray by Wilhelm Roentgen almost 100 years ago led to the development of x-ray devices that permitted us to look through objects that appeared opaque in visible light. This led in turn to the development of, among other things, medical x-ray imaging, which has been central to the emergence of modern medicine and accurate diagnosis in the 20th century.

One of the early dreams for Roentgen's x-rays was the possibility of using them to examine structures microscopically. Our ability to resolve structural features depends ultimately upon the wavelength of the probing light. The smallest objects that we can see in the light microscope are roughly the size of a single wave of visible light. As soon as it was understood that x-rays were a form of short-wavelength radiation, it became clear that they offered an opportunity to see objects orders of magnitude smaller than could be seen with a conventional microscope. Although such high-resolution x-ray microscopy was theoretically possible, various technical limitations, especially the lack of a source of focusable x-rays, erected a barrier that has only recently been overcome.

There was, however, one way to avoid the barrier. Light *scattered* from an object can also provide structural information at a resolution comparable to the wavelength of the probing light beam. Based on this fact, W. H. Bragg, in the early part of the 20th century, developed the technique of x-ray crystallography to deduce structure at the molecular and atomic level. In the 1940s, Dennis Gabor added a new method that also uses the diffractive field—holography. In holography the image of an object can be wholly reconstructed from the light it scatters, and if short-wavelength x-rays are used, it is possible in principle to carry out holography at a microscopic level, seeing inside whole objects at high resolution. Here too, however, a suitable source of x-rays did not exist: True x-ray microscopy remained an elusive goal.

LOOKING AT LIFE IN A NEW LIGHT

For more than two decades, lasers have dominated the visible and infrared regions of the electromagnetic spectrum. During this same period, the most powerful sources of x-ray and ultraviolet radiation (collectively, the XUV region) have been synchrotron light sources, where electrons circulating in an accelerator at relativistic velocities emit light as a by-product of their motion. Missing so far in the XUV has been light with many of the useful properties that are associated with the laser—the very properties needed to fulfill the goal of x-ray microscopy.

In essence, the Advanced Light Source (ALS), now under construction at the Lawrence Berkeley Laboratory, will provide such light to the experimental scientist (Fig. 1-1 and Table 1-1).¹ Though not a laser, the ALS will offer researchers laserlike radiation of unprecedented brightness at ultraviolet and soft x-ray photon energies. Following its completion in the spring of 1993, biologists can hope to examine dynamic processes in living cells, chemists will be able to study chemical reactivity at a new level of precision, and materials scientists will tackle questions that can lead to new generations of semiconductor devices. Indeed, because specially designed “third-generation” synchrotron light sources such as the ALS are unique in producing such light, plans are afoot around the world to build several similar facilities. In addition, in the U.S., the Advanced Photon Source, a facility complementary to the ALS for generating intense x-rays at still higher photon energies, is now under construction at the Argonne National Laboratory.

Table 1-1. Summary of ALS performance parameters.

Beam energy, nominal (GeV)	1.5
Energy range (GeV)	1.0–1.9
Average current (mA)	400
Horizontal emittance, rms (m-rad)	10^{-8}
Number of straight sections	12
Straight section length available for insertion devices (m)	5
Nominal bunch length, FWHM (ps)	30–50
Beam lifetime (hr)	6

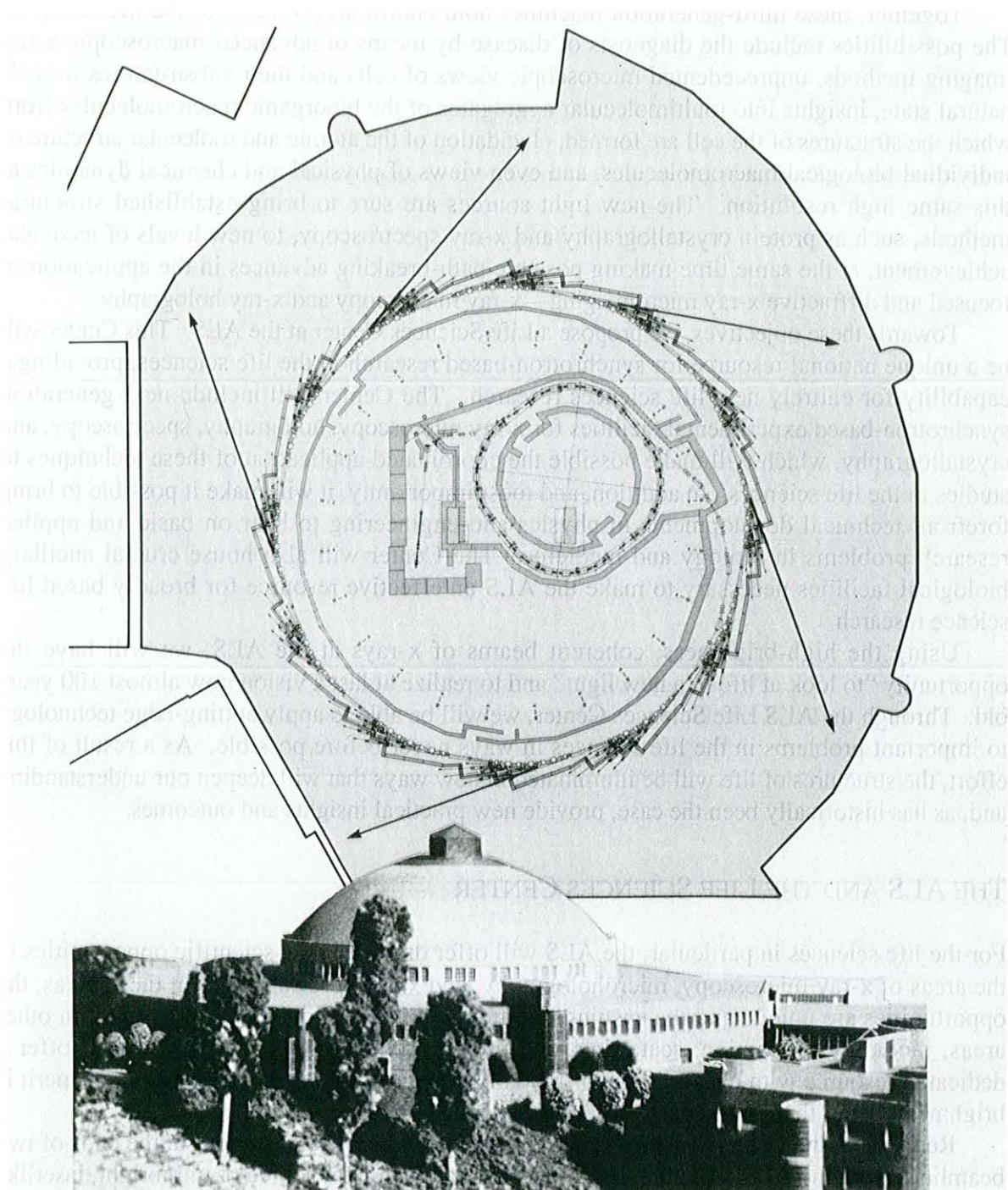


Figure 1-1. Two views of the Advanced Light Source, now under construction. Above is a plan view, showing a hypothetical complement of five insertion devices and beamlines, as well as the locations of the other available beamline ports. The size of the existing building is shown by the circle of I-beams well inside the storage ring. The lower illustration is a photograph of a detailed architectural model of the ALS building, showing in particular the success of the design in preserving the character of the historic 184-Inch Synchrocyclotron building.

OVERVIEW

Together, these third-generation machines hold enormous promise for the life sciences. The possibilities include the diagnosis of disease by means of advanced macroscopic x-ray imaging methods, unprecedented microscopic views of cells and their substructures in their natural state, insights into multimolecular aggregates of the bioorganic macromolecules from which the structures of the cell are formed, elucidation of the atomic and molecular structure of individual biological macromolecules, and even views of physical and chemical dynamics at this same high resolution. The new light sources are sure to bring established structural methods, such as protein crystallography and x-ray spectroscopy, to new levels of technical achievement, at the same time making possible path-breaking advances in the application of focused and diffractive x-ray microimaging—x-ray microscopy and x-ray holography.

Towards these objectives, we propose a Life Sciences Center at the ALS. This Center will be a unique national resource for synchrotron-based research in the life sciences, providing a capability for entirely new life sciences research. The Center will include next-generation synchrotron-based experimental facilities for x-ray microscopy, holography, spectroscopy, and crystallography, which will make possible the coordinated application of these techniques to studies in the life sciences. In addition, and most importantly, it will make it possible to bring forefront technical developments in physics and engineering to bear on basic and applied research problems in biology and medicine. The Center will also house crucial ancillary biological facilities necessary to make the ALS an effective resource for broadly based life science research.

Using the high-brightness, coherent beams of x-rays at the ALS, we will have the opportunity “to look at life in a new light” and to realize at last a vision now almost 100 years old. Through the ALS Life Sciences Center, we will be able to apply cutting-edge technology to important problems in the life sciences in ways never before possible. As a result of this effort, the structures of life will be illuminated in new ways that will deepen our understanding and, as has historically been the case, provide new practical insights and outcomes.

THE ALS AND THE LIFE SCIENCES CENTER

For the life sciences in particular, the ALS will offer dramatic new scientific opportunities in the areas of x-ray microscopy, microholography, and x-ray spectroscopy. In these areas, the opportunities are unique and the ensuing research will break altogether new ground; in other areas, including diffraction, scattering, and protein crystallography, the ALS will offer a dedicated resource with capabilities substantially equal to—or, where the measure of merit is brightness, better than—the best x-ray sources now available.

Research at the Center will center initially around experimental stations at the ends of two beamlines from the ALS. The first beamline, from an undulator source of ultrabright, laserlike soft x-rays, will illuminate two x-ray microscope stations, one for use in ongoing research programs and the other for use in developing new imaging techniques. A third experimental station will be available for microholography and diffractive imaging. The undulator will also have the capability of illuminating three additional stations, one with unmodified “white” light, a second with x-rays of 1–3 keV, and a third with radiation suited to x-ray microscopy. These three stations are not developed as part of the initial scope of the Life Sciences Center. The

second beamline, from a wiggler source of both soft and hard x-rays, will branch into two experimental areas, one broadly designated as being for spectroscopy, the other for diffraction. Section 3 outlines in more detail some of the scientific opportunities that will unfold with this complement of experimental facilities.

The ALS will be housed in an enlarged version of the domed hall that was the home of the historic 184-Inch Synchrocyclotron at LBL (Fig. 1-2). A mezzanine will provide space for offices and light laboratories for the 250 or so users who may be on site at any time when all the beamlines are in operation. In addition, participants at several topical workshops held to identify scientific opportunities at the ALS and to pinpoint user needs have consistently called for the provision of substantial ancillary facilities. Biologists, chemists, and materials scientists are all agreed that the forefront science promised by the availability of high-brightness XUV radiation at the ALS requires the ability to prepare, manipulate, and characterize samples in a laboratory near an ALS experimental station. It is no longer sufficient to prepare and characterize samples at a distant laboratory, pacify them in some way, transport them to the synchrotron light source for a measurement, then return the samples to the laboratory, and so on. In many cases, this approach never was satisfactory. This is particularly true in the life sciences, where it is often necessary to prepare, characterize, and measure delicate and/or transitory samples in a short time. *No fully adequate biology facilities now exist at any synchrotron light source in the U.S., making these sources unsuitable for most life scientists.*² To exploit the opportunities offered by synchrotron radiation, the Life Sciences Center will offer a full range of biological research facilities within the ALS facility and in an adjacent building. Therefore, in addition to two beamlines and their associated experimental end stations, the Center will include laboratory and office facilities in a portion of the ALS mezzanine and in the existing Building 80, shown in Fig. 1-2.

These facilities are an acknowledgment of the complexity of modern biological research. Measurements made with the use of synchrotron radiation are typically only one step in a complete experiment that may require preparation of fresh specimens, use of complex sample-handling systems, and evaluation of specimens in one or more ways before and after x-ray measurements. To allow users to carry out the full range of necessary activities, the Center will be equipped with (1) a light and electron microscopy laboratory, (2) a cell and tissue culture facility, (3) an animal-handling area, including a surgery station, and (4) a biochemistry (wet) laboratory containing instrumentation for cellular, subcellular, and molecular separation and for optical spectroscopy. Also available will be computer facilities, machine and electronics shops, and a microfabrication area for components of the x-ray microscopes. There will also be office space for scientists using the facilities of the Center.

In summary, the scope of the ALS Life Sciences Center project includes:

- Two insertion devices—one undulator and one wiggler
- An undulator beamline equipped for microimaging and microholography
- A wiggler beamline equipped for diffraction and spectroscopy
- 13,300 gross square feet of fully equipped support laboratory and office space

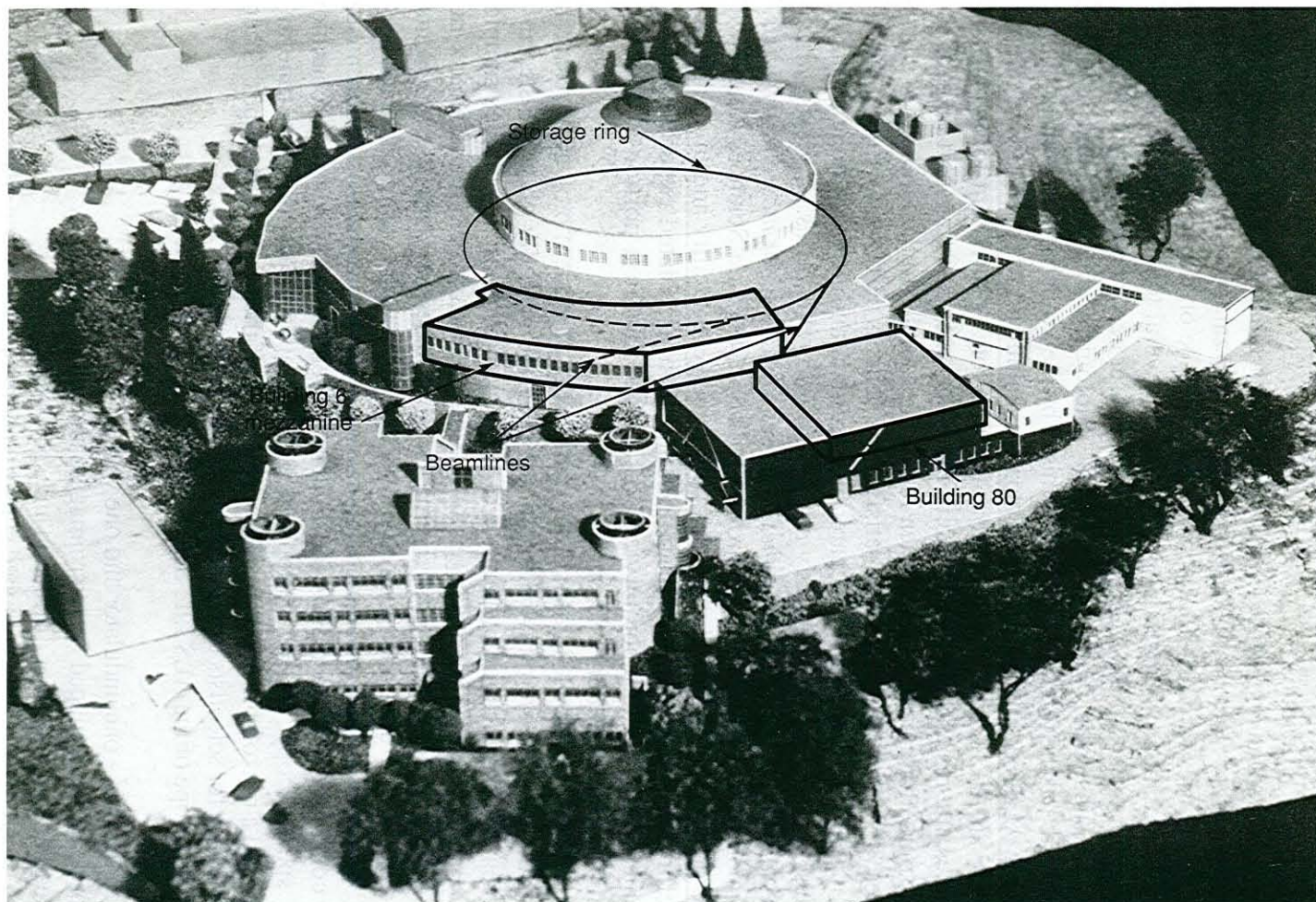


Figure 1-2. A second photograph of the architectural model, showing schematically the scope of the ALS Life Sciences Center project. The project includes two insertion devices (a wiggler and an undulator), together with their beamlines and experimental end stations, and 13,300 gross square feet of fully equipped laboratory and office space, located at the end stations, on the mezzanine of the ALS building (Building 6), and in the adjacent Building 80.

The estimated cost of the project is \$30.7 million (in then-year dollars); it is scheduled to commence in FY 1993 and to be completed in FY 1995.

LBL is strongly committed to operating the ALS as a national user facility open to all qualified scientists. The concrete expression of user community needs will come with the formation of participating research teams whose members will devote both time and resources to the instrumentation of the ALS beamlines, including the experimental stations. Both insertion-device teams (IDTs) and bending-magnet teams (BMTs) are envisaged. In return for their effort and commitment of resources, members of the IDTs and BMTs will receive privileged access to the beamlines and experimental stations that they help develop. However, in keeping with the intent to operate a national user facility that is open to all qualified users, a certain fraction of the beam time of every beamline will be made available to users who are not members of these research teams. The fraction of time available to general users will usually range from 25% to 75%, depending on the type of beamline and the resources invested by the research teams. In line with the goal of the Life Sciences Center, that is, to serve the life sciences community broadly, it is expected that this kind of general availability of the beamlines will be an essential feature of the Center's operation. Indeed, the Center is explicitly intended to serve three communities of ALS life sciences researchers: (1) external scientists who are committed to long-term research programs centered around the use of synchrotron radiation, usually as members of IDTs; (2) internal Laboratory scientists through the LBL/ALS Working Group on Life Sciences, some of whose members will have offices and laboratories in the Center; and (3) general users from within and from outside the Laboratory who have shorter-term interests in the use of synchrotron radiation.

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2.

INTRODUCTORY PHYSICAL CONCEPTS

THE special quality of the light produced by the ALS is its high spectral *brightness*, a composite measure of several laserlike virtues: the intensity of the light, the narrowness of its spectral distribution, and the ease with which it can be focused to a small spot (Fig. 2-1). The coherent light from a high-quality laser is the brightest ordinarily available. Over a substantial portion of the spectral range of the ALS, which extends from photon energies of roughly 10 eV to 10 keV, the ALS light will be partially coherent. It is for this reason that the ALS light is said to be laserlike, especially at photon energies below about 1 keV.

Coherence means that the peaks and troughs of all waves within the area illuminated by a light beam are in step (in phase) at any instant (transverse or spatial coherence) and remain so as the wave propagates (longitudinal or temporal coherence). Light diffracted through a pinhole is spatially coherent if the pinhole is small enough. More generally, the criterion for spatial coherence is that the product of the area of the light source (such as the area of the pinhole) and the solid angle into which it emits be no larger than the square of the wavelength of the light. Since this is the diffraction condition, spatially coherent light is said to be *diffraction limited*. The criterion for temporal coherence is that the waves all have the same wavelength; that is, the light is spectrally pure or monochromatic.

Although not all of the light from the ALS will be diffraction limited, a substantial fraction will. Moreover, this spatially coherent portion can be selected by the use of apertures, such as pinholes, which effectively reduce the source size. Although this improvement comes at the expense of photon flux, the ALS sources will be bright enough that the usable coherent flux will be uniquely plentiful. Most of the ALS radiation will also be centered in a narrow spectral line of width $\Delta\lambda$, with a spectral purity ($\lambda/\Delta\lambda$) equal to about 100. With advanced monochromators, the spectral purity can be increased to between 1000 and 10,000, or even more, but, as with the use of apertures, this improvement comes at the expense of flux. In summary, spatial filtering with a pinhole and temporal filtering with a monochromator will allow one to obtain the pure phase fronts necessary for demanding experiments such as wavelength-limited microscopy, holography, and interferometry.¹

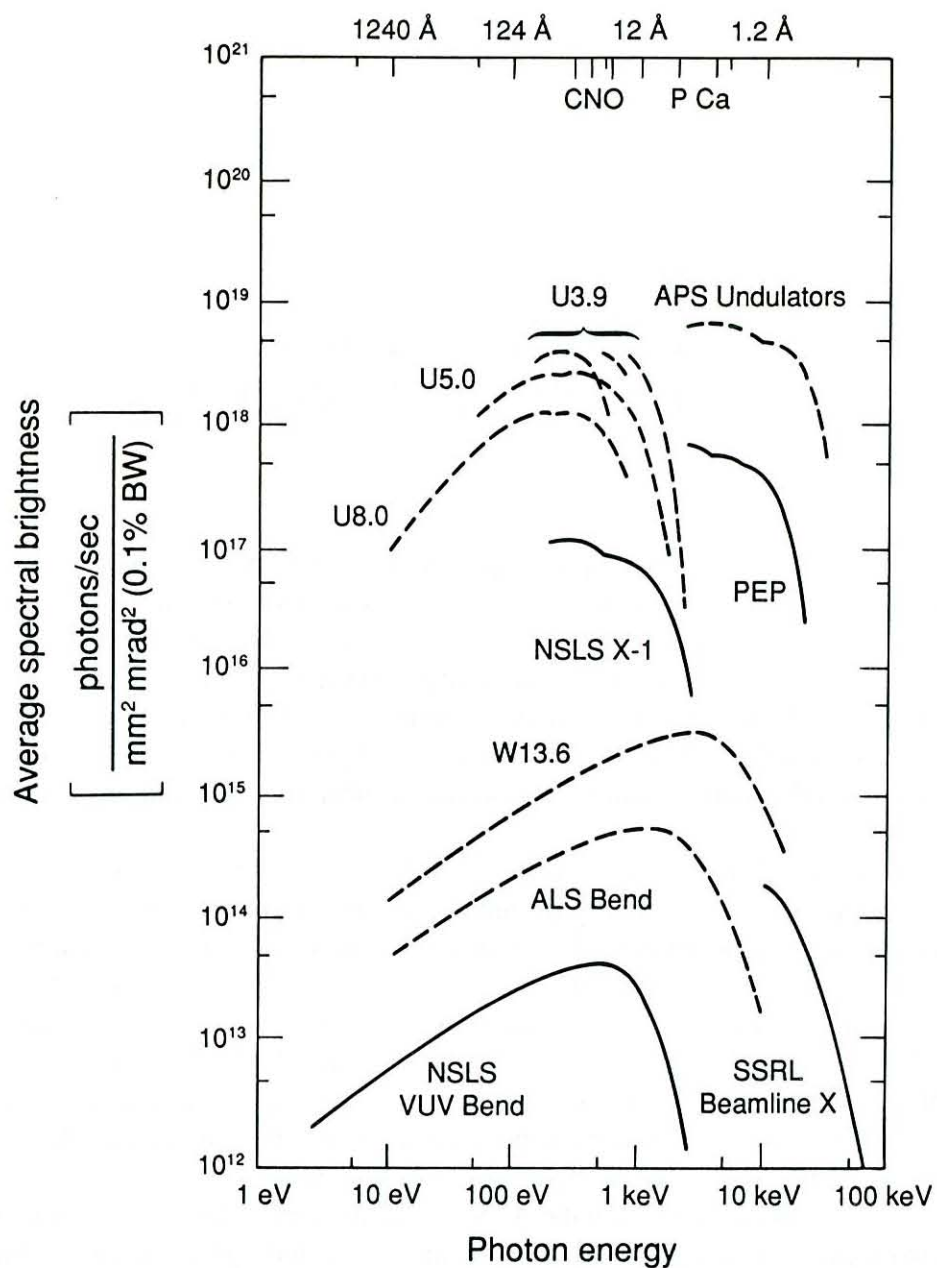


Figure 2-1. A plot of time-averaged spectral brightness predicted for the ALS and for other operating and proposed sources. The dashed curves show the brightness for the insertion devices of Table 2-1 (page 15), as well as the bending magnets. Predictions are also shown for the 7-GeV Advanced Photon Source at Argonne National Laboratory. The solid curves show achieved results at NSLS and at the Stanford Synchrotron Radiation Laboratory (SSRL). PEP is a high-energy physics facility at Stanford that also has a small number of synchrotron radiation beamlines operated by SSRL.

Two special and interrelated features of the ALS make this laserlike light possible. The first is the tightly focused electron beam in the ALS storage ring. On the average, the electrons in any accelerator beam circulate smoothly around the ring. But within the beam, individual electrons buzz around like the molecules in a gas, giving the beam a finite cross-sectional area. Since the electron beam is the source of the light, the beam cross section corresponds to the area of the source. Moreover, the random transverse motions of the electrons within the beam generate a spread in the solid angle into which the light is emitted. A parameter of the electron beam called the *emittance* measures the product of the beam size and divergence. In accordance with the diffraction condition, the emittance therefore sets the minimum wavelength at which all the radiation can be diffraction limited. The crucial property of the ALS storage ring is its extremely low emittance.

The storage ring sets limits on the quality of the synchrotron radiation, but it does not guarantee that they will be achieved. For this, the second feature of the ALS comes into play, namely, the extensive use of periodic magnetic structures called *undulators* in the long straight sections of the storage ring. In brief, an undulator consists of a linear array of dipole (north-south) magnets of alternating polarity (Fig. 2-2). The near-universal use of permanent-magnet material in these devices is an innovation pioneered by Klaus Halbach at LBL. Synchrotron

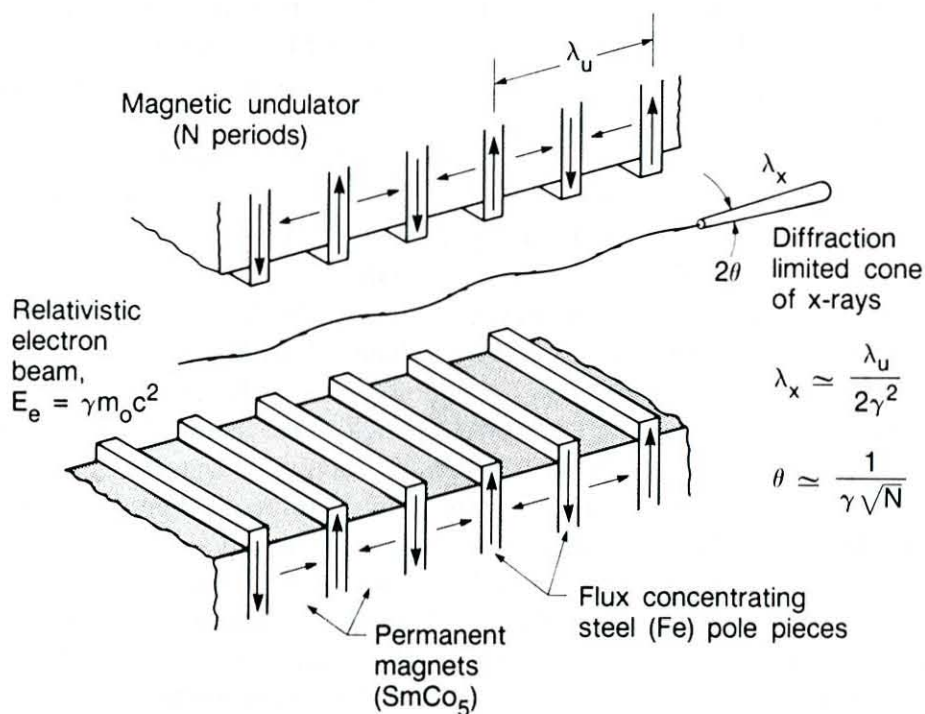


Figure 2-2. A schematic of a permanent-magnet undulator. Partially coherent x-rays are produced when a thin, pencillike beam of relativistic electrons traverses the alternating magnetic structure.

radiation is generated when the alternating magnetic fields bend the electron beam into a roughly sinusoidal trajectory. It is this radiation that has the best coherence properties. Undulator radiation is temporally coherent over distances up to a coherence length l_c that is determined by the spectral purity of the light; that is, $l_c = \lambda^2/\Delta\lambda$. Since the spectral purity $\lambda/\Delta\lambda$ is proportional to the number of periods, N , in the undulator, long undulators with a large N generate the most temporally coherent light. Similarly, the radiation from a long undulator is largely diffraction limited for wavelengths longer than the minimum set by the electron-beam emittance.

Even at wavelengths below the minimum, much of the light will continue to be partially coherent. It can be shown that the radiated photon power that is partially coherent (the coherent power) in this spectral region is proportional to the cube of the wavelength. *All in all, because of the low-emittance storage ring and the use of long undulators, the ALS will be the first synchrotron light facility optimized to deliver to the researcher's sample intense fluxes of coherent radiation at photon energies well into the XUV* (Fig. 2-3).

With spectral brightness comes the ability to focus the light to very small spot sizes. Coherent light is the most focusable of all. Consider a Fresnel zone plate, which is a device to focus XUV radiation (Fig. 2-4). It consists of a very large number of concentric rings of alternating x-ray-absorbing and x-ray-transmitting materials with the radial width of the rings decreasing from the center outward. Its focusing action on an incident plane wave can be visualized as that of a circular diffraction grating. The angle through which the wave is diffracted increases from the center (wide) rings to the outer (narrow) rings in such a way that each part of the diffracted wave meets at a focal spot whose radius is approximately the width of the outermost ring. If the incident radiation is not diffraction limited, light waves will be incident on the zone plate at significantly different angles and will be diffracted through a comparable range of angles, thereby increasing the size of the focal spot. If the radiation is not spectrally pure, the distance of the focal spot from the lens will be different for each wavelength, thereby enlarging the spot size at any one distance.

Accordingly, spectral brightness brings with it the possibility of diverse spatially resolved experiments, from simple microscopic imaging to advanced combinations of microscopy with spectroscopy. Here it is the combination of a photon flux sufficient to elicit a measurable signal, focused into a small enough area to provide the desired spatial resolution, that makes such experiments possible. For example, zone plates having an outer zone width of 40 nm have recently been used to focus soft x-rays to a spot 50 nm in diameter at the National Synchrotron Light Source (NSLS), using the radiation from an undulator, and at BESSY in Berlin. In the first round of experiments at NSLS with a scanning x-ray microscope built around zone plates, researchers showed they could image the interior of individual zymogen granules, subcellular components about 1 μm in diameter, in an aqueous environment and without any deliberate alterations such as staining, fixing, or sectioning (see Fig. 3-2).² Subsequent experiments have improved the resolution obtained in the earliest images.

Even without improvements in zone plate technology, the spectral brightness of the ALS, which will be more than 100 times that available with existing facilities in this spectral range, will dramatically enhance the capabilities of x-ray microscopy, possibly including time-resolved imaging of dynamic processes, and of combined microscopy/spectroscopy, such as

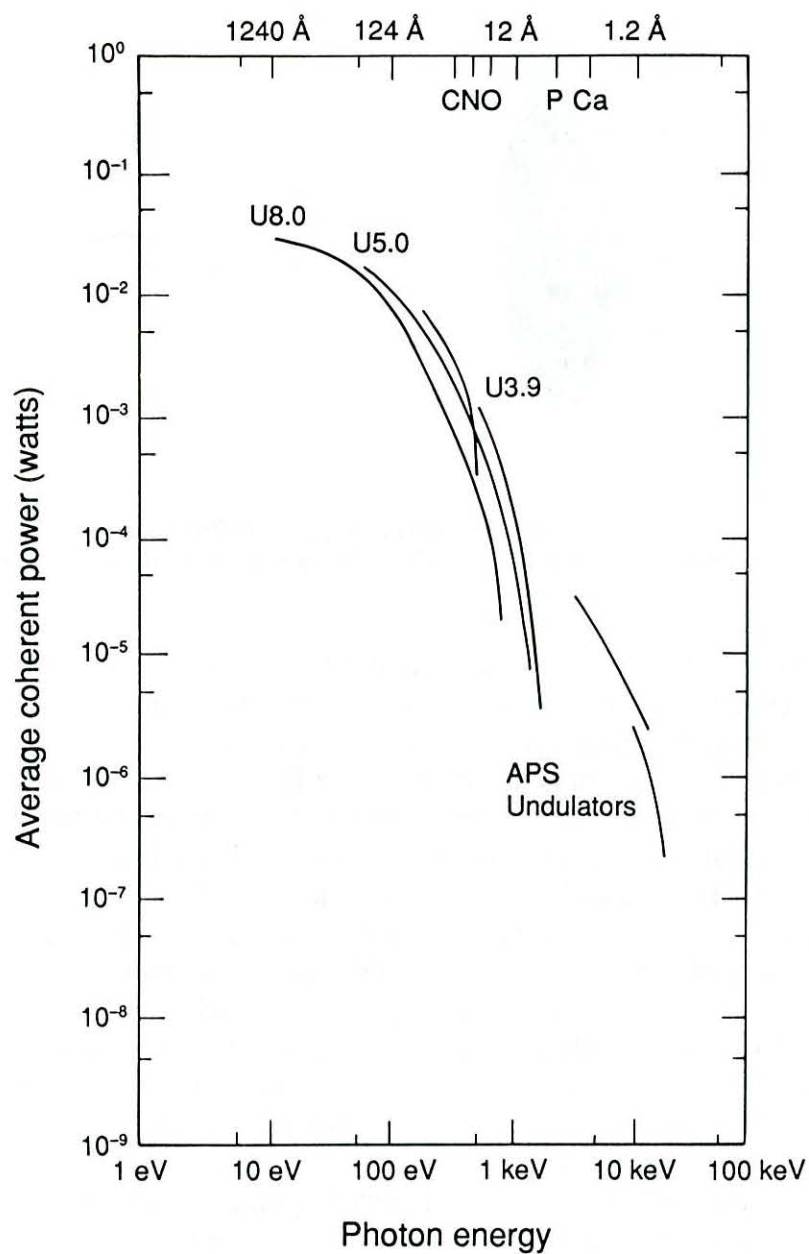


Figure 2-3. A plot of average coherent power for the ALS and for the planned Advanced Photon Source. Coherent power is defined here as having full transverse coherence and a 1- μ m longitudinal coherence.

elemental mapping by tuning the XUV photon energy to the absorption edges of biologically important elements. Moreover, by the time the ALS is operating, zone plate technology will have advanced significantly, perhaps providing x-ray lenses having a spatial resolution approaching 20 nm.

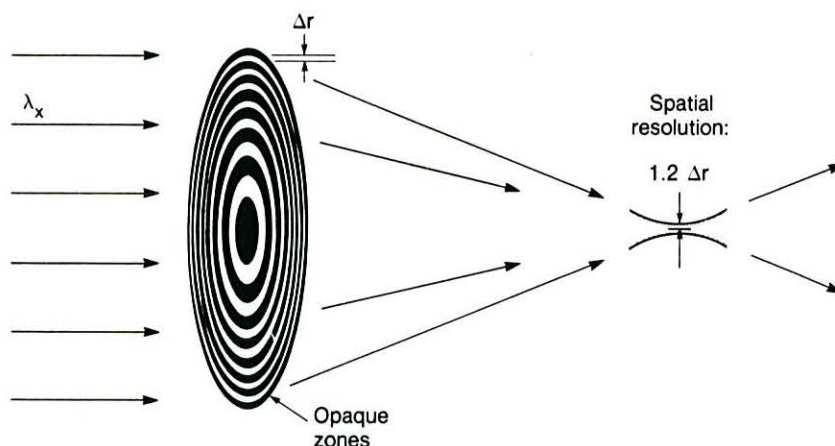


Figure 2-4. A schematic diagram of a Fresnel zone plate. Diffraction from the variably spaced rings focuses a plane wave to a small spot whose radius is 1.2 times the width of the outer zone.

Because coherence preserves phase relationships, the coherent light from the ALS can also be exploited in experiments that depend on this property, holography being the prime example. Once again, preliminary holographic imaging experiments on zymogen granules have been carried out at NSLS with undulator radiation (see Fig. 3-3).³ The superposition of waves diffracted while passing through a granule with the waves of an undiffracted beam forms the many interference fringes that constitute the hologram. These fringes are seen in Fig. 3-3 as the numerous periodic ring and line features. Analysis of images of test objects shows a system resolution of 60 nm, and the first biological images numerically reconstructed by computer actually show features smaller than 100 nm. Holographic imaging is complementary to scanning x-ray microscopy in that, in principle, it can provide three-dimensional information about biological structures (although this has not yet been demonstrated), whereas it is less likely to provide time-resolved images with synchrotron radiation because of the much larger photon dose needed to generate a hologram—a consequence of the nature of current hologram-recording and image-reconstruction processes.

Although undulators will provide the high-brightness XUV radiation that will be the unique contribution of the ALS to extending the frontiers of science, they will not be the only radiation sources. The ALS storage ring has 12 straight sections. One will be reserved for the injection of electrons into the storage ring from a booster synchrotron, and one will be partially taken up by radio-frequency cavities that feed energy into the electron beam. That leaves ten full and one partial straight section that will be available for a mix of undulators and wigglers, collectively called *insertion devices*. A *wiggler* is also a periodic magnet structure, but it is optimized to generate an intense photon flux over a continuous, broad spectrum extending to the hard x-ray region, although it does this at the expense of spectral brightness.

At the normal 1.5-GeV operating energy of the ALS storage ring, the high-brightness undulators will cover the spectral range below about 2.0 keV. At this same operating energy, wigglers will be able to reach to about 15 keV. The wigglers thereby extend the photon-energy range of the ALS well beyond that available with the undulators, into the spectral region where

the *K*- and *L*-edges of most elements important to biologists lie. W wigglers will also be useful sources of radiation for x-ray crystallography of macromolecules.

Finally, the large dipole magnets that bend the electron beam in the storage ring into its roughly circular trajectory will be sources of highly useful XUV radiation. Like wigglers, bending magnets generate a broad, continuous spectrum of light. Although somewhat lower than that of the light from ALS wigglers, the spectral brightness of the ALS bending-magnet radiation will compare very favorably with that of radiation from other synchrotron sources because of the ALS's low-emittance electron beam. At the ALS, there is the possibility of 48 ports for the extraction of radiation from bending magnets. The large number makes the use of

Table 2-1. Parameters for a selected complement of ALS insertion devices. The actual insertion devices that are constructed will depend on user needs.

Name	Period (cm)	No. of periods	Photon energy range (eV) ^a	Critical energy (keV)
Undulators				
U8.0	8.0	61	5.4–220 ^b [16.2–660] [27–1100]	–
U5.0	5.0	98	52–380 [156–1140] [260–1900]	–
U3.9	3.9	123	169–500 [507–1500] [845–2500]	–
Wiggler				
W13.6	13.6	16	–	3.1

^aThe photon energy of the fundamental and of the third and fifth harmonics (shown in brackets) as the deflection parameter *K* decreases from its maximum value to approximately 0.5.

^bBelow about 8 eV in the fundamental, the peak field in undulator U8.0 exceeds the bending-magnet field and may affect storage ring operation.

bending-magnet radiation an attractive option for researchers needing long-term and regular access to XUV light, but not necessarily to radiation of the highest spectral brightness. This is in contrast to the situation for insertion devices. Because of the small number of straight sections for insertion devices, the demand for them is likely to be high and access more limited.

Based on user requirements expressed at several topical workshops and in letters of interest from prospective IDTs, design studies are under way on a selection of three undulators, one wiggler, and the beamlines to carry the XUV radiation to experimental areas. Although this set of insertion devices covers the ALS spectral range and well illustrates the expected performance of the ALS, the final mix of undulators and wigglers and their exact performance characteristics will depend on the needs of the user community as expressed in IDT proposals. To aid in the evaluation of these proposals, LBL has appointed a Program Review Panel consisting of nine non-LBL scientists respected for their research achievements in a broad range of fields.

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3.

NEW SCIENTIFIC OPPORTUNITIES

THE scientific case for a center for life sciences research at the Advanced Light Source ultimately rests with the rough equivalence between the size of the feature one hopes to resolve and the wavelength of the probing light. Because the wavelength of x-rays is far shorter than that of visible light, far smaller features can, in principle, be discerned. If this theoretical equivalence can be approached in practice, using the techniques discussed below (among others), x-rays offer a profound opportunity to deepen our understanding of biological structure and structure-function relationships. In addition, beyond this relationship between resolution and wavelength, x-rays offer other features that make them particularly valuable as probes of biological matter.

Accordingly, the history of x-rays as a probe of matter in biology and medicine is an extraordinarily rich one. From the field of medical diagnostics to basic studies of the detailed structure of proteins and nucleic acids, x-rays have been central to advances in 20th century biomedical science. Now, as we look to the future, unique new opportunities for the use of x-rays in biological research appear on the horizon, in great part fostered by the construction of new synchrotron radiation sources such as the ALS. These new opportunities are related primarily to issues of structure and the relationship between structure and function, particularly for a range of size scales encompassing questions of macromolecular structure and subcellular organization—that is, for objects ranging in size from less than 1 to roughly 10^4 nm. Although there are also important potential uses of synchrotron radiation sources for studies at higher levels of organization, including whole organisms, these possibilities will not be considered further here.

The Center's scientific goals include, primarily, (1) new applications of x-ray methods already established and widely used, such as protein crystallography; (2) full realization of the promise of newly emerging synchrotron-based microimaging methods, such as x-ray microscopy and holography; and (3) assessing the feasibility of new technical approaches, such as merging spectroscopy and spatially resolved x-ray microimaging, and the development of novel means of extending imaging resolution towards the theoretical limits. In this section, we do not discuss technical development in depth, but rather consider primarily the value of

pursuing such developments for research in the life sciences, specifically in relation to the major experimental thrusts of the proposed program—protein crystallography, focused and diffractive x-ray imaging, and x-ray spectroscopy.

The following summary of scientific opportunities reflects the views of participants at several workshops that have been held over the past few years on potential applications of synchrotron light to biological questions, as well as the views of the Life Sciences Group at the ALS. In particular, much of the discussion is derived from the reports of participants at the Workshop on Life Sciences at the Advanced Light Source, held in San Francisco in February 1988. Participants at that meeting included biologists familiar with high-brightness x-ray sources, as well as many with no special knowledge of them. Also present were physicists and engineers whose specialties were x-ray sources, optics, and detection. In the discussion below, particular scientific problems will be highlighted to illustrate the importance of the three central methodological approaches—microscopic imaging, spectroscopy, and x-ray diffraction and scattering—as probes of structure and function in biology and medicine.

MICROSCOPIC IMAGING

For as long as biologists have been looking at cells and their parts in the microscope, they have dreamed of getting closer, seeing more detail, achieving higher resolution. As they have learned more about the chemistry and physics of the cell, they have also imagined extending their vision, with the same high spatial resolution, to the chemical constituents of the cell, even to particular reactive states, as they exist in situ—and all this with quantitative precision. Finally, in looking, they have also dreamed of following chemical and physical changes in the cell and its substructures as they evolve in real time at the same high resolution. While these “utopian” dreams have not yet been realized, biologists, often in collaboration with physical scientists, have been hard at work seeking new and better means towards their fulfillment.

The greatest new scientific opportunity for the life sciences at the ALS is that it will permit construction of x-ray microscopes and holographic imaging devices of a character and degree of development not heretofore possible. In conjunction with novel approaches for improved resolution, the promise of high-resolution microscopic x-ray imaging appears to be within reach. These new imaging techniques offer exciting possibilities that will carry us further down the road to fulfillment of the biologist’s dream—most importantly, permitting examination for the first time of a wide variety of biological material in its natural state at resolutions never before achieved, resolutions that may approach 20 nm by the time the ALS is commissioned.

Until the development of the electron microscope, our knowledge of the internal organization of cells was limited to what could be observed in the light microscope, that is, limited to objects larger than the wavelength of visible light. In many cells, only the nucleus could be seen with any certainty, and it was argued by some that there was nothing else to be seen. The electron microscope extended our “visual acuity” greatly and permitted us to see remarkable structural diversity within cells. However, obtaining this new knowledge has not been without cost. It requires that high-energy electrons be passed through the sample, that it

be viewed in vacuum, and that only very thin specimens be examined because of the short mean-free-path of electrons. For common transmission electron microscopy, the cell's major constituent, water, must be removed and replaced (usually with plastic), heavy atoms must be added to provide contrast, and attempts must be made to "fix" structural features in place within the cell through the addition of cross-linking agents such as glutaraldehyde. These and other procedures used in high-resolution electron microscopy that greatly modify the sample under study raise questions about how faithful the images actually are to the natural object. Furthermore, owing to these same constraints, dynamic measurements on cells and isolated cellular substructures cannot be made.

Thus, although electron microscopy has proved to be an extraordinarily valuable tool—the "gold standard" for cell ultrastructure—it remains useful, indeed important, to seek other means of high-resolution imaging, both to accomplish what electron microscopy cannot and simply to examine ultrastructure in a complementary fashion. In particular, although x-ray microscopy currently lacks the high resolution of the electron microscope, it offers the opportunity of viewing cellular structure and substructure by a means that does not require any of the preparative procedures required for electron microscopy. As a consequence, it can be a "critical" tool for evaluating the faithfulness of electron microscopic images to natural structures. It is this feature, the potential for viewing the object in its unaltered natural state, that is central to the usefulness of x-ray microimaging. It offers the possibility of viewing many structures in their native states at high resolution for the first time.

Imaging with soft x-rays—x-rays with wavelengths between roughly 1 and 5 nm—can be "natural" because (1) such radiation can penetrate objects several micrometers thick, and thus sectioning can be avoided; (2) the object can be viewed while suspended in water at atmospheric pressure and body temperature; and (3) water is transparent in the soft x-ray "water window" (between 2.3 and 4.4 nm), whereas various elements normally present in biological material, particularly carbon and nitrogen, absorb x-rays at the same wavelengths (Fig. 3-1). This last virtue allows for contrast based on spatially resolved variations in the concentrations of natural substances, rather than by adding foreign ones. For these reasons, the object potentially can be studied microscopically in its natural state, that is, without chemical or physical alteration beyond removal from the cell or tissue. For the same reasons, the method also offers the possibility of following dynamic events at supramolecular and ultrastructural resolution.

In addition, the presence of discrete absorption edges for elements of biological interest in the x-ray domain opens the door to the possibility of elemental mapping, a technique that would exploit differences in elemental absorption at different wavelengths. Not only is it possible to measure quantitatively the presence of particular elements in a spatially resolved fashion, but also organic chemical content can often be usefully determined from elemental information.¹⁻³ More generally, if combined with spectroscopy, this method has the potential to provide a variety of direct information regarding the chemical form and reactive state of specific bioorganic molecules within the cell, as well as within isolated substructures.

Although its potential has long been recognized, high-resolution microscopic imaging with x-rays has only recently become a practical possibility.⁴⁻⁷ As is often the case, new technical advances have brought its promise closer to realization. In particular, three technologies—

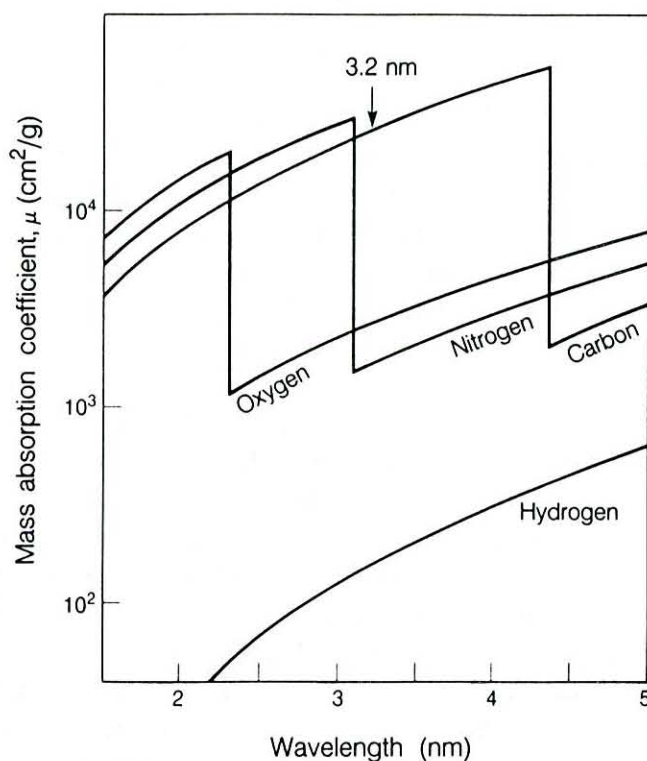
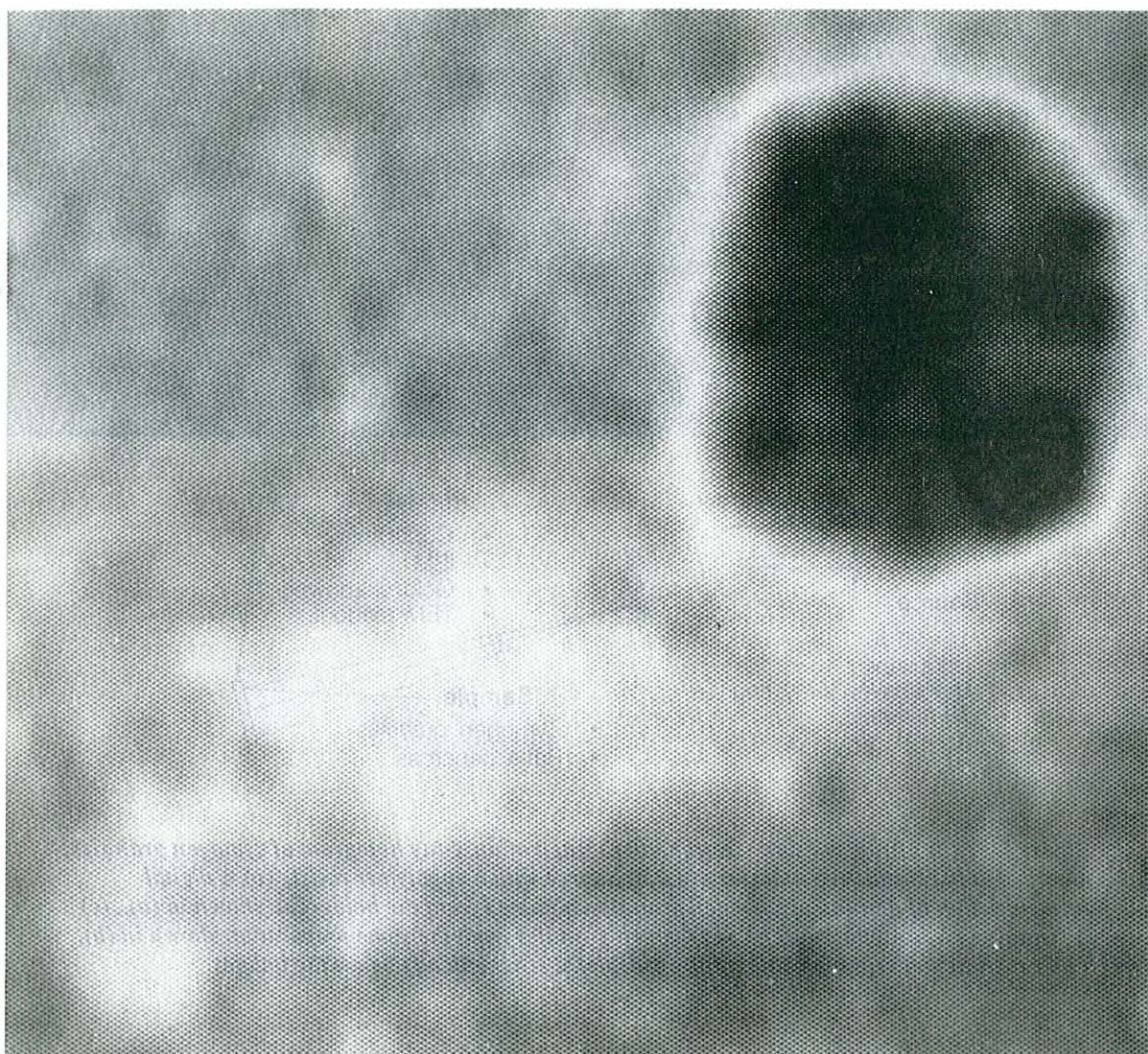


Figure 3-1. The soft x-ray water window between 2.3 and 4.4 nm. Carbon and nitrogen provide contrast with relatively transparent water.

source design, optics, and detector technology—have benefited from recent dramatic improvements.

The emergence of low-emittance storage rings and long periodic magnet structures (undulators) have provided brighter radiation, with greatly improved focusability.⁸ The x-ray ring at NSLS was a major step in that direction, and the next-generation machines, including the ALS, will bring us to a point where a significant fraction of the generated soft x-rays will be focusable to limits set by the finite wavelength of the radiation. These beams of high brightness and coherence form the basis for bringing the promise of soft x-ray imaging to fruition, and they have already made possible the recent scanning x-ray images of the interior of a subcellular structure, the zymogen granule, whole and unaltered during preparation for microscopic viewing, at resolutions approaching 50 nm (Fig. 3-2),^{1-3, 9} as well as holograms of the same structure at approximately 50-nm resolution (Fig. 3-3).^{10, 11}

For scanning or imaging microscopy, the recent advances have also depended on modern electron-beam lithography to fabricate diffraction-limited Fresnel zone plate lenses. The latest zone plates constructed in a collaborative effort between IBM and the Center for X-Ray Optics at LBL provide a theoretical resolution of about 40–50 nm (Fig. 3-4).¹² Resolution as great as 20 nm seems within reach in the next several years.



1,000 Å
square

Figure 3-2. An x-ray micrograph of a zymogen granule (a subcellular secretory structure extracted from the pancreas of a rat), obtained at a wavelength of 3.2 nm. The image shows the general form of the granule (about 1 μm in diameter) in its watery environment, its nonuniform nature, and a feature in the lower right-hand corner of the granule. Smaller features are near the limit of spatial resolution. To make the image, the granule was exposed to a radiation dose of about 1 megarad. The transmitted x-ray intensity can be used directly to estimate protein content.

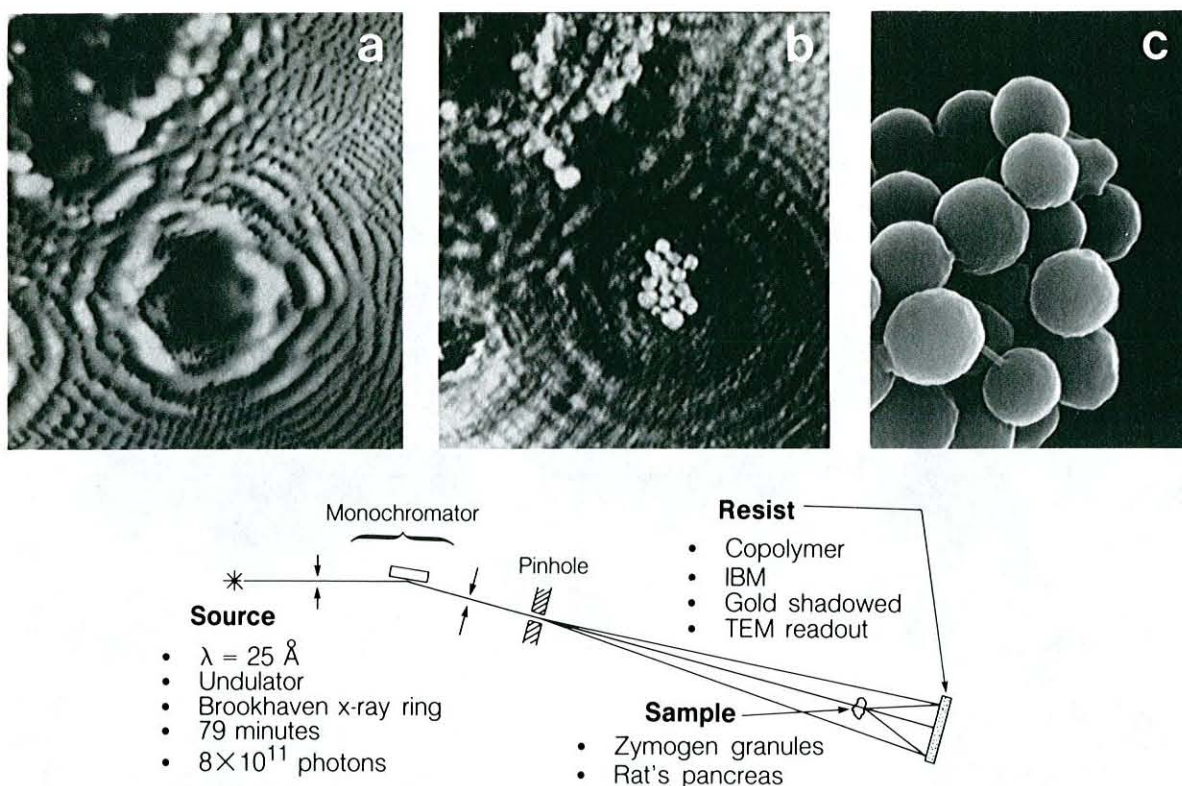


Figure 3-3. (a) A transmission electron micrograph of an x-ray hologram of zymogen granules, recorded at the National Synchrotron Light Source with a copolymer resist. (b) A digital reconstruction of a group of zymogen granules, obtained from the hologram shown in (a). (c) A scanning electron micrograph of zymogen granules from the same preparation shown in (b). The experimental setup for holography is depicted schematically below the images.

Finally, the availability of sensitive detectors, and, for scanning, accurate stepping systems capable of moving the sample stage in very small steps, provide a capability of quantitatively collecting x-rays with a precision consistent with source-lens resolution.

The high-brightness, focusable synchrotron radiation, sensitive detectors, and, for microscopy uses, zone plate lenses of high resolution permit the study of feature sizes sufficiently small to obtain much new information about the native structure of many subcellular components. In addition, the concomitant high flux offers the potential for following a variety of biologically interesting processes, since it will be possible to obtain images within reasonable exposure times (as little as a millisecond at the ALS).

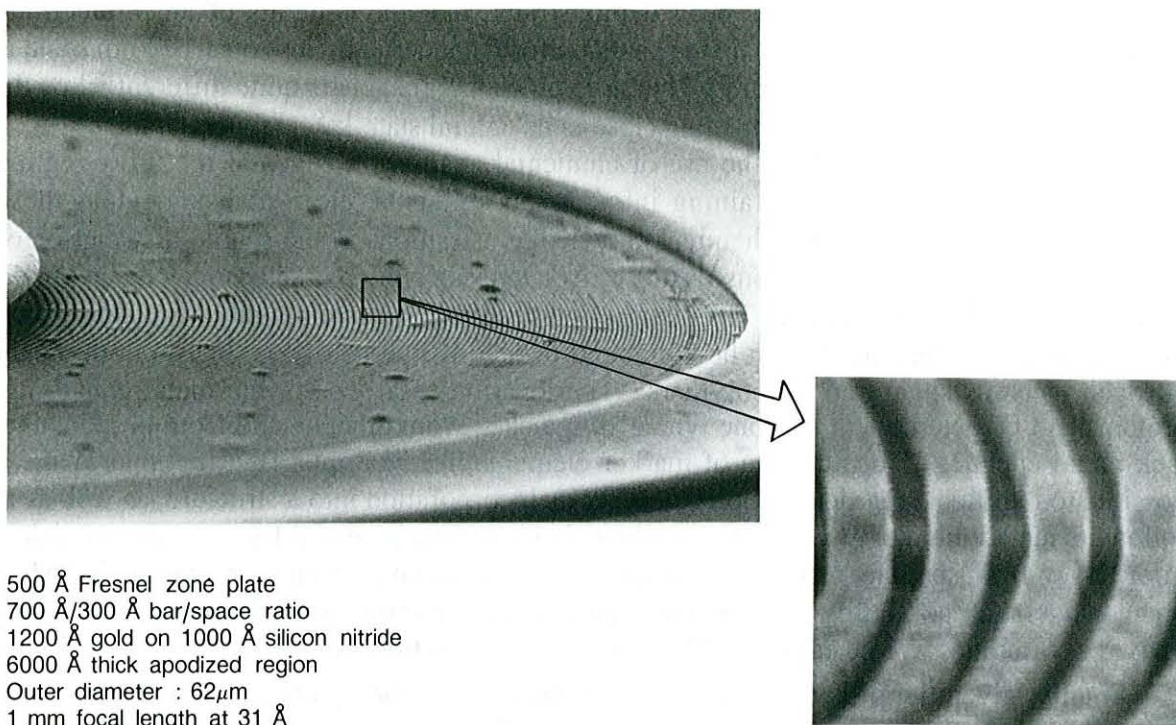


Figure 3-4. A scanning electron micrograph of a 62-μm-diameter Fresnel zone plate, showing the concentric rings of opaque gold on a transparent silicon nitride substrate.

Thus, imaging with soft x-rays will allow, for the first time, resolution of a wide range of cellular substructure in its natural state. The ability to study the sample at high resolution in a physiological aqueous environment, at atmospheric pressure and physiological temperatures, opens the door to the possibility of dynamic imaging of processes on a microscopic scale, within the cell or its components. As a result, x-ray imaging will permit experiments of a type not presently possible, whose accomplishment is likely to deepen our understanding of cell structure and function.

X-ray microscopy and related diffractive imaging techniques are particularly well-suited for structural studies at supramolecular and ultrastructural levels of organization. Even at the current level of development, with resolutions perhaps approaching 20 nm, unprecedented views of the native structures of many isolated cell parts can be obtained. And innumerable further questions suggest themselves. What is the appearance of mitochondria, chloroplasts, lysosomes, peroxisomes, the wide variety of secretion granules and related vesicle structures, the nucleus, and so forth, when probed with x-rays? What can we learn of the organization of the macromolecular aggregates contained within and comprising these structures, as well as those found elsewhere in the cell (for example, in microtubules, ribosomes, and muscle fibrils), when they are viewed without preparative alteration, suspended in aqueous media? How closely do our electron microscopic images of these objects match their appearance in their native states? Differences are likely to be found, but what will they be and how

substantial? For example, it has been demonstrated that the contents of an intracellular component, the zymogen granule, that appears uniform and structureless on a 100-nm scale in electron micrographs (after standard preparative procedures) appears quite different when the object is viewed with x-rays in something close to its natural state.¹⁻³

Beyond visual information, the use of elemental absorption edges in the x-ray regime provides the opportunity for obtaining information about the elemental content of these structures. In conjunction with chemical knowledge, variations in the spatial distribution of protein and other major organic constituents of isolated subcellular structures can be measured quantitatively at high resolution. The distribution of nitrogen-containing hydrocarbons, such as proteins and nucleic acids, can be compared to that of hydrocarbons that do not contain nitrogen, such as sugar and fat polymers. The location of at least some metal-containing proteins can be determined, and one type distinguished from others—and from proteins that lack metal chelates. The addition of marker elements, for example, fluorine, may make it possible to highlight a particular molecule after its incorporation into a structure, as well as to follow its metabolic fate in a spatially resolved fashion. The potential for obtaining chemical information from spatially resolved x-ray microimaging becomes even more impressive when one considers the possibility of combining spectroscopic information with spatial resolution. These opportunities will be considered further in the next section (see Spectroscopy).

Finally, given the possibility of imaging objects in physiological environments, and of being able to alter that environment, the potential exists to follow structural changes as they evolve in real time as a result of particular perturbations. For example, the secretion granule shown in Fig. 3-2 is known to release its predominantly protein contents in a graded fashion under a variety of conditions. Following the effect of such changes on structure at high resolution, as they evolve in real time, will provide a new and unique microscopic capability with broad applications to the study of any cellular component whose character, chemical or physical, can be altered after it is isolated from the cell—which, in practice, is to say all such structures, from chromosomes to chromaffin granules, to mitochondria, to a wide variety of macromolecular complexes.

While the path to important experimental studies on isolated subcellular structures is perhaps the simplest, the potential for valuable work at the cellular level is no less exciting, although it is likely to be technically more complex and demanding. The same characteristics of x-ray imaging apply, with the potential for structural analysis of native samples and the possibility of dynamic measurements. Perhaps to a greater degree than for isolated cellular substructure, cells to be studied and scientific problems to be approached must be chosen with care and, especially, with an appreciation of the strengths and limitations of x-ray imaging methods.

To take a specific example of the possibilities of x-ray imaging, we might choose the central and ubiquitous cellular process of secretion, which will be an important focus of research proposed for the Center. A great variety of intracellular structures are thought to be part of a system in which many different organic cell products are shuttled around the cell in vesicles or granules in a complex traffic pattern. These processes are presumed to occur in preparation for secretion, to effect its occurrence, and to construct, repair, and maintain cellular structures in general, including those not involved in secretion. Many of the structures thought

to be a part of this system are known to us primarily, if not solely, from electron microscopy. This poses the uncertainty about native structure already alluded to, but beyond that, with a few possible exceptions, the proposed processes, in particular the (ordered) movement of vesicles from place to place within the cell and the fusion of the secretion granule to the cell membrane to effect the exit of products from the cell, have never been observed directly. That is, they have not been observed as real-time events, as, for example, cell division can be followed in the light microscope. As a result, the proposed processes have, of necessity, almost invariably been hypothetical constructs developed from a variety of electron microscopic images and associated biochemical evidence. To follow such ultrastructural events in real time, and to assess their occurrence, properties, and quantitative characteristics dynamically, would greatly deepen our understanding of them and of cellular activities generally.

Similarly, validation of the central model for muscle contraction, the sliding filament-cross bridge model, has been hampered by the absence of direct evidence for the proposed events. Although a variety of indirect physical evidence, as well as biochemical and molecular structural information, are suggestive, understanding how the cross bridges power the translation of the filaments as events in space has been elusive. To actually observe shortening at high resolution in real time would be an important advance.

The ability to produce highly focused, tunable x-ray beams also offers a new kind of radiobiologic probe that will permit graded doses of radiation of chosen wavelength (and therefore of specific photoelectron energy) to be deposited at local intracellular sites. This will allow the researcher to ablate particular small structures within cells and to determine the effect of such treatment on specific processes of interest. Although x-ray imaging deposits far less energy on the sample than does electron microscopy, radiation effects still need to be assessed. Radiobiologic questions of the effect of local damage on molecular, organellar, or cellular function, and on the spread of damage, can be examined in detail never before possible.

X-ray microimaging also offers the opportunity of greatly enriching our knowledge of cellular pathology, because it allows examination of diseased tissue in its natural state at high resolution, as well as providing the potential of elemental mapping. For example, high concentrations of cellular inclusions found in various disease states, such as calcium-containing spicules of certain degenerative neurologic disorders, can be identified and studied in tissue unaltered during preparation for viewing.

X-ray imaging may also be of great value in the study of cell-cell communication, such as at the nerve synapse, where we will be able to examine the topology of whole, unsectioned, and unaltered material to gain a better understanding of the number and distribution of dendritic connections. Similarly, the true topography of the surface of cells is often unclear because it is readily altered by preparative treatments required for electron microscopic viewing. Soft x-ray imaging will permit examination of such structures without chemical or physical alteration and can provide an image that is more faithful to the true nature of the cell's surface.

SPECTROSCOPY

X-ray spectroscopy has an excellent record of achievement in several areas of biological, biochemical, and biophysical research, and the parameters of the ALS offer exciting new opportunities in this area. Central to x-ray spectroscopy is the ability to associate spectral features with particular elements, or even elemental states. This is generally done by examining spectral features near particular elemental absorption edges or by means of fluorescent emission.

It has long been known that the x-ray absorption spectrum of materials is characterized by sharp steps, or "edges," corresponding to the binding energy of the electrons in the various atomic shells. On closer examination at sufficient resolution, it becomes clear that such edges are not pure steps, but show amplitude modulations on the high-energy side of the edge that look like either pure sine waves or a mixture of several sine waves of different frequency. These structures usually have an amplitude of a few percent of the edge jump, or less, and extend for a kilovolt or so beyond the edge energy. They constitute the extended x-ray absorption fine structure (EXAFS). Close to the edge, there is often x-ray absorption near-edge structure (XANES) that is not sinusoidal in appearance and is typically of larger amplitude and narrower width than the EXAFS.

EXAFS arises from the behavior of the photoelectron wave as it emerges from the atom following a photoelectric absorption event and propagates outward toward the neighboring atoms. The wave is scattered by the nearest neighboring atom (we assume for the moment that there is only one neighbor) and the once-scattered wave produces a finite amplitude back at the emitting site. This amplitude is superposed on the original emitted amplitude, which may either increase or decrease as a result. Such increases or decreases will modulate the a priori probability of the process and hence the x-ray intensity at the detector.

EXAFS experiments consist of tuning the incoming energy (hence the value of synchrotron radiation) and measuring the transmitted flux with high accuracy for about 1 keV beyond the absorption edge. This has the effect of tuning the emitted photoelectron energy from zero at the edge to about 1 keV. The once-scattered amplitude at the emitting site is thus modulated sinusoidally as the electron wavelength is tuned smoothly through the range of values corresponding to this energy range. The result of this for a single neighbor is a single decaying-sinusoid EXAFS spectrum. If there are several nearest neighbors at the same distance, the size of the effect is strengthened and the modulations increase in amplitude. If there is another neighbor at a greater distance, the fractional wavelength change needed to produce a full period of modulation is less, thus the frequency of the EXAFS is greater. One may therefore infer atomic distances from the frequency of the EXAFS modulations, by performing suitable Fourier analyses.

EXAFS thus provides information about the number and distance of the atoms in the immediate neighborhood of the atom whose edge is being investigated. Different atoms also have different, but known, backscattering strengths, so there is some ability to match EXAFS data to candidate models of the chemical environment of the chosen atom. Since the mid-1970s, EXAFS has been developed into a highly accurate (resolution around 0.01 angstrom) means to measure the coordination numbers and atomic distances of atoms in any material

where there are not multiple possibilities for the results of such a measurement. For biological research, its main application has been to metalloproteins, where there is a single, fairly heavy metal atom whose chemistry is of great functional importance. The early work was done on the iron atom in hemoglobin, but many more studies involving different heavy atoms have now been done. The great beauty of the technique lies in its ability to investigate the chemical and structural environment of an atom, even though that atom may be deeply buried inside a complex macromolecule.

The extra capabilities that the ALS will bring to EXAFS, beyond what is already available, is the investigation of very dilute materials and the analysis of material that is spatially localized within some particular sample feature—a combination of microimaging and spectroscopy.

The value of XANES stems from the fact that an electron photoemitted from a core level with energy very close to its binding energy must be entering a state within the energy region occupied by the bonding electrons. The matrix element for such a transition depends strongly on the detailed character of the bonding electrons and is therefore an effective probe of their spatial structure. In particular, for dipole transitions, the matrix element depends on the orientation of the chemical bonds relative to the incoming electric vector, so that additional information can be obtained for oriented samples by exploiting the polarized nature of synchrotron radiation. In addition, the edge can be used to investigate such questions as the oxidation state of the atom being measured, as discussed below for the example of sulfur.

Special attention at the ALS is likely to be centered on spectroscopy at lower energies and on the development of spatially localized spectroscopy. This latter possibility makes the development of spectroscopy in the x-ray region particularly important. In addition, the penetration of x-rays at wavelengths below about 5 nm makes spectroscopic analysis an important tool for studies on intact cells and isolated cellular structures, even in the absence of spatial resolution. Finally, x-rays make possible the spectroscopic analysis of certain elements such as sulfur, the so-called “spectroscopically silent atoms,” which are normally undetectable by methods such as NMR and EPR spectroscopy.

The ALS will provide photons in two energy regions that will be at the forefront of innovative biological spectroscopy. The first regime is that from 2 to 4 keV, which contains the *K*-edges of the elements phosphorus, sulfur, chlorine, potassium, and calcium, all of great importance and interest in biology. Sulfur is especially noteworthy, and x-ray spectroscopy offers a singular means for studying this element in intact biological systems. Sulfur residues play a major role as a chelator of iron, zinc, copper, and other physiologically important metals. Disulfide bonds are also involved in the stabilization of the structure of proteins, and the redox state of thiol is known to play an important role in modulating the enzymatic activity of many of the most important soluble and membrane-bound enzymes. In many metalloenzymes and nucleic acid-binding proteins, sulfur is a ligand to the metal. Another very interesting and potentially valuable aspect of sulfur spectroscopy is that the oxidative state of the tissue may be reflected in the oxidative state(s) of the large number of thiol residues present in each cell. In toxicology the importance of the redox state of cellular thiols is now clear. This is of interest in the study of cellular stress and may also provide a useful, rather general measure of the effects of radiation on cell function.

Preliminary data, summarized in Fig. 3-5, have clearly shown that the near-edge features can be resolved for the large (about 10-eV) range of sulfur K-edge shifts, which correspond to the element's wide range of oxidation states (from -2 to +6). These near-edge features suggest that the dominant intracellular thiols will be well-resolved and will exhibit measurable changes in edge position if significant changes in oxidation state occur. The two sulfur-containing amino acids found in all cells are cysteine and methionine. The absorption features of the most common oxidation states of cysteine and methionine are shown in Fig. 3-6; they are easily distinguishable. An x-ray spectrum of whole fresh human red blood cells indicates that most of the sulfur in these cells is in the S-H state, with some suggestion of S-S states (Fig. 3-7).

Among its many roles in biology, phosphorus is important as a component of nucleic acids, as a component of the energy currency of cells, ATP, and as a redox agent. Recent studies indicate that the phosphorylation of proteins and lipids is an important step in the regulation of cellular biochemical pathways. Considerable new information about phosphorus-containing molecules will derive from their study by x-ray absorption spectroscopy (XAS).

Chlorine is also metabolically active and can exist in several oxidized forms. It seems to play a major role in the defense mechanism mediated by leukocytes. Two other elements,

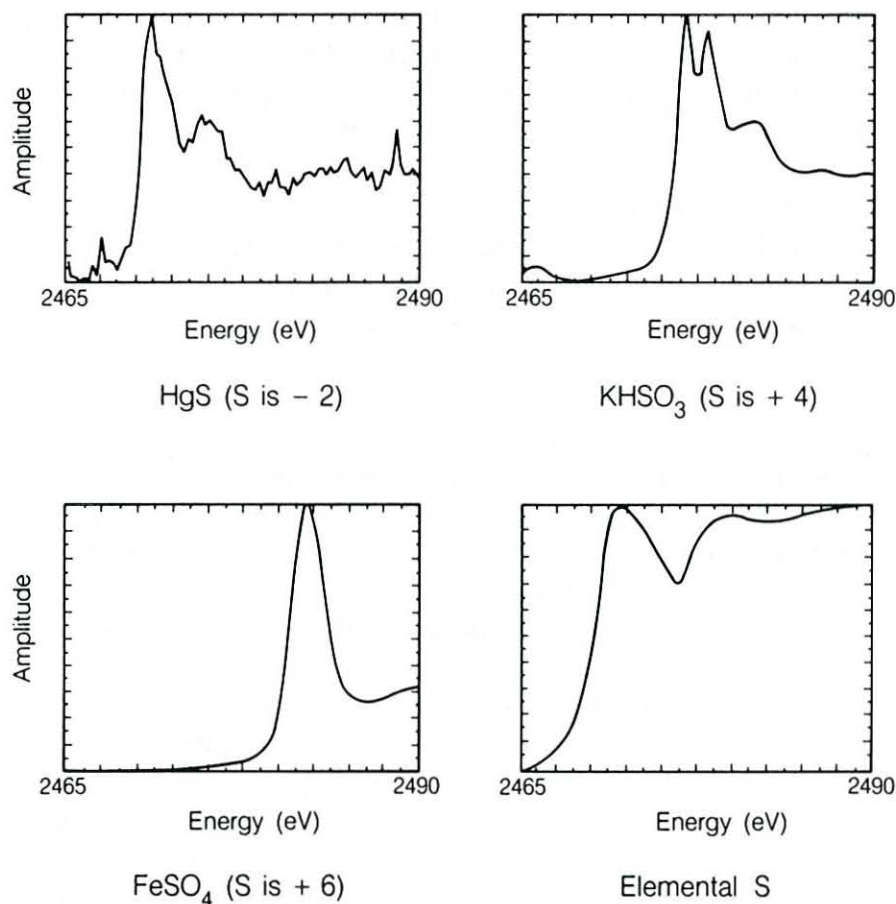


Figure 3-5. Four sulfur K-edge x-ray absorption spectra, showing the shifts in the edge position due to different oxidation states.

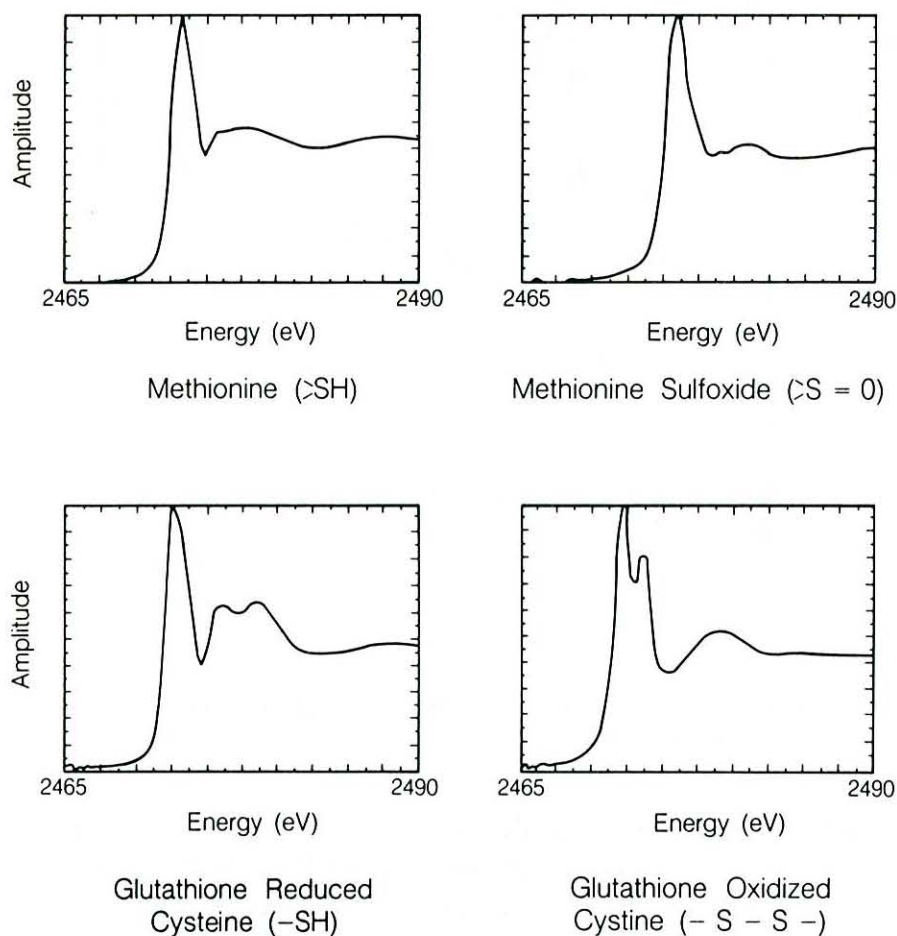


Figure 3-6. K-edge x-ray absorption spectra for the sulfur-containing amino acids methionine and cysteine, showing the clearly distinguishable absorption features of the most common oxidation states of sulfur in these molecules.

sodium and potassium, are, along with chlorine, the central electrolytes of cells. These ions are crucial to cellular work and survival because of their osmotic and charge- and gradient-dependent effects. Being able to assess concentrations and changes in concentration of these electrolytes within cells with high spatial resolution and in a time-resolved fashion would be an achievement of great value in cellular physiology and biophysics.

The second energy regime of particular interest is between 0.3 and 1.2 keV, where one finds the *L*-edges of the first series of transition elements, almost all of which are biologically important, as well as the *K*-edges of important light elements. It is in this range that the undulators planned for the ALS offer the greatest promise for high brightness, and the ability to carry out spatially resolved spectroscopy for elements in this region would be of important potential value.

One of the most interesting developments at the Life Sciences Center would be the confluence of microimaging and spectroscopy. Spatially resolved spectroscopy would provide a wholly new dimension to our understanding of biological systems. In the simplest case, one

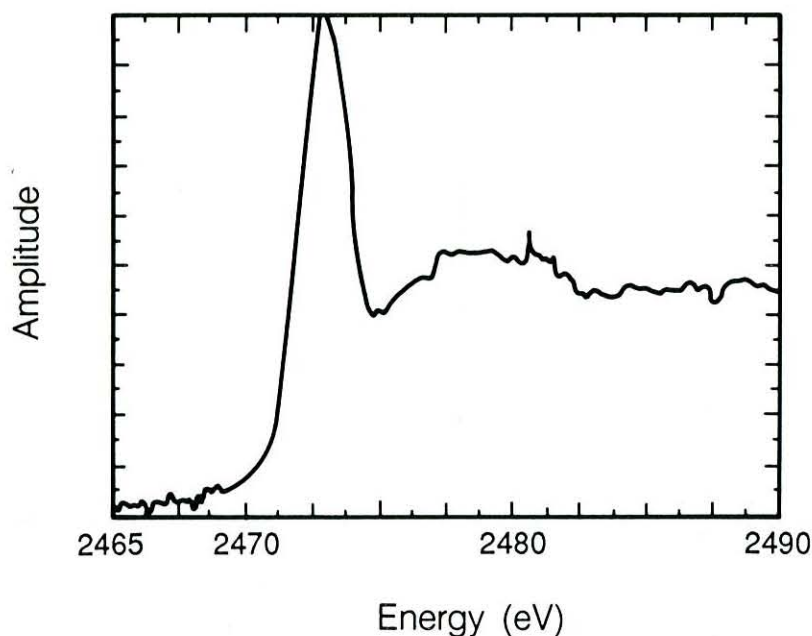


Figure 3-7. *A sulfur K-edge absorption spectrum for whole, fresh human red blood cells. Most of the sulfur in these cells is in the S-H state.*

asks for the two-dimensional elemental distribution within a tissue section or across a cell. While the sensitivity of elemental concentrations varies from element to element, data have clearly demonstrated detectability at the level of tens or hundreds of femtograms for elements such as chlorine, potassium, calcium, iron, manganese, copper, and zinc. Figure 3-8 suggests the possibilities for a microprobe based on grazing-incidence multilayer focusing elements; a scan along a blue-green algae filament reveals variations in the iron concentrations at the ppb level as the filament is scanned. Figure 3-9 is the spectrum of the fluorescence from a $10 \times 10 \mu\text{m}$ area of an NBS spectroscopic (wheat flour) standard, and Fig. 3-10 is the spectrum of a zymogen granule. The next extrapolation then posits that at any coordinate one could obtain the x-ray absorption spectrum for a given element, hence its chemical form and state. The increase in information thus obtained would be enormous. The excellent optical properties of the ALS and its insertion devices are ideally matched to this concept, and the potential for its development is worth a significant measure of effort.

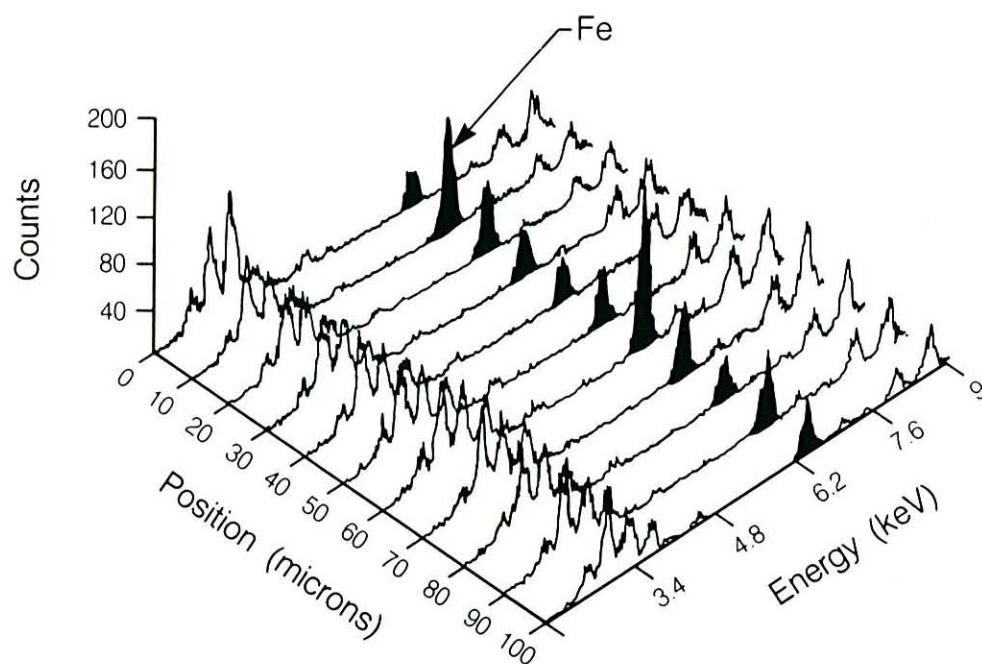


Figure 3-8. A series of x-ray microprobe spectra, taken along the length of a photoactive blue-green algae filament. Variations in the concentration of iron can be detected at the level of a few parts per billion.

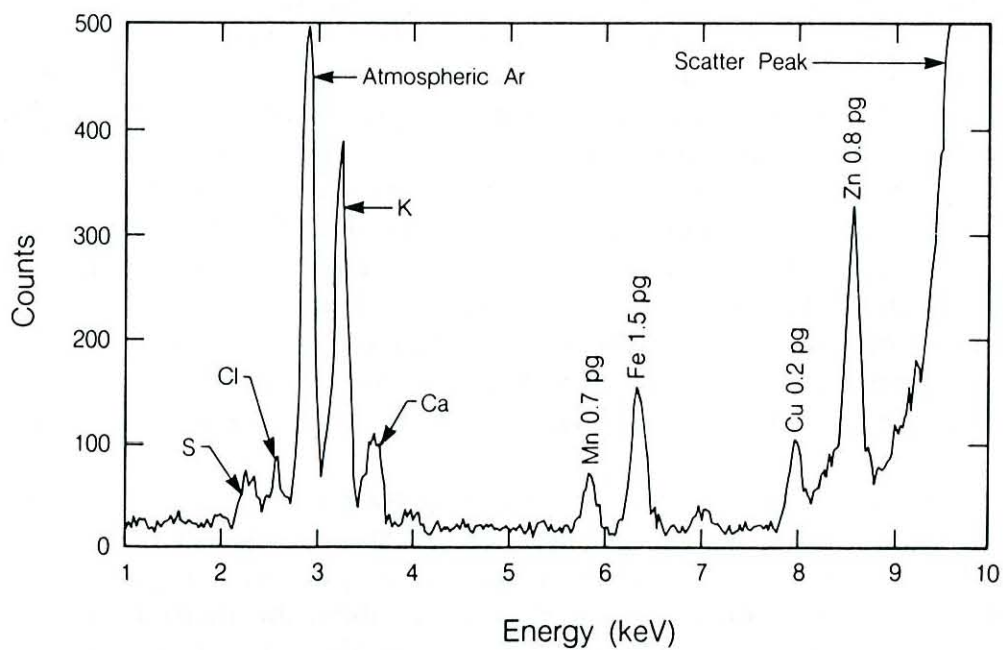


Figure 3-9. An x-ray microprobe spectrum of an NBS wheat flour standard sample, showing sub-picogram sensitivity for several elements.

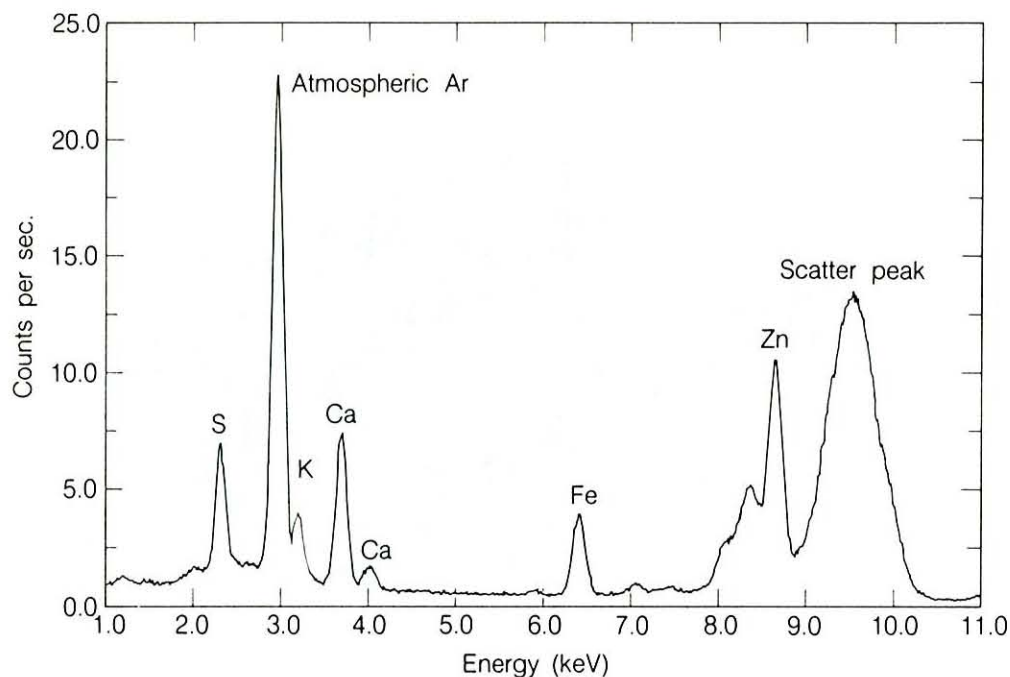


Figure 3-10. *An x-ray microprobe spectrum of a zymogen granule.*

DIFFRACTION AND SCATTERING

Despite being optimized for the production of soft x-rays, the ALS is nonetheless well-suited for x-ray diffraction studies at the shorter wavelengths (0.15 nm) required for the satisfactory resolution of macromolecules. Indeed, careful comparisons have been carried out between the ALS W13.6 wiggler and two established crystallography sources: the A1 wiggler at the Cornell synchrotron radiation facility and the Beamline 7.1 wiggler at SSRL.¹³ At a 10-keV photon energy, all three of these sources produce essentially the same flux; however, the brightness of the ALS source is significantly better (theoretically, 100-fold better) than the other two. (Recently commissioned sources at these facilities are brighter than the older sources, though still not as bright as the ALS wiggler is expected to be. Their fluxes are roughly comparable to those of the sources used in the comparison.) For some experiments, flux is the more important parameter of merit, but in others—for example, a measurement on a small crystal with a large unit cell (say, a virus)—brightness can give the ALS a considerable advantage.

Most of the detailed information that we have regarding the detailed structure of the two central classes of biological macromolecules—nucleic acids and proteins—is derived from analyses of the diffraction patterns produced by passing x-ray beams through crystalline arrays of these structures. In addition, our modern ideas about the transmission of genetic information, as well as our notions about the catalytic functions of enzymes, also owe a great deal to x-ray crystallographic studies of biological macromolecules. An impressive example of x-ray diffraction work is the structure of the *c-H-ras* oncogene protein—a protein involved in

normal signal transmission and implicated in certain human cancers—which is shown in Fig. 3-11.¹⁴ This structure was derived from the diffraction pattern shown in Fig. 3-12.

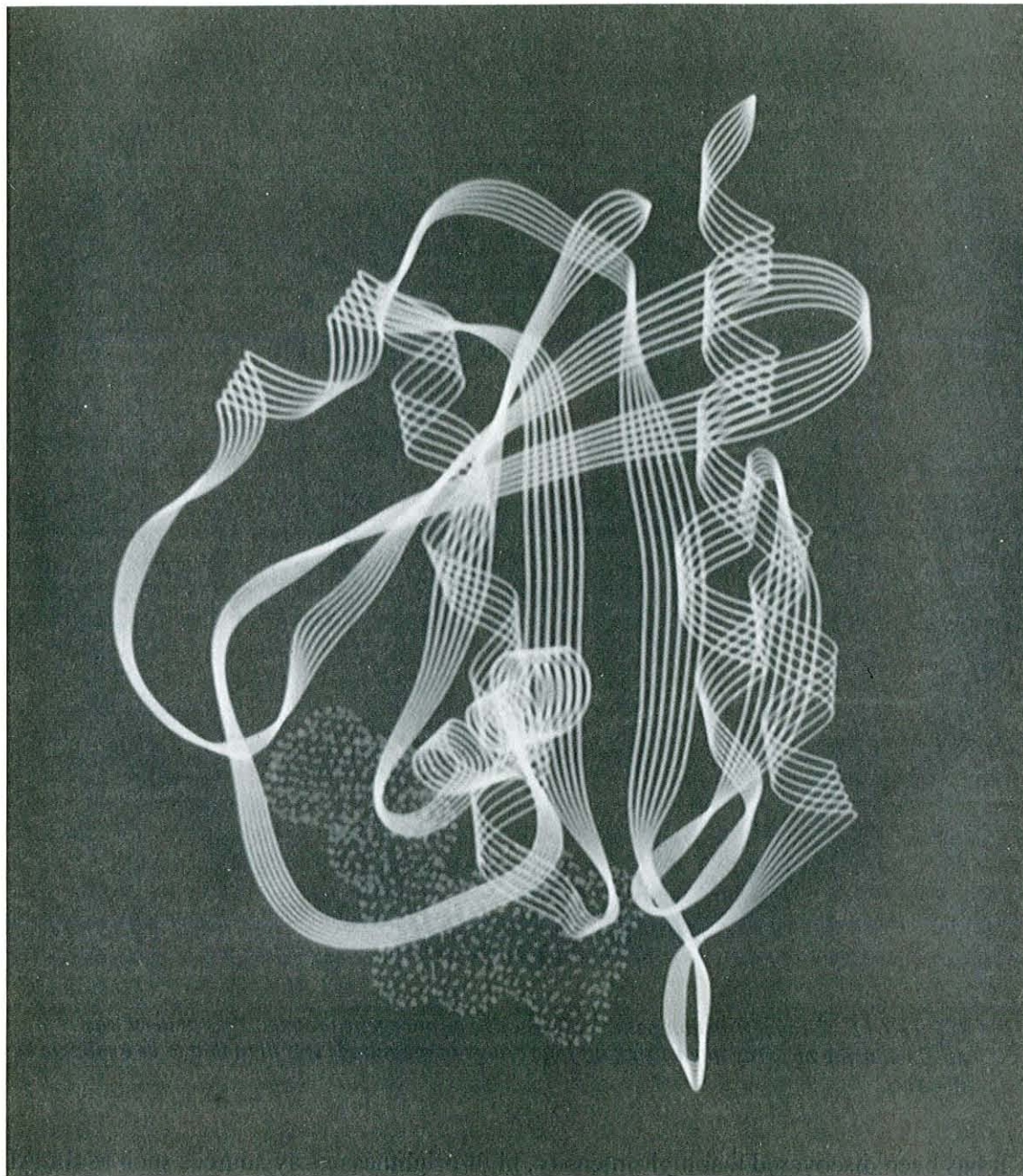


Figure 3-11. A computer-generated image of the structural backbone of the c-H-ras oncogene protein, together with a molecule of a guanosine triphosphate analog, as determined by x-ray diffraction. This protein is involved in the normal transmission of signals for human cell growth; a mutant form has been found in several cancers.

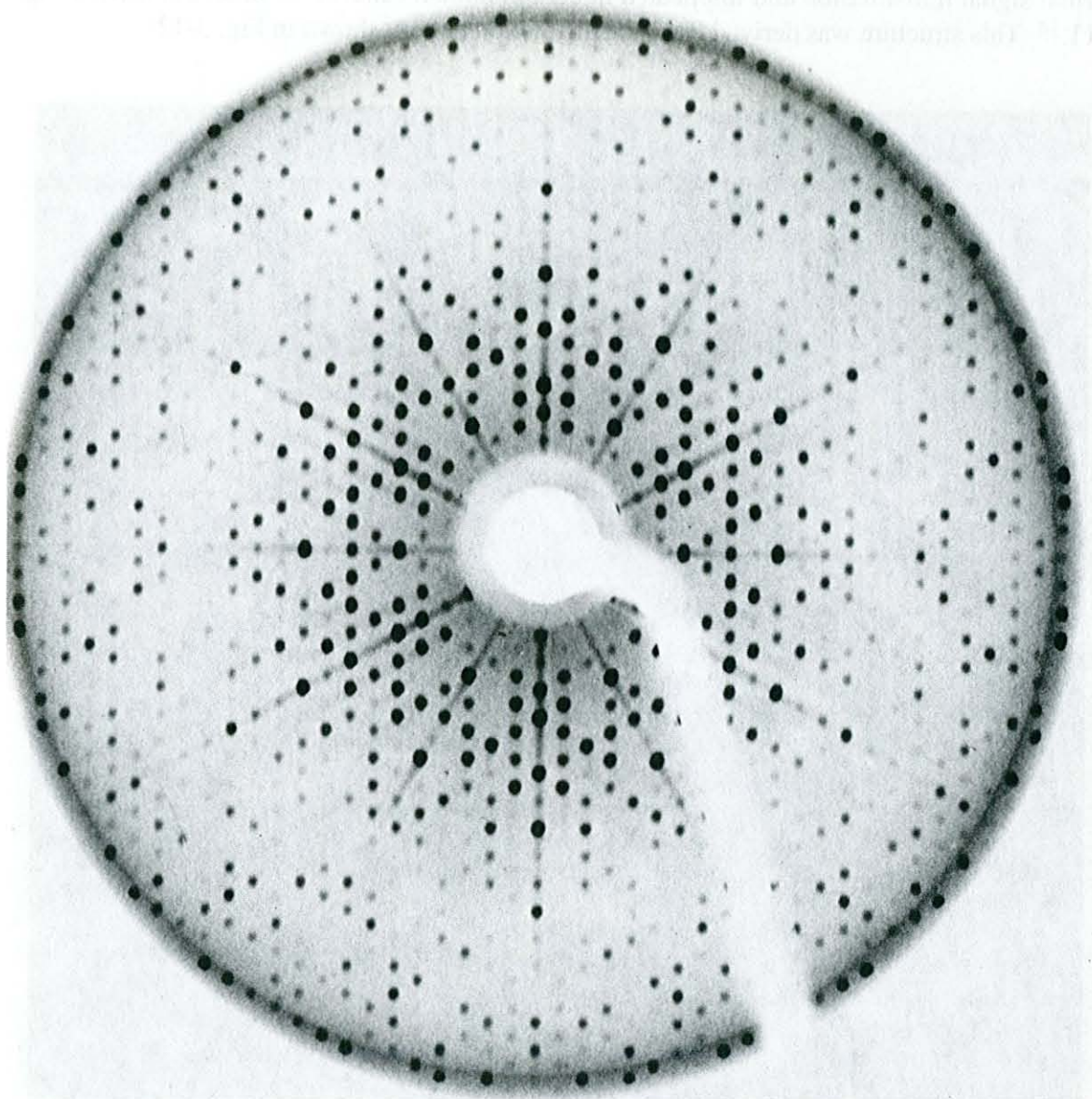


Figure 3-12. X-ray diffraction pattern of the c-H-ras oncogene protein. This pattern was obtained using an x-ray intensity about four orders of magnitude less than that to be available at the ALS.

It has been discovered that high-intensity, high-brightness x-ray sources such as the ALS have valuable advantages for protein crystallographic work. They greatly reduce exposure time, thus allowing for the collection of information far more rapidly than is possible with ordinary laboratory x-ray sources—at the same time greatly reducing the level of damage to the specimen. (Somewhat surprisingly, many crystalline biological samples will tolerate significantly larger radiation doses if those doses are delivered rapidly, as they are at

synchrotron radiation sources.) In addition, the small beam size, which permits examination of very small crystals, may help overcome one of the central problems in this area, namely, the inability to form crystals of substantial size. And finally, tunability at an absorption edge permits the difference in scattering across the edge to be used to "phase" diffraction maxima—a central limiting step in protein structure determination.¹⁵

For the future, there are prospects for exploiting newly developed techniques not yet in general use. Cryogenics, for example, can be used to stabilize crystals for an extended period of time and, as a result, provides a great improvement in the ability to collect data. In addition, the use of the Laue method might be expanded; this technique, using high-intensity white light, permits all data for a crystal to be collected in a single snapshot. Using this method, dynamical studies of changes in macromolecular structure are likely to become increasingly feasible: The time characteristics of the ALS will permit the study of events on a nanosecond, or even sub-nanosecond, time scale.

As the first and necessary objective of structural analysis, protein crystallography since its beginning has been devoted to establishing structure, independent of function. From this work, the notion developed that a single unique three-dimensional structure, namely, the one obtained from the crystal, described the molecular anatomy of the protein. Attempts to relate structure to function then focused in great part on the active sites of enzymes—how substrate affinity is determined and how catalytic activity occurs. With the exception of the active site itself, the surface of the protein was thought to be of little functional or structural interest. It has subsequently been demonstrated that the binding of substrates and end products to the surface of the protein, away from the active site, alters the catalytic rate (autoregulation of enzyme action) and that changes in the protein's structure can be induced by these interactions. In recent years, it has become increasingly clear that many proteins can undergo substantial reversible changes in structure in response to environmental shifts. Although these changes were at first thought only to reflect a transition from active (natural) to inactive (unnatural) states, it has become clear that at least some proteins are pleomorphic (and polyfunctional) and that such structural changes have to do with, among others things, the ability of proteins to interact with each other, with nucleic acids, and with membranes. Seeking to establish and follow variations in the tertiary structure and surface topography of proteins—indeed, for other oriented systems as well, such as membranes—represents an important area of structure-function analysis that is only in its infancy. The potential for carrying out such studies at the ALS, particularly in regard to the dynamics of structural change, represents an opportunity for exciting and valuable research on the structure and structure-function relationships of a wide variety of proteins.

The use of undulator radiation for soft x-ray scattering studies also offers great promise. The ability to match the wavelength of radiation in the soft x-ray and far UV regime to the characteristic size of various biological forms provides a powerful new probe into the microstructure of living organisms on a size scale ranging from one to hundreds of nanometers. The use of radiation with controlled polarization provides a way to study the symmetry and response of important biological systems and subsystems, such as muscle, microtubules, the internal structure of cell organelles and granules, and other important features. Longer wavelengths will allow small-angle scattering measurements to be performed

at larger angles, thus extending the range of size variations available for study and making it possible to overcome important measurement constraints in data collection. Longer wavelengths may be appropriately matched to longer spacings of interest in biological systems. Long-distance undulations, for example, in bone, muscle, or collagen can be measured and changes assessed. It may be possible to follow crystal nucleation to search for the best conditions for crystal growth. X-ray scattering from a large collection of like biological objects may provide a means of determining not only number, size, and size distribution, but internal structure as well.

Studies of the shape of the (0, 0, 0) diffraction spot in ordered systems and of the small-angle pattern generally, in disordered systems, have been practiced since the earliest days of x-ray research. The experiment is carried out with a fixed wavelength and provides low-frequency ($0.001\text{--}0.05\text{ \AA}^{-1}$ typically), usually angle-averaged structural information. In return for the low quantity of the information, the radiation damage is shared harmlessly over many nominally similar samples, and data collection can be very rapid, thus allowing time-dependent studies. A common approach is to measure the response as indicated by the small-angle pattern to various stimuli such as changes in temperature, pressure, electric field, etc. In addition, anomalous scattering has recently been used to give information about the spatial distribution of particular elements.

In biology there have been many studies of various macromolecules in solution with globular, coiled, fibrous, or other shapes. The measurements can be interpreted to give the radius of gyration, width, length, and other gross conformational data, averaged over the population in the solution. Some biological structures have periodicities in the few-hundred- to few-thousand-angstrom range, and these give peaks in the small-angle pattern corresponding to ordinary diffraction maxima. If the orientation of the samples is systematic in some way (as in bundles of fibers or a membrane), then this can be exploited to give more detailed structural information.

The main interest in these kinds of experiments is naturally focused on macromolecules that cannot be crystallized and on heterogeneous structures at the supramolecular level. There are many opportunities for fundamental studies of such questions as enzyme kinetics and molecular tumbling rates, for the measurement of deliberately induced conformational changes in biologically active macromolecules, and for evaluating higher-level order and structural change in macromolecular and organellar complexes.

The special contribution that a high-brightness source such as the ALS can bring to this field will be high angular resolution, that is, unusually high "Q resolution," meaning the ability to access coarse structures in the $0.1\text{--}1\text{-}\mu\text{m}$ range, in addition to the smaller ones normally measured. It will also offer the extra capability to study small or highly dilute samples and to do scattering at longer wavelengths, leading to still higher Q resolution.

Polarization-dependent scattering has also been discussed as a valuable means of seeking polarized structures with periods in the soft x-ray–far-UV size domain. For example, the possibility of discerning changes in chiral pitch between 1 and 100 nm in biological helices (for example, polypeptide α -helix, DNA double helix, nucleosome, chromatin solenoid, higher-order chromatin structures, muscle actin, tubules, and microfilaments) is obviously of interest. Although the possibility of such studies is of great interest, penetration becomes an

increasingly difficult and limiting problem, as the wavelength of interest lengthens into the UV regime. Further thought must be given to how this limitation might be overcome. Inventive sample preparation may be of particular help. Often these studies would require high-intensity circularly polarized radiation in the wavelength region from 0.1 to 200 nm. The development of the insertion devices or beamline components required to generate such radiation is being investigated, and solutions have been identified over most of the spectral range of interest.

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NEW SCIENTIFIC OPPORTUNITIES

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4.

SPECIAL RESEARCH FACILITIES

THE Advanced Light Source, in proper perspective, is merely a tool for producing photon beams—beams that arise from the bending magnets of the ring and, more importantly, from insertion devices in the ring's straight sections. These insertion devices and their beamlines therefore occupied a position of central importance in the design of the ALS, and they lie at the heart of the ALS Life Sciences Center. This section describes two such insertion devices, together with two insertion device beamlines specifically designed for life sciences research.

INSERTION DEVICES

The ALS, operating at 1.5 GeV, is optimum for insertion device operation in the vacuum ultraviolet (VUV) and soft x-ray spectral regions. On a time-averaged basis, an undulator in such a storage ring is the brightest source available in these photon energy ranges. In addition, at photon energies below and above this optimum region, the ALS's undulators and wigglers (respectively) still offer very useful capabilities.

Insertion Device Performance

As the source for soft x-rays, we chose one of the undulator designs described by the ALS project team in *An ALS Handbook*,¹ undulator U3.9. This device has been carefully designed and analyzed as a radiation source so that we have excellent performance data readily available. *According to the calculated performance figures, this undulator will provide the highest average coherent power in the world by a considerable margin.* Performance data are summarized in Figs. 4-1 and 4-2 and in Table 4-1a.

Undulators radiate a spectrum with sharp peaks consisting of a fundamental wavelength and harmonics. The fundamental is a peak whose width is of order $1/N$, where N is the

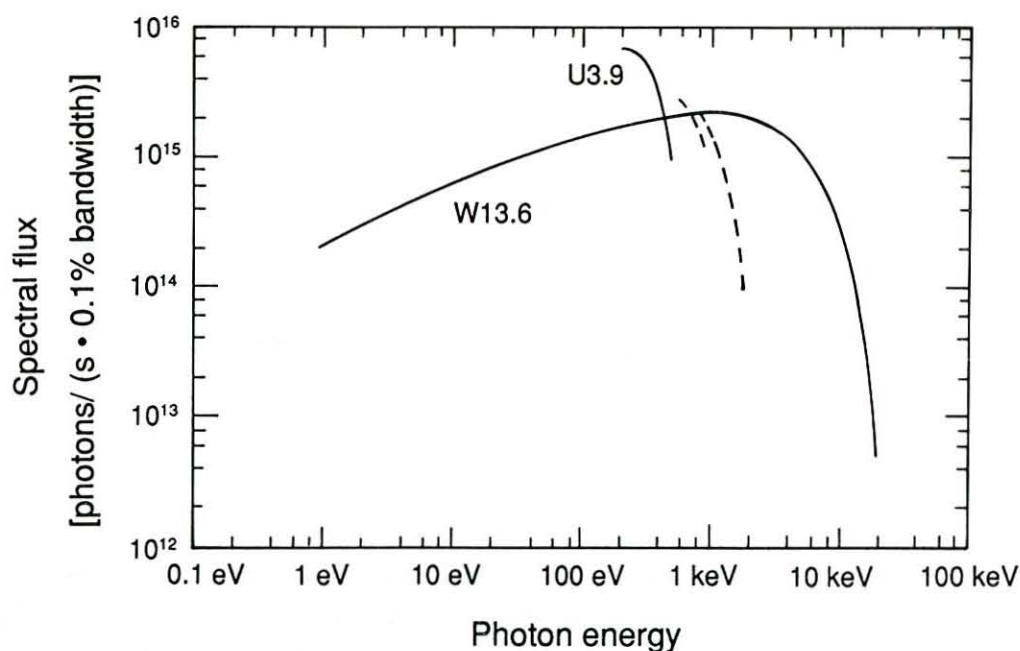


Figure 4-1. A plot of spectral flux as a function of energy for the undulator and wiggler chosen for the ALS Life Sciences Center. For the wiggler, we assume a 5-mr collection angle. Each undulator curve—for the fundamental (solid line) and for the third and fifth harmonics (dashed lines)—is the locus of narrow peaks of radiation, tuned by altering the undulator gap.

number of undulator periods, and the harmonics are sharper still. For each electron, the most useful radiation at the fundamental wavelength lies in a narrow cone about the axis of the system, with an rms half-angle equal to $(\lambda/L)^{1/2}$, where λ is wavelength of the fundamental and L is the length of the undulator. The fundamental wavelength depends on the magnet gap and can be tuned over a certain range by varying the gap. The U3.9 device has 123 periods, each of length 3.9 cm, to give a total length of 4.8 meters. The output at the fundamental wavelength can be tuned over the range 2.5–7.3 nm (169–500 eV); it lies within a cone of rms half-angle equal to approximately 0.03 milliradians. By using the third and fifth harmonics, the spectral range 0.5–2.4 nm (507–2500 eV) can also be covered. As an example of the type of spectrum provided by the device, we show in Fig. 4-3 the on-axis spectral brightness for a gap setting that gives a fundamental wavelength of 4.25 nm (290 eV).

For the ALS undulators, we anticipate that the first, third, and fifth harmonics will provide useful output. Harmonics of higher order are also present, and though more sensitive to construction errors, they may provide substantial fluxes of higher-energy photons in the same beam—potentially, a very valuable asset. This point is important, because it is generally possible to design beamline optical systems to handle wider energy ranges than can be covered with the fundamental radiation of an undulator. As a rough guide, the useful operating range of an undulator is considered to lie between the energy of the fundamental at the largest achievable K value and the energy of the fifth harmonic at $K = 0.5$. (K is the so-called deflection parameter, equal to $0.934 \lambda_u B_0$, where λ_u is the magnet period in centimeters and B_0 is the peak magnetic field in teslas.)

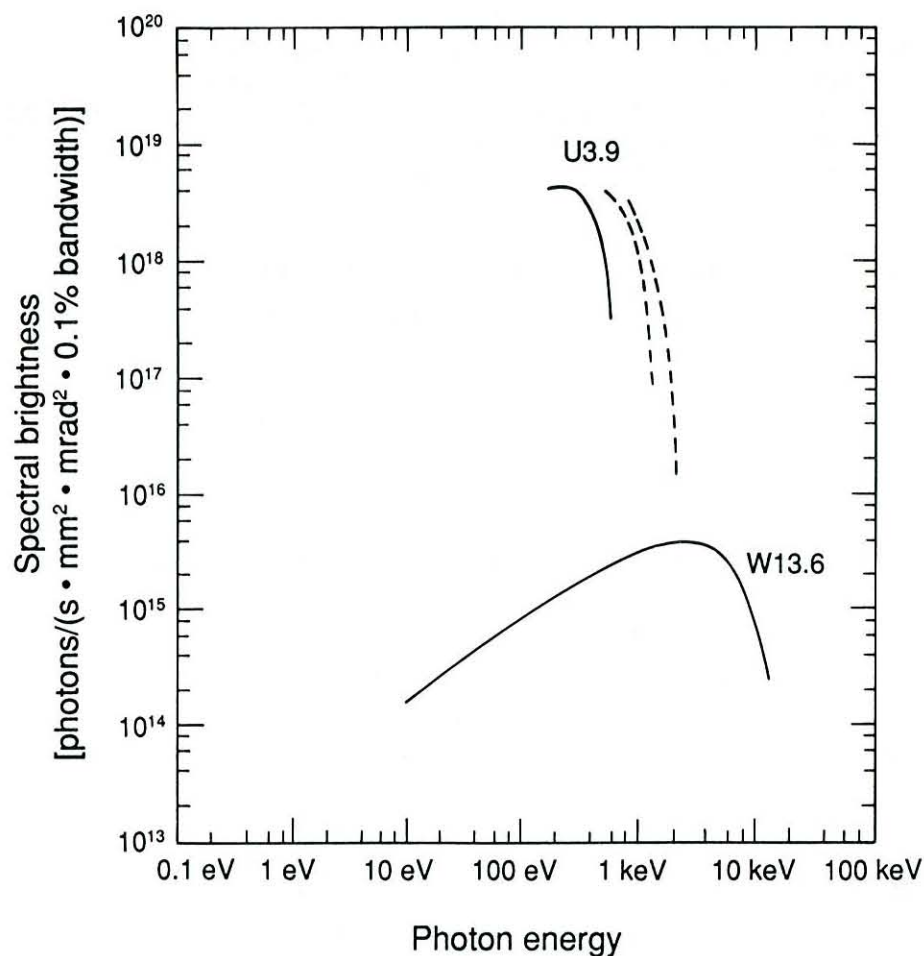


Figure 4-2. A plot of spectral brightness as a function of energy for the undulator and wiggler chosen for the ALS Life Sciences Center. For the undulator, curves are shown for the fundamental (solid line) and for the third and fifth harmonics (dashed lines).

The spectral flux in the central cone increases with K ; thus, for a given total length of undulator and for a given desired photon energy, it is usually better to choose a higher value of K . In addition, the larger K also implies a shorter period length, hence a further increase in flux by virtue of the larger number of periods, N . However, the validity of this rule is limited by power considerations: As the value of K becomes large, the undulator effectively becomes a wiggler for large harmonic numbers n , and the total power generated, most of which is in unwanted spectral regions, may become unacceptably large. (For the insertion devices considered here, the total power is limited to a few kilowatts.)

Higher photon energies are generally obtained by using a shorter period length; however, there is a lower limit to the practical period length of an undulator, because the magnetic field decreases rapidly as the ratio of the period length to the magnet gap becomes small. U3.9 is the shortest-period insertion device now being proposed for the ALS.

Table 4-1 (following pages). Detailed performance characteristics of the two insertion devices included in the ALS Life Sciences Center, both at an electron energy of 1.5 GeV: (a) undulator U3.9 and (b) wiggler W13.6 with a gap of 1.5 cm. For the undulator, characteristics are given for the fundamental and for the third and fifth harmonics, for several values of K. The symbols used are explained below. The magnetic performance of the insertion devices was calculated by assuming a hybrid structure based on neodymium-iron.

BO(T)	Peak magnetic field for undulators and wigglers.
BRI	Spectral brightness, i.e., flux per unit phase-space area [photons/(s-mm ² -mr ² -0.1% bandwidth)].
E(GeV)	Beam energy.
ECR(keV)	Critical energy for wigglers and bending magnets.
EP(keV)	Photon energy.
F	Spectral flux. For undulators the flux in the central cone; for wigglers and bending magnets, the flux within a 5-mr horizontal angle and all vertical angles [photons/(s-0.1% bandwidth)].
FDEN1	Spectral flux per unit horizontal angle [photons/(s-mr-0.1% bandwidth)].
FDEN2	Spectral flux per unit solid angle [photons/(s-mr ² -0.1% bandwidth)].
I(A)	Beam current.
K	Peak deflection parameter for undulators.
LAMDW(cm)	Period length of undulators and wigglers.
N	Number of magnet periods (undulators and wigglers).
n	Harmonic number for undulator radiation.
NPOLE	Number of wiggler poles.
PCEN(W)	Power transmitted through a pinhole whose angular size is equal to that of the central angular cone at the fundamental frequency.
PDEN1	Power emitted (all frequencies) per unit horizontal angle [W/mr].
PDEN2	Power emitted (all frequencies) per unit solid angle [W/mr ²].
PTOT(kW)	Total power (all angles and all frequencies) emitted by undulators and wigglers.
SIGPX(mr)	Horizontal rms beam divergence in the straight section.
SIGPY(mr)	Vertical rms beam divergence in the straight section.
SIGX(mm)	Horizontal rms beam size in the straight section.
SIGY(mm)	Vertical rms beam size in the straight section.
XLEN(m)	Length of undulators and wigglers.

Table 4-1a. Undulator U3.9.

E(GeV)	I(Amp)	SIGX(mm)	SIGY(mm)	SIGPX(mr)	SIGPY(mr)	N	LAMBDW(cm)	XLEN(m)
1.50	0.400	0.330	0.063	0.030	0.016	123	3.90	4.8
	K	B0(T)	PTOT(kW)	PDEN2(W/(mr**2))	PCEN(W)			
	0.03	0.01	1.85E-04	1.52E+00	9.56E-03			
	n	EP(keV)	F(#/s,0.1%BW)	FDEN2	BRI			
	1	5.48E-01	6.33E+12	1.00E+15	7.60E+15			
	3	1.64E+00	2.16E+06	5.17E+08	3.94E+09			
	5	2.74E+00	7.91E-01	2.12E+02	1.62E+03			
	K	B0(T)	PTOT(kW)	PDEN2(W/(mr**2))	PCEN(W)			
	0.50	0.14	5.15E-02	2.98E+02	1.99E+00			
	n	EP(keV)	F(#/s,0.1%BW)	FDEN2	BRI			
	1	4.87E-01	1.48E+15	2.20E+17	1.67E+18			
	3	1.46E+00	2.97E+13	6.88E+15	5.25E+16			
	5	2.43E+00	6.53E+11	1.71E+14	1.31E+15			
	K	B0(T)	PTOT(kW)	PDEN2(W/(mr**2))	PCEN(W)			
	1.20	0.33	2.97E-01	8.53E+02	7.25E+00			
	n	EP(keV)	F(#/s,0.1%BW)	FDEN2	BRI			
	1	3.19E-01	4.62E+15	5.40E+17	4.07E+18			
	3	9.56E-01	1.11E+15	2.24E+17	1.71E+18			
	5	1.59E+00	3.10E+14	7.35E+16	5.61E+17			
	K	B0(T)	PTOT(kW)	PDEN2(W/(mr**2))	PCEN(W)			
	2.12	0.58	9.26E-01	1.54E+03	2.02E+01			
	n	EP(keV)	F(#/s,0.1%BW)	FDEN2	BRI			
	1	1.69E-01	6.23E+15	4.73E+17	3.52E+18			
	3	5.06E-01	3.17E+15	4.82E+17	3.65E+18			
	5	8.44E-01	1.95E+15	3.74E+17	2.85E+18			

Table 4-1b. Wiggler W13.6.

E(GeV)	I(Amp)	SIGX(mm)	SIGY(mm)	SIGPX(mr)	SIGPY(mr)
1.50	0.400	0.330	0.063	0.030	0.016
NPOLE	LAMBDW(cm)	XLEN(m)	B0(T)	ECR(keV)	PTOT(kW)
32	13.60	2.18	2.07	3.10	5.31E+00
	EP(keV)	F	FDEN1	FDEN2	PDEN2(W/(mr**2))
					7.27E+02
					BRI
	5.000E-03	5.878E+14	1.176E+14	1.529E+13	9.123E+13
	1.000E-02	7.355E+14	1.471E+14	2.426E+13	1.448E+14
	5.000E-02	1.212E+15	2.425E+14	7.070E+13	4.219E+14
	1.000E-01	1.477E+15	2.953E+14	1.116E+14	6.660E+14
	5.000E-01	2.083E+15	4.166E+14	3.060E+14	1.825E+15
	1.000E+00	2.161E+15	4.321E+14	4.384E+14	2.614E+15
	3.098E+00*	1.537E+15	3.073E+14	5.551E+14	3.305E+15
	5.000E+00	9.720E+14	1.944E+14	4.541E+14	2.699E+15
	1.000E+01	2.482E+14	4.963E+13	1.688E+14	9.986E+14
	2.000E+01	1.298E+13	2.597E+12	1.282E+13	7.508E+13
	5.000E+01	1.218E+09	2.437E+08	1.935E+09	1.102E+10
	1.000E+02	1.890E+02	3.780E+01	3.828E+02	2.120E+03

Many x-ray techniques used in the biological sciences require x-rays in the 8- to 20-keV region. Protein crystallography, for example, requires x-rays of wavelengths commensurate with atomic dimensions, and fluorescent analysis of elements of intermediate atomic number requires x-rays of energy sufficient to excite the characteristic *K* or *L* radiation of the elements in question. To perform such experiments at the ALS requires a wiggler rather than an undulator as the insertion device. Whereas an undulator produces a soft x-ray spectrum having tunable sharp peaks and a radiation pattern that is sharply peaked in the forward direction, a wiggler produces a broadly peaked (or white) spectrum of harder x-rays, which is spread into a

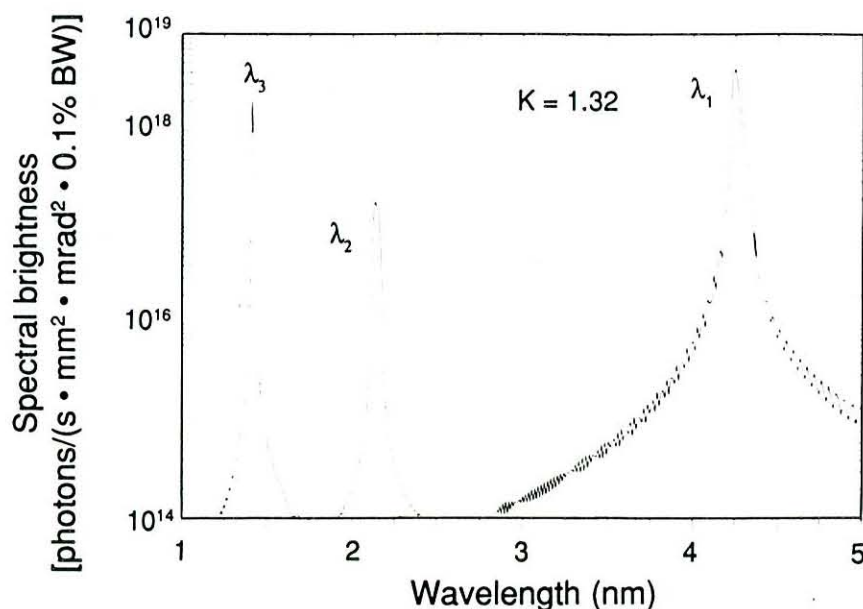


Figure 4-3. A plot of on-axis spectral brightness from the U3.9 undulator, with the gap set to give a fundamental at 4.25 nm (290 eV).

relatively wide fan of radiation emerging from the insertion device. Therefore, as a complement to the U3.9 undulator, the Life Sciences Center will include a wiggler of the type described in *An ALS Handbook*.¹ Its performance is summarized in Figs. 4-1 and 4-2 and in Table 4-1b. With a 2.0-cm gap, the spectrum of this 13.6-cm-period wiggler extends to almost 20 keV; the spectral peak is in the 2- to 6-keV region. An intense x-ray source of this kind offers a variety of experimental opportunities in the biological sciences.

Mechanical Description

A typical ALS permanent-magnet insertion device, as proposed here, is shown in Fig. 4-4. Each such device consists of a magnetic structure, a support/drive system, and a vacuum system.

The magnetic structures are of the hybrid configuration, with construction similar to the wigglers for the SSRL Beamlines VI and X. For the ALS, we will use a relatively new permanent-magnet material, neodymium-iron (Nd-Fe), as the current-sheet-equivalent material in the structures. This material has a stronger remanent field, is more durable, and is less expensive than samarium-cobalt. A cross section of a typical magnetic configuration is shown in Fig. 4-5, along with a corresponding quarter-period magnetic flux plot. Shown in the figure is a configuration made up of keeper assemblies, each consisting of a keeper, a pole, and oriented permanent-magnet material, bolted to a backing beam. Also shown in the cross section are tuning studs, variable magnetic shunts that allow fine tuning of the magnetic fields. Based on our fabrication experience, most insertion devices do not require the use of these tuning studs, but they will be provided as insurance.

Permanent-magnet rotators are provided as field end correctors. The backing beams, to which the keeper assemblies are attached, are sized so that the maximum gap deflection will be less than 50 μm under peak-field operation.

The support structure and drive system designs are similar for both insertion devices, with four-post support structure configurations similar to those used for the Beamline VI and X insertion devices. The structures extend only 24 inches inward and outward from the electron-beam center line, which allows for an adequate aisle within the accelerator tunnel. The maximum structure height is 94 inches, allowing the devices to fit within the 8-foot-high tunnel. Each device has a single drive system for opening and closing the magnetic gap for magnetic field adjustment. The drive mechanism is a roller-screw/chain system similar to those used on the SSRL Beamline VI and X wigglers. This system consists of four right-handed roller-screw/nut assemblies on the upper half and four left-handed roller-screw/nut assemblies on the lower half of the insertion device, coupled together with four drive shafts. These assemblies are driven by a stepper motor and a reduction unit through a roller chain and sprocket arrangement. Magnet gap position is encoded via a rotary encoder, with provision for a high-resolution linear encoder to be used in conjunction with a monochromator. Limit switches and mechanical stops provide system protection.

The vacuum chambers are of the rigid type, similar to that fabricated for the SSRL Beamline X wiggler. For ease of commissioning, the vacuum chambers in the insertion regions will initially have a beam-stay-clear gap of 2 cm. Adding 0.5 cm for fabrication

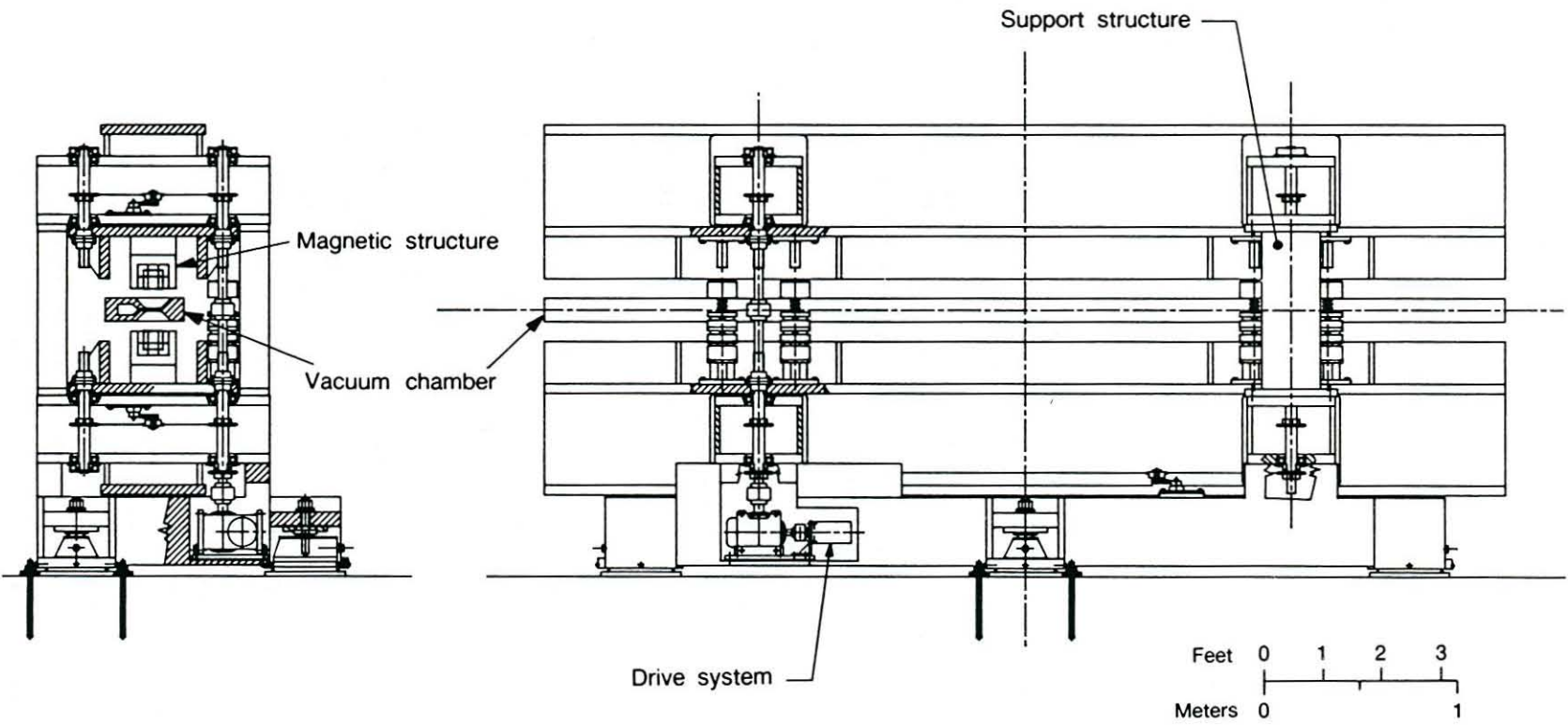


Figure 4-4. An end view and a side view of a typical ALS insertion device.

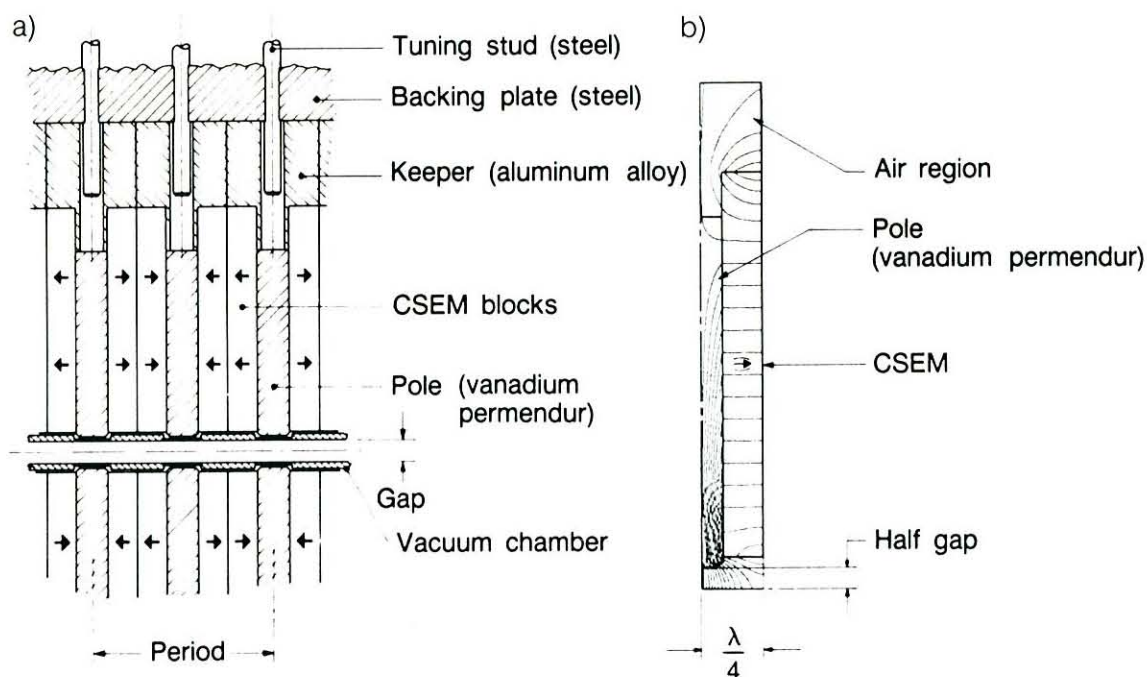


Figure 4-5. (a) A cross section and (b) a quarter-period magnetic flux plot for a hybrid insertion device. The current-sheet-equivalent material (CSEM) is neodymium-iron.

allowances and chamber thicknesses, the minimum magnet gap will be 2.5 cm during commissioning. After commissioning, the insertion devices will be retrofitted with chambers having 1.0-cm minimum vertical apertures, which will allow for operation with magnetic gaps as small as 1.5 cm. Figure 4-6 shows a typical transverse cross section of the vacuum chamber, together with wiggler W13.6.

UNDULATOR BEAMLINE FOR BIOLOGICAL RESEARCH

As part of the ALS Life Sciences Center, an undulator on the ALS will provide soft x-ray beams for a wide variety of imaging studies in life sciences research. One of the key features of the ALS will be its ability to make soft x-ray images in a very short time (of the order of a millisecond), and this has a determining effect on the style of utilization. Specifically, it indicates that one can have several experiments using the same source, with generous access to beam time for all.

An important requirement in life sciences research is to have adequate facilities for preparing and characterizing samples by means unrelated to the use of synchrotron radiation and to have these facilities as closely integrated with the x-ray-imaging systems as possible. The Life Sciences Center exploits the favorable floor layout of the ALS to address these needs in a new and unique way.

X-ray microscopy is still in a relatively early phase of evolution (mainly in the hands of physicists), and important improvements to the technique can still be expected.² To encourage

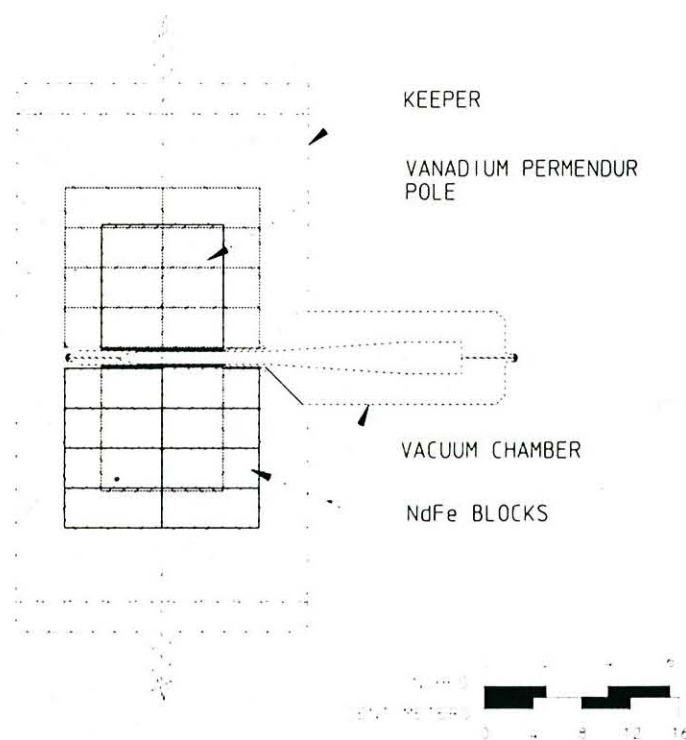


Figure 4-6. A cross section of wiggler W13.6 with a 1-cm-vertical-aperture vacuum chamber, designed to fit a 1.5-cm gap.

this type of activity, at the same time allowing regular and predictable user service, we propose two separate instruments, one to be kept in a standard operating mode at essentially all times and another that is open for some user service but is also available for developing improvements and new ideas.

The x-ray microscope development work that has taken place in the U.S. has focused to a considerable extent on the scanning x-ray microscope (the x-ray analogue of the scanning light or electron microscope).³ This type of system has the advantage of delivering the minimum possible dose to the sample and of being naturally suited to quantitative chemical microanalysis and computerized image processing. It also makes it convenient to keep the sample in its normal environment of water, under normal atmospheric pressure. We plan to take advantage of the experience gained in this technology by the activities of, among others, the Stony Brook group in operating scanning microscopes at the NSLS and to construct two microscopes of this type. The proposed system can also be readily adapted to use an imaging (Göttingen-type) microscope. In addition to the microscopes, a special beam channel will be provided for diffractive imaging by methods such as x-ray holography,⁴ a field where LBL has played a pioneering role, and an open, uncommitted port will be available for other forms of imaging, such as "flash" imaging, contact microradiography, and other new ideas that may arise.

Technical Requirements

The x-ray beams for scanning x-ray microscopy and diffractive imaging must be fully spatially coherent and sufficiently monochromatic to have enough temporal coherence for the job.⁵ This latter requirement is satisfied if the number of temporally coherent waves is equal to the number of zones of the zone plate x-ray lenses used in the microscope. This requirement (and the somewhat similar needs of holography and diffraction) are met by having a monochromator with resolving power $\lambda/\Delta\lambda$ of about 1000. We describe a way to achieve this below; it is not a demanding requirement. Spatial coherence is achieved by means of spatial filtering, which is easy to do, and which will not cause a large loss of flux for an ALS undulator source because these devices are fairly close to diffraction limited (single mode), especially at lower energies, and deliver correspondingly high average coherent power.

The x-ray wavelengths needed in this type of work span the region from about 0.5 to 7 nm, with special importance given to the so-called water-window region between the oxygen *K*-edge (2.3 nm) and the carbon *K*-edge (4.4 nm). Within the latter range, water is essentially transparent, whereas carbon- and nitrogen-containing materials give absorption contrast. At shorter wavelengths, there are still many important studies to do, but the imaging methods required are generally different from those considered here and are addressed below in the description of the wiggler beamline. It is important that the x-ray beam be wavelength tunable over the entire operating range.

It is very desirable for biological experiments to have the sample mounted on a horizontal microscope stage. However, synchrotron radiation beams are initially horizontal, and in the soft x-ray region, it is difficult to achieve the 90° deflection needed to get a vertical beam unless one sacrifices efficiency and tunability. Our approach to this problem is to use the best available technology (and to make developmental efforts to improve it) to provide a vertical beam for one of the two microscopes. This microscope would have a horizontal sample stage situated at bench height in a biology laboratory on the floor above the main experimental area and would thus offer an especially convenient working environment; however, there would be some compromises in exposure speed and wavelength tunability. The other microscope would have a horizontal beam and a vertical stage, still in a biology laboratory environment, and would require none of the above compromises.

Table 4-2 thus summarizes the capabilities that we wish to make available; the necessary technical systems are described below.

Elements of the Design

X-Ray Microscopes. As discussed just above, the Center will incorporate two scanning microscopes, although we will build them so that the conversion to an imaging microscope would be straightforward, should it be required in the future. The scanning x-ray microscope, like its cousins using light or electrons, operates by first forming, by means of a lens, a finely focused probe, which is held stationary and whose position defines the focal plane of the

Table 4-2. Descriptive characteristics and capabilities of the Life Sciences Center undulator beam channels and experimental stations.

Beam channel name	Floor level	X-ray beam type	Microscope type	Comments
1	upper	monochromatic soft x-ray	horizontal stage, scanning	some compromise of speed and tunability
2	lower	monochromatic soft x-ray	initially open station	no compromise of the type above
3	lower	monochromatic soft x-ray	holography, diffraction	
4	lower	monochromatic soft x-ray	vertical stage, scanning	no compromise of the type above
5	lower	monochromatic harder x-ray	1–3 keV, vertical stage, scanning	
6	lower	white	none	uncommitted port

instrument. The instrument operates by scanning the sample in a raster pattern (as in the formation of a television picture) through the focal plane. The image is accumulated and stored in a computer by counting x-rays at each point of the raster and using the x-ray count as the strength (grey level) of the picture at that point. The x-ray beam is focused by means of a Fresnel zone plate lens,⁶ as described in Section 3. The smallest possible focus is roughly equal to the spacing of the narrowest lines at the edge of the plate. The obtainable resolution of these devices is thus determined by the quality of the available microfabrication capability for making the zone plates.

Monochromator. The optical layout for the undulator beamline is shown schematically in Fig. 4-7. This scheme provides four possible output channels: a “white beam” port; an upper beam, which goes to the laboratory at the upper (mezzanine) level; and a lower beam, which is best seen in the plan view and which can be switched to either of two experimental stations. The dimensions and angles are distorted for clarity in Fig. 4-7. The beamline includes a spherical grating monochromator of a type that is becoming quite standard in present-day synchrotron

The diagram illustrates the layout of the ESRF X-ray beamline, divided into two main horizontal sections: the **Laboratory on mezzanine level** and the **Main floor level**.

Laboratory on mezzanine level:

- Undulator U3.9:** The source of the X-ray beam.
- Cooled apertures:** Two sets of apertures used for beam conditioning.
- G:** A bending magnet.
- Slits S1, S2:** Beam slits for defining the beam size.
- Rotatable M1:** A spherical mirror that can rotate.
- M2, M3, M4, M5:** Spherical mirrors used for beam transport and focusing.
- F1, F2:** Focal points or filters.
- Holography and diffraction system:** A system for studying the structure of materials.
- RM:** Retractable multilayer.
- Open station ②:** A station for sample insertion.
- SA:** Sample.
- ZP1:** Zone plate.
- Coherent optics development:** A system for developing coherent optics.
- Scanning X-ray microscope:** A microscope for high-resolution imaging.
- SA ①:** Sample.
- ZP2:** Zone plate.
- Coherent optics development:** A system for developing coherent optics.

Main floor level:

- Spherical grating monochromator:** A monochromator for selecting the X-ray wavelength.
- G:** A bending magnet.
- White beam port:** A port for the white beam.
- Slit S1:** A beam slit.
- S2, S3:** Beam slits.
- M1:** A spherical mirror.
- M2,3:** Spherical mirrors.
- F1,2:** Focal points or filters.
- Open station ②:** A station for sample insertion.
- SA:** Sample.
- ZP1:** Zone plate.
- Coherent optics development:** A system for developing coherent optics.

Legend:

- M - Spherical mirror
- ZP - Zone plate
- xF - 50x50 μm^2 focal spot
- SA - Sample
- RM - Retractable multilayer

radiation practice.⁷ The monochromator has only one grating, with 300 lines/mm, working in negative order, and uses the source as the entrance slit. After some power-reducing apertures, the beam from the source impinges on the grating as the first element, which is therefore intensively water-cooled. The instrument has two fixed output arms, each with an exit slit and each providing a fully tunable source over the entire wavelength range. When one arm has been set to provide a chosen wavelength, the other arm still gives some light which may be useful. There are some interesting possibilities here, such as supplying the first harmonic to one microscope and the third harmonic to the other. This can be done with the system described here if line U1 receives 0.9-nm radiation and L1 or L2 receives 2.7-nm radiation. It is also possible to feed both arms with x-rays in the water-window wavelength region.

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The throughput and resolution of the system are given in Fig. 4-8 and Table 4-3. The rates quoted in Fig. 4-8 translate into exposure times for a picture of roughly a millisecond. For applications that do not use a zone plate, the coherent photon rate could be obtained by removing the zone-plate efficiency factor of 0.03.

The choice of this type of system was dictated by the need for highest efficiency, tolerance to overall system geometrical instabilities, and the moderate resolution requirement. The simplicity of the system derives, in part, from the low numerical aperture of diffraction-limited soft x-ray beams. The optical fabrication tolerance involved is around one second of arc, which is quite severe, but it only needs to be held over an area of 1 mm x 24 mm, which is the size of the footprint of the central cone on the grating.

A major reason for choosing a design for this scheme that has no entrance slit is its tolerance to moderate-sized movements of the source. For vertical movements, the effect is a shift of the wavelength scale. For horizontal ones, the intermediate image of the source and the

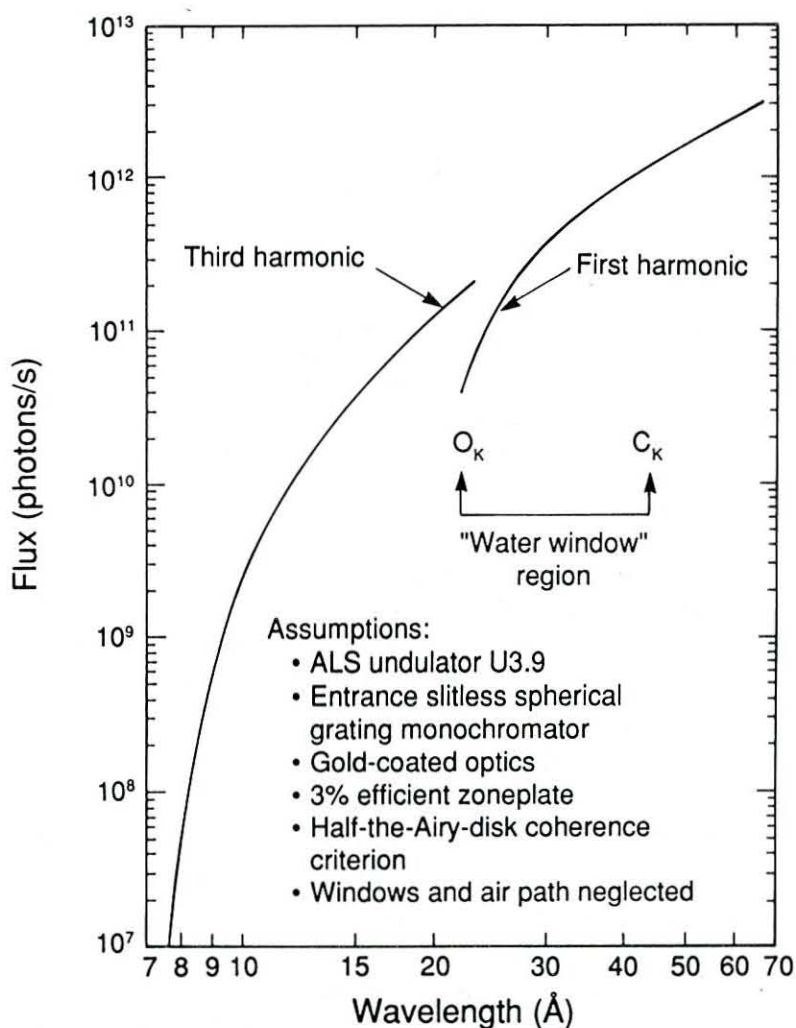


Figure 4-8. A plot of the undulator beamline output in photons per second onto a zone plate focal spot, for the assumptions indicated in the figure.

Table 4-3. Monochromator resolution for the spherical grating design proposed for the U3.9 beamline.

Wavelength (nm)	Resolution (nm), lower beam	Resolution (nm), upper beam
0.7	0.0009	0.0011
1.0	0.0009	0.0012
1.5	0.0010	0.0012
2.0	0.0010	0.0012
3.0	0.0011	0.0013
4.0	0.0012	0.0014
5.0	0.0013	0.0015
6.0	0.0014	0.0016
7.0	0.0016	0.0016

final image in the scanning microscope (the one through which the sample is scanned) will all move by the same fractional amount that the source moved. For example, suppose the source is displaced vertically by one standard deviation of its Gaussian spatial distribution, that is, about 60 μm , or about 40% of its full width. This would give a wavelength shift of 40% of the resolution function width (5×10^{-4} nm or $\lambda/6000$ at 3.0 nm). Now consider a horizontal shift of the same absolute amount, which is 20% of a horizontal standard deviation. In this case, the affected sample pixels would suffer a displacement of 20% of their width. These are small effects for fairly large perturbations of the beam. Had we chosen to use a real entrance slit (as opposed to using the source as the effective slit) or a real pinhole at the intermediate focus, then the source movements discussed above would have led to large (up to 35%) changes in the throughput of the system.

Optical Transfer to the Experiment. In each beam channel, the beam is conveyed to the entry point of the experiment by a pair of grazing-incidence spherical mirrors. This, again, works well as an imaging scheme because of the low numerical aperture of the beam and provides appropriate demagnification to image the source to a 50- μm -diameter intermediate focus. In the horizontal direction, a spherical mirror images the source, and in the vertical direction, a spherical mirror images the exit slit. The intermediate focus provides the source of light for the zone plate lenses of the scanning microscopes and for holography and diffraction. We note that all of the optical surfaces used in this scheme are spherical. This is the shape that is obtainable with the best figure and finish, and it gives the surest way to achieve the required optical fabrication tolerances.

Optics Required for a Vertical Beam. The only established technologies that could be used to deflect a soft x-ray beam by about 90° are natural crystals and multilayer reflectors.⁸ The latter devices consist of multiple layers of materials arranged to operate essentially as a man-made Bragg reflector. Unfortunately, like all Bragg reflectors, they only reflect x-ray wavelengths that satisfy the Bragg condition. Normally, for a given reflector and reflecting angle, that means only one wavelength. The use of either crystals or multilayers is thus incompatible with wavelength tunability. One could mitigate this to some degree by having a variety of different crystals and multilayers to give perhaps a dozen or so wavelengths that could be selected. This is not totally satisfactory, but we believe that the goal of a horizontal stage is sufficiently desirable as to be worth the compromise. Furthermore, there are two other approaches, each of which has been successfully demonstrated once in a particular spectral region, and which we must consider promising but unproven in our region. These are graded-thickness multilayers and whispering-gallery reflectors. Both these approaches promise wide-band reflection capability, which would thus allow tunability. We plan to carry out research and development to further our understanding of the possibilities of these approaches.

Manufacture of Optical Components. Two types of optical components are essential to the operation of any facility of this type: zone plates and multilayer reflectors. To obtain the best resolution, zone plates with very fine outer-ring spacing are needed. Present technology, including that practiced by LBL's Center for X-Ray Optics, allows the manufacture of plates with spacing of about 40 nm, and therefore resolution of about 50 nm. Over the next few years, we expect to push this toward a goal of about 10–20 nm, at which point further progress will be possible only by changes in the methods used. The manufacturing process that we will use employs the latest electron-beam writing techniques, which were developed for making masks for the semiconductor industry. This effort is part of an existing collaboration between LBL and the IBM Yorktown Heights Research Center. The manufacture of multilayer mirrors is also carried out by the Center for X-Ray Optics at LBL, which has a state-of-the-art facility. The multilayers required by this program will be made there and will be optimized for highest efficiency at the near 45° angles needed to provide a vertical beam of soft x-rays for the applications considered in this program.

Architectural Layout. The layout of the ALS facility allows each undulator source and its associated beamlines and experimental stations to have about 1000 square feet of dedicated experimental floor area in the immediate neighborhood of the station. In addition to this, there will be a mezzanine floor 16 ft (floor-to-floor) above part of the main floor. Further details of the building layout are given in Section 5 and to some extent in Fig. 4-7. All of the beamline downstream of a point 21 meters from the source lie under the mezzanine. It is thus possible to supplement the area of the main floor by using a laboratory located on the mezzanine, and there are strong sociological reasons for favoring this approach in the case of a biology facility. The most favorable environment for doing life sciences research with synchrotron radiation would be a well-equipped biology laboratory in which the apparatus needed to produce synchrotron radiation was not much in evidence. We believe the scheme presented here goes as far as one can toward this ideal. The upper-level x-ray microscope sample position is at bench level in a

laboratory that is otherwise free of x-ray equipment. The x-ray beam illuminates the sample by passing into the microscope through a small hole in the bench. The sample will be in air and will be almost as easy to load as it is in a light microscope.

WIGGLER BEAMLINE FOR BIOLOGICAL RESEARCH

We propose two branch lines and two experimental stations (comprising four experimental setups) for the wiggler beamline. One branch line is designed for spectroscopy (EXAFS, near-edge structure measurements, etc.) and for microprobe studies. The second will be devoted mainly to crystallography, but experimental equipment for small-angle scattering is also provided.

Crystallography Branch Line

Branch Line Design. The technical requirements for the protein crystallography branch line are determined by the nature of the proposed measurements. The design adopted here supports standard methods employing photographic rotation cameras with phasing by isomorphous replacement, at the same time making allowance for the increasing use of anomalous dispersion. This latter method involves the exploitation of the wavelength tunability of synchrotron radiation to use the edges of any reasonably heavy atom that may occur naturally in the crystal (or that can be introduced by a predictable chemical procedure) to phase the diffraction pattern. The intensities of each spot and its Friedel pair are measured at three wavelengths, one far below, one at, and one far above the edge. From these data the phases of the spots may often be obtained analytically. This approach can save time by eliminating the need to prepare heavy-atom derivatives. Moreover, in some cases, it allows one to eliminate errors and other problems associated with the use of many different crystals.

Given these advantages of anomalous dispersion, we require a sufficient photon-energy tuning range to access the *K*- or *L*-edges of all the elements that will be used. The technical characteristics of the proposed branch line are given in Table 4-4, which indicates an available tuning range of 3–15 keV. Such a range covers the elements up to lead. To get the best anomalous dispersion differences, it is desirable to use the dip in f' (the real part of the atomic scattering factor) that occurs near the edge. The resolution of 10^{-4} is needed if one is to set on this narrow feature.

The optical layout of the branch line is shown in Fig. 4-9. The beam from the wiggler is first collimated in the vertical plane by the cylindrical mirror, M1, which will be made by elastic bending of a water-cooled, flat metal mirror. The beam then impinges on the first crystal, C1, of a standard ultrahigh-vacuum, double-crystal monochromator. This system has three mechanical motions: rotation of the first crystal and rotation and translation of the second crystal. The overall effect is to provide a monochromatic x-ray output beam at a fixed height. The mechanism also includes features allowing the convenient interchange of crystals, to allow other crystals such as germanium and multilayer-coated reflectors to be used.

The first crystal receives a heat load that is fairly large, but not as large in total power or power density as those being planned at other synchrotron radiation facilities. Table 4-5

Table 4-4. Characteristics of the crystallography branch line.

Source critical energy (keV)	3.1
Wiggler deflection parameter, K	26
Width of wiggler radiation fan (mr)	18
Source output at 10 keV [photons/(s-mr-0.1% BW)] (integrated over all vertical angles)	10^{14}
Collected solid angle (mr ²)	2×0.3
Beam area at optical system (mm ²)	28×4
Spot size at sample (mm ²)	0.2×0.1
Convergence angles at sample (mr ²)	2×0.3
X-ray resolving power	10^4
X-ray flux at sample at 10 keV (photons/s)	6×10^{12}
Useful tuning range, defined as >10% of the flux at 10 keV (keV)	3–15

includes numerical values for these loads. We anticipate that standard water-cooling techniques, similar to those that LBL has used successfully with mirrors, will be adequate. The second crystal, C2, and the second mirror, M2, receive very small power loads and are designed accordingly. The last mirror is a toroid made by elastic bending of a cylindrical, fused-silica mirror of 22-mm radius. This radius provides focusing in the horizontal (sagittal) plane and limits the horizontal acceptance of the system to 2 mr. The elastically bent radius provides focusing of the initially collimated beam in the vertical (tangential) plane. The final result is almost a 1:1 image of the source, and this is applied to the sample. The adjustable focus of the M2 mirror can be used to enlarge (defocus) the spot size in the vertical direction to match the size of larger samples if this is desired.

Branch Line Performance. The phase-space data for the x-ray beam are given in Table 4-4. We consider two examples of the use of these data. In the first, we consider a fairly large crystal, 0.5×0.5 mm², with a moderate unit cell size of 50 angstroms—such as might be found for an enzyme. In the second example, we consider a more challenging case of a smaller

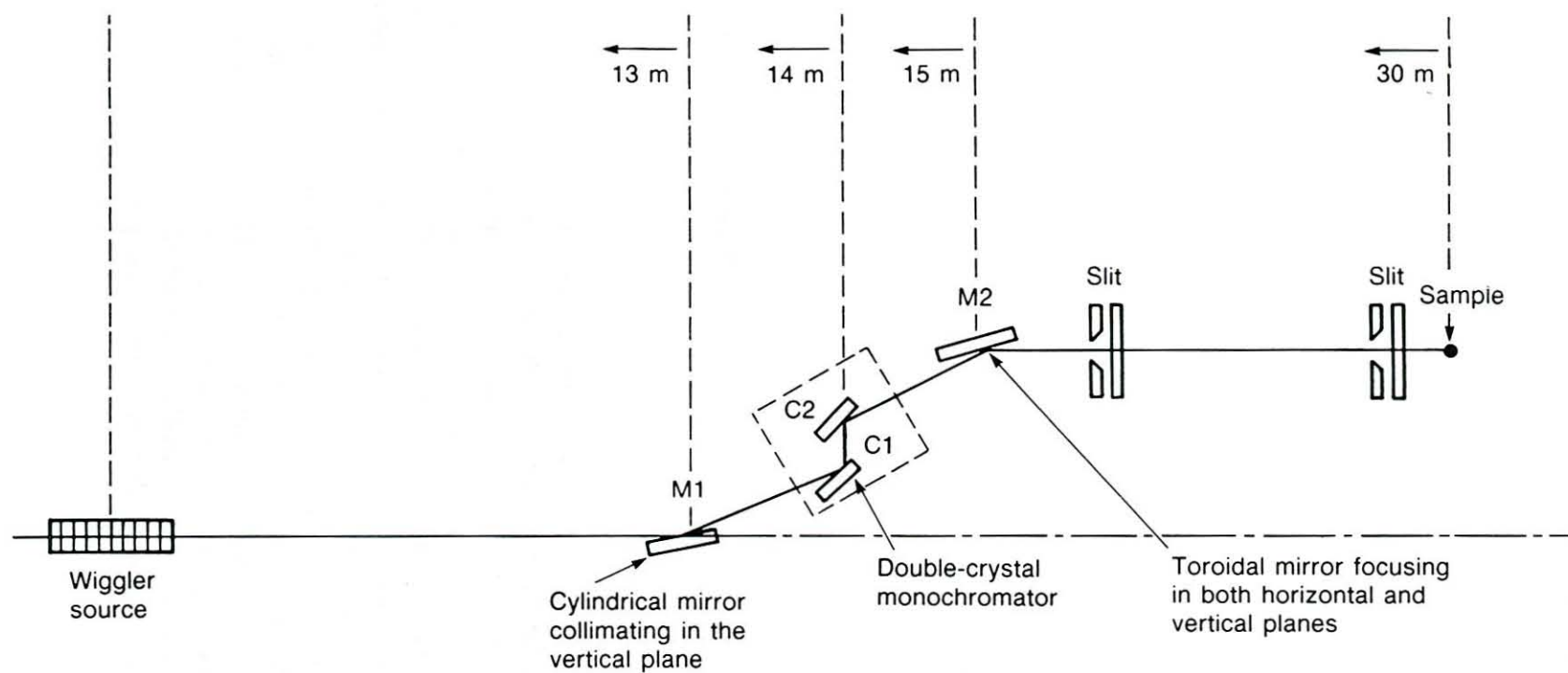


Figure 4-9. Optical layout for the protein crystallography branch line. The deflection angles, equal to 5 mr, have been exaggerated for clarity. The distances indicated are distances to the source.

Table 4-5. Characteristics of the optical system for the crystallography branch line.

	First mirror	Crystals	Second mirror
Material	Pt-coated, Ni-plated metal	Silicon (111)	Pt-coated fused silica
Surface shape	Cylinder	Flat	Toroid
Beam incidence angle (mr)	5	199 (at 10 keV)	5
Tangential radius (km)	17.07	infinity	9.80
Sagittal radius (m)	infinity	infinity	0.0227
Distance from source (m)	13	14	15
Active surface area (mm ²)	780 x 28	20 x 28 (at 10 keV)	780 x 28
Maximum incident power (kW)	0.60	0.48 (first) small (second)	small
Maximum surface power density (W/cm ²)	1.9	59 (first) small (second)	small

crystal, $0.1 \times 0.1 \text{ mm}^2$, and a unit cell of 1000 angstroms—as one might find for a virus. If the entire beam is to be applied to the experiment, the spatial size of the beam must be no larger than the crystal and the divergence angle must be no larger than the value (found by differentiating the Bragg equation) that guarantees separation of neighboring orders. For the first example, the phase-space acceptance is $(0.5 \times 0.5) \times (2.5 \times 2.5) \text{ mm}^2\text{-mr}^2$, so that the conditions are fulfilled and the entire beam can be accepted. The experiment is thus underfilled, so that the data rate depends on the source flux. Flux is therefore the figure of merit for the source. In the second example, the phase-space acceptance is much smaller, and both the spatial and angular acceptance of the experiment are overfilled, implying that some beam must be lost by closing down beam-defining slits (see Figure 4-9). In this case, the data rate depends on the source brightness. This branch line should thus be considered to have advanced performance for experiments on small crystals with large unit cells and a performance similar to that of existing synchrotron radiation sources for experiments on larger crystals with small unit cells.

Experimental Equipment for Crystallography. This branch line includes an imaging-plate detector system to acquire the diffraction patterns. A system to rapidly change and scan the plates will also be built, so that the diffraction data are available almost immediately for computer analysis. The design provides for a sample alignment stage with a capability for sample cooling. Diagnostic instrumentation are also furnished, to allow rapid focusing and calibration of the x-ray beam.

Experimental Equipment for Small-Angle Scattering. A small-angle scattering camera is included in the beamline design, essentially as a separate experimental station, which can be used as an alternative to the wide-angle crystallography station. It consists of two parts, a sample holder and a special detector operating at a large distance. The existing beamline and monochromator system would be used unchanged and would give a wavelength tunability that would support anomalous scattering. The resolution provided by a silicon monochromator is much better than required for most scattering experiments, and it would be appropriate to invoke the multilayer option for these experiments. The important parameter is the angular resolution, and this is achieved by the same slit system that is provided for crystallography.

The special features of the sample holder is an ability, achieved with various attachments, to provide an environment that is controlled with regard to temperature, pressure, chemical environment, electric field, and/or orientation to the beam. The detector we propose is a one-dimensional multiplexed detector that can accept data very rapidly. Suitable electronics and interfaces to the beamline computer system are provided. The state of the art of these general types of detector is changing rapidly, and it is likely that new capabilities will be available by the time we purchase a system. Two-dimensional or energy-resolving detectors may be readily available, in which case they can be used to enhance the performance of the beamline. The flight path to the detector is provided with suitable plumbing, so that various options of windows and atmospheres (air, helium, or vacuum) can be exercised.

The same system that we describe here can be adapted for wider-angle scattering, using the image plate or film system included in the crystallography station. A further option is to use the small-angle camera with the low-energy monochromator at the spectroscopy station for ultrahigh Q resolution studies.

Spectroscopy/Microprobe Branch Line

Branch Line Design. The layout of the spectroscopy/microprobe branch line is essentially identical to that of the crystallography branch line (Fig. 4-9), apart from a few special features entailed by the lower energies to be exploited in spectroscopic studies. The spectroscopy/microprobe branch line will be equipped with a monochromator capable of windowless operation and able to provide state-of-the-art performance at energies of 2.0 keV and below. The monochromator will be preceded by a mirror that will pre-collimate the beam for incidence on the first crystal. For microprobe studies, the monochromator will have a feature that allows the incoming beam to pass through untouched, so that the microprobe optics (which includes its own monochromator) can image the source at large demagnification.

Silicon is the most widely used synchrotron radiation monochromator crystal, and the technology is well-developed. It has a $2d$ spacing of $6.271 \text{ \AA}$ and is tunable through the energy range 2–20 keV. This energy range will allow EXAFS/XANES investigations involving elements with atomic numbers greater than 16 (sulfur). Extension to elements of lower atomic number, such as aluminum, will require a monochromator equipped with a crystal of longer d -spacing, such as beryl ($10\bar{1}0$): $2d = 15.954 \text{ \AA}$, energy range = 0.8–9.0 keV. However, beryl is more fragile than silicon in hostile thermal environments, and it will require protection from the high-power levels of the wiggler beam. Accordingly, the branch line design includes a pre-monochromator of low resolution at the entrance to the high-resolution monochromator, to remove most of the power. We anticipate using multilayer technology in the fabrication of this pre-monochromator, so as to provide the best possible resolution-flux tradeoff in the traditionally difficult region between 1 and 3 keV.

End Station Design. The experimental station for this branch line will be located in a special large hutch designed to facilitate the semiautomated interchange of experiments. The main experimental systems for the two primary types of experiments will be located on rigid tables, mounted in turn on rails, so that the systems can be interchanged without dismantling either. Experimental systems for both EXAFS/XANES and the x-ray microprobe are included in the design. Additional table space will also be available, so that experimental systems provided by users might be built off-line, then moved into the beam with equal convenience.

Experimental Equipment for Spectroscopy. For spectroscopy the branch line will be equipped with a multielement detector system for the study of fluorescent EXAFS of dilute biological samples. Other special detector systems designed for the 1- to 3-keV region are also included in the conceptual design, along with standard sample cells and mounts, computer, software, and electronics.

Microprobe Experimental Equipment. In an x-ray fluorescent microprobe, x-rays of a suitable energy are focused to a small spot (about $1 \mu\text{m}$ or less) on the specimen. These incident x-rays excite the K or L shells of the elements within the sample, causing them to emit characteristic fluorescent radiation, which is then detected by an energy-dispersive solid-state detector. Alternatively, an array of wavelength-dispersive detectors, such as single-crystal Bragg spectrometers, can be used. This kind of instrument allows the simultaneous assay of a number of elements in a microscopic volume of biological material, and by scanning, the distribution of a particular element or elements within the sample can be mapped. In a prototype instrument developed at LBL, the sensitivity for detection of elements with atomic numbers up to $Z = 30$ (zinc) was tens of femtograms.⁹ An increase of the energy to 15 keV will allow detection of most elements of biological interest, by either K or L fluorescence.

The optimum microprobe beamline uses white radiation. Multilayer optics, used in a Kirkpatrick-Baez crossed-mirror configuration, are used to demagnify the source of radiation within the wiggler, and thus to provide a small focal spot. A spot size of less than $10 \mu\text{m}$ square has already been achieved, and, with improved optics, we expect to achieve a spot size of $1 \mu\text{m}$ or less by the time this biology facility becomes operational. The multilayers also

provide a degree of spectral selectivity ($E/\Delta E \approx 10$) that is a better match to the requirements of a microprobe than is the high resolution obtainable with a silicon-crystal monochromator.

The components of the microprobe include a two-mirror focusing system, a sample-positioning stage with sub-micrometer resolution, a light microscope/TV setup for accurate positioning of sample features under the focal spot, and a Si(Li) detector to measure fluorescent x-rays.

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5.

CONVENTIONAL FACILITIES

THIS section briefly describes the conventional facilities included in the scope of the project to build a Life Sciences Center at the ALS. A schedule and a summary of the cost estimate are included in Section 6. More detailed information on the conceptual design of the conventional facilities can be found in Appendix A.

The Life Sciences Center will be located in existing Buildings 6 and 80, within the ALS complex, as shown in Figs. 5-1 and 5-2. This location provides users of the Center with direct access to the ALS experimental facilities, thus assuring optimum integration of associated research and development activities. This cost-effective use of existing space and available utilities also ensures negligible environmental impact. The Center will occupy a total of 13,300 gross square feet (GSF): 7300 GSF in the ALS building itself (Building 6) and 6000 GSF on the extended mezzanine level of the contiguous Building 80.

Two ALS beamlines dedicated to the Life Sciences Center will be located in the experimental area on the first floor of Building 6, directly below the mezzanine-level space occupied by the Center. Self-contained, modular wet laboratories of 1225 and 975 GSF will be provided as parts of the end stations on the two beamlines, as shown in Fig. 5-3.

Space on the mezzanine level of Building 6 will be provided to the Life Sciences Center as unfinished open space, with all required utilities and services stubbed into the area. Construction of the Center will include the cost of improvements necessary to finish and outfit the space for laboratories, cold rooms, offices, and ancillary storage areas, as shown in Fig. 5-4. One beamline will be reflected vertically from the ALS experimental area into the mezzanine-level laboratory area. Appropriate HVAC, power, lighting, partitions, integrated communications systems, and other services will be provided as required.

The existing mezzanine in Building 80 will be extended to accommodate the facilities of the Life Sciences Center. Modifications will be necessary to existing HVAC, power, lighting, partitions, and integrated communications systems. The modified space will contain a large biochemistry wet laboratory, a microscopy suite, a surgery room, a cell and tissue culture laboratory, and supporting facilities, including dishwashing equipment, cold room, and a storage/equipment room. The plan for the second floor of Building 80 is shown in Fig. 5-5. A new passenger/service elevator of 5000-lb capacity will be provided to allow handicapped

CONVENTIONAL FACILITIES

access to the second floor. The elevator will also serve the Life Sciences Center facilities on the mezzanine level of the ALS building.

A schedule of net areas, functions, and occupancy for the Center is provided in Table 5-1.

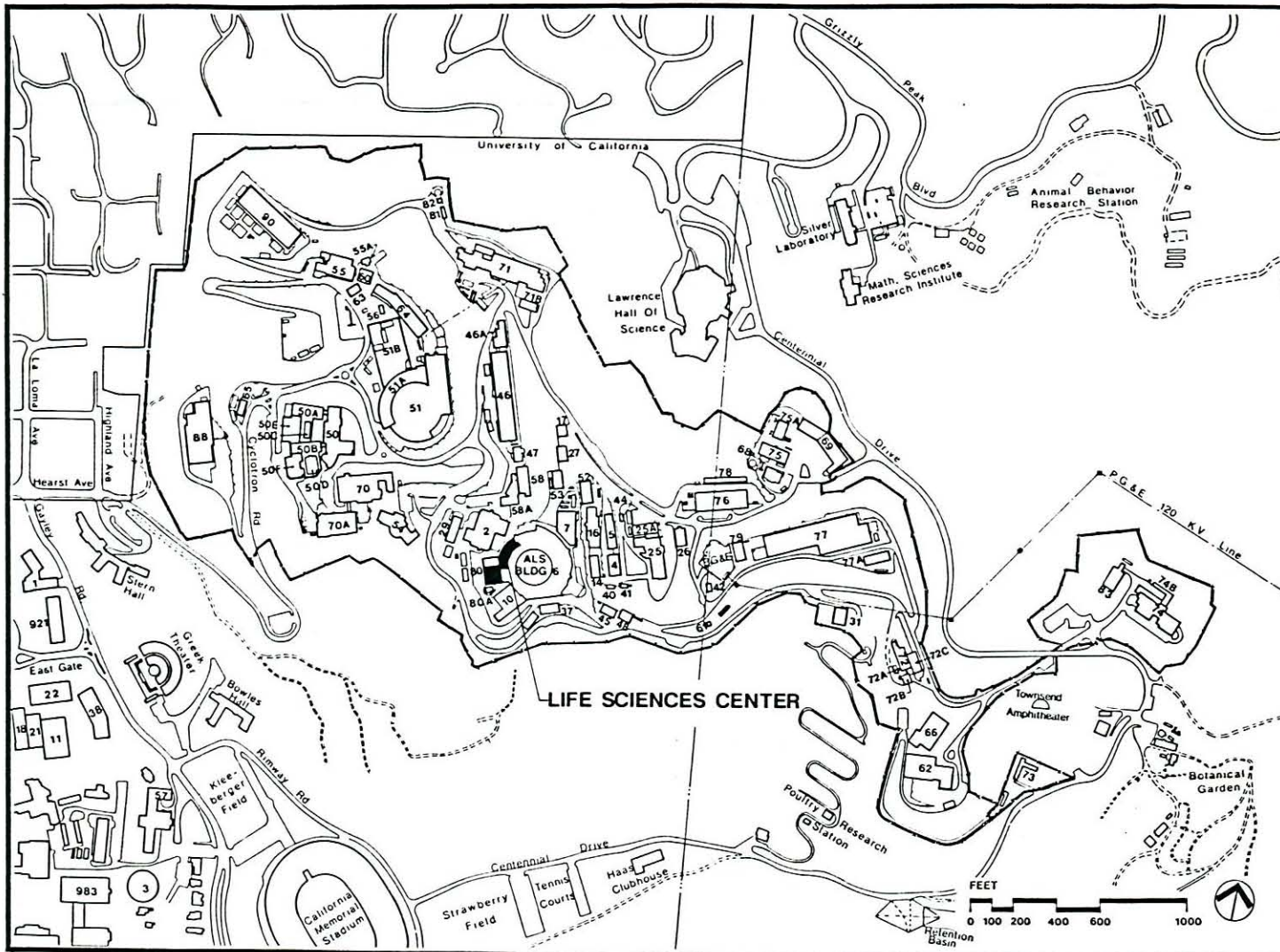


Figure 5-1. Site plan of the Lawrence Berkeley Laboratory, showing the proposed location of the ALS Life Sciences Center.

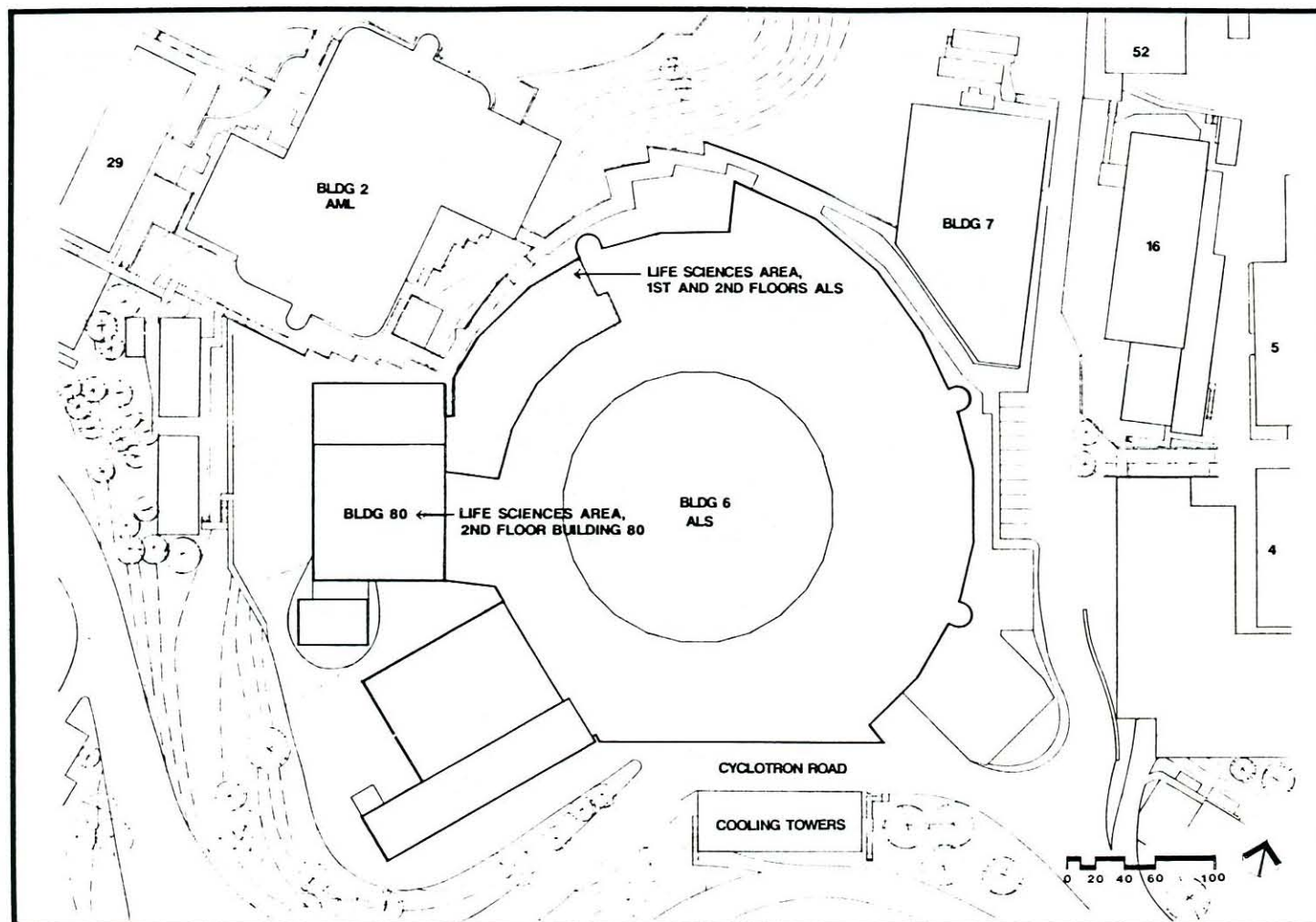


Figure 5-2. Plan view of the ALS complex, showing the locations of Buildings 6 and 80.

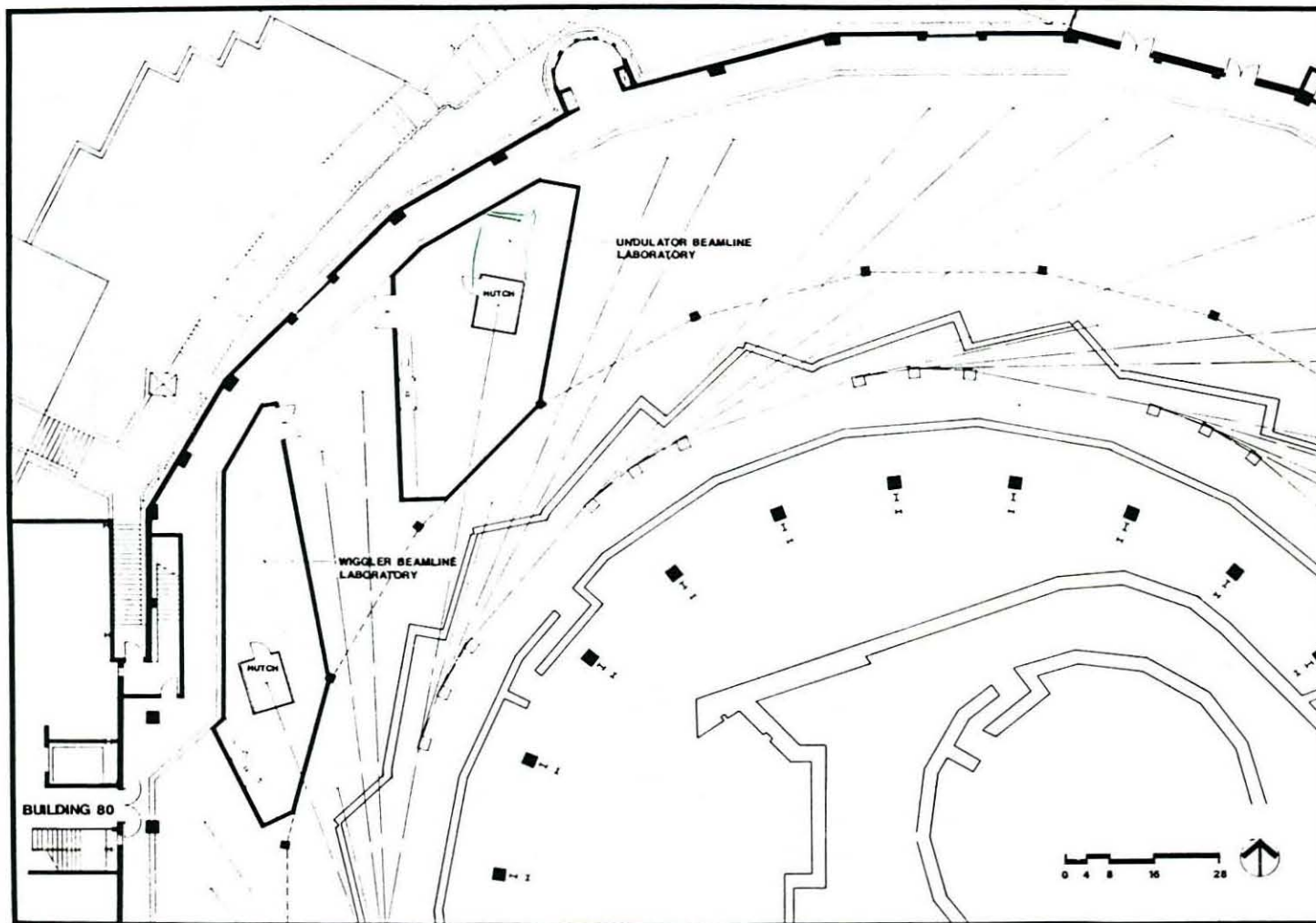


Figure 5-3. Plan view of a portion of the ALS experimental area in Building 6. Each of the beamline experimental stations is associated with a modular wet laboratory.

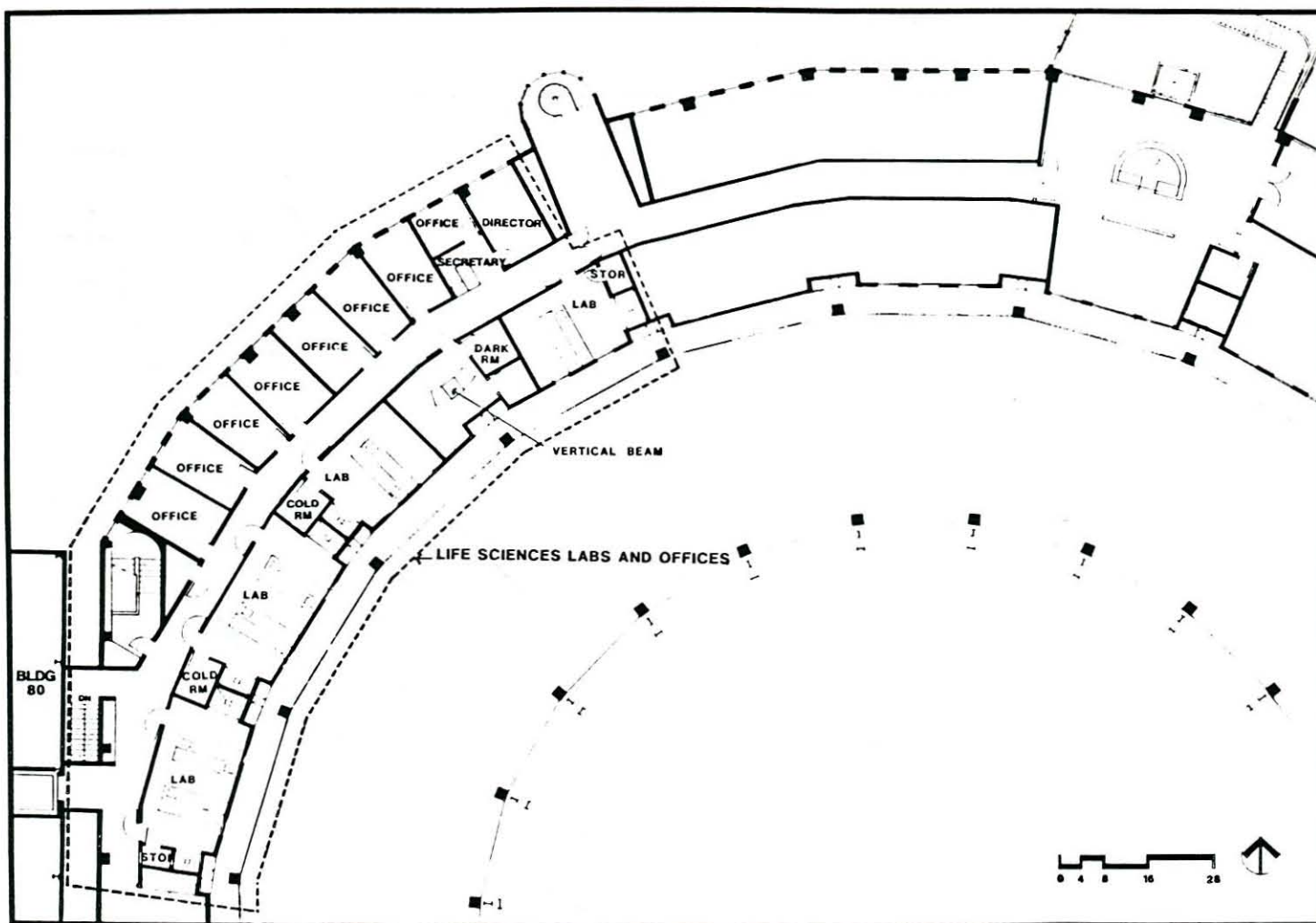


Figure 5-4. Plan view of a portion of the mezzanine of Building 6. The part within the dashed line is included in the scope of the Life Sciences Center project.

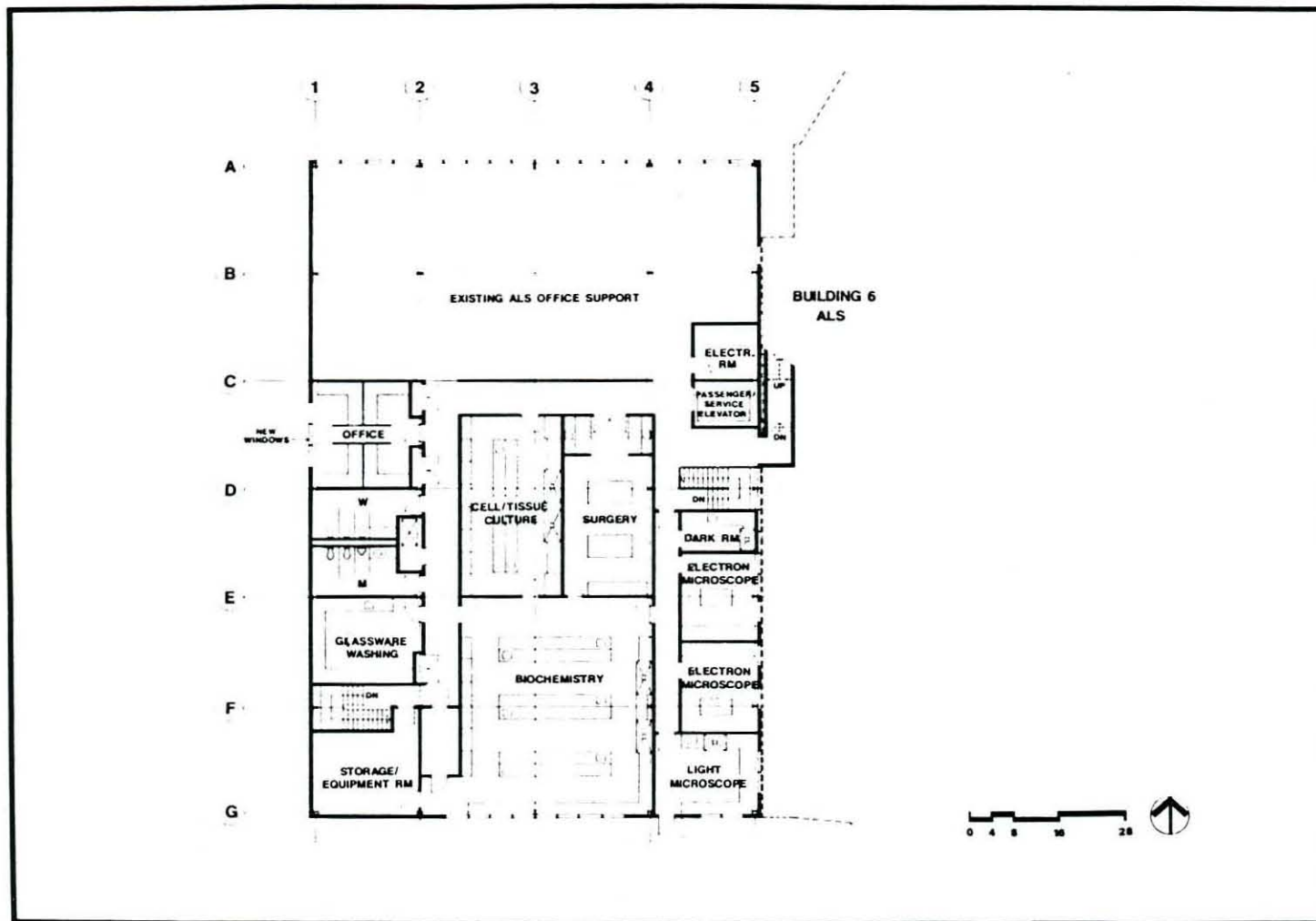


Figure 5-5. Plan view of the second floor of Building 80.

CONVENTIONAL FACILITIES

Table 5-1. A summary of net areas, functions, and occupancy of the conventional facilities in Buildings 6 and 80.

	Net area (sq. ft.)			
	Labs	Lab offices	Other	Occupants
BUILDING 80				
Biochemistry	1,430			
Microscopy suite	1,035			
Surgery	530			
Cell and tissue culture	595			
Laboratory offices		400		
Glassware, dishwashing			300	
Cold room			80	
Storage/equipment room			310	
Subtotal, Bldg 80	3,590	400	690	18
BUILDING 6				
Beamline laboratories	2,200			
Mezzanine				
Laboratories	1,990			
Laboratory offices		1,470		
Cold rooms			120	
Storage			195	
Subtotal, Bldg 6	4,190	1,470	315	14
Total, both buildings	7,780	1,870	1,005	32
Total net usable area: 10,655 sq. ft.				
Gross enclosed areas (sq.ft.)				
Building 80:	6,000			
Building 6:	7,300			
Total gross enclosed area: 13,300 sq. ft.				

6.

SCHEDULE AND COST ESTIMATE

THE scope of the ALS Life Sciences Center project includes two insertion devices, together with their associated beamlines and experimental end stations; 13,300 gross square feet of conventional facilities, including offices and support laboratories, fully equipped for light and electron microscopy, cell and tissue culture, and a range of preparative and analytical procedures; engineering, design, and inspection; project management and administration; and contingencies. The cost estimate does not include the cost of R&D or the preoperational costs associated with project commissioning.

SCHEDULE

The project schedule has been developed under the following assumptions:

- Construction funding will begin in FY 1993, and the project will be completed in three years.
- The project will be accompanied by an R&D program for insertion device and beamline studies, engineering models, and development of unique components.
- There will be preoperational funding available in each of the construction years to lay the organizational groundwork for productive use of the Center as a national user facility, as well as to ensure efficient commissioning of the insertion devices and beamlines.

With these assumptions, we have developed a project schedule with the following significant features:

- The schedules for conventional construction and for fabrication of the special research facilities are not strongly interdependent. It is only necessary that the beamline laboratories and the affected space in the mezzanine (Building 6) be near completion before installation of the undulator beamline and experimental stations.

SCHEDULE AND COST ESTIMATE

- Work on the more technologically advanced undulator facilities will begin one quarter earlier than work on the wiggler facilities.
- The time required for engineering, design, fabrication, and installation of the undulator facilities defines the length of the project; all aspects of conventional construction can be completed within about two-and-a-half years.

Figure 6-1 shows the project schedule in bar-chart form.

COST ESTIMATE

The work breakdown structure (WBS) is a complete compilation of all the work elements in this construction project. It defines the scope of the project in terms of the work to be done, and it provides a structure for collecting costs in an organized fashion. An abbreviated WBS for the Life Sciences Center is the basis for the cost estimate summary shown in Table 6-1. Level 1, the item with a single-digit code, represents the entire project. Level 2 gives the breakdown into the major categories of project management and administration (1.1), special research facilities (1.2), conventional facilities (1.3), and contingencies (1.4). Still lower levels of the WBS subdivide the project into ever-finer detail. The cost summary of Table 6-1 shows detail in some cases down to level 5. Note that engineering, design, and inspection (ED&I) is a separate level 3 item for both special research facilities and conventional facilities.

The full cost estimate was developed in terms of FY 1990 dollars, then escalated to obtain the total estimated cost (TEC) of the project. The estimate includes project management and administration, ED&I, and deliverables, as well as costs for providing environmental, safety, and health-related support. Contingencies were estimated separately at WBS level 2 for management, at levels 4 and 5 for special research facilities, and at levels 3 and 4 for conventional facilities.

Table 6-2 is a more abbreviated cost summary, in which escalation is shown as a separate item and the TEC is given in then-year dollars. To determine the escalation, and thus the TEC, a funding profile consistent with the schedule of Fig. 6-1 was developed, and escalation was applied to calculate the cost profile in then-year dollars. The escalation rates, given in Table 6-3, come from the latest available Department of Energy guidelines for construction projects. This table shows how the \$25.05 million cost estimate, in FY 1990 dollars, escalates to \$30.70 million in then-year dollars over the life of the project.

Table 6-4 is a project cost summary in terms of then-year dollars. Here, escalation has been included in each of the cost categories and thus does not appear explicitly as a separate line.

Finally, Table 6-5 is a cost schedule by major categories. This table breaks down the costs for each fiscal year into major cost categories, thus showing the cost profiles for major systems. An obligations schedule for the entire project is also given at the bottom of the table.

ELEMENT	FY93	FY94	FY95
1.1 Project Management			
1.2 Special Research Facilities			
Wiggler Facilities			
EDI			
Wiggler			
Wiggler Beamline(s)			
Installation			
Undulator Facilities			
EDI			
Undulator			
Undulator Beamline(s)			
Installation			
1.3 Conventional Facilities			
EDI			
Conventional Construction			
Special Facilities			
Standard Equipment			

Figure 6-1. Overall project schedule for the ALS Life Sciences Center.

SCHEDULE AND COST ESTIMATE

Table 6-1. Summary of the bottom-up cost estimate. All costs are shown in thousands of FY 1990 dollars.

1..	Life Sciences Center - TEC (all costs shown in FY1990 K\$)	25,050
1.1.	Project Management & Administration	1,422
1.2.	Special Research Facilities	13,352
1.2.1	Engineering, Design, & Inspection	3,739
1.2.1.1	EDI, Wiggler Facility	2,175
1.2.1.1.1	EDI, Wiggler	601
1.2.1.1.2	EDI, Wiggler Beamline Frontend	199
1.2.1.1.3	EDI, Diffraction Facility	614
1.2.1.1.4	EDI, Spectroscopy/Microprobe Facility	761
1.2.1.2	EDI, Undulator Facility	1,564
1.2.1.2.1	EDI, Undulator	466
1.2.1.2.2	EDI, Undulator Beamline Frontend	160
1.2.1.2.3	EDI, Soft X-ray Imaging Facility	938
1.2.2	Wiggler Facility	5,536
1.2.2.1	Wiggler	1,102
1.2.2.2	Wiggler Beamline Frontend	597
1.2.2.3	Diffraction Facility	1,767
1.2.2.3.1	Crystallography Branchline	1,172
1.2.2.3.2	Crystallography Station	454
1.2.2.3.3	Small Angle Scattering Station	142
1.2.2.4	Spectroscopy/Microprobe Facility	2,069
1.2.2.4.1	Spectroscopy/Microprobe Branchline	1,562
1.2.2.4.2	Spectroscopy Station	239
1.2.2.4.3	Microprobe Station	268
1.2.3	Undulator Facility	4,077
1.2.3.1	Undulator	1,047
1.2.3.2	Undulator Beamline Frontend	514
1.2.3.3	Soft X-ray Imaging Facility	2,517
1.2.3.3.1	Main Beamline	1,021
1.2.3.3.2	Main Scanning Microscope Station	604
1.2.3.3.3	R/D Scanning Microscope Station	494
1.2.3.3.4	Diffraction Imaging Station	399

Table 6-1 continued.

1.3.	Conventional Facilities	5,368
1.3.1	Engineering, Design, & Inspection	506
1.3.2	Construction	3,075
1.3.2.1	Improvements to Land	12
1.3.2.2	Building 80 Improvements	1,170
1.3.2.3	Building 6 Improvements	766
1.3.2.4	Site Utilities	84
1.3.2.5	Special Facilities	1,043
1.3.3	Standard Equipment	1,787
1.3.3.1	Biochemistry	1,067
1.3.3.2	Microscopy	109
1.3.3.3	Cell and Tissue Culture	139
1.3.3.4	Surgical Suite	80
1.3.3.5	General Support Equipment	392
1.4.	Contingency	4,909
1.4.1	Special Research Facilities & Mgt	3,830
1.4.2	Conventional Facilities	1,079

SCHEDULE AND COST ESTIMATE

Table 6-2. Project cost summary. All figures are given in thousands of FY 1990 dollars, except the total estimated cost, which is given in thousands of then-year dollars.

1	Life Sciences Center (TEC, then-year \$)		\$ 30,700
1.1	Project Management & Administration		1,422
1.2	Special Research Facilities		13,352
1.2.1	Engineering, Design & Inspection	3,739	
1.2.2	Wiggler Facility	5,536	
1.2.3	Undulator Facility	4,077	
1.3	Conventional Facilities		5,368
1.3.1	Engineering, Design & Inspection	506	
1.3.2	Construction	3,075	
1.3.3	Standard Equipment	1,787	
1.4	Contingency		4,909
1.4.1	Special Research Facilities and Mgmt.	3,830	
1.4.2	Conventional Facilities	1,079	
	Escalation		5,650

Table 6-3. Escalation schedule. Costs are given in thousands of dollars.

	FY90	FY91	FY92	FY93	FY94	FY95	Total
FY 1990 \$				3,515	9,490	12,045	25,050
Inflation (%)		3.6	4.5	5.1	5.6	5.7	
Escalation factor	1.000	1.036	1.083	1.138	1.202	1.270	
Then-year \$				4,000	11,400	15,300	30,700

Table 6-4. Project cost summary in thousands of then-year dollars.

1.	Life Sciences Center (TEC)		\$ 30,700
1.1	Project Management & Administration		1,711
1.2	Special Research Facilities		16,289
1.2.1	Engineering, Design & Inspection	4,520	
1.2.2	Wiggler Facility	6,773	
1.2.3	Undulator Facility	4,996	
1.3	Conventional Facilities		6,669
1.3.1	Engineering, Design & Inspection	596	
1.3.2	Construction	3,831	
1.3.3	Standard Equipment	2,243	
1.4	Contingency		6,031
1.4.1	Special Research Facilities and Mgmt.	4,691	
1.4.2	Conventional Facilities	1,340	

Table 6-5. Cost schedule by major categories, in thousands of then-year dollars. An obligation schedule for the complete project is given at the bottom of the table.

	FY93	FY94	FY95	Total
1.1 Project Mgmt. & Administration	540	570	602	1,711
1.2 Special Research Facilities				
Wiggler Facility	1,365	4,025	4,013	9,404
Undulator Facility	967	2,944	2,974	6,885
1.3 Conventional Facilities	331	1,927	4,411	6,669
1.4 Contingency	796	1,935	3,300	6,031
Costs, totals by year	4,000	11,400	15,300	30,700
Obligations, totals by year	5,100	15,300	10,300	30,700

ALS LIFE SCIENCES CENTER

SECTION 1

INTRODUCTION

Project Description

This section summarizes the conventional facilities included in the scope of the Advanced Light Source (ALS) Life Sciences Center project. More detailed information covering scope, cost and schedule is included in sections that follow.

The Life Sciences Center will be located in existing Buildings 6 and 80 within the ALS Complex as shown on the drawings in Section 5. This location provides the Center with direct access to the ALS experimental facilities for optimum integration of associated research and development activities. Drawing T-1 shows the location of the proposed Center on the Lawrence Berkeley Laboratory (LBL) site, Drawing A-1 shows its site location within the ALS Complex.

The Center will occupy a total of 13,300 gross square feet (GSF); 5,100 GSF on the mezzanine level and 2,200 GSF on the first level of new ALS Building 6, and 6,000 GSF on an extended mezzanine floor in Building 80 which is contiguous to ALS Building 6.

Two ALS beamlines dedicated to the Life Sciences Center will be located in the experimental area on the first floor of the ALS Building directly below mezzanine level space occupied by the Center. Two self-contained 1,225 GSF and 975 GSF modular wet laboratories will be provided at each beamline end station as shown on the Drawing A-3.

Space on the mezzanine level of ALS Building 6 will be provided to the Life Sciences Center as unfinished open space with all required utilities and services stubbed into the area. The Life Sciences Center Project will fund the cost of improvements necessary to finish and outfit the space for laboratories, cold rooms, offices and ancillary storage areas as shown on the Drawing A-4. One branch of one beamline will be reflected vertically into the mezzanine level laboratory area. Appropriate HVAC, power, lighting, partitions, integrated communication systems, and other facilities will be provided as required.

An existing mezzanine in Building 80 will be extended to accommodate the Life Sciences Center facilities. Utilities and services for conversion of the area to Life Sciences laboratory space, including required HVAC, power, lighting, partitions and integrated communication systems will be provided as required. The modified space will contain a large Biochemistry Wet Laboratory, Microscopy Suite, Surgery Room, Cell and Tissue Culture Laboratory and supporting facilities including glassware dishwashing equipment, cold room, and storage as shown on Drawing A-2.

A new elevator will be provided for Building 80 mezzanine handicapped access. This elevator will also serve the Life Sciences portion of the mezzanine located in the ALS Building.

A central feature of the Life Sciences Center will be well developed biological research laboratories. To effectively pursue a broadly-based research in the life sciences at the ALS, a variety of different laboratory facilities are required. As noted in the overview: "Biologists, chemists, and materials scientists are all in agreement that the forefront science promised by the availability of high-brightness XUV radiation at the ALS requires the ability to prepare, manipulate, and characterize samples in a laboratory near an ALS experimental station. It is no longer sufficient to prepare and characterize samples at a distant laboratory, pacify them in some way, transport them to the synchrotron light source for a measurement, then return the samples to the laboratory, and so on. In some cases, this approach never was satisfactory. This is particularly true in the life sciences, where it is often necessary to prepare, characterize, and measure delicate and/or transitory samples in a short time."

Towards fulfilling these needs, the Life Sciences Center will include a fully equipped and staffed group of special purpose laboratories, as well as general purpose wet laboratories. The special purpose laboratories include the following:

1. **A Biochemical (Wet) Laboratory** will provide the necessary equipment for cellular, subcellular, and molecular separation, for optical spectroscopy, and for a range of biochemical analyses. This laboratory will house centrifuges, ultracentrifuges, a variety of electrophoresis and chromatography equipment, high pressure liquid chromatography, liquid scintillation and gamma counters, various types of vis-uv spectrophotometers, and a variety of other equipment commonly needed for biochemical and related work. In the biochemical laboratory, the scientist will be able to prepare and evaluate material prior to study at an ALS experimental station, evaluate the same material after the beamline science has been completed, and carry out other aspects of a complete experimental study that may require not only the biochemical laboratory, but other resources of the Center.
2. **A Cell and Tissue Culture Laboratory** with the equipment necessary to culture cells and tissues will include incubators, laminar flow hoods, a large sterilizer, and other equipment commonly needed for cell and tissue culture work. Scientists wanting to study cells or tissues that are kept in culture will be able to do so under the best possible circumstances, being able to keep their material in the proper environment within a stone's throw from the ALS experimental station. Among other things, this will make it possible to follow a variety of short term changes in cultured cells; for example, changes within a cell cycle.
3. **A Surgical Station** for both small and large animal surgery will include a wash area, surgical tables and operating lights, animal handling area, and an operating microscope and associated video display. The surgical facility will make it possible to study cells and tissues derived from most animal sources. Often cells and tissues can only be studied satisfactorily over a period of minutes, up to perhaps an hour or two, after their removal from the animal. Without the capability of preparing the sample at the site, experiments on a broad range of biological material would

not be possible. Moreover, this facility will make it possible to carry out studies in which the animal is maintained under anesthesia, experimental changes introduced, and samples drawn periodically over time for study at an ALS experimental station.

4. **A Light and Electron Microscopy Laboratory** for the evaluation of samples prior and subsequent to study at an ALS experimental station, will include a variety of light microscopes, as well as scanning and transmission microscopes. This facility is important not only to characterize and evaluate samples microscopically, but to provide comparative microscopic modalities for the ALS X-ray imaging facility, as well as to provide ancillary microscopic capabilities necessary for X-ray image analysis when recording media such as X-ray resists are required.

In addition to these laboratories, there will be a laboratory for cleaning experimental glassware, preparing deionized and distilled water, as well as temperature controlled rooms. Visiting scientists will have access to LBL machine shops and microfabrication facilities. Office space available to the visiting scientist will be equipped with computer stations connected to a Life Sciences Center microcomputer, such as a microvax, which in turn will be connected to the LBL Vax cluster. In addition, image and data processing capabilities will be available for the reduction and analysis for data generated at ALS experimental stations.

Alternative Solutions Considered

By definition the ALS Life Sciences Center must be in close proximity and have direct access to the ALS for optimum integration of associated research and development.

The Light Source Building Addition to Building 6 is under construction with completion anticipated in FY 1991. Construction of a shell for a mezzanine above the ALS experimental area is included in the current ALS project to be made available for research users as unfinished open space. The location of the ALS beamlines to be dedicated to the Life Sciences Center determined the location of space for the Center on both the experimental floor and the mezzanine level of Building 6. One beamline will be reflected vertically from the first floor experimental area into the mezzanine laboratory area. No other solution was considered for the Life Sciences Center in Building 6.

The construction of a new mezzanine floor in Building 80 was selected for the additional laboratory space required for the Life Sciences Center because the Building 6 Addition, now under construction, will adjoin Building 80 providing optimum integration of Life Sciences activities in both buildings.

An alternative solution to the construction of a new mezzanine in Building 80 which was considered was the possibility of adding a third floor to this building. It was determined that the mezzanine scheme was more economical than the third floor scheme.

In summary, benefits of using the existing space in Buildings 6 and 80 within the ALS Center include:

- Close proximity and direct access to the Advanced Light Source for optimum integration of associated research and development.
- Cost effective use of existing buildings and available utilities and services.
- Negligible environmental impact.

Another alternative considered was the use of the first floor of existing Building 10 for development of the additional laboratory space for the Life Sciences Center. Upon further study, it became apparent that the development of Building 80 mezzanine was an equally cost effective solution providing for excellent functional intergration while preserving the Building 10 space for future development.

Basis of Conceptual Design for Conventional Facilities

The conceptual design of conventional facilities for the Life Sciences Center at the ALS was developed by the LBL Plant Engineering staff with the assistance of the following consultants.

- Gerson-Overstreet, Architects
- Keller and Gannon, Engineers-Architects

Cost estimates for conventional facilities were performed by LBL's Derek Daniels, Professional Estimator, based upon quantity take-off from drawings and specifications produced by LBL and the above consultants. Estimates for Scientific Equipment listed in Schedules I and II were taken from vendor quotations or catalog data with appropriate discounts. Estimates were initially prepared in December of 1988, reviewed and revised as necessary in December 1989.

Back-up data for both estimates, conventional facilities and scientific equipment, are included in Section 9.

Method of Performance

General

A Project Manager, assigned by LBL, will be responsible for coordinating efforts of the project team and for reporting status relative to scope, schedule and cost for the duration of the project.

Design

Design program and conceptual design will be prepared by the LBL Plant Engineering Department based upon programmatic criteria supplied by the LBL Life Sciences Directorate.

An Architect-Engineering firm with appropriate laboratory design experience will be selected for Title I and II design services and for technical oversight during

construction. Independent reviews of the structural design and the cost estimate will be arranged by LBL.

Construction

Construction will be accomplished by a lump-sum contract awarded after competitive bidding. Construction contract administration and inspection will be accomplished by LBL.

Procurement

Standard equipment and certain special facilities will be procured directly by LBL after competitive bidding. Otherwise procurement will be the responsibility of the construction contractor.

ALS LIFE SCIENCES CENTER

SECTION 2

PROJECT DESCRIPTION

General

This section describes project design criteria for conventional facilities construction within Building 80 and the Light Source Addition to Building 6 for the ALS Life Sciences Center.

Conventional Facilities Design Criteria

A. General

1. In compliance with the 1989 LBL Long Range Development Plan and approved by DOE.
2. Environmental Safety: In compliance with DOE, OSHA, State of California, and LBL standards.

B. Architectural

1. Occupancy: 32 researchers; 18 in 80, 14 in 6.
2. Occupancy Classification
 - a. ALS Building: B-2
 - b. Building 80: B-2
3. Fire Resistivity
 - a. ALS Building: One hour at external walls, two hours at adjacent buildings, non combustible construction.
 - b. Building 80: Two hours at adjacent ALS, no hour rating and sprinklered otherwise.
4. Schedule of Net Areas and Occupancy (chart follows).
5. Code Compliance: 1988 Uniform Building Code.
6. Handicapped Requirements: In compliance with ANSI standards.

SCHEDULE OF NET AREAS

	Net Area - Sq. Ft.			
	Labs	Lab Offices	Other	Occupants
<u>Building 80</u>				
Biochemistry	1,430			
Microscopy Suite	1,035			
Surgery	530			
Cell and Tissue Culture	595			
Laboratory Offices		400		
Glassware, Dishwashing			300	
Cold Room			80	
Storage/Equipment Room			310	
Subtotal Building 80:	3,590	400	690	18
<u>ALS BUILDING</u>				
<u>First Floor*</u>				
Laboratories-Beam Line:	2,200			
<u>Second Floor</u>				
Laboratories	1,990			
Laboratory Offices		1,470		
Cold Rooms			120	
Storage			195	
Subtotal Building 6:	4,190	1,470	315	14
Subtotal All Floors:	7,780	1,870	1,005	32
Total Net Usable Area:	10,655 sq. ft.			
<u>Gross Enclosed Areas</u>				
Building 80:	6,000 sq. ft.			
Building 6:	7,300 sq. ft.			
Total Gross Enclosed:	13,300 sq. ft.			

*Modular wall wet lab enclosures within existing building.

C. Civil/Structural

1. Conventional facilities are improvements within existing structures.
2. Existing structures comply with 1988 Uniform Building Code and LBL "Lateral Force (Wind and Earthquake) Design Criteria," August 15, 1989.

D. Mechanical (see Basis of Design in Section 9)

1. Inside Design Conditions: Laboratories and administrative offices provided with air conditioning:

Summer: 76°F db

Winter: 72°F db

2. Heating: Hot water supplied from the existing system.
3. Air Handling Systems: Tempered 100% outside air to static pressure controlled variable air volume (VAV) terminal boxes for laboratory spaces. Fan-powered variable air volume terminal units for office spaces. Fume hoods incorporating face velocity controllers and variable air volume laboratory exhaust systems.
4. Automatic Control System: Direct digital control (DDC) with connection to the existing facility automation system on site.
5. Mechanical Cooling: Chilled water supplied from the existing system.
6. Fire Protection: Modification of the existing fire sprinkler systems to suit the new layouts.
7. Utilities Provided:

Compressed air

Non-potable industrial hot and cold water

Low conductivity water (LCW)

Natural gas

Treated water (Building 80 only)

Laboratory acid waste separation and collection

Industrial water, low conductivity water, treated water, natural gas, and compressed air will be extended into these areas from the existing systems located in the facility.

E. Electrical

1. Power and Lighting:

Large process loads - 480V
Area lighting - 277V
Standby generator - 300KVA (existing)
Interior lighting - fluorescent
Lighting level - 50 footcandles

2. Communications:

Integrated Communications System (ICS)
Closed-circuit intercom
Local paging system

3. Energy Monitoring and Control System (existing)

4. Fire Alarm and Security:

Fire call boxes
Fire alarm bells
Card key door entry control

APPLICABLE CODES AND DESIGN REFERENCES

Applicable requirements and recommendations in the following codes and references will be followed in the design. These codes, as listed, should be included in the construction specifications. Codes and references will be the latest editions except where specifically noted otherwise:

A. Codes

1. 10 CFR Part 435 Energy Conservation Voluntary Energy Performance Standards (Mandatory for Federal Buildings)
2. 29 CFR Part 1926, Safety and Health Regulations for Construction, Department of Labor
3. 29 CFR Part 1910, Occupational Safety and Health Standards, Department of Labor
4. 40 CFR Parts 264 and 265, Environmental Protection Agency
5. National Fire Codes, National Fire Protection Association (NFPA)
6. National Electrical Safety Code, ANSI C2
7. National Electric Code, NFPA 70 (NEC-1990) latest edition
8. Safety Code for Building Construction, ANSI A10.2
9. California Code of Regulations, Title 8, General Industrial Safety Orders, Construction Safety Orders
10. California Code of Regulations, Title 19 - Public Safety, Chapter 1; Title 24, Part 2 - California Building Code; and Title 24, Part 3 - California Electrical Code
11. Uniform Building Code
12. Uniform Mechanical Code
13. Uniform Fire Code
14. Uniform Plumbing Code
15. Occupational Safety and Health Act
16. Federal, state, and local air-pollution and water-pollution control regulations
17. AMCA Fan Test Code

18. NBSIR 78-1305A Test Procedures
19. LBL Lateral Force (Wind and Earthquake) Design Criteria, August 15, 1989

B. Design References

1. Department of Energy General Design Criteria Manual, DOE 6430.1A
2. Rules and Procedures for the Design and Operation of Hazardous Research Equipment, LBL Pub 3001
3. LBL Long Range Site Development Plan
4. NBS Handbook 135, Life Cycle Cost Manual for the Federal Energy Management Program
5. The ASHRAE Handbook and Product Directory:
 - a. HVAC Systems and Applications Volume: 1987
 - b. Fundamentals Volume: 1989
 - c. Equipment Volume: 1988
 - d. Refrigeration Volume: 1986
6. Standards for Natural and Mechanical Ventilating, ASHRAE Standard 62-73 (ANSI B194.1-1977)
7. Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) Standards
8. Standards and Codes of the American Society of Mechanical Engineers (ASME)
9. American Water Works Association (AWWA) Standards
10. National Environmental Balancing Bureau (NEBB)
11. American Welding Society Handbook and Standards (AWS)
12. Standards of the American Society for Testing and Materials (ASTM)
13. American National Standard Specifications for Making Buildings and Facilities Accessible and Usable by the Physically Handicapped. ANSI A117.1-1961. REAF-1971
14. Recommended Outdoor Design Temperatures, Northern California Golden Gate Chapter, ASHRAE, November 1977

15. Industrial Ventilation Manual by the American Conference of Governmental Industrial Hygienists (ACGIH)
16. Earthquake-Resistive Construction for Mechanical Systems, Light Fixtures, and Ceilings, Ayres & Hayakawa, July 1972
17. Guidelines for Seismic Restraints of Mechanical Systems and Plumbing Piping Systems, SMACNA, October 13, 1982
18. Design Evaluation Guidelines for DOE Facilities Subject to Natural Phenomena, UCRL 15910, Draft May 1989
19. American National Standards Institute (ANSI) Standards
20. National Electrical Manufacturers' Association (NEMA) Standards
21. Institute of Electrical and Electronics Engineers (IEEE) Standards
22. Underwriters' Laboratories, Inc. (UL) Standards and "Building Materials, Fire Protection Equipment, and Fire Resistive Directories"
23. Factory Mutual Engineering Corp. (FM) Approval Guide and FM Loss Prevention Data
24. Insulated Cable Engineers' Association (ICEA) Standards
25. National Electrical Testing Association (NETA) Standards
26. Illuminating Engineering Society (IES) Lighting Handbook
27. Department of Energy Electrical Safety Criteria for Research and Development Activities, DOE/EV-0051/1, August 1979
28. Standard for Fire Protection of DOE Electronic Computer/Data Processing Systems, Jan 1984 (DOE/EP-0108, Formerly Wash 1245-1). See paragraph 101.4.
29. A Building Planning Guide for Communication Wiring, International Business Machines Corp., G320-8059-1, March 1984
30. American Institute of Steel Construction, Manual of Steel Construction, eighth edition
31. American Concrete Institute, ACI Manual of Concrete Practice, Parts 1 through 5, latest edition
32. ANSI/IES RP7 "Practice for Industrial Lighting"
33. LBL Building Automation System Design Criteria and Design Guidelines

QUALITY ASSURANCE PROCEDURES FOR DESIGN, CONSTRUCTION, FACILITY ACCEPTANCE AND PROJECT CLOSEOUT

Acceptable project completion requires that all safety, operational, and contract requirements be met. Quality assurance procedures during project development, design, and construction assure that all requirements will be met. The established system to review, inventory, and document facility construction, acceptance, and project closeout includes the following elements:

- Engineering
 - The LBL Plant Engineering Department assisted by selected consultants provides quality control and assurance measures during design and construction.
 - The Plant Engineering Department has a multidisciplinary Design Management Group and a Project Management Group. Each significant project is assigned to a Project Manager (PM) who is responsible for cost, scope and schedule for the life of the project. The PM is also responsible for construction quality control and is assigned a staff including a Project Engineer or Architect (PAE) and multidisciplinary support team, construction manager if necessary, contract administrator, and construction inspector. The Project Engineer/Architect is responsible for design and technical quality control. The work of each member of the PAE's support team is reviewed by the appropriate Section Leader from the Design Management Group. The PM develops a Project Management Plan which is reviewed and approved by Plant Management and DOE-SAN.
 - The design and cost estimates are reviewed and a plan check carried out at completion of schematics and during and after Title I and Title II designs are completed. An independent third party plan check is made of the seismic design and an independent cost estimate is made by a consulting cost estimator at completion of Title I and Title II to compare with the A/E's cost estimates. Plans and specifications are also reviewed by the LBL Fire Protection Engineer, the LBL Fire Marshal, the LBL Environment and Safety Hazards Control (E&SHC) Department and the LBL Construction and Maintenance Department at each stage of design development. When applicable, a consulting geotechnical firm provides appropriate geotechnical data and reviews the design at each stage of design and during construction.
 - An internal sign-off sheet covering all LBL design disciplines, PAE, PM, Fire Protection Engineer, Fire Marshal, E&SHC, Plant Management, third party reviews, and the Client is completed at the end of Title I, Title II and Title III. (A sample form follows.)
- Construction
 - Contract documents are reviewed by LBL's technical staff for compliance with DOE and LBL design criteria.
 - The Construction Inspector reviews and the Executive Architect/Engineer (if

any) and Plant Engineering's staff of engineers accept or reject all materials and workmanship in accordance with contract documents.

- A submittal control system for materials, shop drawings, test reports, and certifications assures that all necessary reviews for compliance with specifications, codes and other requirements such as provisions for the handicapped have been made.
- A Construction Inspector observes construction activities and reports to LBL's Project Architect/Engineer. Daily inspection reports are maintained in a file or a project logbook.
- A Contract Administrator reviews contract documentation for compliance with contract provisions.
- A Safety Engineer (from the Environment and Safety Hazards Control Department) and the Fire Marshal make periodic inspections of construction to assure compliance with codes and regulations.
- Specialty inspections in accordance with the Uniform Building Code are made of rebar, structural steel, welding, concrete, etc., to assure compliance with specifications. Appropriate testing laboratories are utilized for support as necessary. The A/E of record is required to inspect the construction during appropriate times and provides interpretation of the contract documents whenever necessary.
- Changes
 - Reviewed in accordance with UCLBL Construction Subcontracting Manual.
 - If project contingency funds are involved, the proposed change is reviewed to ensure that it is due to unforeseen, uncertain, and/or unpredictable conditions or incomplete design.
- Final Inspection and Acceptance

The following items are accomplished by the Inspector and the A/E working together:

- Preliminary inspection and list of incomplete work.
- Equipment testing and operational instruction of LBL personnel.
- Final inspection walk-through and punch list.
- Inspection of correctional and completion work (punch list work).
- Inventory of all operational manuals, instructions, guarantees.
- Internal sign-off sheet: Acknowledgment of completion and acceptance of all work under construction contract by the LBL project team and all interested

parties, i.e., Fire Marshal, E&SHC, etc.

- Changes
 - The LBL A/E team and Executive Architect/Engineer review any proposed change and provide justification and an independent cost estimate. The subcontractor's proposed cost is evaluated relative to LBL's cost estimate, and a contract price is negotiated. Availability of project funds is verified. If all project and contract requirements are met, a Change Order is executed.
- Project Closeout
 - After final acceptance of the facility, LBL audits all charges to assure that all costs are in proper accounts.
 - LBL sends the cost closing statement to DOE-SAN.
 - Project authorization closed by DOE-SAN.

PROJECT REVIEW AND APPROVAL
(Projects ≥ \$250K TEC)

Project Title		
Job Number	Subcontract No/PB No	Documents Prepared By:
☐ PRELIM (TITLE I)	☐ FINAL (TITLE II)	☐ CONSTR COMPLETE (TITLE III)
☐ SPECIFICATIONS	☐ DRAWINGS	
1. <u>DESIGN MANAGEMENT</u>		2. <u>PROJECT MANAGEMENT</u>
<u>Design Team</u>	<u>Section Leaders</u>	
Proj A/E _____		Project Manager _____
Arch _____	Arch _____	Inspector _____
Civil _____	Civil _____	
Mech _____	Mech _____	3. <u>PURCHASING</u>
Elec _____	Elec _____	Contract Admin _____
Energy _____	Energy _____	(Titles II & III only)
FP Engr _____		(Last to sign for Title III)
4. Environment & Safety Hazards Control Dept		9. Third Party Structural Review or Recommendation (Memo Attached)
Date _____		Date _____
5. Fire Marshal		10. Quality Assurance
Date _____		Date _____
6. Construction and Maintenance Dept		11. Value Engineering Coordinator
Date _____		Date _____
7. Handicap Barriers Review		12. Client/Division Head
Date _____		Date _____
8. Third Party Hazardous Material Review or Recommendation (Memo Attached)		13. Plant Engineering Dept
Date _____		Date _____

Sign-offs (Title I) indicate that project scope and criteria fully define Title II design requirements.

Sign-offs (Title II) indicate that construction documents comply with applicable sections of DOE General Design Criteria Manual 6430.1A and that they're complete and ready for construction.

Sign-offs (Title III) indicate that work was completed in accordance with construction documents.

SUPPLEMENTARY PROJECT DATA FACILITY UTILIZATION

Title and Location of Project ALS LIFE SCIENCES CENTER Project No. 93-LBL
Lawrence Berkeley Laboratory, Berkeley, California

Site-wide Requirements/Assets for CATEGORY 10, Office

Other Projects Affecting this Category: Safety and Support Services Fac, Human Genome Lab, Chemical Dynamics Research Lab, etc.

Unit of Measure: GSF (square feet (SF) or other unit)

UTILIZATION OF EXISTING ASSETS (FACILITIES) IN THIS CATEGORY:

A. Total requirement for this category:	<u>543,600</u>	in SF or other unit.
B. The <u>total</u> existing assets in this category:	<u>461,200</u>	SF,
C. Less amount of existing, substandard assets:	<u>375,500</u>	SF,
D. Equals amount of existing, <u>adequate</u> assets:	<u>85,700</u>	SF.
E. Existing <u>adequate</u> assets, less total requirement for this category equals excess/(deficiency) of <u>adequate</u> assets:	<u>(457,900)</u>	SF. (D minus A)

CHANGES TO ASSET LEVELS RESULTING FROM THIS PROJECT:

F. The additional assets created in this category by the project:	<u>1,900</u>	SF,
G. Less assets removed from this category by the project through excessing, demolition, etc.:	<u>0</u>	SF,
H. Equals net increase/(decrease) of assets in this category due to the project:	<u>1,900</u>	SF. (F minus G)

PROJECTED ASSET STATUS AFTER COMPLETION OF THIS PROJECT:

I. Existing excess or (deficiency) of <u>adequate</u> assets, plus this project's increases, equal excess or (deficiency) of <u>adequate</u> assets projected for this category:	<u>(456,000)</u>	SF. (E plus F)
J. <u>Total</u> existing assets, plus net increase/(decrease) of assets in this category due to the project, less total requirement, equal <u>total</u> excess/(deficiency) of assets projected for this category:	<u>(80,500)</u>	SF. (B plus H minus A)

SUPPLEMENTARY PROJECT DATA FACILITY UTILIZATION

Title and Location of Project ALS LIFE SCIENCES CENTER Project No. 93-LBL
Lawrence Berkeley Laboratory, Berkeley, California

Site-wide Requirements/Assets for CATEGORY 73 , Light Lab

Other Projects Affecting this Category: Human Genome, Chemical Dynamics Research Lab , etc.

Unit of Measure: GSF (square feet (SF) or other unit)

UTILIZATION OF EXISTING ASSETS (FACILITIES) IN THIS CATEGORY:

A. Total requirement for this category:	<u>328,500</u>	in SF or other unit.
B. The <u>total</u> existing assets in this category:	<u>283,000</u>	SF,
C. Less amount of existing, substandard assets:	<u>189,400</u>	SF,
D. Equals amount of existing, <u>adequate</u> assets:	<u>93,600</u>	SF.
E. Existing <u>adequate</u> assets, less total requirement for this category equals excess/(deficiency) of <u>adequate</u> assets:	<u>(234,900)</u>	SF. (D minus A)

CHANGES TO ASSET LEVELS RESULTING FROM THIS PROJECT:

F. The additional assets created in this category by the project:	<u>5,800</u>	SF,
G. Less assets removed from this category by the project through excessing, demolition, etc.:	<u>0</u>	SF,
H. Equals net increase/(decrease) of assets in this category due to the project:	<u>5,800</u>	SF. (F minus G)

PROJECTED ASSET STATUS AFTER COMPLETION OF THIS PROJECT:

I. Existing excess or (deficiency) of <u>adequate</u> assets, plus this project's increases, equal excess or (deficiency) of <u>adequate</u> assets projected for this category:	<u>(229,100)</u>	SF. (E plus F)
J. <u>Total</u> existing assets, plus net increase/(decrease) of assets in this category due to the project, less total requirement, equal <u>total</u> excess/(deficiency) of assets projected for this category:	<u>(39,700)</u>	SF. (B plus H minus A)

SUPPLEMENTARY PROJECT DATA FACILITY UTILIZATION

Title and Location of Project ALS LIFE SCIENCES CENTER Project No. 93-LBL
Lawrence Berkeley Laboratory, Berkeley, California

Site-wide Requirements/Assets for CATEGORY 40 , Storage

Other Projects Affecting this Category: Safety and Support, Chemical Dynamics Research Lab , etc.

Unit of Measure: GSF (square feet (SF) or other unit)

UTILIZATION OF EXISTING ASSETS (FACILITIES) IN THIS CATEGORY:

A. Total requirement for this category:	<u>99,000</u>	in SF or other unit.
B. The <u>total</u> existing assets in this category:	<u>93,000</u>	SF,
C. Less amount of existing, substandard assets:	<u>49,000</u>	SF,
D. Equals amount of existing, <u>adequate</u> assets:	<u>44,000</u>	SF.
E. Existing <u>adequate</u> assets, less total requirement for this category equals excess/(deficiency) of <u>adequate</u> assets:	<u>(55,000)</u>	SF. (D minus A)

CHANGES TO ASSET LEVELS RESULTING FROM THIS PROJECT:

F. The additional assets created in this category by the project:	<u>300</u>	SF,
G. Less assets removed from this category by the project through excessing, demolition, etc.:	<u>0</u>	SF,
H. Equals net increase/(decrease) of assets in this category due to the project:	<u>300</u>	SF. (F minus G)

PROJECTED ASSET STATUS AFTER COMPLETION OF THIS PROJECT:

I. Existing excess or (deficiency) of <u>adequate</u> assets, plus this project's increases, equal excess or (deficiency) of <u>adequate</u> assets projected for this category:	<u>(54,700)</u>	SF. (E plus F)
J. <u>Total</u> existing assets, plus net increase/(decrease) of assets in this category due to the project, less total requirement, equal <u>total</u> excess/(deficiency) of assets projected for this category:	<u>(5,700)</u>	SF. (B plus H minus A)

SUPPLEMENTARY PROJECT DATA FACILITY UTILIZATION

Title and Location of Project ALS LIFE SCIENCES CENTER Project No. 93-LBL
Lawrence Berkeley Laboratory, Berkeley, California

Site-wide Requirements/Assets for CATEGORY 80 , Miscellaneous

Other Projects Affecting this Category: Safety and Support, Human Genome, Chemical Dynamics Research Lab , etc.

Unit of Measure: GSF (square feet (SF) or other unit)

UTILIZATION OF EXISTING ASSETS (FACILITIES) IN THIS CATEGORY:

A. Total requirement for this category:	<u>195,600</u>	in SF or other unit.
B. The <u>total</u> existing assets in this category:	<u>168,300</u>	SF,
C. Less amount of existing, substandard assets:	<u>106,800</u>	SF,
D. Equals amount of existing, <u>adequate</u> assets:	<u>61,500</u>	SF.
E. Existing <u>adequate</u> assets, less total requirement for this category equals excess/(deficiency) of <u>adequate</u> assets:	<u>(134,100)</u>	SF. (D minus A)

CHANGES TO ASSET LEVELS RESULTING FROM THIS PROJECT:

F. The additional assets created in this category by the project:	<u>100</u>	SF,
G. Less assets removed from this category by the project through excessing, demolition, etc.:	<u>0</u>	SF,
H. Equals net increase/(decrease) of assets in this category due to the project:	<u>100</u>	SF. (F minus G)

PROJECTED ASSET STATUS AFTER COMPLETION OF THIS PROJECT:

I. Existing excess or (deficiency) of <u>adequate</u> assets, plus this project's increases, equal excess or (deficiency) of <u>adequate</u> assets projected for this category:	<u>(134,000)</u>	SF. (E plus F)
J. <u>Total</u> existing assets, plus net increase/(decrease) of assets in this category due to the project, less total requirement, equal <u>total</u> excess/(deficiency) of assets projected for this category:	<u>(27,200)</u>	SF. (B plus H minus A)

ALS LIFE SCIENCES CENTER

SECTION 3

BASIS OF COST ESTIMATE FOR CONVENTIONAL FACILITIES AND SCIENTIFIC EQUIPMENT

The cost estimate for the construction of conventional facilities improvements for the Life Sciences Center at Buildings 6 and 80 was prepared by LBL's Professional Estimator, Derek Daniels, based upon quantity take-offs from conceptual design drawings and specifications developed by the LBL Plant Engineering Department assisted by consulting engineers and architects. Architectural drawings were prepared by Gerson-Overstreet, Architects and the LBL Plant Engineering Department. Mechanical engineering design, drawings and energy use estimates were accomplished by Keller and Gannon, Engineers and Architects. Electrical, civil and structural designs were prepared by LBL.

Conventional Construction Cost Estimates are dated December 1989 and represent FY 1990 costs. Summary Cost Estimates in FY 1990 \$K and "Then Year" (TY) \$K for Conventional Facilities are included in this section (see Tables A and B). Detailed cost estimates are included in Section 9. Escalation is based upon "Anticipated Economic Escalation Rates for DOE Construction Projects" updated August 1990, namely 3.1% in FY 1990, 3.6% in FY 1991, 4.5% in FY 1992, 5.1% in FY 1993, 5.6% in FY 1994 and 5.7% in FY 1995. Escalated costs are shown in TY \$K in Table B.

Cost estimates for scientific equipment in Schedule I, Special Facilities, have been based upon vendor quotations received in October 1988, which are included in Section 9 in FY 1989 \$K. These prices have been escalated to FY 1990 \$K in Schedule I.

Cost estimates for scientific equipment in Schedule II, Standard Equipment, are based upon discounted catalog data which have been included in Section 9. A more detailed breakdown of the Standard Equipment summarized in Schedule II is also included in Section 9 in FY 1989 \$K. These prices have been escalated to FY 1990 \$K in Schedule II.

An ED&I Analysis for Conventional Facilities is included in Section 9. All Conventional Facilities estimates have been integrated into the Work Breakdown Structure for the entire project (see Appendix B).

ALS LIFE SCIENCES CENTER SUMMARY COST ESTIMATE AND FINANCIAL SCHEDULE CONVENTIONAL FACILITIES

(Amounts in Then-Year \$K)

Date A/E Work Initiated:	2nd Qtr. FY 1993
Date Physical Construction Starts:	2nd Qtr. FY 1994
Date Construction Ends:	4th Qtr. FY 1995

Financial Schedule, Conventional Facilities Only: (rounded)

<u>Fiscal Year</u>	<u>Obligations</u>	<u>Costs</u>
1993	\$ 489	\$ 389
1994	4,826	2,342
1995	2,694	5,278

Summary of Cost Estimate:

WBS

1.3.1	ED&I (@ about 15% of Construction)	\$ 596
1.3.2	CONSTRUCTION	3,832
	Land Improvements	15
	Building 80 Improvements	1,449
	Building 6 Improvements	955
	Site Utilities	101
	Special Facilities (Summary Schedule I)	1,312
1.3.3	STANDARD EQUIPMENT (Summary Schedule II)	<u>2,243</u>
	Subtotal	6,671
	Contingencies at approximately 20%	<u>1,338</u>
	Conventional Facilities - Total Estimated Cost	8,009

ALS LIFE SCIENCES CENTER																								
CONVENTIONAL FACILITIES																								
BA/BO SCHEDULE (TY\$K)																								
WBS NO.	WBS ELEMENT	TOTAL BUDGET	FY 1993								FY 1994				FY 1995									
			1		2		3		4		1		2		3		4							
			O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
1.0	Engineering, Design & Inspection	596																						
1.1	LBL Activities																							
1.1.1	Engineering	153				77/77							41/41										35/35	
1.1.2	Consultants	19												19/19										
1.1.3	Inspection	85												42/42						43/43				
1.2	A/E Activities																							
1.2.1	Title I	95				95/95																		
1.2.2	Title II	177							177/159						0/18									
1.2.3	Title III	67					67/0							0/33				0/34						
2.0	Construction	3832																						
2.1.1	Land Improvements	15											15/15											
2.1.2	Building 80 Improvements	1449												1449/647				0/802						
2.1.3	Building 6 Improvements	955												955/316				0/639						
2.1.4	Site Utilities	101											101/101											
2.1.5	Special Facilities-Schedule I	1312														220/220		1092/1092						
3.0	Standard Equipment	2243														1121/475		1122/1768						
	Contingency by Year	1338/1338	73 / 58								863 / 415				402 / 865									
	Total BA/BO by Year	8009/8009	489 / 389								4826 / 2342				2694 / 5278									
	Current Funding Plan	8009	489								4826				2694									

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ALS LIFE SCIENCES CENTER
OBLIGATIONS AND COSTS SCHEDULE DETAIL
(FY 1990 \$K)

TABLE A

DESCRIPTION	TOTAL	FY 1993		FY 1994		FY 1995	
		O	C	O	C	O	C
<u>LBL Activities</u>							
Engineering	129	68	68	34	34	27	27
Consultants	16			16	16		
Inspection	<u>69</u>	<u>—</u>	<u>—</u>	<u>35</u>	<u>35</u>	<u>34</u>	<u>34</u>
Subtotal	214	68	68	85	85	61	61
<u>Architect/Engineer</u>							
Title I	83	83	83				
Title II	155	155	140	0	15		
Title III	<u>54</u>	<u>54</u>	<u>0</u>	<u>0</u>	<u>27</u>	<u>0</u>	<u>27</u>
Subtotal	292	292	223	0	42	0	27
Total ED&I	506	360	291	85	127	61	88
<u>Construction</u>							
Land Improvements	12			12	12		
Building 80	1,170			1,170	540	0	630
Building 6	766			766	263	0	503
Site Utilities	<u>84</u>			<u>84</u>	<u>84</u>	<u>—</u>	<u>—</u>
Subtotal	2,032			2,032	899	0	1,133
<u>Special Facilities</u>	1,043			183	183	860	860
Total Construction and Special Facilities	3,075			2,215	1,082	860	1,993
<u>Standard Equipment</u>	<u>1,787</u>	<u>—</u>	<u>—</u>	<u>893</u>	<u>395</u>	<u>894</u>	<u>1,392</u>
Subtotal	5,368	360	291	3,193	1,604	1,815	3,473
Contingency (20%)	<u>1,079</u>	<u>63</u>	<u>50</u>	<u>698</u>	<u>347</u>	<u>318</u>	<u>682</u>
TOTAL	6,447	423	341	3,891	1,951	2,133	4,155

ALS LIFE SCIENCES CENTER
OBLIGATIONS AND COSTS SCHEDULE DETAIL
(TY \$K)

TABLE B

DESCRIPTION	TOTAL	1.138		1.202		1.27	
		FY 1993		FY 1994		FY 1995	
		O	C	O	C	O	C
<u>LBL Activities</u>							
Engineering	153	77	77	41	41	35	35
Consultants	19			19	19		
Inspection	<u>85</u>	<u>—</u>	<u>—</u>	<u>42</u>	<u>42</u>	<u>43</u>	<u>43</u>
Subtotal	257	77	77	102	102	78	78
<u>Architect/Engineer</u>							
Title I	95	95	95				
Title II	177	177	159	0	18		
Title III	<u>67</u>	<u>67</u>	<u>0</u>	<u>0</u>	<u>33</u>	<u>0</u>	<u>34</u>
Subtotal	339	339	254	0	51	0	34
Total ED&I	596	416	331	102	153	78	112
<u>Construction</u>							
Land Improvements	15			15	15		
Building 80	1,449			1,449	647	0	802
Building 6	955			955	316	0	639
Site Utilities	<u>101</u>			<u>101</u>	<u>101</u>	<u>—</u>	<u>—</u>
Subtotal	2,520			2,520	1,079	0	1,441
<u>Special Facilities</u>	1,312			220	220	1,092	1,092
Total Construction and Special Facilities	3,832			2,740	1,299	1,092	2,533
<u>Standard Equipment</u>	<u>2,243</u>	<u>—</u>	<u>—</u>	<u>1,121</u>	<u>475</u>	<u>1,122</u>	<u>1,768</u>
Subtotal	6,671	416	331	3,963	1,927	2,292	4,413
Contingency (20%)	<u>1,338</u>	<u>73</u>	<u>58</u>	<u>863</u>	<u>415</u>	<u>402</u>	<u>865</u>
TOTAL	8,009	489	389	4,826	2,342	2,694	5,278

ALS LIFE SCIENCES CENTER
CONVENTIONAL FACILITIES
CONTINGENCY ANALYSIS
(FY 1990 \$K)

	Estimated Cost (\$K)	Contingency (%)	Contingency (\$K)
<u>LBL Activities</u>			
Engineering	129	15	19
Consultants	16	25	4
Inspection	69	25	17
<u>Architect/Engineer</u>			
Title I	83	18	15
Title II	155	18	28
Title III	54	18	10
<u>Construction Contract</u>			
Improvements to Land	12	25	3
Building 80	1,170	25	293
Building 6	766	25	192
Site Utilities	84	25	21
Special Facilities	1,043	20	209
<u>Standard Equipment</u>	<u>1,787</u>	15	<u>268</u>
Subtotal	5,368		1,079
Contingency (20%)	<u>1,079</u>		
TOTAL	6,447		

ALS LIFE SCIENCES CENTER
CONVENTIONAL FACILITIES

SCHEDULE I
(FY 1990 \$K)

<u>Special Facilities</u>	<u>Cost</u>
Laboratory Furniture and Standard Fume Hoods	
Building 80	174*
Building 6	124*
Cold Rooms	
Building 80 (1)	18*
Building 6 (2)	37*
Laminar Flow Hoods (3)	<u>44*</u>
Subtotal	397*
Scientific Equipment **	
Digital Scanning Electron Microscope with Analytical Workstation	268
High Resolution Microscope with Cryoworkstation	206
Confocal Microscope	89
Image Analysis Package	<u>83</u>
Subtotal	646
TOTAL	1,043

* Included in Construction and A/E Subcontracts (\$397K)

** Based on vendor quotes in October 1988, increased by 3.1% to escalate to FY 1990 \$K.

ALS LIFE SCIENCES CENTER
CONVENTIONAL FACILITIES

SCHEDULE II
(FY 1990 \$K)

<u>Standard Equipment</u>		<u>Cost</u>
Biochemistry*		1,067
Centrifuges	251	
Spectrophotometers	189	
Balances	61	
Isotope Counters	42	
Separation Equipment	221	
General Laboratory Equipment	303	
Microscopy*		109
Darkroom Equipment	54	
General Laboratory Equipment	55	
Cell and Tissue Culture*		139
Incubators	47	
Sterilizer	38	
General Laboratory Equipment	54	
Surgical Suite*		80
Operating Tables, Surgical		
Instruments and Special Lighting	20	
Operating Microscope and		
Video Equipment	49	
General Laboratory Equipment	11	
General Support Equipment**		392
Computation Equipment	254	
Equipment for Glass Washing		
and Handling	88	
Office Furniture	37	
Office Equipment	13	
TOTAL		1,787

* Based on FY 1989 catalog prices which have been escalated 3.1% to FY 1990 \$K
 ** See Section 9 for Detail Listing

ALS LIFE SCIENCES CENTER

ESCALATION ANALYSIS

Based on DOE "Anticipated Economic Escalation Rates" (updated August 1990).

										<u>%</u>	
FY 1990	Dec 1989	-	Sep 1990	9	mo	@	3.1	=	2.3		
FY 1991	Oct 1990	-	Sep 1991	12	mo	@	3.6	=	3.6		
FY 1992	Oct 1991	-	Sep 1992	12	mo	@	4.5	=	4.5		
FY 1993	Oct 1992	-	Sep 1993	12	mo	@	5.1	=	5.1		
FY 1994	Oct 1993	-	Sep 1994	12	mo	@	5.6	=	5.6		
FY 1995	Oct 1994	-	Nov 1994	1	mo	@	5.7	=	<u>0.5</u>		
Total Compounded Escalation										24.0	

ALS LIFE SCIENCES CENTER CONSTRUCTION COST SUMMARY

	<u>Estimate December 1989</u>	<u>Escalate 24% to November 1994</u>
Land Improvements	12,190	15,120
Building 80 Improvements	1,169,610	1,450,320
Building 6 Improvements	765,820	949,620
Site Utilities	84,350	104,590
Special Facilities	<u>1,043,000</u>	<u>1,293,320</u>
Total Estimated Construction Cost	3,074,970	3,812,970*

*Compares to \$3,832,000 when escalated on a year by year basis as shown in Table B.

ALS LIFE SCIENCES CENTER

ESTIMATE SUMMARY DETAIL

Summary by D. Daniels, LBL; Prices by D. Daniels, R. Baker and K&G

Estimate Date
December 1989

Buildings

<u>DIV</u>		<u>Building 80</u>	<u>Building 6</u>
2	Demolition	98,640	---
3	Concrete	16,950	---
5	Metals	134,290	15,100
6	Wood and Plastics	6,080	17,850
7	Thermal/Moisture Protection	10,020	---
8	Doors/Windows	31,930	25,570
9	Finishes	145,960	227,520
10	Specialties	7,570	1,530
12	Furnishings	2,100	---
13	Special Construction (Beamline "Hutches")	---	20,000
14	Conveying Systems	90,000	---
15	Mechanical: Plumbing	83,000	77,000
	HVAC	184,000	152,000
	Fire Protection	5,200	5,500
16	Electrical	<u>143,110</u>	<u>85,750</u>
	Subtotal Direct Cost	958,850	627,820
	General Conditions/Mobilize	7%	67,120
	Estimating Contingency	<u>In Project Contingency</u>	<u>In Project Contingency</u>
		1,025,970	671,770
	Bond	2%	20,520
	Prime Contractor OH & Fee	12%	<u>123,120</u>
			<u>80,610</u>
	Total Estimated Construction Cost at November 1989	<u>1,169,610</u>	<u>765,820</u>
	Total Escalated Construction Cost to November 1994	24% <u>1,450,320</u>	<u>949,620</u> <u>2,399,940</u>

ALS LIFE SCIENCES CENTER
ESTIMATE SUMMARY DETAIL (Continued)

Improvements to Land

		<u>Building 80</u>	<u>Building 6</u>
Div 2 Sitework		10,000	---
General Conditions/Mobilize	7%	700	---
Estimating Contingency		<u>In Project Contingency</u>	<u>In Project Contingency</u>
		10,700	---
Bond	2%	210	---
Prime Contractor OH & Fee	12%	<u>1,280</u>	---
Total Estimated Construction Cost at November 1989		<u>12,190</u>	---
Total Estimated Construction Cost to November 1994	24%	<u>15,120</u>	<u>15,120</u>

Site Utilities

Div 15 Mechanical		10,000	5,000
Div 16 Electrical		<u>34,450</u>	<u>19,700</u>
Subtotal Direct Cost		44,450	24,700
General Conditions/Mobilize	7%	3,110	1,730
Estimating Contingency		<u>In Project Contingency</u>	<u>In Project Contingency</u>
		47,560	26,430
Bond	2%	950	530
Prime Contractor OH & Fee	12%	<u>5,710</u>	<u>3,170</u>
Total Estimated Construction Cost at November 1989		<u>54,220</u>	<u>30,130</u>
Total Escalated Construction Cost to November 1994	24%	<u>67,230</u>	<u>37,360</u> <u>104,590</u>

DEPARTMENTAL PRICE CHANGE INDEX

FY 1992 GUIDANCE

ANTICIPATED ECONOMIC ESCALATION RATESDOE CONSTRUCTION PROJECTS

FISCAL YEAR	ENERGY RESEARCH AND NUCLEAR		FOSSIL		CONSERVATION/SOLAR		DEFENSE PROGRAMS, EP & GENERAL CONSTRUCTION	
	INDEX	%CHANGE	INDEX	% CHANGE	INDEX	% CHANGE	INDEX	%CHANGE
1990	1.000	NA	1.000	NA	1.000	NA	1.000	NA
1991	1.036	3.6	1.033	3.3	1.034	3.4	1.039	3.9
1992	1.082	4.5	1.079	4.5	1.078	4.3	1.093	5.1
1993	1.138	5.1	1.135	5.2	1.130	4.9	1.152	5.5
1994	1.201	5.6	1.199	5.6	1.190	5.3	1.215	5.4
1995	1.269	5.7	1.268	5.7	1.255	5.5	1.280	5.3
1996	1.342	5.7	1.341	5.7	1.324	5.5	1.349	5.4

Based on the materials and labor data contained in the Energy Supply Planning Model and appropriate escalation rates forecasted by Data Resources, Incorporated, it would be expected that DOE projects conform to those rates shown above. DOE Order 5700.3C requires that any local rates different from those above be submitted to the ICE Staff for approval, prior to their use. Additional advice and assistance can be obtained from the Independent Cost Estimating Staff (FTS 896-9697).

DEPARTMENTAL PRICE CHANGE INDEX

AUGUST 1990 UPDATE

HISTORICAL AND ANTICIPATED ECONOMIC ESCALATION RATES FOR DOE CONSTRUCTION PROJECTS

<u>FISCAL</u> <u>YEAR</u>	<u>ENERGY RESEARCH</u> <u>AND NUCLEAR</u>	<u>FOSSIL</u>	<u>CONSERVATION/SOLAR</u>	<u>DEFENSE PROGRAM, EP,</u> <u>& GENERAL CONSTRUCTION</u>
Historical				
1974	10.4	11.3	10.7	9.6
1975	14.5	15.4	15.3	13.0
1976	6.1	6.0	5.7	5.2
1977	6.2	6.3	6.0	6.0
1978	7.1	7.3	6.8	7.3
1979	9.1	9.6	9.1	8.9
1980	9.7	10.1	10.7	9.7
1981	9.2	9.4	9.1	8.1
1982	6.8	6.6	6.5	6.3
1983	3.0	2.6	2.9	3.1
1984	2.4	2.2	2.4	2.4
1985	2.1	1.9	2.0	1.6
1986	1.3	0.6	1.3	1.1
1987	1.9	1.8	1.8	1.8
1988	4.0	4.7	4.0	3.2
1989	4.2	4.4	4.5	3.2
1990	3.1	2.4	3.0	2.9
Anticipated				
1991	3.6	3.3	3.4	3.9
1992	4.5	4.5	4.3	5.1
1993	5.1	5.2	4.9	5.4
1994	5.6	5.4	5.3	5.4
1995	5.7	5.7	5.5	5.3
1996	5.7	5.7	5.5	5.4
1997	5.8	5.8	5.5	5.6
1998	5.9	5.9	5.6	5.7
1999	6.0	6.1	5.7	5.9
2000	6.1	6.1	5.8	6.0

Based on the materials and labor data contained in the Energy Supply Planning Model and appropriate escalation rates forecasted by Data Resources, Incorporated (DRI), it would be expected that DOE projects would generally conform to, or be less than, those rates shown above. Should a submission reflect a higher escalation rate, the rate must be derived from a locally-produced forecasting model validated by the Independent Cost Estimating (ICE) Staff. Additional advice and assistance can be obtained from the ICE Staff (FTS 896-9697).

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SECTION 4

BASIS OF PROJECT TIME SCHEDULE FOR CONVENTIONAL FACILITIES

It is assumed that project funding will be made available for commitments by LBL on January 1, 1993.

Prior to that time LBL will evaluate environmental conditions and prepare recommendations for NEPA documentation for DOE consideration beginning in November 1991 for completion by July 1992. It is anticipated that an Environmental Assessment (EA) will be performed with a finding of no significant impact, however the EA will be scheduled with sufficient contingency to permit an Environmental Impact Statement to be prepared if necessary before construction is scheduled.

A/E selection will take place between January and July 1992 during which time the Design Program necessary for A/E fee negotiations and a Project Management Plan for DOE will also be completed.

A/E fee negotiations will take place between October 1 and December 1, 1992 contingent upon assurance by DOE-SAN that the project is in the FY 1993 budget.

Alternative solutions including environmental considerations have been carefully studied in the process of developing this conceptual design, thus it is anticipated that the existing solution will be specified for A/E design.

The Project Time Schedule that follows is based upon the foregoing assumptions.

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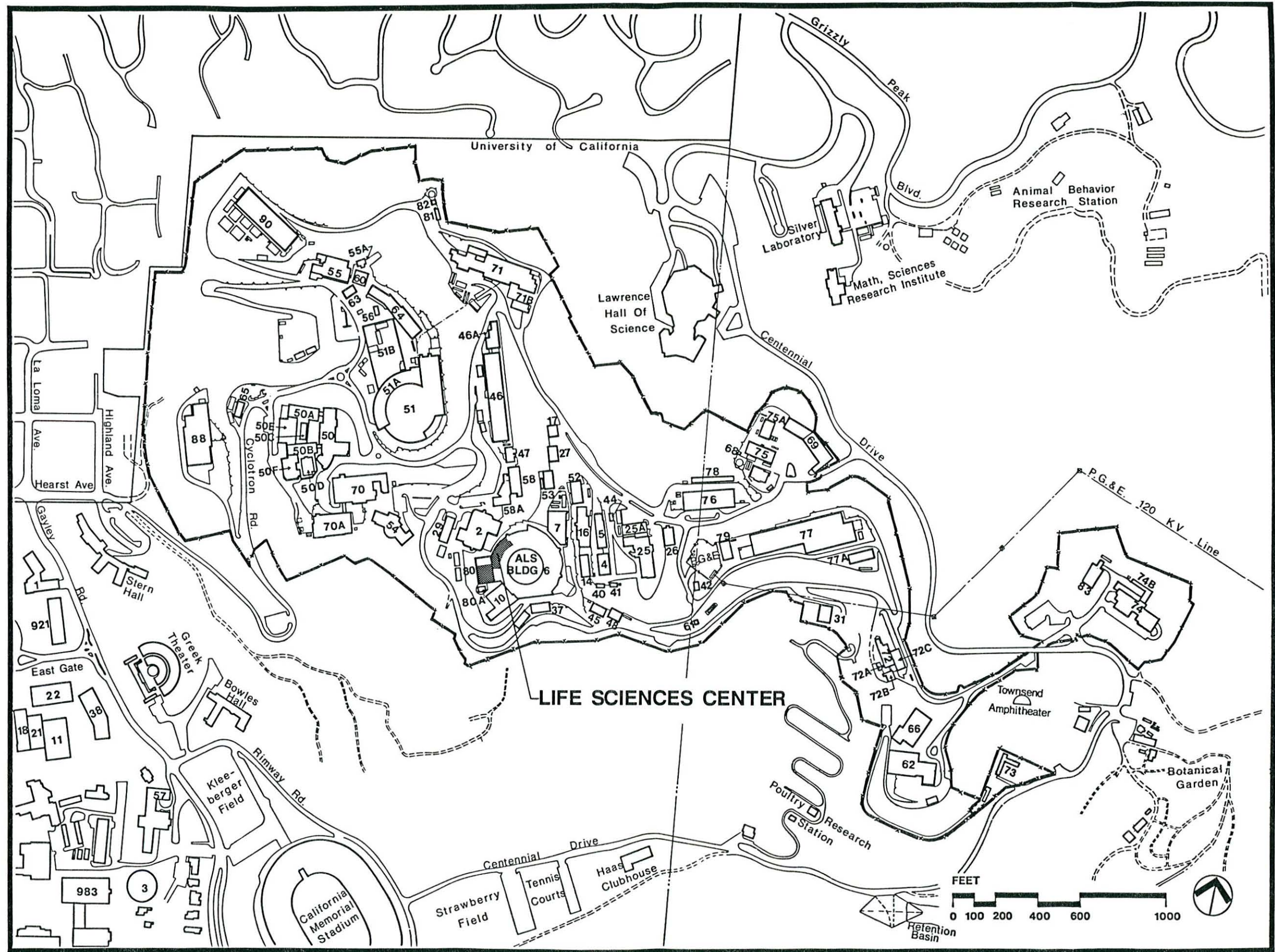
TIME SCHEDULE

	FY 1993				FY 1994				FY 1995			
	1	2	3	4	1	2	3	4	1	2	3	4
FY 1991 A/E SELECTION NEGOTIATION APPROVAL												
TITLE I DESIGN												
TITLE II DESIGN												
BID AND AWARD												
TITLE III CONSTRUCTION												
LAND IMPROVEMENTS												
UTILITIES												
BUILDING IMPROVEMENTS												
BUILDING SPECIAL FACILITIES												
STANDARD EQUIPMENT												
LIGHT SOURCE SPECIAL RESEARCH FACILITIES												

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SECTION 5 PROJECT DRAWINGS

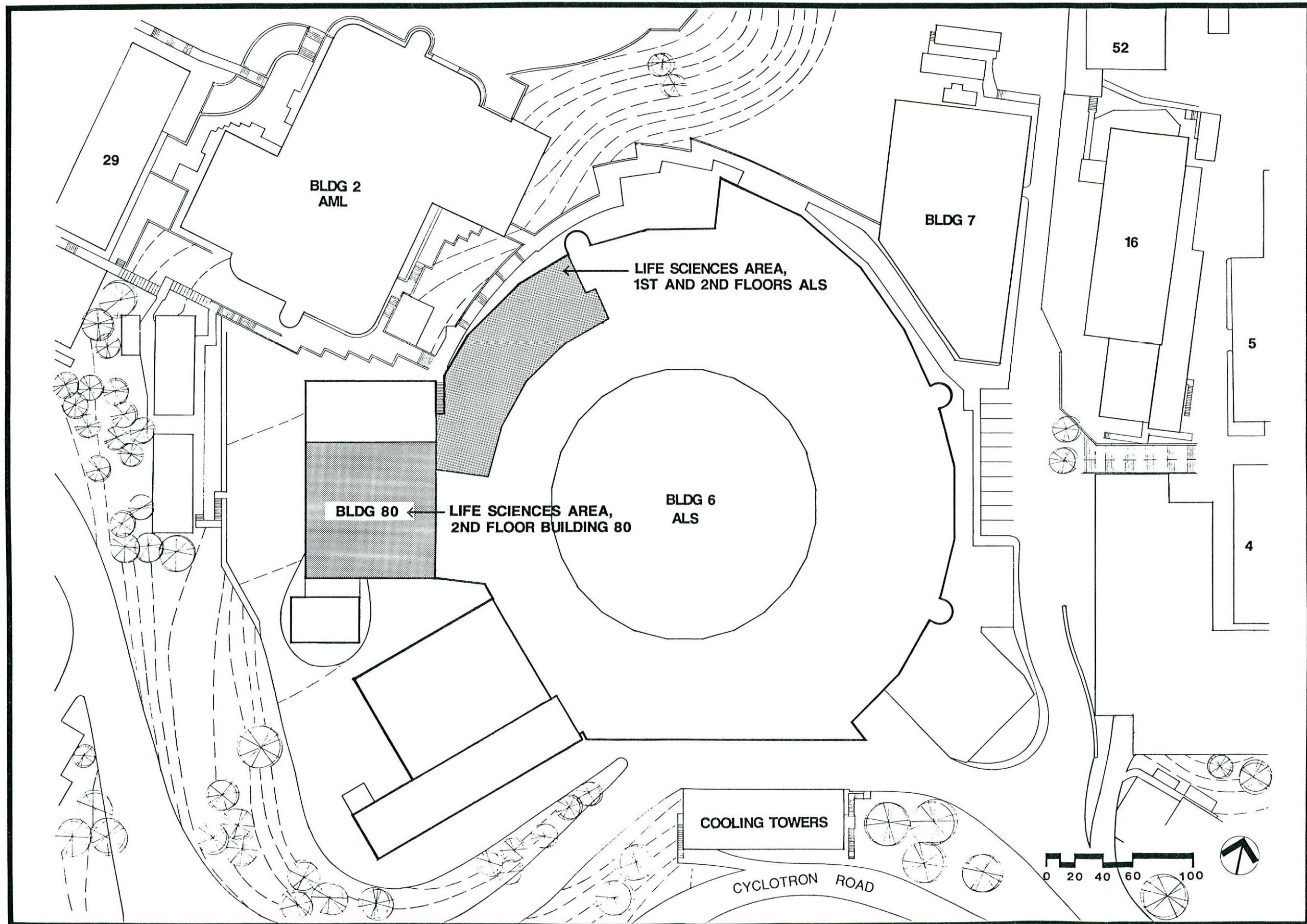
T-1	Location Plan
T-2	Site Plan
A-1	Building 80 - Second Floor Plan
A-2	ALS Building - Partial First Floor Plan
A-3	ALS Building - Partial Mezzanine Plan
S-1	Building 80 - First and Second Floor Framing Plan
M-1	Building 80 - Second Floor Mechanical Plan
M-2	Building 80 - Roof Mechanical Plan
M-3	ALS Building - Partial First Floor Mechanical Plan
M-4	ALS Building - Partial Mezzanine Mechanical Plan
M-5	Airflow Diagrams
M-6	Control Diagram
E-1	Building 6 - Single Line Diagram
E-2	Building 80 - Single Line Diagram



T-1

ALS LIFE SCIENCES CENTER
LOCATION PLAN

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UNIVERSITY OF CALIFORNIA



ALS LIFE SCIENCES CENTER

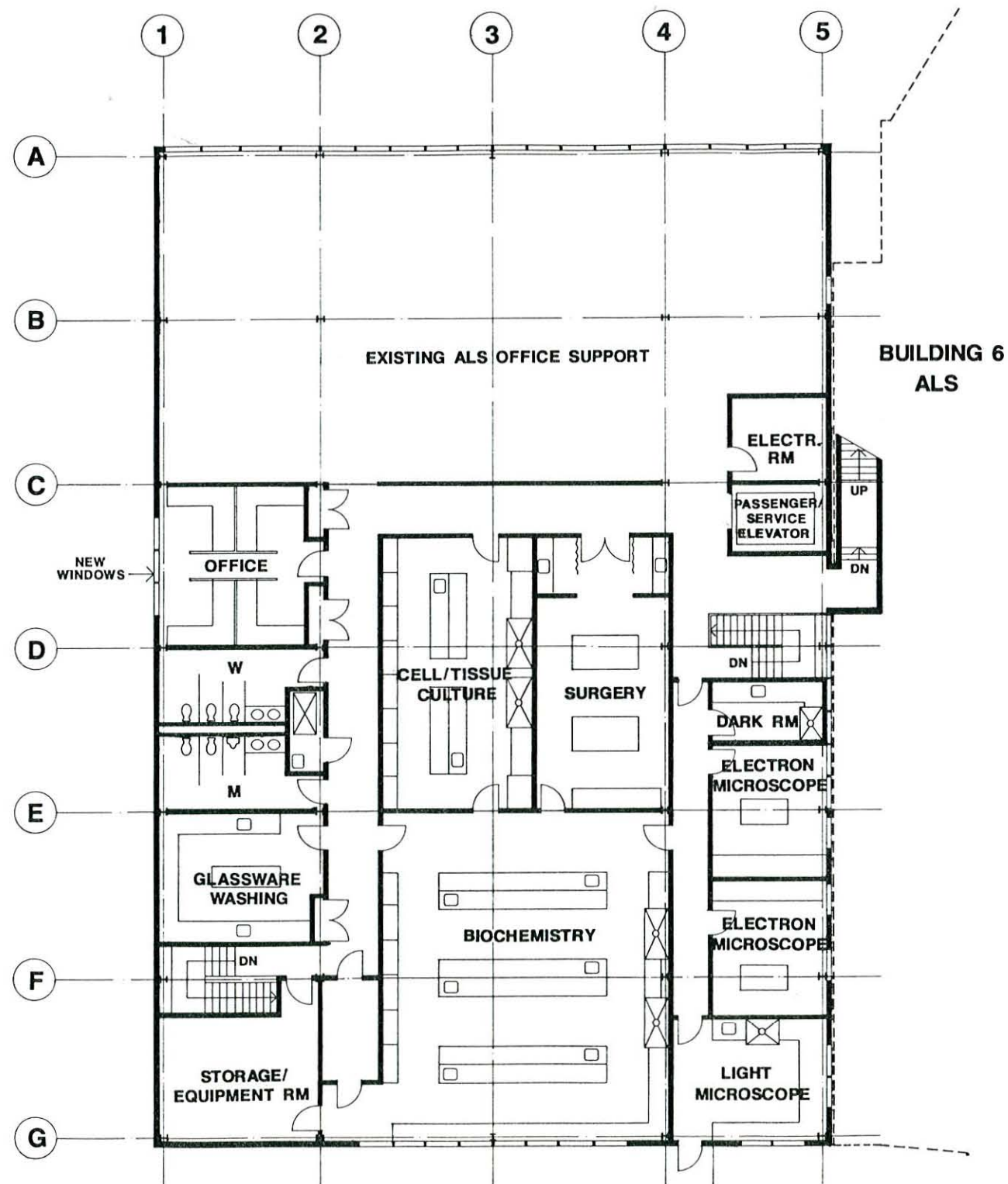
SITE PLAN

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA



T-2

1

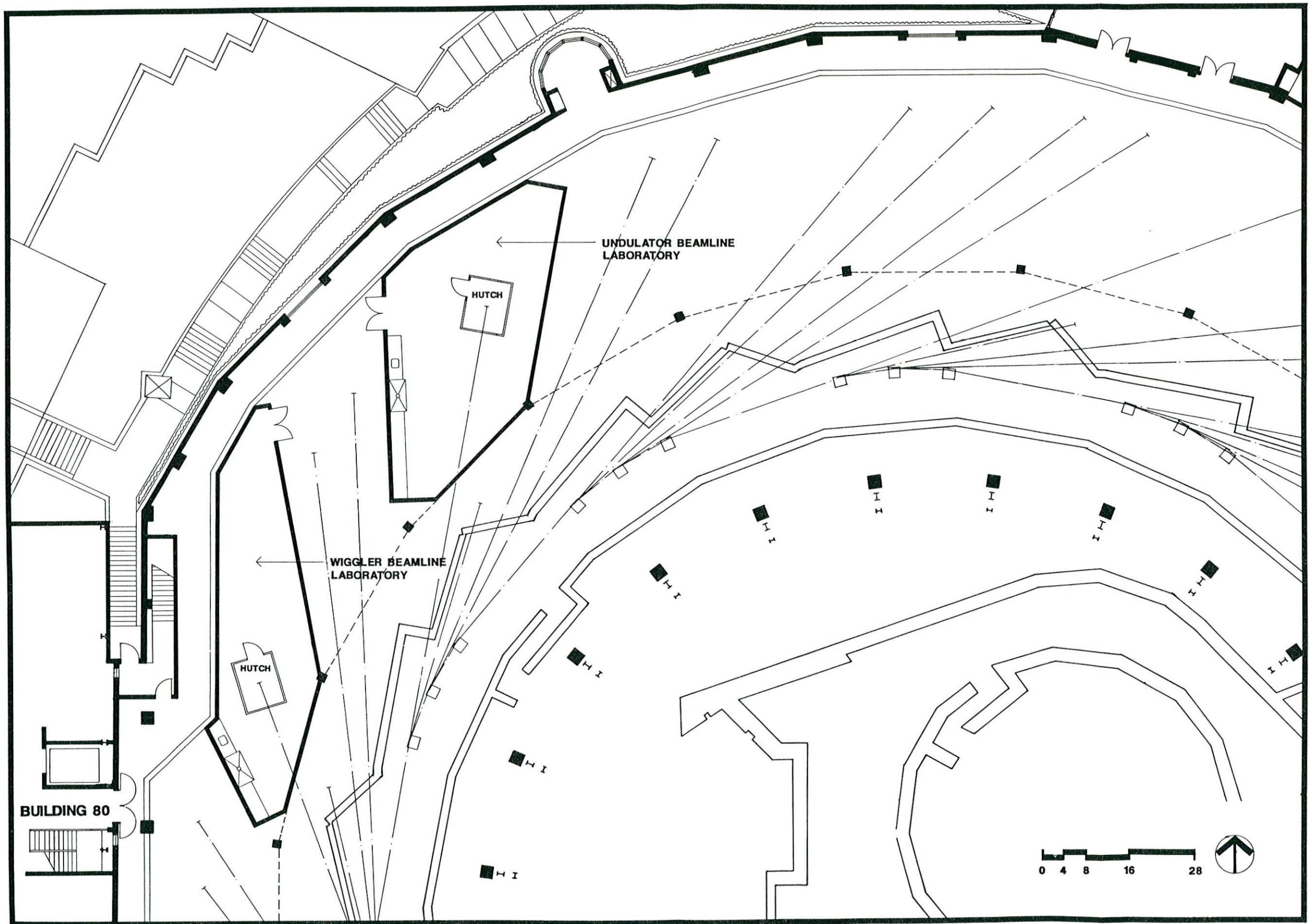


A-1

ALS LIFE SCIENCES CENTER
BUILDING 80 - SECOND FLOOR PLAN

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA





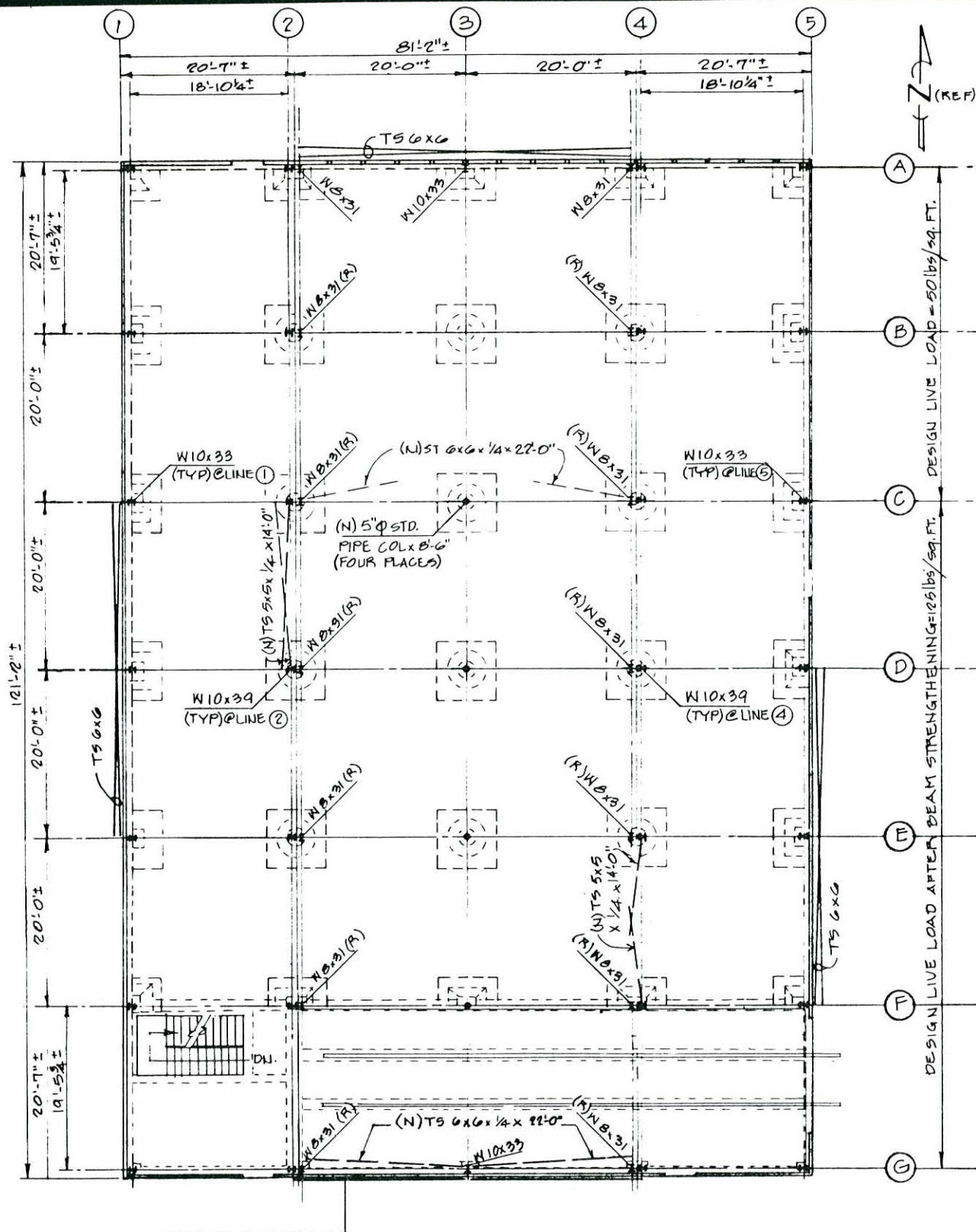
DETACHED POST REORDER NO. 13342

A-2

ALS LIFE SCIENCES CENTER
ALS BUILDING - PARTIAL FIRST FLOOR PLAN

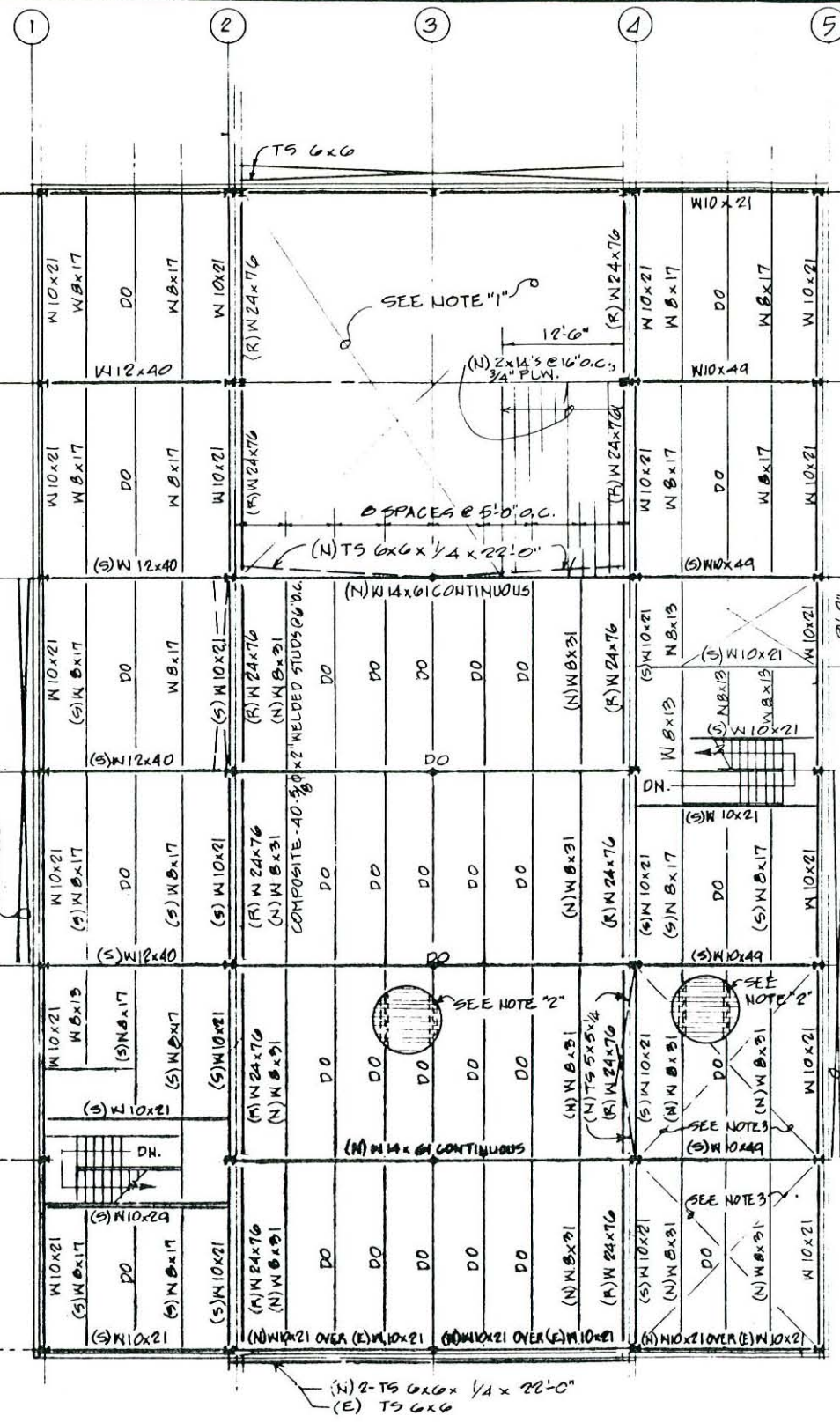
LAWRENCE BERKELEY LABORATORY
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ALL MEMBERS ARE EXISTING UNLESS NOTED (NEW)

MAIN FLOOR PLAN



ALL MEMBERS ARE EXISTING UNLESS NOTED (NEW)

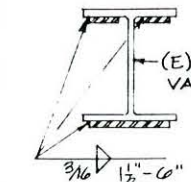
(N) SECOND FLOOR

(E) MEZZANINE PLAN

SCHEDULE OF STRENGTHENED BEAMS

(SEE SECT. X-X)

SECTION	TOP FES	BOTT. FES
(S)W 8x17	2-#2x2x16	1-#2x4x16
(S)W10x21	2-#2x2x16	1-#2x4x16
(S)W10x24	2-#2x2x16	1-#2x4x16
(S)W12x40	2-#2x2x16	1-#2x4x16



NOTE:
REMOVE & REINSTALL ARCHITECTURAL, ELECTRICAL & MECHANICAL WORK AS REQUIRED TO INSTALL (N) BEAM STRENGTHENING

NOTES

- (E) WOOD FRAMING COL A2, A4, C2 & C4 NOT SHOWN & TO REMAIN AS IS UNSTRENGTHENED
- (N) 1 1/2" - 3" DECKING 2" CONC. FILL REINF: 4x4/8x8 MESH AT AREA: C2, C4, G2, G4, & AREA: E4, E5, G4, G5.
- (R) EXISTING WOOD BRACINGS & PLYWOOD OVER AREA: E4, E5, G4 & G5

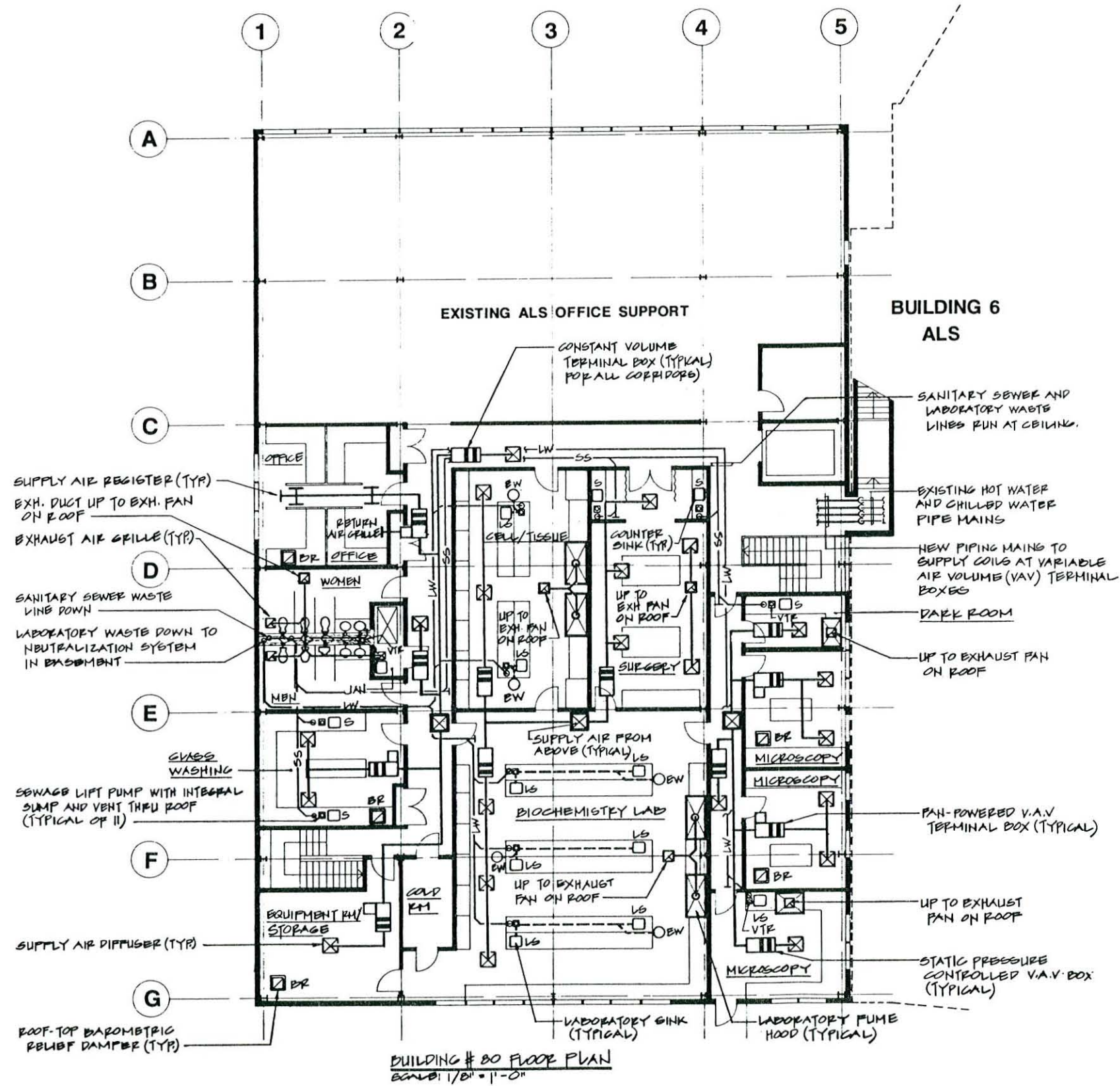
ABBREVIATIONS

- (E) EXISTING (ALL (E) UNLESS NOTED OTHERWISE)
(N) NEW
(R) REMOVE
(S) STRENGTHENED, SEE SCHEDULE ABOVE



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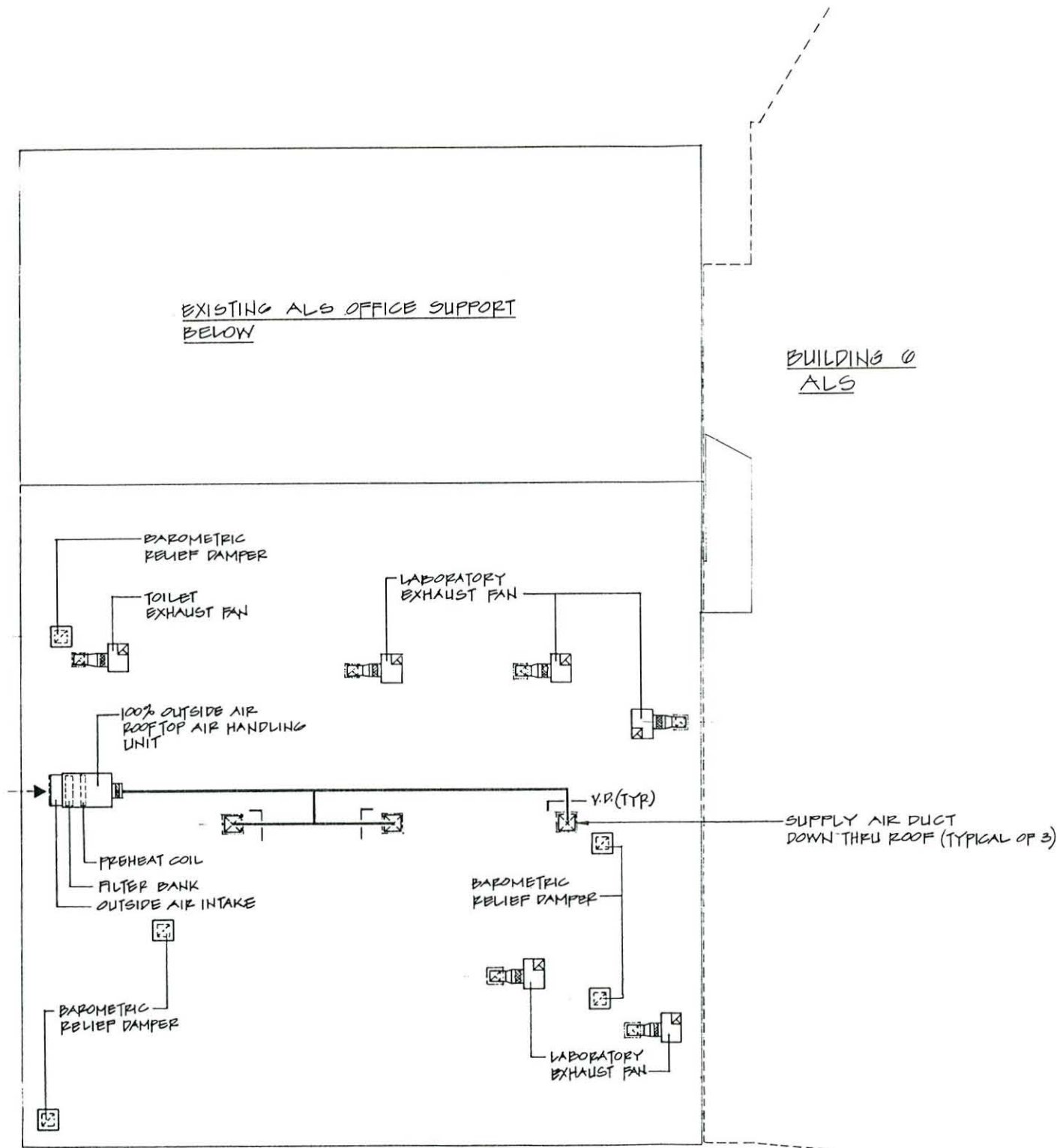




ALS LIFE SCIENCES CENTER
BUILDING 80 -
SECOND FLOOR MECHANICAL PLAN

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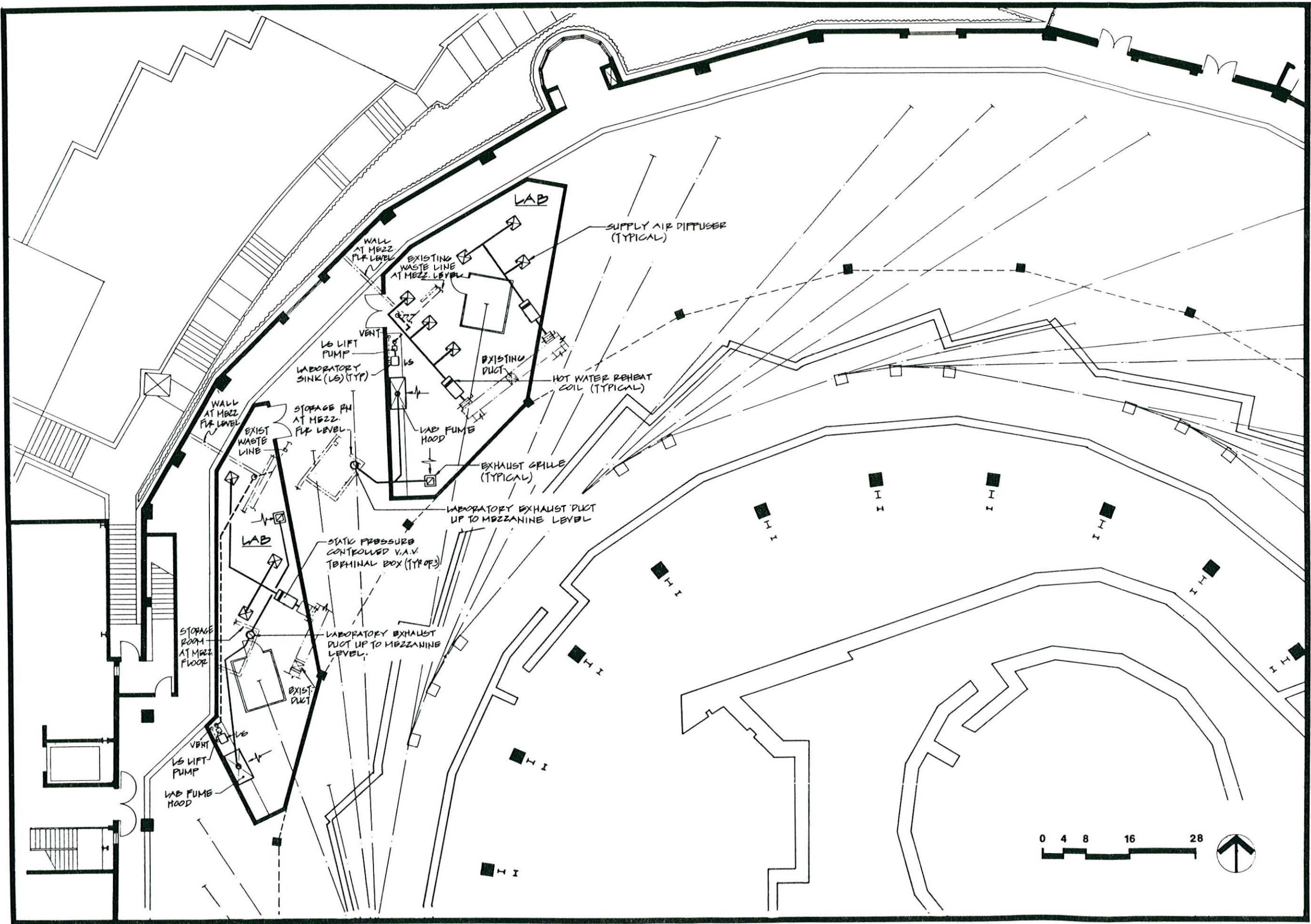
BUILDING #80 ROOF PLAN
SCALE: 1/8" = 1'-0"

M -2

ALS LIFE SCIENCES CENTER
BUILDING 80
ROOF MECHANICAL PLAN

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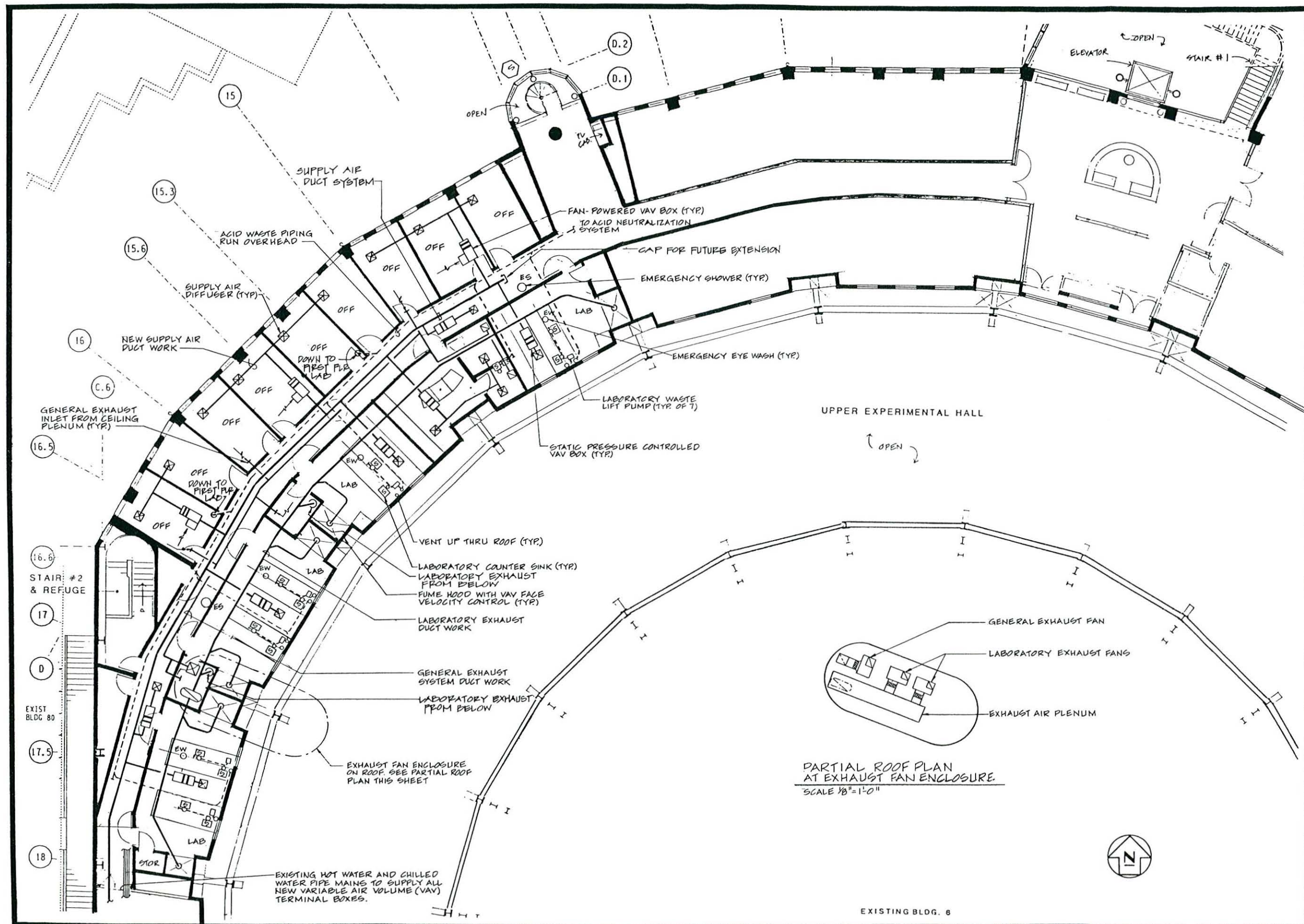


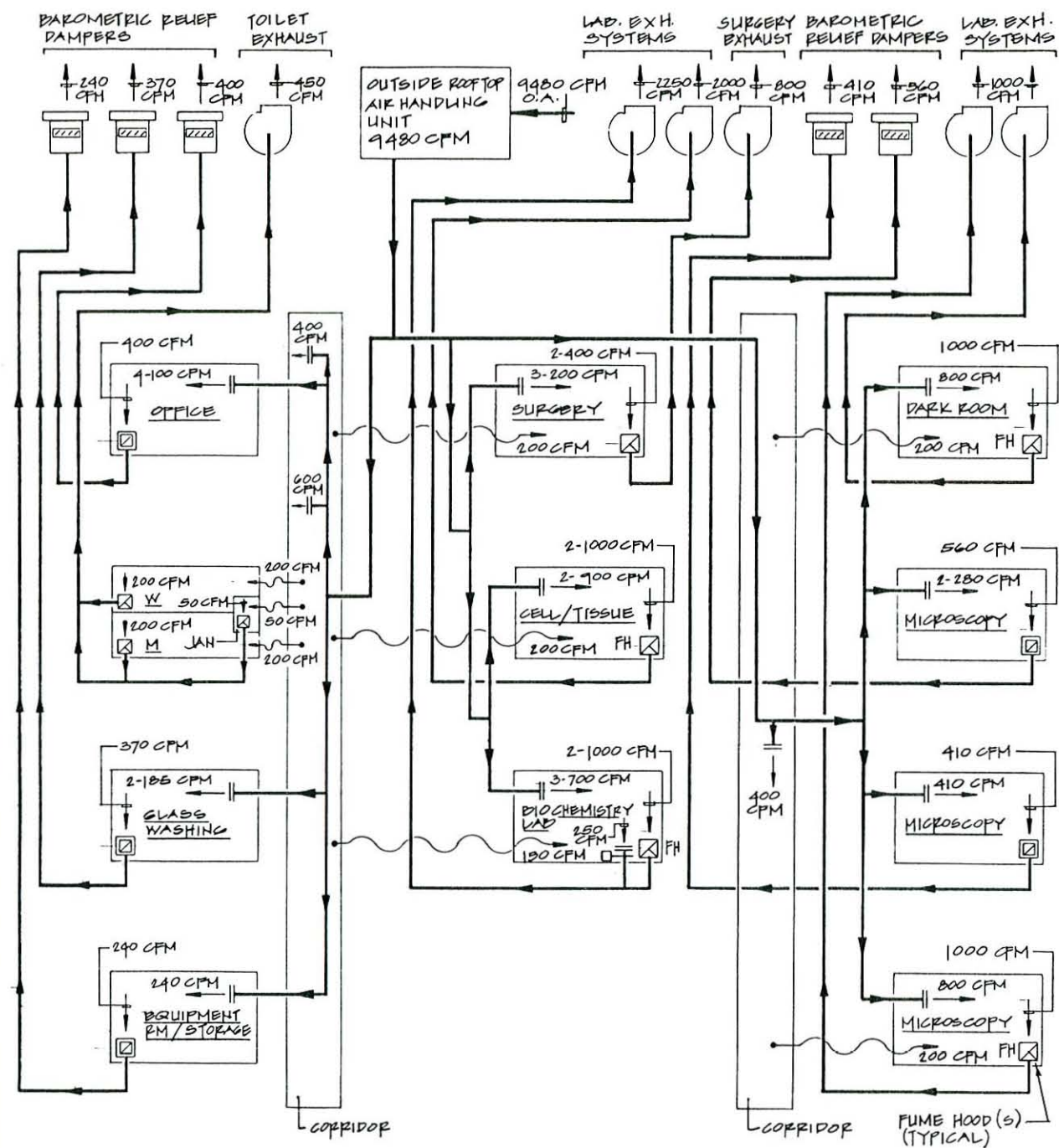
M -3

ALS LIFE SCIENCES CENTER
ALS BUILDING -
PARTIAL FIRST FLOOR MECHANICAL PLAN

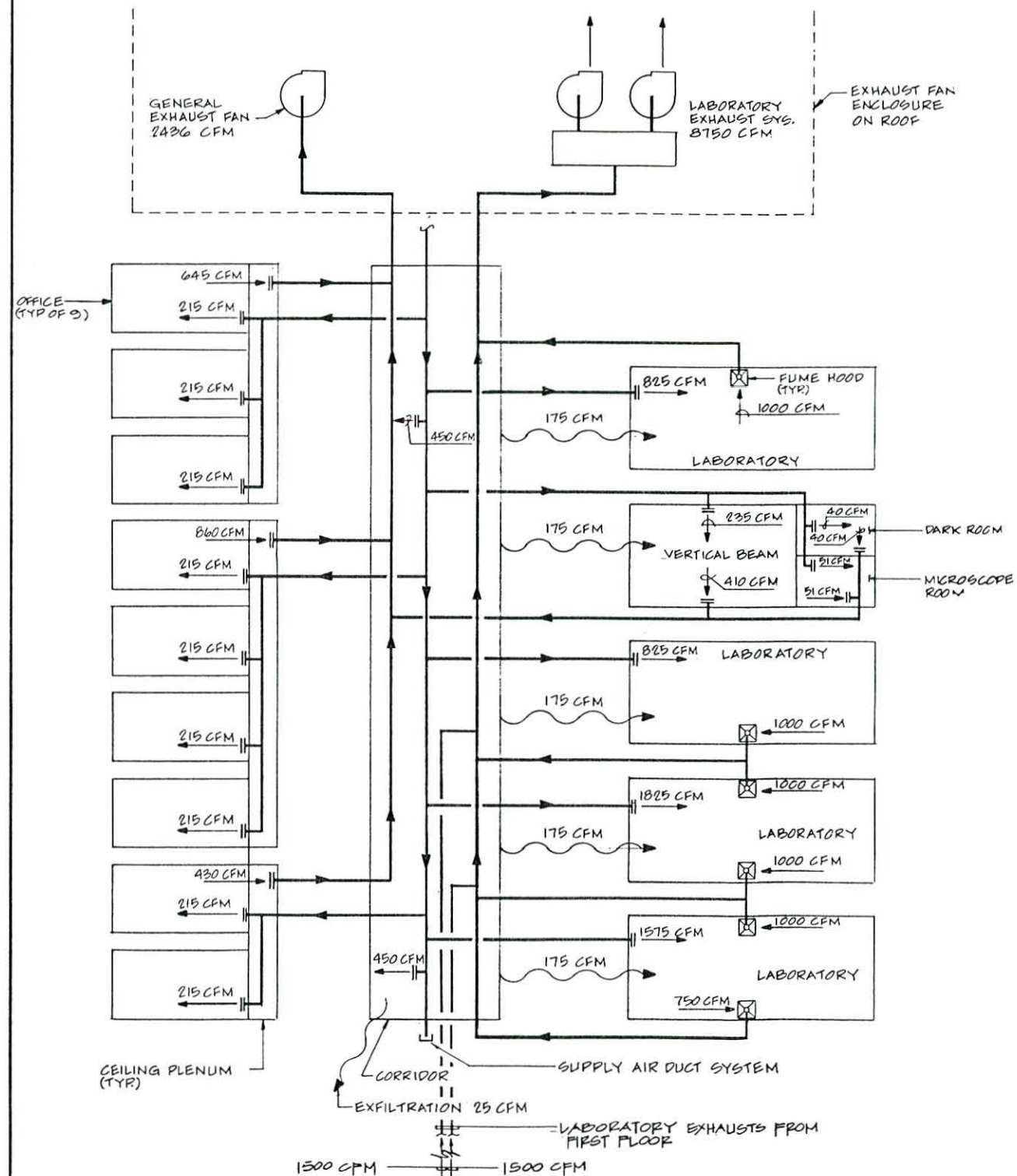
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LIFE SCIENCES CENTER BLDG #80 - AIR FLOW DIAGRAM
NO SCALE



LIFE SCIENCES CENTER BLDG #6 - AIR FLOW DIAGRAM
NO SCALE

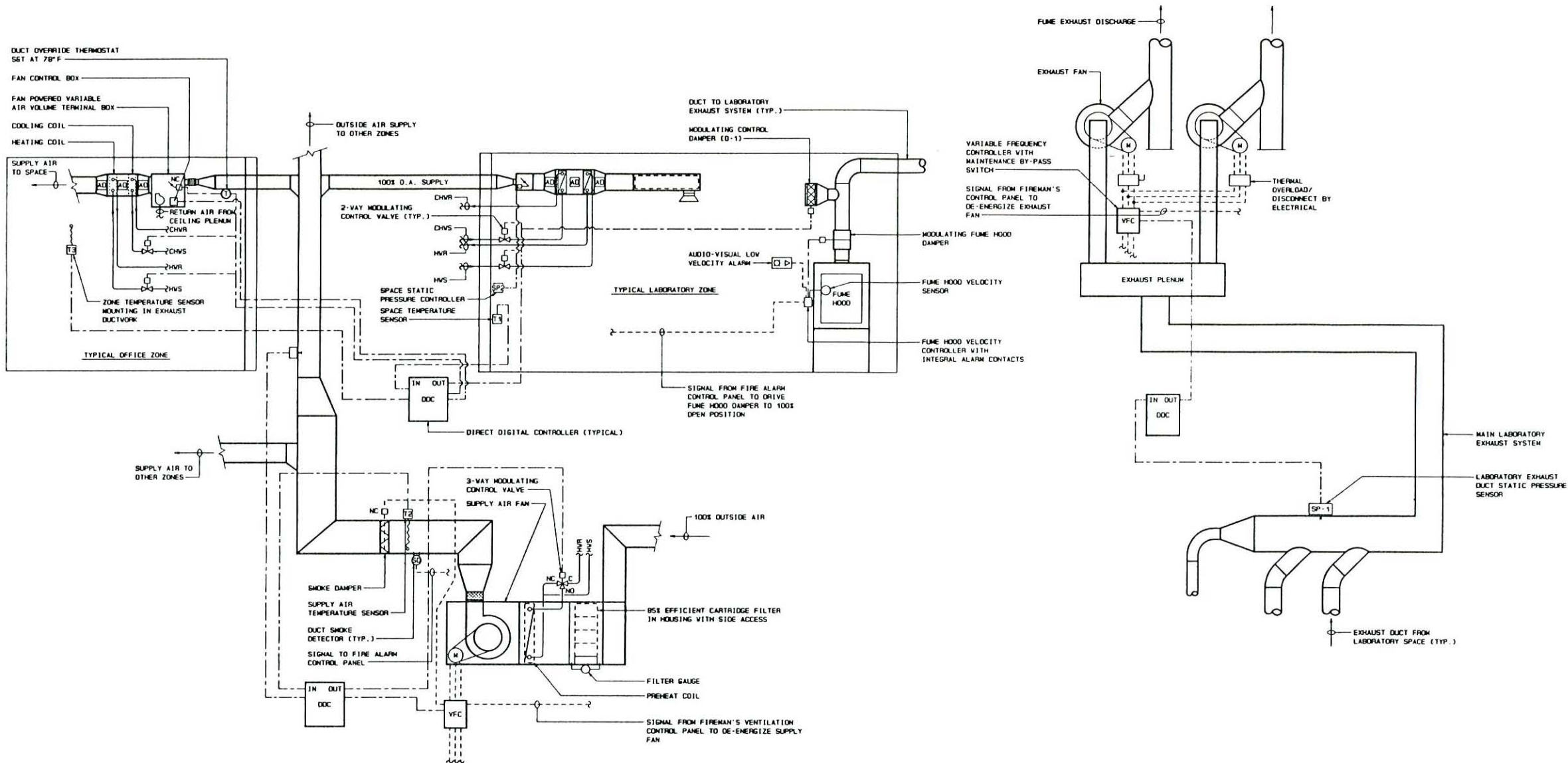
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AIRFLOW DIAGRAMS

M-5



TYPICAL LABORATORY/OFFICE ZONE CONTROL DIAGRAM
NO SCALE

SEQUENCE OF OPERATION

GENERAL:

THE SUPPLY AIR FANS AND EXHAUST FANS ARE ENERGIZED MANUALLY AND SHALL OPERATE CONTINUOUSLY.

FUME HOOD CAPACITY CONTROL:

THE FUME HOOD VELOCITY CONTROLLER WITH ASSOCIATED VELOCITY SENSOR MOUNTED IN THE FUME HOOD SHALL MODULATE THE CONTROL DAMPER AT THE FUME HOOD DISCHARGE TO MAINTAIN THE DESIRED FUME HOOD FACE VELOCITY. LABORATORY EXHAUST FAN CAPACITY CONTROL WILL BE MAINTAINED BY A DIRECT DIGITAL CONTROLLER (DDC) WITH ASSOCIATED STATIC PRESSURE SENSORS (SP-1) IN THE EXHAUST DUCTWORK. A SEPARATE DUCT STATIC PRESSURE SENSOR WILL BE PROVIDED FOR THE LABORATORY EXHAUST SYSTEM. AS FUME HOOD DAMPERS MODULATE CLOSED THE DDC SHALL SENSE THE REDUCTION IN PRESSURE AND THROUGH THE VARIABLE FREQUENCY CONTROLLER REDUCE FAN SPEED TO MAINTAIN REQUIRED STATIC PRESSURE.

LABORATORY STATIC PRESSURE CONTROL:

SPACE STATIC PRESSURE CONTROLLER WITH INTEGRAL SENSOR MOUNTED BETWEEN THE LABORATORY SPACE AND ADJACENT CORRIDOR SHALL MODULATE THE SUPPLY AIR V.A.V. TERMINAL BOX TO MAINTAIN THE LABORATORY AT A NEGATIVE 0.03" STATIC PRESSURE WITH RESPECT TO THE CORRIDOR. SUPPLY FAN CAPACITY CONTROL WILL BE MAINTAINED BY THE DDC UTILIZING THE ASSOCIATED STATIC PRESSURE SENSOR IN THE SUPPLY AIR DUCTWORK. AS THE V.A.V. TERMINAL BOX DAMPERS MODULATE CLOSED THE DDC SHALL SENSE THE INCREASE IN PRESSURE AND THROUGH THE VARIABLE FREQUENCY CONTROLLER REDUCE FAN SPEED TO MAINTAIN REQUIRED STATIC PRESSURE.

LABORATORY COOLING:

DIRECT DIGITAL CONTROLLER (DDC) WITH ASSOCIATED SPACE TEMPERATURE SENSOR (T-1) SHALL MODULATE OPEN THE 2-WAY CONTROL VALVE AT THE ZONE COOLING COIL TO MAINTAIN THE SPACE AT THE DESIRED TEMPERATURE. WITH THE VALVE FULL OPEN, SHOULD INSUFFICIENT COOLING BE AVAILABLE BECAUSE OF LOW FUME HOOD AIR FLOW, THE DDC SHALL MODULATE OPEN CONTROL DAMPER (D-1) AS REQUIRED TO MAINTAIN DESIRED SPACE TEMPERATURE.

LABORATORY HEATING:

DIRECT DIGITAL CONTROLLER (DDC) WITH ASSOCIATED SPACE TEMPERATURE SENSOR (T-1) SHALL MODULATE OPEN THE 2-WAY CONTROL VALVE AT THE ZONE HEATING COIL TO MAINTAIN THE SPACE AT THE DESIRED TEMPERATURE. SUPPLY AIR TEMPERATURE SHALL BE MAINTAINED AT 80 DEGREES (F). BY A DDC WITH ASSOCIATED TEMPERATURE SENSOR (T-2) IN THE SUPPLY AIR DUCT (AVERAGING TYPE). THE DDC SHALL MODULATE THE 3-WAY CONTROL VALVE AT THE PREHEAT COIL AS REQUIRED.

OFFICE COOLING:

DIRECT DIGITAL CONTROLLER (DDC) WITH ASSOCIATED ZONE TEMPERATURE SENSOR MOUNTED IN THE EXHAUST DUCTWORK SHALL MODULATE OPEN THE CHILLED WATER 2-WAY CONTROL VALVE. VARIABLE AIR VOLUME DAMPER SHALL BE FULL OPEN. A DUCT MOUNTED TEMPERATURE OVERRIDE THERMOSTAT WILL BREAK THE CONTROL SIGNAL TO THE V.A.V. DAMPER WHEN THE TEMPERATURE EXCEEDS 70 DEGREES F. CAUSING THE DAMPER TO RETURN TO MINIMUM POSITION. AT THIS TIME THE DDC SHALL SEND A SIGNAL TO ENERGIZE THE V.A.V. TERMINAL FAN.

OFFICE HEATING:

DIRECT DIGITAL CONTROLLER (DDC) WITH ASSOCIATED SPACE TEMPERATURE SENSOR (T-1) SHALL MODULATE CLOSED THE VARIABLE AIR VOLUME DAMPER AS LESS COOLING IS REQUIRED. WHEN THE DAMPER IS AT MINIMUM POSITION. IF ADDITIONAL HEATING IS REQUIRED, THE DDC SHALL MODULATE OPEN THE HOT WATER 2-WAY CONTROL VALVE.

SAFETY:

THE FUME HOOD VELOCITY CONTROLLER SHALL BE EQUIPPED WITH AN AUDIO-VISUAL ALARM THAT SHALL BE ACTIVATED WHEN FUME HOOD FACE VELOCITY FALLS BELOW SET POINT. THE AUDIO PORTION OF THE ALARM SHALL BE PROVIDED WITH AN ALARM SILENCE SWITCH. THE SUPPLY FANS SHALL BE INTERLOCKED TO THE FIREMAN'S CONTROL PANEL AND SHALL BE OPERABLE FROM THAT REMOTE LOCATION. WHEN SMOKE IS SENSED WITHIN A LABORATORY ZONE THE FIRE ALARM PANEL SHALL ENERGIZE A CONTACT IN THE FUME HOOD VELOCITY CONTROLLER TO DRIVE THE FUME HOOD DAMPER TO THE 100% OPEN POSITION. A DUCT SMOKE DETECTOR IN THE SUPPLY AIR DUCTWORK SHALL BE CONNECTED TO THE FIRE ALARM CONTROL PANEL. A SMOKE DAMPER AT THE DISCHARGE OF THE SUPPLY FAN SHALL BE INTERLOCKED TO THE STARTER AND SHALL ONLY BE OPEN WHEN THE FAN IS OPERATING.

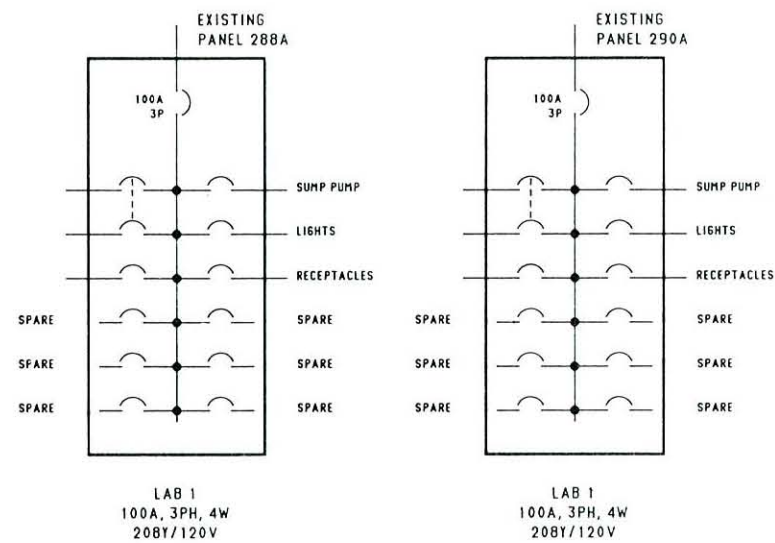
M-6

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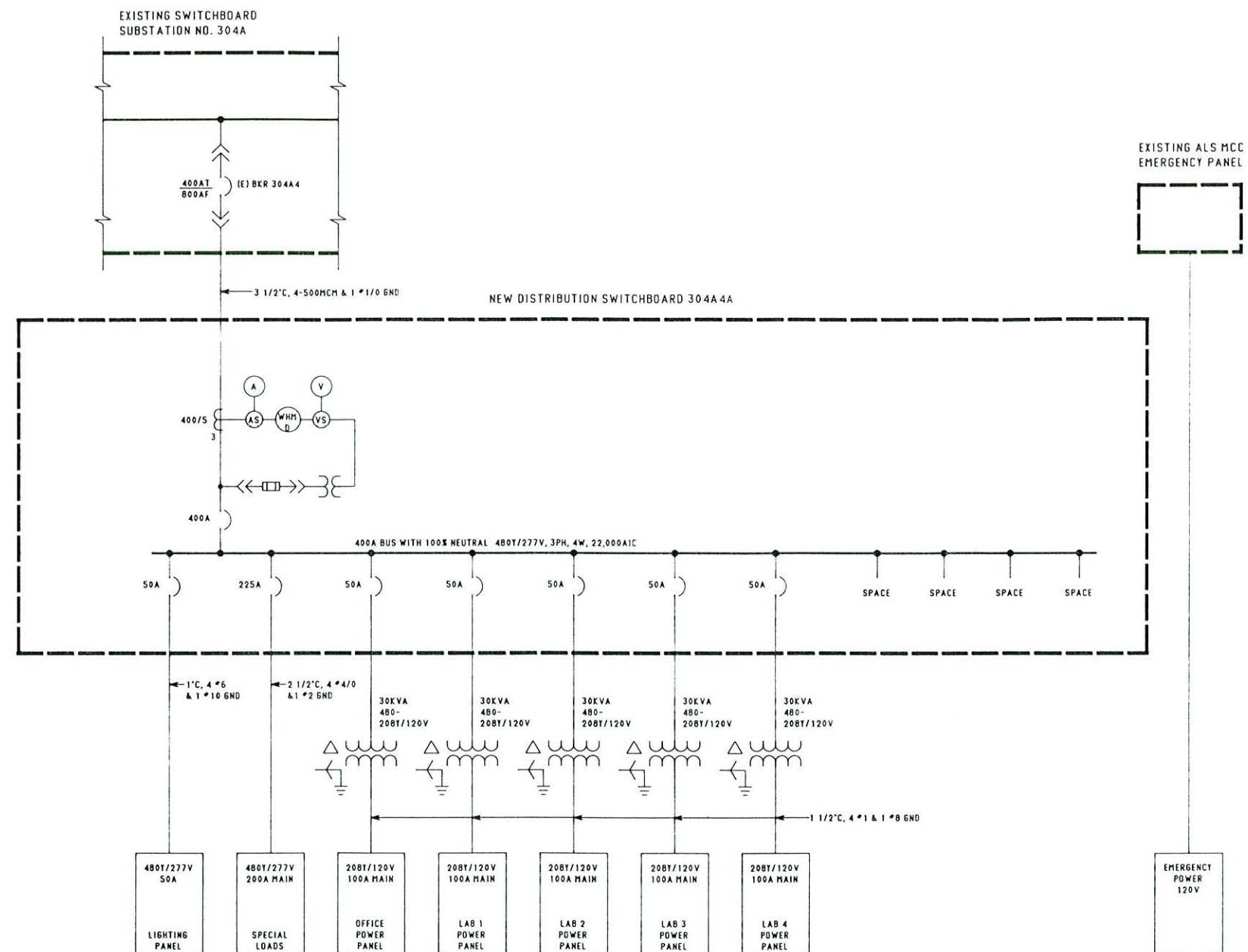
CONTROL DIAGRAM

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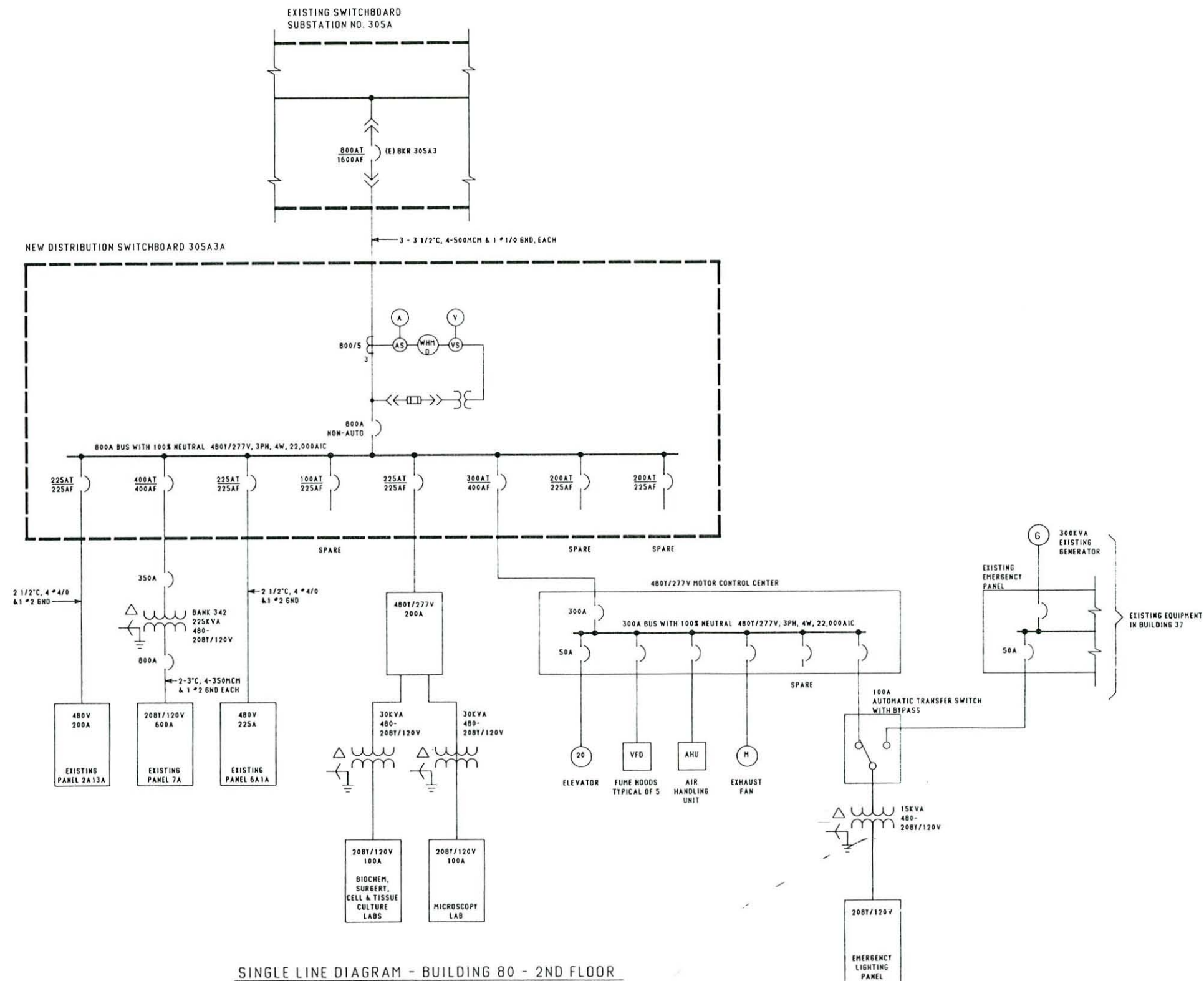




BEAM LINE LAB POWER - 1ST FLOOR
PANELS ARE LOCATED ON COLUMN LINE C



SINGLE LINE DIAGRAM - BUILDING 6 MODIFICATIONS - 2ND FLOOR LABS



SINGLE LINE DIAGRAM - BUILDING 80 - 2ND FLOOR

ALS LIFE SCIENCES CENTER

SECTION 6

OUTLINE SPECIFICATIONS

Division	1	GENERAL REQUIREMENTS
		01060 Regulatory Requirements
		01200 Project Meetings
		01300 Submittals
		01400 Quality Control
		01530 Barriers
Division	2	SITE WORK
		02050 Demolition
		02500 Paving and Surfacing
Division	3	NOT APPLICABLE
Division	4	NOT APPLICABLE
Division	5	METALS
		05500 Metal Fabrications
Division	6	WOOD AND PLASTIC
		06100 Rough Carpentry
Division	7	THERMAL AND MOISTURE PROTECTION
		07210 Building Insulation
		07900 Sealants
Division	8	DOORS AND WINDOWS
		08001 Hollow Metal Doors and Frames
		08211 Wood Doors
		08510 Aluminum Windows
		08710 Finish Hardware
		08800 Glazing
Division	9	FINISHES
		09250 Gypsum Wallboard
		09510 Acoustical Ceilings
		09650 Resilient Flooring

Division	10	SPECIALTIES
		10500 Miscellaneous Specialties
		10600 Modular Workstations
Division	11	EQUIPMENT
		11650 Laboratory Furniture
Division	12	NOT APPLICABLE
Division	13	SPECIAL CONSTRUCTION
		13650 Prefabricated Laboratory Modules
Division	14	CONVEYING SYSTEMS
		14240 Hydraulic Elevators
Division	15	MECHANICAL
		15010 General Provisions
		15050 Basic Materials and Methods
		15300 Fire Protection
		15400 Plumbing
		15500 Heating, Ventilating, and Air Conditioning Equipment
		15950 Controls
		15992 Air and Water Balancing
Division	16	ELECTRICAL
		16000 General Electrical
		16050 Basic Materials and Methods
		16400 Service and Distribution System
		16500 Lighting
		16700 Communications System
		16721 Fire Alarm System

DIVISION 1 - GENERAL REQUIREMENTS

SECTION 01060 - REGULATORY REQUIREMENTS

A. Codes and Design Standards:

1. Codes listed in Section 2 should be included in the construction specifications; codes shall be latest editions except where specifically noted otherwise.
2. Design Standards:
 - a. Structural Steel:
 - 1) AISC Standard Specifications for the Design, Fabrication, and Erection of Structural Steel for Buildings.
 - 2) AISC Code of Standard Practice for Steel Buildings and Bridges.
 - 3) AWS Structural Welding Code D1.1.
 - 4) AISC Specification for Structural Joints Using ASTM A325 or A490 Bolts.
 - 5) ASTM Standards.
 - 6) SSPC Steel Structures Painting Council.
 - b. Metal Decking
 - 1) Steel Deck Institute - SDI Standard #1.
 - 2) AISI Specification for the Design of Light Gauge, Cold Formed, Steel Structural Members.
 - 3) American Welding Society Standards.

SECTION 01200 - PROJECT MEETINGS

- A. Preconstruction conference.
- B. Billing meetings, at the last progress meeting each month.
- C. Periodic progress meetings, twice each month.
- D. Guarantees, bonds, and service and maintenance contracts meetings.

SECTION 01300 - SUBMITTALS

A. Schedules:

1. Progress schedule.
2. Proposed cash-flow schedule.
3. Schedule of values.
4. Submittal schedule.

B. Products list.

C. Shop drawings, product data, and samples.

D. Certificates of compliance.

SECTION 01400 - QUALITY CONTROL

A. Testing laboratory's services.

B. Testing agency's services.

SECTION 01530 - BARRIERS

A. Tree and plant protection.

B. Barricades.

DIVISION 2 - SITE WORK

SECTION 02050 - DEMOLITION

- A. Remove existing work shown to be removed and as required to install the new work. Protect existing facilities remaining operational during demolition work. Repair existing work damaged during demolition and construction.

SECTION 02500 - PAVING AND SURFACING

- A. Replace asphalt concrete and road paving disturbed by utility trenching. Match existing paving.

DIVISION 5 - METALS

SECTION 05500 - METAL FABRICATIONS

- A. Standard Rolled Steel Sections: ASTM A36.
- B. High-Strength Bolts: ASTM A325.
- C. Anchor Bolts: ASTM A307.
- D. Welding: AWS D1.1.
- E. Non-shrink grout.

DIVISION 6 - WOOD AND PLASTIC

SECTION 06100 - ROUGH CARPENTRY

- A. Lumber: Douglas fir, construction grade, WCLIB No. 16, S4S.
- B. Plywood: Douglas fir, exterior and interior types.
- C. Fireproofing: Clean, odorless, paintable, non-corrosive pressure process using mineral salts; use on exposed lumber and plywood.
- D. Rough Hardware: Types, strengths, materials, and sizes suitable for the intended purposes; galvanized, cadmium-plated, or non-corrosive metal for exterior use.

DIVISION 7 - THERMAL AND MOISTURE PROTECTION

SECTION 07210 - BUILDING INSULATION

- A. Thermal: Inorganic glass-fiber or mineral-fiber blankets, foil-faced.

SECTION 07900 - SEALANTS

- A. General Exterior Building Sealing: Two-component gun-grade non-sag rubber-based elastomeric; FS TT-S-00227E, Type II, Class A.
- B. Traffic-Bearing Horizontal Surfaces: Two-part puncture-resistant polyurethane, durometer hardness 25 to 50 after 14 days.
- C. Interior Building Sealing, Except As Otherwise Specified: Single-component gun-grade paintable acrylic-latex water-based; WOODMONT "Chem-Calk 600" or approved equal.
- D. Acoustical Sealing: Permanently plastic non-skinning paintable synthetic-polymer-based; PRESSTITE "No. 579.64 Acoustical Sealant" or approved equal.
- E. Sanitary Sealing: FS TT-S-001543A, Class A single-component primerless flexible mildew-resistant silicone rubber; DOW-CORNING "Dow-Corning Silicone Rubber Bathtub Caulk," Catalog No. 8640, or approved equal.
- F. Sealant Backup: Compatible with sealant material.

DIVISION 8 - DOORS AND WINDOWS

SECTION 08001 - HOLLOW METAL DOORS AND FRAMES

A. Interior Door Frames

1. Steel: Cold- or hot-rolled sheet steel, 16-gauge. One- piece welded construction.
2. Finish: Manufacturer's standard baked-on rust-inhibitive primer.

SECTION 08211 - WOOD DOORS

A. Prefinished solid-core wood veneer.

SECTION 08510 - ALUMINUM WINDOWS

- #### A. Aluminum frame system with baked-on color finish, profile and color to match existing.

SECTION 08710 - FINISH HARDWARE

- A. Exterior Doors: Butts, panic hardware, threshold, closer, and weatherstripping at head, jamb, and sill.
- B. Standard Office and Laboratory Doors: Butts, lockset, closer, 3/4-hour-rated hardware; polished chrome and stainless steel.
- C. Locksets: SCHLAGE, non-removable cores.
- D. Electric Latch Release: Magnetic-card-actuated, LBL standard.

SECTION 08800 - GLAZING

- A. Float Glass: 1/4", clear.
- B. Tempered Glass: 1/4", clear.

DIVISION 9 - FINISHES

SECTION 09250 - GYPSUM WALLBOARD

- A. ASTM C36 standard and Type X fire-rated gypsum wallboard, 5/8" thick, with tapered edges.
- B. Accessories: Fasteners and joint-treatment materials of standard manufacture.

SECTION 09510 - ACOUSTICAL CEILINGS

- A. Suspension System: Exposed "T" suspension system, Roblin Products, Chicago Metallic Corp., or equal.
- B. Acoustical Units: 24" x 24" x 5/8" thick, lay-in mineral board, Armstrong's Travertone, Conwed's Natural Fissured, or equal.

SECTION 09650 - RESILIENT FLOORING

- A. Vinyl Composition Tiles (VCT): 12"x 12" 1/8"-thick selected from standard patterns and colors.
- B. Sheet Vinyl: MIPOLAM "220 Series," TARKETT "Multi-Floor," or equal.
- C. Rubber Base: 4"-high x 1/8" thick, color as selected.

DIVISION 10 - SPECIALTIES

SECTION 10500 - MISCELLANEOUS SPECIALTIES

- A. Fire Extinguisher Cabinets (FEC): Recessed 25" x 10-1/2" x 4"-deep view door with curved projection (extinguishers provided by LBL).
- B. Fire Hose Cabinets (FHC): Recessed steel frame with full wire glass door, to house 75 feet of 1-1/2" fire hose and fire extinguisher, fire hose rack assembly (fire extinguisher provided by LBL); LARSEN "HCS 3030R," MUCKLE "301 R-1" with #900-75 hose, or approved equal.
- C. Horizontal Blinds: Aluminum 1" venetian blinds, LEVOLOR LORENTZEN "Riviera," HUNTER DOUGLAS "Flexalum Decor," or approved equal.

SECTION 10600 - MODULAR WORKSTATIONS

- A. Panels shall be capable of supporting a variety of work surfaces, drawer systems, shelving, file units, tackboards, panel-mounted ambient light fixtures, task lights and various accessories. Panels shall be constructed of steel frames, hardboard substrate and surfaced with a fabric covering or a plastic laminate finish. Panels shall be nominally 2" thick and have a vertical dimension of 62", 66" and 80".

Power and communications cables shall be supplied to the panels through a base raceway.

DIVISION 11 - EQUIPMENT

SECTION 11650 - LABORATORY FURNITURE

A. Laboratory Furniture

1. Fume hoods.
2. Metal base and wall cabinets.
3. Manufacturers: HAMILTON, PERMALAB, or equal.

DIVISION 13 - SPECIAL CONSTRUCTION

SECTION 13650 - PREFABRICATED LABORATORY MODULES

- A. Interior Laboratory Modules, dimensions as shown.
- B. Construction shall be non-combustible for installation within a type II, 1 hour rated structure (Building 6).
- C. Structural components and design of same shall comply with both UBC and LBL design criteria.
- D. Modules shall be complete and self-contained except for external plumbing and electrical connections by others.
 - 1. Included:
 - a. Plumbing, electrical, HVAC and fire protection to meet the operational requirements given in Divisions 15 and 16 of this Specification.
 - b. Laboratory furniture, and interior/exterior finishes to meet the requirements stated within the other applicable Divisions of this specification.
- E. Installation of modules on the existing concrete floor of Building 6 shall be in accordance with LBL Seismic Design Criteria, and as indicated on the drawing.

DIVISION 14 - CONVEYING SYSTEMS

SECTION 14240 - HYDRAULIC ELEVATORS

- A. Passenger/Service Elevator: 5,000 lbs capacity, 5 stops.
- B. Elevator car with two doors.
- C. Hoistway entrances.
- D. Signals and fixtures.
- E. Machine room and hoistway equipment.

DIVISION 15 - MECHANICAL

SECTION 15010 GENERAL PROVISIONS

A. Scope: All mechanical materials and installations in strict accordance with the following codes:

- Uniform Mechanical Code 1988
- Uniform Plumbing Code 1988
- Uniform Building Code 1988
- NFPA 13-1989
- NFPA 72-1989

SECTION 15050 - BASIC MATERIALS AND METHODS

A. Scope: Specifies pipe, fittings, valves, specialties, supports, anchors, mechanical identifications, and insulation.

B. Materials:

1. Piping:

- a. Domestic hot and cold water piping; Type L hard drawn copper with soldered fittings; as per ASTM B-78, B 585-74.
- b. Industrial hot and cold water piping; Type L hard drawn copper with soldered fittings; as per ASTM B-78, B 585-74.
- c. Chilled and Hot Water Piping: Black steel pipe with welded or threaded connections, or copper with soldered fittings.
- d. Natural Gas Piping: Black steel pipe with threaded or welded connections.
- e. Compressed Air and Miscellaneous Industrial Gas Piping: Type L hard drawn copper with soldered fittings.
- f. Low Conductivity Water (LCW) Piping: Natural polypropylene or polyvinylidene fluoride (PVDF) with butt-fused joints.
- g. Fire Sprinkler Piping: Black steel pipe with threaded or grooved connections.

- h. Domestic Waste Piping: Cast iron service weight piping with bell-and spigot joints for below grade. Indoors above grade use cast-iron service weight piping with bell-and-spigot or hubless joints for 2-1/2-inch and larger, galvanized steel pipe with cast-iron drainage fittings for 2-inch pipe and smaller.
 - i. Vent piping 2 - inch and smaller, galvanized steel or DHV copper tubing; 3-inch and larger, cast iron with hubless joints.
 - j. Industrial Waste and Vent Piping: Polypropylene drainage (DWV) piping with heat fused joints.
 - k. Pipe Escutcheons: Sheet steel, solid or split hinged; chrome for finished occupied areas, prime painted at unoccupied areas.
2. Mechanical Insulation:
- a. Insulate all domestic and industrial hot water piping with 1-inch-thick, pre-molded, high-density fiberglass with an all service jacket (ASJ).
 - b. Insulate hot water and chilled water with pre-molded, high-density fiberglass with an ASJ. Thickness to be established based on temperature differences expected.
 - c. All air conditioning supply air ductwork downstream of heating and cooling coils to be lined with internal thermal insulation.

C. Execution:

Mechanical Identification: All valves, pipe, ducting, and equipment in the ceiling space and mechanical rooms to be tagged and marked for identification purposes.

SECTION 15300 - FIRE PROTECTION

- A. Scope: Ordinary Hazard Group II wet pipe sprinkler system throughout the building.
- B. Materials:
 - 1. Piping: Schedule 40 steel with 175-pound banded cast-iron threaded, or 250-pound flanged fittings, or grooved-end, flexible couplings.
 - 2. Valves: UL listed and F.M. approved butterfly valves.
 - 3. Sprinklers: Pendant, upright, or sidewall type.
 - 4. Sprinkler Risers: UL-listed flow and control devices.

SECTION 15400 - PLUMBING

A. Fixtures:

1. Laboratory Sinks: Stainless steel mounted in counters.
2. Emergency Eyewash and Shower: Free standing type, provided in areas where chemical use is expected.

B. Soil and Waste: Floor drains to be heavy cast iron.

D. Plumbing Equipment: To include acid waste plumbing and neutralization systems.

SECTION 15500 - HEATING, VENTILATING, AND AIR CONDITIONING EQUIPMENT

A. Air-Handling Unit: Factory-fabricated penthouse rooftop-type air handler. Air-handling system shall be matched with bag filter (85% efficient), mixing box and supply fan section.

B. Low Pressure Ductwork: All supply and general exhaust ductwork shall be galvanized steel constructed in conformance with ASHRAE and SMACNA standards.

C. Power Ventilators: V-belt drive, roof-mounted centrifugal exhauster. Motors with vibration isolation. Low sound levels in accordance with AMCA standard 300-67 testing methods.

D. Variable Air Volume Terminal Boxes: Pressure-dependent type, including chilled water and hot water coil section.

E. Diffusers, Registers, and Grilles: To suit application.

F. Fume-Hood Face Velocity Control System: Electronic-type velocity controller set to maintain 100 feet per minute with associated velocity sensor mounted in the fume-hood and damper/actuator assembly installed the fume-hood exhaust duct.

G. Laboratory Exhaust Fans: Centrifugal type, single width, single inlet, suitable for roof mounting. All surfaces in the air stream shall be coated for acid resistance and corrosion protection.

H. Laboratory Exhaust Ductwork: Industrial grade standardized factory machine formed duct with longitudinal seams and flanged and gasketed connections. All interior surfaces of laboratory ductwork shall be coated for acid resistance and corrosion protection.

SECTION 15950 - CONTROLS

- A. Scope: To include requirements for provision and installation of all temperature controls and associated alarm systems. Control systems shall be of the direct digital type (DDC) suitable for connection to the existing (BAS) facility automation system on site.

SECTION 15992 - AIR AND WATER BALANCING

- A. Scope: To include requirements for balancing all air and hydronic systems.

DIVISION 16 - ELECTRICAL

SECTION 16000 - GENERAL ELECTRICAL

- A. Conform to applicable standards of ANSI, ASTM, CBM, ETL, ICEA, IEEE, IES, ISA, NEMA, NETA, NFPA and UL.
- B. Conform to rules and regulations of the California Administrative Codes including, but not limited to, Title 8 - Chapter 4, Subchapter 5.

SECTION 16050 - BASIC MATERIALS AND METHODS

- A. General: Building raceways, pullboxes, outlet boxes, conductors for general low-voltage wiring, wiring devices, supports, attachments and grounding, including routine insulation resistance, continuity and rotation tests.
- B. Materials
 - 1. Rigid, intermediate and flexible conduit and electrical metallic tubing.
 - 2. Secondary cable, copper 600V cables with No. 12 AWG minimum for power circuits and No. 14 AWG minimum for control circuits. Feeder cable sizes as shown on drawings. Cable for the fire alarm system is specified in the Section dealing with that system.
 - 3. Wiring devices, ivory switch handles or receptacles and stainless steel faceplates, including duplex outlets.

SECTION 16400 - SERVICE AND DISTRIBUTION SYSTEM

- A. General: Dry-type transformers, panelboards, switchboards, motor control center, transfer switch and equipment disconnect switches.
- B. Equipment
 - 1. Includes main and feeder circuit breakers, transformers, lighting and power panelboards, switchboards, motor control centers and equipment switches.
 - 2. Dry-type transformers, UL-rated 220 degree C insulation, designed for 185 degrees C ultimate temperature with 40 degree C ambient, 115 degree C average temperature rise and 30 degree C hot spot allowance. Provide quiet-type transformers with a sound level not exceeding 45 decibels. Provide transformers with taps and earthquake motion-restrained vibration isolaters.
 - 3. Motor control center, copper busses, combination starters, 300 amp vertical buss and separate control power transformers.

SECTION 16500 - LIGHTING

- A. General: Fluorescent lighting for indoor locations with high pressure sodium for exterior locations.
- B. Fixtures
 - 1. Fluorescent, two tube 277V, energy efficient ballast for general lighting.
 - 2. Fluorescent exit lights.
- C. Control
 - 1. Infrared sensors or/connection to the EMCS.

SECTION 16700 - COMMUNICATIONS SYSTEM

- A. General: Integrated Communication System (ICS), Energy Management and Control System (EMCS) and building-wide paging system.
- B. Materials
 - 1. Minimum conduit size, one inch.
 - 2. Terminal cabinets, minimum size 24 inches high by 20 inches wide by 4 inches deep.
 - 3. ICS hallway cabletray, 6 inch by 6 inch, 2 inch conduit stub into rooms.
- C. Devices
 - 1. Wall or ceiling mounted speakers, volume controls, amplifier and microphones.
 - 2. Universal Receptacle (UR) for voice and data services.
 - 3. Supplemental Universal Receptacle (SUR) for local area networking, point to point data links, alarms, etc.

SECTION 16721 - FIRE ALARM SYSTEM

- A. General: Manual stations, alarm bells, door holders and zone water flow switch.
- B. Materials
 - 1. Minimum conduit size: 3/4 inch.

2. Wiring, solid copper conductor as follows:

- a. System 3 wiring, 600V insulation meeting NFPA 70, not less than No. 14 AWG for audible signaling devices and No. 16 AWG for alarm initiating devices.
- b. MX-316 or MX-203 wiring, 300V insulation meeting NFPA 70, two twisted pair No. 18 AWG minimum configuration with each pair individually shielded for the signaling trunk and single or multiple twisted pair with an overall shield, not less than 18 AWG for single pair and No. 22 AWG for multiple pair for alarm initiating devices.

C. Devices

1. Control panel: Add modules to the existing Pyrotronics System 3 panel.
2. Manual stations: Interior stations, Gamewell Model No. 21868-8 with back box No. 43480.
3. Alarm bells: Pyrotronics BDC-624 polarized 24V vibrating bell.

ALS LIFE SCIENCES CENTER

SECTION 7

ENERGY CONSERVATION

Various energy conservation features must be evaluated during the building design phase. Some of the specific items to be considered are summarized as follows:

Active Solar Energy Collection System

An analysis must be performed to determine the economic feasibility of providing an active solar energy collection system to furnish heat energy for domestic hot water, space heating, or a combination of both.

Use of Variable Air Volume (VAV) Air Distribution

Variable Air Volume (VAV) air distribution will be utilized throughout the facility. This feature of the design will provide a reduction of the supply air quantity in response to a reduction in load, producing associated fan, cooling, and heating energy savings.

Variable air volume fume hood exhaust systems will also be utilized. A face velocity control system with associated sensor in the fume hood will modulate a damper assembly in the exhaust outlet of each fume hood. This system will maximize energy conservation by minimizing the energy utilized to condition pressure controllers, which will regulate the quantity of supply air as required to maintain the laboratories at a pressure of -0.03-inches water column with respect to the adjacent corridors.

Energy Monitoring and Control System (EMCS) and Direct Digital Control (DDC)

The mechanical systems provided under the design will be compatible with the existing EMCS Facility Automation System on site. A direct digital control system must be utilized throughout the facility. This system will be used for both temperature and duct static pressure control. This system will allow precise temperature/static pressure control, permit night temperature setback, and allow interface to the site energy monitoring and control system (EMCS) via coaxial cable or telephone lines.

Lighting Systems

All areas of the building will be provided with an efficient lighting system capable of maintaining footcandle levels recommended in the IES Handbook. Design of the system shall comply with all requirements identified in California Title 24. Lighting controls should consider the use of two-level switching and incorporate occupancy sensors to eliminate unnecessary use of lighting. Given the anticipated design and usage of the facility, it is expected that fluorescent lighting fixtures will be used primarily. Consideration should be given to the use of solid state electronic ballasts for these fixtures.

ALS LIFE SCIENCES CENTER

SECTION 8

SAFETY AND ENVIRONMENTAL CONSIDERATIONS

Safety Considerations

An initial safety assessment review has been completed. A Safety Analysis Document will be filed before the start of construction.

Operational Safety Procedures (OSPs) are mandatory for all potentially-hazardous experiments. The OSPs are reviewed by the Environment and Safety Hazards Control Department and the appropriate subcommittee(s) of the Safety Review Committee. As a standard procedure of the LBL safety program, all areas are inspected for compliance with federal OSHA and LBL standards.

Lawrence Berkeley Laboratory complies with DOE 5480.1A, 29 CFR 1910 and 29 CFR 1926. Design review of equipment and laboratory facilities and review of experimental procedure is expected to reduce any hazards to a "low hazard" classification.

Environmental Considerations

An initial environmental review has been made for this project. No adverse environmental impacts are expected on or off site. The project will have no impact on archeology, atmosphere, climate, flora, fauna or waste. There will be no underground tanks. A very small increase in the number of visiting scientists is expected, but this was evaluated and accounted for in the Environmental Assessment for the 1-2 GeV Synchrotron Light Source. The project is not located in a flood plain or wet lands. There are no environmental issues that will require unusual design or scheduling considerations.

It is anticipated that an Environmental Assessment (EA) will be performed with a finding of no significant impact.

ALS LIFE SCIENCES CENTER

SECTION 9

DETAILED SUPPORTING DATA

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ALS LIFE SCIENCES CENTER

ED&I ANALYSIS (FY 1990 \$K)

LBL Activities

Engineering

• Title I (3 MM at 7.38/mo)			=	22
Proj Arch 1 x .4 time x 3	=	1.2MM		
Proj Team 3 x .2 time x 3	=	1.8		
• Title II (7 MM at 7.38/mo)			=	52
Proj Arch 1 x .4 x 7	=	2.8MM		
Proj Team 3 x .2 x 7	=	4.2		
• Title III (7.5 MM at 7.38/mo)			=	55
Proj Arch 1 x .17 x 16	=	2.7MM		
Proj Team 3 x .10 x 16	=	4.8		
• Inspection (9.4 MM at 7.38/mo)			=	69
Inspectors (combo) .5 x 16	=	8.0		
Equipment Installation 2 x 7	=	1.4		
• Consultants and Vendors			=	16
Independent Seismic Reviews		2		
Independent Cost Estimate		5		
Advertisements		3		
Printing		6		
				<u>214</u>

A/E Activities

12.5% of designed construction costs (2,333)	
including Special Facilities of 397	292

Total Estimated ED&I	506
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ALS LIFE SCIENCES CENTER

BASIS FOR ARCHITECTURAL DESIGN

Demolition - Building 80

Remove all existing partitions, ceilings and floor finishes as indicated on the drawings. Laboratory equipment and cabinet work to be salvaged for re-use.

New Construction - Buildings 80 (2nd Floor) and 6 (Mezzanine)

1. Exterior Wall System at Building 6 (existing): New gypsum board finish over existing insulation. The interior separating wall (mezzanine from ALS high bay area) is in place. New paint finish.
2. Exterior Wall System at Building 80 (existing): Finished inside typical. New finish: Darkroom - gypsum board; bathrooms - ceramic tile. New aluminum window in the office area to match existing.
3. Interior Partitions at Buildings 80 and 6: New non-combustible metal studs finished with gypsum board, painted. Demountable partitions to structure at beamline laboratories.
4. Ceilings: Building 80 - exposed; Building 6 Mezzanine suspended T-bar system with lay-in accoustical panels, 9 feet high.
5. Floor Finish: Vinyl composition tile, 12" x 12" x 1/8", trimmed at walls with rubber base.
6. Fume Hoods and Laboratory Furniture: New; metal base and wall cabinets.
7. Bathrooms: Ceramic tile floor and walls; gypsum board ceiling.
8. Building 80: Modular demountable partitions with prewired base and modular furniture, plus carpeting will be furnished in the "open plan" office area.

BASIS FOR DESIGN

1. MECHANICAL SYSTEMS

A. DESIGN PARAMETERS

Design temperatures and heat transfer factors are taken from the ASHRAE Handbook of Fundamentals, 1985, Weather Data.

- Outside Design Temperatures:

	<u>Summer</u>	<u>Winter</u>
Laboratories	85°F.db/65°F.wb	34°F.db
Other	80°F.db/63°F.wb	

- Inside Design Temperatures:

Laboratories and administrative offices provided with air conditioning:

Summer: 76°F db
Winter: 72°F db

Given the relatively mild climate that exists in the San Francisco Bay Area, control of the space relative humidity is not required. Humidity within the conditioned spaces will remain between 30% and 70% without the use of special systems or controls.

- Heat Transfer "U" Factors:

For purpose of preliminary calculations, the following nominal values have been used.

Building 6

	<u>Summer</u>	<u>Winter</u>
Roof:	0.05 BTU/ft ² -Hr-°F	0.05 BTU/Hr-ft ² -°F
Wall:	0.07 BTU/ft ² -Hr-°F	0.07 BTU/Hr-ft ² -°F
Windows:	0.35 BTU/ft ² -Hr-°F	0.31 BTU/Hr-ft ² -°F

Building 80

	<u>Summer</u>	<u>Winter</u>
Roof:	0.12 BTU/ft ² -Hr-°F	0.12 BTU/Hr-ft ² -°F
Wall:	0.13 BTU/ft ² -Hr-°F	0.13 BTU/Hr-ft ² -°F
Windows:	1.06 BTU/ft ² -Hr-°F	1.02 BTU/Hr-ft ² -°F

When making modifications to the envelope of the existing building, insulation should be added to walls, and any modified glazing should be of double-pane type, in order to achieve heat transfer factors closer to those indicated for Building 6 above.

B. HEATING

Heat for both those portions of the Life Science Center to be located within Building 6, as well as within Building 80, will be supplied from the existing hot water heating system in Building 6. Under this contract the existing hot water supply and return mains will be tapped and new insulated branch piping extended to heating coils located in the variable air volume terminal units. The total heating load required for the Life Science Center is calculated to be approximately 603,100 BTUH, with an additional heating load of approximately 36,600 BTUH imposed by the ALS support area on the first floor if required.

C. AIR CONDITIONING

In order to comply with the inside temperatures for personnel comfort identified in Chapter V, Paragraph 7 of DOE 6430.1, the entire building areas occupied by the Life Science Center will be air conditioned. The system supplying the laboratory areas will be of the variable air volume type, utilizing terminal boxes located in the ceiling spaces. The variable air volume terminal boxes will be modulated by space pressure controllers which will regulate the quantity of supply air, as required to maintain the laboratories at a pressure of -0.03-inches water column with respect to the adjacent corridors. In order to provide the required makeup air for the fume hoods, as well as ensure a safe working environment, the laboratory systems will utilize 100 percent outside air.

Outside air for the laboratories on the second floor of Building 6 will be provided by the existing air handling unit supplying this area. Outside air for the laboratories to be located on the second floor of Building 80 will be supplied from a new penthouse-type air handling unit located on the roof of Building 80. The air handling unit will be provided with a filter bank and hot water preheat coil. Disposable filters having an efficiency of approximately 85% (ASHRAE 52-68) will be utilized. All supply air ductwork located downstream of the variable air volume terminal boxes will be insulated.

Heat for these areas will be supplied by hot water coils mounted adjacent to the variable air volume terminal boxes.

Cooling for these areas will be supplied by chilled water coils mounted adjacent to the variable air volume terminal boxes. Chilled water will be provided by the existing chilled water system within Building 6. The total cooling load for the Life Science Center is calculated to be approximately 475,000 BTUH,

with an additional load of approximately 80,000 BTUH required to condition the ALS support area on the first floor if desired.

Temperature control for the laboratory spaces will be maintained by a direct digital control (DDC) system incorporating temperature sensors in each laboratory. The DDC system will modulate control valves at the heating and cooling coils as required to maintain the desired space temperature.

Office and support areas will be served by a system utilizing fan-powered variable air volume terminal units. During periods when heating is required, the variable air volume terminal units will modulate to minimum supply air quantities. Should additional heat be required, the zone temperature direct digital control (DDC) system will modulate open the hot water control valve at the associated heating coil. During periods when cooling is required, the system will first utilize free outside air cooling whenever available. Should the outside air temperature rise above the inside design condition, the variable air volume terminal units will drive to minimum position, and the integral fans in the terminal units will be energized, providing return air to the zones. The zone temperature direct digital control system will then modulate the chilled water control valves at the variable air volume terminal units as required to maintain space temperature. Outside air for the office and support areas will be supplied from the air handling units serving the laboratory spaces.

All air handling units will be provided with fan capacity control utilizing variable frequency drives. The direct digital control (DDC) system, with associated static pressure sensors located in the supply air ductwork, shall modulate the variable frequency drives to maintain the required duct static pressure.

D. SPECIALIZED LABORATORY AND GENERAL EXHAUST

Variable air volume fume hood exhaust systems will be utilized. A face velocity control system with associated sensor in the fume hood will modulate a damper assembly in the exhaust outlet of each fume hood within Building 6. Multiple fume hoods will be ganged together and ducted to exhaust plenums on the roof. Each plenum will be provided with multiple exhaust fans to produce high system reliability. Given the minimal headroom within Building 80, only fume hoods within individual rooms will be ducted together. Smaller individual exhaust fans will then be located on the roof directly above the associated laboratory. Variable frequency drives will be utilized to modulate exhaust fan capacity to suit air flow requirements established by controllers located at the fume hoods.

A general exhaust system will also be provided for the Life Science Center area located within Building 6. The general exhaust system will be utilized to remove from the building the outside air that is brought in for ventilation and free cooling

when available. The general exhaust system will be provided with a variable frequency drive, such that the exhaust air quantities can be adjusted as required to maintain a slight positive pressure in the building. Due to restricted headroom, relief of outside air brought into Building 80 for free cooling will be through rooftop barometric dampers located above the various spaces.

E. MECHANICAL COOLING

Cooling for both that portion of the Life Science Center to be located within Building 6, as well as on the second floor of Building 80, will be supplied from the existing chilled water system serving Building 6. Under this contract the existing chilled water supply and return mains will be tapped and new insulated branch piping extended to cooling coils located at the variable air volume terminal units.

F. PLUMBING AND PROCESS PIPING SYSTEMS

All plumbing fixtures will be provided and installed in accordance with the Uniform Plumbing Code (UPC). The design of the plumbing system shall be in accordance with DOE Manual 6430.1A.

Process piping systems will be provided as required. Process piping will be routed in the ceiling spaces of the laboratory areas. Process piping systems to be included are as follows:

- Compressed air
- Non-potable industrial hot and cold water
- Low-conductivity water (LCW)
- Natural gas
- Treated water

Industrial water, low conductivity water, treated water, natural gas, and compressed air will be extended into these areas from the existing systems located in the facility.

In order to accommodate the acid waste to be generated, laboratory areas will drain to small tanks and will be pumped overhead to acid neutralization systems. As the buildings are existing, this method will minimize construction costs and eliminate the need for a double contained piping system.

G. FIRE PROTECTION SYSTEM

Existing fire protection systems within the facility will be modified to suit the revised wall layout.

HVAC LOAD CALCULATIONS

COMPUTATION SHEET

COMPUTED BY: BWJ
CHECKED BY:
DATE: 12-7-89
REV:

LBL - LIFE
SCIENCES CENTER

PROJECT: 16-199-09-I

MECHANICAL CALCULATIONS

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COMPUTATION SHEET

COMPUTED BY: RJB
CHECKED BY: BWJ
DATE: 12-7-89
REV:

LBL - LIFE
SCIENCES CENTER
COOLING SUMMARY

PROJECT: 16-199-09-I

SHEET NO. 1 OF 56 SHEETS

BUILDING 6

<u>ROOM</u>	<u>SUPPLY CFM</u>	<u>O.A. CFM</u>	<u>COOLING LOAD BTUH</u>
Offices (9)	215 (9)	15 (9)	4,570 (9)
	1,935	135	41,130
Lab (East)	825	825	15,670
Vertical Beam	235	235	7,370
Darkroom	40	40	1,270
Microscope Room	50	50	1,600
Lab	825	825	15,800
Lab	1,825	1,825	27,550
Lab (West)	1,575	1,575	24,820
Corridor	900	900	<u>13,730</u>
Subtotal			148,940 + 25%
		Say	<u>186,175</u> BTUH

BUILDING 80

<u>ROOM</u>	<u>SUPPLY CFM</u>	<u>TRANSMISSION/ VENT LOAD</u>	<u>MAKEUP O.A.</u>	<u>O.A. LOAD</u>
Microscopy	800	14,928	1,000	10,800
Microscopy	405	8,969	-	-
Microscopy	550	12,225	-	-
Darkroom	800	2,073	1,000	10,800
Biochem Lab	2,250	50,380	2,400	25,920
Surgery	775	18,759	775	8,370
Cell/Tissue	1,800	12,152	2,000	21,600
Equipment Room	250	5,061	-	-

COMPUTATION SHEET

COMPUTED BY: RJB
 CHECKED BY: BWJ
 DATE: 11-12-89
 REV:

LBL - LIFE
 SCIENCES CENTER
 COOLING SUMMARY

PROJECT: 16-199-09-I

SHEET NO. 2 OF 56 SHEETS

COOLING SUMMARY (CONT.)

BUILDING 80 (CONT.)

Glass Wash	365	8,371	-	-
Offices	230	5,482	-	-
Offices	140	3,598	-	-
Corridors	-	<u>11,612</u>	-	<u>-</u>

Subtotal	153,610	77,490
----------	---------	--------

Subtotal Combined	231,100 + 25%
	Say <u>288,875</u> BTUH

TOTAL COOLING LOAD

Building 6	186,175 BTUH
Building 80	<u>288,875</u> BTUH

475,050 BTUH
 Or 39.6 Say 40 tons

COMPUTATION SHEET

COMPUTED BY: RJB
CHECKED BY: BWJ
DATE: 11-12-89
REV:

LBL - LIFE
SCIENCES CENTER
HEATING SUMMARY

PROJECT: 16-199-09-I

SHEET NO. 3 OF 56 SHEETS

BUILDING 6

<u>ROOM</u>	<u>MINIMUM CFM</u>	<u>O.A. CFM</u>	<u>HEATING LOAD BTUH</u>
Offices (9)	110 (9)	15 (9)	1,500
	990	135	13,500
Lab (East)	1,000	1,000	39,750
Vertical Beam	120	120	5,180
Darkroom	20	20	890
Microscope Room	25	25	1,120
Lab	1,000	1,000	39,640
Lab	2,000	2,000	75,780
Lab (West)	<u>1,750</u>	<u>1,750</u>	<u>69,030</u>
Subtotal	6,905	6,050	244,890

BUILDING 80

<u>ROOM</u>	<u>SUPPLY CFM</u>	<u>TRANSMISSION/ LOAD</u>	<u>MAKEUP O.A.</u>	<u>O.A. LOAD</u>
Microscopy	800	7,596	1,000	41,800
Microscopy	200	9,199	15	615
Microscopy	225	5,764	15	615
Darkroom	800	831	1,000	41,000
Biochem Lab	2,250	18,326	2,400	98,400
Surgery	775	2,257	775	31,775
Cell/Tissue	1,800	2,709	2,000	82,000
Equipment Room	125	3,468	-	-

COMPUTATION SHEET

COMPUTED BY: RJB
CHECKED BY: BWJ
DATE: 11-12-89
REV:

LBL - LIFE
SCIENCES CENTER
HEATING SUMMARY

PROJECT: 16-199-09-I

SHEET NO. 4 OF 56 SHEETS

HEATING SUMMARY (CONT.)

BUILDING 80 (CONT.)

Glass Wash	365	2,249	30	1,230
Offices	230	1,900	30	1,230
Offices	140	912	30	1,230
Corridors	-	<u>3,908</u>	-	<u>-</u>
Subtotals		59,119		299,095
Subtotal Combined				358,214 BTUH

TOTAL HEATING LOAD

Building 6	244,890
Building 80	<u>358,214</u>

603,104 BTUH
(Approx. 20 boiler HP)

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

COMPUTED BY J C CASE
CHECKED BY _____
DATE 11-12-1989
REV. _____ 19__

LBL - LIFE SCIENCES
MECHANICAL DESIGN
CRITERIA

PROJECT 16-199-09
SHEET NO. 6 OF 54 SHEETS

BUILDING 6WEATHER DATA:

FROM ASHRAE FUNDAMENTALS, 1985 WEATHER DATA:

	<u>SUMMER</u>	<u>WINTER</u>
LABORATORIES	85°F D.B./65°F WB	34°F DB
OTHER	80°F D.B./63°F WB	34°F DB

INSIDE DESIGN TEMPERATURES:

SUMMER: 76°F DB WINTER: 72°F DB

U-VALUES

FOR THE PURPOSE OF PRELIMINARY CALCULATIONS
THE FOLLOWING VALUES HAVE BEEN USED

	<u>SUMMER</u>	<u>WINTER</u>
ROOF	.05 BTU/ft ² ·HL·F	.05
WALL	.07 "	.07
WINDOWS	.35 "	.31 BTU/ft ² ·F

COMPUTATION SHEET

COMPUTED BY J.C. CASE
 CHECKED BY _____
 DATE 11-12- 1989
 REV. _____ 19____

LBL - LIFE SCIENCES
MECHANICAL DESIGN
CLTD

PROJECT 16-199-09
 SHEET NO. 6 OF 56 SHEETS

BUILDING 6
CLTD FOR WALLS.

FROM ASHRAE 1985 FUNDAMENTALS
 TABLES 6, 7, GROUP E WALL 8" BLOCK

FOR GROUP E WALLS, @ 1600 HOURS
 AND TABLE 9 LATITUDE MONTH MAY/JULY

	<u>CLTD</u>	<u>LM</u>
N	17	0
NE	26	0
E	34	0
SE	36	0
S	32	1
SW	32	0
W	27	0
NW	20	0

$K = 1.0$ ASSUME DARK COLORING + INDUSTRIAL AREA

$T_R = 76^\circ F$ INDOOR DESIGN TEMP.

$T_o = 85^\circ F$ OUTDOOR DESIGN TEMP.

THEREFORE THE CORRECTED CLTD
 SHALL BE (PER ASHRAE)

$$\begin{aligned}
 CLTD_{CORR} &= [(CLTD + LM) \times K + (78 - T_R) + (T_o - 85)] \\
 &= (CLTD + LM) \times 1.0 + (78 - 76) + (85 - 85) \\
 &= (CLTD + LM) \times 1.0 + 2
 \end{aligned}$$

COMPUTATION SHEET

COMPUTED BY J C CASE
CHECKED BY _____
DATE 11-12-1987
REV. _____ 19__

LBL - LIFE SCIENCES
MECHANICAL DESIGN
CLTD

PROJECT 16-199-09
SHEET NO. 7 OF 56 SHEETS

BUILDING 6

	CLTD	LM	CORR	=	CLTD _{CORR}
N	= 17	+ 0	+ 2	=	19
NE	= 26	+ 0	+ 2	=	28
E	= 34	+ 0	+ 2	=	36
SE	= 36	+ 0	+ 2	=	38
S	= 32	+ 1	+ 2	=	35
SW	= 32	+ 0	+ 2	=	34
W	= 27	+ 0	+ 2	=	29
NW	= 20	+ 0	+ 2	=	22

ROOF CLTD

1985 FUNDAMENTALS, CHAP 26 TABLE 5,
ROOF TYPE 9, WITH SUSPENDED CEILING,
@ 1600 HRS

$$CLTD = 34$$

$$LM = 1$$

$$F = 1.0 \quad \text{FACTOR FOR CEILING SPACE VENTILATION}$$

1 = NO VENTILATION

$$K = 1.0 \quad \text{DARK COLOR}$$

$$CLTD_{CORR} = [(CLTD + LM) \cdot K + (78 - 76) + 85 - 85] F$$

$$CLTD_{CORR} = [(34 + 1) \times 1.0 + (78 - 76) + (85 - 85)] 1.0$$

$$\text{ROOF } CLTD_{CORR} = 37$$

COMPUTATION SHEET

COMPUTED BY J.C. CASE
 CHECKED BY _____
 DATE 11-12- 1989
 REV. _____ 19____

LBL - LIFE SCIENCES
SHGF

PROJECT 16-179-09
 SHEET NO. 8 OF 54 SHEETS

BUILDING 6

MAXIMUM SHGF FOR FENESTRATION

FROM CHAPTER 26 TABLE 11, MSHGF @ 40°N

IN JULY

MSHGF

CLF (MEDIUM CONST ROOM)
 @ 1600

N	38	.74
NE/NW	163	.26/.42
E/W	216	.26/.50
SE/SW	170	.33/.58
S	109	.47

ASSUME SHADING COEFFICIENT OF 0.80

COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY _____
DATE 11-12-1988
REV. _____ 19__

LBL - LIFE SCIENCES
COOLING LOAD
BLDG #6 OFFICES (TYP)

PROJECT 16-199-09

SHEET NO. 9 OF 56 SHEETS

Space Used For

Size

10

x

16

=

160

SQ FT x

14

=

2240

CU FT

ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
SOLAR GAIN-GLASS				
Glass	28	SQ FT x 163	x .42 x .8	1530
Glass		SQ FT x	x	
Glass		SQ FT x	x	
Glass		SQ FT x	x	
Skylight		SQ FT x	x	
SOLAR & TRANS. GAIN-WALLS & ROOF				
Wall	112	SQ FT x 22	x .05	120
Wall		SQ FT x	x	
Wall		SQ FT x	x	
Wall		SQ FT x	x	
Roof-Sun	160	SQ FT x 37	x .07	410
Roof-Shaded		SQ FT x	x	
TRANS. GAIN-EXCEPT WALLS & ROOF				
All Glass		SQ FT x	x	
Partition		SQ FT x	x	
Ceiling		SQ FT x	x	
Floor		SQ FT x	x	
Infiltration		CFM x	x 1.08	
INTERNAL HEAT				
People		PEOPLE x 315		320
Power	400 WATTS (1 PC)	WATTS x 3.4		1370
Lights	1.0 W/5F	WATTS x 3.4		550
Appliances, Etc.		x		
Additional Heat Gains		x		
SUB TOTAL				4300
Storage		SQ FT x	x (-)	
SUB TOTAL				
Safety Factor	5	%		210
ROOM SENSIBLE HEAT				4510
SUPPLY DUCT HEAT GAIN		SUPPLY DUCT % LEAK, LOSS	FAN % H. P.	
Outdoor Air		CFM x	F x BF x 1.08	
EFFECTIVE ROOM SENSIBLE HEAT				
LATENT HEAT				
Infiltration		CFM x	GR/LB x 0.68	
People		PEOPLE x		
Steam		LB/HR x 1050		
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.		SQ x 1/100 x	GR/LB x	
SUB TOTAL				
Safety Factor		%		
ROOM LATENT HEAT				
SUPPLY DUCT LEAKAGE LOSS		%		
Outdoor Air		CFM x	GR/LB x BF x 0.68	
EFFECTIVE ROOM LATENT HEAT				
EFFECTIVE ROOM TOTAL HEAT				
OUTDOOR AIR HEAT				
Sensible:	15	CFM x 4	F x (1-0) BF x 1.08	60
Latent:		CFM x	GR/LB x (1-0) BF x 0.68	
RETURN DUCT HEAT GAIN		RETURN DUCT % LEAK, GAIN	HP % PUMP	
SUB TOTAL				
GRAND TOTAL HEAT				4570

Estimate for

LOCAL TIME SUN TIME

Peak Load

LOCAL TIME SUN TIME

Hours of Operation

CONDITIONS	DB	WB	% RH	DP	GR/LB
OUTDOOR (OA)	80				
ROOM (RM)	76				
DIFFERENCE	4				

VENTI-LATION

1

PEOPLE x 15

CFM/PERSON = 15

SQ FT x

CFM/SQ FT =

CFM VENTILATION

INFIL-TRATION

SWINGING REVOLVING DOORS

PEOPLE x

CFM/PERSON =

OPEN DOORS

DOORS x

CFM/DOOR =

EXHAUST FAN

CRACK

FEET x

CFM/FT =

CFM INFILTRATION

CFM OUTDOOR AIR THRU APPARATUS

ESHF

APPARATUS DEWPOINT

EFFECTIVE SENS HEAT FACTOR

EFFECTIVE ROOM SENS. HEAT

EFFECTIVE ROOM TOTAL HEAT

ADP

INDICATED ADP =

F

SELECTED ADP =

F

TEMP. RISE

DEHUMIDIFIED AIR QUANTITY

(1-) BF x (T_{RM} - T_{ADP}) F =

CFM

EFFECTIVE ROOM SENS. HEAT

CFM

OUTLET TEMP. DIFF.

ROOM SENS. HEAT

CFM

FIRM-OUTLET AIR

SUPPLY AIR QUANTITY

SUPPLY CFM

ROOM SENS. HEAT

CFM

DESIRE DIFF

CFM

CFM

CFM

RESULTING ENT & LVG CONDITIONS AT APPARATUS

EDB

T_{RM} F +

CFM

(T_{OA} - T_{RM}) F = T_{EOB}

LDB

T_{ADP} F +

BF x (T_{EOB} - T_{ADP}) F = T_{LOB}

FROM PSYCH. CHART: T_{WB} F, T_{LB} F

NOTES

215 CFM TOTAL

15 CFM O.A.

4,570 BTUH

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

COMPUTED BY J C CASE
 CHECKED BY _____
 DATE 11-12-1987
 REV. _____ 19__

LBL - LIFE SCIENCES

COOLING LOAD

BLDG #6 LAB (EAST)

PROJECT 16-199-69SHEET NO. 10 OF 56 SHEETS

Space Used For
 Size 23 * 20 = 460 SQ FT * 14 = 6440 CU FT

Estimate for LOCAL TIME Peak Load LOCAL TIME
 SUN TIME SUN TIME

ITEM AREA OR QUANTITY SUN GAIN OR TEMP. DIFF. FACTOR BTU/HOUR

SOLAR GAIN-GLASS
 Glass SQ FT * *
 Glass SQ FT * *
 Glass SQ FT * *
 Glass SQ FT * *
 Skylight SQ FT * *

SOLAR & TRANS. GAIN-WALLS & ROOF
 Wall SQ FT * *
 Wall SQ FT * *
 Wall SQ FT * *
 Wall SQ FT * *
 Roof-Sun 460 SQ FT * 37 * 05 850
 Roof-Shaded SQ FT * *

TRANS. GAIN-EXCEPT WALLS & ROOF
 All Glass SQ FT * *
 Partition SQ FT * *
 Ceiling SQ FT * *
 Floor SQ FT * *

Infiltration CFM * * 1.08

INTERNAL HEAT
 People 3 PEOPLE * 315 950
 Power 2.5 W/5F HP-OKW * 3.413 3830
 Lights 1.0 W/5F WATTS * 3.413 1570
 Appliances, Etc. *
 Additional Heat Gains *

SUB TOTAL 7240
 Storage SQ FT * * (-) 1
 SUB TOTAL

Safety Factor 5 % 360
 ROOM SENSIBLE HEAT 7650

SUPPLY DUCT HEAT GAIN % LEAK. LOSS % FAN %
 Outdoor Air CFM * F * BF * 1.08

EFFECTIVE ROOM SENSIBLE HEAT 7650

LATENT HEAT
 Infiltration CFM * GR/LB * 0.68
 People PEOPLE *
 Steam LB/HR * 1050
 Appliances, Etc.
 Additional Heat Gains
 Vapor Trans. SQ * 1/100 * GR/LB *

SUB TOTAL
 Safety Factor %

ROOM LATENT HEAT
 SUPPLY DUCT LEAKAGE LOSS %
 Outdoor Air CFM * GR/LB * BF * 0.68

EFFECTIVE ROOM LATENT HEAT
 EFFECTIVE ROOM TOTAL HEAT 825

OUTDOOR AIR HEAT
 Sensible 825 CFM * 9 F * (1 - 0 BF) * 1.08 8020
 Latent: CFM * GR/LB * (1 - BF) * 0.68

RETURN DUCT HEAT GAIN % LEAK. GAIN % HP PUMP % DEMUM. & PIPE LOSS %
 SUB TOTAL

GRAND TOTAL HEAT 15670

Hours of Operation
 CONDITIONS DB WB % RH DP GR/LB
 OUTDOOR (OA) 35
 ROOM (RM) 76
 DIFFERENCE 9

OUTDOOR AIR
 VENTILATION PEOPLE * CFM/PERSON =
 SQ FT * CFM/SQ FT =
 CFM VENTILATION 3

SWINGING REVOLVING DOORS PEOPLE * CFM/PERSON =
 OPEN DOORS DOORS * CFM/DOOR =
 EXHAUST FAN
 CRACK FEET * CFM/FT =
 CFM INFILTRATION 1

CFM OUTDOOR AIR THRU APPARATUS 3

APPARATUS DEWPOINT
 ESHF EFFECTIVE SENS HEAT FACTOR = EFFECTIVE ROOM SENS. HEAT / EFFECTIVE ROOM TOTAL HEAT =

ADP INDICATED ADP = F SELECTED ADP = F

DEHUMIDIFIED AIR QUANTITY
 TEMP RISE (1 - BF) * (T_{RM} - F - T_{ADP} - F) = F
 DEHUM. CFM 1.08 * F TEMP. RISE

OUTLET TEMP. DIFF. 1.08 * ROOM SENS. HEAT = F (RM-OUTLET AIR)
 CFM_{DA}

SUPPLY AIR QUANTITY
 SUPPLY CFM 7650 ROOM SENS. HEAT = 355 CFM_{SA}
 1.08 * 20 F DESIRED DIFF

BYPASS CFM CFM_{SA} - CFM_{DA} = CFM_{BA}

RESULTING ENT & LVG CONDITIONS AT APPARATUS
 EDB T_{RM} * F + CFM_{DA} * (T_{OA} - F - T_{RM} - F) = T_{EDB} * F
 CFMT

LOB T_{ADP} * F + BF * (T_{EDB} - F - T_{ADP} - F) = T_{LOB} * F
 FROM PSYCH. CHART: T_{EDB} * F, T_{LOB} * F

NOTES

Hood Requirements =

1000 CFM

Room Requirements =

825 CFM

15,670 BTUH

9-19

* IF THIS IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
 WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
 WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

COMPUTED BY J CASE
 CHECKED BY _____
 DATE 11-12-1989
 REV. _____ 19 _____

LBL - LIFE SCIENCES
COOLING LOADS
BLDG 6, VERTICAL BEAM

PROJECT 16-199-09
 SHEET NO. 11 OF 56 SHEETS

Space Used For
 Size 17 x 16 = 272 SQ FT x 14 = 3808 CU FT

Estimate for LOCAL TIME SUN TIME Peak Load LOCAL TIME SUN TIME

ITEM AREA OR QUANTITY SUN GAIN OR TEMP. DIFF. FACTOR BTU/HOUR

SOLAR GAIN-GLASS
 Glass SQ FT x x
 Glass SQ FT x x
 Glass SQ FT x x
 Glass SQ FT x x
 Skylight SQ FT x x

SOLAR & TRANS. GAIN-WALLS & ROOF
 Wall SQ FT x x
 Wall SQ FT x x
 Wall SQ FT x x
 Wall SQ FT x x
 Roof-Sun 272 SQ FT x 37 x 05 500
 Roof-Shaded SQ FT x x

TRANS. GAIN-EXCEPT WALLS & ROOF
 All Glass SQ FT x x
 Partition SQ FT x x
 Ceiling SQ FT x x
 Floor SQ FT x x
 Infiltration CFM x x 1.08

INTERNAL HEAT
 People 2 PEOPLE x 315 630
 Power 3.0 W/SF HP OR KW x 2790
 Lights 1.0 W/SF WATTS x 3.4 x 730
 Appliances, Etc. x
 Additional Heat Gains x

SUB TOTAL 4350
 Storage SQ FT x x (-)
 SUB TOTAL
 Safety Factor 5 % 240

ROOM SENSIBLE HEAT 5090

SUPPLY DUCT HEAT GAIN % + LEAK. LOSS % + H. P. %

Outdoor Air CFM x F x BF x 1.08

EFFECTIVE ROOM SENSIBLE HEAT

LATENT HEAT
 Infiltration CFM x GR/LB x 0.68
 People PEOPLE x
 Steam LB/HR x 1050
 Appliances, Etc.
 Additional Heat Gains

Vapor Trans. SQ x 1/100 x GR/LB x

SUB TOTAL

Safety Factor %

ROOM LATENT HEAT

SUPPLY DUCT LEAKAGE LOSS %

Outdoor Air CFM x GR/LB x BF x 0.68

EFFECTIVE ROOM LATENT HEAT

EFFECTIVE ROOM TOTAL HEAT

OUTDOOR AIR HEAT
 Sensible: 235 CFM x 9 F x (1-0) BF x 1.08 2280
 Latent: CFM x GR/LB x (1-0) BF x 0.68

RETURN DUCT HEAT GAIN % + LEAK. GAIN % + PUMP % + PIPE LOSS %
 SUB TOTAL
 GRAND TOTAL HEAT 7370

Hours of Operation
 CONDITIONS DB WB % RH DP GR/LB
 OUTDOOR (OA) 83
 ROOM (RM) 76
 DIFFERENCE 9

OUTDOOR AIR
 VENTILATION PEOPLE x CFM/PERSON =
 SQ FT x CFM/SQ FT =
 CFM VENTILATION

SWINGING REVOLVING DOORS PEOPLE x CFM/PERSON =
 OPEN DOORS DOORS x CFM/DOOR =
 EXHAUST FAN
 CRACK FEET x CFM/FT =
 CFM INFILTRATION

CFM OUTDOOR AIR THRU APPARATUS

APPARATUS DEWPOINT
 ESHF EFFECTIVE SENS HEAT FACTOR EFFECTIVE ROOM SENS. HEAT EFFECTIVE ROOM TOTAL HEAT =

ADP INDICATED ADP = F SELECTED ADP = F

DEHUMIDIFIED AIR QUANTITY
 TEMP RISE (1- BF) x (TRM - F - TADP - F) = F
 DEHUM. CFM EFFECTIVE ROOM SENS. HEAT = CFM_{OA}
 1.08 x F TEMP. RISE

OUTLET TEMP. DIFF. ROOM SENS. HEAT = F (RM-OUTLET AIR)
 1.08 x CFM_{OA}

SUPPLY AIR QUANTITY
 SUPPLY CFM 5090 ROOM SENS. HEAT = 235 CFM_{SA}
 1.08 x 20 F DESIRED DIFF
 BYPASS CFM CFM_{SA} - CFM_{OA} = CFM_{BA}

RESULTING ENT & LVG CONDITIONS AT APPARATUS
 EDB TRM - F + CFM_{OA} x (TOA - F - TRM - F) = T_{EDB} - F
 CFM_T
 LDB T_{ADP} - F + BF x (T_{EDB} - F - T_{ADP} - F) = T_{LDB} - F
 FROM PSYCH. CHART: T_{WB} - F, T_{LB} - F

NOTES

235 CFM O.A.

7370 BTUH

9-20

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

12

COMPUTED BY J C CASE
 CHECKED BY _____
 DATE 11-12-1957
 REV. _____ 19 _____

LBL - LIFE SCIENCES
COOLING LOAD
BLDG #6, DARK ROOM

PROJECT 16-199-09
 SHEET NO. 12 OF 56 SHEETS

Space Used For
 Size 6 x 10 = 60 SQ FT x 14 = 840 CU FT

ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
------	------------------	-------------------------	--------	----------

SOLAR GAIN-GLASS

Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Skylight	SQ FT x	x		

SOLAR & TRANS. GAIN-WALLS & ROOF

Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Roof-Sun	<u>60</u> SQ FT x <u>3.7</u>	<u>.05</u>		<u>110</u>
Roof-Shaded	SQ FT x	x		

TRANS. GAIN-EXCEPT WALLS & ROOF

All Glass	SQ FT x	x		
Partition	SQ FT x	x		
Ceiling	SQ FT x	x		
Floor	SQ FT x	x		
Infiltration	CFM x	x	1.08	

INTERNAL HEAT

People	PEOPLE x	<u>315</u>		<u>520</u>
Power	<u>1.0 W/SE</u> HP OR KW x			<u>205</u>
Lights	<u>1.0 W/SE</u> WATTS x <u>3.4</u> x			<u>205</u>
Appliances, Etc.	x			
Additional Heat Gains	x			
SUB TOTAL				<u>930</u>
Storage	SQ FT x	x (-)		
SUB TOTAL				<u>40</u>
Safety Factor	<u>5</u> %			<u>40</u>

ROOM SENSIBLE HEAT

SUPPLY DUCT HEAT GAIN	% + LEAK. LOSS	% + H. P.	%	
Outdoor Air	CFM x	F x	BF x 1.08	
EFFECTIVE ROOM SENSIBLE HEAT				<u>930</u>

LATENT HEAT

Infiltration	CFM x	GR/LB x 0.68		
People	PEOPLE x			
Steam	LB/HR x 1050			
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.	SQ x 1/100 x	GR/LB x		
SUB TOTAL				
Safety Factor	%			

ROOM LATENT HEAT

SUPPLY DUCT LEAKAGE LOSS	%			
Outdoor Air	CFM x	GR/LB x	BF x 0.68	
EFFECTIVE ROOM LATENT HEAT				
EFFECTIVE ROOM TOTAL HEAT				

OUTDOOR AIR HEAT

Sensible:	<u>40</u> CFM x <u>9</u>	F x (1 - 0)	BF x 1.08	<u>390</u>
Latent:	CFM x	GR/LB x (1 - 0)	BF x 0.68	

RETURN DUCT HEAT GAIN

RETURN DUCT HEAT GAIN	% + LEAK. GAIN	% + PUMP	% + PIPE LOSS	%
SUB TOTAL				
GRAND TOTAL HEAT				<u>1270</u>

Estimate for LOCAL TIME SUN TIME Peak Load LOCAL TIME SUN TIME

Hours of Operation

CONDITIONS	DB	WB	% RH	DP	GR/LB
OUTDOOR (OA)	<u>85</u>				
ROOM (RM)	<u>76</u>				
DIFFERENCE	<u>9</u>				

OUTDOOR AIR

VENTILATION PEOPLE x CFM/PERSON =
 SQ FT x CFM/SQ FT =
 CFM VENTILATION

SWINGING REVOLVING DOORS PEOPLE x CFM/PERSON =
 OPEN DOORS DOORS x CFM/DOOR =
 EXHAUST FAN
 CRACK FEET x CFM/FT =
 CFM INFILTRATION

CFM OUTDOOR AIR THRU APPARATUS

APPARATUS DEWPOINT

ESHF EFFECTIVE SENS HEAT FACTOR =
 EFFECTIVE ROOM SENS. HEAT / EFFECTIVE ROOM TOTAL HEAT =

ADP INDICATED ADP = F SELECTED ADP = F

DEHUMIDIFIED AIR QUANTITY

TEMP RISE (1 - BF) x (T_{RM} - T_{ADP}) + T_{ADP} = F
 DEHUM. CFM EFFECTIVE ROOM SENS. HEAT = CFM_{OA}
 1.08 x F TEMP. RISE

OUTLET TEMP. DIFF. ROOM SENS. HEAT = F (RM - OUTLET AIR)
 1.08 x CFM_{OA}

SUPPLY AIR QUANTITY

SUPPLY CFM ROOM SENS. HEAT = 40 CFM_{SA}
 1.08 x 20 F DESIRED DIFF.

BYPASS CFM CFM_{SA} - CFM_{OA} = CFM_{SA}

RESULTING ENT & LVG CONDITIONS AT APPARATUS

EDB T_{RM} F + CFM_{OA} x (T_{OA} - T_{RM}) / CFM_{SA} = T_{EDB}

LDB T_{ADP} F + BF x (T_{EDB} - T_{ADP}) + T_{ADP} = T_{LDB}
 FROM PSYCH. CHART: T_{WB} = F, T_{LWB} = F

NOTES

40 CFM O.A.

1,270 BTUH

9-21

*IF THIS ΔT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
 WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
 WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

COMPUTED BY J C CASE
 CHECKED BY _____
 DATE 11-12-1959
 REV. _____ 19__

LBL. LIFE SCIENCES
COOLING LOAD
BLDG #6, MICROSCOPE RM

PROJECT 16-199-09
 SHEET NO. 13 OF 56 SHEETS

ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
SOLAR GAIN-GLASS				
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Skylight	SQ FT x	x		
SOLAR & TRANS. GAIN-WALLS & ROOF				
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Roof-Sun	<u>60</u> SQ FT x <u>37</u>	x <u>.05</u>		<u>116</u>
Roof-Shaded	SQ FT x	x		
TRANS. GAIN-EXCEPT WALLS & ROOF				
All Glass	SQ FT x	x		
Partition	SQ FT x	x		
Ceiling	SQ FT x	x		
Floor	SQ FT x	x		
Infiltration	CFM x	x 1.08		
INTERNAL HEAT				
People	<u>1</u> PEOPLE x <u>315</u>			<u>320</u>
Power	<u>7.0 W/SF</u> - HP OR KW x			<u>410</u>
Lights	<u>1.0 W/SF</u> WATTS x 3.4 x			<u>210</u>
Appliances, Etc.	x			
Additional Heat Gains	x			
SUB TOTAL				<u>1050</u>
Storage	SQ FT x	x (-)		
SUB TOTAL				
Safety Factor	<u>5</u> %			<u>50</u>
ROOM SENSIBLE HEAT				<u>1100</u>
SUPPLY DUCT HEAT GAIN	% + LEAK. LOSS	% + H. P.	%	
Outdoor Air	CFM x	F x	BF x 1.08	
EFFECTIVE ROOM SENSIBLE HEAT				
LATENT HEAT				
Infiltration	CFM x	GR/LB x 0.68		
People	PEOPLE x			
Steam	LB/HR x 1050			
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.	SQ x 1/100 x	GR/LB x		
SUB TOTAL				
Safety Factor	%			
ROOM LATENT HEAT				
SUPPLY DUCT LEAKAGE LOSS	%			
Outdoor Air	CFM x	GR/LB x	BF x 0.68	
EFFECTIVE ROOM LATENT HEAT				
EFFECTIVE ROOM TOTAL HEAT				
OUTDOOR AIR HEAT				
Sensible:	<u>51</u> CFM x <u>9</u>	F x (1-)	BF x 1.08	<u>500</u>
Latent:	CFM x	GR/LB x (1-)	BF x 0.68	
RETURN DUCT HEAT GAIN	% + LEAK. GAIN	% + PUMP	SUB TOTAL	
GRAND TOTAL HEAT				<u>1600</u>

Estimate for		LOCAL TIME	Peak Load	LOCAL TIME
SUN TIME				
Hours of Operation				
CONDITIONS	DB	WB	% RH	DP
OUTDOOR (OA)	<u>85</u>			
ROOM (RM)	<u>76</u>			
DIFFERENCE	<u>9</u>			
OUTDOOR AIR				
VENTI-LATION	PEOPLE x	CFM/PERSON =		
	SQ FT x	CFM/SQ FT =		
		CFM VENTILATION		
SHING REVOLVING DOORS	PEOPLE x	CFM/PERSON =		
OPEN DOORS	DOORS x	CFM/DOOR =		
EXHAUST FAN				
CRACK	FEET x	CFM/FT =		
		CFM INFILTRATION		
CFM OUTDOOR AIR THRU APPARATUS				
APPARATUS DEWPOINT				
ESHF	EFFECTIVE SENS HEAT FACTOR	EFFECTIVE ROOM SENS. HEAT	EFFECTIVE ROOM TOTAL HEAT =	
ADP	INDICATED ADP =	F	SELECTED ADP =	F
DEHUMIDIFIED AIR QUANTITY				
TEMP RISE	(1-) BF x (TRM -) F - TADP	F		
DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT		CFM _{OA}	
	1.08 x	F TEMP. RISE		
OUTLET TEMP. DIFF.	ROOM SENS. HEAT		F (RM-OUTLET AIR)	
	1.08 x	CFM _{OA}		
SUPPLY AIR QUANTITY				
SUPPLY CFM	ROOM SENS. HEAT		CFM _{SA}	
	1.08 x	20 F DESIRED DIFF		
BYPASS CFM	CFM _{SA} -	CFM _{OA} =	CFM _{SA}	
RESULTING ENT & LVG CONDITIONS AT APPARATUS				
EOB	T _{RM} F +	CFM _{OA} x (T _{OA} - T _{RM}) F	T _{EOB} F	
		CFM _{SA}		
LOB	T _{ADP} F +	BF x (T _{EOB} - T _{ADP}) F	T _{LOB} F	
	FROM PSYCH. CHART: T _{WB} F, T _{WB} F			

NOTES

51 CFM O.A.

1600 BTUH

9-22

*IF THIS &T IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
 WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
 WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

COMPUTED BY JE CASE
 CHECKED BY _____
 DATE 11-12-1987
 REV. _____ 19__

LBL- LIFE SCIENCES
COOLING LOAD
BLDG #6, LAB 15.3-16

PROJECT 16-199-09
 SHEET NO. 14 OF 56 SHEETS

Space Used For
 Size 20 x 20 = 400 SQ FT x 14 = 5600 CU FT

Estimate for LOCAL TIME
 Peak Load LOCAL TIME

ITEM AREA OR QUANTITY SUN GAIN OR TEMP. DIFF. FACTOR BTU/HOUR

SOLAR GAIN-GLASS
 Glass SQ FT x x
 Glass SQ FT x x
 Glass SQ FT x x
 Glass SQ FT x x
 Skylight SQ FT x x

SOLAR & TRANS. GAIN-WALLS & ROOF
 Wall SQ FT x x
 Wall SQ FT x x
 Wall SQ FT x x
 Wall SQ FT x x
 Roof-Sun 400 SQ FT x 37 x .05 740
 Roof-Shaded SQ FT x x

TRANS. GAIN-EXCEPT WALLS & ROOF
 All Glass SQ FT x x
 Partition SQ FT x x
 Ceiling SQ FT x x
 Floor SQ FT x x
 Infiltration CFM x x 1.08

INTERNAL HEAT
 People 6 PEOPLE x 315 1890
 Power 2.5 W/SF x 5600 x 3.415 3415
 Lights 1.0 W/SF x 5600 x 3.415 1370
 Appliances, Etc. x
 Additional Heat Gains x

SUB TOTAL 7410
 Storage SQ FT x x ()
 SUB TOTAL
 Safety Factor 5 % 370
 ROOM SENSIBLE HEAT 7780

SUPPLY DUCT HEAT GAIN % + LEAK. LOSS % + H. P. %
 Outdoor Air CFM x F x BF x 1.08
 EFFECTIVE ROOM SENSIBLE HEAT

LATENT HEAT
 Infiltration CFM x GR/LB x 0.68
 People PEOPLE x
 Steam LB/HR x 1050
 Appliances, Etc.
 Additional Heat Gains
 Vapor Trans. SQ x 1/100 x GR/LB x
 SUB TOTAL
 Safety Factor %

ROOM LATENT HEAT
 SUPPLY DUCT LEAKAGE LOSS %
 Outdoor Air CFM x GR/LB x BF x 0.68
 EFFECTIVE ROOM LATENT HEAT
 EFFECTIVE ROOM TOTAL HEAT

OUTDOOR AIR HEAT
 Sensible: 825 CFM x 9 F x (1-0) BF x 1.08 8020
 Latent: CFM x GR/LB x (1-0) BF x 0.68

RETURN DUCT HEAT GAIN % + LEAK. GAIN % + H. P. %
 SUB TOTAL
 GRAND TOTAL HEAT 15800

Hours of Operation
 CONDITIONS DB WB % RH DP GR/LB
 OUTDOOR (OA)
 ROOM (RM)
 DIFFERENCE

OUTDOOR AIR
 VENTILATION PEOPLE x CFM/PERSON =
 SQ FT x CFM/SQ FT =
 CFM VENTILATION

INFILTRATION
 SWINGING REVOLVING DOORS PEOPLE x CFM/PERSON =
 OPEN DOORS DOORS x CFM/DOOR =
 EXHAUST FAN
 CRACK FEET x CFM/FT =
 CFM INFILTRATION
 CFM OUTDOOR AIR THRU APPARATUS

APPARATUS DEWPOINT
 ESHF EFFECTIVE ROOM SENS. HEAT FACTOR = EFFECTIVE ROOM TOTAL HEAT =
 ADP INDICATED ADP = F SELECTED ADP = F

DEHUMIDIFIED AIR QUANTITY
 TEMP. RISE (1- BF) x (TRM - TADP - F) = F
 DRYUM. CFM EFFECTIVE ROOM SENS. HEAT = CFM_{DA}
 1.08 x F TEMP. RISE
 OUTLET TEMP. DIFF. ROOM SENS. HEAT = F (RM-OUTLET AIR)
 1.08 x CFM_{DA}

SUPPLY AIR QUANTITY
 SUPPLY CFM 7780 ROOM SENS. HEAT = 360 CFM_{SA}
 1.08 x 20 F DESIRED DIFF.
 BYPASS CFM_{SA} - CFM_{DA} = CFM_{BA}

RESULTING ENT & LVG CONDITIONS AT APPARATUS
 EDB TRM F + CFM_{DA} x (T_{OA} - F) - T_{RM} F = T_{EDB} F
 CFMT
 LDB T_{ADP} F + BF x (T_{EDB} - F) - T_{ADP} F = T_{LDB} F
 FROM PSYCH. CHART: T_{EDB} F, T_{LDB} F

NOTES

Hood Requirement Are:
 1000 CFM
 Room Requirements Are:
 825 CFM O.A.
 15,800 BTUH

9-23

*IF THIS ΔT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
 WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
 WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

COMPUTED BY J CASE
 CHECKED BY _____
 DATE 11-12-1987
 REV. _____ 19__

LBL- LIFE SCIENCES

COOLING LOAD

BLDG #6 LAB ROOM (16) + (17)

PROJECT 16-199-09SHEET NO. 15 OF 56 SHEETS

Space Used For
 Size 27 x 20 = 540 SQ FT x 17 = 7260 CU FT

Estimate for LOCAL TIME SUN TIME Peak Load LOCAL TIME SUN TIME

ITEM AREA OR QUANTITY SUN GAIN OR TEMP. DIFF. FACTOR BTU/HOUR

SOLAR GAIN-GLASS

Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Skylight	SQ FT x	x		

SOLAR & TRANS. GAIN-WALLS & ROOF

Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Roof-Sun	<u>540</u> SQ FT x <u>37</u>	x	<u>.05</u>	<u>1000</u>
Roof-Shaded	SQ FT x	x		

TRANS. GAIN-EXCEPT WALLS & ROOF

All Glass	SQ FT x	x		
Partition	SQ FT x	x		
Ceiling	SQ FT x	x		
Floor	SQ FT x	x		
Infiltration	CFM x	x	<u>1.08</u>	

INTERNAL HEAT

People	<u>6</u> PEOPLE x <u>315</u>			<u>1890</u>
Power	<u>2.5 w/KF</u> HP OR KW x <u>3.413</u>			<u>4610</u>
Lights	<u>1.0 w/SF</u> WATTS x <u>3.413</u>			<u>1840</u>
Appliances, Etc.	x			
Additional Heat Gains	x			

SUB TOTAL 7540Storage SQ FT x 1

SUB TOTAL

Safety Factor 5 % 470ROOM SENSIBLE HEAT 9510

SUPPLY DUCT HEAT GAIN % + LEAK. LOSS % + H. P. %

Outdoor Air CFM x F x BF x 1.08

EFFECTIVE ROOM SENSIBLE HEAT

LATENT HEAT

Infiltration CFM x GR/LB x 0.68

People PEOPLE x

Steam LB/HR x 1050

Appliances, Etc.

Additional Heat Gains

Vapor Trans. SQ x 1/100 x GR/LB x

SUB TOTAL

Safety Factor %

ROOM LATENT HEAT

SUPPLY DUCT LEAKAGE LOSS %

Outdoor Air CFM x GR/LB x BF x 0.68

EFFECTIVE ROOM LATENT HEAT

EFFECTIVE ROOM TOTAL HEAT

OUTDOOR AIR HEAT

Sensible 1825 CFM x 9 F x (1 - 0) BF x 1.08 17740

Latent: CFM x GR/LB x (1 - BF) x 0.68

RETURN DUCT HEAT GAIN % + LEAK. GAIN % + H. P. %

SUB TOTAL

GRAND TOTAL HEAT 27550

Hours of Operation

CONDITIONS DB WB %RH DP GR/LB

OUTDOOR (OA) 85ROOM (RM) 76DIFFERENCE 9

OUTDOOR AIR

VENTI- LATION PEOPLE = CFM/PERSON =

SQ FT = CFM/SQ FT =

CFM VENTILATION

SWINGING REVOLVING DOORS PEOPLE = CFM/PERSON =

OPEN DOORS DOORS = CFM/DOOR =

EXHAUST FAN

CRACK FEET = CFM/FT =

CFM INFILTRATION

CFM OUTDOOR AIR THRU APPARATUS

APPARATUS DEWPOINT

ESHF EFFECTIVE SENS HEAT FACTOR = EFFECTIVE ROOM SENS. HEAT / EFFECTIVE ROOM TOTAL HEAT

ADP INDICATED ADP = F SELECTED ADP = F

DEHUMIDIFIED AIR QUANTITY

TEMP RISE (1 - BF) x (T_{RM} - T_{ADP}) = FDEHUM. CFM EFFECTIVE ROOM SENS. HEAT = CFM_{DA}

1.08 x F TEMP. RISE

OUTLET TEMP. DIFF. ROOM SENS. HEAT = CFM_{DA}1.08 x CFM_{DA}

SUPPLY AIR QUANTITY

SUPPLY CFM 9810 ROOM SENS. HEAT = 754 CFM_{SA}1.08 x 20 F DESIRED DIFFBYPASS CFM CFM_{SA} - CFM_{DA} = CFM_{BA}

RESULTING ENT & LVG CONDITIONS AT APPARATUS

EDB T_{RM} F + CFM_{DA} (T_{OA} - T_{RM}) F = T_{EDB} FLDB T_{ADP} F + BF (T_{EDB} - T_{ADP}) F = T_{LDB} FFROM PSYCH. CHART: T_{EDB} F, T_{LDB} F

NOTES

HOOD REQUIREMENTS

2,000 CFM

ROOM REQUIREMENTS ARE:

1,825 CFM

27,550 BTUH

9-24

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

COMPUTED BY J CASE
 CHECKED BY _____
 DATE 11-12 1959
 REV. _____ 19____

LBL - LIFE SCIENCES
COOLING LOAD
BLDG #6 LAB (WEST)

PROJECT 16-149-09
 SHEET NO. 12 OF 58 SHEETS

Space Used For
 Size 20 x 26 = 520 SQ FT x 14 = 7280 CU FT

ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
------	------------------	-------------------------	--------	----------

SOLAR GAIN-GLASS

Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Skylight	SQ FT x	x		

SOLAR & TRANS. GAIN-WALLS & ROOF

Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Roof-Sun	<u>520</u> SQ FT x <u>37</u>	x <u>.05</u>		<u>960</u>
Roof-Shaded	SQ FT x	x		

TRANS. GAIN-EXCEPT WALLS & ROOF

All Glass	SQ FT x	x		
Partition	SQ FT x	x		
Ceiling	SQ FT x	x		
Floor	SQ FT x	x		
Infiltration	CFM x	x 1.08		

INTERNAL HEAT

People	<u>6</u> PEOPLE x <u>315</u>			<u>1890</u>
Power	<u>25 WSE</u> HP OR KW x <u>3.413</u>			<u>440</u>
Lights	<u>10 WSE</u> WATTS x <u>3.413</u>			<u>1770</u>
Appliances, Etc.	x			
Additional Heat Gains	x			
SUB TOTAL				<u>4100</u>

ROOM SENSIBLE HEAT

Storage	SQ FT x	x (-)		
SUB TOTAL				<u>4100</u>
Safety Factor	<u>5 %</u>			<u>450</u>
ROOM SENSIBLE HEAT				<u>4550</u>

SUPPLY DUCT HEAT GAIN

SUPPLY DUCT HEAT GAIN	% LEAK. LOSS	PAN % + H. P.	%
Outdoor Air	CFM x	F x	BF x 1.08

EFFECTIVE ROOM SENSIBLE HEAT

Infiltration	CFM x	GR/LB x 0.68		
People	PEOPLE x			
Steam	LB/HR x 1050			
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.	SQ x 1/100 x	GR/LB x		
SUB TOTAL				
Safety Factor	%			
ROOM LATENT HEAT				

SUPPLY DUCT LEAKAGE LOSS

Outdoor Air	CFM x	GR/LB x	BF x 0.68	
EFFECTIVE ROOM LATENT HEAT				
EFFECTIVE ROOM TOTAL HEAT				

OUTDOOR AIR HEAT

Sensible:	<u>1575</u> CFM x <u>9</u> F x (1 - <u>0</u>)	BF x 1.08		<u>15310</u>
Latent:	CFM x	GR/LB x (1 - <u>0</u>)	BF x 0.68	

RETURN DUCT HEAT GAIN

RETURN DUCT HEAT GAIN	% LEAK. GAIN	HP % + PIPE LOSS	%	
SUB TOTAL				
GRAND TOTAL HEAT				<u>24920</u>

Estimate for LOCAL TIME SUN TIME Peak Load LOCAL TIME SUN TIME

Hours of Operation

CONDITIONS	DB	WB	% RH	DP	GR/LB
OUTDOOR (OA)	<u>85</u>				
ROOM (RM)	<u>76</u>				
DIFFERENCE	<u>9</u>				

OUTDOOR AIR

VENTILATION PEOPLE = _____ CFM/PERSON = _____
 SQ FT = _____ CFM/SQ FT = _____
 CFM VENTILATION = _____

SWINGING REVOLVING DOORS PEOPLE = _____ CFM/PERSON = _____
 OPEN DOORS DOORS = _____ CFM/DOOR = _____
 INFILTRATION EXHAUST FAN _____
 CRACK FEET = _____ CFM/FT = _____
 CFM INFILTRATION = _____

CFM OUTDOOR AIR THRU APPARATUS = _____

APPARATUS DEWPOINT

ESHF EFFECTIVE SENS HEAT FACTOR = $\frac{\text{EFFECTIVE ROOM SENS. HEAT}}{\text{EFFECTIVE ROOM TOTAL HEAT}}$ = _____

ADP INDICATED ADP = _____ F SELECTED ADP = _____ F

DEHUMIDIFIED AIR QUANTITY

TEMP RISE (1 - _____ BF) x (T_{RM} - T_{ADP} - F) = _____ F

DEHUM. CFM EFFECTIVE ROOM SENS. HEAT = _____ CFM_{OA}
 1.08 x F TEMP. RISE

OUTLET TEMP. DIFF. ROOM SENS. HEAT = _____ F (RM-OUTLET AIR)
 1.08 x CFM_{OA}

SUPPLY AIR QUANTITY

SUPPLY CFM ROOM SENS. HEAT = 440 CFM_{OA}
 1.08 x 20 F DESIRED DIFF

BYPASS CFM CFM_{OA} = _____ CFM_{OA} = _____ CFM_{OA}

RESULTING ENT & LVG CONDITIONS AT APPARATUS

EOB T_{RM} F + $\frac{\text{CFM}_{OA} (T_{OA} - T_{RM})}{\text{CFM}}$ = T_{EOB} F

LDB T_{ADP} F + $\frac{\text{BF} (T_{EOB} - T_{ADP})}{\text{CFM}}$ = T_{LOB} F

FROM PSYCH. CHART: T_{EOB} F, T_{LOB} F

NOTES

HOOD REQUIREMENTS ARE
 1,750 CFM

Room REQUIREMENTS ARE
 1,575 CFM

24,820 BTUH

9-25
 *IF THIS ΔT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY
 SUPPLY AIR QUANTITY FORMULA.
 WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
 WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

17

COMPUTED BY J CASE
 CHECKED BY _____
 DATE 11-12-1969
 REV. _____ 19__

LEL - LIFE SCIENCES
COOLING LOAD
BDG #6 CORRIDOR

PROJECT K-199-09
 SHEET NO. 17 OF 56 SHEETS

Space Used For _____
 Size 6 x 150 = 900 SQ FT x 14 = 12,600 CU FT

ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
------	------------------	-------------------------	--------	----------

SOLAR GAIN-GLASS

Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Skylight	SQ FT x	x		

SOLAR & TRANS. GAIN-WALLS & ROOF

Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Roof-Sun	SQ FT x	<u>57</u> x <u>05</u>		<u>1670</u>
Roof-Shaded	SQ FT x	x		

TRANS. GAIN-EXCEPT WALLS & ROOF

All Glass	SQ FT x	x		
Partition	SQ FT x	x		
Ceiling	SQ FT x	x		
Floor	SQ FT x	x		
Infiltration	CFM x	x	1.08	

INTERNAL HEAT

People	PEOPLE x			
Power	HP OR KW x			
Lights	<u>10 W/FT</u> x <u>3.4</u> x <u>3.4</u>			<u>3570</u>
Appliances, Etc.	x			
Additional Heat Gains	x			

SUB TOTAL 4740Storage SQ FT x 1SUB TOTAL 240Safety Factor 5 %ROOM SENSIBLE HEAT 4980

SUPPLY DUCT HEAT GAIN % + LEAK. LOSS % + H. P. %

Outdoor Air CFM x F x BF x 1.08EFFECTIVE ROOM SENSIBLE HEAT 4980

LATENT HEAT

Infiltration CFM x GR/LB x 0.68

People PEOPLE x

Steam LB/HR x 1050

Appliances, Etc.

Additional Heat Gains

Vapor Trans. SQ x 1/100 x GR/LB x

SUB TOTAL

Safety Factor %

ROOM LATENT HEAT

SUPPLY DUCT LEAKAGE LOSS %

Outdoor Air CFM x GR/LB x BF x 0.68

EFFECTIVE ROOM LATENT HEAT

EFFECTIVE ROOM TOTAL HEAT 8750

OUTDOOR AIR HEAT

Sensible: 900 CFM x 9 x (1 - 0) x BF x 1.08Latent: CFM x GR/LB x (1 - 0) x BF x 0.68

RETURN DUCT HEAT GAIN % + LEAK. GAIN % + PUMP % + PIPE LOSS %

SUB TOTAL

GRAND TOTAL HEAT 13730

Estimate for _____ LOCAL TIME _____ Peak Load _____ LOCAL TIME _____

Hours of Operation

CONDITIONS	DB	WB	%RH	DP	GR/LB
OUTDOOR (OA)	<u>85</u>				
ROOM (RM)	<u>76</u>				
DIFFERENCE	<u>9</u>				

OUTDOOR AIR

VENTIL. LATION PEOPLE x CFM/PERSON = _____
 SQ FT x CFM/SQ FT = _____
 CFM VENTILATION 2

BRINGING REVOLVING DOORS PEOPLE x CFM/PERSON = _____

OPEN DOORS DOORS x CFM/DOOR = _____

EXHAUST FAN

CRACK FEET x CFM/FT = _____

CFM INFILTRATION 2CFM OUTDOOR AIR THRU APPARATUS 2

APPARATUS DEWPOINT

ESHF EFFECTIVE SENS. HEAT FACTOR = EFFECTIVE ROOM SENS. HEAT / EFFECTIVE ROOM TOTAL HEAT = _____

AOP INDICATED AOP = _____ F SELECTED AOP = _____ F

DEHUMIDIFIED AIR QUANTITY

TEMP. RISE $(1 - \text{BF}) \times (T_{RM} - T_{AOP}) + T_{AOP} - T_{DB}$ = _____ FDEHUM. CFM EFFECTIVE ROOM SENS. HEAT / $1.08 \times F_{TEMP. RISE}$ = _____ CFM_{DA}OUTLET TEMP. DIFF. ROOM SENS. HEAT / $1.08 \times$ = _____ CFM_{DA}

FIRM-OUTLET AIR

SUPPLY AIR QUANTITY

SUPPLY CFM 4980 ROOM SENS. HEAT = 730 CFM_{SA}BYPASS CFM 1.08 x 20 F DESIRED DIFF = _____ CFM_{SA}CFM_{SA} = _____ CFM_{DA} = _____ CFM_{SA}

RESULTING ENT & LVG CONDITIONS AT APPARATUS

EOD $T_{RM} - F + \frac{CFM_{DA}}{CFM_{SA}} (T_{OA} - T_{RM}) + T_{AOP} - F = T_{EOD} - F$ LDB $T_{AOP} - F + \frac{CFM_{DA}}{CFM_{SA}} (T_{EOD} - T_{AOP}) + T_{AOP} - F = T_{LDB} - F$ FROM PSYCH. CHART: $T_{EOD} - F, T_{LDB} - F$

NOTES

900 CFM O.A.

13,730 BTUH

9-26

*IF THIS ΔT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
 *WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
 *WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

COMPUTED BY: RJB
CHECKED BY: BWJ
DATE: 11-12-89
REV:

LBL - LIFE SCIENCES
MECHANICAL DESIGN
CRITERIA

PROJECT: 16-199-09-I

SHEET NO. 18 OF 56 SHEETS

BUILDING 80

WEATHER DATA:

From ASHRAE Fundamentals, 1985 Weather Data

	<u>SUMMER</u>	<u>WINTER</u>
Laboratories	85°F DB/65°F WB	34°F DB
Other	80°F DB/63°F WB	34°F DB

INSIDE DESIGN TEMPERATURES

Summer: 76°F

Winter 72°F DB

U - VALUES

<u>ROOF</u>	<u>(R) WINTER</u>	<u>(R) SUMMER</u>
O.A.	0.17	0.25
3 in. lightweight concrete	2.58	2.58
1 in. fiberglass	4.00	4.00
I.A.	<u>0.92</u>	<u>0.92</u>
	7.67	7.75
U = 1/12 (BTU/ft ² -HR-°F)	0.12	0.12

COMPUTATION SHEET

COMPUTED BY: RJB
CHECKED BY: BWJ
DATE: 11-12-89
REV:

LBL - LIFE SCIENCES
MECHANICAL DESIGN
CRITERIA

PROJECT: 16-199-09-I

SHEET NO. 19 OF 56 SHEETS

BUILDING 80

<u>WALLS</u>	<u>(R) WINTER</u>	<u>(R) SUMMER</u>
O.A.	0.170	0.250
Metal siding	0.008	0.008
Airspace	0.680	0.680
1-1/2-in. fiberglass	6.000	6.000
Metal siding	0.008	0.008
I.A.	<u>0.680</u>	<u>0.680</u>
	7.600	7.600
U = 1/R (BTU/ft ² -HR-°f)	0.13	

Windows:

Single pane with emittance 1.02

COMPUTATION SHEET

COMPUTED BY: RJB
CHECKED BY: BWJ
DATE: 11-12-89
REV:

LBL - LIFE
SCIENCES CENTER
CDR

PROJECT: 16-199-09-I

SHEET NO. 20 OF 56 SHEETS

BUILDING 80

CLTD FOR WALLS

From ASHRAE 1985 Fundamentals
Tables 6, 7, 8 Group G, Walls, at 1600 hours, and
Table 9, Latitude Month May/July

	<u>CLTD</u>	<u>LM</u>
N	24	0
NE	26	0
E	29	0
SE	30	0
S	37	1
SW	63	0
W	67	0
NW	47	0

K = 1 Assume dark coloring, industrial area.

T_r = 76°F indoor design temperature

T_o = 85°F outdoor design temperature

Therefore, the corrected LLTD shall be (per ASHRAE):

$$\begin{aligned}\text{CLTD corr.} &= [(\text{CLTD} + \text{LM}) \times K + (78 - T_r) + (T_o - 85)] \\ &= [(\text{CLTD} + \text{LM}) \times 1 + 2]\end{aligned}$$

COMPUTATION SHEET

COMPUTED BY: RJB
CHECKED BY: BWJ
DATE: 11-12-89
REV:

LBL - LIFE
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PROJECT: 16-199-09-I

SHEET NO. 21 OF 56 SHEETS

BUILDING 80

	<u>CLTD</u>	<u>CLTD CORR.</u>
N	24	26
NE	26	28
E	29	31
SE	30	32
S	37	40
SW	63	65
W	67	69
NW	47	49

ROOF CLTD

1985 Fundamentals, Chapter 26, Table 5

Roof Type 4, with suspended ceiling

At 1600 hours

CLTD = 43

LM = 1

f = 1 (no ceiling space ventilation)

K = 1 dark color

CLTD corr. = $[(CLTD + LM) \times K + (78-76) + (85-85)]f$
= 46

GLASS CLTD

Page 26.14, ASHRAE Fundamentals, at 1600 hours CLTD = 14

COMPUTATION SHEET

COMPUTED BY: RJB
CHECKED BY: BWJ
DATE: 11-12-89
REV:

LBL - LIFE
SCIENCES CENTER
SHGF

PROJECT: 16-199-09-I

SHEET NO. 22 OF 56 SHEETS

BUILDING 80

MAXIMUM SHGF FOR FENESTRATION

From Chapter 26, Table 11, MSHGK at 40°N
In TU Y

	<u>MSGF</u>	<u>CLF (MED. CONST. FOAM)</u> <u>AT 1600</u>
N	38	0.74
NE/NW	163	0.26/0.42
E/W	216	0.26/0.50
SE/SW	170	0.33/0.58
S	109	0.47

Assume shading coefficient of 0.80.

COMPUTATION SHEET

COMPUTED BY 253
CHECKED BY BW
DATE 11/12/1987
REV. 19

BUILDING 80
LBC-LIFE SCIENCES
Cooling Load
MICROSCOPY (SE corner)

PROJECT 16-199-09
SHEET NO. 23 OF 56 SHEETS

Space Used For				
Size	18	x	15	= 270 SQ FT x 9 1/2' = 2565 CU FT
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
SOLAR GAIN-GLASS				
Glass	70	SQ FT x 216	x .26	3 931
Glass	70	SQ FT x 109	x .47	3 386
Glass		SQ FT x	x	
Glass		SQ FT x	x	
Skylight		SQ FT x	x	
SOLAR & TRANS. GAIN-WALLS & ROOF				
Wall	80	SQ FT x 31	x .13	322
Wall	110	SQ FT x 40	x .13	572
Wall		SQ FT x	x	
Wall		SQ FT x	x	
Roof-Sun	270	SQ FT x 46	x .12	1 490
Roof-Shaded		SQ FT x	x	
TRANS. GAIN-EXCEPT WALLS & ROOF				
All Glass	190	SQ FT x 14	x 1.02	1 999
Partition		SQ FT x	x	
Ceiling		SQ FT x	x	
Floor		SQ FT x	x	
Infiltration		CFM x	x 1.08	
INTERNAL HEAT				
People	1	PEOPLE x 230		230
Power	1.5 (3.4)	HP OR KW x 270		459
Lights	1.5	WATTS x 3.4 x 270		1 377
Appliances, Etc.		x		
Additional Heat Gains		x		
SUB TOTAL				
Storage		SQ FT x	x (-)	
SUB TOTAL				
Safety Factor	5 %			13 966
ROOM SENSIBLE HEAT				
14 664				
SUPPLY DUCT HEAT GAIN				
Outdoor Air	15	CFM x 4	F x .1 BF x 1.08	6
EFFECTIVE ROOM SENSIBLE HEAT				
14 670				
LATENT HEAT				
Infiltration		CFM x	GR/LB x 0.68	
People	1	PEOPLE x	190	190
Steam		LB/HR x 1050		
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.		SQ x 1/100 x	GR/LB x	
SUB TOTAL				
Safety Factor	5 %			10
ROOM LATENT HEAT				
200				
SUPPLY DUCT LEAKAGE LOSS				
Outdoor Air		CFM x	GR/LB x BF x 0.68	
EFFECTIVE ROOM LATENT HEAT				
200				
EFFECTIVE ROOM TOTAL HEAT				
14 870				
OUTDOOR AIR HEAT				
Sensible:	15	CFM x 4	F x (1 - 0.1) BF x 1.08	58
Latent:		CFM x	GR/LB x (1 - 0.1) BF x 0.68	
RETURN DUCT HEAT GAIN				
Return Duct		HP	SUB TOTAL	
HEAT GAIN	% + LEAK. GAIN	% + PUMP	% + PIPE LOSS	%
GRAND TOTAL HEAT				
14 928				

Estimate for		LOCAL TIME SUN TIME	Peak Load	LOCAL TIME SUN TIME
Hours of Operation				
CONDITIONS	DB	WB	% RH	DP
OUTDOOR (OA)	80			
ROOM (RM)	76			
DIFFERENCE	4			
OUTDOOR AIR				
VENTI- LATION	1	PEOPLE x 15	CFM/PERSON = 15	
		SQ FT x	CFM/SQ FT =	
			CFM VENTILATION	
INFIL- TRATION				
SWINGING REVOLVING DOORS		PEOPLE x	CFM/PERSON =	
OPEN DOORS		DOORS x	CFM/DOOR =	
EXHAUST FAN				
CRACK		FEET x	CFM/FT =	
			CFM INFILTRATION	
CFM OUTDOOR AIR THRU APPARATUS				
APPARATUS DEWPOINT				
ESHF	EFFECTIVE SENS HEAT FACTOR	EFFECTIVE ROOM SENS. HEAT		
		EFFECTIVE ROOM TOTAL HEAT		
				.98
ADP	INDICATED ADP =	F	SELECTED ADP =	F
DEHUMIDIFIED AIR QUANTITY				
TEMP RISE	(1 -	BF) x (T _{RM} -	T _{ADP} -	F) =
DEHUM. CFM		EFFECTIVE ROOM SENS. HEAT		CFM _D
	1.08 x	F TEMP. RISE		
OUTLET TEMP. DIFF.		ROOM SENS. HEAT		F (RM - OUTLET AIR)
	1.08 x	CFM _{OA}		
SUPPLY AIR QUANTITY				
SUPPLY CFM	14664	ROOM SENS. HEAT		CFM _{SA}
	1.08 x	20 F	DESIRED DIFF	
BYPASS CFM		CFM _{SA} -	CFM _{OA} =	CFM _{BA}
RESULTING ENT & LVO CONDITIONS AT APPARATUS				
EDB	T _{RM} -	F +	CFM _{OA} x (T _{OA} -	T _{RM} -
			CFM _I	F) = T _{EOB} -
LDB	T _{ADP} -	F +	BF x (T _{EOB} -	T _{ADP} -
			F) = T _{LDB} -	F
FROM PSYCH. CHART: T _{EWB} -				

NOTES

ASSUME WINDOWS ARE 9'4"

HIGH FROM ELEVATIONS DRAWING

SHEET A-3

ASSUME OUTSIDE WALLS ARE 10 FT.

HIGH FROM ELEVATIONS DRAWING

SHEET A-3

9-32

*IF THIS AT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.

WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.

WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

BUILDING 80

LBL - LIFE SCIENCES

COOLING LOAD

MICROSCOPY (1 N. OF SE CORNER)

COMPUTED BY RJB
CHECKED BY BWJ
DATE 11/12/87 1987
REV. _____ 19____

PROJECT 16-199-09
SHEET NO. 24 OF 36 SHEETS

Space Used For
Size 16 1/2 x 13 1/2 = 223 SQ FT x 9 1/2 = 2116 CU FT

ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
------	------------------	-------------------------	--------	----------

SOLAR GAIN-GLASS

Glass	<u>70</u> SQ FT x <u>216</u> x <u>.26</u>			<u>3931</u>
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Skylight	SQ FT x	x		

SOLAR & TRANS. GAIN-WALLS & ROOF

Wall	<u>95</u> SQ FT x <u>31</u> x <u>.13</u>			<u>383</u>
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Roof-Sun	<u>223</u> SQ FT x <u>46</u> x <u>.12</u>			<u>1230</u>
Roof-Shaded	SQ FT x	x		

TRANS. GAIN-EXCEPT WALLS & ROOF

All Glass	<u>70</u> SQ FT x <u>14</u> x <u>1.02</u>			<u>1000</u>
Partition	SQ FT x	x		
Ceiling	SQ FT x	x		
Floor	SQ FT x	x		
Infiltration	CFM x	x	<u>1.08</u>	

INTERNAL HEAT

People	<u>1</u> PEOPLE x <u>230</u>			<u>230</u>
Power	<u>563.4</u> HP OR KW x <u>223</u>			<u>379</u>
Lights	<u>1.5</u> WATTS x <u>3.4</u> x <u>223</u>			<u>1137</u>
Appliances, Etc.	x			
Additional Heat Gains	x			

SUB TOTAL

Storage	SQ FT x	x (-)		
SUB TOTAL				<u>8290</u>
Safety Factor	<u>5</u> %			<u>915</u>

ROOM SENSIBLE HEAT

SUPPLY DUCT HEAT GAIN	% + LEAK. LOSS	% + H. P.	%	
Outdoor Air	<u>15</u> CFM x <u>4</u> F x <u>1</u> BF x <u>1.08</u>			<u>6</u>
EFFECTIVE ROOM SENSIBLE HEAT				<u>8711</u>

LATENT HEAT

Infiltration	CFM x	GR/LB x <u>0.68</u>		
People	<u>1</u> PEOPLE x <u>190</u>			<u>190</u>
Steam	LB/HR x <u>1050</u>			
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.	SQ x <u>1/100</u> x	GR/LB x		
SUB TOTAL				<u>190</u>
Safety Factor	<u>5</u> %			<u>19</u>

ROOM LATENT HEAT

SUPPLY DUCT LEAKAGE LOSS	%			
Outdoor Air	CFM x	GR/LB x	BF x <u>0.68</u>	
EFFECTIVE ROOM LATENT HEAT				<u>200</u>

EFFECTIVE ROOM TOTAL HEAT

EFFECTIVE ROOM TOTAL HEAT				<u>8911</u>
----------------------------------	--	--	--	-------------

OUTDOOR AIR HEAT

Sensible:	<u>15</u> CFM x <u>4</u> F x <u>1</u> BF x <u>1.08</u>			<u>58</u>
Latent:	CFM x	GR/LB x <u>1</u>	BF x <u>0.68</u>	

RETURN DUCT HEAT GAIN

RETURN DUCT HEAT GAIN	% + LEAK. GAIN	% + PUMP	% + PIPE LOSS	%
GRAND TOTAL HEAT				<u>8769</u>

Estimate for LOCAL TIME SUN TIME Peak Load LOCAL TIME SUN TIME

Hours of Operation

CONDITIONS	DB	WB	% RH	DP	GR/LB
OUTDOOR (OA)	<u>80</u>				
ROOM (RM)	<u>76</u>				
DIFFERENCE	<u>4</u>				

OUTDOOR AIR

VENTILATION	<u>1</u> PEOPLE x <u>15</u> CFM/PERSON = <u>15</u>
	SQ FT x _____ CFM/SQ FT = _____
	CFM VENTILATION
SWINGING REVOLVING DOORS	PEOPLE x _____ CFM/PERSON = _____
OPEN DOORS	DOORS x _____ CFM/DOOR = _____
EXHAUST FAN	
CRACK	FEET x _____ CFM/FT = _____
	CFM INFILTRATION
	CFM OUTDOOR AIR THRU APPARATUS

APPARATUS DEWPOINT

ESHF	EFFECTIVE ROOM SENS. HEAT FACTOR = <u>8711</u>	EFFECTIVE ROOM TOTAL HEAT = <u>8711</u>	DEWPOINT = <u>78</u>
ADP	INDICATED ADP = _____ F	SELECTED ADP = _____ F	

DEHUMIDIFIED AIR QUANTITY

TEMP RISE	(1 - _____ BF) x (TRM _____ F - TADP _____ F) = _____ F
DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT = _____ CFM _{DA}
	1.08 x _____ F TEMP. RISE
OUTLET TEMP. DIFF.	ROOM SENS. HEAT = _____ F (RM-OUTLET AIR)
	1.08 x _____ CFM _{DA}

SUPPLY AIR QUANTITY

SUPPLY CFM	ROOM SENS. HEAT = <u>403</u> CFM _{SA}
	1.08 x <u>20</u> F DESIRED DIFF
BYPASS CFM	CFM _{SA} - _____ CFM _{DA} = _____ CFM _{BA}

RESULTING ENT & LVG CONDITIONS AT APPARATUS

EOB	T _{RM} _____ F + _____ CFM _{DA} x (T _{OA} _____ F - T _{RM} _____ F) = T _{EOB} _____ F
LOB	T _{ADP} _____ F + _____ BF = (T _{EOB} _____ F - T _{ADP} _____ F) = T _{LOB} _____ F
	FROM PSYCH. CHART: T _{EOB} _____ F, T _{LOB} _____ F

NOTES

COMPUTATION SHEET

BUILDING 80

LIFE SCIENCES

COOLING LOAD

COMPUTED BY: RJB
CHECKED BY: BWJ
DATE: 11-10- 1989
REV: _____ 198

Microcopy (2 V. of Section 112)

PROJECT 16-199-09
SHEET NO. 25 OF 56 SHEETS

Space Used For
Size 16 1/2 x 13 1/2 = 223 SQ FT x 9 1/2 = 2116 CU FT

ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
------	------------------	-------------------------	--------	----------

SOLAR GAIN-GLASS

Glass	<u>117</u> SQ FT x <u>216</u> x <u>.26</u>			<u>6571</u>
Glass	SQ FT x			
Glass	SQ FT x			
Glass	SQ FT x			
Skylight	SQ FT x			

SOLAR & TRANS. GAIN-WALLS & ROOF

Wall	<u>43</u> SQ FT x <u>31</u> x <u>.13</u>			<u>173</u>
Wall	SQ FT x			
Wall	SQ FT x			
Wall	SQ FT x			
Roof-Sun	<u>223</u> SQ FT x <u>96</u> x <u>.12</u>			<u>1230</u>
Roof-Shaded	SQ FT x			

TRANS. GAIN-EXCEPT WALLS & ROOF

All Glass	<u>117</u> SQ FT x <u>14</u> x <u>1.02</u>			<u>1671</u>
Partition	SQ FT x			
Ceiling	SQ FT x			
Floor	SQ FT x			
Infiltration	CFM x		<u>1.08</u>	

INTERNAL HEAT

People	<u>1</u> PEOPLE x <u>230</u>			<u>230</u>
Power	<u>15(3.4)</u> HP OR KW x <u>223</u>			<u>379</u>
Lights	<u>1.5</u> WATTS x <u>3.4</u> x <u>223</u>			<u>1137</u>
Appliances, Etc.				
Additional Heat Gains				

SUB TOTAL

Storage	SQ FT x			
Safety Factor	<u>5</u> %			
ROOM SENSIBLE HEAT				<u>11961</u>

SUPPLY DUCT HEAT GAIN

SUPPLY DUCT HEAT GAIN	% LEAK. LOSS	FAN % H.P.	%
Outdoor Air	<u>15</u> CFM x <u>4</u> F x <u>.1</u> BF x <u>1.08</u>		
EFFECTIVE ROOM SENSIBLE HEAT			

LATENT HEAT

Infiltration	CFM x	GR/LB x <u>0.68</u>		
People	<u>1</u> PEOPLE x <u>190</u>			<u>190</u>
Steam	LB/HR x <u>1050</u>			
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.	SQ x <u>1/100</u> x	GR/LB x		
SUB TOTAL				<u>190</u>

Safety Factor

ROOM LATENT HEAT				<u>200</u>
SUPPLY DUCT LEAKAGE LOSS				
Outdoor Air	CFM x	GR/LB x	BF x <u>0.68</u>	
EFFECTIVE ROOM LATENT HEAT				<u>200</u>
EFFECTIVE ROOM TOTAL HEAT				<u>12167</u>

OUTDOOR AIR HEAT

Sensible:	<u>15</u> CFM x <u>4</u> F x <u>(1-.1)</u> BF x <u>1.08</u>			
Latent:	CFM x	GR/LB x <u>(1-.1)</u> BF x <u>0.68</u>		<u>58</u>
RETURN DUCT HEAT GAIN	% LEAK. GAIN	HP % PUMP	% DEHAUM. & PIPE LOSS	%
GRAND TOTAL HEAT				<u>12225</u>

Estimate for LOCAL TIME SUN TIME Peak Load LOCAL TIME SUN TIME

Hours of Operation

CONDITIONS	DB	WB	% RH	DP	GR/LB
OUTDOOR (OA)	<u>80</u>				
ROOM (RM)	<u>76</u>				
DIFFERENCE	<u>4</u>				

OUTDOOR AIR

VENTILATION	<u>1</u> PEOPLE x <u>15</u> CPM/PERSON = <u>15</u>
	SQ FT = CPM/SQ FT =
	CFM VENTILATION

INFILTRATION

SWINGING REVOLVING DOORS	PEOPLE = CPM/PERSON =
OPEN DOORS	DOORS = CPM/DOOR =
EXHAUST FAN	
CRACK	FEET = CPM/FT =
	CFM INFILTRATION

CFM OUTDOOR AIR THRU APPARATUS

APPARATUS DEWPOINT

ESHF	EFFECTIVE SENS HEAT FACTOR = <u>11967</u>
	EFFECTIVE ROOM SENS. HEAT = <u>11967</u>
	EFFECTIVE ROOM TOTAL HEAT = <u>12167</u>

ADP INDICATED ADP = F SELECTED ADP = F

DEHUMIDIFIED AIR QUANTITY

TEMP. RISE

(1- BF) = (TRM - F - TADP - FI) = F
DEHUM. CPM
EFFECTIVE ROOM SENS. HEAT = CPM
1.08 x F TEMP. RISE
OUTLET TEMP. DIFF.
ROOM SENS. HEAT = CFM
1.08 x CFM

SUPPLY AIR QUANTITY

SUPPLY CPM	<u>11,961</u>
ROOM SENS. HEAT = <u>554</u> CFM	
1.08 x <u>20</u> F DESIRED DIFF	
BYPASS CPM	
CFM _{SA} - CFM _{OA} = CFM _{SA}	

RESULTING ENT & LVG CONDITIONS AT APPARATUS

EDB	TRM - F + CFM _{OA} (T _{OA} - T _{RM}) = T _{EDB}
LDB	T _{ADP} - F + BF (T _{EDB} - T _{ADP}) = T _{LDB}
	FROM PSYCH. CHART: T _{WB} , F, T _{LB}

NOTES

9-34

*IF THIS AT IS TOO HIGH, DETERMINE SUPPLY CPM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CPM.
WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CPM.

COMPUTATION SHEET

BUILDING 80
L3L-LIFE SCIENCES
COOLING LOAD
DATE 200 M

COMPUTED BY 203
CHECKED BY BWJ
DATE 11/12/1989
REV. 19

PROJECT 16-199-09
SHEET NO. 26 OF 56 SHEETS

ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
Space Used For Size $7\frac{1}{2} \times 13\frac{1}{2} = 101$ SQ FT $\times 9\frac{1}{2} = 962$ CU FT				
SOLAR GAIN-GLASS				
Glass	SQ FT	x		
Glass	SQ FT	x		
Glass	SQ FT	x		
Glass	SQ FT	x		
Skylight	SQ FT	x		
SOLAR & TRANS. GAIN-WALLS & ROOF				
Wall	75 SQ FT	31 x .13		302
Wall	SQ FT	x		
Wall	SQ FT	x		
Wall	SQ FT	x		
Roof-Sun	101 SQ FT	46 x .12		558
Roof-Shaded	SQ FT	x		
TRANS. GAIN-EXCEPT WALLS & ROOF				
Air Glass	SQ FT	x		
Partition	SQ FT	x		
Ceiling	SQ FT	x		
Floor	SQ FT	x		
Infiltration	CFM	x 1.08		
INTERNAL HEAT				
People	1 (20%)	PEOPLE x 730		46
Power	1.5 (20%)	WATTS x 3.4		1030
Lights				
Appliances, Etc.				
Additional Heat Gains				
SUB TOTAL				1496
Storage	SQ FT	x (-)		
SUB TOTAL				97
Safety Factor	5 %			
ROOM SENSIBLE HEAT				2035
SUPPLY DUCT LEAKAGE LOSS				
Outdoor Air	CFM	F x BF x 1.08		
EFFECTIVE ROOM SENSIBLE HEAT				2035
LATENT HEAT				
Infiltration	CFM	GR/LB x 0.68		
People	1 (20%)	PEOPLE x 170		35
Steam	LB/HR	x 1050		
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.	SQ x 1/100	GR/LB x		
SUB TOTAL				38
Safety Factor	5 %			
ROOM LATENT HEAT				40
SUPPLY DUCT LEAKAGE LOSS				
Outdoor Air	CFM	GR/LB x BF x 0.68		
EFFECTIVE ROOM LATENT HEAT				40
EFFECTIVE ROOM TOTAL HEAT				2075
OUTDOOR AIR HEAT				
Sensible:	CFM	F x (1 - BF) x 1.08		
Latent:	CFM	GR/LB x (1 - BF) x 0.68		
RETURN DUCT LEAKAGE LOSS				
Outdoor Air	CFM	HP x 1.08		
SUB TOTAL				
GRAND TOTAL HEAT				2075

Estimate for		LOCAL TIME SUN TIME	Peak Load	LOCAL TIME SUN TIME
Hours of Operation				
CONDITIONS	DB	WB	% RH	DP
OUTDOOR (OA)	80			
ROOM (RM)	76			
DIFFERENCE	4			
OUTDOOR AIR				
VENTILATION	PEOPLE	CFM/PERSON		
	SQ FT	CFM/SQ FT		
CFM VENTILATION				
SWINGING REVOLVING DOORS	PEOPLE	CFM/PERSON		
OPEN DOORS	DOORS	CFM/DOOR		
EXHAUST FAN				
CRACK	FEET	CFM/FT		
CFM INFILTRATION				
CFM OUTDOOR AIR THRU APPARATUS				
APPARATUS DEWPOINT				
ESHF	EFFECTIVE SENS HEAT FACTOR	EFFECTIVE ROOM TENS. HEAT		178
		EFFECTIVE ROOM TOTAL HEAT		2075
ADP	INDICATED ADP	F	SELECTED ADP	F
DEHUMIDIFIED AIR QUANTITY				
TEMP. RISE	(1 - BF) x (T _{RM} - T _{ADP})	F		
OUTLET TEMP. DIFF.				
EFFECTIVE ROOM SENS. HEAT				
ROOM SENS. HEAT				
FIRM-OUTLET AIR				
SUPPLY AIR QUANTITY				
SUPPLY CFM	2033	ROOM SENS. HEAT		74
	1.08 x 20	F	DESIRED DIFF	
BYPASS CFM		CFM _{RA}		CFM _{DA}
RESULTING ENT & LVO CONDITIONS AT APPARATUS				
EDB	T _{RM} F + (T _{OA} - T _{RM}) F			T _{EDB} F
LDB	T _{ADP} F + (T _{EDB} - T _{ADP}) F			T _{LDB} F
FROM PSYCH. CHART: T _{EDB} F, T _{LDB} F				

NOTES

COMPUTATION SHEET

BUILDING 80
LIB-LIFE SCIENCES
COOLING LOAD
BIOCHEMISTRY LAB

COMPUTED BY RJB
CHECKED BY BWJ
DATE 11/12/1987
REV. 15

PROJECT 16-199-09
SHEET NO. 27 OF 56 SHEETS

Space Used For				
Size	Area or Quantity	Sun Gain or Temp. Diff.	Factor	BTU/HOUR
= 1442 SQ FT x 9 1/2 = 13,599 CU FT				
SOLAR GAIN-GLASS				
Glass 289	SQ FT x 109	x .47		14 805
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Skylight	SQ FT x	x		
SOLAR & TRANS. GAIN-WALLS & ROOF				
Wall 111	SQ FT x 40	x .13		577
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Roof-Sun 1442	SQ FT x 46	x .12		7960
Roof-Shaded	SQ FT x	x		
TRANS. GAIN-EXCEPT WALLS & ROOF				
All Glass 289	SQ FT x 14	x 1.02		4127
Partition	SQ FT x	x		
Ceiling	SQ FT x	x		
Floor	SQ FT x	x		
Infiltration	CFM x	x 1.08		
INTERNAL HEAT				
People 6	PEOPLE x 230			1380
Power 2.5(34)	HP OR KW x 1442			12 257
Lights 1	WATTS x 3.4 x 1442			9 903
Appliances, Etc.	x			
Additional Heat Gains	x			
SUB TOTAL				
Storage	SQ FT x	x (-)		
SUB TOTAL				46 009
Safety Factor 5%				2 300
ROOM SENSIBLE HEAT				48 309
SUPPLY DUCT LEAKAGE LOSS				
Outdoor Air 90	CFM x 9	F x 1 BF x 1.08		87
EFFECTIVE ROOM SENSIBLE HEAT				48 396
LATENT HEAT				
Infiltration	CFM x	GR/LB x 0.68		
People 6	PEOPLE x 190			1 140
Steam	LB/HR x 1050			
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.	SQ x 1/100 x	GR/LB x		
SUB TOTAL				1 140
Safety Factor 5%				57
ROOM LATENT HEAT				1 197
SUPPLY DUCT LEAKAGE LOSS				
Outdoor Air	CFM x	GR/LB x BF x 0.68		
EFFECTIVE ROOM LATENT HEAT				1 197
EFFECTIVE ROOM TOTAL HEAT				49 593
OUTDOOR AIR HEAT				
Sensible: 90	CFM x 9	F x (1-) BF x 1.08		787
Latent:	CFM x	GR/LB x (1-) BF x 0.68		
SUB TOTAL				
RETURN DUCT HEAT GAIN	% + LEAK. GAIN	% + PUMP	% + DEMUM. & % + PIPE LOSS	
GRAND TOTAL HEAT				50 380

Estimate for		LOCAL TIME	Peak Load	LOCAL TIME
SUN TIME		SUN TIME		
Hours of Operation				
CONDITIONS	DB	WB	% RH	DP
OUTDOOR (OA)	85			
ROOM (RM)	76			
DIFFERENCE	9			
OUTDOOR AIR				
VENTILATION	6	PEOPLE x 15	CFM/PERSON = 90	
		SQ FT x	CFM/SQ FT =	
			CFM VENTILATION	
SWINGING REVOLVING DOORS				
PEOPLE x		CFM/PERSON =		
OPEN DOORS				
DOORS x		CFM/DOOR =		
EXHAUST FAN				
CRACK	FEET x	CFM/FT =		
CFM INFILTRATION				
CFM OUTDOOR AIR THRU APPARATUS				
APPARATUS DEWPOINT				
ESHF	EFFECTIVE SENS. HEAT FACTOR	EFFECTIVE ROOM SENS. HEAT	EFFECTIVE ROOM TOTAL HEAT	
				.78
ADP	INDICATED ADP =	SELECTED ADP =		
DEHUMIDIFIED AIR QUANTITY				
TEMP. RISE	(1-) BF x (TRM - TADP -) F =			
DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT			CFM _{DA}
	1.08 x	F TEMP. RISE		
OUTLET TEMP. DIFF.	ROOM SENS. HEAT		F (RM-OUTLET AIR)	
	1.08 x	CFM _{DA}		
SUPPLY AIR QUANTITY				
SUPPLY CFM	ROOM SENS. HEAT			CFM _{SA}
	1.08 x 20 F	DESIRED DIFF		
BYPASS CFM	CFM _{SA} -	CFM _{DA} =		CFM _{BA}
RESULTING ENT & LVG CONDITIONS AT APPARATUS				
EDB	TRM - F +	CFM _{DA} x (TOA - F - TRM -) F =		T _{EDB} - F
		CFM _{DA}		
LDB	TADP - F +	BF x (T _{EDB} - F - TADP -) F =		T _{LDB} - F
		FROM PSYCH. CHART: T _{WB} - F, T _{LB} - F		

NOTES

9-36

* IF THIS AT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY
USING BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

BUILDING 30

LBL-LIFE SCIENCES

COOLING LOAD

SURGERY

COMPUTED BY BJB
CHECKED BY BWJ
DATE 11/12/1987
REV. 19

PROJECT 16-199-09

SHEET NO. 28 OF 50 SHEETS

ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
Space Used For				
Size <u>33</u> x <u>15</u> = <u>495</u> SQ FT x <u>9 1/2</u> = <u>4702</u> CU FT				
SOLAR GAIN-GLASS				
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Skylight	SQ FT x	x		
SOLAR & TRANS. GAIN-WALLS & ROOF				
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Roof-Sun	<u>495</u> SQ FT x <u>46</u>	x <u>.12</u>		<u>2752</u>
Roof-Shaded	SQ FT x	x		
TRANS. GAIN-EXCEPT WALLS & ROOF				
All Glass	SQ FT x	x		
Partition	SQ FT x	x		
Ceiling	SQ FT x	x		
Floor	SQ FT x	x		
Infiltration	CFM x	x <u>1.00</u>		
INTERNAL HEAT				
People	<u>6</u> PEOPLE x <u>230</u>			<u>1380</u>
Power	<u>2</u> (3.4) HP OR KW x <u>495</u>			<u>3366</u>
Lights	<u>5</u> WATTS x <u>3.4</u> x <u>495</u>			<u>8415</u>
Appliances, Etc.	x			
Additional Heat Gains	x			
SUB TOTAL				
Storage	SQ FT x	x (-)		
SUB TOTAL				<u>15895</u>
Safety Factor	<u>5</u> %			<u>795</u>
ROOM SENSIBLE HEAT				<u>16688</u>
SUPPLY DUCT HEAT GAIN	SUPPLY DUCT % + LEAK. LOSS	PAH % + H.P.	%	
Outdoor Air	<u>90</u> CFM x <u>9</u>	F x <u>.1</u>	BF x <u>1.00</u>	<u>81</u>
EFFECTIVE ROOM SENSIBLE HEAT				<u>16775</u>
LATENT HEAT				
Infiltration	CFM x	GR/LB x <u>0.68</u>		
People	<u>6</u> PEOPLE x	<u>190</u>		<u>1140</u>
Steam	LB/HR x <u>1050</u>			
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.	SQ x <u>1/100</u> x	GR/LB x		
SUB TOTAL				<u>1140</u>
Safety Factor	<u>5</u> %			<u>57</u>
ROOM LATENT HEAT				<u>1197</u>
SUPPLY DUCT LEAKAGE LOSS				
Outdoor Air	CFM x	GR/LB x	BF x <u>0.68</u>	
EFFECTIVE ROOM LATENT HEAT				<u>1197</u>
EFFECTIVE ROOM TOTAL HEAT				<u>17972</u>
OUTDOOR AIR HEAT				
Sensible:	<u>90</u> CFM x <u>9</u>	F x (-) <u>.1</u>	BF x <u>1.00</u>	<u>787</u>
Latent:	CFM x	GR/LB x (-)	BF x <u>0.68</u>	
RETURN DUCT HEAT GAIN	RETURN DUCT % + LEAK. GAIN	HP % + PUMP	SUB TOTAL % + PIPE LOSS	
GRAND TOTAL HEAT				<u>18759</u>

Estimate for		LOCAL TIME	Peak Load	LOCAL TIME
		SUN TIME		SUN TIME
Hours of Operation				
CONDITIONS	DB	WB	% RH	DP
OUTDOOR (OA)	<u>85</u>			
ROOM (RM)	<u>76</u>			
DIFFERENCE	<u>9</u>			
OUTDOOR AIR				
VENTILATION	<u>6</u> PEOPLE x <u>15</u>	CFM/PERSON = <u>90</u>		
	SQ FT x	CFM/SQ FT =		
		CFM VENTILATION		
INFILTRATION				
BRINDING REVOLVING DOORS	PEOPLE x	CFM/PERSON =		
OPEN DOORS	DOORS x	CFM/DOOR =		
EXHAUST FAN				
CRACK	FEET x	CFM/FT =		
		CFM INFILTRATION		
CFM OUTDOOR AIR THRU APPARATUS				
APPARATUS DEW POINT				
ESHF	EFFECTIVE SENS HEAT FACTOR	EFFECTIVE ROOM SENS. HEAT		
		EFFECTIVE ROOM TOTAL HEAT	<u>.92</u>	
ADP	INDICATED ADP =	SELECTED ADP =		
DEHUMIDIFIED AIR QUANTITY				
TEMP RISE	(1- BF) x (TRM F - TADP F)	F =		
DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT	CFM _{DA}		
	1.00 x F TEMP. RISE			
OUTLET TEMP. DIFF.	ROOM SENS. HEAT	CFM _{DA}		
	1.00 x CFM _{DA}	FIRM-OUTLET AIR		
SUPPLY AIR QUANTITY				
SUPPLY CFM	<u>1688</u> ROOM SENS. HEAT	= <u>773</u> CFM _{SA}		
	1.00 x <u>20</u> F DESIRED DIFF			
BYPASS CFM	CFM _{SA} -	CFM _{DA} =		
RESULTING ENT & LVO CONDITIONS AT APPARATUS				
EDB	T _{RM} F +	CFM _{DA} + (T _{OA} F - T _{RM} F) = T _{EDB} F		
LDB	T _{ADP} F +	BF x (T _{EDB} F - T _{ADP} F) = T _{LDB} F		
FROM PSYCH. CHART: T _{WB} F, T _{LB} F				

NOTES

9-37

IF THIS AT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

BUILDING 80
LBL-LIFE SCIENCES
COOLING LOAD
CELL/TISSUE

COMPUTED BY: **RJB**
CHECKED BY: **BWJ**
DATE: **11/02** 19**80**
REV. _____ 19____

PROJECT: **16-199-09**
SHEET NO. **29** OF **56** SHEETS

ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
Space Used For				
Size	33 x 18	= 594 SQ FT	x 9 1/2	= 5643 CU FT
SOLAR GAIN-GLASS				
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Skylight	SQ FT x	x		
SOLAR & TRANS. GAIN-WALLS & ROOF				
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Roof-Sun	594 SQ FT x 46	x .12		3 279
Roof-Shaded	SQ FT x	x		
TRANS. GAIN-EXCEPT WALLS & ROOF				
All Glass	SQ FT x	x		
Partition	SQ FT x	x		
Ceiling	SQ FT x	x		
Floor	SQ FT x	x		
Infiltration	CFM x	x	1.08	
INTERNAL HEAT				
People	4 PEOPLE x 230			920
Power	2 (5.4) HP OR KW x 594			4 031
Lights	1 WATTS x 3.4 x 594			2 020
Appliances, Etc.	x			
Additional Heat Gains	x			
SUB TOTAL				
Storage	SQ FT x	x (-)		
SUB TOTAL				10 258
Safety Factor	5 %			513
ROOM SENSIBLE HEAT				10 771
SUPPLY DUCT LEAKAGE LOSS				
Outdoor Air	60 CFM x 9 F x .1 BF x 1.08			58
EFFECTIVE ROOM SENSIBLE HEAT				10 829
LATENT HEAT				
Infiltration	CFM x	GR/LB x 0.68		
People	4 PEOPLE x 190			760
Steam	LB/HR x 1050			
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.	SQ x 1/100 x	GR/LB x		
SUB TOTAL				760
Safety Factor	5 %			38
ROOM LATENT HEAT				798
SUPPLY DUCT LEAKAGE LOSS				
Outdoor Air	CFM x	GR/LB x	BF x 0.68	
EFFECTIVE ROOM LATENT HEAT				798
EFFECTIVE ROOM TOTAL HEAT				11 627
OUTDOOR AIR HEAT				
Sensible:	60 CFM x 9 F x (1 - .1) BF x 1.08			525
Latent:	CFM x	GR/LB x (1 - .1) BF x 0.68		
RETURN DUCT LEAKAGE LOSS				
Outdoor Air	CFM x	GR/LB x	BF x 0.68	
SUB TOTAL				
GRAND TOTAL HEAT				12 152

Estimate for	LOCAL TIME SUN TIME	Peak Load	LOCAL TIME SUN TIME
Hours of Operation			
CONDITIONS	DB	WB	% RH DP GR/LB
OUTDOOR (OA)	85		
ROOM (RM)	76		
DIFFERENCE	9		
OUTDOOR AIR			
VENTILATION	4 PEOPLE x 15	CFM/PERSON = 60	
	SQ FT x	CFM/SQ FT =	
		CFM VENTILATION	
INFILTRATION			
SWINGING REVOLVING DOORS	PEOPLE x	CFM/PERSON =	
OPEN DOORS	DOORS x	CFM/DOOR =	
EXHAUST FAN			
CRACK	FEET x	CFM/FT =	
		CFM INFILTRATION	
CFM OUTDOOR AIR THRU APPARATUS			
APPARATUS DEWPOINT			
ESHF	EFFECTIVE SENS HEAT FACTOR	EFFECTIVE ROOM SENS. HEAT	.93
		EFFECTIVE ROOM TOTAL HEAT	11 627
ADP	INDICATED ADP =	SELECTED ADP =	F
DEHUMIDIFIED AIR QUANTITY			
TEMP RISE	(1 - BF) x (T _{RM} - T _{ADP})	F =	F
DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT		CFM ₀
	1.08 x F TEMP. RISE		
OUTLET TEMP. DIFF.	ROOM SENS. HEAT	F (RM-OUTLET AIR)	
	1.08 x CFM ₀		
SUPPLY AIR QUANTITY			
SUPPLY CFM	ROOM SENS. HEAT	479	CFM _{1A}
	1.08 x 20 F DESIRED DIFF		
BYPASS CFM	CFM _{1A} - CFM _{0A}		CFM _{BA}
RESULTING ENT & LVG CONDITIONS AT APPARATUS			
EDB	T _{RM} F + CFM _{0A} (T _{OA} - T _{RM}) F		T _{EDB} F
	CFM ₁		
LDB	T _{ADP} F + BF (T _{EDB} - T _{ADP}) F		T _{LDB} F
	FROM PSYCH. CHART: T _{EDB} F, T _{LDB} F		

NOTES

9-38

* IF THIS ΔT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

BUILDING 80
LBL - LIFE SCIENCES
COOLING LOAD
EQUIPMENT ROOM (STORAGE)

COMPUTED BY RJB
CHECKED BY BWT
DATE 11/21 1967
REV. 19

PROJECT 16-199-09
SHEET NO. 30 OF 56 SHEETS

Space Used For					Estimate for		LOCAL TIME		Peak Load		LOCAL TIME	
Size							SUN TIME				SUN TIME	
Size <u>324</u> SQ FT x <u>9 1/2</u> = <u>3578</u> CU FT												
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR		Hours of Operation						
SOLAR GAIN-GLASS						CONDITIONS	DB	WB	% RH	DP	GR/LB	
Glass	SQ FT x	x				OUTDOOR (OA)	<u>80</u>					
Glass	SQ FT x	x				ROOM (RM)	<u>76</u>					
Glass	SQ FT x	x				DIFFERENCE	<u>4</u>					
Glass	SQ FT x	x				OUTDOOR AIR						
Skylight	SQ FT x	x				PEOPLE = _____ CFM/PERSON = _____						
SOLAR & TRANS. GAIN-WALLS & ROOF						SQ FT = _____ CFM/SQ FT = _____						
Wall	<u>180</u> SQ FT x <u>90</u>	x <u>.13</u>		<u>936</u>		CFM VENTILATION ☐						
Wall	<u>160</u> SQ FT x <u>69</u>	x <u>.13</u>		<u>1935</u>		SWINGING REVOLVING DOORS _____ PEOPLE = _____ CFM/PERSON = _____						
Wall	SQ FT x	x				OPEN DOORS _____ DOORS = _____ CFM/DOOR = _____						
Wall	SQ FT x	x				EXHAUST FAN _____						
Roof-Sun	<u>324</u> SQ FT x <u>46</u>	x <u>.12</u>		<u>1788</u>		CRACK _____ FEET = _____ CFM/FT = _____						
Roof-Shaded	SQ FT x	x				CFM INFILTRATION ☐						
TRANS. GAIN-EXCEPT WALLS & ROOF						CFM OUTDOOR AIR THRU APPARATUS ☐						
All Glass	SQ FT x	x				APPARATUS DEWPOINT						
Partition	SQ FT x	x				EFFECTIVE ROOM SENS. HEAT = _____						
Ceiling	SQ FT x	x				EFFECTIVE ROOM TOTAL HEAT = _____						
Floor	SQ FT x	x				INDICATED ADP = _____ F SELECTED ADP = _____ F						
Infiltration	CFM x	x 1.08				DEHUMIDIFIED AIR QUANTITY						
INTERNAL HEAT						TEMP. RISE (1 - _____) (T _{RM} - T _{ADP}) = _____ F						
People	PEOPLE x					EFFECTIVE ROOM SENS. HEAT = _____ CFM _{OA}						
Power	HP OR KW x					1.08 x F TEMP. RISE						
Lights	<u>2 (-30%)</u> WATTS x <u>3.4</u>	<u>324</u>		<u>661</u>		ROOM SENS. HEAT = _____ F (RM - OUTLET AIR)						
Appliances, Etc.	x					1.08 x _____ CFM _{OA}						
Additional Heat Gains	x					SUPPLY AIR QUANTITY						
SUB TOTAL						SUPPLY CFM <u>5061</u> ROOM SENS. HEAT = <u>239</u> CFM _{OA}						
Storage	SQ FT x	x (1 -)				1.08 x <u>20</u> F DESIRED DIFF						
SUB TOTAL						BYPASS CFM _____ CFM _{OA} = _____ CFM _{OA}						
Safety Factor	<u>5%</u>			<u>291</u>		RESULTING ENT & LVG CONDITIONS AT APPARATUS						
ROOM SENSIBLE HEAT						EOD T _{RM} F + _____ CFM _{OA} (T _{OA} - T _{RM}) = T _{EOD} F						
EFFECTIVE ROOM SENSIBLE HEAT						LDB T _{ADP} F + _____ CFM _{OA} (T _{EOD} - T _{ADP}) = T _{LDB} F						
LATENT HEAT						FROM PSYCH. CHART: T _{EOD} F, T _{LDB} F						
Infiltration	CFM x	GR/LB x 0.68				NOTES						
People	PEOPLE x											
Steam	LB/HR x 1050											
Appliances, Etc.												
Additional Heat Gains												
Vapor Trans.	SQ x 1/100 x	GR/LB x										
SUB TOTAL												
Safety Factor	%											
ROOM LATENT HEAT												
SUPPLY DUCT LEAKAGE LOSS												
Outdoor Air	CFM x	GR/LB x	BF x 0.68									
EFFECTIVE ROOM LATENT HEAT												
EFFECTIVE ROOM TOTAL HEAT												
OUTDOOR AIR HEAT												
Sensible:	CFM x	F x (1 - BF) x 1.08										
Latent:	CFM x	GR/LB x (1 - BF) x 0.68										
RETURN DUCT HEAT GAIN												
RETURN DUCT LEAK. GAIN												
HP PUMP												
SUB TOTAL												
DEHUM. & PIPE LOSS												
GRAND TOTAL HEAT												

COMPUTATION SHEET

BUILDING 30
LIB-LIFE SCIENCES
COOLING LOAD
GLASS WASHING

COMPUTED BY: **203**
 CHECKED BY: **BWJ**
 DATE: **11/16/1984**
 REV: **19**

PROJECT: **16-199-09**

SHEET NO. **31** OF **56** SHEETS

Space Used For
 Size **16** x **20** = **320** SQ FT x **9 1/2** = **3040** CU FT

ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
SOLAR GAIN-GLASS				
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Skylight	SQ FT x	x		
SOLAR & TRANS. GAIN-WALLS & ROOF				
Wall	SQ FT x	x		
Wall	160 SQ FT x 69	x 1.13		1 435
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Roof-Sun	320 SQ FT x 46	x 1.12		1 760
Roof-Shaded	SQ FT x	x		
TRANS. GAIN-EXCEPT WALLS & ROOF				
All Glass	SQ FT x	x		
Partition	SQ FT x	x		
Ceiling	SQ FT x	x		
Floor	SQ FT x	x		
Infiltration	CFM x	x 1.08		
INTERNAL HEAT				
People	2 PEOPLE x 730			1 460
Power	2.5 (3.4) HP OR KW x 320			2 720
Lights	1 WATTS x 3.4 x 320			1 088
Appliances, Etc.	x			
Additional Heat Gains	x			
SUB TOTAL				
Storage	SQ FT x	x (-)		
SUB TOTAL				7 469
Safety Factor	5 %			575
ROOM SENSIBLE HEAT				7 842
SUPPLY DUCT HEAT GAIN				
Outdoor Air	30 CFM x 4 F x 1 BF x 1.08			13
EFFECTIVE ROOM SENSIBLE HEAT				7 855
LATENT HEAT				
Infiltration	CFM x	GR/LB x 0.68		
People	2 PEOPLE x 170			380
Steam	LB/HR x 1050			
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.	SQ x 1/100 x	GR/LB x		
SUB TOTAL				580
Safety Factor	5 %			19
ROOM LATENT HEAT				391
SUPPLY DUCT LEAKAGE LOSS				
Outdoor Air	CFM x	GR/LB x	BF x 0.68	
EFFECTIVE ROOM LATENT HEAT				399
EFFECTIVE ROOM TOTAL HEAT				8 254
OUTDOOR AIR HEAT				
Sensible:	30 CFM x 4 F x (1 - 1) BF x 1.08			117
Latent:	CFM x	GR/LB x (1 - 1) BF x 0.68		
RETURN DUCT HEAT GAIN				
Return Duct	HP	DEHUM. &	SUB TOTAL	
HEAT GAIN	% + LEAK. GAIN	% + PUMP	% + PIPE LOSS	%
GRAND TOTAL HEAT				8 571

Estimate for	LOCAL TIME SUN TIME	Peak Load	LOCAL TIME SUN TIME
Hours of Operation			
CONDITIONS	DB	WB	% RH DP GR/LB
OUTDOOR (OA)	80		
ROOM (RM)	76		
DIFFERENCE	4		
OUTDOOR AIR			
VENTI- LATION	2 PEOPLE = 15 CFM/PERSON = 30		
	SQ FT = CFM/SQ FT =		
	CFM VENTILATION		
APPARATUS DEWPOINT			
ESHF	EFFECTIVE ROOM SENS. HEAT = 7855		
	EFFECTIVE ROOM TOTAL HEAT = 8254		
ADP	INDICATED ADP = F SELECTED ADP = F		
DEHUMIDIFIED AIR QUANTITY			
TEMP RISE	(1 - BF) (TRM - F - TADP - F) = F		
DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT = 1.08 x F TEMP. RISE = CFM		
OUTLET TEMP. DIFF.	ROOM SENS. HEAT = 1.08 x CFM _{DA} (FIRM-OUTLET AIR)		
SUPPLY AIR QUANTITY			
SUPPLY CFM	7842 ROOM SENS. HEAT = 1.08 x 20 F DESIRED DIFF = 363 CFM _{SA}		
BYPASS CFM	CFM _{SA} - CFM _{DA} = CFM _{SA}		
RESULTING ENT & LVG CONDITIONS AT APPARATUS			
EOB	T _{RM} F + CFM _{DA} (T _{OA} - F - T _{RM} - F) = T _{EOB} F		
LDB	T _{ADP} F + BF = (T _{EOB} - F - T _{ADP} - F) = T _{LDB} F		
	FROM PSYCH. CHART: T _{EOB} F, T _{LDB} F		

NOTES

9-40

*IF THIS AT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
 WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
 WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

BUILDING 30
LIFE SCIENCES
COOLING LOAD
OFFICE, WALL (T/P & 2)

COMPUTED BY BJB
CHECKED BY BWH
DATE 11/42/1989
REV. _____ 19__

PROJECT 16-199-09
SHEET NO. 32 OF 56 SHEETS

Space Used For
Size 10 x 10 = 100 SQ FT x 9 1/2 = 950 CU FT

Estimate for LOCAL TIME SUN TIME Peak Load LOCAL TIME SUN TIME

ITEM AREA OR QUANTITY SUN GAIN OR TEMP. DIFF. FACTOR BTU/HOUR

Hours of Operation CONDITIONS DB WB % RH DP GR/LB

SOLAR GAIN-GLASS

OUTDOOR (OA) 80 ROOM (RM) 76 DIFFERENCE 4

Glass SQ FT x x
Glass SQ FT x x
Glass SQ FT x x
Glass SQ FT x x
Skylight SQ FT x x

VENTILATION 1 PEOPLE x 15 CFM/PERSON = 15
SQ FT x CFM/SQ FT =
CFM VENTILATION

SOLAR & TRANS. GAIN-WALLS & ROOF

SWINGING REVOLVING DOORS PEOPLE x CFM/PERSON =
OPEN DOORS DOORS x CFM/DOOR =
EXHAUST FAN
CRACK FEET x CFM/FT =
CFM INFILTRATION

Wall 100 SQ FT x 61 x .13 87
Wall SQ FT x x
Wall SQ FT x x
Wall SQ FT x x
Roof-Sun 100 SQ FT x 46 x .12 552
Roof-Shaded SQ FT x x

CFM OUTDOOR AIR THRU APPARATUS
APPARATUS DEWPOINT
EFFECTIVE ROOM SENS. HEAT
EFFECTIVE ROOM TOTAL HEAT = 193
2683
ADP INDICATED ADP = F SELECTED ADP = F

TRANS. GAIN-EXCEPT WALLS & ROOF

DEHUMIDIFIED AIR QUANTITY

All Glass SQ FT x x
Partition SQ FT x x
Ceiling SQ FT x x
Floor SQ FT x x
Infiltration CFM x x 1.00

TEMP RISE (1 - BF) x (T_{RM} - T_{ADP}) = F
DEHUM. CFM EFFECTIVE ROOM SENS. HEAT = CFM_{DA}
1.00 x F TEMP. RISE
OUTLET TEMP. DIFF. 1.00 x CFM_{DA} = F (RM-OUTLET AIR)

INTERNAL HEAT

SUPPLY AIR QUANTITY

People 1 PEOPLE x 230 230
Power .5 (3.4) HP OR KW x 100 170
Lights 1.5 WATTS x 3.4 x 100 510
Appliances, Etc. x
Additional Heat Gains x
SUB TOTAL 2929
Storage SQ FT x x (-) SUB TOTAL 2929
Safety Factor 5% 118
ROOM SENSIBLE HEAT 2977

2477 ROOM SENS. HEAT = 115 CFM_{SA}
1.00 x 20 F DESIRED DIFF
BYPASS CFM CFM_{SA} - CFM_{DA} = CFM_{BA}

SUPPLY DUCT HEAT GAIN

RESULTING ENT & LVO CONDITIONS AT APPARATUS

Outdoor Air 15 CFM x 4 F x 1 BF = 1.00
EFFECTIVE ROOM SENSIBLE HEAT 2983
LATENT HEAT
Infiltration CFM x GR/LB x 0.68
People 1 PEOPLE x 190 190
Steam LB/HR x 1050
Appliances, Etc.
Additional Heat Gains
Vapor Trans. SQ x 1/100 x GR/LB x
SUB TOTAL 190
Safety Factor 5% 10
ROOM LATENT HEAT 200

EDB T_{RM} + F + CFM_{DA} (T_{OA} - T_{RM}) = T_{EDB} F
CFM_{DA}
LDB T_{ADP} + F + BF = T_{EDB} F - T_{ADP} = T_{LDB} F
FROM PSYCH. CHART: T_{EDB} F, T_{LDB} F

EFFECTIVE ROOM SENSIBLE HEAT

NOTES

OUTDOOR AIR HEAT
Sensible: 15 CFM x 4 F x (1 - BF) = 1.00 58
Latent: CFM x GR/LB x (1 - BF) x 0.68
RETURN DUCT HEAT GAIN % + LEAK. GAIN % + PUMP HP DEMUM. & % + PIPE LOSS %
SUB TOTAL
GRAND TOTAL HEAT 2741

THERE ARE TWO OF THESE TYPE OFFICES

GRAND TOTAL HEAT

NOTES

ROOM LATENT HEAT

NOTES

SUPPLY DUCT LEAKAGE LOSS

NOTES

OUTDOOR AIR

NOTES

EFFECTIVE ROOM LATENT HEAT

NOTES

EFFECTIVE ROOM TOTAL HEAT

NOTES

OUTDOOR AIR HEAT

NOTES

Sensible: 15 CFM x 4 F x (1 - BF) = 1.00

NOTES

Latent: CFM x GR/LB x (1 - BF) x 0.68

NOTES

RETURN DUCT HEAT GAIN % + LEAK. GAIN % + PUMP HP DEMUM. & % + PIPE LOSS %

NOTES

GRAND TOTAL HEAT

NOTES

GRAND TOTAL HEAT

NOTES

GRAND TOTAL HEAT

NOTES

GRAND TOTAL HEAT

NOTES

GRAND TOTAL HEAT

NOTES

COMPUTATION SHEET

Engineers-Architects

COMPUTED BY 123 B
 CHECKED BY BW
 DATE 11/12/1981
 REV. 19

BUILDING 80
LBL-LIFE SCIENCES
COOLING LOAD
OFFICE, INTERIOR (10000)

PROJECT 16-199-09
 SHEET NO. 33 OF 56 SHEETS

Space Used For					Estimate for		LOCAL TIME	Peak Load	LOCAL TIME	
Size <u>10</u> x <u>10</u> = <u>100</u> SQ FT x <u>9 1/2</u> = <u>950</u> CU FT										
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR	Hours of Operation					
					CONDITIONS	DB	WB	% RH	DP	GR/LB
SOLAR GAIN-GLASS					OUTDOOR (OA)	<u>80</u>				
Glass	SQ FT x	x			ROOM (RM)	<u>76</u>				
Glass	SQ FT x	x			DIFFERENCE	<u>4</u>				
Glass	SQ FT x	x			OUTDOOR AIR					
Skylight	SQ FT x	x			VENTILATION	<u>1</u> PEOPLE = <u>15</u> CPM/PERSON = <u>15</u>				
						SQ FT =		CFM/SQ FT =		
SOLAR & TRANS. GAIN-WALLS & ROOF					BRINDING REVOLVING DOORS PEOPLE = CPM/PERSON =					
Wall	SQ FT x	x			OPEN DOORS DOORS = CPM/DOOR =					
Wall	SQ FT x	x			EXHAUST FAN					
Wall	SQ FT x	x			CRACK FEET = CPM/FT =					
Wall	SQ FT x	x			CFM INFILTRATION					
Roof-Sun	<u>100</u> SQ FT x <u>96</u> x <u>.12</u>			<u>552</u>	CFM OUTDOOR AIR THRU APPARATUS					
Roof-Shaded	SQ FT x	x			APPARATUS DEWPOINT					
					ESHF	EFFECTIVE ROOM SENS. HEAT FACTOR	<u>1541</u>	EFFECTIVE ROOM SENS. HEAT	<u>1791</u>	<u>.88</u>
TRANS. GAIN-EXCEPT WALLS & ROOF					ADP INDICATED ADP = F SELECTED ADP = F					
All Glass	SQ FT x	x			DEHUMIDIFIED AIR QUANTITY					
Partition	SQ FT x	x			TEMP RISE (1- BF) = (T _{RM} - T _{ADP}) F = F					
Ceiling	SQ FT x	x			EFFECTIVE ROOM SENS. HEAT 1.00 x F TEMP. RISE = CPM ₀					
Floor	SQ FT x	x			ROOM SENS. HEAT 1.00 x CPM _{0A} = F (RM-OUTLET AIR)					
Infiltration	CFM x	x	1.00		SUPPLY AIR QUANTITY					
					SUPPLY CPM <u>1535</u> ROOM SENS. HEAT = <u>71</u> CPM _{SA}					
					1.00 x <u>20</u> F DESIRED DIFF = CPM _{SA}					
					BYPASS CPM CPM _{SA} - CPM _{0A} = CPM _{BA}					
INTERNAL HEAT					RESULTING ENT & LVG CONDITIONS AT APPARATUS					
People	<u>1</u> PEOPLE x <u>230</u>			<u>230</u>	EDB	T _{RM} F + CPM _{0A} (T _{0A} - T _{RM}) F = T _{EDB} F				
Power	<u>15</u> (54) HP OR KW x <u>100</u>			<u>170</u>	FROM PSYCH. CHART: T _{WB} F, T _{DB} F					
Lights	<u>15</u> WATTS x 3.4 x <u>100</u>			<u>510</u>						
Appliances, Etc.	x									
Additional Heat Gains	x									
SUB TOTAL										
Storage	SQ FT x	x (-)								
SUB TOTAL										
Safety Factor	<u>5</u> %			<u>73</u>						
ROOM SENSIBLE HEAT										
SUPPLY DUCT HEAT GAIN % + LEAK. LOSS % + H. P. %										
Outdoor Air	<u>15</u> CPM x <u>4</u> F x <u>1</u> BF x 1.00			<u>6</u>						
EFFECTIVE ROOM SENSIBLE HEAT										
LATENT HEAT										
Infiltration	CFM x GR/LB x 0.68									
People	<u>1</u> PEOPLE x <u>170</u>			<u>170</u>						
Steam	LB/HR x 1050									
Appliances, Etc.										
Additional Heat Gains										
Vapor Trans.	SQ x 1/100 x GR/LB x									
SUB TOTAL										
Safety Factor	<u>5</u> %			<u>10</u>						
ROOM LATENT HEAT										
SUPPLY DUCT LEAKAGE LOSS %										
Outdoor Air	CFM x GR/LB x BF x 0.68									
EFFECTIVE ROOM LATENT HEAT										
EFFECTIVE ROOM TOTAL HEAT										
OUTDOOR AIR HEAT										
Sensible:	<u>15</u> CPM x <u>4</u> F x (1- BF) x 1.00			<u>58</u>						
Latent:	CFM x GR/LB x (1- BF) x 0.68									
RETURN DUCT HEAT GAIN % + LEAK. GAIN % + PUMP % + PIPE LOSS %										
SUB TOTAL										
GRAND TOTAL HEAT										

THERE ARE TWO OF THESE TYPE OFFICE

COMPUTATION SHEET

BUILDING 30

LBL - LIFE SCIENCES

COOLING LOAD

CORRIDORS

COMPUTED BY RJB
CHECKED BY BW
DATE 11/18/1989
REV. 19

PROJECT 16-199-09
SHEET NO. 34 OF 30 SHEETS

Space Used For					Estimate for		LOCAL TIME SUN TIME		Peak Load		LOCAL TIME SUN TIME	
Size <u>x</u> = <u>857</u> SQ FT x <u>9 1/2</u> = <u>8136</u> CU FT												
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR	Hours of Operation							
SOLAR GAIN-GLASS					CONDITIONS	DB	WB	% RH	DP	GR/LB		
Glass	SQ FT x	x			OUTDOOR (OA)							
Glass	SQ FT x	x			ROOM (RM)							
Glass	SQ FT x	x			DIFFERENCE							
Glass	SQ FT x	x			OUTDOOR AIR							
Skylight	SQ FT x	x			VENTI- LATION	PEOPLE x _____ CFM/PERSON = _____						
SOLAR & TRANS. GAIN-WALLS & ROOF					SQ FT x _____ CFM/SQ FT = _____							
Wall	SQ FT x	x			CFM VENTILATION							
Wall	SQ FT x	x			SWINGING REVOLVING DOORS _____ PEOPLE x _____ CFM/PERSON = _____							
Wall	SQ FT x	x			OPEN DOORS _____ DOORS x _____ CFM/DOOR = _____							
Wall	SQ FT x	x			EXHAUST FAN _____							
Roof-Sun	<u>857</u> SQ FT x <u>46</u> x <u>12</u>			<u>4751</u>	CRACK _____ FEET x _____ CFM/FT = _____							
Roof-Shaded	SQ FT x	x			CFM INFILTRATION							
TRANS. GAIN-EXCEPT WALLS & ROOF					CFM OUTDOOR AIR THRU APPARATUS							
All Glass	SQ FT x	x			APPARATUS DEWPOINT							
Partition	SQ FT x	x			EFFECTIVE ROOM SENS. HEAT							
Ceiling	SQ FT x	x			EFFECTIVE ROOM TOTAL HEAT							
Floor	SQ FT x	x			INDICATED ADP = _____ F SELECTED ADP = _____ F							
Infiltration	CFM x	x	1.08		DEHUMIDIFIED AIR QUANTITY							
INTERNAL HEAT					TEMP. RISE (1- _____ BP) x (TRM _____ F - TADP _____ F) = _____ F							
People	PEOPLE x				EFFECTIVE ROOM SENS. HEAT = _____ CFM _{DA}							
Power	<u>1.5</u> (3.4) HP OR KW x <u>857</u>			<u>1957</u>	1.08 x F _{TEMP. RISE}							
Lights	<u>1.5</u> WATTS x <u>3.4</u> x <u>857</u>			<u>4371</u>	ROOM SENS. HEAT = _____ F (RM-OUTLET AIR)							
Appliances, Etc.	x				1.08 x _____ CFM _{DA}							
Additional Heat Gains	x				SUPPLY AIR QUANTITY							
SUB TOTAL					ROOM SENS. HEAT = <u>538</u> CFM _{DA}							
Storage	SQ FT x	x (-)			1.08 x <u>20</u> F DESIRED DIFF.							
SUB TOTAL					CFM _{DA} = _____ CFM _{DA} = _____ CFM _{DA}							
Safety Factor	<u>5</u> %				RESULTING ENT & LVG CONDITIONS AT APPARATUS							
ROOM SENSIBLE HEAT					EDB T _{RM} _____ F + _____ CFM _{DA} x (T _{OA} _____ F - T _{RM} _____ F) = T _{EDB} _____ F							
SUPPLY DUCT HEAT GAIN	% + LEAK. LOSS	% + H. P.	%		LDB T _{ADP} _____ F + _____ BP x (T _{EDB} _____ F - T _{ADP} _____ F) = T _{LDB} _____ F							
Outdoor Air	CFM x	F x	BF x 1.08		FROM PSYCH. CHART: T _{EDB} _____ F, T _{LDB} _____ F							
EFFECTIVE ROOM SENSIBLE HEAT					NOTES							
LATENT HEAT												
Infiltration	CFM x	GR/LB x 0.68										
People	PEOPLE x											
Steam	LB/HR x 1050											
Appliances, Etc.												
Additional Heat Gains												
Vapor Trans.	SQ x 1/100 x	GR/LB x										
SUB TOTAL												
Safety Factor	%											
ROOM LATENT HEAT												
SUPPLY DUCT LEAKAGE LOSS	%											
Outdoor Air	CFM x	GR/LB x	BF x 0.68									
EFFECTIVE ROOM LATENT HEAT												
EFFECTIVE ROOM TOTAL HEAT												
OUTDOOR AIR HEAT												
Sensible:	CFM x	F x (1- _____ BF) x 1.08										
Latent:	CFM x	GR/LB x (1- _____ BF) x 0.68										
SUB TOTAL												
RETURN DUCT HEAT GAIN	% + LEAK. GAIN	% + PUMP	% + PIPE LOSS	%								
GRAND TOTAL HEAT												

9-43

*IF THIS AT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

BUILDING 30

COOLING LOAD
1ST FLOOR ALS SUPPORT

COMPUTED BY 12513
CHECKED BY [Signature]
DATE 11/12/1987
REV. 19

PROJECT 16-199-09
SHEET NO. 35 OF 56 SHEETS

Space Used For
Size $\times = 1600 \text{ SQ FT} \times 9/2 = 15200 \text{ CU FT}$

Estimate for LOCAL TIME Peak Load LOCAL TIME

ITEM AREA OR QUANTITY SUN GAIN OR TEMP. DIFF. FACTOR BTU/HOUR

Hours of Operation CONDITIONS DB WB % RH DP GR/LB

SOLAR GAIN-GLASS
Glass 187 SQ FT $\times 216 \times 1.26 = 10,502$
Glass 373 SQ FT $\times 109 \times 1.47 = 19,109$

OUTDOOR (OA) 80
ROOM (RM) 76
DIFFERENCE 4

Glass SQ FT $\times$
Skylight SQ FT $\times$

VENTILATION 10 PEOPLE $\times 15 \text{ CFM/PERSON} = 150$
SQ FT $\times$ CFM/SQ FT =
CFM VENTILATION

SOLAR & TRANS. GAIN-WALLS & ROOF
Wall 63 SQ FT $\times 31 \times 1.13 = 253$
Wall 227 SQ FT $\times 90 \times 1.13 = 1,800$

SWINGING REVOLVING DOORS PEOPLE $\times$ CFM/PERSON =
OPEN DOORS DOORS $\times$ CFM/DOOR =
EXHAUST FAN

Wall SQ FT $\times$
Roof-Sun 1600 SQ FT $\times 96 \times 1.12$
Roof-Shaded SQ FT $\times$

INFILTRATION CRACK FEET $\times$ CFM/FT =
CFM INFILTRATION

TRANS. GAIN-EXCEPT WALLS & ROOF
All Glass 414 SQ FT $\times 19 \times 1.02 = 22,848$

APPARATUS DEWPOINT
EFFECTIVE ROOM SENS. HEAT
EFFECTIVE ROOM TOTAL HEAT = 197
72 486

Partition SQ FT $\times$
Ceiling SQ FT $\times$
Floor SQ FT $\times$
Infiltration CFM $\times$ 1.08

ADP INDICATED ADP = F SELECTED ADP = F
DEHUMIDIFIED AIR QUANTITY

INTERNAL HEAT
People 10 PEOPLE $\times 230 = 2,300$
Power .5 (54) HP OR KW $\times 1600 = 8720$
Lights 1.5 WATTS $\times 3.4 \times 1600 = 8160$

TEMP. RISE $(1 - \text{BF}) \times (\text{TRM} - \text{F} - \text{TADP} - \text{F}) =$
DEHUM. CFM EFFECTIVE ROOM SENS. HEAT = CFM
1.08 $\times$ F TEMP. RISE

Appliances, Etc. $\times$
Additional Heat Gains $\times$
SUB TOTAL

OUTLET TEMP. DIFF. ROOM SENS. HEAT = F (RM-OUTLET AIR)
1.08 $\times$ CFM_{OA}

Storage SQ FT $\times$ (-)
SUB TOTAL 67,072
Safety Factor 5 % 3,359
ROOM SENSIBLE HEAT 70,426

SUPPLY AIR QUANTITY
70,426 ROOM SENS. HEAT = 3,260 CFM_{SA}
1.08 $\times$ 20 F DESIRED DIFF

SUPPLY DUCT HEAT GAIN % $\times$ LEAK. LOSS % $\times$ H. P. %
Outdoor Air 150 CFM $\times 9 \text{ F} \times 1 \text{ BF} \times 1.08 = 65$

BYPASS CFM CFM_{SA} - CFM_{OA} = CFM_{RA}
RESULTING ENT & LVO CONDITIONS AT APPARATUS

EFFECTIVE ROOM SENSIBLE HEAT 70,491

EDB T_{RM} F $\times$ CFM_{OA} $\times$ (T_{OA} - F - T_{RM} - F) = T_{EDB} F
LDB T_{ADP} F $\times$ BF $\times$ (T_{EDB} - F - T_{ADP} - F) = T_{LDB} F
FROM PSYCH. CHART: T_{WB} F, T_{LWB} F

LATENT HEAT
Infiltration CFM $\times$ GR/LB $\times 0.68$
People 10 PEOPLE $\times 190 = 1,900$
Steam LB/HR $\times 1050$

NOTES

Appliances, Etc.
Additional Heat Gains
Vapor Trans. SQ $\times 1/100 \times$ GR/LB $\times$
SUB TOTAL 1,900

Safety Factor 5 % 95
ROOM LATENT HEAT

SUPPLY DUCT LEAKAGE LOSS %
Outdoor Air CFM $\times$ GR/LB $\times$ BF $\times 0.68$

EFFECTIVE ROOM LATENT HEAT 1,995
EFFECTIVE ROOM TOTAL HEAT 72,486

OUTDOOR AIR HEAT
Sensible: 150 CFM $\times 9 \text{ F} \times (1 - 1 \text{ BF}) \times 1.08 = 583$
Latent: 150 CFM $\times$ GR/LB $\times (1 - 1 \text{ BF}) \times 0.68$

RETURN DUCT HEAT GAIN % $\times$ LEAK. GAIN % $\times$ PUMP % $\times$ PIPE LOSS %
SUB TOTAL
GRAND TOTAL HEAT 75,069

9-44
*IF THIS AT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
*WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
*WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

36

COMPUTED BY J CASE
 CHECKED BY _____
 DATE 11-12-1988
 REV. _____ 19 _____

LBL - LIFE SCIENCES
HEATING LOAD
BLDG "G, LAB (EAST)

PROJECT 16-174-09
 SHEET NO. 36 OF 56 SHEETS

Space Used For					Estimate for		LOCAL TIME		Peak Load		LOCAL TIME	
Size <u>73</u> x <u>20</u> = <u>1460</u> SQ FT x <u>14</u> = <u>6440</u> CU FT							SUN TIME				SUN TIME	
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR		Hours of Operation						
SOLAR GAIN-GLASS						CONDITIONS	DB	WB	% RH	DP	GR/LB	
Glass	SQ FT x	x				OUTDOOR (OA)	<u>36</u>					
Glass	SQ FT x	x				ROOM (RM)	<u>72</u>					
Glass	SQ FT x	x				DIFFERENCE	<u>-36</u>					
Glass	SQ FT x	x				OUTDOOR AIR						
Skylight	SQ FT x	x				VENTILATION	PEOPLE x _____ CFM/PERSON = _____					
SOLAR & TRANS. GAIN-WALLS & ROOF						SQ FT x _____ CFM/SQ FT = _____						
Wall	SQ FT x	x				CFM VENTILATION <u>5</u>						
Wall	SQ FT x	x				SPRING REVOLVING DOORS _____ PEOPLE x _____ CFM/PERSON = _____						
Wall	SQ FT x	x				OPEN DOORS _____ DOORS x _____ CFM/DOOR = _____						
Wall	SQ FT x	x				EXHAUST FAN _____						
Roof-Sun	<u>1460</u> SQ FT x <u>36</u> x <u>.05</u>				<u>830</u>	CRACK _____ FEET x _____ CFM/FT = _____						
Roof-Shaded	SQ FT x	x				CFM INFILTRATION <u>15</u>						
TRANS. GAIN-EXCEPT WALLS & ROOF						CFM OUTDOOR AIR THRU APPARATUS <u>5</u>						
All Glass	SQ FT x	x				APPARATUS DEWPOINT						
Partition	SQ FT x	x				ESHF	EFFECTIVE SENS HEAT FACTOR	EFFECTIVE ROOM SENS. HEAT = _____				
Ceiling	SQ FT x	x				EFFECTIVE ROOM TOTAL HEAT = _____						
Floor	SQ FT x	x				ADP	INDICATED ADP = _____ F SELECTED ADP = _____ F					
Infiltration	CFM x	x	1.08			DEHUMIDIFIED AIR QUANTITY						
INTERNAL HEAT						TEMP RISE	(1 - _____ BF) x (T _{RM} - T _{ADP}) = _____ F					
People	PEOPLE x					DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT = _____ CFM _{DA}					
Power	HP OR KW x					1.08 x F _{TEMP. RISE} = _____						
Lights	WATTS x 3.4 x					OUTLET TEMP. DIFF.	ROOM SENS. HEAT = _____ F _{RM-OUTLET AIR}					
Appliances, Etc.	x					1.08 x CFM _{DA} = _____						
Additional Heat Gains	x					SUPPLY AIR QUANTITY						
SUB TOTAL						SUPPLY CFM	ROOM SENS. HEAT = _____ CFM _{SA}					
Storage	SQ FT x	x (-)				1.08 x F DESIRED DIFF = _____						
SUB TOTAL						BYPASS CFM	CFM _{SA} - CFM _{DA} = _____ CFM _{BA}					
Safety Factor	<u>5</u> %				<u>40</u>	RESULTING ENT & LVG CONDITIONS AT APPARATUS						
ROOM SENSIBLE HEAT <u>770</u>						EDB	T _{RM} F + _____ CFM _{DA} (T _{OA} - T _{RM}) = T _{EDB} F					
SUPPLY DUCT HEAT GAIN						LDB	T _{ADP} F + _____ BF (T _{EDB} - T _{ADP}) = T _{LDB} F					
Outdoor Air	CFM x	F x	BF x 1.08			FROM PSYCH. CHART: T _{EDB} F, T _{LDB} F						
EFFECTIVE ROOM SENSIBLE HEAT <u>770</u>						NOTES						
LATENT HEAT						HOOD REQUIREMENT = 1000 CFM						
Infiltration	CFM x	GR/LB x 0.68				ROOM REQUIREMENT						
People	PEOPLE x					1000 CFM						
Steam	LB/HR x 1050					39,750 BTUH						
Appliances, Etc.												
Additional Heat Gains												
Vapor Trans.	SQ x 1/100 x	GR/LB x										
SUB TOTAL												
Safety Factor	%											
ROOM LATENT HEAT												
SUPPLY DUCT LEAKAGE LOSS												
Outdoor Air	CFM x	GR/LB x	BF x 0.68									
EFFECTIVE ROOM LATENT HEAT												
EFFECTIVE ROOM TOTAL HEAT <u>770</u>												
OUTDOOR AIR HEAT												
Sensible:	1000 CFM x <u>36</u> F x (1 - BF) x 1.08				<u>38,880</u>							
Latent:	CFM x	GR/LB x (1 - BF) x 0.68										
RETURN DUCT HEAT GAIN	% x LEAK. GAIN	% x PUMP	% x PIPE LOSS									
GRAND TOTAL HEAT <u>770</u>												

E-5074

AIR CONDITIONING LOAD ESTIMATE

(REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

37

COMPUTED BY J CASE
 CHECKED BY _____
 DATE 11/12/1984
 REV. _____ 19__

LEL - LIFE SCIENCES
HEATING LOADS
PLUMBING, VERTICAL STAIR

PROJECT 16-179-09
 SHEET NO. 37 OF 56 SHEETS

Space Used For					Estimate for		LOCAL TIME		Peak Load		LOCAL TIME		
Size <u>17</u> x <u>16</u> = <u>272</u> SQ FT x <u>14</u> = <u>3808</u> CU FT							SUN TIME				SUN TIME		
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR	Hours of Operation								
					CONDITIONS	DB	WB	% RH	DP	GR/LB			
SOLAR GAIN-GLASS					OUTDOOR AIR								
Glass	SQ FT x	x			OUTDOOR (OA)	<u>36</u>							
Glass	SQ FT x	x			ROOM (RM)	<u>72</u>							
Glass	SQ FT x	x			DIFFERENCE	<u>-36</u>							
Glass	SQ FT x	x											
Skylight	SQ FT x	x											
SOLAR & TRANS. GAIN-WALLS & ROOF													
Wall	SQ FT x	x											
Wall	SQ FT x	x											
Wall	SQ FT x	x											
Wall	SQ FT x	x											
Roof-Sun	<u>272</u> SQ FT x <u>36</u>	x	<u>1.05</u>	<u>490</u>									
Roof-Shaded	SQ FT x	x											
TRANS. GAIN-EXCEPT WALLS & ROOF													
All Glass	SQ FT x	x											
Partition	SQ FT x	x											
Ceiling	SQ FT x	x											
Floor	SQ FT x	x											
Infiltration	CFM x	x	<u>1.08</u>										
INTERNAL HEAT													
People	PEOPLE x												
Power	HP OR KW x												
Lights	WATTS x <u>3.4</u>												
Appliances, Etc.	x												
Additional Heat Gains	x												
SUB TOTAL				<u>490</u>									
Storage	SQ FT x	x (1-)											
SUB TOTAL													
Safety Factor	<u>5</u> %												
ROOM SENSIBLE HEAT				<u>510</u>									
SUPPLY DUCT HEAT GAIN	% + LEAK. LOSS	% + H. P.	%										
Outdoor Air	CFM x	F x	BF x <u>1.08</u>										
EFFECTIVE ROOM SENSIBLE HEAT													
LATENT HEAT													
Infiltration	CFM x	GR/LB x <u>0.68</u>											
People	PEOPLE x												
Steam	LB/HR x <u>1050</u>												
Appliances, Etc.													
Additional Heat Gains													
Vapor Trans.	SQ x <u>1/100</u> x	GR/LB x											
SUB TOTAL													
Safety Factor	%												
ROOM LATENT HEAT													
SUPPLY DUCT LEAKAGE LOSS	%												
Outdoor Air	CFM x	GR/LB x	BF x <u>0.68</u>										
EFFECTIVE ROOM LATENT HEAT													
EFFECTIVE ROOM TOTAL HEAT													
OUTDOOR AIR HEAT													
Sensible:	<u>120</u> CFM x <u>36</u>	F x (1-)	BF x <u>1.08</u>	<u>4670</u>									
Latent:	CFM x	GR/LB x (1-)	BF x <u>0.68</u>										
RETURN DUCT HEAT GAIN	% + LEAK. GAIN	% + PUMP	% + PIPE LOSS										
SUB TOTAL													
GRAND TOTAL HEAT				<u>5130</u>									

Estimate for		LOCAL TIME		Peak Load		LOCAL TIME	
		SUN TIME				SUN TIME	
Hours of Operation							
CONDITIONS	DB	WB	% RH	DP	GR/LB		
OUTDOOR (OA)	<u>36</u>						
ROOM (RM)	<u>72</u>						
DIFFERENCE	<u>-36</u>						
OUTDOOR AIR							
VENTILATION	PEOPLE x _____ CFM/PERSON = _____						
	SQ FT x _____ CFM/SQ FT = _____						
	CFM VENTILATION <u>5</u>						
APPARATUS DEWPOINT							
ESHF	EFFECTIVE SENS HEAT FACTOR	EFFECTIVE ROOM SENS. HEAT / EFFECTIVE ROOM TOTAL HEAT = _____					
ADP	INDICATED ADP = _____ F	SELECTED ADP = _____ F					
DEHUMIDIFIED AIR QUANTITY							
TEMP. RISE	(1- _____ BF) x (T _{RM} - T _{ADP} - F) = _____ F						
DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT / 1.08 x F _{TEMP. RISE} = _____ CFM _{DA}						
OUTLET TEMP. DIFF.	ROOM SENS. HEAT / 1.08 x CFM _{DA} = _____ F _{RM-OUTLET AIR}						
SUPPLY AIR QUANTITY							
SUPPLY CFM	ROOM SENS. HEAT / 1.08 x F DESIRED DIFF = _____ CFM _{SA}						
BYPASS CFM	CFM _{SA} - CFM _{DA} = _____ CFM _{BA}						
RESULTING ENT & LVG CONDITIONS AT APPARATUS							
EDB	T _{RM} - F + (CFM _{DA} / (T _{OA} - T _{RM} - F)) = T _{EDB} F						
LDB	T _{ADP} - F + (BF x (T _{EDB} - T _{ADP} - F)) = T _{LDB} F						
FROM PSYCH. CHART: T _{EDB} = _____ F, T _{LDB} = _____ F							
NOTES							
FROM AC LOAD,							
CFM = 235 MAXIMUM							
TURNDOWN RATIO 50%							
∴ CFM = 120							
5,130 BTUH							

E-5024

AIR CONDITIONING LOAD ESTIMATE (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

33

COMPUTED BY J CASE
 CHECKED BY _____
 DATE 11-12-1989
 REV. _____ 19 _____

LBL - LIFE SCIENCES
HEATING LOAD
BLDG "G, TANK ROOM

PROJECT 16-179-09
 SHEET NO. 38 OF 56 SHEETS

Space Used For					Estimate for		LOCAL TIME	Peak Load	LOCAL TIME		
Size <u>6</u> x <u>10</u> = <u>60</u> SQ FT x <u>14</u> = <u>840</u> CU FT							SUN TIME		SUN TIME		
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR		Hours of Operation					
SOLAR GAIN-GLASS						CONDITIONS	DB	WB	% RH	DP	GR/LB
Glass	SQ FT x	x				OUTDOOR (OA)	<u>36</u>				
Glass	SQ FT x	x				ROOM (RM)	<u>72</u>				
Glass	SQ FT x	x				DIFFERENCE	<u>36</u>				
Skylight	SQ FT x	x				OUTDOOR AIR					
SOLAR & TRANS. GAIN-WALLS & ROOF						VENTILATION	<u>1</u> PEOPLE x <u>15</u> CFM/PERSON = <u>15</u>				
Wall	SQ FT x	x					SQ FT x		CFM/SQ FT =		
Wall	SQ FT x	x				CFM VENTILATION <u>15</u>					
Wall	SQ FT x	x				APPARATUS DEWPOINT					
Wall	SQ FT x	x				ESHF	EFFECTIVE ROOM SENS. HEAT FACTOR	EFFECTIVE ROOM SENS. HEAT	EFFECTIVE ROOM TOTAL HEAT		
Roof-Sun	<u>60</u> SQ FT x <u>32</u> x <u>0.5</u>				<u>110</u>	ADP	INDICATED ADP =	F	SELECTED ADP =	F	
Roof-Shaded	SQ FT x	x				DEHUMIDIFIED AIR QUANTITY					
TRANS. GAIN-EXCEPT WALLS & ROOF						TDBP	(1 - <u>BF</u>) x (T _{RM} - T _{ADP}) x F =				
All Glass	SQ FT x	x				DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT = CFM _{DA}				
Partition	SQ FT x	x				OUTLET	ROOM SENS. HEAT = F _{RM-OUTLET AIR}				
Ceiling	SQ FT x	x				DIFF.	1.08 x F DESIRED DIFF = CFM _{SA}				
Floor	SQ FT x	x				SUPPLY AIR QUANTITY					
Infiltration	CFM x	x	1.08			SUPPLY CFM	ROOM SENS. HEAT = CFM _{SA}				
INTERNAL HEAT						BYPASS CFM	CFM _{SA} - CFM _{DA} = CFM _{BA}				
People	PEOPLE x					RESULTING ENT & LVG CONDITIONS AT APPARATUS					
Power	HP OR KW x					EDB	T _{RM} x F + (CFM _{DA} x (T _{OA} - T _{RM}) x F) = T _{EDB}				
Lights	WATTS x 3.4 x					LDB	T _{ADP} x F + (BF x T _{EDB} - T _{ADP}) x F = T _{LDB}				
Appliances, Etc.	x					FROM PSYCH. CHART: T _{WB} = F, T _{WB} = F					
Additional Heat Gains	x					NOTES					
SUB TOTAL						FROM AC LOADS					
Storage	SQ FT x	x (-)				CFM = 40 MAXIMUM					
SUB TOTAL						TURNDOWN 50% :					
Safety Factor	%					20 CFM					
ROOM SENSIBLE HEAT						890 BTUH					
SUPPLY DUCT HEAT GAIN	% + LEAK. LOSS	% + M. P.	%								
Outdoor Air	CFM x	F x	BF x 1.08								
EFFECTIVE ROOM SENSIBLE HEAT											
LATENT HEAT											
Infiltration	CFM x	GR/LB x 0.68									
People	PEOPLE x										
Steam	LB/HR x 1050										
Appliances, Etc.											
Additional Heat Gains											
Vapor Trans.	SQ x 1/100 x	GR/LB x									
SUB TOTAL											
Safety Factor	%										
ROOM LATENT HEAT											
SUPPLY DUCT LEAKAGE LOSS	%										
Outdoor Air	CFM x	GR/LB x	BF x 0.68								
EFFECTIVE ROOM LATENT HEAT											
EFFECTIVE ROOM TOTAL HEAT											
OUTDOOR AIR HEAT											
Sensible:	<u>20</u> CFM x <u>36</u> F x (1 - <u>0</u>) BF x 1.08				<u>780</u>						
Latent:	CFM x	GR/LB x (1 - BF) x 0.68									
RETURN DUCT HEAT GAIN	% + LEAK. GAIN	% + PUMP	% + PIPE LOSS	%							
GRAND TOTAL HEAT						<u>890</u>					

E-5074

AIR CONDITIONING LOAD ESTIMATE

(REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

9-47

*IF THIS AT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
 WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
 WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

39

COMPUTED BY J CASE
 CHECKED BY _____
 DATE 11-12-1989
 REV. _____ 19 _____

LBL - LIFE SCIENCES
HEATING LOADS
BLDG #6, MICROSCORE RM

PROJECT 16-199-09
 SHEET NO. 39 OF 36 SHEETS

Space Used For					Estimate for		LOCAL TIME		Peak Load		LOCAL TIME	
Size <u>6</u> x <u>10</u> = <u>60</u> SQ FT x <u>14</u> = <u>840</u> CU FT					Hours of Operation		CONDITIONS		DB		WB	
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR	COND.	DB	WB	%RH	DP	GR/LB		
SOLAR GAIN-GLASS												
Glass	SQ FT x	x			OUTDOOR (OA)	<u>36</u>						
Glass	SQ FT x	x			ROOM (RM)	<u>72</u>						
Glass	SQ FT x	x			DIFFERENCE	<u>36</u>						
Glass	SQ FT x	x			OUTDOOR AIR							
Skylight	SQ FT x	x			VENTILATION							
					PEOPLE x _____ CFM/PERSON = _____							
					SQ FT x _____ CFM/SQ FT = _____							
					CFM VENTILATION <u>36</u>							
					SWINGING REVOLVING DOORS _____ PEOPLE x _____ CFM/PERSON = _____							
					OPEN DOORS _____ DOORS x _____ CFM/DOOR = _____							
					EXHAUST FAN _____							
					CRACK _____ FEET x _____ CFM/FT = _____							
					CFM INFILTRATION <u>110</u>							
					CFM OUTDOOR AIR THRU APPARATUS <u>36</u>							
					APPARATUS DEWPOINT							
					ESHF EFFECTIVE SENS HEAT = EFFECTIVE ROOM SENS. HEAT / EFFECTIVE ROOM TOTAL HEAT = _____							
					ADP INDICATED ADP = _____ F SELECTED ADP = _____ F							
					DEHUMIDIFIED AIR QUANTITY							
					TEMP RISE (1 - BF) x (TRM - F - TADP - F) = _____ F							
					DEHUM. CFM EFFECTIVE ROOM SENS. HEAT = _____ CFM _{DA}							
					1.08 x F TEMP. RISE							
					OUTLET TEMP. DIFF. ROOM SENS. HEAT = _____ F (RM-OUTLET AIR) = _____							
					1.08 x CFM _{DA}							
					SUPPLY AIR QUANTITY							
					SUPPLY CFM ROOM SENS. HEAT = _____ CFM _{SA}							
					1.08 x F DESIRED DIFF							
					BYPASS CFM CFM _{SA} - CFM _{DA} = _____ CFM _{BA}							
					RESULTING ENT & LVG CONDITIONS AT APPARATUS							
					EOD TRM - F + (CFM _{DA} x (TOA - F - TRM - F)) / CFM = T _{EDS} = _____ F							
					LOD TADP - F + (BF x (T _{EDS} - TADP - F)) = T _{LOD} = _____ F							
					FROM PSYCH. CHART: T _{EDS} = _____ F, T _{LOD} = _____ F							
NOTES												
FROM AC LOAD, 51 CFM												
MAXIMUM TURNDOWN												
RATIO, 50% 1.												
CFM = 26 CFM												
1120 BTUH												
9-48												
*IF THIS &T IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.												
WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM. WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.												
INTERNAL HEAT												
People	PEOPLE x											
Power	HP OR KW x											
Lights	WATTS x 3.4 x											
Appliances, Etc.	x											
Additional Heat Gains	x											
SUB TOTAL												
Storage	SQ FT x	x (-)										
SUB TOTAL												
Safety Factor	%											
ROOM SENSIBLE HEAT <u>110</u>												
SUPPLY DUCT HEAT GAIN	% + LEAK. LOSS	% + H. P.	%									
Outdoor Air	CFM x	F x	BF x 1.08									
EFFECTIVE ROOM SENSIBLE HEAT <u>110</u>												
LATENT HEAT												
Infiltration	CFM x	GR/LB x 0.68										
People	PEOPLE x											
Steam	LB/HR x 1050											
Appliances, Etc.												
Additional Heat Gains												
Vapor Trans.	SQ x 1/100 x	GR/LB x										
SUB TOTAL												
Safety Factor	%											
ROOM LATENT HEAT												
SUPPLY DUCT LEAKAGE LOSS	%											
Outdoor Air	CFM x	GR/LB x	BF x 0.68									
EFFECTIVE ROOM LATENT HEAT												
EFFECTIVE ROOM TOTAL HEAT <u>1120</u>												
OUTDOOR AIR HEAT												
Sensible: <u>26</u>	CFM x <u>36</u>	F x (1 - 0)	BF x 1.08									
Latent:	CFM x	GR/LB x (1 - 0)	BF x 0.68									
RETURN DUCT HEAT GAIN	% + LEAK. GAIN	% + PUMP	% + PIPE LOSS									
SUB TOTAL												
GRAND TOTAL HEAT <u>1120</u>												

E-5024

AIR CONDITIONING LOAD ESTIMATE (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

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COMPUTED BY J CASE
 CHECKED BY _____
 DATE 11-12-89
 REV. _____ 19__

LFL LIFE SERVICES

HEATING LOAD

FLDG #6, LAR RMN (15.3) (16)

PROJECT 16-199-09SHEET NO. 40 OF 56 SHEETS

Space Used For _____
 Size 70 x 20 = 1400 SQ FT x 14 = 19600 CU FT

ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
SOLAR GAIN-GLASS				
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Skylight	SQ FT x	x		
SOLAR & TRANS. GAIN-WALLS & ROOF				
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Roof-Sun	<u>400</u> SQ FT x <u>36</u>	x <u>1.05</u>		<u>720</u>
Roof-Shaded	SQ FT x	x		
TRANS. GAIN-EXCEPT WALLS & ROOF				
All Glass	SQ FT x	x		
Partition	SQ FT x	x		
Ceiling	SQ FT x	x		
Floor	SQ FT x	x		
Infiltration	CFM x	x	1.08	
INTERNAL HEAT				
People	PEOPLE x			
Power	HP OR KW x			
Lights	WATTS x 3.4 x			
Appliances, Etc.	x			
Additional Heat Gains	x			
SUB TOTAL				<u>720</u>
Storage	SQ FT x	x (-)		
SUB TOTAL				
Safety Factor	<u>5</u>			<u>40</u>
ROOM SENSIBLE HEAT				<u>720</u>
SUPPLY DUCT HEAT GAIN	SUPPLY DUCT % + LEAK. LOSS	FAN % + H. P.	%	
Outdoor Air	CFM x	F x	BF x 1.08	
EFFECTIVE ROOM SENSIBLE HEAT				
LATENT HEAT				
Infiltration	CFM x	GR/LB x 0.68		
People	PEOPLE x			
Steam	LB/HR x 1050			
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.	SQ x 1/100 x	GR/LB x		
SUB TOTAL				
Safety Factor	%			
ROOM LATENT HEAT				
SUPPLY DUCT LEAKAGE LOSS	%			
Outdoor Air	CFM x	GR/LB x	BF x 0.68	
EFFECTIVE ROOM LATENT HEAT				
EFFECTIVE ROOM TOTAL HEAT				
OUTDOOR AIR HEAT				
Sensible:	<u>1400</u> CFM x <u>36</u>	F x (1- BF) x 1.08		<u>38830</u>
Latent:	CFM x	GR/LB x (1- BF) x 0.68		
RETURN DUCT HEAT GAIN	RETURN DUCT % + LEAK. LOSS	HP % + PUMP	% + DEMUM. & PIPE LOSS	%
GRAND TOTAL HEAT				<u>39640</u>

Estimate for		LOCAL TIME SUN TIME	Peak Load	LOCAL TIME SUN TIME
Hours of Operation				
CONDITIONS	DB	WB	% RH	DP
OUTDOOR (OA)	<u>36</u>			
ROOM (RM)	<u>72</u>			
DIFFERENCE	<u>-36</u>			
OUTDOOR AIR				
VENTILATION	PEOPLE x	CFM/PERSON =		
	SQ FT x	CFM/SQ FT =		
	CFM VENTILATION <u>8</u>			
INFILTRATION	SWINGING REVOLVING DOORS	PEOPLE x	CFM/PERSON =	
	OPEN DOORS	DOORS x	CFM/DOOR =	
	EXHAUST FAN			
	CRACK	FEET x	CFM/FT =	
	CFM INFILTRATION <u>14</u>			
CFM OUTDOOR AIR THRU APPARATUS <u>8</u>				
APPARATUS DEWPOINT				
ESHF	EFFECTIVE SENS HEAT FACTOR	EFFECTIVE ROOM SENS. HEAT	EFFECTIVE ROOM TOTAL HEAT	
AOP	INDICATED ADP =	F	SELECTED ADP =	F
DEHUMIDIFIED AIR QUANTITY				
TEMP RISE	(1- BF) x (TRM - TADP) + F	TADP	F	
DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT	1.08 x	F TEMP. RISE	CFM _{OA}
OUTLET TEMP. DIFF.	ROOM SENS. HEAT	1.08 x	F	CFM _{OA}
FROM PSYCH. CHART: T _{WB} = F, T _{LB} = F				
SUPPLY AIR QUANTITY				
SUPPLY CFM	ROOM SENS. HEAT	1.08 x	F DESIRED DIFF	CFM _{SA}
BYPASS CFM	CFM _{SA}	CFM _{OA}	CFM _{SA}	CFM _{SA}
RESULTING ENT & LVG CONDITIONS AT APPARATUS				
EDB	T _{RM} + F + (CFM _{OA} x (T _{OA} - T _{RM}) / CFM)	F	T _{EDB}	F
LDB	T _{ADP} + F + (BF x (T _{EDB} - T _{ADP}) / (1- BF))	F	T _{LDB}	F
FROM PSYCH. CHART: T _{WB} = F, T _{LB} = F				

NOTES

HOOD REQUIREMENTS

1000 CFM OA39,640 BTUH

9-49

*IF THIS AT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
 WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
 WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

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COMPUTED BY J CASE
 CHECKED BY _____
 DATE 11-12-1989
 REV. _____ 19 _____

LEL - LIFE SCIENCES
HEATING LOAD
FLY - LAB BTWN (16) + (17)

PROJECT 16-199-03
 SHEET NO. 41 OF 52 SHEETS

Space Used For					Estimate for		LOCAL TIME		Peak Load		LOCAL TIME	
Size <u>27</u> x <u>20</u> = <u>540</u> SQ FT x <u>14</u> = <u>7560</u> CU FT							SUN TIME				SUN TIME	
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR	Hours of Operation							
					CONDITIONS	DB	WB	% RH	DP	GR/LB		
SOLAR GAIN-GLASS					OUTDOOR AIR							
Glass	SQ FT x	x			OUTDOOR (OA)	<u>72</u>						
Glass	SQ FT x	x			ROOM (RM)	<u>72</u>						
Glass	SQ FT x	x			DIFFERENCE	<u>36</u>						
Glass	SQ FT x	x										
Skylight	SQ FT x	x										
SOLAR & TRANS. GAIN-WALLS & ROOF												
Wall	SQ FT x	x										
Wall	SQ FT x	x										
Wall	SQ FT x	x										
Wall	SQ FT x	x										
Roof-Sun	<u>540</u> SQ FT x <u>36</u> x <u>.05</u>			<u>970</u>								
Roof-Shaded	SQ FT x	x										
TRANS. GAIN-EXCEPT WALLS & ROOF												
All Glass	SQ FT x	x										
Partition	SQ FT x	x										
Ceiling	SQ FT x	x										
Floor	SQ FT x	x										
Infiltration	CFM x	x	1.08									
INTERNAL HEAT												
People	PEOPLE x											
Power	HP OR KW x											
Lights	WATTS x <u>3.4</u> x											
Appliances, Etc.	x											
Additional Heat Gains	x											
SUB TOTAL				<u>970</u>								
Storage	SQ FT x	x (1-)										
SUB TOTAL												
Safety Factor	<u>5</u> %			<u>50</u>								
ROOM SENSIBLE HEAT				<u>1020</u>								
SUPPLY DUCT HEAT GAIN	SUPPLY DUCT % + LEAK. LOSS	FAN % + H. P.	%									
Outdoor Air	CFM x	F x	BF x 1.08									
EFFECTIVE ROOM SENSIBLE HEAT												
LATENT HEAT												
Infiltration	CFM x	GR/LB x 0.68										
People	PEOPLE x											
Steam	LB/HR x 1050											
Appliances, Etc.												
Additional Heat Gains												
Vapor Trans.	SQ x 1/100 x	GR/LB x										
SUB TOTAL												
Safety Factor	%											
ROOM LATENT HEAT												
SUPPLY DUCT LEAKAGE LOSS	%											
Outdoor Air	CFM x	GR/LB x	BF x 0.68									
EFFECTIVE ROOM LATENT HEAT												
EFFECTIVE ROOM TOTAL HEAT												
OUTDOOR AIR HEAT												
Sensible:	<u>2000</u> CFM x <u>36</u> F x (1- 0) BF x 1.08			<u>77,760</u>								
Latent:	CFM x	GR/LB x (1- BF) x 0.68										
RETURN DUCT HEAT GAIN	RETURN DUCT % + LEAK. GAIN	HP % + PUMP	%									
SUB TOTAL												
GRAND TOTAL HEAT				<u>78,730</u>								

NOTES

HOOD REQUIREMENTS

2,000 CFM

78,730 BTU/H

9-50

IF THIS AT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.

WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.

WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

Keller & Gannon

Engineers-Architects

42

COMPUTED BY J CASE
 CHECKED BY _____
 DATE 11-12-1989
 REV. _____ 19__

LFL - LIFE SCIENCES
HEATING LOAD
FL. 26 - LAB (WEST)

PROJECT 16-194-09
 SHEET NO. 42 OF 57 SHEETS

Space Used For					Estimate for		LOCAL TIME		Peak Load		LOCAL TIME	
Size <u>20</u> x <u>26</u> = <u>520</u> SQ FT x <u>14</u> = <u>7280</u> CU FT							SUN TIME				SUN TIME	
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR		Hours of Operation						
SOLAR GAIN-GLASS						CONDITIONS	DB	WB	% RH	DP	GR/LB	
Glass	SQ FT x	x				OUTDOOR (OA)	<u>36</u>					
Glass	SQ FT x	x				ROOM (RM)	<u>72</u>					
Glass	SQ FT x	x				DIFFERENCE	<u>-36</u>					
Glass	SQ FT x	x				OUTDOOR AIR						
Skylight	SQ FT x	x				VENTILATION	PEOPLE x _____ CFM/PERSON = _____					
SOLAR & TRANS. GAIN-WALLS & ROOF						SQ FT x _____ CFM/SQ FT = _____						
Wall	SQ FT x	x				CFM VENTILATION ☒						
Wall	SQ FT x	x				SWINGING REVOLVING DOORS _____ PEOPLE x _____ CFM/PERSON = _____						
Wall	SQ FT x	x				OPEN DOORS _____ DOORS x _____ CFM/DOOR = _____						
Wall	SQ FT x	x				EXHAUST FAN _____						
Roof-Sun	SQ FT x	x				CRACK _____ FEET x _____ CFM/FT = _____						
Roof-Shaded <u>520</u>	SQ FT x <u>36</u>	x <u>.05</u>			<u>970</u>	CFM INFILTRATION ☒						
TRANS. GAIN-EXCEPT WALLS & ROOF						CFM OUTDOOR AIR THRU APPARATUS ☒						
All Glass	SQ FT x	x				APPARATUS DEWPOINT						
Partition	SQ FT x	x				EASHF EFFECTIVE SENS. HEAT FACTOR = EFFECTIVE ROOM SENS. HEAT = _____						
Ceiling	SQ FT x	x				EASHF EFFECTIVE ROOM SENS. HEAT = EFFECTIVE ROOM TOTAL HEAT = _____						
Floor	SQ FT x	x				ADP INDICATED ADP = _____ F SELECTED ADP = _____ F						
Infiltration	CFM x	x 1.08				DEHUMIDIFIED AIR QUANTITY						
INTERNAL HEAT						TDMP RISE (1- _____ BP) x (TRM _____ F - TADP _____ F) = _____ F						
People	PEOPLE x					DEHUM. CFM 1.08 x F TEMP. RISE = _____ CFM _{DA}						
Power	HP OR KW x					OUTLET TDMP DIFF. 1.08 x ROOM SENS. HEAT = _____ CFM _{DA}						
Lights	WATTS x 3.4 x					SUPPLY AIR QUANTITY						
Appliances, Etc.	x					SUPPLY CFM ROOM SENS. HEAT = _____ CFM _{SA}						
Additional Heat Gains	x					1.08 x F DESIRED DIFF = _____ CFM _{SA}						
SUB TOTAL						BYPASS CFM CFM _{SA} - CFM _{DA} = _____ CFM _{BA}						
Storage	SQ FT x	x (- 1)				RESULTING ENT & LVG CONDITIONS AT APPARATUS						
SUB TOTAL						EDB T _{RM} F + _____ CFM _{DA} x (T _{OA} - T _{RM}) F = T _{EDB} F						
Safety Factor <u>5%</u>					<u>50</u>	LDB T _{ADP} F + _____ BP = (T _{EDB} - T _{ADP}) F = T _{LDB} F						
ROOM SENSIBLE HEAT ☒						FROM PSYCH. CHART: T _{EDB} F, T _{LDB} F						
SUPPLY DUCT HEAT GAIN	% x LEAK. LOSS	% x H. P.	%			NOTES						
Outdoor Air	CFM x	F x	BF x 1.08			HOOD REQUIREMENTS						
EFFECTIVE ROOM SENSIBLE HEAT ☒						1,750 CFM						
LATENT HEAT						69,050 BTUH						
Infiltration	CFM x	GR/LB x 0.68										
People	PEOPLE x											
Steam	LB/HR x 1050											
Appliances, Etc.												
Additional Heat Gains												
Vapor Trans.	SQ x 1/100 x	GR/LB x										
SUB TOTAL												
Safety Factor	%											
ROOM LATENT HEAT												
SUPPLY DUCT LEAKAGE LOSS												
Outdoor Air	CFM x	GR/LB x	BF x 0.68									
EFFECTIVE ROOM LATENT HEAT												
EFFECTIVE ROOM TOTAL HEAT ☒												
OUTDOOR AIR HEAT												
Sensible:	1,750 CFM x	36 F x (1- 0)	BF x 1.08		<u>63,040</u>							
Latent:	CFM x	GR/LB x (1- 0)	BF x 0.68									
RETURN DUCT HEAT GAIN	% x LEAK. GAIN	% x PUMP	% x PIPE LOSS									
GRAND TOTAL HEAT ☒						<u>69,050</u>						

9-51

*IF THIS ΔT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
 WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
 WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

BUILDING 30

COMPUTED BY 253
CHECKED BY Buy
DATE 11-12-1984
REV. 15

LIFE SCIENCES
HEATING LOAD
MICROCOPY (S.E. CORNER)

PROJECT 16-199-09
SHEET NO. 43 OF 52 SHEETS

Space Used For					Estimate for		LOCAL TIME		Peak Load		LOCAL TIME	
Size	x	=	SQ FT x	=	CU FT	Hours of Operation	CONDITIONS	DB	WB	% RH	DP	GR/LB
SOLAR GAIN-GLASS												
Glass	SQ FT x	x				OUTDOOR (OA)	34					
Glass	SQ FT x	x				ROOM (RM)	72					
Glass	SQ FT x	x				DIFFERENCE	38					
Skylight	SQ FT x	x				OUTDOOR AIR						
SOLAR & TRANS. GAIN-WALLS & ROOF												
Wall	190 SQ FT x	38 x	1.13		939	VENTILATION	PEOPLE x	CFM/PERSON =				
Wall	SQ FT x	x					SQ FT x	CFM/SQ FT =				
Wall	SQ FT x	x					CFM VENTILATION					
Wall	SQ FT x	x				INFLTRATION	SWINGING REVOLVING DOORS	PEOPLE x	CFM/PERSON =			
Roof-Sun	270 SQ FT x	38 x	1.12		1231		OPEN DOORS	DOORS x	CFM/DOOR =			
Roof-Shaded	SQ FT x	x					EXHAUST FAN					
TRANS. GAIN-EXCEPT WALLS & ROOF												
All Glass	140 SQ FT x	38 x	1.02		5426		CRACK	FEET x	CFM/FT =			
Partition	SQ FT x	x					CFM INFILTRATION					
Ceiling	SQ FT x	x				CFM OUTDOOR AIR THRU APPARATUS						
Floor	SQ FT x	x				APPARATUS DEWPOINT						
Infiltration	CFM x	x	1.08			ESHF	EFFECTIVE SENS. HEAT FACTOR	EFFECTIVE ROOM SENS. HEAT	EFFECTIVE ROOM TOTAL HEAT			
INTERNAL HEAT												
People	PEOPLE x					ADP	INDICATED ADP =	F	SELECTED ADP =	F		
Power	HP OR KW x					DEHUMIDIFIED AIR QUANTITY						
Lights	WATTS x 3.4 x					TEMP. RISE	(1 - BF) x (T _{RM} - T _{ADP})	F	T _{ADP}	F		
Appliances, Etc.	x					DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT		CFM _{DA}			
Additional Heat Gains	x					OUTLET TEMP. DIFF.	ROOM SENS. HEAT		CFM _{DA}	F _{RM-OUTLET AIR}		
SUB TOTAL												
Storage	SQ FT x	x (-)				SUPPLY CFM	ROOM SENS. HEAT		CFM _{SA}			
SUB TOTAL												
Safety Factor	%					BYPASS CFM	1.00 x F DESIRED DIFF		CFM _{SA}	CFM _{DA}	CFM _{BA}	
ROOM SENSIBLE HEAT												
SUPPLY DUCT HEAT GAIN	% + LEAK. LOSS	% + H. P.	%			RESULTING ENT & LVG CONDITIONS AT APPARATUS						
Outdoor Air	CFM x	F x	BF x 1.08			EDB	T _{RM} + (CFM _{OA} / CFM) (T _{OA} - T _{RM})	F	T _{EDB}			
EFFECTIVE ROOM SENSIBLE HEAT												
LATENT HEAT												
Infiltration	CFM x	GR/LB x 0.68				LDB	T _{ADP} + (BF / (1 - BF)) (T _{EDB} - T _{ADP})	F	T _{LDB}			
People	PEOPLE x					FROM PSYCH. CHART: T _{EDB} , T _{LDB}						
Steam	LB/HR x 1050					NOTES						
Appliances, Etc.												
Additional Heat Gains												
Vapor Trans.	SQ x 1/100 x	GR/LB x										
SUB TOTAL												
Safety Factor	%											
ROOM LATENT HEAT												
SUPPLY DUCT LEAKAGE LOSS	%											
Outdoor Air	CFM x	GR/LB x	BF x 0.68									
EFFECTIVE ROOM LATENT HEAT												
EFFECTIVE ROOM TOTAL HEAT												
OUTDOOR AIR HEAT												
Sensible:	CFM x	F x (1 - BF) x 1.08										
Latent:	CFM x	GR/LB x (1 - BF) x 0.68										
SUB TOTAL												
RETURN DUCT HEAT GAIN	% + LEAK. GAIN	% + PUMP	% + PIPE LOSS									
GRAND TOTAL HEAT												

9-52

*IF THIS AT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

COMPUTED BY RJB
CHECKED BY BW
DATE 11-2-1989
REV. 15

BUILDING 30
LBL-LIFE SCIENCES
HEATING LOAD
MICROCOPY (INCL. S.I.E.)

PROJECT 16-199-09
SHEET NO. 44 OF 56 SHEETS

Space Used For				
Size <u>16' 1/2 x 13' 1/2 = 223</u> SQ FT x <u>9' 1/2 = 216</u> CU FT				
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
SOLAR GAIN-GLASS				
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Skylight	SQ FT x	x		
SOLAR & TRANS. GAIN-WALLS & ROOF				
Wall	<u>95</u> SQ FT x <u>38</u>	x <u>1.13</u>		<u>969</u>
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Roof-Sun	<u>223</u> SQ FT x <u>38</u>	x <u>1.12</u>		<u>1017</u>
Roof-Shaded	SQ FT x	x		
TRANS. GAIN-EXCEPT WALLS & ROOF				
All Glass	<u>70</u> SQ FT x <u>38</u>	x <u>1.02</u>		<u>2713</u>
Partition	SQ FT x	x		
Ceiling	SQ FT x	x		
Floor	SQ FT x	x		
Infiltration	CFM x	x	1.08	
INTERNAL HEAT				
People	PEOPLE x			
Power	HP OR KW x			
Lights	WATTS x 3.4 x			
Appliances, Etc.	x			
Additional Heat Gains	x			
				SUB TOTAL
Storage	SQ FT x	x ()		
				SUB TOTAL
Safety Factor	%			
				ROOM SENSIBLE HEAT <u>9197</u>
SUPPLY DUCT HEAT GAIN	% + LEAK. LOSS	% + M. P.	%	
Outdoor Air	CFM x	F x	BF x 1.08	
				EFFECTIVE ROOM SENSIBLE HEAT
LATENT HEAT				
Infiltration	CFM x	GR/LB x 0.68		
People	PEOPLE x			
Steam	LB/HR x 1050			
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.	SQ x 1/100 x	GR/LB x		
				SUB TOTAL
Safety Factor	%			
				ROOM LATENT HEAT
SUPPLY DUCT LEAKAGE LOSS	%			
Outdoor Air	CFM x	GR/LB x	BF x 0.68	
				EFFECTIVE ROOM LATENT HEAT
				EFFECTIVE ROOM TOTAL HEAT
OUTDOOR AIR HEAT				
Sensible:	CFM x	F x (1- BF) x 1.08		
Latent:	CFM x	GR/LB x (1- BF) x 0.68		
RETURN DUCT HEAT GAIN	% + LEAK. GAIN	% + PUMP	% + PIPE LOSS	
				GRAND TOTAL HEAT

Estimate for		LOCAL TIME	Peak Load	LOCAL TIME
		SUN TIME		SUN TIME
Hours of Operation				
CONDITIONS	DB	WB	% RH	DP
OUTDOOR (OA)				
ROOM (RM)				
DIFFERENCE				
OUTDOOR AIR				
VENTILATION	PEOPLE x	CFM/PERSON =		
	SQ FT x	CFM/SQ FT =		
		CFM VENTILATION		
INFILTRATION	SWINGING REVOLVING DOORS	PEOPLE x	CFM/PERSON =	
	OPEN DOORS	DOORS x	CFM/DOOR =	
	EXHAUST FAN			
	CRACK	FEET x	CFM/FT =	
			CFM INFILTRATION	
CFM OUTDOOR AIR THRU APPARATUS				
APPARATUS DEWPOINT				
ESHF	EFFECTIVE SENS. HEAT FACTOR	EFFECTIVE ROOM SENS. HEAT	EFFECTIVE ROOM TOTAL HEAT =	
ADP	INDICATED ADP =	F	SELECTED ADP =	F
DEHUMIDIFIED AIR QUANTITY				
TEMP. RISE	(1- BF) x (TRM - TADP)	F - TADP	F	
DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT			CFM _{DA}
	1.08 x	F TEMP. RISE		
OUTLET TEMP. DIFF.	ROOM SENS. HEAT		F (RM - OUTLET AIR)	
	1.08 x			CFM _{DA}
SUPPLY AIR QUANTITY				
SUPPLY CFM	ROOM SENS. HEAT			CFM _{SA}
	1.08 x	F DESIRED DIFF		
BYPASS CFM	CFM _{SA} -	CFM _{DA}		CFM _{BA}
RESULTING ENT & LVG CONDITIONS AT APPARATUS				
EOB	TRM	F +	CFM _{DA} (T _{OA} - F - TRM) F	T _{EOB}
		CFM _{DA}		
LOB	TADP	F +	BF (T _{EOB} - TADP) F	T _{LOB}
			FROM PSYCH. CHART: T _{WB} , T _{WB} , T _{WB}	

NOTES

9-53

*IF THIS ΔT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

BUILDING 30

LBC-LIFE SCIENCES

HEATING LOAD

MICROSCOPE (2ND F.B.E.)

COMPUTED BY **RJB**
CHECKED BY **BWJ**
DATE **11-12-1989**
REV. **15**

PROJECT **16-199-09**
SHEET NO. **45** OF **56** SHEETS

Space Used For					Estimate for		LOCAL TIME		Peak Load		LOCAL TIME	
Size	x	=	SQ FT x	=	CU FT	Hours of Operation	CONDITIONS	DB	WB	%RH	DP	GR/LB
SOLAR GAIN-GLASS						OUTDOOR AIR						
Glass	SQ FT x		x			VENTILATION	PEOPLE	=	CFM/PERSON	=		
Glass	SQ FT x		x				SQ FT	=	CFM/SQ FT	=		
Glass	SQ FT x		x			CFM VENTILATION						
Glass	SQ FT x		x									
Skylight	SQ FT x		x									
SOLAR & TRANS. GAIN-WALLS & ROOF						APPARATUS DEWPOINT						
Wall	93 SQ FT x	38	x	1.13	202	ESHF	EFFECTIVE SENS. HEAT FACTOR	=	EFFECTIVE ROOM SENS. HEAT	=	EFFECTIVE ROOM TOTAL HEAT	=
Wall	SQ FT x		x									
Wall	SQ FT x		x									
Wall	SQ FT x		x									
Roof-Sun	223 SQ FT x	38	x	1.12	1017							
Roof-Shaded	SQ FT x		x									
TRANS. GAIN-EXCEPT WALLS & ROOF												
All Glass	117 SQ FT x	38	x	1.02	9535							
Partition	SQ FT x		x									
Ceiling	SQ FT x		x									
Floor	SQ FT x		x									
Infiltration	CFM x		x	1.08								
INTERNAL HEAT						DEHUMIDIFIED AIR QUANTITY						
People	PEOPLE x					TEMP RISE	(1 - BF) x (T _{RM} - T _{ADP}) x F	=		=		
Power	HP OR KW x					DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT	=		=	CFM _{DA}	
Lights	WATTS x 3.4 x						1.08 x F _{TEMP. RISE}	=		=		
Appliances, Etc.	x					OUTLET TEMP. DIFF.	ROOM SENS. HEAT	=		=	F _{RM-OUTLET AIR}	
Additional Heat Gains	x						1.08 x CFM _{DA}	=		=		
SUB TOTAL						SUPPLY AIR QUANTITY						
Storage	SQ FT x		x	(-)		SUPPLY CFM	ROOM SENS. HEAT	=		=	CFM _{SA}	
SUB TOTAL						DEHUM. CFM						
Safety Factor	%						1.08 x F DESIRED DIFF	=		=	CFM _{SA}	
ROOM SENSIBLE HEAT						DEHUM. CFM						
SUPPLY DUCT HEAT GAIN	% + LEAK. LOSS						CFM _{SA} - CFM _{DA}	=		=	CFM _{SA}	
Outdoor Air	CFM x		F x	BF x 1.08		RESULTING ENT & LVG CONDITIONS AT APPARATUS						
EFFECTIVE ROOM SENSIBLE HEAT						EDB						
LATENT HEAT						LDB						
Infiltration	CFM x		GR/LB x 0.68			NOTES						
People	PEOPLE x											
Steam	LB/HR x 1050											
Appliances, Etc.												
Additional Heat Gains												
Vapor Trans.	SQ x 1/100 x		GR/LB x									
SUB TOTAL												
Safety Factor	%											
ROOM LATENT HEAT												
SUPPLY DUCT LEAKAGE LOSS												
Outdoor Air	CFM x		GR/LB x	BF x 0.68								
EFFECTIVE ROOM LATENT HEAT												
EFFECTIVE ROOM TOTAL HEAT												
OUTDOOR AIR HEAT												
Sensible:	CFM x		F x (1 - BF) x 1.08									
Latent:	CFM x		GR/LB x (1 - BF) x 0.68									
RETURN DUCT HEAT GAIN	% + LEAK. GAIN											
RETURN DUCT	HP											
HEAT GAIN	% + PIPE LOSS											
SUB TOTAL												
GRAND TOTAL HEAT												

COMPUTATION SHEET

BUILDING 30

LDC-LIFE SCIENCES

HEATING LOAD

PAVILION

COMPUTED BY **RJB**
CHECKED BY **BW**
DATE **11-12-1989**
REV. _____ 15.

PROJECT **16-199-09**
SHEET NO. **46** OF **52** SHEETS

Space Used For				
Size	x	=	SQ FT x	=
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
SOLAR GAIN-GLASS				
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Skylight	SQ FT x	x		
SOLAR & TRANS. GAIN-WALLS & ROOF				
Wall	75 SQ FT x 38	.13		370
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Roof-Sun	101 SQ FT x 38	.12		461
Roof-Shaded	SQ FT x	x		
TRANS. GAIN-EXCEPT WALLS & ROOF				
All Glass	SQ FT x	x		
Partition	SQ FT x	x		
Ceiling	SQ FT x	x		
Floor	SQ FT x	x		
Infiltration	CFM x	x	1.08	
INTERNAL HEAT				
People	PEOPLE x			
Power	HP OR KW x			
Lights	WATTS x 3.4			
Appliances, Etc.	x			
Additional Heat Gains	x			
SUB TOTAL				
Storage	SQ FT x	x (-)		
SUB TOTAL				
Safety Factor	%			
ROOM SENSIBLE HEAT				
SUPPLY DUCT HEAT GAIN	% + LEAK. LOSS	% + H. P.	%	
Outdoor Air	CFM x	F x	BF x 1.08	
EFFECTIVE ROOM SENSIBLE HEAT				
LATENT HEAT				
Infiltration	CFM x	GR/LB x 0.68		
People	PEOPLE x			
Steam	LB/HR x 1050			
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.	SQ x 1/100 x	GR/LB x		
SUB TOTAL				
Safety Factor	%			
ROOM LATENT HEAT				
SUPPLY DUCT LEAKAGE LOSS	%			
Outdoor Air	CFM x	GR/LB x	BF x 0.68	
EFFECTIVE ROOM LATENT HEAT				
EFFECTIVE ROOM TOTAL HEAT				
OUTDOOR AIR HEAT				
Sensible:	CFM x	F x (1- BF) x 1.08		
Latent:	CFM x	GR/LB x (1- BF) x 0.68		
RETURN DUCT HEAT GAIN	% + LEAK. GAIN	% + PUMP	% + PIPE LOSS	
GRAND TOTAL HEAT				

Estimate for		LOCAL TIME SUN TIME	Peak Load	LOCAL TIME SUN TIME
Hours of Operation				
CONDITIONS	DB	WB	% RH	DP
OUTDOOR (OA)				
ROOM (RM)				
DIFFERENCE				
OUTDOOR AIR				
VENTILATION	PEOPLE x	CFM/PERSON =		
	SQ FT x	CFM/SQ FT =		
		CFM VENTILATION		
BRINGING REVOLVING DOORS	PEOPLE x	CFM/PERSON =		
OPEN DOORS	DOORS x	CFM/DOOR =		
EXHAUST FAN				
CRACK	FEET x	CFM/FT =		
		CFM INFILTRATION		
CFM OUTDOOR AIR THRU APPARATUS				
APPARATUS DEWPOINT				
ESHF	EFFECTIVE ROOM SENS. HEAT FACTOR	EFFECTIVE ROOM SENS. HEAT	EFFECTIVE ROOM TOTAL HEAT =	
ADP	INDICATED ADP =	F	SELECTED ADP =	F
DEHUMIDIFIED AIR QUANTITY				
TEMP. RISE	(1- BF) x (T _{RM} - T _{ADP})	F	F	
DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT		CFM _{OA}	
	1.08 x	F TEMP. RISE		
OUTLET TEMP. DIFF.	ROOM SENS. HEAT		CFM _{OA}	
	1.08 x	F	CFM _{OA}	
SUPPLY AIR QUANTITY				
SUPPLY CFM	ROOM SENS. HEAT		CFM _{OA}	
	1.08 x	F DESIRED DIFF		
BYPASS CFM	CFM _{OA} -	CFM _{OA}	CFM _{OA}	
RESULTING ENT & LVG CONDITIONS AT APPARATUS				
EDB	T _{RM} - F +	CFM _{OA} x (T _{OA} - T _{RM})	F = T _{EDB} - F	
		CFM _{OA}		
LDB	T _{ADP} - F +	BF x (T _{EDB} - T _{ADP})	F = T _{LDB} - F	
		FROM PSYCH. CHART: T _{WB} - F, T _{WB} - F		

NOTES

9-55

*IF THIS ΔT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
THEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
THEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

BUILDING 80

LBL-LIFE SCIENCES

HEATING LOAD

PROCHAM LAB

COMPUTED BY **RJB**
CHECKED BY **RW**
DATE **11-12-1987**
REV. **19**

PROJECT **16-199-09**

SHEET NO. **47** OF **52** SHEETS

Space Used For					Estimate for		LOCAL TIME		Peak Load		LOCAL TIME																									
Size	x	=	SQ FT x	=	CU FT	Hours of Operation	DB	WB	% RH	DP	GR/LB																									
SOLAR GAIN-GLASS						<table border="1"> <tr> <td>CONDITIONS</td> <td>DB</td> <td>WB</td> <td>% RH</td> <td>DP</td> <td>GR/LB</td> </tr> <tr> <td>OUTDOOR (OA)</td> <td>34</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>ROOM (RM)</td> <td>72</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>DIFFERENCE</td> <td>38</td> <td></td> <td></td> <td></td> <td></td> </tr> </table>							CONDITIONS	DB	WB	% RH	DP	GR/LB	OUTDOOR (OA)	34					ROOM (RM)	72					DIFFERENCE	38				
CONDITIONS	DB	WB	% RH	DP	GR/LB																															
OUTDOOR (OA)	34																																			
ROOM (RM)	72																																			
DIFFERENCE	38																																			
Glass	SQ FT x	x				OUTDOOR AIR PEOPLE = _____ CFM/PERSON = _____ SQ FT = _____ CFM/SQ FT = _____ CFM VENTILATION = _____ SWINGING REVOLVING DOORS _____ PEOPLE = _____ CFM/PERSON = _____ OPEN DOORS _____ DOORS = _____ CFM/DOOR = _____ EXHAUST FAN _____ CRACK _____ FEET = _____ CFM/FT = _____ CFM INFILTRATION = _____ CFM OUTDOOR AIR THRU APPARATUS = _____ APPARATUS DEWPOINT EFFECTIVE ROOM SENS. HEAT = _____ EFFECTIVE ROOM TOTAL HEAT = _____ INDICATED ADP = _____ F SELECTED ADP = _____ F DEHUMIDIFIED AIR QUANTITY (1 - BF) x (TRM - TADP - F) = _____ F EFFECTIVE ROOM SENS. HEAT = _____ CFM _{DA} 1.08 x F _{TEMP. RISE} ROOM SENS. HEAT = _____ F _{RM-OUTLET AIR} 1.08 x CFM _{DA} SUPPLY AIR QUANTITY ROOM SENS. HEAT = _____ CFM _{SA} 1.08 x F DESIRED DIFF CFM _{SA} - CFM _{DA} = _____ CFM _{RA} RESULTING ENT & LVG CONDITIONS AT APPARATUS T _{RM} = F + (CFM _{DA} / CFM _{RA}) x (T _{OA} - T _{RM}) = T _{EOB} T _{ADP} = F + BF x (T _{EOB} - T _{ADP}) = T _{LOB} FROM PSYCH. CHART: T _{EOB} = _____ F, T _{LOB} = _____ F																														
Glass	SQ FT x	x																																		
Glass	SQ FT x	x																																		
Glass	SQ FT x	x																																		
Skylight	SQ FT x	x																																		
SOLAR & TRANS. GAIN-WALLS & ROOF																																				
Wall	111 SQ FT x	38	x	1.13	548																															
Wall	SQ FT x	x																																		
Wall	SQ FT x	x																																		
Wall	SQ FT x	x																																		
Roof-Sun	1442 SQ FT x	38	x	1.12	6576																															
Roof-Shaded	SQ FT x	x																																		
TRANS. GAIN-EXCEPT WALLS & ROOF																																				
All Glass	289 SQ FT x	38	x	1.02	11202																															
Partition	SQ FT x	x																																		
Ceiling	SQ FT x	x																																		
Floor	SQ FT x	x																																		
Infiltration	CFM x	x	1.08																																	
INTERNAL HEAT																																				
People	PEOPLE x																																			
Power	HP OR KW x																																			
Lights	WATTS x 3.4 x																																			
Appliances, Etc.	x																																			
Additional Heat Gains	x																																			
SUB TOTAL																																				
Storage	SQ FT x	x	(-)																																	
SUB TOTAL																																				
Safety Factor	%																																			
ROOM SENSIBLE HEAT						18 326																														
SUPPLY DUCT HEAT GAIN																																				
Outdoor Air																																				
EFFECTIVE ROOM SENSIBLE HEAT																																				
LATENT HEAT																																				
Infiltration	CFM x	GR/LB x	0.68																																	
People	PEOPLE x																																			
Steam	LB/HR x 1050																																			
Appliances, Etc.																																				
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Vapor Trans.	SQ x 1/100 x	GR/LB x																																		
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Safety Factor	%																																			
ROOM LATENT HEAT																																				
SUPPLY DUCT LEAKAGE LOSS																																				
Outdoor Air	CFM x	GR/LB x	BF x 0.68																																	
EFFECTIVE ROOM LATENT HEAT																																				
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Sensible:	CFM x	F x (1 - BF) x 1.08																																		
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HP & PUMP																																				
SUB TOTAL																																				
DEHUM. & PIPE LOSS																																				
GRAND TOTAL HEAT																																				

9-56

*IF THIS ΔT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

BUILDING 80
LBG-LIFE SCIENCES
HEATING LOAD
SURVEY

COMPUTED BY **RJB**
CHECKED BY **BW**
DATE **11-12-1989**
REV. _____ 19____

PROJECT **16-199-09**
SHEET NO. **48** OF **52** SHEETS

Space Used For _____					Estimate for _____		LOCAL TIME SUN TIME		Peak Load		LOCAL TIME SUN TIME	
Size _____					_____		_____		_____		_____	
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR	Hours of Operation							
					CONDITIONS	DB	WB	% RH	DP	GR/LB		
SOLAR GAIN-GLASS												
Glass	SQ FT x	x										
Glass	SQ FT x	x										
Glass	SQ FT x	x										
Glass	SQ FT x	x										
Skylight	SQ FT x	x										
SOLAR & TRANS. GAIN-WALLS & ROOF												
Wall	SQ FT x	x										
Wall	SQ FT x	x										
Wall	SQ FT x	x										
Wall	SQ FT x	x										
Roof-Sun	495 SQ FT x 58	x 1.12		2257								
Roof-Shaded	SQ FT x	x										
TRANS. GAIN-EXCEPT WALLS & ROOF												
All Glass	SQ FT x	x										
Partition	SQ FT x	x										
Ceiling	SQ FT x	x										
Floor	SQ FT x	x										
Infiltration	CFM x	x 1.08										
INTERNAL HEAT												
People	PEOPLE x											
Power	HP OR KW x											
Lights	WATTS x 3.4 x											
Appliances, Etc.	x											
Additional Heat Gains	x											
SUB TOTAL												
Storage	SQ FT x	x (- 1)										
SUB TOTAL												
Safety Factor	%											
ROOM SENSIBLE HEAT				2257								
SUPPLY DUCT LEAKAGE LOSS												
Outdoor Air	CFM x	F x	BF x 1.08									
EFFECTIVE ROOM SENSIBLE HEAT												
LATENT HEAT												
Infiltration	CFM x	GR/LB x 0.68										
People	PEOPLE x											
Steam	LB/HR x 1050											
Appliances, Etc.												
Additional Heat Gains												
Vapor Trans.	SQ x 1/100 x	GR/LB x										
SUB TOTAL												
Safety Factor	%											
ROOM LATENT HEAT												
SUPPLY DUCT LEAKAGE LOSS												
Outdoor Air	CFM x	GR/LB x	BF x 0.68									
EFFECTIVE ROOM LATENT HEAT												
EFFECTIVE ROOM TOTAL HEAT												
OUTDOOR AIR HEAT												
Sensible:	CFM x	F x (1 - BF) x 1.08										
Latent:	CFM x	GR/LB x (1 - BF) x 0.68										
SUB TOTAL												
RETURN DUCT GAIN	% + LEAK. GAIN	% + PUMP	% + PIPE LOSS	%								
GRAND TOTAL HEAT												

Estimate for _____		LOCAL TIME SUN TIME		Peak Load		LOCAL TIME SUN TIME	
Hours of Operation							
CONDITIONS	DB	WB	% RH	DP	GR/LB		
OUTDOOR (OA)							
ROOM (RM)							
DIFFERENCE							
OUTDOOR AIR							
VENTI-LATION	PEOPLE x	CFM/PERSON =					
	SQ FT x	CFM/SQ FT =					
		CFM VENTILATION					
SWINGING REVOLVING DOORS	PEOPLE x	CFM/PERSON =					
OPEN DOORS	DOORS x	CFM/DOOR =					
EXHAUST FAN							
CRACK	FEET x	CFM/FT =					
		CFM INFILTRATION					
		CFM OUTDOOR AIR THRU APPARATUS					
APPARATUS DEWPOINT							
ESHF	EFFECTIVE SENS HEAT FACTOR	EFFECTIVE ROOM SENS. HEAT	EFFECTIVE ROOM TOTAL HEAT =				
ADP	INDICATED ADP =	F	SELECTED ADP =	F			
DEHUMIDIFIED AIR QUANTITY							
TEMP RISE	(1 - BF) x (T _{RM} - T _{ADP}) =	F					
DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT	CFM _{OA}					
	1.08 x F _{TEMP. RISE}						
OUTLET TEMP. DIFF.	ROOM SENS. HEAT	CFM _{OA}					
	1.08 x F _{TEMP. RISE}						
SUPPLY AIR QUANTITY							
SUPPLY CFM	ROOM SENS. HEAT	CFM _{SA}					
	1.08 x F _{DESIRED DIFF}						
BYPASS CFM	CFM _{SA} - CFM _{OA}	CFM _{SA}					
RESULTING ENT & LVO CONDITIONS AT APPARATUS							
EDB	T _{RM} - F + CFM _{OA} x (T _{OA} - T _{RM}) =	T _{EDB}	F				
	CFM _{SA}						
LDB	T _{ADP} - F + BF x (T _{EDB} - T _{ADP}) =	T _{LDB}	F				
		FROM PSYCH. CHART: T _{EDB} = F, T _{LDB} = F					
NOTES							

COMPUTATION SHEET

BUILDING 80

COMPUTED BY **RJB**
CHECKED BY **BW**
DATE **11-12-1981**
REV. **1981**

LBL-LIFE SCIENCES
HEATING LOAD
CELL/TISSUE

PROJECT **16-199-09**
SHEET NO. **47** OF **56** SHEETS

Space Used For					Estimate for		LOCAL TIME		Peak Load		LOCAL TIME																																																																																																																																																																																																																																																																															
Size	x	=	SQ FT x	=	CU FT	SUN TIME				SUN TIME																																																																																																																																																																																																																																																																																
<table border="1"> <thead> <tr> <th>ITEM</th> <th>AREA OR QUANTITY</th> <th>SUN GAIN OR TEMP. DIFF.</th> <th>FACTOR</th> <th>BTU/HOUR</th> </tr> </thead> <tbody> <tr> <td colspan="5">SOLAR GAIN-GLASS</td> </tr> <tr> <td>Glass</td> <td>SQ FT x</td> <td>x</td> <td></td> <td></td> </tr> <tr> <td>Glass</td> <td>SQ FT x</td> <td>x</td> <td></td> <td></td> </tr> <tr> <td>Glass</td> <td>SQ FT x</td> <td>x</td> <td></td> <td></td> </tr> <tr> <td>Glass</td> <td>SQ FT x</td> <td>x</td> <td></td> <td></td> </tr> <tr> <td>Skylight</td> <td>SQ FT x</td> <td>x</td> <td></td> <td></td> </tr> <tr> <td colspan="5">SOLAR & TRANS. 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GAIN-EXCEPT WALLS & ROOF</td> </tr> <tr> <td>All Glass</td> <td>SQ FT x</td> <td>x</td> <td></td> <td></td> </tr> <tr> <td>Partition</td> <td>SQ FT x</td> <td>x</td> <td></td> <td></td> </tr> <tr> <td>Ceiling</td> <td>SQ FT x</td> <td>x</td> <td></td> <td></td> </tr> <tr> <td>Floor</td> <td>SQ FT x</td> <td>x</td> <td></td> <td></td> </tr> <tr> <td>Infiltration</td> <td>CFM x</td> <td>x</td> <td>1.08</td> <td></td> </tr> <tr> <td colspan="5">INTERNAL HEAT</td> </tr> <tr> <td>People</td> <td>PEOPLE x</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Power</td> <td>HP OR KW x</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Lights</td> <td>WATTS x 3.4 x</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Appliances, Etc.</td> <td>x</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Additional Heat Gains</td> <td>x</td> <td></td> <td></td> <td></td> </tr> <tr> <td colspan="4">SUB TOTAL</td> <td></td> </tr> <tr> <td>Storage</td> <td>SQ FT x</td> <td>x (-)</td> <td></td> <td></td> </tr> <tr> <td colspan="4">SUB TOTAL</td> <td></td> </tr> <tr> <td>Safety Factor</td> <td>%</td> <td></td> <td></td> <td></td> </tr> <tr> <td colspan="4">ROOM SENSIBLE HEAT</td> <td>2789</td> </tr> <tr> <td>SUPPLY DUCT HEAT GAIN</td> <td>SUPPLY DUCT % LEAK. LOSS</td> <td>FAN % H. P.</td> <td>%</td> <td></td> </tr> <tr> <td>Outdoor Air</td> <td>CFM x</td> <td>F x</td> <td>BF x 1.08</td> <td></td> </tr> <tr> <td colspan="4">EFFECTIVE ROOM SENSIBLE HEAT</td> <td></td> </tr> <tr> <td colspan="4">LATENT HEAT</td> <td></td> </tr> <tr> <td>Infiltration</td> <td>CFM x</td> <td>GR/LB x 0.68</td> <td></td> <td></td> </tr> <tr> <td>People</td> <td>PEOPLE x</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Steam</td> <td>LB/HR x 1050</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Appliances, Etc.</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Additional Heat Gains</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Vapor Trans.</td> <td>SQ x 1/100 x</td> <td>GR/LB x</td> <td></td> <td></td> </tr> <tr> <td colspan="4">SUB TOTAL</td> <td></td> </tr> <tr> <td>Safety Factor</td> <td>%</td> <td></td> <td></td> <td></td> </tr> <tr> <td colspan="4">ROOM LATENT HEAT</td> <td></td> </tr> <tr> <td>SUPPLY DUCT LEAKAGE LOSS</td> <td>%</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Outdoor Air</td> <td>CFM x</td> <td>GR/LB x</td> <td>BF x 0.68</td> <td></td> </tr> <tr> <td colspan="4">EFFECTIVE ROOM LATENT HEAT</td> <td></td> </tr> <tr> <td colspan="4">EFFECTIVE ROOM TOTAL HEAT</td> <td></td> </tr> <tr> <td colspan="4">OUTDOOR AIR HEAT</td> <td></td> </tr> <tr> <td>Sensible:</td> <td>CFM x</td> <td>F x (1- BF) x 1.08</td> <td></td> <td></td> </tr> <tr> <td>Latent:</td> <td>CFM x</td> <td>GR/LB x (1- BF) x 0.68</td> <td></td> <td></td> </tr> <tr> <td colspan="4">SUB TOTAL</td> <td></td> </tr> <tr> <td>RETURN DUCT HEAT GAIN</td> <td>RETURN DUCT % LEAK. 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P.	%		Outdoor Air	CFM x	F x	BF x 1.08		EFFECTIVE ROOM SENSIBLE HEAT					LATENT HEAT					Infiltration	CFM x	GR/LB x 0.68			People	PEOPLE x				Steam	LB/HR x 1050				Appliances, Etc.					Additional Heat Gains					Vapor Trans.	SQ x 1/100 x	GR/LB x			SUB TOTAL					Safety Factor	%				ROOM LATENT HEAT					SUPPLY DUCT LEAKAGE LOSS	%				Outdoor Air	CFM x	GR/LB x	BF x 0.68		EFFECTIVE ROOM LATENT HEAT					EFFECTIVE ROOM TOTAL HEAT					OUTDOOR AIR HEAT					Sensible:	CFM x	F x (1- BF) x 1.08			Latent:	CFM x	GR/LB x (1- BF) x 0.68			SUB TOTAL					RETURN DUCT HEAT GAIN	RETURN DUCT % LEAK. GAIN	HP % PUMP	DEMUM. & PIPE LOSS %		GRAND TOTAL HEAT				
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COMPUTATION SHEET

BUILDING 80

COMPUTED BY **RJB**
CHECKED BY **BW**
DATE **11/12-1989**
REV. _____

LIFE SCIENCES
HEATING LOAD
EQUIPMENT ROOM/STORAGE

PROJECT **16-199-09**
SHEET NO. **50** OF **58** SHEETS

Space Used For					Estimate for		LOCAL TIME		Peak Load		LOCAL TIME	
Size							SUN TIME				SUN TIME	
Size x = 324 SQ FT x 9 1/2 = 3078 CU FT												
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR		Hours of Operation						
SOLAR GAIN-GLASS						CONDITIONS	DB	WB	% RH	DP	GR/LB	
Glass	SQ FT x	x				OUTDOOR (OA)	54					
Glass	SQ FT x	x				ROOM (RM)	72					
Glass	SQ FT x	x				DIFFERENCE	38					
Skylight	SQ FT x	x				OUTDOOR AIR						
						VENTI-LATION	PEOPLE x _____ CFM/PERSON = _____					
							SQ FT x _____ CFM/SQ FT = _____					
						CFM VENTILATION ☐						
SOLAR & TRANS. GAIN-WALLS & ROOF						SWINGING REVOLVING DOORS _____ PEOPLE x _____ CFM/PERSON = _____						
Wall	SQ FT x	38	1.13	1 680		OPEN DOORS _____ DOORS x _____ CFM/DOOR = _____						
Wall	SQ FT x	x				EXHAUST FAN _____						
Wall	SQ FT x	x				CRACK _____ FEET x _____ CFM/FT = _____						
Roof-Sun	SQ FT x	46	1.12	1 788		CFM INFILTRATION ☐						
Roof-Shaded	SQ FT x	x				CFM OUTDOOR AIR THRU APPARATUS ☐						
TRANS. GAIN-EXCEPT WALLS & ROOF						APPARATUS DEWPOINT						
All Glass	SQ FT x	x				ESHF	EFFECTIVE ROOM SENS. HEAT FACTOR = $\frac{\text{EFFECTIVE ROOM SENS. HEAT}}{\text{EFFECTIVE ROOM TOTAL HEAT}}$					
Partition	SQ FT x	x				ADP	INDICATED ADP = _____ F SELECTED ADP = _____ F					
Ceiling	SQ FT x	x				DEHUMIDIFIED AIR QUANTITY						
Floor	SQ FT x	x				TEMP. RISE	$(1 - \text{BF}) \times (T_{RM} - T_{ADP}) - T_{ADP} \times \text{BF} = \text{_____ F}$					
Infiltration	CFM x	x	1.08			DEHUM. CFM	$\frac{\text{EFFECTIVE ROOM SENS. HEAT}}{1.08 \times F_{\text{TEMP. RISE}}} = \text{_____ CFM}_{OA}$					
INTERNAL HEAT						OUTLET TEMP. DIFF.	$\frac{\text{ROOM SENS. HEAT}}{1.08 \times \text{CFM}_{OA}} = \text{_____ F}_{RM-OUTLET AIR}$					
People	PEOPLE x					SUPPLY AIR QUANTITY						
Power	HP OR KW x					SUPPLY CFM	$\frac{\text{ROOM SENS. HEAT}}{1.08 \times F_{\text{DESIRED DIFF}}} = \text{_____ CFM}_{SA}$					
Lights	WATTS x 3.4					BYPASS CFM	$\text{CFM}_{SA} - \text{CFM}_{OA} = \text{_____ CFM}_{BA}$					
Appliances, Etc.	x					RESULTING ENT & LVG CONDITIONS AT APPARATUS						
Additional Heat Gains	x					EDB	$T_{RM} \times F + \frac{\text{CFM}_{OA} \times (T_{OA} - T_{RM})}{\text{CFM}_T} = T_{EDB}$					
SUB TOTAL						LDB	$T_{ADP} \times F + \frac{\text{BF} \times (T_{EDB} - T_{ADP})}{\text{CFM}_T} = T_{LDB}$					
Storage	SQ FT x	x	()			FROM PSYCH. CHART: $T_{WB} \text{ --- } F, T_{LWB} \text{ --- } F$						
SUB TOTAL						NOTES						
Safety Factor	%											
ROOM SENSIBLE HEAT ☐												
SUPPLY DUCT HEAT GAIN	% x LEAK. LOSS	% x H. P.	%									
Outdoor Air	CFM x	F x	BF x 1.08									
EFFECTIVE ROOM SENSIBLE HEAT ☐												
LATENT HEAT												
Infiltration	CFM x	GR/LB x 0.68										
People	PEOPLE x											
Steam	LB/HR x 1050											
Appliances, Etc.												
Additional Heat Gains												
Vapor Trans.	SQ x 1/100 x	GR/LB x										
SUB TOTAL												
Safety Factor	%											
ROOM LATENT HEAT												
SUPPLY DUCT LEAKAGE LOSS	%											
Outdoor Air	CFM x	GR/LB x	BF x 0.68									
EFFECTIVE ROOM LATENT HEAT												
EFFECTIVE ROOM TOTAL HEAT ☐												
OUTDOOR AIR HEAT												
Sensible:	CFM x	F x (1 - BF) x 1.08										
Latent:	CFM x	GR/LB x (1 - BF) x 0.68										
RETURN DUCT HEAT GAIN	% x LEAK. GAIN	% x PUMP	% x PIPE LOSS									
GRAND TOTAL HEAT ☐												

9-59

*IF THIS ΔT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM. WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

BUILDING 80

COMPUTED BY **233**
CHECKED BY **EW**
DATE **10-12-1969**
REV. _____ 19. _____

LBG-LIFE SCIENCES
HEATING LOAD
GLASS W/STAIN

PROJECT **16-199-09**
SHEET NO. **51** OF **56** SHEETS

Space Used For					Estimate for		LOCAL TIME		Peak Load		LOCAL TIME	
Size	x	=	SQ FT x	=	CU FT	Hours of Operation	CONDITIONS	DB	WB	% RH	DP	GR/LB
SOLAR GAIN-GLASS						OUTDOOR AIR						
Glass	SQ FT x		x			VENTI- LATION	PEOPLE x		CFM/PERSON =			
Glass	SQ FT x		x				SQ FT x		CFM/SQ FT =			
Glass	SQ FT x		x				CFM VENTILATION					
Glass	SQ FT x		x									
Skylight	SQ FT x		x									
SOLAR & TRANS. GAIN-WALLS & ROOF						APPARATUS DEWPOINT						
Wall	SQ FT x		x			ESHF	EFFECTIVE SENS. HEAT FACTOR		EFFECTIVE ROOM SENS. HEAT			
Wall	SQ FT x		x				EFFECTIVE ROOM TOTAL HEAT =					
Wall	SQ FT x		x			ADP	INDICATED ADP =		F	SELECTED ADP =		F
Wall	SQ FT x		x			DEHUMIDIFIED AIR QUANTITY						
Roof-Sun	SQ FT x		x			TEMP RISE	(1 - BF) x (T _{RM} - T _{ADP}) + T _{ADP}		F			
Roof-Shaded	SQ FT x		x			DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT		CFM _{DA}			
TRANS. GAIN-EXCEPT WALLS & ROOF						OUTLET TEMP. DIFF.	ROOM SENS. HEAT		CFM _{DA}			
All Glass	SQ FT x		x			SUPPLY AIR QUANTITY						
Partition	SQ FT x		x			SUPPLY CFM	ROOM SENS. HEAT		CFM _{SA}			
Ceiling	SQ FT x		x			BYPASS CFM	1.08 x F		DESIRED DIFF			
Floor	SQ FT x		x			RESULTING ENT & LVG CONDITIONS AT APPARATUS						
Infiltration	CFM x		x			EDB	T _{RM} +		CFM _{DA} x (T _{OA} - T _{RM})			
INTERNAL HEAT						LDB	T _{ADP} +		BF x (T _{EDB} - T _{ADP})			
People	PEOPLE x					FROM PSYCH. CHART: T _{EDB} , F, T _{LWB} , F						
Power	HP OR KW x					NOTES						
Lights	WATTS x 3.4 x											
Appliances, Etc.	x											
Additional Heat Gains	x											
SUB TOTAL												
Storage	SQ FT x		x									
SUB TOTAL												
Safety Factor	%											
ROOM SENSIBLE HEAT												
SUPPLY DUCT HEAT GAIN	% + LEAK. LOSS											
Outdoor Air	CFM x		F x									
EFFECTIVE ROOM SENSIBLE HEAT												
LATENT HEAT												
Infiltration	CFM x		GR/LB x 0.68									
People	PEOPLE x											
Steam	LB/HR x 1050											
Appliances, Etc.												
Additional Heat Gains												
Vapor Trans.	SQ x 1/100 x		GR/LB x									
SUB TOTAL												
Safety Factor	%											
ROOM LATENT HEAT												
SUPPLY DUCT LEAKAGE LOSS	%											
Outdoor Air	CFM x		GR/LB x									
EFFECTIVE ROOM LATENT HEAT												
EFFECTIVE ROOM TOTAL HEAT												
OUTDOOR AIR HEAT												
Sensible:	CFM x		F x (1 - BF) x 1.08									
Latent:	CFM x		GR/LB x (1 - BF) x 0.68									
RETURN DUCT HEAT GAIN	% + LEAK. GAIN											
RETURN DUCT	HP											
HEAT GAIN	% + PIPE LOSS											
SUB TOTAL												
GRAND TOTAL HEAT												

COMPUTATION SHEET

BUILDING 80

COMPUTED BY **RJB**
CHECKED BY **BWJ**
DATE **11-12-1989**
REV. _____

LDL-LIFE SCIENCES
HEATING LOAD
OFFICE, WALL (TYPICAL)

PROJECT **16-199-09**
SHEET NO. **52** OF **56** SHEETS

Space Used For
Size **10** x **10** = **100** SQ FT x **9 1/2** = **950** CU FT

ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR
SOLAR GAIN-GLASS				
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Glass	SQ FT x	x		
Skylight	SQ FT x	x		
SOLAR & TRANS. GAIN-WALLS & ROOF				
Wall	100 SQ FT x	38 x 1.13		494
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Wall	SQ FT x	x		
Roof-Sun	100 SQ FT x	36 x 1.12		495
Roof-Shaded	SQ FT x	x		
TRANS. GAIN-EXCEPT WALLS & ROOF				
All Glass	SQ FT x	x		
Partition	SQ FT x	x		
Ceiling	SQ FT x	x		
Floor	SQ FT x	x		
Infiltration	CFM x	x 1.08		
INTERNAL HEAT				
People	PEOPLE x			
Power	HP OR KW x			
Lights	WATTS x 3.4 x			
Appliances, Etc.	x			
Additional Heat Gains	x			
SUB TOTAL				
Storage	SQ FT x	x ()		
SUB TOTAL				
Safety Factor	%			
ROOM SENSIBLE HEAT				950
EFFECTIVE ROOM SENSIBLE HEAT				
LATENT HEAT				
Infiltration	CFM x	GR/LB x 0.68		
People	PEOPLE x			
Steam	LB/HR x 1050			
Appliances, Etc.				
Additional Heat Gains				
Vapor Trans.	SQ x 1/100 x	GR/LB x		
SUB TOTAL				
Safety Factor	%			
ROOM LATENT HEAT				
SUPPLY DUCT LEAKAGE LOSS				
Outdoor Air	CFM x	GR/LB x BF x 0.68		
EFFECTIVE ROOM LATENT HEAT				
EFFECTIVE ROOM TOTAL HEAT				
OUTDOOR AIR HEAT				
Sensible:	CFM x	F x (1- BF) x 1.08		
Latent:	CFM x	GR/LB x (1- BF) x 0.68		
RETURN DUCT HEAT GAIN				
RETURN DUCT HEAT GAIN	% x LEAK. GAIN	% x HP PUMP	% x SUB TOTAL DUCT LOSS	%
GRAND TOTAL HEAT				

Estimate for	LOCAL TIME SUN TIME	Peak Load	LOCAL TIME SUN TIME
Hours of Operation			
CONDITIONS	DB	WB	% RH DP GR/LB
OUTDOOR (OA)	34		
ROOM (RM)	72		
DIFFERENCE	-38		
OUTDOOR AIR			
VENTILATION	PEOPLE x	CFM/PERSON =	
	SQ FT x	CFM/SQ FT =	
	CFM VENTILATION		
SWINGING REVOLVING DOORS	PEOPLE x	CFM/PERSON =	
OPEN DOORS	DOORS x	CFM/DOOR =	
EXHAUST FAN			
CRACK	FEET x	CFM/FT =	
	CFM INFILTRATION		
CFM OUTDOOR AIR THRU APPARATUS			
APPARATUS DEWPOINT			
ESHF	EFFECTIVE SENS HEAT FACTOR	EFFECTIVE ROOM SENS. HEAT	EFFECTIVE ROOM TOTAL HEAT
ADP	INDICATED ADP =	F	SELECTED ADP =
DEHUMIDIFIED AIR QUANTITY			
TEMP RISE	(1- BF) x (TRM - TADP - F) =	F	
DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT	1.08 x	F TEMP. RISE
OUTLET TEMP. DIFF.	ROOM SENS. HEAT	1.08 x	F ROOM-OUTLET AIR
SUPPLY AIR QUANTITY			
SUPPLY CFM	ROOM SENS. HEAT	1.08 x	F DESIRED DIFF
BYPASS CFM	CFM _{RA} -	CFM _{DA} =	CFM _{BA}
RESULTING ENT & LVG CONDITIONS AT APPARATUS			
EDB	TRM - F +	CFM _{DA} x (TOA - F - TRM) / CFM _T	F = T _{EDB}
LDB	TADP - F +	BF x (T _{EDB} - TADP) - F	F = T _{LDB}
FROM PSYCH. CHART: T _{WB} = F, T _{LWB} = F			

NOTES

9-61

*IF THIS AT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

BUILDING 80

COMPUTED BY **253**
CHECKED BY **BWJ**
DATE **11/12-1989**
REV. **1**

LIFE SCIENCES

HEATING LOAD

OFFICE, INTERIOR (TYPE 2)

PROJECT **16-199-09**

SHEET NO. **53** OF **56** SHEETS

Space Used For				Estimate for		LOCAL TIME		Peak Load		LOCAL TIME	
Size 10 x 10 = 100 SQ FT x 9 1/2 = 950 CU FT											
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR		Hours of Operation					
						CONDITIONS	DB	WB	% RH	DP	GR/LB
SOLAR GAIN-GLASS						OUTDOOR (OA) 39					
Glass	SQ FT x	x				ROOM (RM)	73				
Glass	SQ FT x	x				DIFFERENCE	-38				
Glass	SQ FT x	x				OUTDOOR AIR					
Glass	SQ FT x	x				VENTILATION					
Skylight	SQ FT x	x				PEOPLE x CFM/PERSON =					
						SQ FT x CFM/SQ FT =					
						CFM VENTILATION					
SOLAR & TRANS. GAIN-WALLS & ROOF						INFILTRATION					
Wall	SQ FT x	x				SWINGING REVOLVING DOORS PEOPLE x CFM/PERSON =					
Wall	SQ FT x	x				OPEN DOORS DOORS x CFM/DOOR =					
Wall	SQ FT x	x				EXHAUST FAN					
Wall	SQ FT x	x				CRACK FEET x CFM/FT =					
Roof-Sun	100 SQ FT x 38 x 1.2				456	CFM INFILTRATION					
Roof-Shaded	SQ FT x	x				CFM OUTDOOR AIR THRU APPARATUS					
TRANS. GAIN-EXCEPT WALLS & ROOF						APPARATUS DEWPOINT					
All Glass	SQ FT x	x				ESHF EFFECTIVE SENS. HEAT FACTOR = EFFECTIVE ROOM SENS. HEAT =					
Partition	SQ FT x	x				ADP INDICATED ADP = F SELECTED ADP = F					
Ceiling	SQ FT x	x				DEHUMIDIFIED AIR QUANTITY					
Floor	SQ FT x	x				TEMP. RISE (1- BF) x (T _{RM} - T _{ADP} - F) =					
Infiltration	CFM x	x 1.08				DRAIN. CFM EFFECTIVE ROOM SENS. HEAT = CFM _{OA}					
						1.08 x F TEMP. RISE					
INTERNAL HEAT						OUTLET TEMP. DIFF.					
People	PEOPLE x					ROOM SENS. HEAT = F _{RM} - OUTLET AIR					
Power	HP OR KW x					1.08 x CFM _{OA}					
Lights	WATTS x 3.4 x					SUPPLY AIR QUANTITY					
Appliances, Etc.	x					SUPPLY CFM ROOM SENS. HEAT = CFM _{SA}					
Additional Heat Gains	x					1.08 x F DESIRED DIFF = CFM _{SA}					
SUB TOTAL						BYPASS CFM CFM _{SA} - CFM _{OA} = CFM _{RA}					
Storage	SQ FT x	x (1-)				RESULTING ENT & LVG CONDITIONS AT APPARATUS					
Safety Factor	%					EDB T _{RM} F + CFM _{OA} (T _{OA} - T _{RM} - F) = T _{EDB} F					
ROOM SENSIBLE HEAT 956						LDB T _{ADP} F + BF (T _{EDB} - T _{ADP} - F) = T _{LDB} F					
SUPPLY DUCT HEAT GAIN						FROM PSYCH. CHART: T _{ESB} F, T _{LDB} F					
Outdoor Air						NOTES					
CFM x F x BF x 1.08											
EFFECTIVE ROOM SENSIBLE HEAT											
LATENT HEAT											
Infiltration	CFM x	GR/LB x 0.68									
People	PEOPLE x										
Steam	LB/HR x 1050										
Appliances, Etc.											
Additional Heat Gains											
Vapor Trans.	SQ x 1/100 x	GR/LB x									
SUB TOTAL											
Safety Factor											
ROOM LATENT HEAT											
SUPPLY DUCT LEAKAGE LOSS											
Outdoor Air	CFM x	GR/LB x	BF x 0.68								
EFFECTIVE ROOM LATENT HEAT											
EFFECTIVE ROOM TOTAL HEAT											
OUTDOOR AIR HEAT											
Sensible:	CFM x	F x (1- BF) x 1.08									
Latent:	CFM x	GR/LB x (1- BF) x 0.68									
RETURN DUCT HEAT GAIN											
RETURN DUCT LEAKAGE LOSS											
HP											
SUB TOTAL											
GRAND TOTAL HEAT											

9-62

*IF THIS ΔT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

BUILDING 30

COMPUTED BY **RJB**
CHECKED BY **BW**
DATE **11-12-1981**
REV. **19**

LBL-LIFE SCIENCES
HEATING LOAD
CORRIDORS

PROJECT **16-199-09**
SHEET NO. **04** OF **52** SHEETS

Space Used For					Estimate for		LOCAL TIME		Peak Load		LOCAL TIME	
Size							SUN TIME				SUN TIME	
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR								
SOLAR GAIN-GLASS												
Glass	SQ FT x	x										
Glass	SQ FT x	x										
Glass	SQ FT x	x										
Glass	SQ FT x	x										
Skylight	SQ FT x	x										
SOLAR & TRANS. GAIN-WALLS & ROOF												
Wall	SQ FT x	x										
Wall	SQ FT x	x										
Wall	SQ FT x	x										
Wall	SQ FT x	x										
Roof-Sun	857 SQ FT x 38	x 1.12		3 908								
Roof-Shaded	SQ FT x	x										
TRANS. GAIN-EXCEPT WALLS & ROOF												
All Glass	SQ FT x	x										
Partition	SQ FT x	x										
Ceiling	SQ FT x	x										
Floor	SQ FT x	x										
Infiltration	CFM x	x	1.08									
INTERNAL HEAT												
People	PEOPLE x											
Power	HP OR KW x											
Lights	WATTS x 3.4											
Appliances, Etc.	x											
Additional Heat Gains	x											
				SUB TOTAL								
Storage	SQ FT x	x (-)										
				SUB TOTAL								
Safety Factor	%											
				ROOM SENSIBLE HEAT	3 908							
SUPPLY DUCT HEAT GAIN												
$\frac{\text{SUPPLY DUCT HEAT GAIN}}{\% \text{ LEAK LOSS}} \times \frac{\text{FAN HP}}{\% \text{ H.P.}} \times \%$												
Outdoor Air	CFM x	F x	BF x 1.08									
				EFFECTIVE ROOM SENSIBLE HEAT								
LATENT HEAT												
Infiltration	CFM x	GR/LB x 0.68										
People	PEOPLE x											
Steam	LB/HR x 1050											
Appliances, Etc.												
Additional Heat Gains												
Vapor Trans.	SQ x 1/100 x	GR/LB x										
				SUB TOTAL								
Safety Factor	%											
				ROOM LATENT HEAT								
SUPPLY DUCT LEAKAGE LOSS												
$\frac{\text{SUPPLY DUCT LEAKAGE LOSS}}{\% \text{ LEAK LOSS}} \times \%$												
Outdoor Air	CFM x	GR/LB x	BF x 0.68									
				EFFECTIVE ROOM LATENT HEAT								
				EFFECTIVE ROOM TOTAL HEAT								
OUTDOOR AIR HEAT												
Sensible:	CFM x	F x (1-)	BF x 1.08									
Latent:	CFM x	GR/LB x (1-)	BF x 0.68									
RETURN DUCT HEAT GAIN												
$\frac{\text{RETURN DUCT HEAT GAIN}}{\% \text{ LEAK LOSS}} \times \frac{\text{HP}}{\% \text{ H.P.}} \times \%$												
				SUB TOTAL								
				GRAND TOTAL HEAT								

Hours of Operation		LOCAL TIME		Peak Load		LOCAL TIME	
CONDITIONS	DB	WB	% RH	DP	GR/LB		
OUTDOOR (OA)	34						
ROOM (RM)	72						
DIFFERENCE	-38						
OUTDOOR AIR							
PEOPLE x _____ CFM/PERSON = _____ SQ FT x _____ CFM/SQ FT = _____ CFM VENTILATION = _____							
SWINGING REVOLVING DOORS _____ PEOPLE x _____ CFM/PERSON = _____ OPEN DOORS _____ DOORS x _____ CFM/DOOR = _____ EXHAUST FAN _____ CRACK _____ FEET x _____ CFM/FT = _____ CFM INFILTRATION = _____							
CFM OUTDOOR AIR THRU APPARATUS							
APPARATUS DEWPOINT							
ESHF	$\frac{\text{EFFECTIVE ROOM SENS. HEAT}}{\text{EFFECTIVE ROOM TOTAL HEAT}} = \frac{\text{EFFECTIVE ROOM SENS. HEAT}}{\text{EFFECTIVE ROOM TOTAL HEAT}}$						
ADP	INDICATED ADP = _____ F SELECTED ADP = _____ F						
DEHUMIDIFIED AIR QUANTITY							
TEMP RISE	$(1 - \text{BF}) \times (T_{RM} - T_{ADP}) - T_{ADP} - F = \text{F}$						
DEHUM. CFM	$\frac{\text{EFFECTIVE ROOM SENS. HEAT}}{1.08 \times F_{\text{TEMP. RISE}}} = \text{CFM}_{OA}$						
OUTLET TEMP. DIFF.	$\frac{\text{ROOM SENS. HEAT}}{1.08 \times \text{CFM}_{OA}} = \text{F}_{RM-OUTLET AIR}$						
SUPPLY AIR QUANTITY							
SUPPLY CFM	$\frac{\text{ROOM SENS. HEAT}}{1.08 \times F_{\text{DESIRED DIFF}}} = \text{CFM}_{SA}$						
BYPASS CFM	$\text{CFM}_{SA} - \text{CFM}_{OA} = \text{CFM}_{BA}$						
RESULTING ENT & LVG CONDITIONS AT APPARATUS							
EDB	$T_{RM} - F + \frac{\text{CFM}_{OA} \times (T_{OA} - T_{RM})}{\text{CFM}_1} = T_{EOB}$						
LDB	$T_{ADP} - F + \frac{\text{BF} \times (T_{EOB} - T_{ADP})}{\text{F}} = T_{LOB}$ FROM PSYCH. CHART: T_{EOB} F, T_{LOB} F						

NOTES

*IF THIS AT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM. WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

COMPUTATION SHEET

COMPUTED BY: RJB
CHECKED BY: BWJ
DATE: 11-12-89
REV:

BUILDING 80
BATHROOM CFM
AND JANITOR'S CLOSET

PROJECT: 16-199-09-I

SHEET NO. 55 OF 56 SHEETS

Women's Bathroom

$$135 \text{ ft}^2 \times 9.5 \text{ ft.} = 1,283 \text{ ft.}^3$$

At 10 air changes/hour

$$1,283 \text{ ft}^3 \times 10 \text{ air changes/hour} \times 1/60 = 214 \text{ cfm}$$

Men's Bathroom

Same as women's: 214 cfm

Janitor's Closet

$$20 \text{ ft}^2 \times 9\text{-}1/2 \text{ feet} = 190 \text{ ft}^3$$

At 10 air changes/hour

$$190 \text{ ft}^3 \times 10 \text{ air changes/hour} \times 1/60 = 32 \text{ cfm}$$

COMPUTATION SHEET

BUILDING 80

COMPUTED BY RJD
CHECKED BY FWJ
DATE 11-12-1989
REV. _____ 19__

HEATING LOAD
2 FLOOR ACS SUPPLY

PROJECT 16-199-09
SHEET NO. 56 OF 56 SHEETS

Space Used For _____					Estimate for _____		LOCAL TIME SUN TIME		Peak Load		LOCAL TIME SUN TIME	
Size	x	=	SQ FT x	=	CU FT							
ITEM	AREA OR QUANTITY	SUN GAIN OR TEMP. DIFF.	FACTOR	BTU/HOUR								
SOLAR GAIN-GLASS												
Glass	SQ FT x	x										
Glass	SQ FT x	x										
Glass	SQ FT x	x										
Glass	SQ FT x	x										
Skylight	SQ FT x	x										
SOLAR & TRANS. GAIN-WALLS & ROOF												
Wall	290 SQ FT x	38 x	1.13		1433							
Wall	SQ FT x	x										
Wall	SQ FT x	x										
Wall	SQ FT x	x										
Roof-Sun	1600 SQ FT x	38 x	1.12		7296							
Roof-Shaded	SQ FT x	x										
TRANS. GAIN-EXCEPT WALLS & ROOF												
All Glass	560 SQ FT x	38 x	1.02		21706							
Partition	SQ FT x	x										
Ceiling	SQ FT x	x										
Floor	SQ FT x	x										
Infiltration	CFM x	x	1.08									
INTERNAL HEAT												
People	PEOPLE x											
Power	HP OR KW x											
Lights	WATTS x 3.4 x											
Appliances, Etc.	x											
Additional Heat Gains	x											
SUB TOTAL												
Storage	SQ FT x	x (-)										
SUB TOTAL												
Safety Factor	%											
ROOM SENSIBLE HEAT					30439							
SUPPLY DUCT HEAT GAIN	% + LEAK. LOSS	% + H. P.	%									
Outdoor Air	150 CFM x	38 F x	1.0 BF x 1.08		6156							
EFFECTIVE ROOM SENSIBLE HEAT												
LATENT HEAT												
Infiltration	CFM x	GR/LB x 0.68										
People	PEOPLE x											
Steam	LB/HR x 1050											
Appliances, Etc.												
Additional Heat Gains												
Vapor Trans.	SQ x 1/100 x	GR/LB x										
SUB TOTAL												
Safety Factor	%											
ROOM LATENT HEAT												
SUPPLY DUCT LEAKAGE LOSS	%											
Outdoor Air	CFM x	GR/LB x	BF x 0.68									
EFFECTIVE ROOM LATENT HEAT												
EFFECTIVE ROOM TOTAL HEAT												
OUTDOOR AIR HEAT												
Sensible:	CFM x	F x (1- BF) x 1.08										
Latent:	CFM x	GR/LB x (1- BF) x 0.68										
RETURN DUCT HEAT GAIN	% + LEAK. GAIN	% + PUMP	% + PIPE LOSS									
SUB TOTAL												
GRAND TOTAL HEAT					36590							

Hours of Operation		LOCAL TIME SUN TIME		Peak Load		LOCAL TIME SUN TIME	
CONDITIONS	DB	WB	% RH	DP	GR/LB		
OUTDOOR (OA)	34						
ROOM (RM)	72						
DIFFERENCE	-38						

VENTILATION		PEOPLE x		CFM/PERSON =	
SQ FT x		CFM/SQ FT =		CFM VENTILATION	
SWINGING REVOLVING DOORS PEOPLE x CFM/PERSON =					
OPEN DOORS DOORS x CFM/DOOR =					
EXHAUST FAN					
CRACK FEET x CFM/FT =					
CFM INFILTRATION					
CFM OUTDOOR AIR THRU APPARATUS					

APPARATUS DEWPOINT	
ESHF	EFFECTIVE ROOM SENS. HEAT FACTOR = EFFECTIVE ROOM TOTAL HEAT =
ADP	INDICATED ADP = F SELECTED ADP = F

DEHUMIDIFIED AIR QUANTITY	
TEMP. RISE	(1- BF) x (TRM - TADP - F) = F
DEHUM. CFM	EFFECTIVE ROOM SENS. HEAT = CFM _{DA}
OUTLET TEMP. DIFF.	ROOM SENS. HEAT = F (RM-OUTLET AIR) = CFM _{DA}

SUPPLY AIR QUANTITY	
SUPPLY CFM	ROOM SENS. HEAT = F DESIRED DIFF = CFM _{SA}
BYPASS CFM	CFM _{SA} - CFM _{DA} = CFM _{BA}

RESULTING ENT & LVG CONDITIONS AT APPARATUS	
EDB	TRM - F + CFM _{DA} x (T _{OA} - TRM - F) = T _{EDB} F
LDB	T _{ADP} - F + BF x (T _{EDB} - T _{ADP} - F) = T _{LDB} F
FROM PSYCH. CHART: T _{WB} = F, T _{LB} = F	

NOTES

9-65

*IF THIS ΔT IS TOO HIGH, DETERMINE SUPPLY CFM FOR DESIRED DIFFERENCE BY SUPPLY AIR QUANTITY FORMULA.
WHEN BYPASSING A MIXTURE OF OUTDOOR AND RETURN AIR, USE SUPPLY CFM.
WHEN BYPASSING RETURN AIR ONLY, USE DEHUMIDIFIED CFM.

ALS LIFE SCIENCES CENTER

BASIS FOR ELECTRICAL DESIGN

Building 80, Life Sciences Second Floor Laboratories and Offices

Building 80 is currently fed from two separate 480 volt feeders. These existing feeder loads and the new loads for the Life Sciences Laboratories will be combined and fed from one 800 amp 480 volt feeder from an existing transformer, Bank 305, located in the Advanced Light Source Substation A3. The two existing 500 MCM feeders from Bank 305 will be paralleled with a new set of 500 MCM for a total of 3-1/c-500 MCM cables per phase. These feeders will supply a new 800 amp switchboard located in Building 80. All 480Y/277 volt panels and 208Y/120 volt stepdown transformers will be fed from this switchboard, along with a new Motor Control Center (MCC). The MCC will be connected to the hillwide Energy Monitoring and Control System (EMCS) and will provide centralized control and monitoring of all of Building 80's HVAC units and other mechanical loads.

The existing power panels in Building 80 are fed from an outdated, 240 volt, delta, unbalanced power system. The Building 80 loads that required this voltage have been mainly removed so the existing transformer will be replaced with a 480-208Y/120 volt transformer and the existing building power panels will be recircuited to accept a balanced power source. The few remaining 240 volt loads will have small boost transformers added to their 208 volt supply.

Laboratory areas will share several 480-208Y/120 volt, 30 kVA, stepdown transformers and associated 208Y/120 volt panels. A common 480Y/277 volt panel will be shared by all laboratories. The duplex outlets in the offices and other small rooms will be fed from a common 208Y/120 volt panel.

Laboratory and office lighting will be 50 foot candles supplied by 277 volt fluorescent fixtures. Hallways, stairways and other areas will be 15-20 footcandles.

A transfer switch with its own dedicated feeder will be fed from the existing 300 kVA standby generator located under the Building 37 cooling towers. This switch in turn will feed a standby panel which will be mainly used for egress and exit lighting and fumehood blowers.

Speakers connected to the hill wide paging system and universal receptacles for the Integrated Communications System (ICS) will be provided in the laboratory and office areas.

Manual call boxes and fire alarm bells will be installed in the laboratory and office areas and connected into the existing Building 80 fire alarm system.

A freight/passenger elevator will be installed with fire recall, seismic safety valves and all the requirements for the handicapped.

Building 6, Life Sciences Laboratories and Offices

The electrical loads for this area will be fed from a new 480Y/277 volt feeder that will be brought into a new 400 amp switchboard from transformer 304 located in the Advanced Light Source Substation A3. A 480Y/277 volt breaker panel will be available for lighting and special laboratory equipment. Each laboratory will have its own 480-208Y/120 volt, 30 kVA transformer and 100 amp breaker panel. The offices will all be powered from a common 208Y/120 volt transformer and breaker panel.

Laboratory and office lighting will be 50 foot candles supplied by 277 volt fluorescent fixtures. Hallways, stairways and other areas will be 15-20 footcandles.

A standby power panel which will be mainly used for egress and exit lighting will be fed from the existing standby panel in the ALS motor control center.

Speakers connected to the hillwide paging system and universal receptacles for the Integrated Communications System (ICS) will be provided in the second floor laboratory and office areas and the first floor beamline laboratories.

Manual call boxes, fire alarm bells and door closers will be installed in the laboratory and office areas and connected into the existing Building 6 fire alarm system.

The beamline laboratories located on the experimental hall floor of the ALS will each have a three phase 208Y/120 volt, 100 amp, column mounted power panel.

Speakers connected to the hillwide paging system and universal receptacles for the Integrated Communications System (ICS) will be provided.

ALS LIFE SCIENCES CENTER
COST ESTIMATE DETAIL
FOR
CONVENTIONAL FACILITIES

RECAPITULATION

PROJECT LIFE SCIENCES CENTER.

ESTIMATE NO. C.D.R.

LOCATION BUILDING 80.

SHEET NO. 1.

ARCHITECT LBL.

DATE DECEMBER, 1989.

SUMMARY BY DD.

PRICES BY DD.

CHECKED BY

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE		UNIT PRICE	TOTAL ESTIMATED LABOR COST	TOTAL
DIV. 2. DEMOLITION.							
Dismantle & remove 15 ton crane & store on site.		L.S.		7500			
Demolish & remove crane tail, beams, columns etc.	15	TONS	500 ⁰⁰	7500			
Demolish suspended ceilings at ground floor office areas.	5000	SF.	1 ⁵⁰	7500			
Demolish & remove partitions.	4664	SF.	2 ⁰⁰	9328			
Remove single door & frame.	20	EA.	50 ⁰⁰	1000			
Remove exterior cladding.	1040	SF.	6 ⁰⁰	6240			
Demolish & remove framed soffit.		L.S.		1000			
Demolish & remove wood counter.		L.S.		500			
Remove extg. floor finish & repair.	5560	SF.	2 ⁰⁰	11120			
Cut-off crane column anchor bolts & grid flat.	40	EA.	20 ⁰⁰	800			
Remove electrical equipment in ceiling space for structural steel access & replace.	1960	SF.	2 ⁰⁰	3920			
Remove mechanical equipment in ditto for ditto, ditto.	1960	SF.	2 ⁰⁰	3920			
Demolish & remove wood joist and plywood floor.	800	SF.	2 ⁵⁰	2000			
Demolish & remove wire mesh fence/balcony & partition wall at mezzanine.	240	LF.	20 ⁰⁰	4800			
			(C/F)	67128			

RECAPITULATION

PROJECT LIFE SCIENCES CENTER.

ESTIMATE NO. C.D.R.

LOCATION BUILDING 80

SHEET NO. 2

ARCHITECT LBL.

DATE DECEMBER, 1987.

SUMMARY BY DD

PRICES BY DD.

CHECKED BY

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE		UNIT PRICE	TOTAL ESTIMATED LABOR COST	TOTAL
DIV. 2. DEMOLITION. (Cont.)			(SF)	67.128			
Remove all built-in cabinets & furniture & store.	3040	S.F.	1.00	3040			
Misc. demolition & repair.		L.S.		5000			
Temporary protection		L.S.		1500			
Removal of scientific equip.				NOT INCLUDED			
Removal of office furniture & equipment.				NOT INCLUDED			
Misc. removal/relocation of electrical equipment		L.S.		5000			
Misc. removal/relocation of mechanical equipment.		L.S.		5000			
Demolish concrete wall & install door at elevator shaft.	560	S.F.	5.00	2800			
Repair concrete floor surface	5160	S.F.	25.00	1540			
Demolish concrete floor for new elevator shaft.	140	S.F.	4.00	560			
Cut hole in existing roof structure for new elevator shaft including all repair work	88	S.F.	30.00	2640			
Demolish roof at BLDG. 6 for new stair well incl. all repair work.	272	S.F.	20.00	5440			
TOTAL TO SUMMARY.				98644			

RECAPITULATION

PROJECT LIFE SCIENCES CENTER.

ESTIMATE ~~NO~~ C.D.R.

LOCATION BUILDING 80

SHEET NO. 4.

HITECT
GINEER LBL.

DATE DECEMBER 1989

SUMMARY BY *DD.*

PRICES BY DD.

CHECKED BY

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL ESTIMATED LABOR COST	TOTAL
DIV. 5. METALS.					
Structural steel framing for infill at mezzanine (2nd) floor.	19 TONS.	1900 [#]	36100		
Detail steel for ditto.	2 TONS.	2200 [#]	4400		
Structural steel plates welded to existing WF beams in ceiling space.	6 TONS.	4000 [#]	24000		
Extra work at perimeter of existing mezzanine opening	242 LF.	10 [#]	2420		
WF beams at new elevator shaft openings in roof & floor	1 TON.	2200 [#]	2200		
Cut existing W8x13 & remove including grind ends of ditto.	12 EA.	500 [#]	6000		
Drill for & set col. anchor bolts in existing conc. floor	16 EA.	75 [#]	1200		
1½" x 3-18 metal deck	3200 SF.	3¼ [#]	10400		
Cut & remove steel beam at exterior wall, re-support at each side & repair all finishes	L.S.		5000		
Steel roof framing & metal deck over new stairwell.	272 SF.	12 [#]	3264		
Steel wall framing & siding at new stairwell.	208 SF	20 [#]	4160		
Metal pan stair & landings with concrete fill.	L.S.		15000		
(C/F)			114144		

ESTIMATE NO. C.D.R.

SHEET NO. 5.

DATE DECEMBER 1989.

PRICES BY DD .

CHECKED BY

MFD. IN U.S.A.

PROJECT LIFE SCIENCES CENTER.

ESTIMATE ~~NO.~~ C.D.R.

LOCATION **BUILDING 80.**

SHEET NO. 6.

ARCHITECT
ENGINEER LBL

DATE DECEMBER 1989

SUMMARY BY DD.

PRICES BY DD.

CHECKED BY

TOTAL TO SUMMARY	6080
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ESTIMATE NO. C.D.R.

SHEET NO. 7.

DATE DECEMBER 1989.

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RECAPITULATION

PROJECT LIFE SCIENCES CENTER.

ESTIMATE NO. C.D.R.

LOCATION BUILDING 80

SHEET NO. 8.

HITECT
ENGINEER *LRL*

DATE DECEMBER 1989.

SUMMARY BY DD.

PRICES BY DD.

CHECKED BY

[illegible]

RECAPITULATION



PROJECT LIFE SCIENCES CENTER.

ESTIMATE NO. C.D.R.

LOCATION BUILDING 80

SHEET NO. 9.

ARCHITECT LBL.

DATE DECEMBER 1989

SUMMARY BY DD.

PRICES BY DD

CHECKED BY

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE		UNIT PRICE	TOTAL ESTIMATED LABOR COST	TOTAL
DN. 9. FINISHES.							
Metal stud partition walls with 5/8" gyp. board ea. side	5332	SF.	6 ⁰⁰	33	792		
2 Hour ditto walls @ elev. shaft.	1120	SF.	15 ⁰⁰	16	800		
Metal framing & gyp. board to existing walls	672	SF.	5 ⁰⁰	33	60		
Metal stud & gyp. boards enclosure to elevator connection	176	SF.	7 ⁰⁰	12	32		
Vinyl tile floor.	6271	SF.	3 ⁰⁰	18	831		
6" Rubber base.	1722	LF.	2 ⁰⁰	3	444		
Suspended acoustical ceiling	2488	S.F.	5 ⁰⁰	12	440		
Suspended gyp. board ceiling.	536	S.F.	4 ⁰⁰	2	144		
Paint susp. gyp. board ceiling.	536	S.F.	70 ⁰⁰	375			
" gyp. board walls.	15072	S.F.	60 ⁰⁰	9043			
" open soffit area w/ pipes etc.	6000	S.F.	1 ⁰⁰	6000			
" misc. metals.		L.S.		5000			
" misc. finish carpentry		L.S.		1000			
" misc. & repair/touch-up.		L.S.		5000			
Repair & renovate structure & finishes at new openings etc. walls of BLDG. 80 for stairs & elevator access.	2	EA.	2500 ⁰⁰	5000			
Repair & renovate finishes at new elevator lobby area at basement, 1st. & 2nd floor.	3	EA.	7500 ⁰⁰	22500			
TOTAL TO SUMMARY.				145961			



RECAPITULATION

PROJECT LIFE SCIENCES CENTER.

ESTIMATE NO. C.D.R.

LOCATION BUILDING 80-

SHEET NO. 10.

ARCHITECT L.B.L.

DATE DECEMBER 1989.

SUMMARY BY DD

PRICES BY DD

CHECKED BY

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE		UNIT PRICE	TOTAL ESTIMATED LABOR COST	TOTAL
<u>DIV. 10. SPECIALTIES.</u>							
Toilet partitions.	5	EA.	600 ⁰⁰	3000			
Urinal screen.	1	EA.	250 ⁰⁰	250			
Chalkboard.	4	EA.	200 ⁰⁰	800			
Tackboard.	4	EA.	170 ⁰⁰	680			
Noticeboard.	1	EA.	450 ⁰⁰	450			
Toilet accessories.		L.S.		3000			
TOTAL TO SUMMARY.				7568			
<u>DIV. 11. EQUIPMENT.</u>							
Laboratory furniture, fume hoods.				SEE SPECIAL FACILITIES.			
<u>DIV. 12. FURNISHINGS.</u>							
Carpet.	44	S.Y.	30 ⁰⁰	1320			
Venetian blinds.	224	SF.	35 ⁰⁰	784			
TOTAL TO SUMMARY.				2104			
<u>DIV. 13. SPECIAL CONSTRUCTION.</u>							
Cold room, 13'x7'. incl. door.	1	EA.	SEE SPECIAL FACILITIES				
<u>DIV. 14. CONVEYING SYSTEMS.</u>							
Hydraulic elevator, 5000 ⁰⁰ , fine-stop.	}	1	EA.	8000 ⁰⁰	90000		
TOTAL TO SUMMARY.				90000			

RECAPITULATION



PROJECT **LIFE SCIENCES CENTER**

ESTIMATE NO. **C.D.R.**

LOCATION **BUILDING 6 — MEZZANINE.**

SHEET NO. **11.**

ARCHITECT **LBL.**

DATE **DECEMBER 1989.**

SUMMARY BY **DD**

PRICES BY **DD**

CHECKED BY

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE		UNIT PRICE	TOTAL ESTIMATED LABOR COST	TOTAL
DIV. 5. METALS.							
Misc. iron.	5100	S.F.	1 ⁰⁰	5100			
Cut opening in existing exterior wall for elevator & stair access	2	EA.	5000 ⁰⁰	10000			
TOTAL TO SUMMARY				15100			
DIV. 6. WOOD/PLASTICS.							
Misc. blockings, tongue bucks, etc.	5100	S.F.	1 ⁵⁰	7650			
Misc. shelving, trim, small cabinets.	5100	S.F.	2 ⁰⁰	10200			
TOTAL TO SUMMARY				17850			
DIV. 8. DOORS & WINDOWS.							
Single H.M. doors, frames & finish hardware.	23	EA.	890 ⁰⁰	20470			
PART. ditto ditto ditto.	3	EA.	1700 ⁰⁰	5100			
TOTAL TO SUMMARY				25570			
DIV. 9. FINISHES.							
Metal stud partitions.	11414	S.F.	5 ²⁵	59924			
Gypsum board to metal studs.	15818	S.F.	1 ⁶⁰	25309			
Suspended acoustical ceilings.	5660	S.F.	5 ²⁰	29432			
Vinyl composition tile floor.	5660	S.F.	2 ¹⁰	11886			
Rubber base.	1897	LF.	3 ¹⁵	5976			
Paint gypsum board walls.	15633	S.F.	65 ⁰⁰	10161			
Paint single door/frame.	27	EA.	35 ⁰⁰	945			
Paint finish carpentry.		LS.		1500			
Misc. touch-up & repairs.		L.S.		2000			
De-mountable partitions	4466	S.F.	18 ⁰⁰	80388			
TOTAL TO SUMMARY				227521			



RECAPITULATION

PROJECT **LIFE SCIENCES CENTER**

ESTIMATE NO. **C.D.R.**

LOCATION **BUILDING 6 - MEZZANINE.**

SHEET NO. **12.**

ARCHITECT
ENGINEER **LBL.**

DATE **DECEMBER 1989.**

SUMMARY BY **DD**

PRICES BY **DD**

CHECKED BY

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE		UNIT PRICE	TOTAL ESTIMATED LABOR COST	TOTAL
DIV. 10. SPECIALTIES.							
Signs, notice boards, etc.	5100	SF.	30 ⁴	1530			
TOTAL TO SUMMARY				1530			
DIV. 11. EQUIPMENT.							
Laboratory furniture/fume hoods				SEE SPECIAL FACILITIES.			
DIV. 13. SPECIAL CONSTRUCTION.							
Cold room, 13'x7' incl. door	2	EA.		SEE SPECIAL FACILITIES.			
Beam line "bunches".	2	EA.	6000 ⁰	20000			
TOTAL TO SUMMARY				20000			

RECAPITULATION



PROJECT LIFE SCIENCES CENTER.

ESTIMATE NO. C.D.P.

LOCATION BUILDING 80

SHEET NO. 13.

ARCHITECT LBL.

DATE DECEMBER 1989.

SUMMARY BY DD.

PRICES BY DD

CHECKED BY

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE		UNIT PRICE		TOTAL
SCHEDULE 1. SPECIAL FACILITIES.							
				BUILDING 80		BUILDING 6.	
Laboratory base cabinets	211	LF.	250 ⁰⁰	52750	95 LF.	23750	
" wall "	71	LF.	100 ⁰⁰	7100	95 LF.	9500	
" island " with }	91	LF.	400 ⁰⁰	36400	72 LF.	28800	
re-agent shelf.							
Full height storage cabinets.	59	LF.	300 ⁰⁰	17700	—	—	
Fume hood.	6	EA.	5000 ⁰⁰	30000	8 EA.	40000	
SUB-TOTAL DIRECT COST.				143950		102050	
INCL. PRIME CONTRACTOR GEN. CONDITIONS/BOND/FEE 22%				175620		124500	300120
Cold rooms.	1	EA.	15000 ⁰⁰	15000	2 EA.	30000	
INCL. PRIME CONTRACTOR GEN. CONDITIONS/BOND/FEE 22%				18300		36600	54900
Laminar flow hoods.	3	EA.	12000 ⁰⁰	36000			
INCL. PRIME CONTRACTOR GEN. CONDITIONS/BOND/FEE 22%				43920			43920
SUB-TOTAL SPECIAL FACILITIES IN CONSTRUCTION & A/E CONTRACTS.							398940

MECHANICAL COST ESTIMATE

9-82

ESTIMATING SHEET

 **Keller & Gannon**
Engineers-Architects

COMPUTED BY B. Johnson
CHECKED BY
DATE December 19 89
REV 19

LBL-Life Sciences
Cost Summary
Building #6 & Building #80

PROJECT 16-199-09 I
SHEET NO 1 OF 7 SHEETS

ITEM NO	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT COST	TOTAL COST
	<u>BUILDING 6</u>				
1	HVAC Equipment				\$152,000
2	Plumbing and Process Piping				77,000
3	Fire Protection				5,500
	Mechanical Subtotal (Building 6)				\$234,500
	<u>BUILDING 80</u>				
1	HVAC Equipment				\$184,000
2	Plumbing and Process Piping				83,000
3	Fire Protection				5,200
	Mechanical Subtotal (Building 80)				\$272,200
	Mechanical Total				\$506,700
					9-83

ESTIMATING SHEET

 **Keller & Gannon**
Engineers-Architects

 COMPUTED BY B. Johnson
 CHECKED BY _____
 DATE December 19 89
 REV _____ 19 ____
LBL-Life SciencesHVAC EquipmentBuilding #6PROJECT 16-199-09 ISHEET NO 2 OF 7 SHEETS

ITEM NO	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Laboratory Exhaust Fan	2	EA	2,600	\$ 5,200
2	General Exhaust Fan	1	EA	1,420	1,420
3	Static Pressure Controlled VAV Box with Coils	12	EA	1,350	16,200
4	Supply Diffusers 24" x 24"	30	EA	200	6,000
5	Exhaust Grill 24" x 24"	2	EA	65	130
6	Supply Duct	10,000	lb	3.25	32,500
7	General Exhaust Duct	1,800	lb	5.60	10,080
8	Laboratory Exhaust Duct	3,425	lb	3.10	10,620
9	Duct Insulation @ .25 SF/SF	1,712	SF	2.10	3,595
10	Hot Water Piping with Insulation	350	LF	13.00	4,600
11	Chilled Water Piping with Insulation	200	LF	13.00	2,600
12	Seismic Bracing	1	JOB	LS	5,500
13	Controls	1	JOB	LS	45,000
14	Variable Frequency Drives	2	EA	12,000	24,000
15	Valves and Fittings	1	JOB	LS	3,500
16	Testing and Balancing	1	JOB	LS	<u>5,500</u>
	Subtotal (HVAC)				\$176,450
	Total (Rounded)				\$176,000

ESTIMATING SHEET

 **Keller & Gannon**
Engineers-Architects

 COMPUTED BY B. Johnson
 CHECKED BY _____
 DATE December 19 89
 REV _____ 19 ____

LBL-Life Sciences
Plumbing & Process Piping
Building #6

 PROJECT 16-199-09 I

 SHEET NO. 3 OF 7 SHEETS

ITEM NO	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Laboratory Counter Sink w/ Rough-In	15	EA	850	\$12,750
2	Emergency Shower	2	EA	750	1,500
3	Emergency Eyewash	4	EA	350	1,400
4	Laboratory Waste Lift Pump	9	EA	1,500	13,500
5	Treated Water Piping 4" CU	305	LF	35	10,675
6	Low Conductivity Water 4" CU	305	LF	35	10,675
7	Natural Gas Piping 2" Black Steel	153	LF	12.80	1,960
8	Industrial CW 1-1/2" CU	153	LF	10.10	1,550
9	Industrial HW 1" CU	305	LF	7.40	2,260
10	Domestic CW 1" CU	200	LF	7.40	1,480
11	Acid Waste Piping 4" PP	200	LF	16.50	3,300
12	Acid Neutralization System	1	JOB	LS	7,500
13	Vent Piping 2" PP	125	LF	11.30	1,400
14	100 Gallon Water Heater	1	EA	750	750
15	Recirculation Pump 10 GPM	1	EA	600	600
16	Seismic Bracing	1	JOB	LS	3,000
17	Testing	1	JOB	LS	<u>1,500</u>
	Subtotal (Plumbing and Process)				\$75,800
	Total (Rounded)				\$76,000
					9-85

**Keller & Gannon
Engineers-Architects**

SHEET NO. 4 OF 7 SHEETS

ITEM NO	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Modification of Existing Sprinkler System @ 30% of complete system cost	6,850	SF	.80	<u>\$5,480</u>
	Subtotal				\$5,480
	Total (Rounded)				\$5,500

9-86

ESTIMATING SHEET

 **Keller & Gannon**
Engineers-Architects

 COMPUTED BY B. Johnson
 CHECKED BY _____
 DATE December 1989
 REV _____ 19
LBL-Life SciencesHVAC EquipmentBuilding #80PROJECT 16-199-09 ISHEET NO. 5 OF 7 SHEETS

ITEM NO	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Rooftop Air Handling Unit with Filters, Roof Curb and Preheat Coils	1	EA	15,000	\$ 15,000
2	Laboratory Exhaust Fan	4	EA	1,500	6,000
3	Surgery Exhaust Fan	1	EA	1,500	1,500
4	Barometric Relief Dampers	5	EA	800	4,000
5	Toilet Exhaust Fan	1	EA	650	650
6	Static Pressure Controlled VAV Box with Coils	8	EA	1,500	12,000
7	Fan Powered VAV Box	5	EA	1,750	8,750
8	Supply Diffusers 24" x 24"	30	EA	150	4,500
9	Supply Registers	4	EA	100	400
10	Exhaust Grill 24" x 24"	7	EA	55	390
11	Supply Duct @ 1 lb/SF	4,500	lb	3.25	14,950
12	Laboratory Exhaust Duct @ .5 lb/SF	1,500	lb	5.60	8,400
13	Duct Insulation @ .25 SF/SF	1,378	SF	2.10	2,890
14	Hot Water Piping with Insulation	250	LF	13.00	3,250
15	Chilled Water Piping with Insulation	200	LF	13.00	2,600
16	Seismic Bracing and Roof Support Steel	1	JOB	LS	5,500
17	Controls	1	JOB	LS	45,000
18	Variable Frequency Drives	5	EA	8,000	40,000
19	Valves and Fittings	1	JOB	LS	2,800
20	Testing and Balancing	1	JOB	LS	5,500
	Subtotal (HVAC)				\$184,080
	Total (Rounded)				\$184,000
					9-87

ESTIMATING SHEET

 **Keller & Gannon**
Engineers-Architects

COMPUTED BY B. Johnson
 CHECKED BY _____
 DATE December 1989
 REV _____ 19 _____

LBL-Life Sciences
Plumbing & Process Piping
Building #80

PROJECT 16-199-09 I
 SHEET NO 6 OF 7 SHEETS

ITEM NO	DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT COST	TOTAL COST
1	Laboratory Counter Sink w/ Rough-In	14	EA	800	\$11,200
2	Water Closets w/ Rough-In	5	EA	800	4,000
3	Urinal w/ Rough-In	1	EA	800	800
4	Lavatory w/ Rough-In	4	EA	600	2,400
5	Janitor's Sink w/ Rough-In	1	EA	800	800
6	Emergency Eyewash	5	EA	320	1,600
7	Waste Lift Pump	11	EA	1,500	16,500
8	Treated Water Piping 4" CU	305	LF	35	10,700
9	Low Conductivity Water Piping 4" CU	305	LF	35	10,700
10	Natural Gas Piping 2" Black Steel	152	LF	12.80	1,950
11	Industrial CW 1-1/2" CU	152	LF	10.10	1,540
12	Industrial HW 1" CU	305	LF	7.40	2,260
13	Domestic CW 1" CU	200	LF	7.40	1,480
14	Acid Waste Piping 4" PP	200	LF	16.50	3,300
15	Acid Neutralization System	1	JOB	LS	7,500
16	Vent Piping 2" PP	125	LF	11.30	1,410
17	Seismic Bracing	1	JOB	LS	3,000
18	Testing	1	JOB	LS	<u>1,500</u>
	Subtotal (Plumbing & Process Piping)				\$82,640
	Total (Rounded)				\$83,000
					9-88

**Keller & Gannon
Engineers-Architects**

Building #80

[illegible]

ALS LIFE SCIENCES CENTER
ELECTRICAL COST ESTIMATE

BUILDING 80 SECOND FLOOR LIFE SCIENCES

DATE: 12/1/89

REVISED:

ESTIMATED BY: R. BAKER

CHECKED BY:

ITEM No.	DESCRIPTION	EST. QUANT.	UNIT	UNIT COST	TOTAL COST
1	Allowance for ICS telephone room in basement	0.5	LS	3,000	1,500
2	Relocate ICS closet on the second floor	1	LS	3,000	3,000
3	Relocate ICS closet on the first floor	1	LS	3,000	3,000
4	Install ICS cable trays	144	LF	19.75	2,844
5	Install ICS outlets in each room	12	EA	150	1,800
6	Install 480Y/277V @ 800A switchboard	1	EA	13,620	13,620
7	Modify 240v power panels to 208v	6	EA	470	2,820
8	Add boost transformers to 240v loads fed from 208v	10	EA	320	3,200
9	Relocate transformer 220 on 2nd floor	1	LS	940	940
10	Relocate power panels 6A1A and 220A on 2nd floor	2	EA	940	1,880
11	New feeds to existing 480V power panels 6A & 2A	180	LF	20	3,600
12	Motor Control Center@ 300A	1	EA	1,625	1,625
13	MCC feeder from switchboard	100	LF	30	3,000
14	Size 1 starters w/circuit breaker	7	EA	815	5,705
15	Local disconnect switch	7	EA	275	1,925
16	Motor feeders	50	LF	33	1,650
17	Make electrical connections to mechanical loads	7	EA	50	350
18	Standby power transfer switch	1	EA	3,290	3,290
19	Emergency panels	1	EA	400	400
20	Interior Bldg 80 power conduits	500	FT	20	10,000
21	Transformers 480-208Y/120V @ 30KVA	2	EA	1,725	3,450
22	Transformers 480-208Y/120V @ 15KVA	1	EA	1,350	1,350
23	208Y/120V panel 100A 42 ckt	4	EA	1,500	6,000
24	480Y/277V panel 225A 42 ckt	1	EA	2,425	2,425
25	Recessed fluorescent light fixtures - 2nd floor	6400	SF	4	25,600
26	Light switch, box, conduit and wire - 2nd floor	6400	SF	0.56	3,584
27	Recessed fluorescent light fixtures - 1st floor ex-highbay	3200	SF	4	12,800
28	Light switch, box, conduit and wire - 1st floor ex-highbay	3200	SF	0.56	1,792
29	Duplex receptacles, box, conduit and wire	6400	SF	1.32	8,448
30	Modify fire alarm system add floor water flow switch	1	LS	1,000	1,000
31	Fire alarm bells and pull stations	12	LS	70	840
32	Fire alarm wiring	6400	SF	0.20	1,280
33	Install public address speakers and wiring	6400	SF	0.53	3,392
34	Provide EMCS wiring to mechanical equipment	1	LS	2,000	2,000
35	Elevator wiring and testing	1	LS	3,000	3,000
36					
37					
38					
39					

Subtotal \$143,110

BUILDING 6 SECOND FLOOR OFFICE AND LABORATORY IMPROVEMENTS

DATE: 12/1/89

ESTIMATED BY: R. BAKER

REVISED:

CHECKED BY:

ITEM No.	DESCRIPTION	EST. QUANT.	UNIT	UNIT COST	TOTAL COST
1	Install 480Y/277V @ 400A switchboard	1	EA	5,370	5,370
2	480 & 208V power panel conduits	500	FT	11	5,500
3	Transformers 480-208Y/120V @ 30KVA	5	EA	1725	8,625
4	208Y/120V panel 100A 30 ckt	5	EA	1,500	7,500
5	480Y/277V panel 225A 42 ckt	1	EA	2,425	2,425
6	Make electrical connections to mechanical loads	6	EA	50	300
7	Standby power transfer switch	1	EA	3,290	3,290
8	208Y/120v panel 100A 16 ckt standby power	1	EA	800	800
9	Recessed fluorescent light fixtures - 2nd floor	4300	SF	4	17,200
10	Light switch, box, conduit and wire - 2nd floor	4300	SF	0.56	2,408
11	Duplex receptacles, box, conduit and wire	4300	SF	1.32	5,676
12	Allowance for ICS telephone room on the mezzanine	1	LS	3000	3,000
13	Install ICS cable trays	128	LF	19.75	2,528
14	Install ICS outlets in each room	19	EA	150	2,850
15	Modify fire alarm system add floor water flow switch	1	LS	1,000	1,000
16	Fire alarm bells, pull stations and door closers	15	LS	70	1,050
17	Fire alarm wiring	6400	SF	0.20	1,280
18	Install public address speakers and wiring	4300	SF	0.53	2,279
19	Provide EMCS wiring to mechanical equipment	1	LS	2,000	2,000
20					
21					
22					
23					

Subtotal 75,081

BEAM LINE LABORATORIES EXPERIMENTAL HALL FLOOR

DATE: 12/1/89

ESTIMATED BY: R. BAKER

REVISED:

CHECKED BY:

ITEM No.	DESCRIPTION	EST. QUANT.	UNIT	UNIT COST	TOTAL COST
1	Relocate, supplement & recircuit overhead lights	2200	SF	2	4400
2	Relocate & supplement speakers	2200	SF	0.53	1166
3	Duplex outlets, box, conduit & wire	2200	SF	1.32	2904
4	Relocate 100 amp power panels within Lab walls	2	EA	800	1600
5	Install ICS outlets	4	EA	150	600

Subtotal \$10,670

9-92

BUILDING 6 SECOND FLOOR ELECTRICAL SITE UTILITIES

DATE: 12/1/89

REVISED:

ESTIMATED BY: R. BAKER

CHECKED BY:

ITEM No.	DESCRIPTION	EST. QUANT.	UNIT	UNIT COST	TOTAL COST
1	480Y/277V feeder from SW-A3 to 2nd floor switchboard	300	LF	39	11,700
2	ICS cable pairs to 2nd floor closet	50	EA	50	2,500
3	Emergency power feeder to Bldg 6 2nd flr from Bldg 37	500	LF	11	5,500

Subtotal \$19,700

BUILDING 80 ELECTRICAL SITE UTILITIES

DATE: 12/1/89

REVISED:

ESTIMATED BY: R. BAKER

CHECKED BY:

ITEM No.	DESCRIPTION	EST. QUANT.	UNIT	UNIT COST	TOTAL COST
1	Outside plant cable from ICS Node 2 to Bldg 80	0.5	LS	6,200	3,100
2	Change transformer # 342 from 240V to 208V	1	LS	5,850	5,850
3	Install conduit and cable to 480V switchbd from ALS sub	500	LF	40	20,000
4	Emergency system wiring to Bldg 80 from Bldg 37	500	LF	11	5,500

Subtotal \$34,450

9-93

ALS LIFE SCIENCES CENTER
DETAILS OF ESTIMATE OF SCIENTIFIC
EQUIPMENT UNDER SCHEDULE I
SPECIAL FACILITIES
(In FY 1989 \$K)*

*These costs have been escalated to FY 1990 \$K in Schedule I.

IMAGE ANALYSIS PACKAGE BOOK

Tracor Northern Inc.

2551 West Beltline Highway
Middleton, Wisconsin 53562-2697
(608) 831-6511 Fax: 310-280-2521

QUOTATION NO.

Q801030

Page 1

TO: Dr. Thomas Hayes
University of California
Berkley Labs
22 Donner Lab
Berkley, CA 94720

DATE: October 24, 1988
FOB: Middleton, WI
TERMS: 1/4 of 1% 10 / NET 30
EST. SHIP DATE: 90 days ARO

INQUIRY NO: N/A

::181CA28IE::

ITEM	QTY	MODEL NUMBER AND DESCRIPTION	UNIT PRICE	TOTAL PRICE
<u>TN-8502 High Performance Image Analysis Package</u>				
1	1	TN-8502/BAAC Imaging image processor system with 4 MByte 16 bit image memory (512x512 maximum image resolution), 12.5 MHz M68020 CPU with 1 MByte CPU memory, non-interlaced color imaging monitor, color control monitor, control console, mouse, one 1.2 MByte floppy disk drive, one 80 MByte fixed Winchester disk drive and 150 MByte tape streamer. Requires IPA85, at least 3 MBytes CPU memory and printer (Customer must provide 20 Amp service at 100/115 VAC sites)	51,500.00	51,500.00
2	1	TN-8550-210 "IPA85" image enhancement and analysis software for acquisition, processing and storage of TN-8502 images and feature characterization of stored images. Requires 3 MBytes CPU memory	5,000.00	5,000.00
3	1	TN-8520-214A Printer: 150 CPS HP 2225C parallel port ink jet printer and one extra print head (115 VAC)	800.00	800.00
4	1	TN-8545-212/525 Line grabber: 4 input, 512x480 resolution RS-170/330 video digitizer for use with one RGB or up to 4 monochrome 525 line (60 Hz) video cameras (#3 TN slot; FP-III compatible)	2,750.00	2,750.00
5	1	TN-C1-88063 Photo tube and 0.5x relay lens assembly for RS-170 CCD video cameras (TN-CC10-110 or TN-CC10-111)	850.00	850.00
6	1	TN-CC10-111 CCD integration camera body, RS-170 (525 line) with internal thread "C" mount, integration controller, interface cable kit, and 115 VAC wall transformer (0.025 Lux sensitivity; Mfg's Wnty). Requires TN-8502 system with TN-8545-212/525. TN-CC10-11FL12 lens recommended for maximum field of view on TSM.	3,950.00	3,950.00
7	1	TN-8555-290 SAC interface package including system software and serial cable for software controlled movement of motorized X/Y stage and/or fine "Z" focusing stepping motors. Requires a TN-8502/Bxxx, /Cxxx, or S/Axxx, one available serial port, TN-8605 Stage Automation Controller, and appropriate microscope motorization	2,000.00	2,000.00

Tracor Northern Inc.

2551 West Beltline Highway
Middleton, Wisconsin 53562-2697
(608) 831-6511 Fax: 910-280-2521

QUOTATION NO.

Q801030

Page 2

ITEM	QTY	MODEL NUMBER AND DESCRIPTION	UNIT PRICE	TOTAL PRICE
8	1	TN-8595-214 Small console table (29" x 29" x 30" wide)	300.00	300.00
9	1	TN-8585-211 Installation of a TN-8502 image processor and one operator school credit	2,000.00	2,000.00
10	1	TN-8510-222 2 MByte of additional CPU memory (1 VME slot)	2,200.00	2,200.00
Total				<u>\$71,350.00</u>

OPTIONAL

A. Objective Aperture Automation

A.1	1	TN-8555-221 TSM automation program providing computer controlled extended focus image acquisition. For use with TN-XXXXXX TSM objective lens automation package or TN-XXXXXXXX SAC interface package (SAC option requires both stage and fine "Z" motorization)	2,000.00	2,000.00
A.2	1	TN-8515-286 TSM objective lens automation package for ultra-fine X/Z objective movement. Includes interface cable and objective automation board (1 VME slot). Requires TSM-1E, TN-8502 and TN-8555-221	3,000.00	3,000.00

Option A Total - Add'l \$5,000.00

SUB TOTAL 76350.
TRANSPORTATION ~ 3650
TOTAL \$ 80000

Prices quoted are exclusive of transportation charges. Tracor Northern reserves the right to choose the appropriate air or truck freight carrier for purchased items. Freight charges will be pre-paid and invoiced separately unless otherwise stated above. Items will be shipped FOB Middleton, Wisconsin unless otherwise stated above. Applicable taxes will be invoiced unless an exemption number is provided at time of order and a current physical copy of the customer's exemption certificate is on file at Tracor Northern. Quoted items include a one year warranty unless otherwise stated in their descriptions.

Prices quoted are firm provided your order is placed within 30 days from the date of this quotation. The delivery time quoted is from receipt of your order. Power requirements MUST BE SPECIFIED on all purchase orders if other than 115 VAC, 60 Hz.

BY:

Tam Jelling
Technical Sales Specialist

**DIGITAL SCANNING ELECTRON MICROSCOPE
WITH ANALYTICAL WORKSTATION**

\$ 260 K

QUOTATION NO.

EBQ801039

Page 1

Tracor/ **Electron
Beam
Instruments**

1005 PARKVIEW ROAD
MIDDLETON, WI 53562
408/871-4811
FAX 408/416-1004

TO: Dr. Tom Hayes
Lawrence Berkley Laboratory
University of California
22 Donner Lab
Berkley, CA 94720

DATE: October 26, 1988
FOB: Middleton, WI
TERMS: See PAYMENT TERMS Below
EST. SHIP DATE: 180 days ARO

INQUIRY NO: N/A

::181CA01FG::

ITEM	QTY	MODEL NUMBER AND DESCRIPTION	UNIT PRICE	TOTAL PRICE
1	1	EB-ADEM.1(A8) <u>Digital Scanning Electron Microscope/Analytical Workstation</u>	215,000.00	215,000.00

AUTOMATED DIGITAL ELECTRON MICROSCOPE (ADEM™)

Accelerating Voltage: 0.1 - 30 kV in 100 volt increments
Tungsten Filament electron source: Resolution of 6.5 nm
Magnification: 10x to 250,000x selectable via:

- Continuous zoom
- Preset steps
- Two operator defined settings for instant recall of any magnification setting

Vacuum System Fully Automated and Fail-Safe

- Two-Stage Roughing pump with trap
- 322 l/s Oil Diffusion pump with water cooled baffle
- Fully gauged showing actual vacuum readings of the specimen chamber, specimen airlock, roughing line, and foreline

Automated Six Axis Specimen Stage

- Joystick Control Module for manual and programmed positioning of the specimen stage
- Speed of stage motion is coordinated automatically with magnification, e.g., slower movement at higher magnification
- Each axis motorized and programmable
- Computer eucentric manipulation using tilt, bank, and spin axes at any working distance
- Internal position feedback with all motors inside the vacuum chamber
- Complete Coverage of 305 mm diameter sample
- Ranges of motion:
 - x = 155 mm
 - y = 270 mm
 - z = 90 mm
 - Tilt = -2 to 90 degrees
 - Spin = 360 degree
 - Bank = -60 to +55 degrees

ITEM QTY	MODEL NUMBER AND DESCRIPTION	UNIT PRICE	TOTAL PRICE
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Large Vacuum Chamber

- Internal dimensions: 335 x 600 x 330 mm
- Large Access Door (210 x 260 mm)
- Internal chamber light interlocked to 3 inch viewing port and chamber door

Automatic Specimen Exchange Airlock

- Large specimens (150 mm dia. x 50 mm) accepted via Airlock
- Specimen stage transfers the specimen between the Airlock and the beam automatically

Image Collection and Scanning

- Split screen for simultaneous viewing of different signals and/or magnifications
- Signal mixing of up to four (4) different inputs simultaneously
- Reduced area raster
- Programmable image persistence
- Recursive Kalman frame averaging
- "Beam-on-Demand" automatic beam blanking

Secondary Electron Detector (E-T type)

- Colinear with EDS Detector
- Faraday cage bias variable from +400 to -100 volts

Energy Dispersive X-ray Spectrometer (EDS)

- Automated motorized positioning
- 30 mm² Si(Li) crystal
- 147 eV resolution
- Take-off angle automatically calculated and utilized by Quantitative software
- 40 degree take-off angle at analytical working distance (24 mm)

Backscattered Electron Detector

- Annular Solid State Quadrant design
- High speed amplifier allows use at normal viewing scan speed
- Atomic Number or Topographic contrast imaging
- Automatically Retractable (motorized)

Quantitative Microanalysis

- Completely integrated analysis software is aware of all column conditions
- "One button" quantification
- High speed frame rate x-ray mapping
- Up to 16 different elements mapped simultaneously
- Eight different spectral memories
- Integrated Faraday Cup beam current monitor

ITEM QTY	MODEL NUMBER AND DESCRIPTION	UNIT PRICE	TOTAL PRICE
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Central Processing Unit (CPU)

- State of the art MC68020 32 bit processor
- 3 MBytes CPU memory
- OS-9 operating system
- All software written in "C" language

Mass Storage

- 80 MByte Fixed Winchester Hard Disk
- 1.2 MByte 5 1/4" Floppy Disk
- 150 MByte Streaming Tape Archival Device

Pipeline Image Processor (PIP)

- 16 bit images up to 1024 x 1024 pixels
- 80 ns Clock Speed
- 8 MBytes Dedicated Image Memory

Digital Image Processing includes:

- Digital Filters provide image smoothing, sharpening, edge enhancement, erosion, and dilation
- 2-D Fast Fourier Transformations
- Dynamic Pan and Zoom
- Gamma, Equal Area, Inverse, False Color and Interactive brightness transforms
- Overlay Graphics in a variety of colors
- On-Screen measurements using "mouse" pointing device

Image Recording and Data Output

- 2000 line resolution photographic CRT
- 4 x 5 Polaroid output
- Color and Monochrome output from both viewing monitors
- Exposure settings stored in computer memory provides instant recall for different film types
- 120 CPS Dot matrix printer

Separate Control Console and Electron Column cabinets

- May be positioned up to 20 feet apart

Specimen Holders capable of accepting seven one inch diameter mounts

Tool/Spare Parts Kit

Two (2) High Resolution Full Color Monitors

Mouse Pointing Device

Customer Training

One (1) Set of Instruction Manuals

One Year Warranty

Requirements

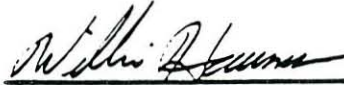
- 4.0 kVA, 115 VAC or 230 VAC single phase 60 Hz service
- Cooling water for diffusion pump
- Dry gas for vacuum backfill
- Compressed gas for valve operation
- Installation (EB-INF1001)

ITEM	QTY	MODEL NUMBER AND DESCRIPTION	UNIT PRICE	TOTAL PRICE
2	1	EB-EGM2001 Lanthanum hexaboride (LaB ₆) cathode gun assembly. Requires item number EB-VSM4001	1,000.00	1,000.00
3	1	EB-VSM4001 20 liters/second ionization pump for gun chamber	6,000.00	6,000.00
4	1	EB-VSM3002 300 liters/second water-cooled turbomolecular vacuum pump (in lieu of standard diffusion pump)	9,500.00	9,500.00
5	1	EB-SOM1001 10 kg Mass Mover Stage. Provides complete coverage of a 150 mm diameter sample which is up to 190 mm in height with a mass of 10 kg or less. Stage motion is limited to the X, Y, and Z axes	800.00	800.00
6	1	EB-XDM2002 Light element energy dispersive X-ray spectrometer with 30 mm ² Si(Li) crystal, 151 eV resolution, and 40° take-off angle at 28 mm working distance. In lieu of standard spectrometer	7,300.00	7,300.00
7	1	EB-CMM1002 Factory expansion of CPU memory to 5 MByte	1,550.00	1,550.00
8	1	EB-SWC2001 Complex particle sizing with chemical characterization. Requires at least 5 MByte of CPU memory	4,500.00	4,500.00
9	1	EB-INF1001 System installation	7,500.00	7,500.00

Total \$253,150.00Transportation ~ 6,850.00\$ 260,000.-PAYMENT TERMS: 80% due within 30 days of shipment, balance due
upon installation.

Prices quoted are exclusive of transportation charges. Tracor Northern reserves the right to choose the appropriate air or truck freight carrier for purchased items. Freight charges will be pre-paid and invoiced separately unless otherwise stated above. Items will be shipped FOB Middleton, Wisconsin unless otherwise stated above. Applicable taxes will be invoiced unless an exemption number is provided at time of order and a current physical copy of the customer's exemption certificate is on file at Tracor Northern. Quoted items include a one year warranty unless otherwise stated in their descriptions.

Prices quoted are firm provided your order is placed within 30 days from the date of this quotation. The delivery time quoted is from receipt of your order. Power requirements MUST BE SPECIFIED on all purchase orders if other than 115 VAC, 60 Hz.

BY: 

Product Specialist

*HIGH RESOLUTION ELECTRON MICROSCOPE
WITH CRYO WORK STATION*

\$ 200K

Carl Zeiss, Inc.

One Zeiss Drive
Thornwood, NY 10594
914-747-1800



October 19, 1988

Quotation #34-180

Jacob Bastacky
Room 116 Donner Lab
Laurence Berkeley Lab
Berkeley, CA 94720

CARL ZEISS HIGH RESOLUTION ELECTRON
MICROSCOPE EM 10 CA/G60

Resolution:	0.3nm point to point
Magnification Range :	20 x to 200,000x
Accelerating Voltage:	20, 40, 60, 80 and 100

Consisting of:

Microscope with control units
Microscope column equipped with apertures
and specimen cartridges for normal and
long objective focal length.
Viewing chamber with central beam stop
and binocular viewing microscope 9x.
Automatic camera system with a plate
and sheet film camera.
Automatic vacuum system with rotary pumps
diffusion pump and absorption trap.
Built-in large vacuum predessicator
High voltage and prestabilizer units.
Emergency transformer, Digital focusing
Focusing aid and darkfield beam tilt
Monostable, guaranteeing reproducible
magnification values better than 1.5%.
Anticontamination device.
Tools and 5 hairpin filaments

Carl Zeiss, Inc.

One Zeiss Drive
Thornwood, NY 10594
914.747.1800



34 07 00-9905	EM 10 CA
34 07 45	60 Universal film holders 3 1/4 x 4"
34 07 64-9903	Anode in case (spare)
34 56 45	Filament holder (spare)
34 07 50	Light-tight case for film holders
96 00 33	TI Coolwell S-74W Water recirculator
96 00 54	2 Alcatel Pumps
96 00 59	Remote light control unit
34 56 56	Oil Mist Filter
34 07 89	± 60° Tilt Goniometer complete, motorized operation
34 07 00-9905	EM 10 CA complete incl. installation, one week training, one year guarantee and service

	DUTY FREE: \$ 154,200.00
Forwarding charges	2,200.00

Total f.o.b. dest.	\$ 156,400.00 ←
	=====

Options:

34 07 35	Cyrostage + Transfer system complete includes new type stage with isolated center cone, Thermocouples and power supply with monitor, cyrotransfer container.	\$ 28,240.00 ←
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One of the following items is highly recommended with the use of the Cyrotransfer:

34 07 35-8080	Adapter for Reichert KF80	\$ 820.00
34-07 35-9007	Adapter for Reichert FC4	1,080.00
34 07 19	Cyro Workstation	12,050.00 ←

SUB TOTAL 196,690. —
LOCAL TRANSP. ~ 3310
TOTAL \$ 200,000

Carl Zeiss, Inc.

One Zeiss Drive
Thornwood, NY 10594
914-747-1800



The price quoted includes installation and one year warranty on all non-expendable parts. Warranty period commences upon receipt of instrument

Validity: 30 days
Delivery: 2 months, a.r.o.

Terms of Payment:

Buyer agrees to pay 30% of the total purchase price at the time of the signing of this contract. An additional 40% of the purchase price shall be paid by check upon receipt of the instrument at the buyer's location and the balance (30%) by check within 30 days after performance of the instrument has been demonstrated by a Zeiss representative.

Taxes: Carl Zeiss, Inc. prices do not include sales, use, excise or similar taxes. Therefore in addition to the price specified the amount of any present or future sales, use, excise or similar tax applied directly to the sale hereunder shall be paid by the purchaser.

Duty Free Importation

Non-Profit Institutions which are entitled to duty free importation under Public Law 89-651, must file with the Department of Commerce on Form DIB-338-P prior to the arrival of the instrument in the United States. If your application for duty free entry is denied, you will be fully responsible for payment of the duty at the prevailing rate.

Weight and Dimensions

The EM 10 CA is shipped in six (6) crates. The gross weight is approximately 2535 pounds (1150 kg) of which the heaviest and largest single unit weight is 1338 pounds (607 kg) and measures 68" x 34" x 50".

Transportation from your receiving area to the final installation site is the responsibility of the buyer. Carl Zeiss, Inc. personnel will support you in supervising the physical move of the Zeiss Electron Microscope within your premises.

Carl Zeiss, Inc.

Dieter Kurz

Dieter Kurz
Manager
Electron Optics Division

9-103

CONFOCAL MICROSCOPE

#86K

Tracor Northern Inc.

2551 West Beltline Highway
Middleton, Wisconsin 53562-2697
(608) 831-6511 Twx: 910-280-2521

QUOTATION NO.

Q801031

Page 1

TO: Dr. Thomas Hayes
University of California
Berkley Labs
• 22 Donner Lab
Berkley, CA 94720

DATE: October 24, 1988
FOB: Middleton, WI
TERMS: 1/4 of 1% 10 / NET 30
EST. SHIP DATE: 90 days ARO

INQUIRY NO: N/A

::181CA21CE::

ITEM	QTY	MODEL NUMBER AND DESCRIPTION	UNIT PRICE	TOTAL PRICE
<u>Confocal Tandem Scanning Reflected Light Microscope (TSM)</u>				
1	1	TN-C1-88001 TSM™-1E Confocal Tandem Scanning Reflected Light Microscope. Stand with ultra-fine X/Z electronically controlled objective movement, controller for scanning disk and electronic objective movement (includes interface port for computer control), 160 mm tube length (uses standard objectives), single objective holder (.800-36 RMS thread), epi-illumination assembly with adjustable field and brightness apertures and three filter slots, three filter holders for 25mm filters, coaxial coarse-fine focus adjustment (40mm travel), 25cm x 33cm optical bench base with protective base cover, microscope dust cover, operator's manual, TN domestic field installation, and accessory kit including 50x oil objective lens, 8x alignment lens, microscope slide support block, alignment tools, and calibration slide	27,000.00	27,000.00
2	1	TN-C1-88003 General purpose scanning disk (includes cartridge)	6,200.00	6,200.00
3	1	TN-C1-88004 Trinocular viewing assembly including binocular observation tubes with adjustable inter-pupillary distance, two 10x widefield eyepieces, vertical camera port less relay lens assembly, selectable 100% visual or 100% photo	4,000.00	4,000.00
4	1	TB-C1-88008 Stage carrier bracket for reflected/transmitted light (accepts condenser carrier for transmitted light option)	580.00	580.00
5	1	TB-C1-88013 Rectangular stepping motor driven stage with 4"x4" travel, glass stage plate, object holder (2.5 micron/step precision)	8,000.00	8,000.00
6	1	TN-C1-88016 Stepping motor drive for fine "Z" focusing mechanism including mounting hardware and cables for interface to stage automation controller (0.5 micron/step precision)	1,800.00	1,800.00
7	1	TN-C1-88017 Stage automation controller (TN-8605) for joystick control of X, Y, and/or Z stepping motors included in TB-C1-88012, TB-C1-88013 or TN-C1-88016 (can be automated with TN-8500 series image analyzer)	6,500.00	6,500.00

Tracor Northern Inc.

2551 West Beltline Highway
Middleton, Wisconsin 53562-2597
(608) 831-6511 Fax 910-280-2521

QUOTATION NO.

Q801031

Page 2

ITEM	QTY	MODEL NUMBER AND DESCRIPTION	UNIT PRICE	TOTAL PRICE
<u>Xenon/Mercury EPI Illumination</u>				
8	1	TB-C1-88024 Power supply for 75 to 200W xenon or mercury bulbs with 0.5% regulation (115/220V)	1,670.00	1,670.00
9	1	TB-C1-88030 Lamphouse, mounting adapter, bulb socket and collector lens for 150W Xenon or 200W mercury	2,625.00	2,625.00
10	1	TB-C1-88033 200W mercury bulb	360.00	360.00
11	1	TB-C1-88032 150W xenon bulb	335.00	335.00
Total				<u>\$59,070.00</u>

NOTE: Customer is responsible for providing appropriate 25mm filters.

NOTE: Customer is responsible for providing appropriate objective lenses.

OPTIONAL

A. Transmitted Light Illumination

A.1	1	TN-C1-88034 Substage illuminator assembly including adjustable field aperture, two filter holders, and protective base cover	2,250.00	2,250.00
A.2	1	TB-C1-88018 100W power supply (110/115 VAC) for tungsten halogen	395.00	395.00
A.3	1	TB-C1-88128 Lamphouse	610.00	610.00
A.4	1	TB-C1-88021 Collector lens for tungsten halogen source	220.00	220.00
A.5	1	TB-C1-88022 Lampsocket for 100W tungsten halogen bulb	250.00	250.00
A.6	1	TB-C1-88023 100W tungsten halogen bulb	20.00	20.00
A.7	1	TB-C1-88035 Condenser carrier (fits TB-C1-88008 stage carrier bracket)	400.00	400.00

Tracor Northern Inc.

2551 West Beltline Highway
Middleton, Wisconsin 53562-2697
(608) 831-6511 Fax 310-280-2521

QUOTATION NO.

Q801031

Page 3

ITEM QTY	MODEL NUMBER AND DESCRIPTION	UNIT PRICE	TOTAL PRICE
A.8 1	TB-C1-88037 Achromat condenser with swing-out top lens and graduated aperture diaphragm; N.A. 0.9, 1.8mm WD	485.00	485.00
Option A Total			<u>\$4,630.00</u>
B.	<u>35mm Format Camera Option</u>		
8.1 1	TB-C1-88071 35mm format, auto exposure via photomultiplier, spot and area metering, auto winding, viewfinder, 2.5x projection lens (UFX-II)	8,015.00	8,015.00
8.2 1	TB-C1-88126 Auto advance 35mm camera back (use on UFX-II)	855.00	855.00
8.3 1	TB-C1-88083 Adapter for auto advance 35mm camera back (use on UFX-II)	165.00	165.00
8.4 1	TN-C1-88087 Photo tube and relay lens assembly for Nikon FX series photomicrographic systems (requires photo tube adapter)	850.00	850.00
8.5 1	TN-C1-88088 Photo tube adapter for Nikon FX series photomicrographic systems	195.00	195.00
Option B Total			<u>\$10,080.00</u>
C.	<u>Polaroid Format Camera Option</u>		
C.1 1	TB-C1-88072 4"x5" polaroid format, auto exposure via photomultiplier, spot and area metering, viewfinder, 2.5x projection lens (UFX-II)	8,235.00	8,235.00
C.2 1	TB-C1-88082 4"x5" Polaroid film holder (type 52, 53, 55 and 59 films)	340.00	340.00
Option C Total			<u>\$8,575.00</u>

NOTE: Option C.1 requires TB-C1-88087 relay lens/adapter called out in Option B.4.

SUB TOTAL 32355
TRANSPORTATION ~ 3645
\$ 36000

Tracor Northern Inc.

2551 West Beltline Highway
Middleton, Wisconsin 53562-2697
(608) 831-6511 Fax: 910-280-2521

QUOTATION NO.

Q801031

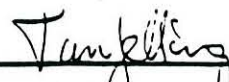
Page 4

ITEM QTY	MODEL NUMBER AND DESCRIPTION	UNIT PRICE	TOTAL PRICE
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Prices quoted are firm provided your order is placed within 30 days from the date of this quotation. The delivery time quoted is from receipt of your order. Power requirements MUST BE SPECIFIED on all purchase orders if other than 115 VAC, 60 Hz.

BY:



Technical Sales Specialist

ALS LIFE SCIENCES CENTER
DETAILS OF ESTIMATE OF SCIENTIFIC
EQUIPMENT UNDER SCHEDULE II
STANDARD EQUIPMENT
(In FY 1989 \$K)*

*These costs have been escalated to FY 1990 \$K in Schedule II

ALS LIFE SCIENCES CENTER

Standard Equipment Detail for Schedule II (In FY 1989 \$K)

Biochemistry		1,034*
Preparative Ultracentrifuge (2)	111	
Tabletop Centrifuge (1)	27	
Refrigerated Centrifuge (4)	101	
Microfuge (2)	4	
Scanning Spectrophotometer (2)	61	
Scanning Spectrophotometer (2)	84	
Scanning Spectrophotometer (3)	38	
Balances (Various)	59	
Top Load Sartorius (6)	16	
Catur Millibal (1)	3	
Sartorius, Micro (1)	9	
Sartorius, Analytic (5)	20	
Assorted Ether	3	
Remote Platform	2	
Platform Scale	1	
Accessories	1	
Tables (4)	4	
Isotope Bench Top Liquid Scintillation Counter	24	
Isotope Gamma Counter System	17	
Separation Equipment	214	
Fraction Collectors (6)	19	
Chromotography Refrigerator	5	
Automatic Dilutors (4)	12	
Densitometer	32	
Electrophoresis Accessories	5	
Hi Press Liquid Chromotography (2)	127	
Electrophoresis (2)	14	

General Laboratory Equipment		294
Water Purification Systems (7)	22	
Carts (12)	7	
Waterbaths and Circulating Waterbaths (16)	43	
Lyophilizer (3)	39	
Freezers (6)	26	
Sonication Equipment (2)	5	
Mixers, Various	9	
Regular Refrigerators (6)	6	
Special Refrigerators (2)	9	
Ovens (4)	13	
PH, Ion and Voltmeters (12)	25	
Pumps, Various	5	
Safety Equipment	5	
Shakers, Various	5	
Homogenizers (3)	9	
Elemental Chemical Analysis	37	
Flame Photometer	13	
Chloride Titrator	3	
Atomic Absorption Photometer	21	
Assorted Lab Glassware, Chemicals, Plasticware, Pipettes, etc.	29	
Microscopy		105
Darkroom Equipment (2)	52	
General Laboratory Equipment	53	
Low Temperature Preparative Facility	22	
Assorted Glassware, Chemicals, Plasticware, Darkroom Supplies and EM Supplies	31	

Cell and Tissue Culture		135
Incubators (4)	46	
Sterilizer (1)	37	
General Laboratory Equipment	52	
Assorted Glassware, Plasticware, Cell Culture Media and Small Equipment		
Surgical Suite		77
Operating Tables, Surgical Instruments and Special Lighting	19	
Operating Table	7	
Surgical Instruments	5	
Light Sources, Theater Light Fiberoptics	7	
Operating Microscope and Video Equipment	47	
Operating Microscope	37	
Video Camera	10	
General Laboratory Equipment	11	
Surgical Supplies (Syringes, Garments, Drapes, Fluids, etc.)		
General Support Equipment		381
Computational Equipment	247	
Microvax	80	
Computer Workstations (24)	167	
Dishwasher	85	
Office Furniture	36	
Office Equipment	13	

*5% added to each category for delivery, handling and installation

BECKMAN

ALL ORDERS
AND CORRESPONDENCE
TO THIS ADDRESS →

BECKMAN INSTRUMENTS, INC.
Stanford Industrial Park
P.O. Box 10015
Palo Alto, Ca. 94303
Bob Cummins (800)742-2345

DATE April 19, 1988

to Center for X Ray Optics
Lawrence Berkeley Laboratory
Berkeley, Ca. 94720

PAGE 1 of 2

QUOTATION NO SFR-0239

ATTENTION Dr. Steven Rothman
YOUR REFERENCE NO 486-4029,4463

PLEASE REFER TO THIS QUOTE NO
IN FUTURE CORRESPONDENCE

ITEM	QTY	PART NO	DESCRIPTION	UNIT PRICE LIST PRICE	DISCOUNTED PRICE
1	1	344200	MODEL L8-80M PREPARATIVE ULTRACENTRIFUGE	\$35,700.00	\$28,203.00
2	1	342184	TYPE 70.1 TI FIXED ANGLE ROTOR	6,600.00	5,214.00
3	1	348179	QUICK-SEAL TUBE KIT FOR TYPE 70.1 TI	570.00	530.10
4	1	339160	TYPE 45 TI FIXED ANGLE ROTOR	7,100.00	5,609.00
5	1	348175	QUICK-SEAL TUBE KIT FOR TYPE 45 TI	1,180.00	1,097.40
6	1	331336	SW 41 TI SWINGING BUCKET ROTOR PACKAGE	8,220.00	6,493.80
7	1	342204	SW 28 SWINGING BUCKET ROTOR PACKAGE	7,150.00	5,648.50
8	1	346457	TL-100 TABLETOP ULTRACENTRIFUGE	20,560.00	18,504.00
9	1	349490	TLA-100.3 FIXED ANGLE ROTOR PACKAGE	3,690.00	3,690.00
10	1	346134	TL5-55 SWINGING BUCKET ROTOR PACKAGE	3,570.00	3,570.00
11	1	344301	J2-21M FLOOR MODEL REFRIGERATED CENTRIFUGE	16,800.00	13,440.00
12	1	346944	JA-18 FIXED ANGLE ROTOR	2,350.00	1,927.00
13	1	339247	JA-14 FIXED ANGLE ROTOR	2,450.00	1,960.00
14	1	346963	JS-13.1 SWINGING BUCKET ROTOR	4,500.00	3,600.00
15	1	336380	JS-7.5 SWINGING BUCKET ROTOR	3,900.00	3,120.00
16	1	349702	6PR TABLETOP REFRIGERATED CENTRIFUGE	4,790.00	4,406.80
17	1	349830	8H-3.7 HORIZONTAL ROTOR	1,100.00	1,012.00
18	4	355804	ADAPTER FOR 15 ml TUBES (\$54/EA)	206.00	200.88
19	4	355806	ADAPTER FOR 50 ml TUBES (\$54/EA)	206.00	200.88
20	4	349849	ADAPTER FOR 250 ml CONICAL BOTTOM TUBES (9.60/EA)	38.40	35.70
21	1	342352	MICROFUGE 12	1,980.00	1,623.60
22	1	345636	TYPE 13.2 FIXED ANGLE ROTOR	455.00	373.10
23	1	523000	DU-70 UV/VIS SCANNING SPECTROPHOTOMETER	14,500.00	13,340.00
24	1	523400	HIGH-SPEED PRINTER/PLOTTER	1,050.00	892.50
25	1	523416	KINETICS/8EL SCAN AUTO-6 TRANSPORT	2,400.00	2,040.00
26	1	523422	PELTIER CONTROLLER	2,400.00	2,040.00
27	1	523409	AUTO-6 PELTIER CELL HOLDER	1,500.00	1,275.00
28	1	523428	TUBE 8EL HOLDER	520.00	442.00
29	1	523429	FILM 8EL HOLDER	520.00	442.00
30	1	596077	8EL SLITS	435.00	404.50
31	1	198649	8EL CUVETTE	175.00	139.34
32	1	523408	SIPPER ACCESSORY	1,800.00	1,530.00
33	1	523404	PELTIER REGULATED FLOW CELL	1,350.00	1,147.50
34	1	523751	TUBING KIT FOR HEATED FLOW CELL	370.00	292.30
35	1	523417	BATCH SAMPLER	4,150.00	3,527.50
36	1	534110	DATA CAPTURE SOFTWARE	780.00	663.00
37	1	597172	DATA TRANSPORTER W/CABLE, 128 K	950.00	374.00

- continued -

TOTAL FOR ACCEPTANCE WITHIN 60 DAYS OF ABOVE DATE
SENT 04-20-88 DAYS FROM RECEIPT OF ORDER

FOR Shipping Point

1500 S. UNIVERSITY BLVD. BERKELEY, CA 94720
TELEPHONE (415) 842-1000

BECKMAN INSTRUMENTS, INC.

Signed

Name Bob Cummins, Sales Representative

The enclosed is a quote for the equipment described on the attached list. It is subject to the terms and conditions of the Beckman Instruments, Inc. Standard Sales Agreement, which is incorporated by reference in this quote. The quote is valid for 60 days from the date of this quote. The equipment is to be delivered to the shipping point. The quote is not valid for equipment to be delivered to the customer's site. The quote is not valid for equipment to be delivered to the customer's site. The quote is not valid for equipment to be delivered to the customer's site.

AND AS ALL ORDERS
AND CORRESPONDENCE
TO THIS ADDRESS

DATE: April 19, 1988

TO: Center for X Ray Optics
Lawrence Berkeley Laboratory
Berkeley, Ca. 94720

PAGE 2 OF 2

QUOTATION NO SFR-0239

ATTENTION: Dr. Steven Rothman
YOUR REFERENCE NO. 486-4029,4463

PLEASE REFER TO THIS QUOTE NO
IN FUTURE CORRESPONDENCE

ITEM	QTY	PART NO	DESCRIPTION	UNIT PRICE	DISCOUNTED PRICE
38	1	120640	<u>MODEL DU 64 SCANNING SPECTROPHOTOMETER</u>	7,600.00	6,992.00
39	1	523701	PRINTER/PLOTTER	1,050.00	892.50
40	1	523712	SIPPER ACCESSORY	1,600.00	1,360.00
41	1	598287	QUANT I SOFT PAC™ MODULE	465.00	395.25
42	1	598288	QUANT II SOFT PAC™ MODULE	670.00	569.50
43	1	598273	KINETICS SOFT PAC™ MODULE	670.00	569.50
44	1	598274	RS-232 INTERFACE	730.00	620.50
45	1	534099	DATA CAPTURE SOFTWARE	750.00	637.50
46	1	585302	<u>LS-3801 BENCH TOP LIQUID SCINTILLATION COUNTER</u>	23,500.00	20,680.00
47	1	599397	VERSA RACK SAMPLE CHANGER	1,500.00	1,320.00
48	1	597049	DATA CAPTURE SOFTWARE	750.00	660.00
49	1	586104	<u>GAMMA 5500 PC READY PLUS GAMMA COUNTER SYSTEM</u>	17,200.00	15,824.00
50	1	239742	<u>SYSTEM GOLD HPLC</u>	48,970.00	45,542.20
51	1	563100	RD 170 RADIOISOTOPE HPLC DETECTOR - GAMMA	3,750.00	3,450.00
52	1	596802	RD 171 RADIOISOTOPE HPLC DETECTOR - BETA	12,500.00	11,500.00
53	1	344473	<u>GENELINE™ TAPE ELECTROPHORESIS SYSTEM</u>	6,350.00	6,350.00
54	1	123000	<u>MODEL pH™ 71 pH METER</u>	1,650.00	1,303.50
55	1	39835	pH ELECTRODE, EPOXY BODY, TEST TUBE SIZE	105.00	82.95
56	1	598976	pH ELECTRODE CABLE	24.50	19.36

NOTE: 1. Priced per GSA Contract numbers GS-00F-93456 and GS-00F-93783 and National Account number SFR-0052
2. Prices good through June 23, 1988

PROPOSAL FOR ACCEPTANCE WITHIN 60 DAYS OF ABOVE DATE

SHIPMENT: 30-60 DAYS FROM RECEIPT OF ORDER

TERMS: F.O.B.

This proposal is subject to buyer's acceptance of the terms and conditions of sale appearing on the reverse side hereof.

BECKMAN INSTRUMENTS, INC.

Signed Bob [Signature]
Name Bob [Signature]

[illegible]

ALS LIFE SCIENCES CENTER

Standard Equipment Detail for Schedule II (In FY 1990 \$K)

Computation Equipment

12	Scientist Workstations		
6	Visitor Workstations		
6	Clerical Workstations		
24	Total	7.15K per station	172
2	Microvax or equivalent (Center Computer Network plus Data Reduction and Storage)	41K each	82
	Subtotal		254

Equipment for Glasswashing and Handling

	Washer/Dryer	17.4
	Distiller	15.0
	Autoclave	40.0
	Glassware and Racks	15.6
	Subtotal	88

Office Furniture and Equipment

19	FTE's plus 6 Visitors	
25	Workstations	
	Standard Desk (1.469)	(1) 0.36
	Table	(1) 0.174
	Chairs	(2) 0.276
	File Cabinet (5 drawer)	(2) 0.36
	Bookcases	(2) 0.144
	Chalkboard	(1) 0.075
	Tackboard	(1) 0.03
	Standard Coat Rack	(1) 0.05
	25 at 1.5K	37.5
	Xerox Machine	10.0
	Fax Machine	3.0
	Subtotal	<u>50</u>
	Total General Support Equipment	392

ALS LIFE SCIENCES CENTER

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APPENDIX B

Project Cost Estimate Details

The cost estimate for the Life Sciences Center was developed in FY1990 dollars, and then escalated to obtain the total estimated cost (TEC). The total cost for the project is \$25.05M in FY1990 dollars; in actual year (escalated) dollars for a three year project schedule (FY1993-FY1995) the Total Estimated Cost is \$30.70M. The FY1990 cost estimate detail information is presented in this Appendix. These cost estimate details are organized into a Work Breakdown Structure (WBS) format that presents a complete compilation of all the work elements in the construction project.

The detailed WBS was developed to insure that all elements of the Life Sciences Center project were evaluated for the design, and then appropriately included in the cost estimate. It defines the scope of the project in terms of the work to be done, and provides a structure for collecting costs in an organized fashion. WBS Level 1, the item with a one-digit code, is the entire project. Level 2 breaks the project down into the major categories of Project Management and Administration (1.1), Special Research Facilities (1.2), Conventional Facilities (1.3), and Contingencies (1.4). Lower levels of the WBS subdivide the project into ever smaller detail. For example, at Level 3, the special research facilities are subdivided into engineering, design, and inspection (EDI, 1.2.1), Wiggler Facility (1.2.3), and Undulator Facility (1.2.3). The WBS and costs, summarized to level 4, are shown in Table B.1, page B-5. The lowest level WBS elements, as well as the summary cost entries, are shown in the "Cost Estimate Report, Summary by WBS Rollup Levels", Table B.2 pages B-6 through B-14. The "Cost Estimate Detail Listing" data is included in Table B.3, pages B-15 through B-42, and includes the detail cost entry data sheet for each of the lowest WBS levels of the project. The contingency analysis summary is presented in Table B.4, pages B-43 through B-44.

The cost estimate includes all construction costs to be incurred after project approval. Project scope includes the special research facilities, conventional facilities, EDI, project management and administration, and contingencies. The estimate does not include R&D activities, preoperational and/or operating costs for any of the equipment or facilities. A project schedule was developed that assumes there will be accompanying research program funds to allow for research and development costs, as well as equipment testing, commissioning, and operation activity.

Basis for the Cost Estimate

Special Research Facilities: Many of the wiggler and undulator facility cost estimate details were derived directly from the latest cost estimate developed and reviewed in November 1989 for the Advanced Light Source (ALS). All of this material was recently developed and assembled (October 1989) by the ALS staff for their DOE Project review in November 1989. The appropriate WBS elements and cost data for specific insertion devices and beamline portions of the Life Sciences Center were extracted directly from this ALS data base, and are included here as the current representation of the estimated cost of such devices. This ALS data base, then, forms the basis for the current Life Sciences Center estimate for the Wiggler and Undulator insertion devices, their beamline 'front ends', and their respective branchlines and monochromator systems.

The general philosophy of this estimate is the same as that used in the ALS costing: current cost estimates are based on optical systems that have actually been fully designed. This means that the size, shape, radii of curvature, construction materials, and fabrication tolerances for all optical components were fixed as was the floor layout including the positions of all components. The original ALS cost estimates were developed with this design detail definition and are appropriate to use as the basis for comparable Life Sciences Center element costs.

The same philosophy was followed for the experimental stations, so that from an optical point of view, the systems were fully defined and scoped. The experimental stations are defined to be the parts downstream of the monochromator exit slit for the undulator line, and the parts downstream of the mirror that delivers light to the sample in the case of the wiggler beamlines. The costs of these experimental stations were obtained, partly from direct experience in cases where individuals in the group had direct relevant and recent information, and partly from others in the community who had current and relevant direct cost information to offer. Several members of the LBL Center for X-Ray Optics were particularly knowledgeable about the computing and hard x-ray optical systems.

Conventional Facilities: For the conventional facilities improvements at Buildings 6 and 80, the estimate was prepared by LBL's professional estimator, Derek Daniels, based on quantity take-offs from conceptual design drawings and specifications developed by the LBL Plant Engineering Department assisted by consulting engineers and architects. The mechanical systems (e.g. HVAC, plumbing and process piping, and fire protection) elements of the estimate for Buildings 6 and 80 were furnished by Keller & Gannon Engineering-Architect Firm. Conventional Construction costs are dated December 1989 and represent FY1990 current costs. The conventional facilities data is included in the WBS and cost estimate data base in these Appendix B tables, but is described and presented in considerably more detail in Appendix A.

Cost estimates for the scientific equipment associated with the conventional construction are shown in Appendix A Section 9. Those items listed in Schedule-I (WBS 1.3.2.5, 'Special Facilities') were based on vendor quotations received in October 1988 and have been escalated to reflect current prices in FY1990 dollars; those items included in Schedule-II (WBS 1.3.3, 'Standard Equipment') were estimated based on discounted catalog data which is included in Appendix A. A more detailed breakdown of the Standard Equipment summarized in Schedule-II is also included in Section 9 of that appendix.

EDI: The portions of the overall cost estimate required for Engineering, Design, and Inspection (EDI) activities were developed in both the conventional construction and special research facilities categories. The conventional facilities EDI includes both the cost of the Architect/Engineer (AE) scope of work and the LBL Plant Engineering activities. These cost details are again discussed in Appendix A. The EDI for the special research facilities was estimated in a manner consistent with the original ALS detail cost estimate procedures.

Contingency: A contingency cost is included in the estimate to reflect the technical and cost uncertainties associated with each of the individual systems. These contingencies reflect past experiences on similar systems. The Contingency Analysis summary is shown in Table B.4. The contingency is grouped into two main categories: 1.4.1 - Special Research Facilities and Project Management/Administration (3,830K\$), and 1.4.2 - Conventional Facilities (1,079K\$).

The 'Special Research Facilities' contingency was developed by examining work category levels as low as WBS level 5. The data for "% Contingency" and "K\$ Contingency" at these levels is indicated on Table B.4. The individual per centage estimates ranged from 20% to 30% depending on the state of the design and the estimated overall uncertainty of the cost estimate. For those elements that were developed directly from the ALS cost data base, the same contingency per centage is used as in the ALS estimate. (e.g. Wiggler and Undulator, Beamline frontends, and EDI; 25%). For the elements that include ALS type monochromators, (e.g. Crystallography branchline and Spectroscopy branchline etc.) the contingency is also estimated at 25%. The end station elements that are defined to be the special experimental equipment parts downstream of the monochromator exit slit for the undulator line, and the parts downstream of the mirror that delivers light to the sample in the case of the wiggler beamlines have a contingency of 30%. The WBS category for Project Management and Administration carries a contingency of 20%. The resulting 'overall effective contingency' for the special research facilities is approximately 26%.

The 'Conventional Facilities' contingency ranges from 15 to 25%, as indicated in Table B.4. For the EDI categories, the contingencies are 15% and 18% for LBL and A/E 'EDI' respectively, and for consultants and inspection categories the estimated contingency is 25%. The Building 6 and Building 80 costs carry an overall contingency percentage of 25% with the special facilities having 20% and the standard equipment having 15%. The resulting 'overall effective contingency' for the conventional facilities is 20%.

The total project contingency of 4,909K\$ represents an 'overall effective contingency' of 24.3% for all project construction costs.

Table B.1
Cost Estimate Summary

All costs shown in FY1990 K\$

1..	Life Sciences Center		25,050
1.1.	Project Management & Administration		1,422
1.2.	Special Research Facilities		13,352
1.2.1	Engineering, Design, & Inspection		3,739
1.2.1.1	EDI, Wiggler Facility	2,175	
1.2.1.2	EDI, Undulator Facility	1,564	
1.2.2	Wiggler Facility		5,536
1.2.2.1	Wiggler	1,102	
1.2.2.2	Wiggler Beamline Frontend	597	
1.2.2.3	Diffraction Facility	1,767	
1.2.2.4	Spectroscopy/Microprobe Facility	2,069	
1.2.3	Undulator Facility		4,077
1.2.3.1	Undulator	1,047	
1.2.3.2	Undulator Beamline Frontend	514	
1.2.3.3	Soft X-ray Imaging Facility	2,517	
1.3.	Conventional Facilities		5,368
1.3.1	Engineering, Design, & Inspection		506
1.3.2	Construction		3,075
1.3.2.1	Improvements to Land	12	
1.3.2.2	Building 80 Improvements	1,170	
1.3.2.3	Building 6 Improvements	766	
1.3.2.4	Site Utilities	84	
1.3.2.5	Special Facilities	1,043	
1.3.3	Standard Equipment		1,787
1.3.3.1	Biochemistry	1,067	
1.3.3.2	Microscopy	109	
1.3.3.3	Cell and Tissue Culture	139	
1.3.3.4	Surgical Suite	80	
1.3.3.5	General Support Equipment	392	
1.4.	Contingency		4,909
1.4.1	Special Research Facilities & Proj Mgt	3,830	
1.4.2	Conventional Facilities	1,079	

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Table B.2

Cost Estimate Report
Summary of Material and Labor
by Rollup Levels

Work Breakdown Structure # -----	Description -----	Material & Labor Total K\$ -----
** *		
1	Life Sciences Center	25,050.0
** **		
1.1	Project Management & Administration	1,422.0
1.2	Special Research Facilities	13,351.5
** ***		
1.2.1	Engineering and Design	3,738.6
** ****		
1.2.1.1	EDI, Wiggler Facility	2,174.5
** *****		
1.2.1.1.1	EDI, Wiggler	601.0
1.2.1.1.2	EDI, Wiggler Beamline Frontend	198.9
1.2.1.1.3	EDI, Diffraction Facility	613.9
1.2.1.1.4	EDI, Spectroscopy/Microprobe Facility	760.5
** ****		
1.2.1.2	EDI, Undulator Facility	1,564.1
** *****		
1.2.1.2.1	EDI, Undulator	465.7
1.2.1.2.2	EDI, Undulator Beamline Frontend	160.4
1.2.1.2.3	EDI, Soft X-ray Imaging Facility	937.9
** ***		
1.2.2	Wiggler Facility	5,535.5
** ****		
1.2.2.1	Wiggler (W13.6)	1,101.5
** *****		
1.2.2.1.1	Magnetic Structure	683.6
** *****		
1.2.2.1.1.1	Magnetic Material	394.6
1.2.2.1.1.2	Model Pole & Pole Assembly	13.2
1.2.2.1.1.3	Pole Assemblies	156.7
1.2.2.1.1.4	End Pole Assemblies	50.0
1.2.2.1.1.5	Backing Beams	32.1
1.2.2.1.1.6	Magnet Structure Assembly	19.2
1.2.2.1.1.7	Magnetic Measurements: Mechanical	6.3
1.2.2.1.1.8	Magnetic Measurements: Electrical	11.2

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Cost Estimate Report
Summary of Material and Labor
by Rollup Levels

Work Breakdown Structure # -----	Description -----	Material & Labor Total K\$ -----
** *****		
1.2.2.1.2	Support & Drive Systems	163.9
** *****		
1.2.2.1.2.1	Support System Fabrication	54.1
1.2.2.1.2.2	Drive System Fabrication	101.9
1.2.2.1.2.3	Local Temperature Control Fabrication	7.7
** *****		
1.2.2.1.3	Vacuum System	146.0
** *****		
1.2.2.1.3.1	Vacuum Chambers	65.2
1.2.2.1.3.2	Pumping Systems & Instrumentation	36.9
1.2.2.1.3.3	Support Structure	14.2
1.2.2.1.3.4	Vacuum Diagnostics	29.6
** *****		
1.2.2.1.4	Control System	25.6
1.2.2.1.5	Magnetic Measurements	57.2
** *****		
1.2.2.1.5.1	Magnetic Measurements: Mechanical	22.6
1.2.2.1.5.2	Magnetic Measurements: Electrical	34.5
** *****		
1.2.2.1.6	Installation	25.0
** *****		
1.2.2.2	Wiggler Beamline Frontend	597.3
** *****		
1.2.2.2.1	Frontend Mechanical Systems	408.0
** *****		
1.2.2.2.1.1	Fixed Aperture	12.4
1.2.2.2.1.2	PBPM #1	47.6
1.2.2.2.1.3	Front End Photon Shutter	41.6
1.2.2.2.1.4	Fast Valve	22.3
1.2.2.2.1.5	Personnel Safety Shut.	28.4
1.2.2.2.1.6	Front End Vacuum System	55.4
1.2.2.2.1.7	Splitting Mirror System	166.6
1.2.2.2.1.8	Front End Mechanical Installation	33.4
** *****		
1.2.2.2.2	Front End Controls: Electronics/Vacuum Pumps	116.1

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Cost Estimate Report
Summary of Material and Labor
by Rollup Levels

Work Breakdown Structure # -----	Description -----	Material & Labor Total KS -----
** *****		
1.2.2.2.2.1	Fixed Aperture Controls	8.7
1.2.2.2.2.2	PBPM #1 Controls	35.5
1.2.2.2.2.3	Photon Shutter Controls	24.6
1.2.2.2.2.4	Fast Valve Controls	22.2
1.2.2.2.2.5	Personnel Safety Shutter Controls	20.6
1.2.2.2.2.6	Vacuum System Controls	4.3
** *****		
1.2.2.2.3	Front End Safety Systems	22.2
1.2.2.2.4	Front End Utilities	26.4
1.2.2.2.5	Front End Mech/Elect System Integration	24.2
** *****		
1.2.2.3	Diffraction Facility	1,767.4
** *****		
1.2.2.3.1	Crystallography Branchline	1,172.0
** *****		
1.2.2.3.1.1	Branch Line Mechanical Systems	926.9
** *****		
1.2.2.3.1.1.1	H&V Beam Defining Apertures	85.6
1.2.2.3.1.1.2	Vertical Deflection Mirrors	250.4
1.2.2.3.1.1.3	Monochromator	365.0
1.2.2.3.1.1.4	Beam Line Diagnostics	39.8
1.2.2.3.1.1.5	Branch Line Vacuum System	67.7
1.2.2.3.1.1.6	Branch Line Mechanical Installation	28.2
1.2.2.3.1.1.7	Defining Slits	90.0
** *****		
1.2.2.3.1.2	Branch Line Electrical Systems	188.2
** *****		
1.2.2.3.1.2.1	Photon Transport Controls & Diagnostics	119.2
1.2.2.3.1.2.2	Monochromator Controls	53.7
1.2.2.3.1.2.3	Branch Line Electrical Installation	15.1
** *****		
1.2.2.3.1.3	Branch Line Safety Systems	9.8
1.2.2.3.1.4	Branch Line Utilities	24.9
1.2.2.3.1.5	Branch Line Mech/Elect System Integration	22.0

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Cost Estimate Report
Summary of Material and Labor
by Rollup Levels

Work Breakdown Structure # -----	Description -----	Material & Labor Total K\$ -----
** *****		
1.2.2.3.2	Crystallography Station	453.6
1.2.2.3.3	Small Angle Scattering Station	141.7
** ****		
1.2.2.4	Spectroscopy/Microprobe Facility	2,069.2
** *****		
1.2.2.4.1	Spectroscopy/Microprobe Branchline	1,562.0
** *****		
1.2.2.4.1.1	Branch Line Mechanical Systems	1,316.9
** *****		
1.2.2.4.1.1.1	H&V Beam Defining Apertures	85.6
1.2.2.4.1.1.2	Vertical Deflection Mirrors (#1&2)	250.4
1.2.2.4.1.1.3	Monochromators	755.0
** *****		
1.2.2.4.1.1.3.1	High Resolution Double Crystal Monochromator	365.0
1.2.2.4.1.1.3.2	Pre-Monochromator Multilayer System	390.0
** *****		
1.2.2.4.1.1.4	Branch Line Diagnostics	39.8
1.2.2.4.1.1.5	Branch Line Vacuum System	67.7
1.2.2.4.1.1.6	Branch Line Mechanical Installation	28.2
1.2.2.4.1.1.7	Defining Slits	90.0
** *****		
1.2.2.4.1.2	Branch Line Electrical Systems	188.2
** *****		
1.2.2.4.1.2.1	Photon Transport Controls & Diagnostics	119.2
1.2.2.4.1.2.2	Monochromator Controls	53.7
1.2.2.4.1.2.3	Branch Line Electrical Installation	15.1
** *****		
1.2.2.4.1.3	Branch Line Safety Systems	9.8
1.2.2.4.1.4	Branch Line Utilities	24.9
1.2.2.4.1.5	Branch Line Mech/Elect System Integration	22.0
** *****		
1.2.2.4.2	Spectroscopy Station	239.4
1.2.2.4.3	Microprobe Station	267.7

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Cost Estimate Report
Summary of Material and Labor
by Rollup Levels

Work Breakdown Structure # -----	Description -----	Material & Labor Total K\$ -----
** ***		
1.2.3	Undulator Facility	4,077.4
** ****		
1.2.3.1	Undulator (U3.9)	1,046.7
** *****		
1.2.3.1.1	Magnetic Structure	615.8
** *****		
1.2.3.1.1.1	Magnetic Material	193.1
1.2.3.1.1.2	Model Pole & Pole Assembly	3.9
1.2.3.1.1.3	Pole Assemblies	291.1
1.2.3.1.1.4	End Pole Assemblies	35.7
1.2.3.1.1.5	Backing Beams	40.4
1.2.3.1.1.6	Magnet Structure Assembly	33.8
1.2.3.1.1.7	Magnetic Measurement: Mechanical	6.3
1.2.3.1.1.8	Magnetic Measurements: Electrical	11.2
** *****		
1.2.3.1.2	Support & Drive Systems	163.9
** *****		
1.2.3.1.2.1	Support System Fabrication	54.1
1.2.3.1.2.2	Drive System Fabrication	101.9
1.2.3.1.2.3	Local Temperature Control	7.7
** *****		
1.2.3.1.3	Vacuum System	155.7
** *****		
1.2.3.1.3.1	Vacuum Chambers	74.9
1.2.3.1.3.2	Pumping Systems & Instrumentation	36.9
1.2.3.1.3.3	Support Structure	14.2
1.2.3.1.3.4	Vacuum Diagnostics	29.6
** *****		
1.2.3.1.4	Control System	25.6
1.2.3.1.5	Magnetic Measurement	57.2
** *****		
1.2.3.1.5.1	Magnetic Measurements: Mechanical	22.6
1.2.3.1.5.2	Magnetic Measurements: Electrical	34.5
** *****		
1.2.3.1.6	Installation	28.2

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Cost Estimate Report
Summary of Material and Labor
by Rollup Levels

Work Breakdown Structure # -----	Description -----	Material & Labor Total K\$ -----
** ****		
1.2.3.2	Undulator Beamline Front End	513.8
** *****		
1.2.3.2.1	Front End Mechanical Systems	289.0
** *****		
1.2.3.2.1.1	Fixed Aperture	12.4
1.2.3.2.1.2	PBPM #1	47.6
1.2.3.2.1.3	Front End Photon Shutter	41.6
1.2.3.2.1.4	Fast Valve	22.3
1.2.3.2.1.5	Personnel Safety Shut.	28.4
1.2.3.2.1.6	PBPM #2	47.6
1.2.3.2.1.7	Front End Vacuum System	55.4
1.2.3.2.1.8	Front End Mechanical Installation	33.4
** *****		
1.2.3.2.2	Front End Controls: Electronics, Vacuum Pumps	151.7
** *****		
1.2.3.2.2.1	Fixed Aperture Controls	8.7
1.2.3.2.2.2	PBPM #1 Controls	35.5
1.2.3.2.2.3	Photon Shutter Controls	24.6
1.2.3.2.2.4	Fast Valve Controls	22.2
1.2.3.2.2.5	Personnel Safety Shutter Controls	20.6
1.2.3.2.2.6	PBPM #2 Controls	35.5
1.2.3.2.2.7	Vacuum System Controls	4.3
** *****		
1.2.3.2.3	Front End Safety Systems	22.2
1.2.3.2.4	Front End Utilities	26.4
1.2.3.2.5	Front End Mech/Elect System Integration	24.2
** ****		
1.2.3.3	Soft X-ray Imaging Facility	2,516.7
** *****		
1.2.3.3.1	Main Branchline	1,020.5
** *****		
1.2.3.3.1.1	Branch Line Mechanical Systems	696.7
** *****		
1.2.3.3.1.1.1	Beam Defining Apertures	85.6
1.2.3.3.1.1.2	Monochromator	474.2
1.2.3.3.1.1.3	Branch Line Diagnostics	39.8

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Summary of Material and Labor
by Rollup Levels

Work Breakdown Structure # -----	Description -----		Material & Labor Total K\$ -----
1.2.3.3.1.1.4	Branch Line Vacuum System	67.7	
1.2.3.3.1.1.5	Branch Line Mechanical Installation	29.2	
** *****			
1.2.3.3.1.2	Branch Line Electrical Systems	266.8	
** *****			
1.2.3.3.1.2.1	Photon Transport Controls & Diagnosticss	197.9	
1.2.3.3.1.2.2	Monochromator Controls	53.7	
1.2.3.3.1.2.3	Branch Line Electrical Installation	15.1	
** *****			
1.2.3.3.1.3	Branch Line Safety Systems	9.8	
1.2.3.3.1.4	Branch Line Utilities	24.9	
1.2.3.3.1.5	Branch Line Mech/Elect System Integration	22.0	
** *****			
1.2.3.3.2	Main Scanning Microscope Station	603.7	
1.2.3.3.3	R/D Scanning Microscope Station	493.5	
1.2.3.3.4	Diffraction Imaging Station	399.0	
** **			
1.3	Conventional Facilities		5,367.7
** ***			
1.3.1	Engineering, Design & Inspection		506.0
** ****			
1.3.1.1	LBL Activities		214.0
** *****			
1.3.1.1.1	Engineering	129.0	
1.3.1.1.2	Consultants	16.0	
1.3.1.1.3	Inspection	69.0	
** ****			
1.3.1.2	A/E Activities		292.0
** *****			
1.3.1.2.1	Title I	83.0	
1.3.1.2.2	Title II	155.0	
1.3.1.2.3	Title III	54.0	
** ***			
1.3.2	Conventional Construction		3,074.7

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Cost Estimate Report
Summary of Material and Labor
by Rollup Levels

Work Breakdown Structure # -----	Description -----	Material & Labor Total K\$ -----
** ****		
1.3.2.1	Improvements to Land	12.1
1.3.2.2	Building 80 Improvements	1,169.6
** *****		
1.3.2.2.1	General Requirements	210.7
1.3.2.2.2	Sitework	98.6
1.3.2.2.3	Concrete	16.9
1.3.2.2.5	Metals	134.2
1.3.2.2.6	Carpentry	6.0
1.3.2.2.7	Thermal and Moisture Protection	10.0
1.3.2.2.8	Doors, Windows & Glass	31.9
1.3.2.2.9	Finishes	145.9
1.3.2.2.10	Specialties	7.5
1.3.2.2.12	Furnishings	2.1
1.3.2.2.14	Conveying Systems	90.0
1.3.2.2.15	Mechanical Work	272.2
1.3.2.2.16	Electrical Work	143.1
** ****		
1.3.2.3	Building 6 Improvements	765.8
** *****		
1.3.2.3.1	General Requirements	138.0
1.3.2.3.5	Metals	15.1
1.3.2.3.6	Carpentry	17.8
1.3.2.3.8	Doors, Windows & Glass	25.5
1.3.2.3.9	Finishes	227.5
1.3.2.3.10	Specialties	1.5
1.3.2.3.13	Special Construction	20.0
1.3.2.3.15	Mechanical Work	234.5
1.3.2.3.16	Electrical Work	85.7
** ****		
1.3.2.4	Site Utilities	84.3
** *****		
1.3.2.4.1	General Requirements	15.2
1.3.2.4.15	Mechanical	15.0
1.3.2.4.16	Electrical	54.1
** ****		
1.3.2.5	Special Facilities	1,042.8
** *****		
1.3.2.5.1	Lab Furniture & Standard Fume Hoods	298.0
1.3.2.5.2	Cold Rooms	54.9

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Summary of Material and Labor
by Rollup Levels

Work Breakdown Structure # -----	Description -----	Material & Labor Total K\$ -----
1.3.2.5.3	Laminar Flow Hoods (3)	43.9
1.3.2.5.4	Scientific Equipment	646.0
** *****		
1.3.2.5.4.1	Digital Scanning Elctrn Microscope w/Workstatn	268.0
1.3.2.5.4.2	HiRes Electron Microscope w/Cryo Workstation	206.0
1.3.2.5.4.3	Confocal Microscope	89.0
1.3.2.5.4.4	Image Analysis Package	83.0
** ***		
1.3.3	Standard Equipment	1,787.0
** ****		
1.3.3.1	Biochemistry	1,067.0
1.3.3.2	Microscopy	109.0
1.3.3.3	Cell and Tissue Culture	139.0
1.3.3.4	Surgical Suite	80.0
1.3.3.5	General Support Equipment	392.0
** **		
1.4	Contingency	4,908.6
** ***		
1.4.1	Special Research Facilities and Management	3,829.6
1.4.2	Conventional Facilities	1,079.0

Table B.3

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Technical Components Cost Estimate

ITM	ITM	UNIT	NBR	UNIT COST	TOTAL	LBR	HRS/	TOTAL CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	COST BASIS	ISC K\$	UNTS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$
** WBS: 1.1 Project Management & Administration											
1	PROJECT DIRECTOR		0	0.00 EU	0.0	1	5300.0	5300 AA	40.35	213.9	213.9
2	CLERICAL SUPPORT		0	0.00	0.0	1	5300.0	5300 AA	40.35	213.9	213.9
3	PROJECT MANAGER		0	0.00	0.0	1	2650.0	2650 ME	54.50	144.4	144.4
4	Proj Conv Fac C.M.		0	0.00	0.0	1	2200.0	2200 PEN	42.00	92.4	92.4
5	QA/Safety Officer		0	0.00	0.0	1	2650.0	2650 ME	54.50	144.4	144.4
6	Supplies & Expenses (12%)		1	106050.00	106.0	0	0.0	0	0.00	0.0	106.0
7	Incremental Indirects		1	270000.00	270.0	0	0.0	0	0.00	0.0	270.0
8	Additional ES&H Support	lot	1	75200.00 eu	75.2	1	4010.0	4010 AA	40.35	161.8	237.0
** Subtotal **					451.2			22110		970.8	1422.0
** WBS: 1.2.1.1.1 EDI, Wiggler											
1	PRELIM & GENERAL ENGINEER		0	0.00	0.0	1	1800.0	1800 ME	54.50	98.1	98.1
2	MAG STRUCTURE ENGINEERING		0	0.00	0.0	1	1800.0	1800 ME	54.50	98.1	98.1
3			0	0.00	0.0	1	200.0	200 EE	52.60	10.5	10.5
4	ENGINEERING SUPPORT		0	0.00	0.0	1	800.0	800 ME	54.50	43.6	43.6
5	SUPPORT/DRIVE SYSTEM ENGR		0	0.00	0.0	1	800.0	800 ME	54.50	43.6	43.6
6			0	0.00	0.0	1	800.0	800 EE	52.60	42.1	42.1
7	VACUUM SYSTEM ENGINEERING		0	0.00	0.0	1	400.0	400 ME	54.50	21.8	21.8
8	ENGR. DURING FABRICATION		0	0.00	0.0	1	1800.0	1800 ME	54.50	98.1	98.1
9	ENGINEERING SUPPLS & EXP	LOT	1	45000.00 EU	45.0	0	0.0	0	0.00	0.0	45.0
10	Additional ES&H Support		1	9000.00 eu	9.0	1	1673.0	1673 ME	54.50	91.2	100.2
** Subtotal **					54.0			10073		547.1	601.1
** WBS: 1.2.1.1.2 EDI, Wiggler Beamline Frontend											
1	Mech Engineering		0	0.00 EU	0.0	1	800.0	800 ME	54.50	43.6	43.6
2	Mech Design		0	0.00 EU	0.0	1	600.0	600 MD	39.20	23.5	23.5
3	Mech Drafting		0	0.00 EU	0.0	1	600.0	600 MF	39.20	23.5	23.5
4	Mech Shops (Inspection)		0	0.00 EU	0.0	1	120.0	120 MS	37.10	4.5	4.5
5	Mech Tech (Inspection)		0	0.00 EU	0.0	1	160.0	160 MJ	35.80	5.7	5.7
6	Elec. Engineering		0	0.00 EU	0.0	1	400.0	400 EE	52.60	21.0	21.0
7	Elec. Coordination		0	0.00 EU	0.0	1	400.0	400 EC	38.00	15.2	15.2
8	Elec Shops (Inspection)		0	0.00 EU	0.0	1	160.0	160 ES	29.80	4.8	4.8
9	Supplies & Expenses		1	24000.00 EU	24.0	0	0.0	0	0.00	0.0	24.0
10	Additional ES&H Support		1	4800.00 eu	4.8	1	520.0	520 ME	54.50	28.3	33.1
** Subtotal **					28.8			3760		170.2	199.0
** WBS: 1.2.1.1.3 EDI, Diffraction Facility											
1	Branchline EDI		0	0.00	0.0	0	0.0	0	0.00	0.0	0.0
2	Mech Engineering		0	0.00	0.0	1	1600.0	1600 ME	54.50	87.2	87.2
3	Mech Design		0	0.00	0.0	1	1200.0	1200 MD	39.20	47.0	47.0
4	Mech Drafting		0	0.00	0.0	1	1200.0	1200 MF	39.20	47.0	47.0
5	Mech Shops (Inspection)		0	0.00	0.0	1	240.0	240 MS	37.10	8.9	8.9
6	Mech Tech (Inspection)		0	0.00	0.0	1	320.0	320 MJ	35.80	11.5	11.5
7	Elec. Engineering		0	0.00	0.0	1	800.0	800 EE	52.60	42.1	42.1
8	Elec. Coordination		0	0.00	0.0	1	800.0	800 EC	38.00	30.4	30.4
9	Elec. Shops (Inspectn)		0	0.00	0.0	1	320.0	320 ES	29.80	9.5	9.5
10	Supplies & Expenses	lot	1	48000.00 eu	48.0	0	0.0	0	0.00	0.0	48.0
11			0	0.00	0.0	0	0.0	0	0.00	0.0	0.0
12	End Station EDI		1	180000.00 eu	180.0	0	0.0	0	0.00	0.0	180.0
13	Additional ES&H Support		1	45600.00 eu	45.6	1	1040.0	1040 ME	54.50	56.7	102.3
** Subtotal **					273.6			7520		340.3	613.9
** WBS: 1.2.1.1.4 EDI, Spectroscopy/Microprobe Facility											
1	Branchline EDI		0	0.00	0.0	0	0.0	0	0.00	0.0	0.0
2	Mech Engineering		0	0.00	0.0	1	2000.0	2000 ME	54.50	109.0	109.0
3	Mech Design		0	0.00	0.0	1	2000.0	2000 MD	39.20	78.4	78.4
4	Mech Drafting		0	0.00	0.0	1	2000.0	2000 MF	39.20	78.4	78.4
5	Mech Shops (Inspection)		0	0.00	0.0	1	300.0	300 MS	37.10	11.1	11.1
6	Mech Tech (Inspection)		0	0.00	0.0	1	400.0	400 MJ	35.80	14.3	14.3
7	Elec. Engineering		0	0.00	0.0	1	1000.0	1000 EE	52.60	52.6	52.6
8	Elec. Coordination		0	0.00	0.0	1	1000.0	1000 EC	38.00	38.0	38.0

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Technical Components Cost Estimate

ITM	ITM	UNIT	NBR	UNIT	TOTAL	LBR	HRS/	TOTAL	CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	COST	ISC	K\$	UNITS	K\$	HRS	CODE	LABOR	LABOR
				BASIS							K\$	K\$
9	Elec. Shops (Inspectn)		0	0.00	0.0	1	400.0	400	ES	29.80	11.9	11.9
10	Supplies & Expenses	lot	1	60000.00 eu	60.0	0	0.0	0		0.00	0.0	60.0
11			0	0.00	0.0	0	0.0	0		0.00	0.0	0.0
12	End Station EDI		1	180000.00 eu	180.0	0	0.0	0		0.00	0.0	180.0
13	Additional ES&H Support		1	48000.00 eu	48.0	1	1445.0	1445	ME	54.50	78.8	126.8
** Subtotal **					288.0			10545			472.5	760.5
** WBS: 1.2.1.2.1 EDI, Undulator												
1	PRELIM & GENERAL ENGINEER		0	0.00	0.0	1	1500.0	1500	ME	54.50	81.8	81.8
2	MAG STRUCTURE ENGINEERING		0	0.00	0.0	1	1200.0	1200	ME	54.50	65.4	65.4
3			0	0.00	0.0	1	200.0	200	EE	52.60	10.5	10.5
4	ENGINEERING SUPPORT		0	0.00	0.0	1	500.0	500	ME	54.50	27.2	27.2
5	SUPPORT/DRIVE SYSTEM ENGR		0	0.00	0.0	1	500.0	500	ME	54.50	27.2	27.2
6			0	0.00	0.0	1	400.0	400	EE	52.60	21.0	21.0
7	VACUUM SYSTEM ENGINEERING		0	0.00	0.0	1	400.0	400	ME	54.50	21.8	21.8
8	ENGR. DURING FABRICATION		0	0.00	0.0	1	1800.0	1800	ME	54.50	98.1	98.1
9	ENGINEERING SUPPLS & EXP	LOT	1	35000.00 EU	35.0	0	0.0	0		0.00	0.0	35.0
10	Additional ES&H Support		1	7000.00 eu	7.0	1	1296.0	1296	ME	54.50	70.6	77.6
** Subtotal **					42.0			7796			423.7	465.7
** WBS: 1.2.1.2.2 EDI, Undulator Beamline Frontend												
1	Mech Engineering		0	0.00 EU	0.0	1	800.0	800	ME	54.50	43.6	43.6
2	Mech Design		0	0.00 EU	0.0	1	600.0	600	MD	39.20	23.5	23.5
3	Mech Drafting		0	0.00 EU	0.0	1	400.0	400	MF	39.20	15.7	15.7
4	Mech Shops (Inspection)		0	0.00 EU	0.0	1	120.0	120	MS	37.10	4.5	4.5
5	Mech Tech (Inspection)		0	0.00 EU	0.0	1	160.0	160	MJ	35.80	5.7	5.7
6	Elec. Engineering		0	0.00 EU	0.0	1	160.0	160	EE	52.60	8.4	8.4
7	Elec. Coordination		0	0.00 EU	0.0	1	160.0	160	EC	38.00	6.1	6.1
8	Elec Shops (Inspection)		0	0.00 EU	0.0	1	80.0	80	ES	29.80	2.4	2.4
9	Supplies & Expenses		1	24000.00 EU	24.0	0	0.0	0		0.00	0.0	24.0
10	Additional ES&H Support		1	4800.00 eu	4.8	1	400.0	400	ME	54.50	21.8	26.6
** Subtotal **					28.8			2880			131.7	160.5
** WBS: 1.2.1.2.3 EDI, Soft X-ray Imaging Facility												
1	Branchline EDI		0	0.00	0.0	0	0.0	0		0.00	0.0	0.0
2	Mech Engineering		0	0.00	0.0	1	1600.0	1600	ME	54.50	87.2	87.2
3	Mech Design		0	0.00	0.0	1	1200.0	1200	MD	39.20	47.0	47.0
4	Mech Drafting		0	0.00	0.0	1	1200.0	1200	MF	39.20	47.0	47.0
5	Mech Shops (Inspection)		0	0.00	0.0	1	240.0	240	MS	37.10	8.9	8.9
6	Mech Tech (Inspection)		0	0.00	0.0	1	320.0	320	MJ	35.80	11.5	11.5
7	Elec. Engineering		0	0.00	0.0	1	800.0	800	EE	52.60	42.1	42.1
8	Elec. Coordination		0	0.00	0.0	1	800.0	800	EC	38.00	30.4	30.4
9	Elec. Shops (Inspectn)		0	0.00	0.0	1	320.0	320	ES	29.80	9.5	9.5
10	Supplies & Expenses	lot	1	48000.00 eu	48.0	0	0.0	0		0.00	0.0	48.0
11			0	0.00	0.0	0	0.0	0		0.00	0.0	0.0
12	End Station EDI		1	450000.00 eu	450.0	0	0.0	0		0.00	0.0	450.0
13	Additional ES&H Support		1	99600.00 eu	99.6	1	1040.0	1040	ME	54.50	56.7	156.3
** Subtotal **					597.6			7520			340.3	937.9
** WBS: 1.2.2.1.1.1 Magnetic Material												
1	NDPE Blocks	ea	1820	197.59 VQ	359.6	0	0.0	0		0.00	0.0	359.6
2	Gauges/Field Coils/Holdrs	lot	1	300.00 EU	0.3	1	160.0	160	MT	26.10	4.2	4.5
3	Measurement Prep		0	0.00	0.0	1	20.0	20	EM	29.80	0.6	0.6
4			0	0.00	0.0	1	20.0	20	EE	52.60	1.1	1.1
5	Measurements	LOT	1	100.00 EU	0.1	0	0.0	0		0.00	0.0	0.1
6	3-Axis H.C. Meas		0	0.00	0.0	220	0.4	79	EM	29.80	2.4	2.4
7	1-Axis H.C. Meas		0	0.00	0.0	1600	0.2	384	EM	29.80	11.4	11.4
8	Surface Measurements		0	0.00	0.0	1820	0.2	328	EM	29.80	9.8	9.8
9	Supervision		0	0.00	0.0	1	100.0	100	EE	52.60	5.3	5.3
** Subtotal **					360.0			1091			34.6	394.7

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Technical Components Cost Estimate

ITM	ITM	UNIT	NBR	UNIT COST	TOTAL	LBR	HRS/	TOTAL CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	COST BASIS	ISC K\$	UNTS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$
** WBS: 1.2.2.1.1.2 Model Pole & Pole Assembly											
1	NdFe Blocks		0	0.00	0.0	24	4.0	96 MS	37.10	3.6	3.6
2	Test Fixture & Assembly	ea	1	100.00 eu	0.1	1	320.0	320 MT	26.10	8.4	8.5
3	Model Measurements		0	0.00	0.0	1	40.0	40 EM	29.80	1.2	1.2
** Subtotal **					0.1			456		13.1	13.2
** WBS: 1.2.2.1.1.3 Pole Assemblies											
1	Vanadium Permendur	ea	90	281.00 A85	25.3	0	0.0	0	0.00	0.0	25.3
2	Keepers	ea	90	456.00 A82	41.0	0	0.0	0	0.00	0.0	41.0
3	Keeper Inspection	lot	1	1000.00 EU	1.0	90	0.2	18 MM	37.10	0.7	1.7
4	Containers	ea	90	30.00 EU	2.7	0	0.0	0	0.00	0.0	2.7
5	Assy Fixtures	ea	4	50.00 A82	0.2	4	60.0	240 MM	37.10	8.9	9.1
6	Assembly	ea	90	10.00 A82	0.9	90	20.0	1800 MM	37.10	66.8	67.7
7	Pole Assembly Mounts	ea	6	350.00 CP	2.1	6	32.0	192 MM	37.10	7.1	9.2
** Subtotal **					73.2			2250		83.5	156.7
** WBS: 1.2.2.1.1.4 End Pole Assemblies											
1	End Pole Keepers	LOT	1	100.00 EU	0.1	8	12.0	96 MM	37.10	3.6	3.7
2	NdFe Block Cutting		0	0.00	0.0	96	4.0	384 MS	37.10	14.2	14.2
3	Assembly - Keepers		0	0.00	0.0	8	16.0	128 MA	37.10	4.7	4.7
4	Rotator		0	0.00	0.0	8	32.0	256 MM	37.10	9.5	9.5
5	Rotator Block Cutting		0	0.00	0.0	24	4.0	96 MS	37.10	3.6	3.6
6	Assemble - Rotator		0	0.00	0.0	8	4.0	32 MA	37.10	1.2	1.2
7	Rotator Linkage	ea	8	100.00 EU	0.8	8	8.0	64 MM	37.10	2.4	3.2
8	Manual Rotatr Drv (Optnl)	ea	8	500.00 CP	4.0	8	16.0	128 MM	37.10	4.7	8.7
9			0	0.00	0.0	8	4.0	32 MA	37.10	1.2	1.2
** Subtotal **					4.9			1216		45.1	50.0
** WBS: 1.2.2.1.1.5 Backing Beams											
1	Backing Beams (2)	LBS	10500	0.28 CP	2.9	2	230.0	460 MM	37.10	17.1	20.0
2			0	0.00	0.0	2	16.0	32 MS	37.10	1.2	1.2
3	Backing Beam Heat Treatmt	ea	2	3000.00 EU	6.0	0	0.0	0	0.00	0.0	6.0
4	Flexible Yoke		0	0.00	0.0	1	16.0	16 MA	37.10	0.6	0.6
5	Shims	lot	1	100.00 EU	0.1	1	40.0	40 MM	37.10	1.5	1.6
6	Pole Shields	lot	1	500.00 EU	0.5	0	0.0	0	0.00	0.0	0.5
7	Pole Shields	LOT	6	50.00 EU	0.3	0	0.0	0	0.00	0.0	0.3
8	Rigging Hardware	lot	1	2000.00 EU	2.0	0	0.0	0	0.00	0.0	2.0
** Subtotal **					11.8			548		20.3	32.2
** WBS: 1.2.2.1.1.6 Magnet Structure Assembly											
1	Keeper Installation Tool		0	0.00	0.0	1	21.0	21 MM	37.10	0.8	0.8
2	Keeper Pole Mount Assembl	ea	6	100.00 EU	0.6	6	36.0	216 MA	37.10	8.0	8.6
3	End Pole Assembly		0	0.00	0.0	4	12.0	48 MM	37.10	1.8	1.8
4	Pole Mount/Back Bm Assy		0	0.00	0.0	1	24.0	24 MM	37.10	0.9	0.9
5	Pole Mount/Bckg Bm Assy	ea	6	100.00 EU	0.6	6	24.0	144 MA	37.10	5.3	5.9
6	Fiducializing	lot	1	100.00 EU	0.1	2	16.0	32 MA	37.10	1.2	1.3
** Subtotal **					1.3			485		18.0	19.3
** WBS: 1.2.2.1.1.7 Magnetic Measurements: Mechanical											
1	Coil & Probe Mounts		0	0.00	0.0	1	40.0	40 MT	26.10	1.0	1.0
2	Assembly Section Setup		0	0.00	0.0	12	12.0	144 MA	37.10	5.3	5.3
** Subtotal **					0.0			184		6.4	6.4
** WBS: 1.2.2.1.1.8 Magnetic Measurements: Electrical											
1	Setup Assembly Sections		0	0.00	0.0	1	16.0	16 EE	52.60	0.8	0.8
2			0	0.00	0.0	12	4.0	48 ES	29.80	1.4	1.4
3	Data Acquire: Assy Sectns		0	0.00	0.0	12	3.0	36 EE	52.60	1.9	1.9
4			0	0.00	0.0	12	8.0	96 ES	29.80	2.9	2.9
5	Data Analysis: Assy Sectns		0	0.00	0.0	1	80.0	80 EE	52.60	4.2	4.2

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ITM	ITM	UNIT	NBR	UNIT COST	TOTAL	LBR	HRS/	TOTAL CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	COST BASIS	ISC K\$	UNTS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$
** Subtotal **					0.0			276		11.2	11.2
** WBS: 1.2.2.1.2.1 Support System Fabrication											
1	Support System Assembly	ea	1	40000.00 EU	40.0	0	0.0	0	0.00	0.0	40.0
2	Associated Parts	lot	1	2355.00 EU	2.4	1	66.0	66 MM	37.10	2.4	4.8
3	Miscellaneous	lot	1	500.00 EU	0.5	1	50.0	50 MM	37.10	1.9	2.4
4	Assembly	lot	1	75.00 EU	0.1	1	187.0	187 MA	37.10	6.9	7.0
** Subtotal **					42.9			303		11.2	54.2
** WBS: 1.2.2.1.2.2 Drive System Fabrication											
1	Roller Screw Assembly	ea	8	3500.00 EU	28.0	0	0.0	0	0.00	0.0	28.0
2	Spring System	ea	1	4104.00 CP	4.1	8	30.0	240 MM	37.10	8.9	13.0
3	Bearing System	lot	1	3120.00 EU	3.1	1	225.0	225 MM	37.10	8.3	11.5
4	Sprocket/Chain System	lot	1	1759.00 CP	1.8	1	90.0	90 MM	37.10	3.3	5.1
5	Gear Box & Mtg.	ea	1	1000.00 EU	1.0	1	38.0	38 MM	37.10	1.4	2.4
6	Encoder System	lot	1	4607.00 CP	4.6	1	40.0	40 MM	37.10	1.5	6.1
7	Motor Mounting Bracket	ea	1	25.00 CP	0.0	1	38.0	38 MM	37.10	1.4	1.4
8	Fan System	lot	1	70.00 CP	0.1	1	38.0	38 MM	37.10	1.4	1.5
9	Miscellaneous	lot	1	950.00 EU	0.9	1	230.0	230 MM	37.10	8.5	9.5
10	Assembly	lot	1	300.00 EU	0.3	1	397.0	397 MA	37.10	14.7	15.0
11	Roller Screw Kinematic Mnt	ea	8	500.00 eu	4.0	1	120.0	120 MM	37.10	4.5	8.5
** Subtotal **					47.9			1456		54.0	102.0
** WBS: 1.2.2.1.2.3 Local Temperature Control Fabrication											
1	Frame & Curtain	lot	1	1300.00 EU	1.3	1	100.0	100 MA	37.10	3.7	5.0
2	Blower & Dryer System	lot	1	1050.00 EU	1.1	1	30.0	30 MA	37.10	1.1	2.2
3	Miscellaneous	lot	1	50.00 EU	0.1	1	15.0	15 MA	37.10	0.6	0.6
** Subtotal **					2.4			145		5.4	7.8
** WBS: 1.2.2.1.3.1 Vacuum Chambers											
1	Vacuum Chamber #1 (2 cm)		0	0.00	0.0	0	0.0	0	0.00	0.0	0.0
2	Material	lbs	1600	2.21 VQ	3.5	0	0.0	0	0.00	0.0	3.5
3	Fabrication		0	0.00	0.0	2	180.0	360 NC	53.10	19.1	19.1
4			0	0.00	0.0	2	140.0	280 MM	37.10	10.4	10.4
5	Fabricate Flanges	lot	1	2000.00 EU	2.0	1	120.0	120 MM	37.10	4.5	6.5
6	Fab Flange Transitions	lot	1	500.00 EU	0.5	6	20.0	120 MM	37.10	4.5	5.0
7	Assemble/Test		0	0.00	0.0	1	320.0	320 MA	37.10	11.9	11.9
8	System Assembly		0	0.00	0.0	1	80.0	80 MA	37.10	3.0	3.0
9	UHV Bakeout		0	0.00	0.0	1	160.0	160 MA	37.10	5.9	5.9
** Subtotal **					6.0			1440		59.2	65.2
** WBS: 1.2.2.1.3.2 Pumping Systems & Instrumentation											
1	Photon Stop/TSP Pump	ea	1	20000.00 EU	20.0	0	0.0	0	0.00	0.0	20.0
2	Ion Pump/TSP Combination	ea	3	4397.00 CP	13.2	0	0.0	0	0.00	0.0	13.2
3	90 deg Elbow to Pump	ea	3	530.00 CP	1.6	0	0.0	0	0.00	0.0	1.6
4	Right Angle Valve	ea	2	876.00 CP	1.8	0	0.0	0	0.00	0.0	1.8
5	View Port	ea	2	206.00 CP	0.4	0	0.0	0	0.00	0.0	0.4
** Subtotal **					36.9			0		0.0	36.9
** WBS: 1.2.2.1.3.3 Support Structure											
1	Vacuum Chamber Support	lot	1	2000.00 EU	2.0	1	160.0	160 MM	37.10	5.9	7.9
2	Ion Pump Supports	ea	3	200.00 EU	0.6	3	20.0	60 MM	37.10	2.2	2.8
3	Installation Fixture	ea	1	500.00 E	0.5	1	80.0	80 MM	37.10	3.0	3.5
** Subtotal **					3.1			300		11.1	14.2
** WBS: 1.2.2.1.3.4 Vacuum Diagnostics											
1	IG Controller	ea	1	755.00 CP	0.8	1	2.0	2 ES	29.80	0.1	0.8
2	Degas Module	ea	1	150.00 CP	0.1	0	0.0	0	0.00	0.0	0.1
3	Second IG Module	ea	1	75.00 CP	0.1	0	0.0	0	0.00	0.0	0.1

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ITM	ITM	UNIT	NBR	UNIT COST	TOTAL LBR	HRS/	TOTAL CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	COST BASIS	ISC K\$	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$
4	Process Control Module	ea	1	350.00 CP	0.3	0	0	0.00	0.0	0.3
5	Rack Mount	ea	1	50.00 CP	0.1	1	1 ES	29.80	0.0	0.1
6	Remote I/O Module	ea	1	30.00 CP	0.0	0	0	0.00	0.0	0.0
7	Dual Convection Module	ea	1	400.00 CP	0.4	0	0	0.00	0.0	0.4
8	UHV Electrometer Module	ea	1	400.00 CP	0.4	0	0	0.00	0.0	0.4
9	IEEE-488 Interface	ea	1	360.00 CP	0.4	0	0	0.00	0.0	0.4
10	Nude Ion Gauge	ea	1	311.00 CP	0.3	1	1 MS	37.10	0.0	0.3
11	IG Cable: 50 feet	ea	1	195.00 CP	0.2	1	1 ES	29.80	0.0	0.2
12	Convection Gauge	ea	1	139.00 CP	0.1	1	1 MS	37.10	0.0	0.2
13	Convection Cable: 50 feet	ea	1	210.00 CP	0.2	1	1 ES	29.80	0.0	0.2
14	IG Connector	ea	1	10.00 EU	0.0	1	1 MS	37.10	0.0	0.0
15	IG Cable Interface	ea	1	50.00 EU	0.1	1	4 ES	29.80	0.1	0.2
16	Ion Pump Controller	ea	3	1948.00 CP	5.8	3	6 ES	29.80	0.2	6.0
17	Ion Pump Cable	ea	3	223.00 CP	0.7	3	12 ES	29.80	0.4	1.0
18	Ion Pump Cable Interface	ea	3	100.00 EU	0.3	3	12 ES	29.80	0.4	0.7
19	IEEE-488 Interface	ea	3	498.00 CP	1.5	0	0	0.00	0.0	1.5
20	ILC Crate	ea	1	1000.00 EU	1.0	1	40 ES	29.80	1.2	2.2
21	ILC	ea	5	1000.00 EU	5.0	1	40 ES	29.80	1.2	6.2
22	Sublimation Controller	ea	1	2000.00 CP	2.0	1	4 ES	29.80	0.1	2.1
23	Sublimation Mux	ea	1	2000.00 EU	2.0	1	80 ES	29.80	2.4	4.4
24	Filament Cables	set	1	500.00 EU	0.5	1	40 ES	29.80	1.2	1.7
** Subtotal **					22.3		246		7.4	29.6
** WBS: 1.2.2.1.4		Control System								
1	Motor MH172	ea	1	1565.00 VQ	1.6	0	0	0.00	0.0	1.6
2			0	0.00	0.0	0	0	0.00	0.0	0.0
3	Fan 172	ea	1	200.00 VQ	0.2	0	0	0.00	0.0	0.2
4	MH172 Driver	ea	1	3321.00 VQ	3.3	0	0	0.00	0.0	3.3
5			0	0.00	0.0	0	0	0.00	0.0	0.0
6	Controller 100010	ea	1	776.00 VQ	0.8	0	0	0.00	0.0	0.8
7	Math 009	ea	1	158.00 VQ	0.2	0	0	0.00	0.0	0.2
8	Indexer/Cont.	ea	1	682.20 VQ	0.7	0	0	0.00	0.0	0.7
9	Card Cage	ea	1	614.00 VQ	0.6	0	0	0.00	0.0	0.6
10	P.S. PSD512	ea	1	278.00 VQ	0.3	0	0	0.00	0.0	0.3
11	UPS	ea	1	350.00 EU	0.3	0	0	0.00	0.0	0.3
12	Redlion Cont. Readout	ea	5	176.00 EU	0.9	0	0	0.00	0.0	0.9
13	Final Installation	lot	1	3000.00 EU	3.0	1	80 EI	29.80	2.4	5.4
14	Final Test		0	0.00	0.0	1	40 EM	29.80	1.2	1.2
15	Shop Installation	lot	1	2000.00 EU	2.0	1	40 EI	29.80	1.2	3.2
16	Shop Test		0	0.00	0.0	1	40 EM	29.80	1.2	1.2
17	ILC	ea	3	1000.00 EU	3.0	3	24 EI	29.80	0.7	3.7
18	ILC Crate	ea	1	1000.00 EU	1.0	1	40 EI	29.80	1.2	2.2
** Subtotal **					17.8		264		7.9	25.7
** WBS: 1.2.2.1.5.1		Magnetic Measurements: Mechanical								
1	Coil & Probe Mounts		0	0.00	0.0	1	40 MU	35.80	1.4	1.4
2	Assembly Section Setup		0	0.00	0.0	12	144 MA	37.10	5.3	5.3
3	Coils	ea	2	105.00 eu	0.2	2	240 MU	35.80	8.6	8.8
4	Gap Spacers		0	0.00	0.0	1	24 MU	35.80	0.9	0.9
5	ID Setup	lot	1	315.00 eu	0.3	1	160 MA	37.10	5.9	6.3
** Subtotal **					0.5		608		22.2	22.7
** WBS: 1.2.2.1.5.2		Magnetic Measurements: Electrical								
1	Setup Assembly Sections		0	0.00	0.0	1	16 EE	52.60	0.8	0.8
2			0	0.00	0.0	12	48 ES	29.80	1.4	1.4
3	Data Acquire: Assy Section		0	0.00	0.0	12	36 EE	52.60	1.9	1.9
4			0	0.00	0.0	12	96 ES	29.80	2.9	2.9
5	Data Analysis: Assy Sectns		0	0.00	0.0	1	80 EE	52.60	4.2	4.2
6	Calibrate Null Coil		0	0.00	0.0	1	20 EE	52.60	1.1	1.1
7			0	0.00	0.0	1	20 ES	29.80	0.6	0.6
8	Code Software Coil Paramt		0	0.00	0.0	1	8 CP	52.60	0.4	0.4
9			0	0.00	0.0	1	8 EE	52.60	0.4	0.4
10	ID Setup: Electronic		0	0.00	0.0	1	16 EE	52.60	0.8	0.8

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ITM	ITM	UNIT	NBR	UNIT	TOTAL	LBR	HRS/	TOTAL	CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	COST	ISC K\$	UNTS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$	
11			0	0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2	
12	ID Setup: Electrical		0	0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2	
13	ID: Data Acquisition		0	0.00	0.0	1	40.0	40 EE	52.60	2.1	2.1	
14			0	0.00	0.0	1	240.0	240 ES	29.80	7.2	7.2	
15	ID: Data Analysis		0	0.00	0.0	1	40.0	40 EE	52.60	2.1	2.1	
16	Data Preparation		0	0.00	0.0	1	80.0	80 ES	29.80	2.4	2.4	
17	Q/C Verification		0	0.00	0.0	1	20.0	20 EE	52.60	1.1	1.1	
18			0	0.00	0.0	1	20.0	20 ES	29.80	0.6	0.6	
19	Shutdown/storage		0	0.00	0.0	1	20.0	20 EE	52.60	1.1	1.1	
20			0	0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2	
** Subtotal **					0.0			928		34.6	34.6	
** WBS: 1.2.2.1.6 Installation												
1	Prepare & Truck to Site	lot	1	525.00 eu	0.5	1	80.0	80 MA	37.10	3.0	3.5	
2	Rigger's Work		0	0.00	0.0	1	50.0	50 ICO	64.70	3.2	3.2	
3	Survey & Alignment		0	0.00	0.0	1	46.0	46 INT	64.70	3.0	3.0	
4	Installation	lot	1	315.00 eu	0.3	1	100.0	100 INT	64.70	6.5	6.8	
5	Vacuum Hookup/Pumpdown	lot	1	105.00 eu	0.1	1	40.0	40 INT	64.70	2.6	2.7	
6	Reinstall Temp Ctrl Housg		0	0.00	0.0	1	40.0	40 INT	64.70	2.6	2.6	
7	Miscellaneous		0	0.00	0.0	1	50.0	50 INT	64.70	3.2	3.2	
** Subtotal **					0.9			406		24.1	5.0	
** WBS: 1.2.2.2.1.1 Fixed Aperture												
1	Water cooled absorbr assmb	ea	1	500.00 eu	0.5	1	120.0	120 MS	37.10	4.5	5.0	
2	Brazing fixtures/tooling	ea	1	200.00 eu	0.2	1	20.0	20 MS	37.10	0.7	0.9	
3	Assemble		0	0.00	0.0	1	80.0	80 MS	37.10	3.0	3.0	
4	Survey/calibration		0	0.00	0.0	1	16.0	16 MS	37.10	0.6	0.6	
5	Vac. checks & bakeout	ea	1	50.00 eu	0.1	1	80.0	80 MS	37.10	3.0	3.0	
** Subtotal **					0.8			316		11.7	12.5	
** WBS: 1.2.2.2.1.2 PBPM #1												
1	Photon BPM System	ea	2	1500.00 A86	3.0	2	160.0	320 MS	37.10	11.9	14.9	
2	Vacuum chamber	ea	1	6000.00 eu	6.0	0	0.0	0	0.00	0.0	6.0	
3	1-axis translt n mechanism	ea	2	2500.00 eu	5.0	2	40.0	80 MS	37.10	3.0	8.0	
4	Assemble	ea	2	500.00 eu	1.0	2	60.0	120 MS	37.10	4.5	5.5	
5	Tank Mounting Hardware	ea	6	200.00 eu	1.2	6	4.0	24 MS	37.10	0.9	2.1	
6	Survey/calibration		0	0.00	0.0	1	32.0	32 MS	37.10	1.2	1.2	
7	Support post	ea	1	3000.00 eu	3.0	0	0.0	0	0.00	0.0	3.0	
8	Bakeout & leak checks	ea	1	100.00 eu	0.1	1	80.0	80 MS	37.10	3.0	3.1	
9	Pre-installation		10	0.00	0.0	1	80.0	80 MS	37.10	3.0	3.0	
10	LCW hardware & connctions	ea	1	300.00 eu	0.3	1	20.0	20 MS	37.10	0.7	1.0	
** Subtotal **					19.6			756		28.0	47.6	
** WBS: 1.2.2.2.1.3 Front End Photon Shutter												
1	Thermal absorber blades	lot	1	1350.00 eu	1.4	2	68.0	136 MS	37.10	5.0	6.4	
2	Vacuum chamber	lot	1	6700.00 eu	6.7	1	320.0	320 MS	37.10	11.9	18.6	
3	Knuckle assembly	lot	1	250.00 eu	0.2	1	99.0	99 MS	37.10	3.7	3.9	
4	Final Assembly/Instillation	lot	1	1600.00 eu	1.6	1	254.0	254 MS	37.10	9.4	11.0	
5	Support post	ea	1	200.00 eu	0.2	1	40.0	40 MS	37.10	1.5	1.7	
** Subtotal **					10.1			849		31.5	41.6	
** WBS: 1.2.2.2.1.4 Fast Valve												
1	Modified Fast Shutter	ea	1	20000.00 eu	20.0	0	0.0	0	0.00	0.0	20.0	
2	Assemble & Test	ea	1	100.00 eu	0.1	1	60.0	60 MS	37.10	2.2	2.3	
** Subtotal **					20.1			60		2.2	22.3	
** WBS: 1.2.2.2.1.5 Personnel Safety Shut.												
1	Lead Plunger	ea	1	550.00 eu	0.6	1	52.0	52 MS	37.10	1.9	2.5	
2	Vacuum System	ea	1	5075.00 eu	5.1	1	190.0	190 MS	37.10	7.0	12.1	
3	Actuator Hardware	ea	1	2700.00 A87	2.7	1	80.0	80 MS	37.10	3.0	5.7	

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ITM	ITM	UNIT	NBR	UNIT COST	TOTAL	LBR	HRS/	TOTAL CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	COST BASIS	ISC K\$	UNTS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$
4	Assemble & Test	ea	1	2400.00 eu	2.4	1	156.0	156 MS	37.10	5.8	8.2
**	Subtotal **				10.7			478		17.7	28.5
**	WBS: 1.2.2.2.1.6			Front End Vacuum System							
1	Bellows Assembly	ea	2	2200.00 AB6	4.4	0	0.0	0	0.00	0.0	4.4
2	4" UHV Isolation Valve	ea	1	10000.00 cp	10.0	0	0.0	0	0.00	0.0	10.0
3	6" UHV Isolation Valve	ea	2	13000.00 cp	26.0	0	0.0	0	0.00	0.0	26.0
4	4" Pipe Tee/Spool	ea	2	1500.00 eu	3.0	0	0.0	0	0.00	0.0	3.0
5	Spool Support Post	ea	1	500.00 eu	0.5	0	0.0	0	0.00	0.0	0.5
6	Shielding Wall Transition	ea	1	2500.00 eu	2.5	0	0.0	0	0.00	0.0	2.5
7	Misc UHV Hardware	lot	1	2500.00 eu	2.5	1	40.0	40 MS	37.10	1.5	4.0
8	Bakeout/leak check	lot	1	500.00 eu	0.5	1	80.0	80 MS	37.10	3.0	3.5
9	S.R. REM to conflat	ea	1	300.00 cp	0.3	1	4.0	4 MS	37.10	0.1	0.4
10	Survey/calibration		0	0.00	0.0	2	16.0	32 MS	37.10	1.2	1.2
**	Subtotal **				49.7			156		5.8	55.5
**	WBS: 1.2.2.2.1.7			Splitting Mirror System							
1	Fab/procure mech parts	lot	1	52200.00 eu	52.2	1	1116.0	1116 MS	37.10	41.4	93.6
2	Fab/procure elec & cntrls	lot	1	16700.00 eu	16.7	1	40.0	40 MS	37.10	1.5	18.2
3			0	0.00	0.0	1	90.0	90 ES	29.80	2.7	2.7
4	Fab/procure vac chamber	lot	1	15350.00 eu	15.3	1	100.0	100 MS	37.10	3.7	19.1
5	Vac pumpng,gages,ps,etc.	lot	1	16850.00 eu	16.9	1	16.0	16 MS	37.10	0.6	17.4
6			0	0.00	0.0	1	16.0	16 EI	29.80	0.3	0.5
7	Assemble,bakeout,test	lot	1	500.00 eu	0.5	1	232.0	232 MS	37.10	8.6	9.1
8	Installation	lot	1	600.00 eu	0.6	1	100.0	100 MU	35.80	3.6	4.2
9			0	0.00	0.0	1	20.0	20 MS	37.10	0.7	0.7
10			0	0.00	0.0	1	20.0	20 ES	29.80	0.6	0.6
11			0	0.00	0.0	1	20.0	20 EM	29.80	0.6	0.6
**	Subtotal **				102.2			1770		64.5	166.7
**	WBS: 1.2.2.2.1.8			Front End Mechanical Installation							
1	Assemble/leak check	lot	3	500.00 eu	1.5	3	16.0	48 MU	35.80	1.7	3.2
2	Transport/set-up	lot	4	200.00 eu	0.8	4	32.0	128 MU	35.80	4.6	5.4
3	Unistrut/misc hardware	lot	1	500.00 eu	0.5	1	40.0	40 MU	35.80	1.4	1.9
4	Tools & Misc	lot	1	500.00 eu	0.5	1	40.0	40 MS	37.10	1.5	2.0
5	Misc. machine shop	lot	1	500.00 eu	0.5	1	40.0	40 MS	37.10	1.5	2.0
6	Lead Shielding Installatn	lot	1	3000.00 eu	3.0	1	80.0	80 MU	35.80	2.9	5.9
7	Shielding Wall modificatn	lot	1	500.00 eu	0.5	1	100.0	100 MU	35.80	3.6	4.1
8	F.E. Support Rail	ea	1	500.00 eu	0.5	1	120.0	120 MS	37.10	4.5	5.0
9	Survey & Alignment	lot	1	200.00 eu	0.2	1	103.0	103 MS	37.10	3.8	4.0
**	Subtotal **				8.0			699		25.4	33.4
**	WBS: 1.2.2.2.2.1			Fixed Aperture Controls							
1	Vacuum Feedthru	ea	1	250.00 eu	0.2	1	8.0	8 MU	35.80	0.3	0.5
2	Electrometer	ea	1	2795.00 cp	2.8	1	8.0	8 ES	29.80	0.2	3.0
3	Eurocard Crate	ea	1	800.00 eu	0.8	1	16.0	16 ES	29.80	0.5	1.3
4	ILC	ea	1	1000.00 eu	1.0	1	16.0	16 ES	29.80	0.5	1.5
5	Cables	lot	1	300.00 eu	0.3	1	16.0	16 ES	29.80	0.5	0.8
6	Installation		0	0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2
7	Test		0	0.00	0.0	1	16.0	16 EM	29.80	0.5	0.5
**	Subtotal **				5.1			120		3.6	8.8
**	WBS: 1.2.2.2.2.2			PBPM #1 Controls							
1	Ion Pump 110/LS	ea	1	4750.00 cp	4.8	1	16.0	16 MS	37.10	0.6	5.3
2	Ion Pump PS	ea	1	2000.00 cp	2.0	1	16.0	16 ES	29.80	0.5	2.5
3	Bias Power Supply	ea	1	500.00 eu	0.5	1	8.0	8 ES	29.80	0.2	0.7
4	Vacuum Feedthru	ea	5	250.00 eu	1.2	5	2.0	10 MS	37.10	0.4	1.6
5	ILC & SBX	ea	2	1400.00 eu	2.8	2	16.0	32 ES	29.80	1.0	3.8
6	Electrometer	ea	4	1695.00 eu	6.8	4	4.0	16 ES	29.80	0.5	7.3
7	Eurocard Crate	ea	1	800.00 eu	0.8	1	16.0	16 ES	29.80	0.5	1.3
8	Motor Controller	ea	1	2400.00 eu	2.4	1	16.0	16 ES	29.80	0.5	2.9

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ITM	ITM	UNIT	NBR	UNIT	COST	TOTAL	LBR	HRS/	TOTAL	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS		COST BASIS	ISC K\$	UNTS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$
9	Water Temp Controller	ea	1		1975.00 cp	2.0	1	16.0	16 MU	35.80	0.6	2.5
10	Cables	lot	1		500.00 eu	0.5	1	16.0	16 ES	29.80	0.5	1.0
11	Installation		0		0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2
12	Test		0		0.00	0.0	1	40.0	40 EM	29.80	1.2	1.2
13	Flow Switch	ea	2		400.00 eu	0.8	2	4.0	8 MU	35.80	0.3	1.1
14	Ion Gauge	ea	1		3000.00 eu	3.0	1	8.0	8 ES	29.80	0.2	3.2
** Subtotal **						27.6			258		8.0	35.6
** WBS: 1.2.2.2.3 Photon Shutter Controls												
1	Ion Pump 400 l/s	ea	1		9900.00 cp	9.9	1	8.0	8 MU	35.80	0.3	10.2
2	Ion Pump PS	ea	1		1975.00 cp	2.0	1	8.0	8 ES	29.80	0.2	2.2
3	Ion Gauge	ea	1		3000.00 eu	3.0	1	8.0	8 ES	29.80	0.2	3.2
4	ILC & SBX	ea	1		1400.00 eu	1.4	1	16.0	16 ES	29.80	0.5	1.9
5	Position Indicators	set	1		500.00 eu	0.5	1	16.0	16 ES	29.80	0.5	1.0
6	Air Solenoids	ea	4		500.00 eu	2.0	4	8.0	32 MU	35.80	1.1	3.1
7	Air Press Interlock	ea	1		500.00 eu	0.5	1	16.0	16 MU	35.80	0.6	1.1
8	Installation		0		0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2
9	Test		0		0.00	0.0	1	24.0	24 EM	29.80	0.7	0.7
** Subtotal **						19.3			168		5.3	24.6
** WBS: 1.2.2.2.2.4 Fast Valve Controls												
1	Ion Gauge	ea	3		3000.00 eu	9.0	3	8.0	24 ES	29.80	0.7	9.7
2	Trigger Unit	ea	1		5000.00 eu	5.0	1	80.0	80 ES	29.80	2.4	7.4
3	ILC	ea	1		1000.00 eu	1.0	1	16.0	16 ES	29.80	0.5	1.5
4	Eurocard Crate	ea	1		800.00 eu	0.8	1	16.0	16 ES	29.80	0.5	1.3
5	Installation		0		0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2
6	Test		0		0.00	0.0	1	40.0	40 EM	29.80	1.2	1.2
** Subtotal **						15.8			216		6.4	22.2
** WBS: 1.2.2.2.2.5 Personnel Safety Shutter Controls												
1	Ion Pump 200 l/s	ea	1		5900.00 cp	5.9	1	8.0	8 MU	35.80	0.3	6.2
2	Ion Pump PS	ea	1		1975.00 cp	2.0	1	8.0	8 ES	29.80	0.2	2.2
3	Ion Gauge	ea	1		3000.00 eu	3.0	1	8.0	8 ES	29.80	0.2	3.2
4	ILC & SBX	ea	1		1400.00 eu	1.4	1	16.0	16 ES	29.80	0.5	1.9
5	Position Indicators	set	1		500.00 eu	0.5	1	16.0	16 ES	29.80	0.5	1.0
6	Air Solenoids	ea	4		500.00 eu	2.0	4	8.0	32 MU	35.80	1.1	3.1
7	Air Press Interlock	ea	1		500.00 eu	0.5	1	16.0	16 MU	35.80	0.6	1.1
8	Installation		0		0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2
9	Test		0		0.00	0.0	1	24.0	24 EM	29.80	0.7	0.7
** Subtotal **						15.3			168		5.3	20.6
** WBS: 1.2.2.2.2.6 Vacuum System Controls												
0	X-connect	ea	1		270.00 cp	0.3	1	24.0	24 ES	29.80	0.7	1.0
1	Cable Set	lot	3		100.00 eu	0.3	3	4.0	12 ES	29.80	0.4	0.7
3	Relay blocks	ea	1		580.00 cp	0.6	1	24.0	24 ES	29.80	0.7	1.3
4	48 Chan Opto-isolator	ea	1		700.00 cp	0.7	1	24.0	24 ES	29.80	0.7	1.4
** Subtotal **						1.8			84		2.5	4.4
** WBS: 1.2.2.2.3 Front End Safety Systems												
1	ILC & SBX	ea	2		1400.00 eu	2.8	0	0.0	0	0.00	0.0	2.8
2	Eurocard Crate	ea	1		800.00 eu	0.8	0	0.0	0	0.00	0.0	0.8
3	Key Panel	ea	1		300.00 cp	0.3	0	0.0	0	0.00	0.0	0.3
4	Monitor Lights Panel	ea	6		250.00 cp	1.5	0	0.0	0	0.00	0.0	1.5
5	Push Button Panel	ea	1		250.00 cp	0.2	0	0.0	0	0.00	0.0	0.2
6	Breaker Panel	ea	1		250.00 cp	0.2	0	0.0	0	0.00	0.0	0.2
7	Cables	lot	1		100.00 eu	0.1	0	0.0	0	0.00	0.0	0.1
8	Wiring Assembly		0		0.00	0.0	1	80.0	80 ES	29.80	2.4	2.4
9	PLIC radiation monitor	ft	100		11.00 cp	1.1	0	0.0	0	0.00	0.0	1.1
10	PLIC Camac HV PS	ea	1		1000.00 eu	1.0	0	0.0	0	0.00	0.0	1.0
11	PLIC Monitoring Card	ea	1		2700.00 cp	2.7	0	0.0	0	0.00	0.0	2.7
12	PLIC Other Electronics	lot	1		3000.00 eu	3.0	1	20.0	20 ES	29.80	0.6	3.6

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ITM	ITM	UNIT	NBR	UNIT COST	TOTAL	LBR	HRS/	TOTAL CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	COST BASIS	ISC K\$	UNTS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$
13	PLIC Installation	lot	1	800.00 eu	0.8	1	8.0	8 EI	29.80	0.2	1.0
14	PLIC Installation	ea	100	1.00 eu	0.1	1	8.0	8 EI	29.80	0.2	0.3
15	Systems Test		0	0.00	0.0	1	80.0	80 EM	29.80	2.4	2.4
16	Video Camera & Lens	ea	1	800.00 cp	0.8	0	0.0	0	0.00	0.0	0.8
17	Video Monitor	ea	1	300.00 cp	0.3	0	0.0	0	0.00	0.0	0.3
18	Coax: camera to monitor	ea	1	50.00 eu	0.1	1	2.0	2 EI	29.80	0.1	0.1
19	Video Connectors	ea	2	5.00 eu	0.0	2	0.5	1 ES	29.80	0.0	0.0
20	Padlocks & misc hardware	lot	1	500.00 eu	0.5	0	0.0	0	0.00	0.0	0.5
** Subtotal **					16.6			199		5.9	22.3
** WBS: 1.2.2.2.4 Front End Utilities											
1	F.E. pneumatic service	lot	1	2000.00 eu	2.0	1	120.0	120 MU	35.80	4.3	6.3
2	F.E. LCU service	lot	1	2000.00 eu	2.0	1	120.0	120 MU	35.80	4.3	6.3
3	Cable trays, conduit, etc	lot	1	2000.00 eu	2.0	1	120.0	120 PE	36.10	4.3	6.3
4	Unistrut & misc hardware	lot	1	1000.00 eu	1.0	1	40.0	40 MS	37.10	1.5	2.5
5	Double elec rack	ea	1	1200.00 eu	1.2	1	16.0	16 ES	29.80	0.5	1.7
6	BA panel 3 ph 30A	ea	1	50.00 cp	0.1	1	0.5	0 EI	29.80	0.0	0.1
7	Breaker panel	ea	2	200.00 cp	0.4	2	4.0	8 EI	29.80	0.2	0.6
8	Plug Strip	ea	2	20.00 eu	0.0	2	1.0	2 EI	29.80	0.1	0.1
9	Rack Fans	ea	2	50.00 cp	0.1	2	1.0	2 ES	29.80	0.1	0.2
10	X-conn blocks & frame	ea	1	500.00 cp	0.5	1	24.0	24 EI	29.80	0.7	1.2
11	Relay blocks & frame	ea	1	500.00 cp	0.5	1	24.0	24 EI	29.80	0.7	1.2
** Subtotal **					9.8			476		16.7	26.5
** WBS: 1.2.2.2.5 Front End Mech/Elect System Integration											
1	Controls Checkout/Debug		0	0.00	0.0	7	16.0	112 MT	26.10	2.9	2.9
2			0	0.00	0.0	7	16.0	112 EM	29.80	3.3	3.3
3			0	0.00	0.0	7	16.0	112 CP	52.60	5.9	5.9
4			0	0.00	0.0	7	16.0	112 EI	29.80	3.3	3.3
5	Safety System Check/Debug		0	0.00	0.0	4	8.0	32 MT	26.10	0.8	0.8
6			0	0.00	0.0	4	8.0	32 EM	29.80	1.0	1.0
7			0	0.00	0.0	4	8.0	32 EI	29.80	1.0	1.0
8	Vacuum System Checks		0	0.00	0.0	4	16.0	64 MT	26.10	1.7	1.7
9			0	0.00	0.0	4	16.0	64 EM	29.80	1.9	1.9
10	Misc. Hardware	lot	1	1000.00 eu	1.0	1	40.0	40 MS	37.10	1.5	2.5
** Subtotal **					1.0			712		23.3	24.3
** WBS: 1.2.2.3.1.1.1 H&V Beam Defining Apertures											
1	Vacuum Chamber	ea	1	12000.00 A87	12.0	0	0.0	0	0.00	0.0	12.0
2	Roughing Valve	ea	1	750.00 cp	0.8	0	0.0	0	0.00	0.0	0.8
3	Tank Support Posts	ea	1	1000.00 eu	1.0	0	0.0	0	0.00	0.0	1.0
4	Tank Mounting Struts	ea	6	200.00 eu	1.2	6	20.0	120 MS	37.10	4.5	5.7
5	Brazed Absorber Assy	ea	4	500.00 eu	2.0	4	100.0	400 MS	37.10	14.8	16.8
6	Brazing & Tooling Fixturs	ea	1	100.00 eu	0.1	2	40.0	80 MS	37.10	3.0	3.1
7	UHV Mounting Hardware	lot	4	500.00 eu	2.0	4	20.0	80 MS	37.10	3.0	5.0
8	Bellows Assembly	ea	4	2000.00 eu	8.0	0	0.0	0	0.00	0.0	8.0
9	Stepper/Encoder Positione	ea	4	2500.00 eu	10.0	0	0.0	0	0.00	0.0	10.0
10	Flanges/misc UHV hardware	lot	10	500.00 eu	5.0	0	0.0	0	0.00	0.0	5.0
11	LCW Hardware	ea	2	300.00 eu	0.6	0	0.0	0	0.00	0.0	0.6
12	Assemble UHV subsystems	ea	4	100.00 eu	0.4	4	20.0	80 MS	37.10	3.0	3.4
13	Survey & Calibration		0	0.00	0.0	4	16.0	64 MS	37.10	2.4	2.4
14	Pumpdown & leakcheck	lot	1	50.00 eu	0.1	1	40.0	40 MS	37.10	1.5	1.5
15	Bakout	lot	1	50.00 eu	0.1	1	80.0	80 MS	37.10	3.0	3.0
16	Assemble Positioners	ea	4	50.00 eu	0.2	4	20.0	80 MS	37.10	3.0	3.2
17	Misc. Assembly Hardware	lot	1	1000.00 eu	1.0	1	40.0	40 MS	37.10	1.5	2.5
18	Pre-installation checkout		0	0.00	0.0	1	40.0	40 MS	37.10	1.5	1.5
19	Prep for transportation	lot	1	50.00 e	0.1	1	8.0	8 MS	37.10	0.3	0.3
** Subtotal **					44.4			1112		41.3	85.7
** WBS: 1.2.2.3.1.1.2 Vertical Deflection Mirrors											
1	Procurement	lot	2	56000.00 eu	112.0	2	60.0	120 MS	37.10	4.5	116.5
2	Fabrication	lot	2	9900.00 eu	19.8	2	1220.0	2440 MS	37.10	90.5	110.3

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ITM	ITM NBR DESCRIPTION	UNIT MEAS	NBR UNITS	UNIT COST COST BASIS	TOTAL ISC K\$	LBR UNTS	HRS/ UNIT	TOTAL CRAFT HRS CODE	CRAFT RATE	TOTAL LABOR K\$	ISC + LABOR K\$
	3 Assemble & Test	lot	2	650.00 eu	1.3	2	292.0	584 MS	37.10	21.7	23.0
	4 Installation	lot	2	50.00 eu	0.1	2	8.0	16 MS	37.10	0.6	0.7
**	Subtotal **				133.2			3160		117.2	250.4
**	WBS: 1.2.2.3.1.1.3 Monochromator	ea	1	365000.00 eu	365.0	0	0.0	0	0.00	0.0	365.0
**	Subtotal **				365.0			0		0.0	365.0
**	WBS: 1.2.2.3.1.1.4 Beam Line Diagnostics										
	1 Diagnostic #1	ea	1	7700.00 eu	7.7	1	208.0	208 MS	37.10	7.7	15.4
	2 Diagnostic #2	ea	1	6700.00 eu	6.7	1	148.0	148 MS	37.10	5.5	12.2
	3 Diagnostic #3	ea	1	6700.00 eu	6.7	1	148.0	148 MS	37.10	5.5	12.2
**	Subtotal **				21.1			504		18.7	39.8
**	WBS: 1.2.2.3.1.1.5 Branch Line Vacuum System										
	1 4" UHV Isolation Valve	ea	4	9460.00 cp	37.8	0	0.0	0	0.00	0.0	37.8
	2 6"cf Spools	ea	4	500.00 cp	2.0	0	0.0	0	0.00	0.0	2.0
	3 6"cf Bellows Assembly	ea	6	2000.00 A86	12.0	0	0.0	0	0.00	0.0	12.0
	4 Spool Support Posts	ea	4	500.00 eu	2.0	0	0.0	0	0.00	0.0	2.0
	5 Misc UHV Hardware	lot	1	2500.00 eu	2.5	1	120.0	120 MS	37.10	4.5	7.0
	6 Bakeout & Leak check	lot	1	2500.00 eu	2.5	1	120.0	120 MS	37.10	4.5	7.0
**	Subtotal **				58.8			240		8.9	67.7
**	WBS: 1.2.2.3.1.1.6 Branch Line Mechanical Installation										
	1 Assemble/Leak check	lot	1	1.00 1000	0.0	1	120.0	120 MS	37.10	4.5	4.5
	2 Transport & setup	lot	3	200.00 eu	0.6	3	32.0	96 MU	35.80	3.4	4.0
	3 Unitstrut & Misc. Hardware	lot	1	500.00 eu	0.5	1	80.0	80 MU	35.80	2.9	3.4
	4 Misc. Mechanical work	lot	1	500.00 eu	0.5	1	40.0	40 MS	37.10	1.5	2.0
	5 Misc. Machine shop	lot	1	500.00 eu	0.5	1	40.0	40 MS	37.10	1.5	2.0
	6 Lead Shielding Installatn	lot	1	1000.00 eu	1.0	1	40.0	40 MU	35.80	1.4	2.4
	7 Support Rail	ea	1	500.00 eu	0.5	1	120.0	120 MS	37.10	4.5	5.0
	8 Survey & Alignment	lot	1	200.00 eu	0.2	1	131.0	131 MS	37.10	4.9	5.1
**	Subtotal **				3.8			667		24.5	28.3
**	WBS: 1.2.2.3.1.1.7 Defining Slits	ea	2	45000.00 eu	90.0	0	0.0	0	0.00	0.0	90.0
**	Subtotal **				90.0			0		0.0	90.0
**	WBS: 1.2.2.3.1.2.1 Photon Transport Controls & Diagnostics										
	1 Ion Pump Controls/Cables	lot	1	53600.00 CP	53.6	4	8.0	32 EI	29.80	1.0	54.6
	2 Ion Gauges/Controls	lot	1	12700.00 eu	12.7	8	8.0	64 EI	29.80	1.9	14.6
	3 Interlocks & Actuators	lot	1	5400.00 eu	5.4	14	2.0	28 EI	29.80	0.8	6.2
	4 Positioning Controls	lot	1	22800.00 eu	22.8	8	8.0	64 EI	29.80	1.9	24.7
	5 Optical Cleaning Controls	lot	1	10000.00 eu	10.0	1	20.0	20 EI	29.80	0.6	10.6
	6 Beam Positioning Controls	ea	1	2100.00 eu	2.1	1	10.0	10 EI	29.80	0.3	2.4
	7 Misc. Hardware	lot	1	5000.00 eu	5.0	1	40.0	40 ES	29.80	1.2	6.2
**	Subtotal **				111.6			258		7.7	119.3
**	WBS: 1.2.2.3.1.2.2 Monochromator Controls										
	1 Programmabl Logic Cntrlr	lot	1	8500.00 eu	8.5	1	20.0	20 EI	29.80	0.6	9.1
	2		0	0.00	0.0	1	40.0	40 CP	52.60	2.1	2.1
	3 Branch Line Device Server	ea	1	7800.00 cp	7.8	1	40.0	40 CP	52.60	2.1	9.9
	4 Network Interface	lot	1	5000.00 eu	5.0	1	10.0	10 EI	29.80	0.3	5.3
	5 Display/Control Station	ea	1	13000.00 eu	13.0	1	40.0	40 CP	52.60	2.1	15.1
	6 TV Display Controls	ea	1	5900.00 eu	5.9	1	20.0	20 EI	29.80	0.6	6.5
	7 24VDC Distribution	lot	1	4000.00 eu	4.0	1	60.0	60 ES	29.80	1.8	5.8
**	Subtotal **				44.2			230		9.6	53.8

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ITM NBR DESCRIPTION	UNIT MEAS	NBR UNITS	UNIT COST COST BASIS	TOTAL ISC K\$	LBR UNTS	HRS/ UNIT	TOTAL CRAFT HRS CODE	CRAFT RATE	TOTAL LABOR K\$	ISC + LABOR K\$
** WBS: 1.2.2.3.1.2.3 Branch Line Electrical Installation										
1 Racks & Trays	lot	1	3450.00 CP	3.5	1	80.0	80 EI	29.80	2.4	5.8
2 Ion Pump Interconnects	ft	600	1.00 eu	0.6	1	16.0	16 EI	29.80	0.5	1.1
3 Ion Gauge Interconnect	ft	600	2.00 eu	1.2	1	32.0	32 EI	29.80	1.0	2.2
4 Intrick/Actuator Intrcnct	ft	400	3.00 eu	1.2	1	40.0	40 EI	29.80	1.2	2.4
5 Position Controls Intrcnct	ft	800	2.50 eu	2.0	1	40.0	40 EI	29.80	1.2	3.2
6 Optical Cleaning Intrcnct	ft	200	1.00 eu	0.2	1	10.0	10 EI	29.80	0.3	0.5
** Subtotal **				8.6			218		6.5	15.1
** WBS: 1.2.2.3.1.3 Branch Line Safety Systems										
1 ILC & SBX	ea	1	1400.00 eu	1.4	0	0.0	0	0.00	0.0	1.4
2 Eurocard Crate	ea	1	800.00 eu	0.8	0	0.0	0	0.00	0.0	0.8
3 Key Panel	ea	1	300.00 cp	0.3	0	0.0	0	0.00	0.0	0.3
4 Monitor Lights Panel	ea	6	250.00 cp	1.5	0	0.0	0	0.00	0.0	1.5
5 Push Button Panel	ea	1	250.00 cp	0.2	0	0.0	0	0.00	0.0	0.2
6 Breaker Panel	ea	1	250.00 cp	0.2	0	0.0	0	0.00	0.0	0.2
7 Cables	lot	1	100.00 eu	0.1	0	0.0	0	0.00	0.0	0.1
8 Wiring Assembly		0	0.00	0.0	1	80.0	80 ES	29.80	2.4	2.4
9 Systems Test		0	0.00	0.0	1	80.0	80 EM	29.80	2.4	2.4
10 Padlocks & Misc. Hardware	lot	1	500.00 eu	0.5	0	0.0	0	0.00	0.0	0.5
** Subtotal **				5.1			160		4.8	9.9
** WBS: 1.2.2.3.1.4 Branch Line Utilities										
1 Pneumatic Service	lot	1	1500.00 eu	1.5	1	120.0	120 MU	35.80	4.3	5.8
2 LCV Service	lot	1	1500.00 eu	1.5	1	120.0	120 MU	35.80	4.3	5.8
3 Cable Trays, Conduit, etc	lot	1	2000.00 eu	2.0	1	120.0	120 PE	36.10	4.3	6.3
4 Unitstrut/Misc. Hardware	lot	1	1000.00 eu	1.0	1	40.0	40 MS	37.10	1.5	2.5
5 Double Elec. Rack	ea	1	1200.00 cp	1.2	0	16.0	0 ES	29.80	0.0	1.2
6 BA panel 3 PH 30A	ea	1	50.00 CP	0.1	1	0.5	0 ESs	0.00	0.0	0.1
7 Breaker Panel	ea	2	200.00 CP	0.4	2	4.0	8 ES	29.80	0.2	0.6
8 Plug Strip	ea	2	20.00 eu	0.0	2	1.0	2 ES	29.80	0.1	0.1
9 Rack Fans	ea	2	50.00 eu	0.1	2	1.0	2 ES	29.80	0.1	0.2
10 X-conn blocks & frame	ea	1	500.00 cp	0.5	1	24.0	24 ES	29.80	0.7	1.2
11 Relay blks & frame	ea	1	500.00 cp	0.5	1	24.0	24 ES	29.80	0.7	1.2
** Subtotal **				8.8			460		16.2	25.0
** WBS: 1.2.2.3.1.5 Branch Line Mech/Elect System Integration										
1 Controls Checkout/Debug		0	0.00	0.0	6	16.0	96 MT	26.10	2.5	2.5
2		0	0.00	0.0	6	16.0	96 EM	29.80	2.9	2.9
3		0	0.00	0.0	6	16.0	96 CP	52.60	5.0	5.0
4		0	0.00	0.0	6	16.0	96 EI	29.80	2.9	2.9
5 Safety Systems Checkout		0	0.00	0.0	4	8.0	32 MT	26.10	0.8	0.8
6		0	0.00	0.0	4	8.0	32 EM	29.80	1.0	1.0
7		0	0.00	0.0	4	8.0	32 EI	29.80	1.0	1.0
8 Vacuum System Checks		0	0.00	0.0	4	16.0	64 MT	26.10	1.7	1.7
9		0	0.00	0.0	4	16.0	64 EM	29.80	1.9	1.9
10 Misc. Hardware	lot	1	1000.00 eu	1.0	1	40.0	40 MS	37.10	1.5	2.5
** Subtotal **				1.0			648		21.1	22.1
** WBS: 1.2.2.3.2 Crystallography Station										
1 Huber Goniometer		1	89250.00	89.2	0	0.0	0	0.00	0.0	89.2
2 Huber Table w/manipulatn		1	21000.00	21.0	0	0.0	0	0.00	0.0	21.0
3 MicroVAX computer system		1	42000.00	42.0	0	0.0	0	0.00	0.0	42.0
4 Data storage & archiving		1	26250.00	26.2	0	0.0	0	0.00	0.0	26.2
5 Electronics & interfaces		1	31500.00	31.5	0	0.0	0	0.00	0.0	31.5
6 Hutch		1	26250.00	26.2	0	0.0	0	0.00	0.0	26.2
7 Image plate scanner		1	162750.00	162.8	0	0.0	0	0.00	0.0	162.8
8 Software		1	54600.00	54.6	0	0.0	0	0.00	0.0	54.6
** Subtotal **				453.6			0		0.0	453.6

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ITM	ITM	UNIT	QTY	UNIT COST	TOTAL	LBR	HRS/	TOTAL CRAFT	CRAFT	TOTAL	ISC +
NR	DESCRIPTION	MEAS	UNITS	COST BASIS	ISC K\$	UNTS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$
** WBS: 1.2.2.3.3 Small Angle Scattering Station											
1	Scatring Cell w/envrn ctrl		1	12600.00	12.6	0	0.0	0	0.00	0.0	12.6
2	Hi/lo pressure/temp cell		1	8400.00	8.4	0	0.0	0	0.00	0.0	8.4
3	Sample rotation fixture		1	10500.00	10.5	0	0.0	0	0.00	0.0	10.5
4	Multiplexing detector		1	52500.00	52.5	0	0.0	0	0.00	0.0	52.5
5	Detector electronics		1	31500.00	31.5	0	0.0	0	0.00	0.0	31.5
6	Plumbing, windows, vac etc.		1	26250.00	26.2	0	0.0	0	0.00	0.0	26.2
** Subtotal **					141.8			0		0.0	141.8
** WBS: 1.2.2.4.1.1 H&V Beam Defining Apertures											
1	Vacuum Chamber	ea	1	12000.00 A87	12.0	0	0.0	0	0.00	0.0	12.0
2	Roughing Valve	ea	1	750.00 cp	0.8	0	0.0	0	0.00	0.0	0.8
3	Tank Support Posts	ea	1	1000.00 eu	1.0	0	0.0	0	0.00	0.0	1.0
4	Tank Mounting Struts	ea	6	200.00 eu	1.2	6	20.0	120 MS	37.10	4.5	5.7
5	Brazed Absorber Assy	ea	4	500.00 eu	2.0	4	100.0	400 MS	37.10	14.8	16.8
6	Brazing & Tooling Fixtures	ea	1	100.00 eu	0.1	2	40.0	80 MS	37.10	3.0	3.1
7	UHV Mounting Hardware	lot	4	500.00 eu	2.0	4	20.0	80 MS	37.10	3.0	5.0
8	Bellows Assembly	ea	4	2000.00 eu	8.0	0	0.0	0	0.00	0.0	8.0
9	Stepper/Encoder Positioner	ea	4	2500.00 eu	10.0	0	0.0	0	0.00	0.0	10.0
10	Flanges/misc UHV hardware	lot	10	500.00 eu	5.0	0	0.0	0	0.00	0.0	5.0
11	LCW Hardware	ea	2	300.00 eu	0.6	0	0.0	0	0.00	0.0	0.6
12	Assemble UHV subsystems	ea	4	100.00 eu	0.4	4	20.0	80 MS	37.10	3.0	3.4
13	Survey & Calibration		0	0.00	0.0	4	16.0	64 MS	37.10	2.4	2.4
14	Pumpdown & leakcheck	lot	1	50.00 eu	0.1	1	40.0	40 MS	37.10	1.5	1.5
15	Bakeout	lot	1	50.00 eu	0.1	1	80.0	80 MS	37.10	3.0	3.0
16	Assemble Positioners	ea	4	50.00 eu	0.2	4	20.0	80 MS	37.10	3.0	3.2
17	Misc. Assembly Hardware	lot	1	1000.00 eu	1.0	1	40.0	40 MS	37.10	1.5	2.5
18	Pre-installation checkout		0	0.00	0.0	1	40.0	40 MS	37.10	1.5	1.5
19	Prep for transportation	lot	1	50.00 eu	0.1	1	8.0	8 MS	37.10	0.3	0.3
** Subtotal **					44.4			1112		41.3	85.7
** WBS: 1.2.2.4.1.1.2 Vertical Deflection Mirrors (#1&2)											
1	Procurement	lot	1	56000.00 eu	56.0	1	60.0	60 MS	37.10	2.2	58.2
2	Fabrication	lot	1	9900.00 eu	9.9	1	1220.0	1220 MS	37.10	45.3	55.2
3	Assemble & Test	lot	1	650.00 eu	0.7	1	292.0	292 MS	37.10	10.8	11.5
4	Installation	lot	1	50.00 eu	0.1	1	8.0	8 MS	37.10	0.3	0.3
** Subtotal **					66.6			1580		58.6	125.2
** WBS: 1.2.2.4.1.1.3.1 High Resolution Double Crystal Monochromator											
1	Double Crystal Monochromtr	ea	1	365000.00 eu	365.0	0	0.0	0	0.00	0.0	365.0
** Subtotal **					365.0			0		0.0	365.0
** WBS: 1.2.2.4.1.1.3.2 Pre-Monochromator Multilayer System											
1	Multilayer System	ea	1	390000.00 eu	390.0	0	0.0	0	0.00	0.0	390.0
** Subtotal **					390.0			0		0.0	390.0
** WBS: 1.2.2.4.1.1.4 Branch Line Diagnostics											
1	Diagnostic #1	ea	1	7700.00 eu	7.7	1	208.0	208 MS	37.10	7.7	15.4
2	Diagnostic #2	ea	1	6700.00 eu	6.7	1	148.0	148 MS	37.10	5.5	12.2
3	Diagnostic #3	ea	1	6700.00 eu	6.7	1	148.0	148 MS	37.10	5.5	12.2
** Subtotal **					21.1			504		18.7	39.8
** WBS: 1.2.2.4.1.1.5 Branch Line Vacuum System											
1	4" UHV Isolation Valve	ea	4	9460.00 cp	37.8	0	0.0	0	0.00	0.0	37.8
2	6"cf Spools	ea	4	500.00 cp	2.0	0	0.0	0	0.00	0.0	2.0
3	6"cf Bellows Assembly	ea	6	2000.00 A86	12.0	0	0.0	0	0.00	0.0	12.0
4	Spool Support Posts	ea	4	500.00 eu	2.0	0	0.0	0	0.00	0.0	2.0
5	Misc UHV Hardware	lot	1	2500.00 eu	2.5	1	120.0	120 MS	37.10	4.5	7.0
6	Bakeout & Leak check	lot	1	2500.00 eu	2.5	1	120.0	120 MS	37.10	4.5	7.0

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ITEM	ITEM	UNIT	NBR	UNIT COST	TOTAL	LBR	HRS/	TOTAL CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	COST BASIS	ISC K\$	UNTS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$
** Subtotal **											
					58.8			240		8.9	67.7
** WBS: 1.2.2.4.1.1.6 Branch Line Mechanical Installation											
1	Assemble/Leak check	lot	1	1.00 1000	0.0	1	120.0	120 MS	37.10	4.5	4.5
2	Transport & setup	lot	3	200.00 eu	0.6	3	32.0	96 MU	35.80	3.4	4.0
3	Unitstrut & Misc. Hardware	lot	1	500.00 eu	0.5	1	80.0	80 MU	35.80	2.9	3.4
4	Misc. Mechanical work	lot	1	500.00 eu	0.5	1	40.0	40 MS	37.10	1.5	2.0
5	Misc. Machine shop	lot	1	500.00 eu	0.5	1	40.0	40 MS	37.10	1.5	2.0
6	Lead Shielding Installatn	lot	1	1000.00 eu	1.0	1	40.0	40 MU	35.80	1.4	2.4
7	Support Rail	ea	1	500.00 eu	0.5	1	120.0	120 MS	37.10	4.5	5.0
8	Survey & Alignment	lot	1	200.00 eu	0.2	1	131.0	131 MS	37.10	4.9	5.1
** Subtotal **											
					3.8			667		24.5	28.3
** WBS: 1.2.2.4.1.1.7 Defining Slits											
1	Defining Slits	ea	2	45000.00 eu	90.0	0	0.0	0	0.00	0.0	90.0
** Subtotal **											
					90.0			0		0.0	90.0
** WBS: 1.2.2.4.1.2.1 Photon Transport Controls & Diagnostics											
1	Ion Pump Controls/Cables	lot	1	53600.00 CP	53.6	4	8.0	32 EI	29.80	1.0	54.6
2	Ion Gauges/Controls	lot	1	12700.00 eu	12.7	8	8.0	64 EI	29.80	1.9	14.6
3	Interlocks & Actuators	lot	1	5400.00 eu	5.4	14	2.0	28 EI	29.80	0.8	6.2
4	Positioning Controls	lot	1	22800.00 eu	22.8	8	8.0	64 EI	29.80	1.9	24.7
5	Optical Cleaning Controls	lot	1	10000.00 eu	10.0	1	20.0	20 EI	29.80	0.6	10.6
6	Beam Positioning Controls	ea	1	2100.00 eu	2.1	1	10.0	10 EI	29.80	0.3	2.4
7	Misc. Hardware	lot	1	5000.00 eu	5.0	1	40.0	40 ES	29.80	1.2	6.2
** Subtotal **											
					111.6			258		7.7	119.3
** WBS: 1.2.2.4.1.2.2 Monochromator Controls											
1	Programmable Logic Controller	lot	1	8500.00 eu	8.5	1	20.0	20 EI	29.80	0.6	9.1
2			0	0.00	0.0	1	40.0	40 CP	52.60	2.1	2.1
3	Branch Line Device Server	ea	1	7800.00 cp	7.8	1	40.0	40 CP	52.60	2.1	9.9
4	Network Interface	lot	1	5000.00 eu	5.0	1	10.0	10 EI	29.80	0.3	5.3
5	Display/Control Station	ea	1	13000.00 eu	13.0	1	40.0	40 CP	52.60	2.1	15.1
6	TV Display Controls	ea	1	5900.00 eu	5.9	1	20.0	20 EI	29.80	0.6	6.5
7	24VDC Distribution	lot	1	4000.00 eu	4.0	1	60.0	60 ES	29.80	1.8	5.8
** Subtotal **											
					44.2			230		9.6	53.8
** WBS: 1.2.2.4.1.2.3 Branch Line Electrical Installation											
1	Racks & Trays	lot	1	3450.00 CP	3.5	1	80.0	80 EI	29.80	2.4	5.8
2	Ion Pump Interconnects	ft	600	1.00 eu	0.6	1	16.0	16 EI	29.80	0.5	1.1
3	Ion Gauge Interconnect	ft	600	2.00 eu	1.2	1	32.0	32 EI	29.80	1.0	2.2
4	Intrick/Actuator Intronnct	ft	400	3.00 eu	1.2	1	40.0	40 EI	29.80	1.2	2.4
5	Position Controls Intronnct	ft	800	2.50 eu	2.0	1	40.0	40 EI	29.80	1.2	3.2
6	Optical Cleaning Intronnct	ft	200	1.00 eu	0.2	1	10.0	10 EI	29.80	0.3	0.5
** Subtotal **											
					8.6			218		6.5	15.1
** WBS: 1.2.2.4.1.3 Branch Line Safety Systems											
1	ILC & SBX	ea	1	1400.00 eu	1.4	0	0.0	0	0.00	0.0	1.4
2	Eurocard Crate	ea	1	800.00 eu	0.8	0	0.0	0	0.00	0.0	0.8
3	Key Panel	ea	1	300.00 cp	0.3	0	0.0	0	0.00	0.0	0.3
4	Monitor Lights Panel	ea	6	250.00 cp	1.5	0	0.0	0	0.00	0.0	1.5
5	Push Button Panel	ea	1	250.00 cp	0.2	0	0.0	0	0.00	0.0	0.2
6	Breaker Panel	ea	1	250.00 cp	0.2	0	0.0	0	0.00	0.0	0.2
7	Cables	lot	1	100.00 eu	0.1	0	0.0	0	0.00	0.0	0.1
8	Wiring Assembly	0	0	0.00	0.0	1	80.0	80 ES	29.80	2.4	2.4
9	Systems Test	0	0	0.00	0.0	1	80.0	80 EM	29.80	2.4	2.4
10	Padlocks & Misc. Hardware	lot	1	500.00 eu	0.5	0	0.0	0	0.00	0.0	0.5
** Subtotal **											
					5.1			160		4.8	9.9

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ITM	ITM	NBR	DESCRIPTION	UNIT	NBR	UNIT	COST	TOTAL	LBR	HRS/	TOTAL	CRAFT	CRAFT	TOTAL	ISC +
				MEAS	UNITS		COST BASIS	ISC K\$	UNTS	UNIT	HRS	CODE	RATE	LABOR K\$	LABOR K\$
** WBS: 1.2.2.4.1.4 Branch Line Utilities															
1	Pneumatic Service	lot	1	1500.00	eu	1.5	1	120.0	120	MU	35.80	4.3	5.8		
2	LCW Service	lot	1	1500.00	eu	1.5	1	120.0	120	MU	35.80	4.3	5.8		
3	Cable Trays, Conduit, etc	lot	1	2000.00	eu	2.0	1	120.0	120	PE	36.10	4.3	6.3		
4	Unitatrust/Misc. Hardware	lot	1	1000.00	eu	1.0	1	40.0	40	MS	37.10	1.5	2.5		
5	Double Elec. Rack	ea	1	1200.00	cp	1.2	0	16.0	0	ES	29.80	0.0	1.2		
6	BA panel 3 PH 30A	ea	1	50.00	CP	0.1	1	0.5	0	ESs	0.00	0.0	0.1		
7	Breaker Panel	ea	2	200.00	CP	0.4	2	4.0	8	ES	29.80	0.2	0.6		
8	Plug Strip	ea	2	20.00	eu	0.0	2	1.0	2	ES	29.80	0.1	0.1		
9	Rack Fans	ea	2	50.00	eu	0.1	2	1.0	2	ES	29.80	0.1	0.2		
10	X-conn blocks & frame	ea	1	500.00	cp	0.5	1	24.0	24	ES	29.80	0.7	1.2		
11	Relay blks & frame	ea	1	500.00	cp	0.5	1	24.0	24	ES	29.80	0.7	1.2		
** Subtotal **								8.8			460		16.2		25.0
** WBS: 1.2.2.4.1.5 Branch Line Mech/Elect System Integration															
1	Controls Checkout/Debug		0	0.00		0.0	6	16.0	96	MT	26.10	2.5	2.5		
2			0	0.00		0.0	6	16.0	96	EM	29.80	2.9	2.9		
3			0	0.00		0.0	6	16.0	96	CP	52.60	5.0	5.0		
4			0	0.00		0.0	6	16.0	96	EI	29.80	2.9	2.9		
5	Safety Systems Checkout		0	0.00		0.0	4	8.0	32	MT	26.10	0.8	0.8		
6			0	0.00		0.0	4	8.0	32	EM	29.80	1.0	1.0		
7			0	0.00		0.0	4	8.0	32	EI	29.80	1.0	1.0		
8	Vacuum System Checks		0	0.00		0.0	4	16.0	64	MT	26.10	1.7	1.7		
9			0	0.00		0.0	4	16.0	64	EM	29.80	1.9	1.9		
10	Misc. Hardware	lot	1	1000.00	eu	1.0	1	40.0	40	MS	37.10	1.5	2.5		
** Subtotal **								1.0			648		21.1		22.1
** WBS: 1.2.2.4.2 Spectroscopy Station															
1	Detectors: misc. equip		1	36750.00		36.8	0	0.0	0		0.00	0.0	36.8		
2	MicroVAX computer system		1	42000.00		42.0	0	0.0	0		0.00	0.0	42.0		
3	Electrometers & interface		1	15750.00		15.8	0	0.0	0		0.00	0.0	15.8		
4	Electronic cntrls & intrfc		1	31500.00		31.5	0	0.0	0		0.00	0.0	31.5		
5	Fluorescence detector		1	10500.00		10.5	0	0.0	0		0.00	0.0	10.5		
6	Software		1	10500.00		10.5	0	0.0	0		0.00	0.0	10.5		
7	Sample cells and mounts		1	18900.00		18.9	0	0.0	0		0.00	0.0	18.9		
8	Hutch (special lrg type)		1	31500.00		31.5	0	0.0	0		0.00	0.0	31.5		
9	Mech sys for exp intrchny		1	42000.00		42.0	0	0.0	0		0.00	0.0	42.0		
** Subtotal **								239.4			0		0.0		239.4
** WBS: 1.2.2.4.3 Microprobe Station															
1	Kirkpatrick-Baez substrat		1	26250.00		26.2	0	0.0	0		0.00	0.0	26.2		
2	Multilayer coatings		1	31500.00		31.5	0	0.0	0		0.00	0.0	31.5		
3	Mirror mounting, alignmt		1	52500.00		52.5	0	0.0	0		0.00	0.0	52.5		
4	Sample mountings w/cntrl		1	10500.00		10.5	0	0.0	0		0.00	0.0	10.5		
5	Piezoelectric scanning		1	31500.00		31.5	0	0.0	0		0.00	0.0	31.5		
6	Computer system		1	42000.00		42.0	0	0.0	0		0.00	0.0	42.0		
7	Electronic cntrls/intrfcs		1	31500.00		31.5	0	0.0	0		0.00	0.0	31.5		
8	Sili detector/cryo system		1	15750.00		15.8	0	0.0	0		0.00	0.0	15.8		
9	Part cst:shared image sys		1	26250.00		26.2	0	0.0	0		0.00	0.0	26.2		
** Subtotal **								267.8			0		0.0		267.8
** WBS: 1.2.3.1.1.1 Magnetic Material															
1	NDFE Blocks	ea	3020	46.93	VQ	141.7	0	0.0	0		0.00	0.0	141.7		
2	Gauges/Field Coils/Holdrs	lot	1	300.00	EU	0.3	1	160.0	160	MT	26.10	4.2	4.5		
3	Measurement Prep		0	0.00		0.0	1	20.0	20	EM	29.80	0.6	0.6		
4			0	0.00		0.0	1	20.0	20	EE	52.60	1.1	1.1		
5	Measurements	LOT	1	100.00	EU	0.1	0	0.0	0		0.00	0.0	0.1		
6	3-Axis H.C. Meas		0	0.00		0.0	300	0.4	108	EM	29.80	3.2	3.2		
7	1-Axis H.C. Meas		0	0.00		0.0	2720	0.2	653	EM	29.80	19.5	19.5		
8	Surface Measurements		0	0.00		0.0	3020	0.2	544	EM	29.80	16.2	16.2		
9	Supervision		0	0.00		0.0	1	120.0	120	EE	52.60	6.3	6.3		

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ITM	ITM	UNIT	NBR	UNIT COST	TOTAL	LBR	HRS/	TOTAL CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	COST BASIS	ISC K\$	UNITS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$
** Subtotal **											
					142.1			1624		51.0	193.1
** WBS: 1.2.3.1.1.2 Model Pole & Pole Assembly											
1	NdFe Blocks		0	0.00	0.0	4	4.0	16 MS	37.10	0.6	0.6
2	Test Fixture & Assembly	ea	1	100.00 eu	0.1	1	80.0	80 MT	26.10	2.1	2.2
3	Model Measurements		0	0.00	0.0	1	40.0	40 EM	29.80	1.2	1.2
** Subtotal **											
					0.1			136		3.9	4.0
** WBS: 1.2.3.1.1.3 Pole Assemblies											
1	Vanadium Permendur	ea	486	32.40 A85	15.7	0	0.0	0	0.00	0.0	15.7
2	Keepers	ea	486	304.00 A82	147.7	0	0.0	0	0.00	0.0	147.7
3	Keeper Inspection	lot	1	1000.00 EU	1.0	486	0.2	97 MM	37.10	3.6	4.6
4	Containers	ea	486	15.00 EU	7.3	0	0.0	0	0.00	0.0	7.3
5	Assy Fixtures	ea	10	50.00 A82	0.5	12	4.0	48 MM	37.10	1.8	2.3
6	Assembly	ea	486	10.00 A82	4.9	486	5.0	2430 MM	37.10	90.2	95.0
7	Pole Assembly Mounts	ea	12	350.00 CP	4.2	12	32.0	384 MM	37.10	14.2	18.4
** Subtotal **											
					181.3			2959		109.8	291.1
** WBS: 1.2.3.1.1.4 End Pole Assemblies											
1	End Pole Keepers	LOT	1	100.00 EU	0.1	8	12.0	96 MM	37.10	3.6	3.7
2	NdFe Block Cutting		0	0.00	0.0	24	4.0	96 MS	37.10	3.6	3.6
3	Assembly - Keepers		0	0.00	0.0	8	8.0	64 MA	37.10	2.4	2.4
4	Rotator		0	0.00	0.0	8	32.0	256 MM	37.10	9.5	9.5
5	Rotator Block Cutting		0	0.00	0.0	24	4.0	96 MS	37.10	3.6	3.6
6	Assemble - Rotator		0	0.00	0.0	8	4.0	32 MA	37.10	1.2	1.2
7	Rotator Linkage	ea	8	100.00 EU	0.8	8	4.0	32 MM	37.10	1.2	2.0
8	Manual Rotatr Drv (Optnl)	ea	8	500.00 CP	4.0	8	16.0	128 MM	37.10	4.7	8.7
9			0	0.00	0.0	8	4.0	32 MA	37.10	1.2	1.2
** Subtotal **											
					4.9			832		30.9	35.8
** WBS: 1.2.3.1.1.5 Backing Beams											
1	Backing Beams (2)	LBS	19200	0.28 CP	5.4	2	304.0	608 MM	37.10	22.6	27.9
2			0	0.00	0.0	2	16.0	32 MS	37.10	1.2	1.2
3	Backing Beam Heat Treatmt	ea	2	3000.00 EU	6.0	0	0.0	0	0.00	0.0	6.0
4	Flexible Yoke		0	0.00	0.0	1	16.0	16 MA	37.10	0.6	0.6
5	Shims	lot	1	100.00 EU	0.1	1	40.0	40 MM	37.10	1.5	1.6
6	Pole Shields	lot	1	500.00 EU	0.5	0	0.0	0	0.00	0.0	0.5
7	Pole Shields	LOT	12	50.00 EU	0.6	0	0.0	0	0.00	0.0	0.6
8	Rigging Hardware	lot	1	2000.00 EU	2.0	0	0.0	0	0.00	0.0	2.0
** Subtotal **											
					14.6			696		25.8	40.4
** WBS: 1.2.3.1.1.6 Magnet Structure Assembly											
1	Keeper Installation Tool		0	0.00	0.0	1	21.0	21 MM	37.10	0.8	0.8
2	Keeper Pole Mount Assembl	ea	12	100.00 EU	1.2	12	36.0	432 MA	37.10	16.0	17.2
3	End Pole Assembly		0	0.00	0.0	4	12.0	48 MM	37.10	1.8	1.8
4	Pole Mount/Back Bm Assy		0	0.00	0.0	1	24.0	24 MM	37.10	0.9	0.9
5	Pole Mount/Bckg Bm Assy	ea	12	100.00 EU	1.2	12	24.0	288 MA	37.10	10.7	11.9
6	Fiducializing	lot	1	100.00 EU	0.1	2	16.0	32 MA	37.10	1.2	1.3
** Subtotal **											
					2.5			845		31.3	33.8
** WBS: 1.2.3.1.1.7 Magnetic Measurement: Mechanical											
1	Coil & Probe Mounts		0	0.00	0.0	1	40.0	40 MT	26.10	1.0	1.0
2	Assembly Section Setup		0	0.00	0.0	12	12.0	144 MA	37.10	5.3	5.3
** Subtotal **											
					0.0			184		6.4	6.4
** WBS: 1.2.3.1.1.8 Magnetic Measurements: Electrical											
1	Setup Assembly Sections		0	0.00	0.0	1	16.0	16 EE	52.60	0.8	0.8
2			0	0.00	0.0	12	4.0	48 ES	29.80	1.4	1.4
3	Data Acquire: Assy Sectns		0	0.00	0.0	12	3.0	36 EE	52.60	1.9	1.9

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ITM	ITM	UNIT	NBR	UNIT COST	TOTAL	LBR	HRS/	TOTAL CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	COST BASIS	ISC K\$	UNTS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$
4			0	0.00	0.0	12	8.0	96 ES	29.80	2.9	2.9
5	Data Analysis: Assy Sectns		0	0.00	0.0	1	80.0	80 EE	52.60	4.2	4.2
**	Subtotal **				0.0			276		11.2	11.2
**	WBS: 1.2.3.1.2.1	Support System Fabrication									
1	Support System Assembly	ea	1	40000.00 EU	40.0	0	0.0	0	0.00	0.0	40.0
2	Associated Parts	lot	1	2355.00 EU	2.4	1	66.0	66 MM	37.10	2.4	4.8
3	Miscellaneous	lot	1	500.00 EU	0.5	1	50.0	50 MM	37.10	1.9	2.4
4	Assembly	lot	1	75.00 EU	0.1	1	187.0	187 MA	37.10	6.9	7.0
**	Subtotal **				42.9			303		11.2	54.2
**	WBS: 1.2.3.1.2.2	Drive System Fabrication									
1	Roller Screw Assembly	ea	8	3500.00 EU	28.0	0	0.0	0	0.00	0.0	28.0
2	Spring System	ea	1	4104.00 CP	4.1	8	30.0	240 MM	37.10	8.9	13.0
3	Bearing System	lot	1	3120.00 EU	3.1	1	225.0	225 MM	37.10	8.3	11.5
4	Sprocket/Chain System	lot	1	1759.00 CP	1.8	1	90.0	90 MM	37.10	3.3	5.1
5	Gear Box & Mtg.	ea	1	1000.00 EU	1.0	1	38.0	38 MM	37.10	1.4	2.4
6	Encoder System	lot	1	4607.00 CP	4.6	1	40.0	40 MM	37.10	1.5	6.1
7	Motor Mounting Bracket	ea	1	25.00 CP	0.0	1	38.0	38 MM	37.10	1.4	1.4
8	Fan System	lot	1	70.00 CP	0.1	1	38.0	38 MM	37.10	1.4	1.5
9	Miscellaneous	lot	1	950.00 EU	0.9	1	230.0	230 MM	37.10	8.5	9.5
10	Assembly	lot	1	300.00 EU	0.3	1	397.0	397 MA	37.10	14.7	15.0
11	Roller Screw Kinematic Hnt	ea	8	500.00 eu	4.0	1	120.0	120 MM	37.10	4.5	8.5
**	Subtotal **				47.9			1456		54.0	102.0
**	WBS: 1.2.3.1.2.3	Local Temperature Control									
1	Frame & Curtain	lot	1	1300.00 EU	1.3	1	100.0	100 MA	37.10	3.7	5.0
2	Blower & Dryer System	lot	1	1050.00 EU	1.1	1	30.0	30 MA	37.10	1.1	2.2
3	Miscellaneous	lot	1	50.00 EU	0.1	1	15.0	15 MA	37.10	0.6	0.6
**	Subtotal **				2.4			145		5.4	7.8
**	WBS: 1.2.3.1.3.1	Vacuum Chambers									
1	Vacuum Chamber #1 (2 cm)	ea	0	0.00	0.0	0	0.0	0	0.00	0.0	0.0
2	Material	lbs	2275	2.21 VQ	5.0	0	0.0	0	0.00	0.0	5.0
3	Fabrication	ea	0	0.00	0.0	2	240.0	480 NC	53.10	25.5	25.5
4		ea	0	0.00	0.0	2	160.0	320 MM	37.10	11.9	11.9
5	Fabricate Flanges	lot	1	2400.00 EU	2.4	1	120.0	120 MM	37.10	4.5	6.9
6	Flange Transitions	lot	1	500.00 EU	0.5	6	20.0	120 MM	37.10	4.5	5.0
7	Assemble/Test	ea	0	0.00	0.0	1	320.0	320 MA	37.10	11.9	11.9
8	System Assembly	ea	0	0.00	0.0	1	80.0	80 MA	37.10	3.0	3.0
9	UHV Bakeout	ea	0	0.00	0.0	1	160.0	160 MA	37.10	5.9	5.9
**	Subtotal **				7.9			1600		67.0	75.0
**	WBS: 1.2.3.1.3.2	Pumping Systems & Instrumentation									
1	Photon Stop/TSP Pump	ea	1	20000.00 EU	20.0	0	0.0	0	0.00	0.0	20.0
2	Ion Pump/TSP Combination	ea	3	4397.00 CP	13.2	0	0.0	0	0.00	0.0	13.2
3	90 deg Elbow to Pump	ea	3	530.00 CP	1.6	0	0.0	0	0.00	0.0	1.6
4	Right Angle Valve	ea	2	876.00 CP	1.8	0	0.0	0	0.00	0.0	1.8
5	View Port	ea	2	206.00 CP	0.4	0	0.0	0	0.00	0.0	0.4
**	Subtotal **				36.9			0		0.0	36.9
**	WBS: 1.2.3.1.3.3	Support Structure									
1	Vacuum Chamber Support	lot	1	2000.00 EU	2.0	1	160.0	160 MM	37.10	5.9	7.9
2	Ion Pump Supports	ea	3	200.00 EU	0.6	3	20.0	60 MM	37.10	2.2	2.8
3	Installation Fixture	ea	1	500.00 EU	0.5	1	80.0	80 MM	37.10	3.0	3.5
**	Subtotal **				3.1			300		11.1	14.2
**	WBS: 1.2.3.1.3.4	Vacuum Diagnostics									
1	IG Controller	ea	1	755.00 CP	0.8	1	2.0	2 ES	29.80	0.1	0.8

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ITM	ITM	UNIT	NBR	UNIT COST	TOTAL	LBR	HRS/	TOTAL CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	COST BASIS	ISC K\$	UNITS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$
2	Degas Module	ea	1	150.00 CP	0.1	0	0.0	0	0.00	0.0	0.1
3	Second IG Module	ea	1	75.00 CP	0.1	0	0.0	0	0.00	0.0	0.1
4	Process Control Module	ea	1	350.00 CP	0.3	0	0.0	0	0.00	0.0	0.3
5	Rack Mount	ea	1	50.00 CP	0.1	1	1.0	1 ES	29.80	0.0	0.1
6	Remote I/O Module	ea	1	30.00 CP	0.0	0	0.0	0	0.00	0.0	0.0
7	Dual Convection Module	ea	1	400.00 CP	0.4	0	0.0	0	0.00	0.0	0.4
8	UHV Electrometer Module	ea	1	400.00 CP	0.4	0	0.0	0	0.00	0.0	0.4
9	IEEE-488 Interface	ea	1	360.00 CP	0.0	0	0.0	0	0.00	0.0	0.0
10	Nude Ion Gauge	ea	1	311.00 CP	0.3	1	1.0	1 MS	37.10	0.0	0.3
11	IG Cable: 50 feet	ea	1	195.00 CP	0.2	1	1.0	1 ES	29.80	0.0	0.2
12	Convection Gauge	ea	1	139.00 CP	0.1	1	1.0	1 MS	37.10	0.0	0.2
13	Convection Cable: 50 feet	ea	1	210.00 CP	0.2	1	1.0	1 ES	29.80	0.0	0.2
14	IG Connector	ea	1	10.00 EU	0.0	1	1.0	1 MS	37.10	0.0	0.0
15	IG Cable Interface	ea	1	50.00 EU	0.1	1	4.0	4 ES	29.80	0.0	0.2
16	Ion Pump Controller	ea	3	1948.00 CP	5.8	3	2.0	6 ES	29.80	0.2	6.0
17	Ion Pump Cable	ea	3	223.00 CP	0.7	3	4.0	12 ES	29.80	0.4	1.0
18	Ion Pump Cable Interface	ea	3	100.00 EU	0.3	3	4.0	12 ES	29.80	0.4	0.7
19	IEEE-488 Interface	ea	3	498.00 CP	1.5	0	0.0	0	0.00	0.0	1.5
20	ILC Crate	ea	1	1000.00 EU	1.0	1	40.0	40 ES	29.80	2.2	2.2
21	ILC	ea	5	1000.00 EU	5.0	1	40.0	40 ES	29.80	2.2	6.2
22	Sublimation Controller	ea	1	2000.00 CP	2.0	1	4.0	4 ES	29.80	0.1	2.1
23	Sublimation Mux	ea	1	2000.00 EU	2.0	1	80.0	80 ES	29.80	2.4	4.4
24	Filament Cables	set	1	500.00 EU	0.5	1	40.0	40 ES	29.80	1.2	1.7
** Subtotal **					22.3			246		7.4	29.6
** WBS: 1.2.3.1.4 Control System											
1	Motor MH172	ea	1	1565.00 VQ	1.6	0	0.0	0	0.00	0.0	1.6
2			0	0.00	0.0	0	0.0	0	0.00	0.0	0.0
3	Fan 172	ea	1	200.00 VQ	0.2	0	0.0	0	0.00	0.0	0.2
4	MH172 Driver	ea	1	3321.00 VQ	3.3	0	0.0	0	0.00	0.0	3.3
5			0	0.00	0.0	0	0.0	0	0.00	0.0	0.0
6	Controller 100010	ea	1	776.00 VQ	0.8	0	0.0	0	0.00	0.0	0.8
7	Math 009	ea	1	158.00 VQ	0.2	0	0.0	0	0.00	0.0	0.2
8	Indexer/Cont.	ea	1	682.20 VQ	0.7	0	0.0	0	0.00	0.0	0.7
9	Card Cage	ea	1	614.00 VQ	0.6	0	0.0	0	0.00	0.0	0.6
10	P.S. PSD512	ea	1	278.00 VQ	0.3	0	0.0	0	0.00	0.0	0.3
11	UPS	ea	1	350.00 EU	0.3	0	0.0	0	0.00	0.0	0.3
12	Redlion Cont. Readout	ea	5	176.00 EU	0.9	0	0.0	0	0.00	0.0	0.9
13	Final Installation	lot	1	3000.00 EU	3.0	1	80.0	80 EI	29.80	2.4	5.4
14	Final Test		0	0.00	0.0	1	40.0	40 EM	29.80	1.2	1.2
15	Shop Installation	lot	1	2000.00 EU	2.0	1	40.0	40 EI	29.80	1.2	3.2
16	Shop Test		0	0.00	0.0	1	40.0	40 EM	29.80	1.2	1.2
17	ILC	ea	3	1000.00 EU	3.0	3	8.0	24 EM	29.80	0.7	3.7
18	ILC Crate	ea	1	1000.00 EU	1.0	1	40.0	40 EI	29.80	1.2	2.2
** Subtotal **					17.8			264		7.9	25.7
** WBS: 1.2.3.1.5.1 Magnetic Measurements: Mechanical											
1	Coil & Probe Mounts		0	0.00	0.0	1	40.0	40 MU	35.80	1.4	1.4
2	Assembly Section Setup		0	0.00	0.0	12	12.0	144 MA	37.10	5.3	5.3
3	Coils	ea	2	105.00 eu	0.2	2	120.0	240 MU	35.80	8.6	8.8
4	Gap Spacers		0	0.00	0.0	1	24.0	24 MU	35.80	0.9	0.9
5	ID Setup	lot	1	315.00 eu	0.3	1	160.0	160 MA	37.10	5.9	6.3
** Subtotal **					0.5			608		22.2	22.7
** WBS: 1.2.3.1.5.2 Magnetic Measurements: Electrical											
1	Setup Assembly Sections		0	0.00	0.0	1	16.0	16 EE	52.60	0.8	0.8
2			0	0.00	0.0	12	4.0	48 ES	29.80	1.4	1.4
3	Data Acquire: Assy Section		0	0.00	0.0	12	3.0	36 EE	52.60	1.9	1.9
4			0	0.00	0.0	12	8.0	96 ES	29.80	2.9	2.9
5	Data Analysis: Assy Sectns		0	0.00	0.0	1	80.0	80 EE	52.60	4.2	4.2
6	Calibrate Null Coil		0	0.00	0.0	1	20.0	20 EE	52.60	1.1	1.1
7			0	0.00	0.0	1	20.0	20 ES	29.80	0.6	0.6
8	Code Software Coil Paramt		0	0.00	0.0	1	8.0	8 CP	52.60	0.4	0.4

ITEM	DESCRIPTION	UNIT	QTY	UNIT COST	TOTAL LBR	HRS/UNIT	TOTAL CRAFT	CRAFT RATE	TOTAL LABOR	ISC + LABOR	
NBR	DESCRIPTION	UNIT	QTY	COST BASIS	KS UNITS	UNIT	HRS CODE	RATE	LABOR KS	LABOR KS	
9			0	0.00	0.0	1	8.0	8 EE	52.60	0.4	0.4
10	ID Setup: Electronic	ea	1	0.00	0.0	1	16.0	16 EE	52.60	0.8	0.8
11		ea	1	0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2
12	ID Setup: Electrical	ea	1	0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2
13	ID: Data Acquisition	ea	1	0.00	0.0	1	40.0	40 EE	52.60	2.1	2.1
14			0	0.00	0.0	1	240.0	240 ES	29.80	7.2	7.2
15	ID: Data Analysis	ea	1	0.00	0.0	1	40.0	40 EE	52.60	2.1	2.1
16	Data Preparation		0	0.00	0.0	1	80.0	80 ES	29.80	2.4	2.4
17	Q/C Verification		0	0.00	0.0	1	20.0	20 EE	52.60	1.1	1.1
18			0	0.00	0.0	1	20.0	20 ES	29.80	0.6	0.6
19	Shutdown/storage		0	0.00	0.0	1	20.0	20 EE	52.60	1.1	1.1
20			0	0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2
** Subtotal **					0.0		928		34.6	34.6	
** WBS: 1.2.3.1.6	Installation										
1	Prepare & Truck to Site	ea	1	525.00 eu	0.5	1	80.0	80 MA	37.10	3.0	3.5
2	Rigger's Work	ea	1	0.00	0.0	1	50.0	50 ICO	64.70	3.2	3.2
3	Survey & Alignment	ea	1	0.00	0.0	1	46.0	46 IMT	64.70	3.0	3.0
4	Installation	lot	1	315.00 eu	0.3	1	100.0	100 IMT	64.70	6.5	6.8
5	Vacuum Hookup/pumpdown	ea	1	105.00 eu	0.1	1	40.0	40 IMT	64.70	2.6	2.7
6	Reinstall Temp Ctrl Housg		0	0.00	0.0	1	40.0	40 IMT	64.70	2.6	2.6
7	Miscellaneous		0	0.00	0.0	1	50.0	50 IMT	64.70	3.2	3.2
7	Miscellaneous		0	0.00	0.0	1	50.0	50 IMT	64.70	3.2	3.2
** Subtotal **					0.9		456		27.3	28.2	
** WBS: 1.2.3.2.1.1	Fixed Aperture										
1	Water cooled absorber assmb ea	ea	1	500.00 eu	0.5	1	120.0	120 MS	37.10	4.5	5.0
2	Brazing fixtures/tooling ea	ea	1	200.00 eu	0.2	1	20.0	20 MS	37.10	0.7	0.9
3	Assemble	ea	1	0.00	0.0	1	80.0	80 MS	37.10	3.0	3.0
4	Survey/calibration	ea	1	0.00	0.0	1	16.0	16 MS	37.10	0.6	0.6
5	Vac. checks & bakeout	ea	1	50.00 eu	0.1	1	80.0	80 MS	37.10	3.0	3.0
** Subtotal **					0.8		316		11.7	12.5	
** WBS: 1.2.3.2.1.2	BPM #1										
1	Photon BPM System	ea	1	1500.00 A86	3.0	2	160.0	320 MS	37.10	11.9	14.9
2	Vacuum chamber	ea	1	6000.00 eu	6.0	0	0.0	0	0.00	0.0	6.0
3	1-axis transln.mechanism ea.	ea	2	2500.00 eu	5.0	2	40.0	80 MS	37.10	3.0	8.0
4	Assemble	ea	2	500.00 eu	1.0	2	60.0	120 MS	37.10	4.5	5.5
5	Tank Mounting Hardware	ea	6	200.00 eu	1.2	6	4.0	24 MS	37.10	0.9	2.1
6	Survey/calibration	ea									

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ITEM NBR	ITEM DESCRIPTION	UNIT MEAS	NBR UNITS	UNIT COST BASIS	TOTAL COST	LBR K\$	PHRS/UNIT	TOTAL CRAFT HRS	CRAFT CODE	CRAFT RATE	TOTAL LABOR K\$	ISC + LABOR K\$
** WBS: 1.2.3.2.1.5 Personnel Safety Shut.												
1	Lead Plunger	ea	1	550.00 eu	0.6	1	52.0	52 MS	37.10	1.9	2.5	
2	Vacuum System	ea	1	5075.00 eu	5.1	1	190.0	190 MS	37.10	7.0	12.1	
3	Actuator Hardware	ea	1	2700.00 A87	2.7	1	80.0	80 MS	37.10	3.0	5.7	
4	Assemble & Test	ea	1	2400.00 eu	2.4	1	156.0	156 MS	37.10	5.8	8.2	
** Subtotal **					10.7	0		478		17.7	28.5	
** WBS: 1.2.3.2.1.6 PBPM #2												
1	Photon BPM System	ea	2	1500.00 A86	3.0	2	160.0	320 MS	37.10	11.9	14.9	
2	Vacuum chamber	ea	1	6000.00 eu	6.0	0	0.0	0	0.00	0.0	6.0	
3	1-axis transltion mechanism	ea	2	2500.00 eu	5.0	2	40.0	80 MS	37.10	3.0	8.0	
4	Assemble	ea	2	500.00 eu	1.0	2	60.0	120 MS	37.10	4.5	5.5	
5	Tank Mounting Hardware	ea	6	200.00 eu	1.2	6	4.0	24 MS	37.10	0.9	2.1	
6	Survey/calibration		0	0.00	0.0	1	32.0	32 MS	37.10	1.2	1.2	
7	Support post	ea	1	3000.00 eu	3.0	0	0.0	0	0.00	0.0	3.0	
8	Bakeout & leak checks	ea	1	100.00 eu	0.1	1	80.0	80 MS	37.10	3.0	3.1	
9	Pre-installation		10	0.00	0.0	1	80.0	80 MS	37.10	3.0	3.0	
10	LCW hardware & connctions	ea	1	300.00 eu	0.3	1	20.0	20 MS	37.10	0.7	1.0	
** Subtotal **					19.6	1		756		28.0	47.6	
** WBS: 1.2.3.2.1.7 Front End Vacuum System												
1	Bellows Assembly	ea	2	2200.00 A86	4.4	0	0.0	0	0.00	0.0	4.4	
2	4" UHV Isolation Valve	ea	1	10000.00 cp	10.0	0	0.0	0	0.00	0.0	10.0	
3	6" UHV Isolation Valve	ea	2	13000.00 cp	26.0	0	0.0	0	0.00	0.0	26.0	
4	4" Pipe Tee/Spool	ea	2	1500.00 eu	3.0	0	0.0	0	0.00	0.0	3.0	
5	Spool Support Post	ea	1	500.00 eu	0.5	0	0.0	0	0.00	0.0	0.5	
6	Shielding Wall Transition	ea	1	2500.00 eu	2.5	0	0.0	0	0.00	0.0	2.5	
7	Misc UHV Hardware	lot	1	2500.00 eu	2.5	1	40.0	40 MS	37.10	1.5	4.0	
8	Bakeout/leak check	lot	1	500.00 eu	0.5	1	80.0	80 MS	37.10	3.0	3.5	
9	S.R. REM to conflat	ea	1	300.00 cp	0.3	1	4.0	4 MS	37.10	10.0	0.4	
10	Survey/calibration		0	0.00	0.0	2	16.0	32 MS	37.10	1.2	1.2	
** Subtotal **					49.7	1		156		5.8	55.5	
** WBS: 1.2.3.2.1.8 Front End Mechanical Installation												
1	Assemble/leak check	lot	3	500.00 eu	1.5	3	16.0	48 MS	35.80	1.7	3.2	
2	Transport/set-up	lot	4	200.00 eu	0.8	4	32.0	128 MS	35.80	4.6	5.4	
3	Unistrut/misc hardware	lot	1	500.00 eu	0.5	1	40.0	40 MS	35.80	1.4	1.9	
4	Tools & Misc	lot	1	500.00 eu	0.5	1	40.0	40 MS	37.10	1.5	2.0	
5	Misc. machine shop	lot	1	500.00 eu	0.5	1	40.0	40 MS	37.10	1.5	2.0	
6	Lead Shielding Installatn	lot	1	3000.00 eu	3.0	1	80.0	80 MS	35.80	2.9	5.9	
7	Shielding Wall modificatn	lot	1	500.00 eu	0.5	1	100.0	100 MS	35.80	3.6	4.1	
8	F.E. Support Rail	ea	1	500.00 eu	0.5	1	120.0	120 MS	37.10	4.5	5.0	
9	Survey & Alignment	lot	1	200.00 eu	0.2	1	103.0	103 MS	37.10	3.8	4.0	
** Subtotal **					8.0	1		699		25.4	33.4	
** WBS: 1.2.3.2.2.1 Fixed Aperture Controls												
1	Vacuum Feedthru	ea	1	250.00 eu	0.2	1	8.0	8 MS	35.80	0.3	0.5	
2	Electrometer	ea	1	2795.00 cp	2.8	1	8.0	8 ES	29.80	0.2	3.0	
3	Eurocard Crate	ea	1	800.00 eu	0.8	1	16.0	16 ES	29.80	0.5	1.3	
4	ILC	ea	1	1000.00 eu	1.0	1	16.0	16 ES	29.80	0.5	1.5	
5	Cables	lot	1	300.00 eu	0.3	1	16.0	16 ES	29.80	0.5	0.8	
6	Installation		0	0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2	
7	Test		0	0.00	0.0	1	16.0	16 ES	29.80	0.5	0.5	
** Subtotal **					5.1	1		120		3.6	8.8	
** WBS: 1.2.3.2.2.2 PBPM #1 Controls												
1	Ion Pump 110/LS	ea	1	4750.00 cp	4.8	1	16.0	16 MS	37.10	0.6	5.3	
2	Ion Pump PS	ea	1	2000.00 cp	2.0	1	16.0	16 ES	29.80	0.5	2.5	
3	Bias Power Supply	ea	1	500.00 eu	0.5	1	8.0	8 ES	29.80	0.2	0.7	
4	Vacuum Feedthru	ea	5	250.00 eu	1.2	5	2.0	10 MS	37.10	0.4	1.6	
5	ILC & SBX	ea	2	1400.00 eu	2.8	2	16.0	32 ES	29.80	1.0	3.8	

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ITM	ITM	UNIT	NBR	UNIT COST	TOTAL	LBR	HRS/	TOTAL CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	COST BASIS	ISC K\$	UNTS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$
6	Electrometer	ea	4	1695.00 eu	6.8	4	4.0	16 ES	29.80	0.5	7.3
7	Eurocard Crate	ea	1	800.00 eu	0.8	1	16.0	16 ES	29.80	0.5	1.3
8	Motor Controller	ea	1	2400.00 eu	2.4	1	16.0	16 ES	29.80	0.5	2.9
9	Water Temp Controller	ea	1	1975.00 cp	2.0	1	16.0	16 MU	35.80	0.6	2.5
10	Cables	lot	1	500.00 eu	0.5	1	16.0	16 ES	29.80	0.5	1.0
11	Installation		0	0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2
12	Test		0	0.00	0.0	1	40.0	40 EM	29.80	1.2	1.2
13	Flow Switch	ea	2	400.00 eu	0.8	2	4.0	8 MU	35.80	0.3	1.1
14	Ion Gauge	ea	1	3000.00 eu	3.0	1	8.0	8 ES	29.80	0.2	3.2
** Subtotal **					27.6			258		8.0	35.6
WBS: 1.2.3.2.2.3 Photon Shutter Controls											
1	Ion Pump 400 l/s	ea	1	9900.00 cp	9.9	1	8.0	8 MU	35.80	0.3	10.2
2	Ion Pump PS	ea	1	1975.00 cp	2.0	1	8.0	8 ES	29.80	0.2	2.2
3	Ion Gauge	ea	1	3000.00 eu	3.0	1	8.0	8 ES	29.80	0.2	3.2
4	ILC & SBX	ea	1	1400.00 eu	1.4	1	16.0	16 ES	29.80	0.5	1.9
5	Position Indicators	set	1	500.00 eu	0.5	1	16.0	16 ES	29.80	0.5	1.0
6	Air Solenoids	ea	4	500.00 eu	2.0	4	8.0	32 MU	35.80	1.1	3.1
7	Air Press Interlock	ea	1	500.00 eu	0.5	1	16.0	16 MU	35.80	0.6	1.1
8	Installation		0	0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2
9	Test		0	0.00	0.0	1	24.0	24 EM	29.80	0.7	0.7
** Subtotal **					19.3			168		5.3	24.6
WBS: 1.2.3.2.2.4 Fast Valve Controls											
1	Ion Gauge	ea	3	3000.00 eu	9.0	3	8.0	24 ES	29.80	0.7	9.7
2	Trigger Unit	ea	1	5000.00 eu	5.0	1	80.0	80 ES	29.80	2.4	7.4
3	ILC	ea	1	1000.00 eu	1.0	1	16.0	16 ES	29.80	0.5	1.5
4	Eurocard Crate	ea	1	800.00 eu	0.8	1	16.0	16 ES	29.80	0.5	1.3
5	Installation		0	0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2
6	Test		0	0.00	0.0	1	40.0	40 EM	29.80	1.2	1.2
** Subtotal **					15.8			216		6.4	22.2
WBS: 1.2.3.2.2.5 Personnel Safety Shutter Controls											
1	Ion Pump 200 l/s	ea	1	5900.00 cp	5.9	1	8.0	8 MU	35.80	0.3	6.2
2	Ion Pump PS	ea	1	1975.00 cp	2.0	1	8.0	8 ES	29.80	0.2	2.2
3	Ion Gauge	ea	1	3000.00 eu	3.0	1	8.0	8 ES	29.80	0.2	3.2
4	ILC & SBX	ea	1	1400.00 eu	1.4	1	16.0	16 ES	29.80	0.5	1.9
5	Position Indicators	set	1	500.00 eu	0.5	1	16.0	16 ES	29.80	0.5	1.0
6	Air Solenoids	ea	4	500.00 eu	2.0	4	8.0	32 MU	35.80	1.1	3.1
7	Air Press Interlock	ea	1	500.00 eu	0.5	1	16.0	16 MU	35.80	0.6	1.1
8	Installation		0	0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2
9	Test		0	0.00	0.0	1	24.0	24 EM	29.80	0.7	0.7
** Subtotal **					15.3			168		5.3	20.6
WBS: 1.2.3.2.2.6 PBPM #2 Controls											
1	Ion Pump 110/Ls	ea	1	4750.00 cp	4.8	1	16.0	16 MS	37.10	0.6	5.3
2	Ion Pump PS	ea	1	2000.00 cp	2.0	1	16.0	16 ES	29.80	0.5	2.5
3	Bias Power Supply	ea	1	500.00 eu	0.5	1	8.0	8 ES	29.80	0.2	0.7
4	Vacuum Feedthru	ea	5	250.00 eu	1.2	5	2.0	10 MS	37.10	0.4	1.6
5	ILC & SBX	ea	2	1400.00 eu	2.8	2	16.0	32 ES	29.80	1.0	3.8
6	Electrometer	ea	4	1695.00 eu	6.8	4	4.0	16 ES	29.80	0.5	7.3
7	Eurocard Crate	ea	1	800.00 eu	0.8	1	16.0	16 ES	29.80	0.5	1.3
8	Motor Controller	ea	1	2400.00 eu	2.4	1	16.0	16 ES	29.80	0.5	2.9
9	Water Temp Controller	ea	1	1975.00 cp	2.0	1	16.0	16 MU	35.80	0.6	2.5
10	Cables	lot	1	500.00 eu	0.5	1	16.0	16 ES	29.80	0.5	1.0
11	Installation		0	0.00	0.0	1	40.0	40 ES	29.80	1.2	1.2
12	Test		0	0.00	0.0	1	40.0	40 EM	29.80	1.2	1.2
13	Flow Switch	ea	2	400.00 eu	0.8	2	4.0	8 MU	35.80	0.3	1.1
14	Ion Gauge	ea	1	3000.00 eu	3.0	1	8.0	8 ES	29.80	0.2	3.2
** Subtotal **					27.6			258		8.0	35.6

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ITM	ITM NBR DESCRIPTION	UNIT MEAS	NBR UNITS	UNIT COST COST BASIS	TOTAL LBR	HRS/ UNIT	TOTAL CRAFT	CRAFT RATE	TOTAL LABOR	ISC +
					ISC K\$	UNTS	HRS CODE		LABOR K\$	LABOR K\$
** WBS: 1.2.3.2.2.7	Vacuum System Controls				US 00.2001					
	0 X-connect	ea	1	270.00 cp	0.3	0.081	24 ES	29.80	0.7	1.0
	1 Cable Set	lot	3	100.00 eu	0.3	0.081	12 ES	29.80	0.4	0.7
	3 Relay blocks	ea	1	580.00 cp	0.6	0.162	24 ES	29.80	0.7	1.3
	4 48 Chan Opto-isolator	ea	1	700.00 cp	0.7	0.162	24 ES	29.80	0.7	1.4
** Subtotal **					1.8		84		2.5	4.4
** WBS: 1.2.3.2.3	Front End Safety Systems				US 00.1000					
	1 ILC & SBX	ea	2	1400.00 eu	2.8	0.0	0	0.00	0.0	2.8
	2 Eurocard Crate	ea	1	800.00 eu	0.8	0.0	0	0.00	0.0	0.8
	3 Key Panel	ea	1	300.00 cp	0.3	0.0	0	0.00	0.0	0.3
	4 Monitor Lights Panel	ea	6	250.00 cp	1.5	0.0	0	0.00	0.0	1.5
	5 Push Button Panel	ea	1	250.00 cp	0.2	0.0	0	0.00	0.0	0.2
	6 Breaker Panel	ea	1	250.00 cp	0.2	0.0	0	0.00	0.0	0.2
	7 Cables	lot	1	100.00 eu	0.1	0.0	0	0.00	0.0	0.1
	8 Wiring Assembly		0	0.00	0.0	80.0	80 ES	29.80	2.4	2.4
	9 PLIC radiation monitor	ft	100	11.00 cp	1.1	0.0	0	0.00	0.0	1.1
	10 PLIC Camac HV PS	ea	1	1000.00 eu	1.0	0.0	0	0.00	0.0	1.0
	11 PLIC Monitoring Card	ea	1	2700.00 cp	2.7	0.0	0	0.00	0.0	2.7
	12 PLIC Other Electronics	lot	1	3000.00 eu	3.0	1.0	20 ES	29.80	0.6	3.6
	13 PLIC Installation	lot	1	800.00 eu	0.8	1.0	8 EI	29.80	0.2	1.0
	14 PLIC Installation	ea	100	1.00 eu	0.1	1.0	8 EI	29.80	0.2	0.3
	15 Systems Test		0	0.00	0.0	1.0	80 EM	29.80	2.4	2.4
	16 Video Camera & Lens	ea	1	800.00 cp	0.8	0.0	0	0.00	0.0	0.8
	17 Video Monitor	ea	1	300.00 cp	0.3	0.0	0	0.00	0.0	0.3
	18 Coax: camera to monitor	ea	1	50.00 eu	0.1	2.0	2 EI	29.80	0.1	0.1
	19 Video Connectors	ea	2	5.00 eu	0.0	0.5	1 ES	29.80	0.0	0.0
	20 Padlocks & misc hardware	lot	1	500.00 eu	0.5	0.0	0	0.00	0.0	0.5
** Subtotal **					16.4		199		5.9	22.3
** WBS: 1.2.3.2.4	Front End Utilities									
	1 F.E. pneumatic service	lot	1	2000.00 eu	2.0	1.0	120 MU	35.80	4.3	6.3
	2 F.E. LCW service	lot	1	2000.00 eu	2.0	1.0	120 MU	35.80	4.3	6.3
	3 Cable trays, conduit, etc	lot	1	2000.00 eu	2.0	1.0	120 PE	36.10	4.3	6.3
	4 Unistrut & misc hardware	lot	1	1000.00 eu	1.0	1.0	40 MS	37.10	1.5	2.5
	5 Double elec rack	ea	1	1200.00 eu	1.2	1.0	16 ES	29.80	0.5	1.7
	6 BA panel 3 ph 30A	ea	1	50.00 cp	0.1	0.5	0 EI	29.80	0.1	0.1
	7 Breaker panel	ea	2	200.00 cp	0.4	2.0	8 EI	29.80	0.2	0.6
	8 Plug Strip	ea	2	20.00 eu	0.0	2.0	2 EI	29.80	0.1	0.1
	9 Rack Fans	ea	2	50.00 cp	0.1	2.0	2 ES	29.80	0.1	0.2
	10 X-conn blocks & frame	ea	1	500.00 cp	0.5	1.0	24 EI	29.80	0.7	1.2
	11 Relay blocks & frame	ea	1	500.00 cp	0.5	1.0	24 EI	29.80	0.7	1.2
** Subtotal **					9.8		476		16.7	26.5
** WBS: 1.2.3.2.5	Front End Mech/Elect System Integration									
	1 Controls Checkout/Debug		0	0.00	0.0	7.0	112 MT	26.10	2.9	2.9
	2		0	0.00	0.0	7.0	112 EM	29.80	3.3	3.3
	3		0	0.00	0.0	7.0	112 CP	52.60	5.9	5.9
	4		0	0.00	0.0	7.0	112 EI	29.80	3.3	3.3
	5 Safety System Check/Debug		0	0.00	0.0	4.0	32 MT	26.10	0.8	0.8
	6		0	0.00	0.0	4.0	32 EM	29.80	1.0	1.0
	7		0	0.00	0.0	4.0	32 EI	29.80	1.0	1.0
	8 Vacuum System Checks		0	0.00	0.0	4.0	64 MT	26.10	1.7	1.7
	9		0	0.00	0.0	4.0	64 EM	29.80	1.9	1.9
	10 Misc. Hardware	lot	1	1000.00 eu	1.0	1.0	40 MS	37.10	1.5	2.5
** Subtotal **					1.0		712		23.3	24.3
** WBS: 1.2.3.3.1.1.1	Beam Defining Apertures				US 00.0000					
	1 Vacuum Chamber	ea	1	12000.00 A87	12.0	0.0	0	0.00	0.0	12.0
	2 Roughing Valve	ea	1	750.00 cp	0.8	0.0	0	0.00	0.0	0.8
	3 Tank Support Posts	ea	1	1000.00 eu	1.0	0.0	0	0.00	0.0	1.0
	4 Tank Mounting Struts	ea	6	200.00 eu	1.2	6.0	120 MS	37.10	4.5	5.7

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ITM	ITM	UNIT	NBR	UNIT	COST	TOTAL	LBR	HRS/	TOTAL	CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	UNIT	COST BASIS	ISC K\$	UNTS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$	
5	Brazed Absorber Assy	ea	4		500.00 eu	2.0	4	100.0	400 MS	37.10	14.8	16.8	
6	Brazing & Tooling Fixtures	ea	1		100.00 eu	0.1	2	40.0	80 MS	37.10	3.0	3.1	
7	UHV Mounting Hardware	lot	4		500.00 eu	2.0	4	20.0	80 MS	37.10	3.0	5.0	
8	Bellows Assembly	ea	4		2000.00 eu	8.0	0	0.0	0	0.00	0.0	8.0	
9	Stepper/Encoder Positioner	ea	4		2500.00 eu	10.0	0	0.0	0	0.00	0.0	10.0	
10	Flanges/misc UHV hardware	lot	10		500.00 eu	5.0	0	0.0	0	0.00	0.0	5.0	
11	LCV Hardware	ea	2		300.00 eu	0.6	0	0.0	0	0.00	0.0	0.6	
12	Assemble UHV subsystems	ea	4		100.00 eu	0.4	4	20.0	80 MS	37.10	3.0	3.4	
13	Survey & Calibration		0		0.00	0.0	4	16.0	64 MS	37.10	2.4	2.4	
14	Pumpdown & Leakcheck	lot	1		50.00 eu	0.1	1	40.0	40 MS	37.10	1.5	1.5	
15	Bakout	lot	1		50.00 eu	0.1	1	80.0	80 MS	37.10	3.0	3.0	
16	Assemble Positioners	ea	4		50.00 eu	0.2	4	20.0	80 MS	37.10	3.0	3.2	
17	Misc. Assembly Hardware	lot	1		1000.00 eu	1.0	1	40.0	40 MS	37.10	1.5	2.5	
18	Pre-installation checkout		0		0.00	0.0	1	40.0	40 MS	37.10	1.5	1.5	
19	Prep for transportation	lot	1		50.00 eu	0.1	1	8.0	8 MS	37.10	0.3	0.3	
** Subtotal **						44.4			1112		41.3	85.7	
*** WBS: 1.2.3.3.1.1.2 Monochromator ***													
1	Exit Slit	lot	3		18050.00 eu	54.1	3	200.0	600 MS	37.10	22.3	76.4	
2	Grating Mount/Scan Mech	ea	1		49000.00 A87	49.0	1	1160.0	1160 MS	37.10	43.0	92.0	
3	Grating Substrates	ea	1		2600.00 eu	2.6	1	464.0	464 MS	37.10	17.2	19.8	
4	Grating Polish/Rule/Coat	ea	3		41000.00 eu	123.0	0	0.0	0	0.00	0.0	123.0	
5	Vacuum System	lot	1		71850.00 eu	71.8	1	960.0	960 MS	37.10	35.6	107.5	
6	Assemble & Bakeout	ea	1		1800.00 eu	1.8	1	680.0	680 MS	37.10	25.2	27.0	
7	Installation	lot	1		450.00 eu	0.5	1	16.0	16 MS	37.10	0.6	1.0	
8			0		0.00	0.0	1	16.0	16 ICO	64.70	1.0	1.0	
9			0		0.00	0.0	1	96.0	96 MU	35.80	3.4	3.4	
10	Survey & Alignment		0		0.00	0.0	1	40.0	40 MS	37.10	1.5	1.5	
11	Pumps	lot	2		8250.00 eu	16.5	0	0.0	0	0.00	0.0	16.5	
12	Ion Gauge Controllers	ea	1		5000.00 eu	5.0	0	0.0	0	0.00	0.0	5.0	
** Subtotal **						324.4			4032		149.9	474.3	
*** WBS: 1.2.3.3.1.1.3 Branch Line Diagnostics ***													
1	Diagnostic #1	ea	1		7700.00 eu	7.7	1	208.0	208 MS	37.10	7.7	15.4	
2	Diagnostic #2	ea	1		6700.00 eu	6.7	1	148.0	148 MS	37.10	5.5	12.2	
3	Diagnostic #3	ea	1		6700.00 eu	6.7	1	148.0	148 MS	37.10	5.5	12.2	
** Subtotal **						21.1			504		18.7	39.8	
*** WBS: 1.2.3.3.1.1.4 Branch Line Vacuum System ***													
1	4" UHV Isolation Valve	ea	4		9460.00 cp	37.8	0	0.0	0	0.00	0.0	37.8	
2	6"cf Spools	ea	4		500.00 cp	2.0	0	0.0	0	0.00	0.0	2.0	
3	6"cf Bellows Assembly	ea	6		2000.00 A86	12.0	0	0.0	0	0.00	0.0	12.0	
4	Spool Support Posts	ea	4		500.00 eu	2.0	0	0.0	0	0.00	0.0	2.0	
5	Misc UHV Hardware	lot	1		2500.00 eu	2.5	1	120.0	120 MS	37.10	4.5	7.0	
6	Bakeout & Leak check	lot	1		2500.00 eu	2.5	1	120.0	120 MS	37.10	4.5	7.0	
** Subtotal **						58.8			240		8.9	67.7	
*** WBS: 1.2.3.3.1.1.5 Branch Line Mechanical Installation ***													
1	Assemble/Leak check	lot	1		1000.00 eu	1.0	1	120.0	120 MS	37.10	4.5	5.5	
2	Transport & Setup	lot	3		200.00 eu	0.6	3	32.0	96 MU	35.80	3.4	4.0	
3	Unitatrust & Misc. Hardware	lot	1		500.00 eu	0.5	1	80.0	80 MU	35.80	2.9	3.4	
4	Misc. Mechanical work	lot	1		500.00 eu	0.5	1	40.0	40 MS	37.10	1.5	2.0	
5	Misc. Machine shop	lot	1		500.00 eu	0.5	1	40.0	40 MS	37.10	1.5	2.0	
6	Lead Shielding Installatn	lot	1		1000.00 eu	1.0	1	40.0	40 MU	35.80	1.4	2.4	
7	Support Rail	ea	1		500.00 eu	0.5	1	120.0	120 MS	37.10	4.5	5.0	
8	Survey & Alignment	lot	1		200.00 eu	0.2	1	131.0	131 MS	37.10	4.9	5.1	
** Subtotal **						4.8			667		24.5	29.3	
*** WBS: 1.2.3.3.1.2.1 Photon Transport Controls & Diagnostics ***													
1	Ion Pump Controls/Cables	lot	1		65400.00 CP	65.4	1	40.0	40 EI	29.80	1.2	66.6	
2	Ion Gauges/Controls	lot	1		18300.00 eu	18.3	1	40.0	40 EI	29.80	1.2	19.5	

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ITM	ITM	UNIT	NBR	UNIT	COST	TOTAL	LBR	HRS	TOTAL	CRAFT	CRAFT	TOTAL	ISC	ISC
NBR	DESCRIPTION	MEAS	UNITS		COST BASIS	ISC K\$	UNTS	UNIT	HRS	CODE	RATE	LABOR K\$	LABOR K\$	LABOR K\$
3	Interlocks & Actuators	lot	1		5400.00 eu			40.0					6.6	
4	Positioning Controls	lot	1		77800.00 eu			80.0					80.2	
5	Optical Cleaning Controls	lot	2		10000.00 eu			20.0					20.6	
6	Beam Positioning Controls	ea	2		2100.00 eu			10.0					4.5	
** Subtotal **														198.0
** WBS: 1.2.3.3.1.2.2 Monochromator Controls														
1	Programmable Logic Controller	lot	1		8500.00 eu			20.0					9.1	
2			0		0.00			40.0					2.1	
3	Branch Line Device Server	ea	1		7800.00 cp			40.0					9.9	
4	Network Interface	lot	1		5000.00 eu			10.0					5.3	
5	Display/Control Station	ea	1		13000.00 eu			40.0					15.1	
6	TV Display Controls	ea	1		5900.00 eu			20.0					6.5	
7	24VDC Distribution	lot	1		4000.00 eu			60.0					5.8	
** Subtotal **														53.8
** WBS: 1.2.3.3.1.2.3 Branch Line Electrical Installation														
1	Racks & Trays	lot	1		3450.00 CP			80.0					5.8	
2	Ion Pump Interconnects	ft	600		1.00 eu			16.0					1.1	
3	Ion Gauge Interconnect	ft	600		2.00 eu			32.0					2.2	
4	Intrck/Actuator Intrcnct	ft	400		3.00 eu			40.0					2.4	
5	Position Controls Intrcnct	ft	800		2.50 eu			40.0					3.2	
6	Optical Cleaning Intrcnct	ft	200		1.00 eu			10.0					0.5	
** Subtotal **														15.1
** WBS: 1.2.3.3.1.3 Branch Line Safety Systems														
1	ILC & SBX	ea	1		1400.00 eu			0.0					1.4	
2	Eurocard Crate	ea	1		800.00 eu			0.0					0.8	
3	Key Panel	ea	1		300.00 cp			0.0					0.3	
4	Monitor Lights Panel	ea	6		250.00 cp			0.0					1.5	
5	Push Button Panel	ea	1		250.00 cp			0.0					0.2	
6	Breaker Panel	ea	1		250.00 cp			0.0					0.2	
7	Cables	lot	1		100.00 eu			0.0					0.1	
8	Wiring Assembly		0		0.00			80.0					2.4	
9	Systems Test		0		0.00			80.0					2.4	
10	Padlocks & Misc. Hardware	lot	1		500.00 eu			0.0					0.5	
** Subtotal **														9.9
** WBS: 1.2.3.3.1.4 Branch Line Utilities														
1	Pneumatic Service	lot	1		1500.00 eu			120.0					5.8	
2	LCW Service	lot	1		1500.00 eu			120.0					5.8	
3	Cable Trays, Conduit, etc	lot	1		2000.00 eu			120.0					6.3	
4	Unitstrut/Misc. Hardware	lot	1		1000.00 eu			40.0					2.5	
5	Double Elec. Rack	ea	1		1200.00 cp			16.0					1.2	
6	BA panel 3 PH 30A	ea	1		50.00 CP			0.5					0.1	
7	Breaker Panel	ea	2		200.00 CP			4.0					0.6	
8	Plug Strip	ea	2		20.00 eu			1.0					0.1	
9	Rack Fans	ea	2		50.00 eu			1.0					0.2	
10	X-conn blocks & frame	ea	1		500.00 cp			24.0					1.2	
11	Relay blks & frame	ea	1		500.00 cp			24.0					1.2	
** Subtotal **														25.0
** WBS: 1.2.3.3.1.5 Branch Line Mech/Elect System Integration														
1	Controls Checkout/Debug		0		0.00			16.0					2.5	
2			0		0.00			16.0					2.9	
3			0		0.00			16.0					5.0	
4			0		0.00			16.0					2.9	
5	Safety Systems Checkout		0		0.00			8.0					0.8	
6			0		0.00			8.0					1.0	
7			0		0.00			8.0					1.0	
8	Vacuum System Checks		0		0.00			16.0					1.7	

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ITEM	ITEM NBR	DESCRIPTION	UNIT MEAS	NBR UNITS	UNIT COST	TOTAL COST	LBR UNITS	HRS/UNIT	TOTAL HRS	CRAFT CODE	CRAFT RATE	TOTAL LABOR K\$	ISC + LABOR K\$
	9			0	0.00	0.0	4	16.0					
	10	Misc. Hardware	lot	1	1000.00	1.0	1	40.0		64 EM	29.80	1.9	1.9
										40 MS	37.10	1.5	2.5
	**	Subtotal **				1.0				648		21.1	22.1
	**	WBS: 1.2.3.3.2 Main Scanning Microscope Station											
	1	Spherical Mirrors		2	10500.00	21.0	0	0.0		0	0.00	0.0	21.0
	2	Mirror mount/steer system		2	26250.00	52.5	0	0.0		0	0.00	0.0	52.5
	3	Multilayer substrates/ctng		1	52500.00	52.5	0	0.0		0	0.00	0.0	52.5
	4	M'layer mounting/steering		1	26250.00	26.2	0	0.0		0	0.00	0.0	26.2
	5	Part cost:support structur		1	31500.00	31.5	0	0.0		0	0.00	0.0	31.5
	6	Building modifications		1	21000.00	21.0	0	0.0		0	0.00	0.0	21.0
	7	Smpl stage/envirom cntrl		1	10500.00	10.5	0	0.0		0	0.00	0.0	10.5
	8	Smpl trgting microscop sys		1	21000.00	21.0	0	0.0		0	0.00	0.0	21.0
	9	White lite interferometer		1	5250.00	5.2	0	0.0		0	0.00	0.0	5.2
	10	Piezoelectrc scan motion		1	21000.00	21.0	0	0.0		0	0.00	0.0	21.0
	11	Position meas intrfrmr		1	15750.00	15.8	0	0.0		0	0.00	0.0	15.8
	12	Interferometer electronic		1	5250.00	5.2	0	0.0		0	0.00	0.0	5.2
	13	Computing sys & interfacs		1	42000.00	42.0	0	0.0		0	0.00	0.0	42.0
	14	Part cost:image system		1	26250.00	26.2	0	0.0		0	0.00	0.0	26.2
	15	Granite table		1	15750.00	15.8	0	0.0		0	0.00	0.0	15.8
	16	Microfab:zone plts/wndws		1	68250.00	68.2	0	0.0		0	0.00	0.0	68.2
	17	Software & controls		1	78750.00	78.8	0	0.0		0	0.00	0.0	78.8
	18	Vacuum hardware		1	63000.00	63.0	0	0.0		0	0.00	0.0	63.0
	19	Electronics & interfaces		1	26250.00	26.2	0	0.0		0	0.00	0.0	26.2
	**	Subtotal **				603.8				0		0.0	603.8
	**	WBS: 1.2.3.3.3 R/D Scanning Microscope Station											
	1	Spherical mirrors		2	10500.00	21.0	0	0.0		0	0.00	0.0	21.0
	2	Mirror mount/steer system		2	26250.00	52.5	0	0.0		0	0.00	0.0	52.5
	3	Part cost:support structur		1	31500.00	31.5	0	0.0		0	0.00	0.0	31.5
	4	Smpl stage/envirom cntrl		1	21000.00	21.0	0	0.0		0	0.00	0.0	21.0
	5	Smpl trgting microscop sys		1	21000.00	21.0	0	0.0		0	0.00	0.0	21.0
	6	White lite intrfrmr focs		1	5250.00	5.2	0	0.0		0	0.00	0.0	5.2
	7	Piezoelectrc scan system		1	21000.00	21.0	0	0.0		0	0.00	0.0	21.0
	8	Position meas intrfrmr		1	15750.00	15.8	0	0.0		0	0.00	0.0	15.8
	9	Interferometer electronics		1	5250.00	5.2	0	0.0		0	0.00	0.0	5.2
	10	Computing sys & interfacs		1	42000.00	42.0	0	0.0		0	0.00	0.0	42.0
	11	Part cost:image dsply sys		1	26250.00	26.2	0	0.0		0	0.00	0.0	26.2
	12	Granite table		1	15750.00	15.8	0	0.0		0	0.00	0.0	15.8
	13	Microfab:zone plts/wndws		1	105000.00	105.0	0	0.0		0	0.00	0.0	105.0
	14	Software and controls		1	21000.00	21.0	0	0.0		0	0.00	0.0	21.0
	15	Vacuum hardware		1	63000.00	63.0	0	0.0		0	0.00	0.0	63.0
	16	Electronics & interfaces		1	26250.00	26.2	0	0.0		0	0.00	0.0	26.2
	**	Subtotal **				493.5				0		0.0	493.5
	**	WBS: 1.2.3.3.4 Diffraction Imaging Station											
	1	Spherical mirrors		2	10500.00	21.0	0	0.0		0	0.00	0.0	21.0
	2	Mirror mount/steer system		2	31500.00	63.0	0	0.0		0	0.00	0.0	63.0
	3	Part cost:support structur		1	31500.00	31.5	0	0.0		0	0.00	0.0	31.5
	4	Smpl stage/envirom cntrl		1	21000.00	21.0	0	0.0		0	0.00	0.0	21.0
	5	Smpl trgting microscop sys		1	21000.00	21.0	0	0.0		0	0.00	0.0	21.0
	6	Computing sys & interfacs		1	42000.00	42.0	0	0.0		0	0.00	0.0	42.0
	7	Part cost:image dsply sys		1	26250.00	26.2	0	0.0		0	0.00	0.0	26.2
	8	Granite table		1	15750.00	15.8	0	0.0		0	0.00	0.0	15.8
	9	Microfab:zone plts/wndws		1	52500.00	52.5	0	0.0		0	0.00	0.0	52.5
	10	CCD detector & interfaces		1	42000.00	42.0	0	0.0		0	0.00	0.0	42.0
	11	Vacuum hardware		1	63000.00	63.0	0	0.0		0	0.00	0.0	63.0
	**	Subtotal **				399.0				0		0.0	399.0
	**	WBS: 1.3.1.1.1 Engineering											
	1	Engineering		1	129000.00	129.0	0	0.0		0	0.00	0.0	129.0

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ITM	ITM	UNIT	NBR	UNIT	UNIT COST	TOTAL	LBR	HRS	TIV	TOTAL CRAFT	CRAFT	TOTAL	ISC	+
NBR	DESCRIPTION	MEAS	UNITS		COST BASIS	ISC	KS	UNTS	UNIT	HRS	CODE	RATE	LABOR	KS
** Subtotal **						00.00	0						0.0	129.0
** Subtotal **						129.0	0			0			0.0	129.0
** WBS: 1.3.1.1.2	Consultants													
1 Consultants			1		16000.00	16.0	0		0.0	0		0.00	0.0	16.0
** Subtotal **						16.0	0			0			0.0	16.0
** WBS: 1.3.1.1.3	Inspection													
1 Inspection			1		69000.00	69.0	0		0.0	0		0.00	0.0	69.0
** Subtotal **						69.0	0			0			0.0	69.0
** WBS: 1.3.1.2.1	Title I													
1 Title I			1		83000.00	83.0	0		0.0	0		0.00	0.0	83.0
** Subtotal **						83.0	0			0			0.0	83.0
** WBS: 1.3.1.2.2	Title II													
1 Title II			1		155000.00	155.0	0		0.0	0		0.00	0.0	155.0
** Subtotal **						155.0	0			0			0.0	155.0
** WBS: 1.3.1.2.3	Title III													
1 Title III			1		54000.00	54.0	0		0.0	0		0.00	0.0	54.0
** Subtotal **						54.0	0			0			0.0	54.0
** WBS: 1.3.2.1	Improvements to Land													
1 General Requirements			1		2190.00	2.2	0		0.0	0		0.00	0.0	2.2
2 Site work			1		10000.00	10.0	0		0.0	0		0.00	0.0	10.0
** Subtotal **						12.2	0			0			0.0	12.2
** WBS: 1.3.2.2.1	General Requirements													
1 General Requirements			1		210760.00	210.8	0		0.0	0		0.00	0.0	210.8
** Subtotal **						210.8	0			0			0.0	210.8
** WBS: 1.3.2.2.2	Sitework													
1 Demolition			1		98640.00	98.6	0		0.0	0		0.00	0.0	98.6
** Subtotal **						98.6	0			0			0.0	98.6
** WBS: 1.3.2.2.3	Concrete													
1 Concrete			1		16950.00	16.9	0		0.0	0		0.00	0.0	16.9
** Subtotal **						16.9	0			0			0.0	16.9
** WBS: 1.3.2.2.5	Metals													
1 Metals			1		134290.00	134.3	0		0.0	0		0.00	0.0	134.3
** Subtotal **						134.3	0			0			0.0	134.3
** WBS: 1.3.2.2.6	Carpentry													
1 Wood & Plastic			1		6080.00	6.1	0		0.0	0		0.00	0.0	6.1
** Subtotal **						6.1	0			0			0.0	6.1
** WBS: 1.3.2.2.7	Thermal and Moisture Protection													
1 Thermal & Moisture Protct			1		10020.00	10.0	0		0.0	0		0.00	0.0	10.0
** Subtotal **						10.0	0			0			0.0	10.0
** WBS: 1.3.2.2.8	Doors, Windows & Glass													
1 Doors & Windows			1		31920.00	31.9	0		0.0	0		0.00	0.0	31.9

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ITM	ITM	UNIT	NBR	UNIT COST	TOTAL	LBR	HRS	TOTAL CRAFT	CRAFT	TOTAL	ISC +
NBR	DESCRIPTION	MEAS	UNITS	COST BASIS	ISC K\$	UNITS	UNIT	HRS CODE	RATE	LABOR K\$	LABOR K\$
** Subtotal **											
					31.9			0		0.0	31.9
2.1	WBS: 1.3.2.2.9	Finishes	1	145960.00	146.0	0	0.0	0	0.00	0.0	146.0
2.1	1 Finishes				146.0			0		0.0	146.0
** Subtotal **											
0.05	WBS: 1.3.2.2.10	Specialties	1	7568.00	7.6	0	0.0	0	0.00	0.0	7.6
0.05	1 Specialties				7.6			0		0.0	7.6
** Subtotal **											
0.05	WBS: 1.3.2.2.12	Furnishings	1	2104.00	2.1	0	0.0	0	0.00	0.0	2.1
0.05	1 Furnishings				2.1			0		0.0	2.1
** Subtotal **											
0.05	WBS: 1.3.2.2.14	Conveying Systems	1	90000.00	90.0	0	0.0	0	0.00	0.0	90.0
0.05	1 Hydraulic Elevator				90.0			0		0.0	90.0
** Subtotal **											
0.05	WBS: 1.3.2.2.15	Mechanical Work	1	83000.00	83.0	0	0.0	0	0.00	0.0	83.0
0.05	1 Plumbing & Process Piping				83.0			0		0.0	83.0
0.05	2 HVAC		1	184000.00	184.0	0	0.0	0	0.00	0.0	184.0
0.05	3 Fire Protection Systems		1	5200.00	5.2	0	0.0	0	0.00	0.0	5.2
** Subtotal **											
0.05	WBS: 1.3.2.2.16	Electrical Work	1	143110.00	143.1	0	0.0	0	0.00	0.0	143.1
0.05	1 Electrical				143.1			0		0.0	143.1
** Subtotal **											
0.05	WBS: 1.3.2.3.1	General Requirements	1	138000.00	138.0	0	0.0	0	0.00	0.0	138.0
0.05	1 General Requirements				138.0			0		0.0	138.0
** Subtotal **											
0.05	WBS: 1.3.2.3.5	Metals	1	15100.00	15.1	0	0.0	0	0.00	0.0	15.1
0.05	1 Metals				15.1			0		0.0	15.1
** Subtotal **											
0.05	WBS: 1.3.2.3.6	Carpentry	1	7650.00	7.7	0	0.0	0	0.00	0.0	7.7
0.05	1 Rough Carpentry				10.2	0	0.0	0	0.00	0.0	10.2
0.05	2 Finish Carpentry				17.9			0		0.0	17.9
** Subtotal **											
0.05	WBS: 1.3.2.3.8	Doors, Windows & Glass	1	25570.00	25.6	0	0.0	0	0.00	0.0	25.6
0.05	1 Metal Doors & Frames				25.6			0		0.0	25.6
** Subtotal **											
0.05	WBS: 1.3.2.3.9	Finishes	1	25309.00	25.3	0	0.0	0	0.00	0.0	25.3
0.05	1 Gypsum Wall Board, Taping				29.4	0	0.0	0	0.00	0.0	29.4
0.05	2 Acoustic Treatment		1	17862.00	17.9	0	0.0	0	0.00	0.0	17.9
0.05	3 Resilient Flooring		1	14606.00	14.6	0	0.0	0	0.00	0.0	14.6
0.05	4 Painting and Wall Covering		1	59924.00	59.9	0	0.0	0	0.00	0.0	59.9
0.05	5 Metal stud partitions		1	80388.00	80.4	0	0.0	0	0.00	0.0	80.4
** Subtotal **											
0.05					227.5			0		0.0	227.5

3600

2200 3800

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Technical Components Cost Estimate

ITM	ITM NBR	DESCRIPTION	UNIT MEAS	NBR UNITS	UNIT COST	TOTAL LBR	HRS/ UNIT	TOTAL CRAFT HRS	CRAFT RATE	TOTAL LABOR K\$	ISC + LABOR K\$
Specialties											
** WBS: 1.3.2.3.10		Specialties		1	1530.00	1.5	0	0.0	0.00	0.0	1.5
** Subtotal **						1.5	0	0.0	0.00	0.0	1.5
Special Construction											
** WBS: 1.3.2.3.13		Special Construction		1	20000.00	20.0	0	0.0	0.00	0.0	20.0
** Subtotal **						20.0	0	0.0	0.00	0.0	20.0
Mechanical Work											
** WBS: 1.3.2.3.15		Mechanical Work									
1		Plumbing & Process Piping		1	77000.00	77.0	0	0.0	0.00	0.0	77.0
2		HVAC		1	152000.00	152.0	0	0.0	0.00	0.0	152.0
3		Fire Protection Systems		1	5500.00	5.5	0	0.0	0.00	0.0	5.5
** Subtotal **						234.5	0	0.0	0.00	0.0	234.5
Electrical Work											
** WBS: 1.3.2.3.16		Electrical Work									
1		2nd flr office/lab improv		1	75081.00	75.1	0	0.0	0.00	0.0	75.1
2		Beamline labs exper floor		1	10670.00	10.7	0	0.0	0.00	0.0	10.7
** Subtotal **						85.8	0	0.0	0.00	0.0	85.8
General Requirements											
** WBS: 1.3.2.4.1		General Requirements		1	15200.00	15.2	0	0.0	0.00	0.0	15.2
** Subtotal **						15.2	0	0.0	0.00	0.0	15.2
Mechanical											
** WBS: 1.3.2.4.15		Mechanical		1	15000.00	15.0	0	0.0	0.00	0.0	15.0
** Subtotal **						15.0	0	0.0	0.00	0.0	15.0
Electrical											
** WBS: 1.3.2.4.16		Electrical		1	54150.00	54.1	0	0.0	0.00	0.0	54.1
** Subtotal **						54.1	0	0.0	0.00	0.0	54.1
Lab Furniture & Standard Fume Hoods											
** WBS: 1.3.2.5.1		Lab Furniture & Standard Fume Hoods									
1		Building 80		1	174000.00	174.0	0	0.0	0.00	0.0	174.0
2		Building 6		1	124000.00	124.0	0	0.0	0.00	0.0	124.0
** Subtotal **						298.0	0	0.0	0.00	0.0	298.0
Cold Rooms											
** WBS: 1.3.2.5.2		Cold Rooms									
1		Building 80		1	18300.00	18.3	0	0.0	0.00	0.0	18.3
2		Building 6		1	36600.00	36.6	0	0.0	0.00	0.0	36.6
** Subtotal **						54.9	0	0.0	0.00	0.0	54.9
Laminar Flow Hoods (3)											
** WBS: 1.3.2.5.3		Laminar Flow Hoods (3)									
1		Hoods		1	43920.00	43.9	0	0.0	0.00	0.0	43.9
** Subtotal **						43.9	0	0.0	0.00	0.0	43.9
Digital Scanning Elctrn Microscope w/Workstatn											
** WBS: 1.3.2.5.4.1		Digital Scanning Elctrn Microscope w/Workstatn									
1		Digital Scanning Microscope		1	268000.00	268.0	0	0.0	0.00	0.0	268.0
** Subtotal **						268.0	0	0.0	0.00	0.0	268.0
Hires Electron Microscope w/Cryo Workstation											
** WBS: 1.3.2.5.4.2		Hires Electron Microscope w/Cryo Workstation									
1		High Res Elctrn Microscop		1	206000.00	206.0	0	0.0	0.00	0.0	206.0
** Subtotal **						206.0	0	0.0	0.00	0.0	206.0

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Technical Components Cost Estimate

ITM NBR	ITM DESCRIPTION	UNIT MEAS	NBR UNITS	UNIT COST	TOTAL COST	LBR UNITS	HRS/UNIT	TOTAL HRS	CRAFT CODE	CRAFT RATE	TOTAL LABOR K\$	ISC + LABOR K\$
** WBS: 1.3.2.5.4.3 Confocal Microscope												
1	Confocal Microscope		1	89000.00	89.0	0	0.0	0	0.00	0.0	89.0	
** Subtotal **					89.0			0		0.0	89.0	
** WBS: 1.3.2.5.4.4 Image Analysis Package												
1	Image Analysis Package		1	83000.00	83.0	0	0.0	0	0.00	0.0	83.0	
** Subtotal **					83.0			0		0.0	83.0	
** WBS: 1.3.3.1 Biochemistry												
1	Centrifuges		1	251000.00	251.0	0	0.0	0	0.00	0.0	251.0	
2	Spectrophotometers		1	189000.00	189.0	0	0.0	0	0.00	0.0	189.0	
3	Balances		1	61000.00	61.0	0	0.0	0	0.00	0.0	61.0	
4	Isotope counters		1	42000.00	42.0	0	0.0	0	0.00	0.0	42.0	
5	Separation equipment		1	221000.00	221.0	0	0.0	0	0.00	0.0	221.0	
6	General lab equipment		1	303000.00	303.0	0	0.0	0	0.00	0.0	303.0	
** Subtotal **					1067.0			0		0.0	1067.0	
** WBS: 1.3.3.2 Microscopy												
1	Darkroom equipment		1	54000.00	54.0	0	0.0	0	0.00	0.0	54.0	
2	General lab equipment		1	55000.00	55.0	0	0.0	0	0.00	0.0	55.0	
** Subtotal **					109.0			0		0.0	109.0	
** WBS: 1.3.3.3 Cell and Tissue Culture												
1	Incubators		1	47000.00	47.0	0	0.0	0	0.00	0.0	47.0	
2	Sterilizer		1	38000.00	38.0	0	0.0	0	0.00	0.0	38.0	
3	General lab equipment		1	54000.00	54.0	0	0.0	0	0.00	0.0	54.0	
** Subtotal **					139.0			0		0.0	139.0	
** WBS: 1.3.3.4 Surgical Suite												
1	Tables, instruments, lighting		1	20000.00	20.0	0	0.0	0	0.00	0.0	20.0	
2	Microscope & video equip		1	49000.00	49.0	0	0.0	0	0.00	0.0	49.0	
3	General lab equipment		1	11000.00	11.0	0	0.0	0	0.00	0.0	11.0	
** Subtotal **					80.0			0		0.0	80.0	
** WBS: 1.3.3.5 General Support Equipment												
1	Computational equipment		1	254000.00	254.0	0	0.0	0	0.00	0.0	254.0	
2	Glass Wash/Handling Equip		1	88000.00	88.0	0	0.0	0	0.00	0.0	88.0	
3	Office furniture		1	37000.00	37.0	0	0.0	0	0.00	0.0	37.0	
4	Office equipment		1	13000.00	13.0	0	0.0	0	0.00	0.0	13.0	
** Subtotal **					392.0			0		0.0	392.0	
** WBS: 1.4.1 Special Research Facilities and Management												
1	Special Research Facility		1	3544033.00	3544.0	0	0.0	0	0.00	0.0	3544.0	
2	Project Mgmt & Admin		1	285590.00	285.6	0	0.0	0	0.00	0.0	285.6	
** Subtotal **					3829.6			0		0.0	3829.6	
** WBS: 1.4.2 Conventional Facilities												
1	Conventional Facilities		1	1079000.00	1079.0	0	0.0	0	0.00	0.0	1079.0	
** Subtotal **					1079.0			0		0.0	1079.0	
*** Total ***					19238.4			135116		5686.4	24924.8	

Table B.4
Contingency Analysis Table
(All costs shown in FY1990 K\$)

WBS No.	Description	Base Costs	Contingencies		
			%	K\$	K\$
			Conting.	Conting.	Conting.
1..	Life Sciences Center	25,050			4,909
1.1.	Project Management & Administration	1,422	20		286
1.2.	Special Research Facilities	13,352			3,544
1.2.1	Engineering, Design, & Inspection	3,739			
1.2.1.1	EDI, Wiggler Facility	2,175	27		587
1.2.1.2	EDI, Undulator Facility	1,564	27		422
1.2.2	Wiggler Facility	5,536			
1.2.2.1	Wiggler	1,102	25		275
1.2.2.2	Wiggler Beamline Frontend	597	25		151
1.2.2.3	Diffraction Facility	1,767			
1.2.2.3.1	Crystallography Branchline	1,172	25		293
1.2.2.3.2	Crystallography Station	454	30		136
1.2.2.3.3	Small Angle Scattering Stat	142	30		43
1.2.2.4	Spectroscopy/Microprobe Facility	2,069			
1.2.2.4.1	Spect./Micropr. Branchline	1,562	25		391
1.2.2.4.2	Spectroscopy Station	239	30		72
1.2.2.4.3	Microprobe Station	268	30		80
1.2.3	Undulator Facility	4,077			
1.2.3.1	Undulator	1,047	25		262
1.2.3.2	Undulator Beamline Frontend	514	25		129
1.2.3.3	Soft X-ray Imaging Facility	2,517			
1.2.3.3.1	Main Beamline	1,021	25		255
1.2.3.3.2	Main Scan. Microscope Sta.	604	30		181
1.2.3.3.3	R/D Scan/Microscope Sta.	494	30		148
1.2.3.3.4	Diffraction Imaging Sta.	399	30		120

Table B.4, Continued
Contingency Analysis Table

(All costs shown in FY1990 K\$)

			% Conting.	K\$ Conting	K\$ Conting Subtotal
1.3.	Conventional Facilities	5,368			1,079
1.3.1	Engineering, Design, & Inspection	506			
1.3.1.1	LBL Activities	214			
1.3.1.1.1	Engineering	129	15	19	
1.3.1.1.2	Consultants	16	25	4	
1.3.1.1.3	Inspection	69	25	17	
1.3.1.2	Architect/Engineering Activities	292	18	53	
1.3.2	Construction	3,075			
1.3.2.1	Improvements to Land	112	25	3	
1.3.2.2	Building 80 Improvements	1,170	25	290	
1.3.2.3	Building 6 Improvements	766	25	191	
1.3.2.4	Site Utilities	84	25	21	
1.3.2.5	Special Facilities	1,043	20	209	
1.3.3	Standard Equipment	1,787			
1.3.3.1	Biochemistry	1,067	15	163	
1.3.3.2	Microscopy	1,099	15	16	
1.3.3.3	Cell and Tissue Culture	139	15	21	
1.3.3.4	Surgical Suite	80	15	12	
1.3.3.5	General Support Equipment	392	15	59	
1.4.	Contingency	4,909			
1.4.1	Special Research Facilities & Proj Mgt.	3,830			
1.4.2	Conventional Facilities	1,079			

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