# ALS Life Sciences Center

## *Conceptual Design Report*

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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 largest 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, rather than visible light, it is possible to carry out holography at a microscopic level, seeing inside whole objects at high resolution. True x-ray microscopy, however, 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 watch processes unfold 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, has been proposed for construction at the Argonne National Laboratory.

***Table 1-1. ALS performance goals established by potential users.***

| | |
|---|---|
| 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 |
| Bunch length, $2\sigma$ (ps) | 20–50 |
| Beam lifetime (hr) | >6 |

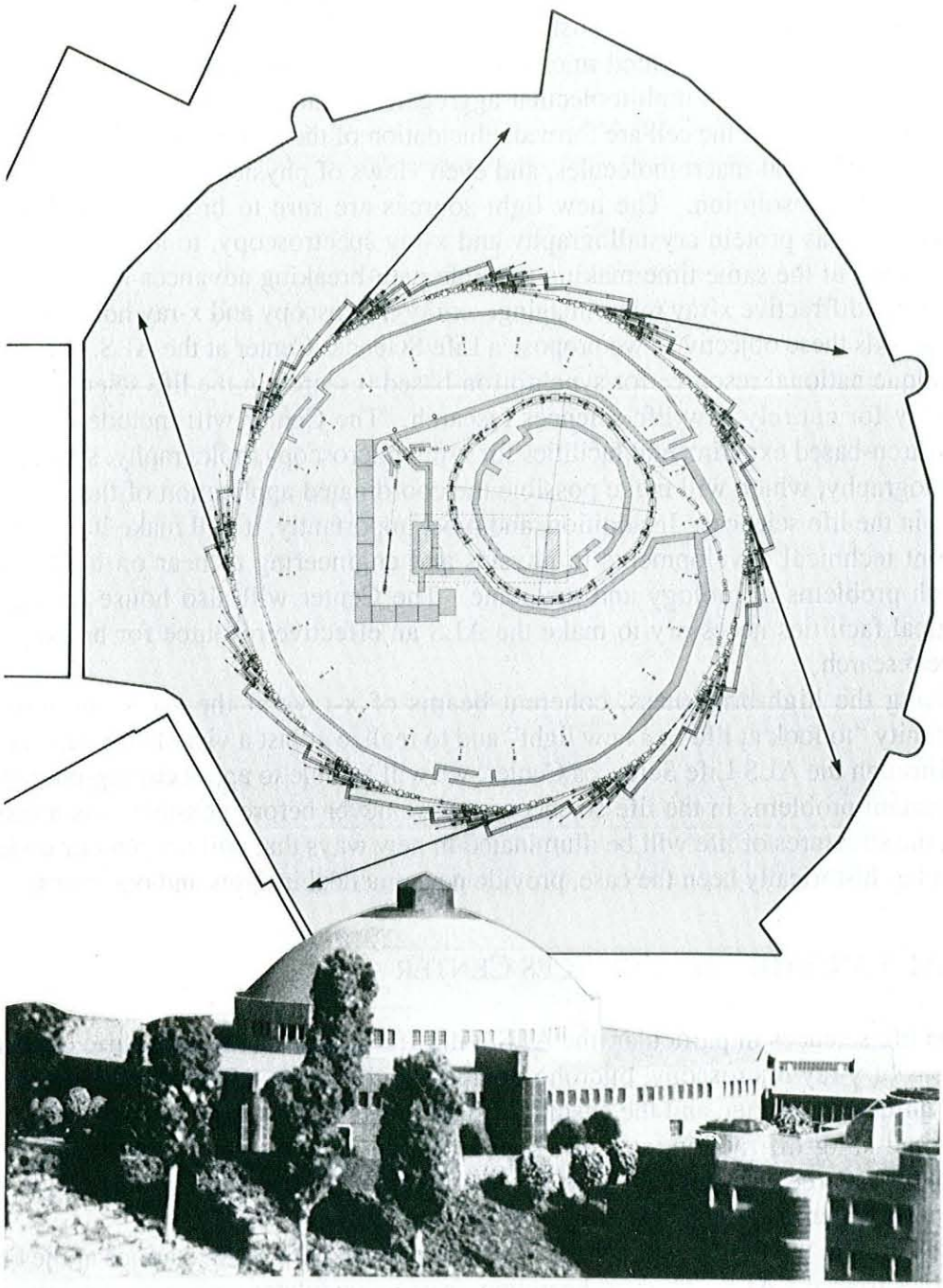

***Figure 1-1. Two views of the Advanced Light Source, now under construction. Above is a plan view, showing an initial complement of insertion devices and beamlines, as well as the envisioned full set of 60 beamlines. The size of the existing building is shown by the circle of I-beams well inside the 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.***

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, and a fourth, uncommitted port will provide unmodified "white" light from the undulator. 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 office and light laboratory space 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 10, 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 the 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
- 11,100 gross square feet of fully equipped support laboratory and office space

The estimated cost of the project is $25.4 million (in then-year dollars); it is scheduled to commence in FY 1991 and to be completed in FY 1993.

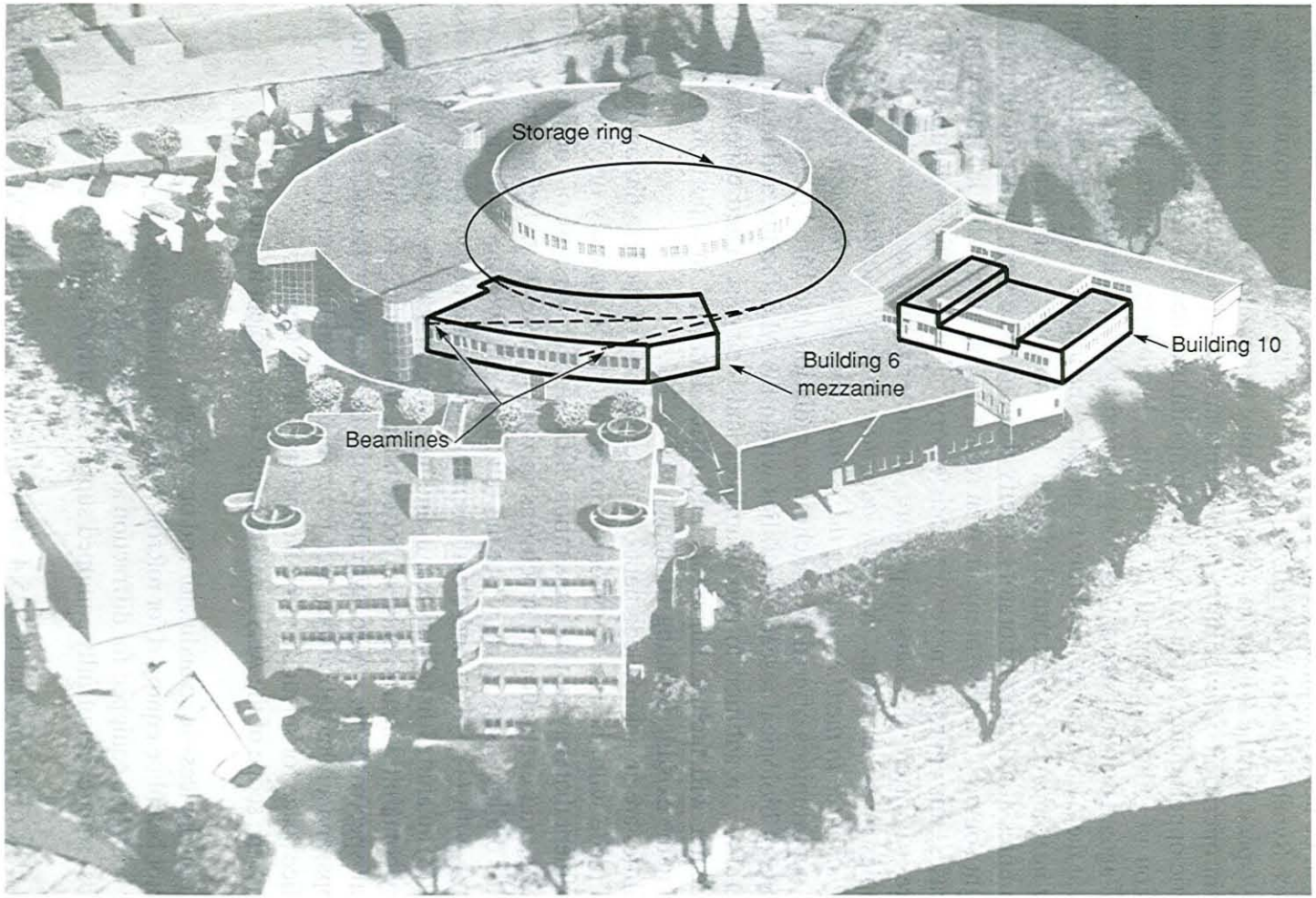


*Figure 1-2. A second photograph of the architectural model, showing schematically the scope of the ALS Life Sciences Center project. The project includes two insertion devices (a wiggler and an undulator), together with their beamlines and experimental end stations, and 11,100 gross square feet of fully equipped laboratory and office space, located at the end stations, on the mezzanine of the ALS building (Building 6), and in the adjacent Building 10.*

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. Accordingly, the Center is 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 and BMTs; (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]

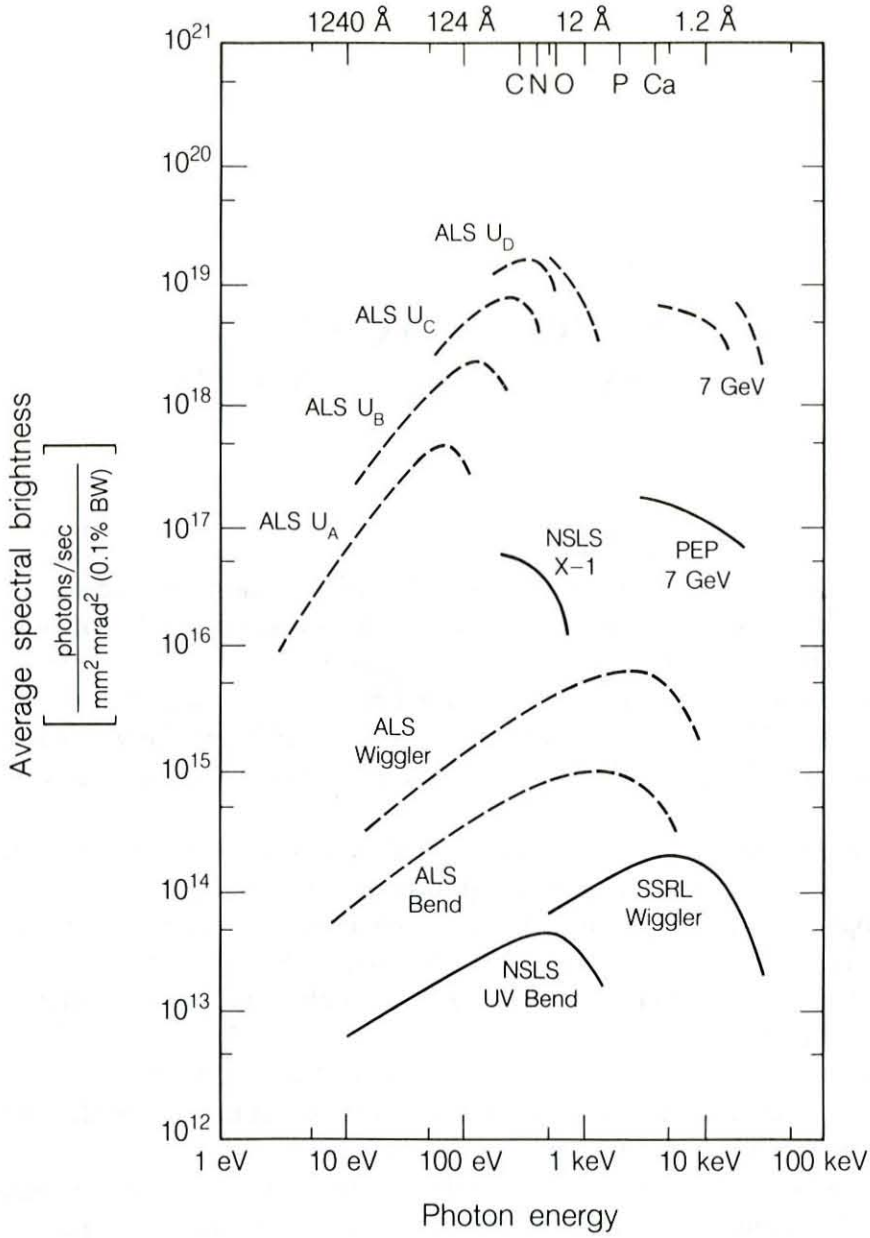


***Figure 2-1. A plot of time-averaged spectral brightness predicted for the ALS and for other operating and proposed sources. The dashed curves show the brightness for the insertion devices of Table 2-1 (page 15), as well as the bending magnets. Predictions are also shown for the proposed 7-GeV Advanced 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

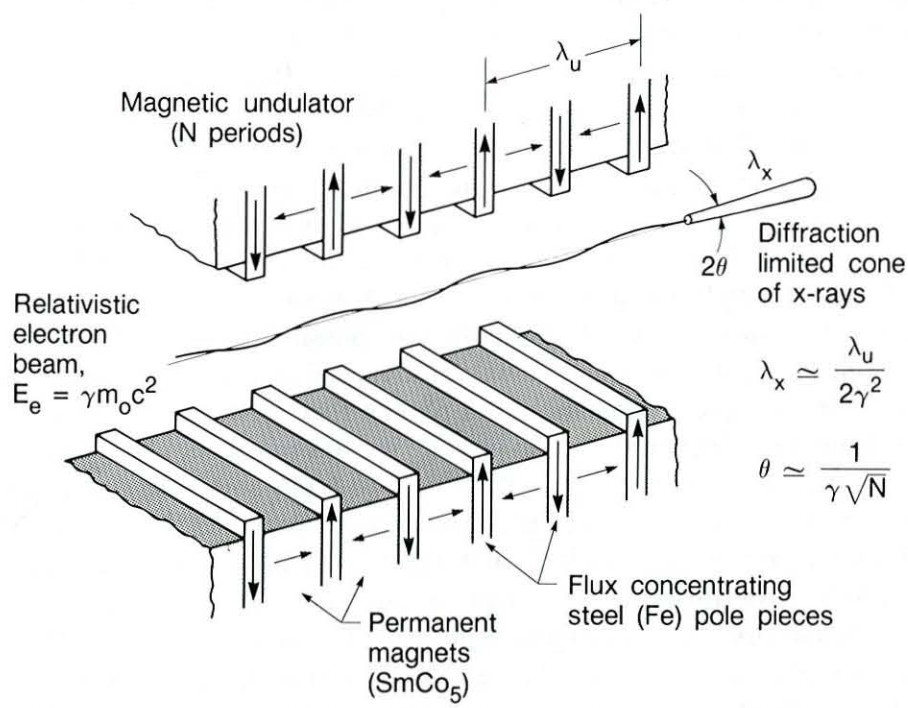


***Figure 2-2. A schematic of a permanent-magnet undulator. Partially coherent x-rays are produced when a thin, pencillike beam of relativistic electrons traverses the alternating magnetic structure.***

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 able 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, the ability to focus soft x-rays to a spot 75 nm in diameter was recently demonstrated at the National Synchrotron Light Source (NSLS) with zone plates having an outer zone width of 50 nm and the radiation from an undulator. More recently, at BESSY in Berlin, zone plates with 40-nm outer zone widths have yielded a spot size of 50 nm. 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]

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

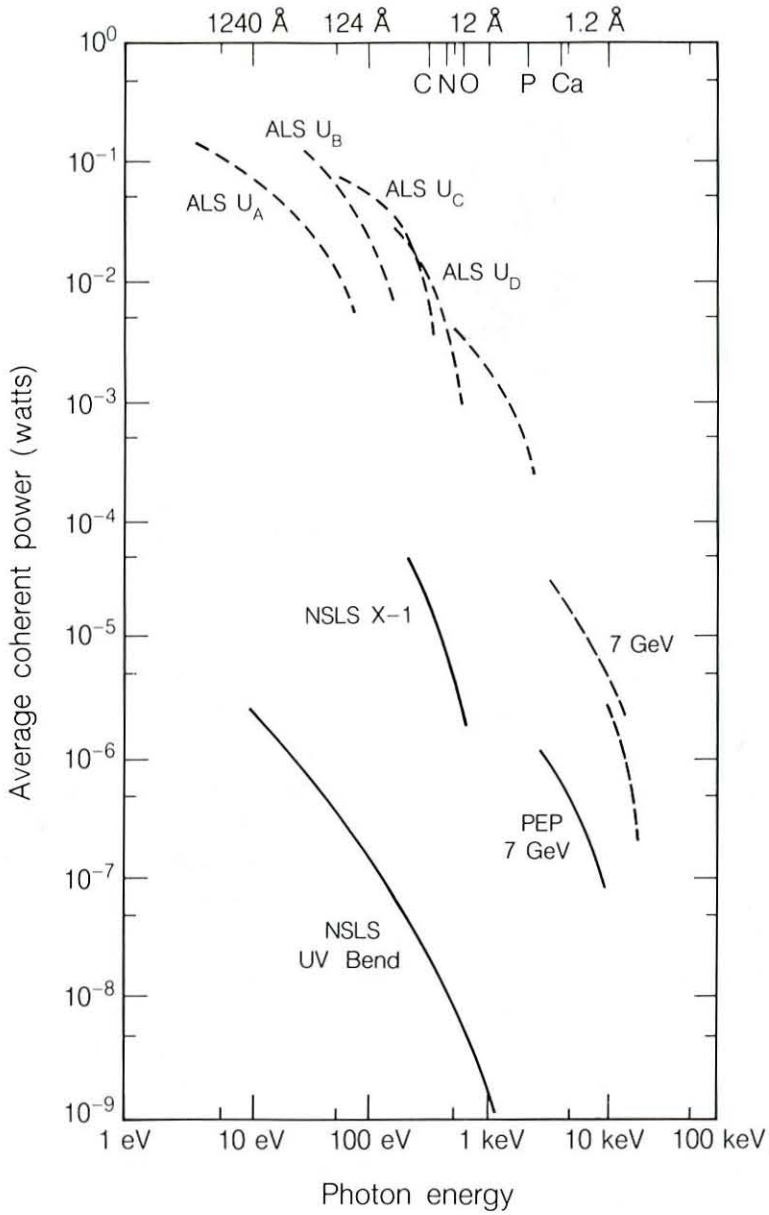


***Figure 2-3. A plot of average coherent power for the ALS and for other operating and proposed sources. Coherent power is defined here as having full transverse coherence and a 1-μm longitudinal coherence.***

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 10 nm.

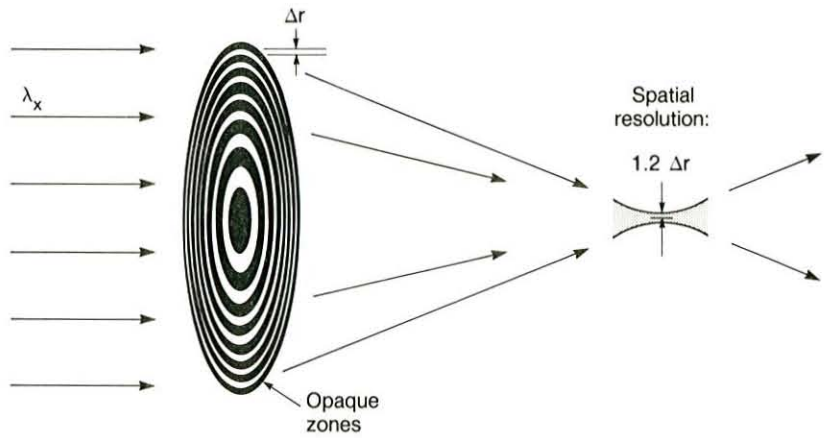


***Figure 2-4. A schematic diagram of a Fresnel zone plate. Diffraction from the variably spaced rings focuses a plane wave to a small spot whose radius is 1.2 times the width of the outer zone.***

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. Fringe spacings in the holograms suggest a resolution of 60 nm, and the first 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 1.5 keV. (The ALS can run at electron beam energies up to 1.9 GeV, which would broaden the undulator spectral range to about 2.6 keV, but the electron-beam emittance is degraded somewhat and the beamlines must be

designed to operate at the higher photon energies.) At the normal 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. Wigglers will also be useful sources of radiation for x-ray crystallography of macromolecules.

***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** | | | | |
| U20.0 | 20.0 | 23 | 0.5–95 [1.5–285] | – |
| U9.0 | 9.0 | 53 | 5–211 [15–633] | – |
| U5.0 | 5.0 | 98 | 50–380 [150–1140] | – |
| U3.65 | 3.65 | 134 | 183–550 [550–1650] | – |
| **Wiggler** | | | | |
| W13.6 | 13.6 | 16 | – | 3.1 |

[a]The photon energy of the fundamental and the third harmonic (shown in brackets) as the deflection parameter *K* decreases from its maximum value to 0.5.

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 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.

The ALS construction project contains funds sufficient for a selection of four undulators, one wiggler, and the beamlines to carry the XUV radiation to experimental areas. The funds also cover two front ends for bending-magnet radiation. Accordingly, a "strawman" set of four generic undulators that cover the ALS spectral range and a wiggler have been designed to illustrate the expected ALS performance (Table 2-1). Additional insertion devices, bending-magnet ports, and beamlines are expected in future years, funded separately through private industry, federal agencies, or other sources.

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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 10 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 (l) 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 chemical 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—

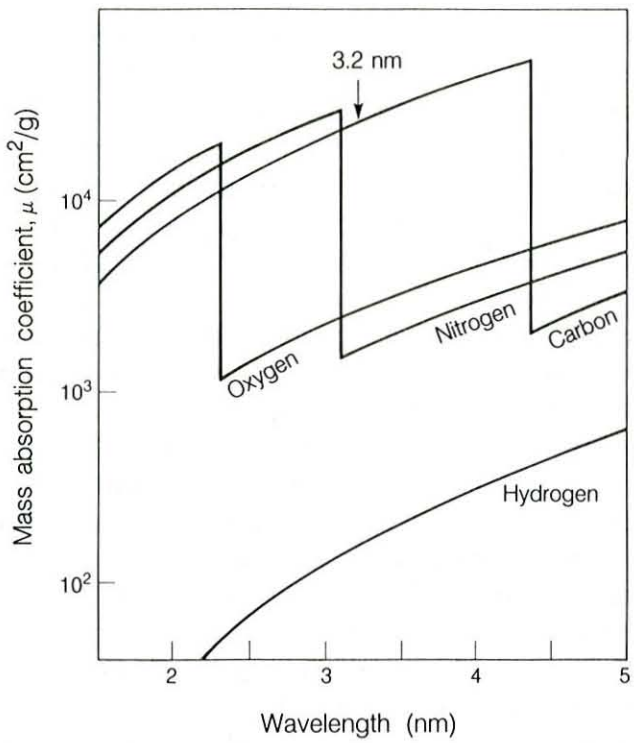
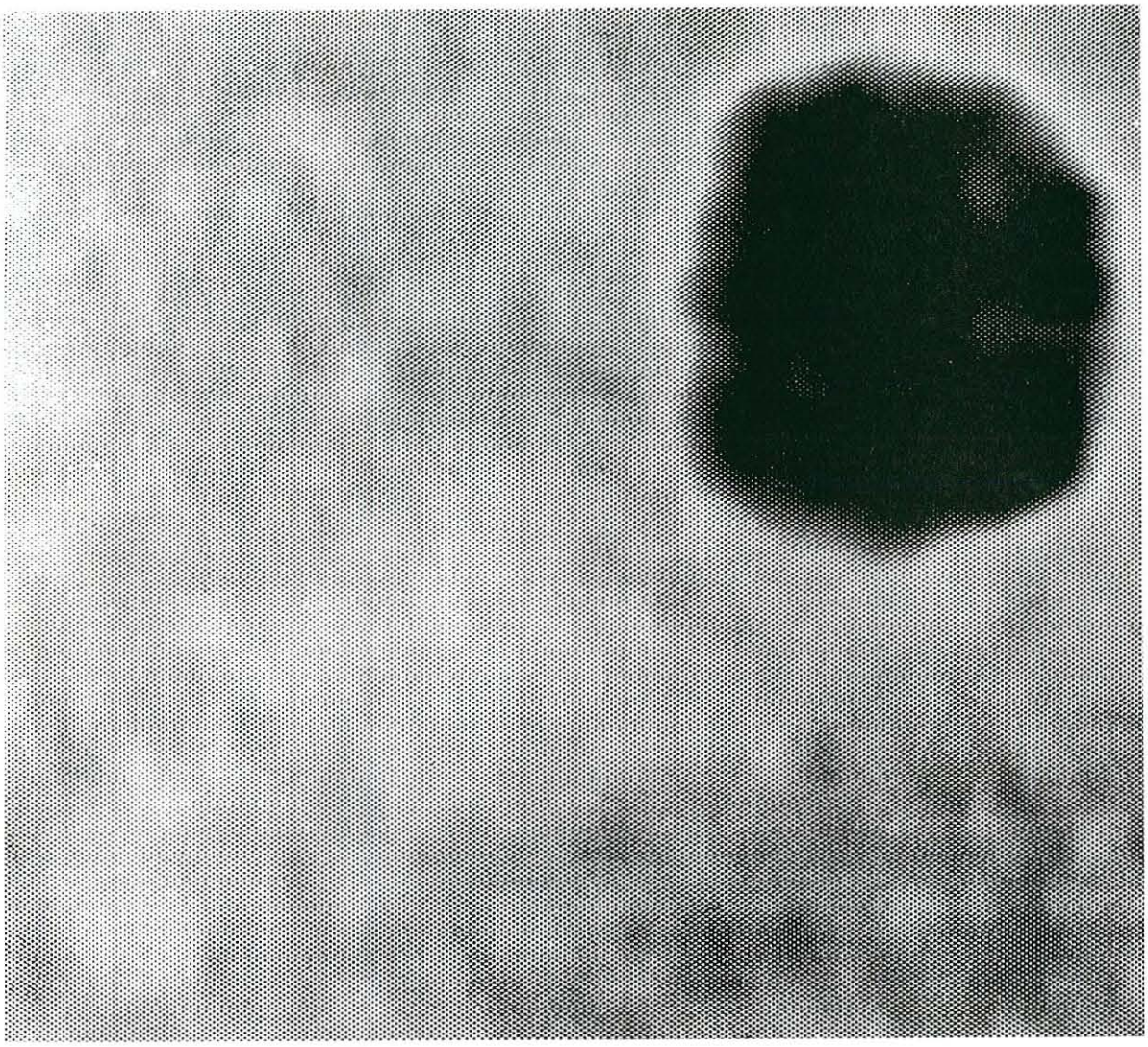



***Figure 3-1. The soft x-ray water window between 2.3 and 4.4 nm. Carbon and nitrogen provide contrast with relatively transparent water.***

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 most 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 a resolution of about 100 nm (Fig. 3-2),[1–3, 9] as well as holograms of the same structure at 100-nm resolution or better (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 50–60 nm (Fig. 3-4).[12] Resolution as great as 10 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.***

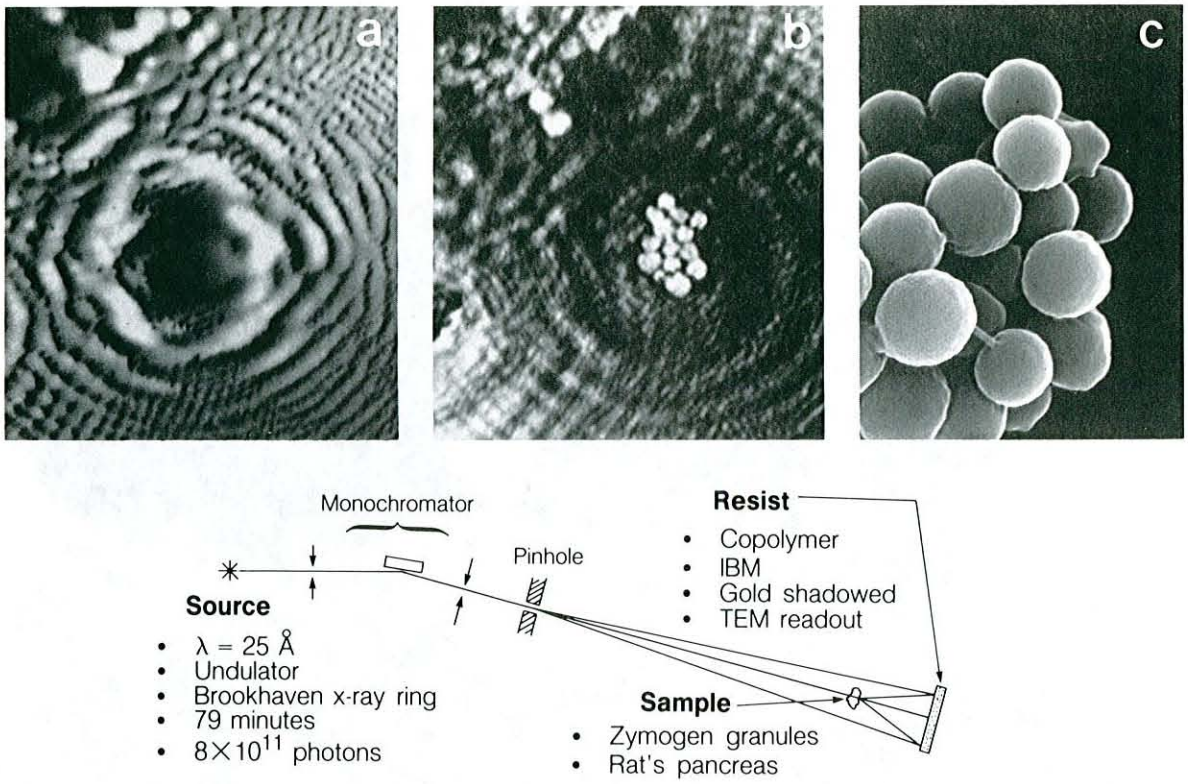



***Figure 3-3. (a) A transmission electron micrograph of an x-ray hologram of zymogen granules, recorded at the National Synchrotron Light Source with a copolymer resist. (b) A digital reconstruction of a group of zymogen granules, obtained from a hologram similar to the one shown in (a). (c) A scanning 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).

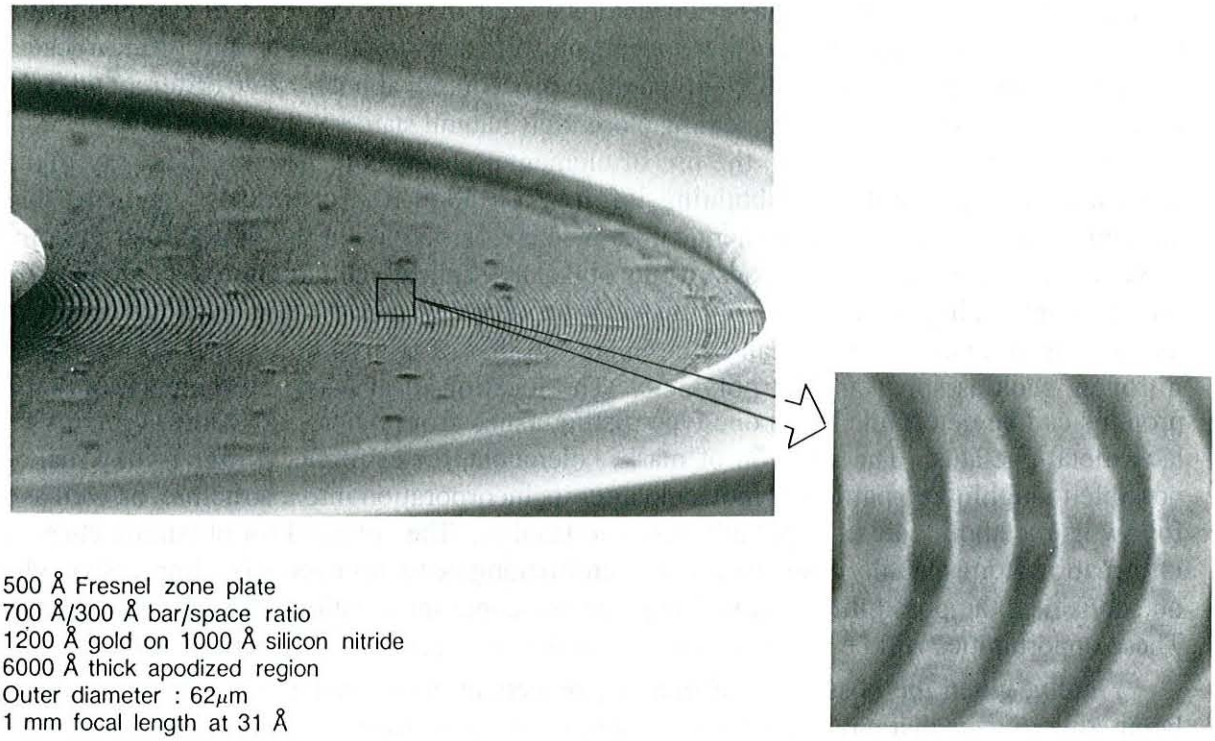



***Figure 3-4. A scanning electron micrograph of a 62-μm-diameter Fresnel zone plate, showing the concentric rings of opaque gold on a transparent silicon nitride substrate.***

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 10 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 chemical 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 chemical 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,

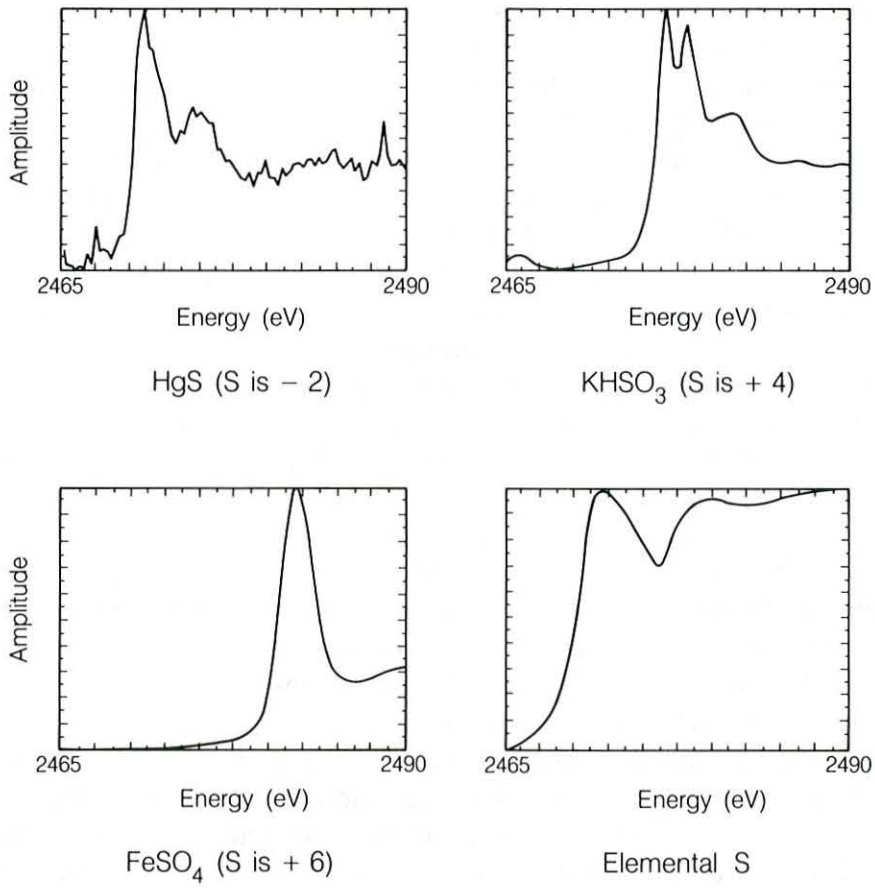



***Figure 3-5. Four sulfur* K*-edge x-ray absorption spectra, showing the shifts in the edge position due to different oxidation states.***

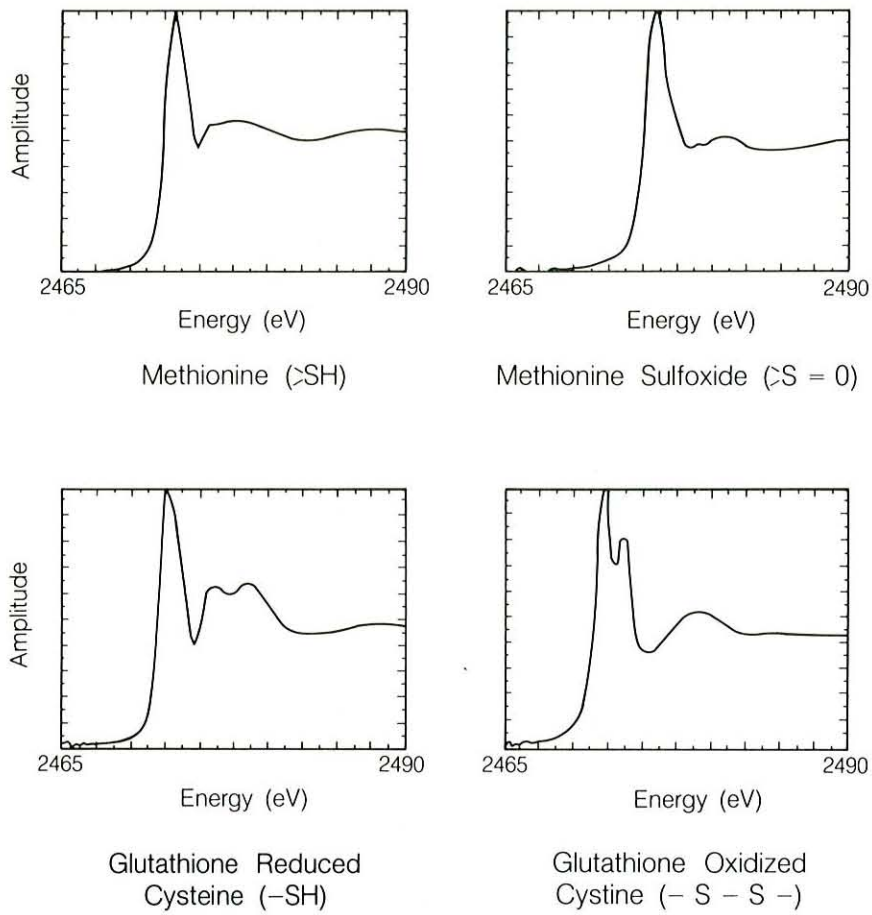



***Figure 3-6.* K-edge x-ray absorption spectra for the sulfur-containing amino acids methionine and cysteine, showing the clearly distinguishable absorption features of the most common oxidation states of sulfur in these molecules.**

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 the *L*-edges of the first series of transition elements and the *K*-edges of light elements such as oxygen and sodium occur. Virtually all of these elements participate in one or more biological functions. 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

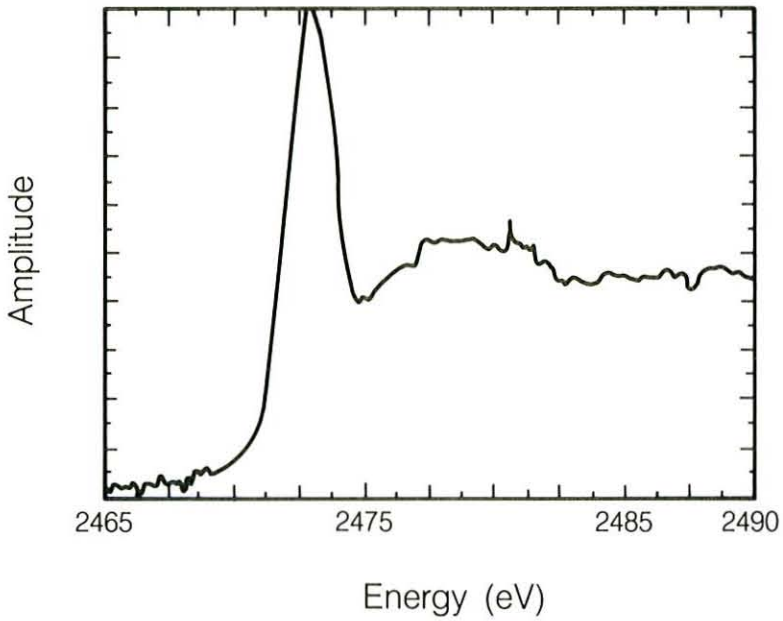



***Figure 3-7. A sulfur K-edge absorption spectrum for whole, fresh human red blood cells. Most of the sulfur in these cells is in the S-H state.***

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 200-femtogram level for elements such as chlorine, potassium, calcium, iron, manganese, copper, and zinc. Figure 3-8 shows the spatial resolution capabilities of a present-day x-ray 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 x 10 μm 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.

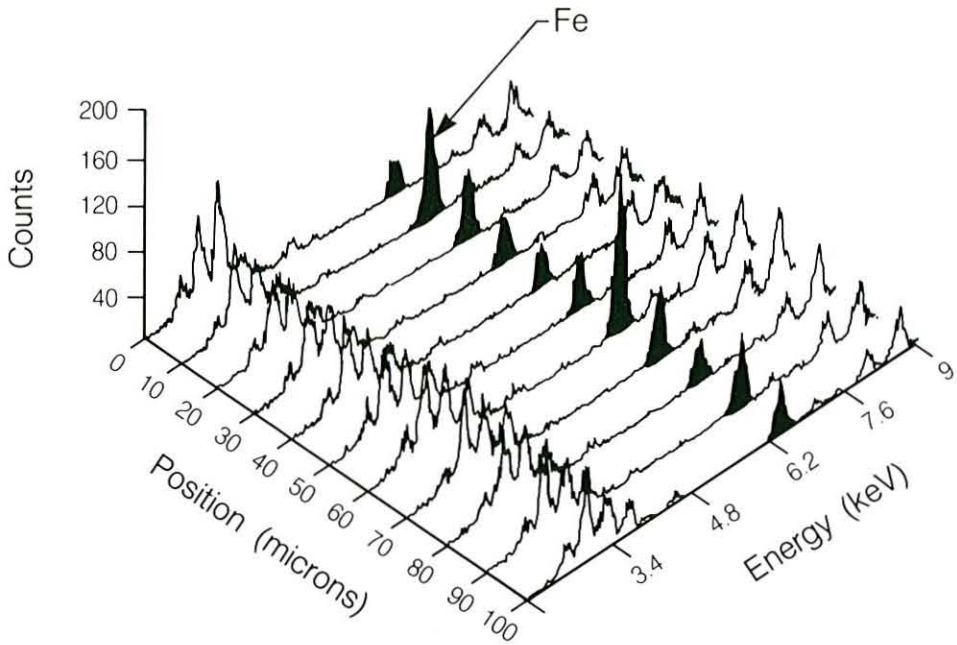



***Figure 3-8. A series of x-ray microprobe spectra, taken along the length of a photoactive blue-green algae filament. Variations in the concentration of iron can be detected at the level of a few parts per billion.***

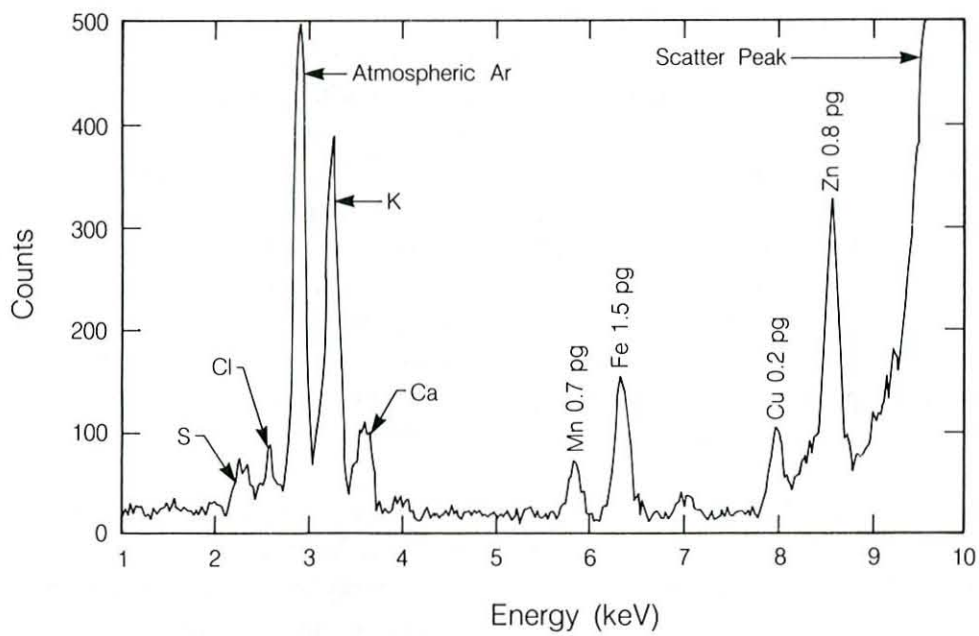



***Figure 3-9. An x-ray microprobe spectrum of an NBS wheat flour standard sample, showing sub-picogram sensitivity for several elements.***

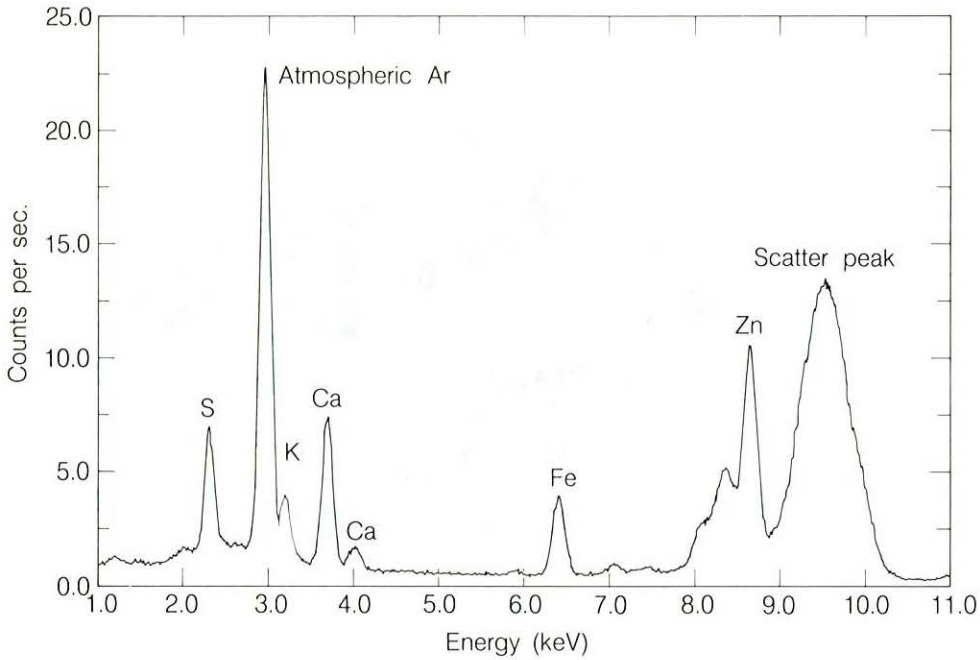



***Figure 3-10. An x-ray microprobe spectrum of a zymogen granule.***

## 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 higher energies (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

stimulus-secretion coupling in the pancreas—which is shown in Fig. 3-11.[14] This structure was derived from the diffraction pattern shown in Fig. 3-12, which was obtained at SSRL.

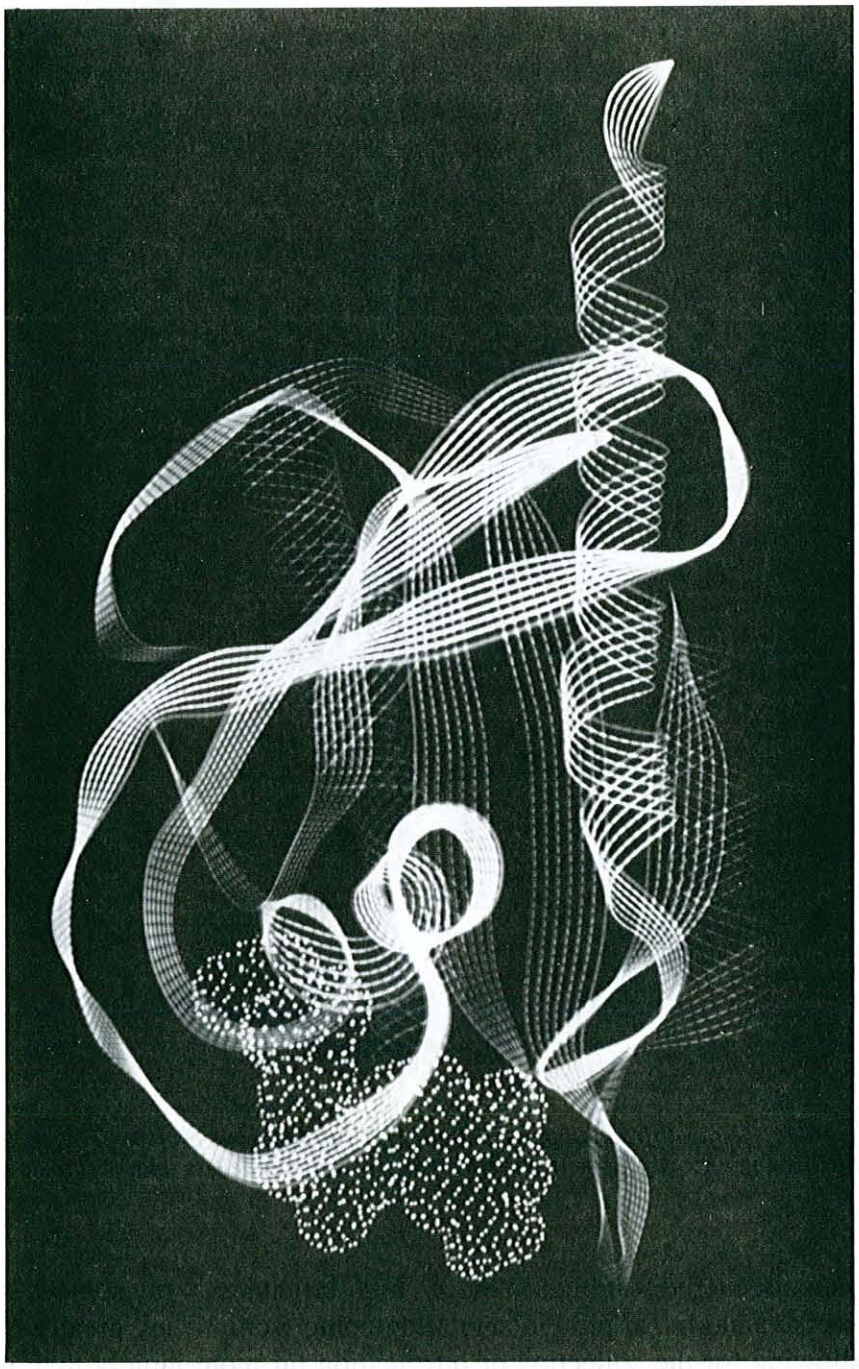


***Figure 3-11. A computer-generated image of the structural backbone of the c-H-*ras *oncogene protein, as determined by x-ray diffraction [A. M. deVos et al.,* Science *239, 888 (1988)]. This protein is involved in the coupling of stimulus to secretion in the pancreas.***

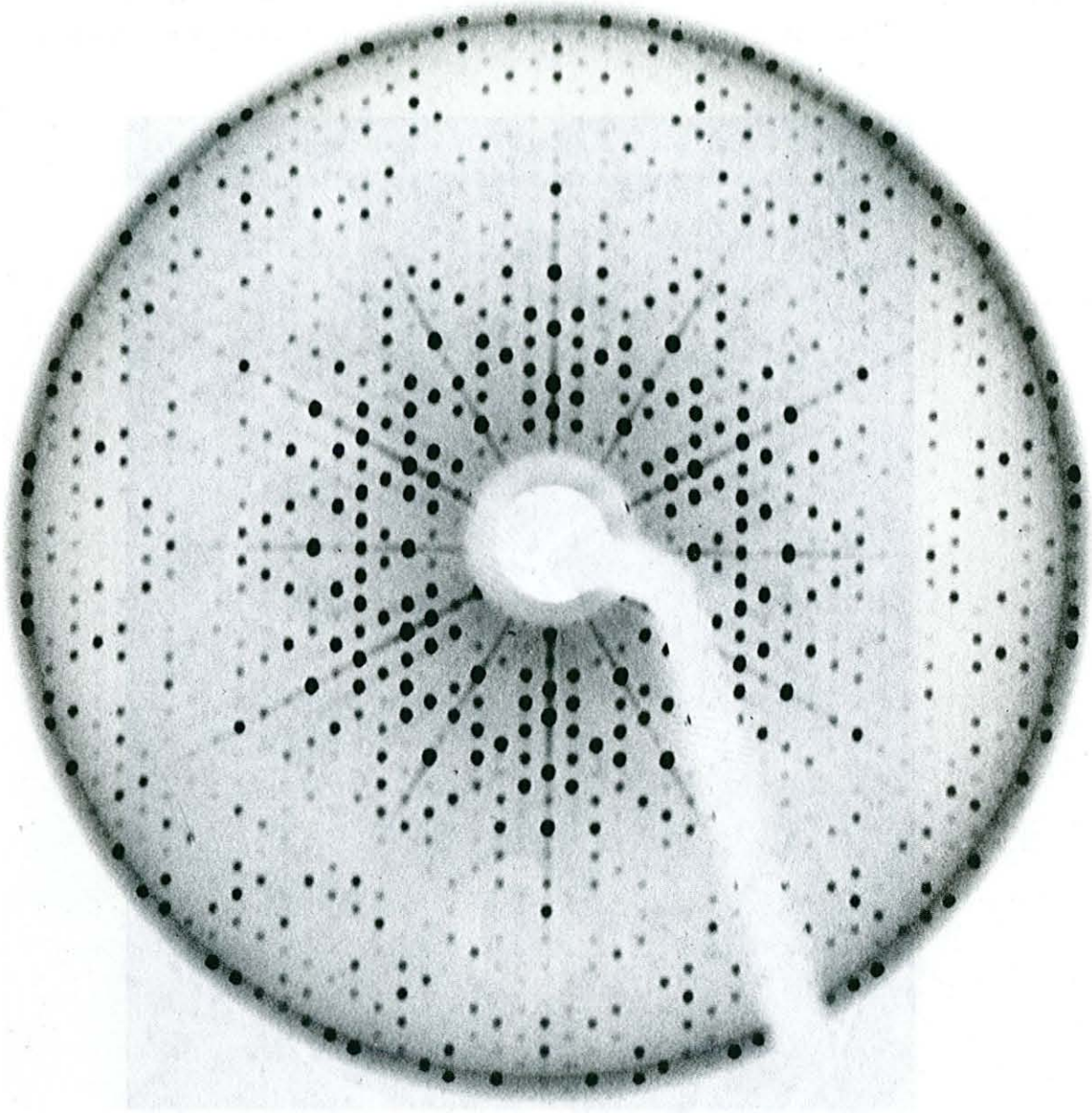


***Figure 3-12. X-ray diffraction pattern of the c-H-*ras *oncogene protein. This pattern was obtained using an x-ray intensity several orders of magnitude less than that to be available at the ALS.***

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 (0.001–0.05 $Å^{-1}$ 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- to 1-μm 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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# 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 proposed by the ALS project team in their original design study,[1] undulator U3.65. 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

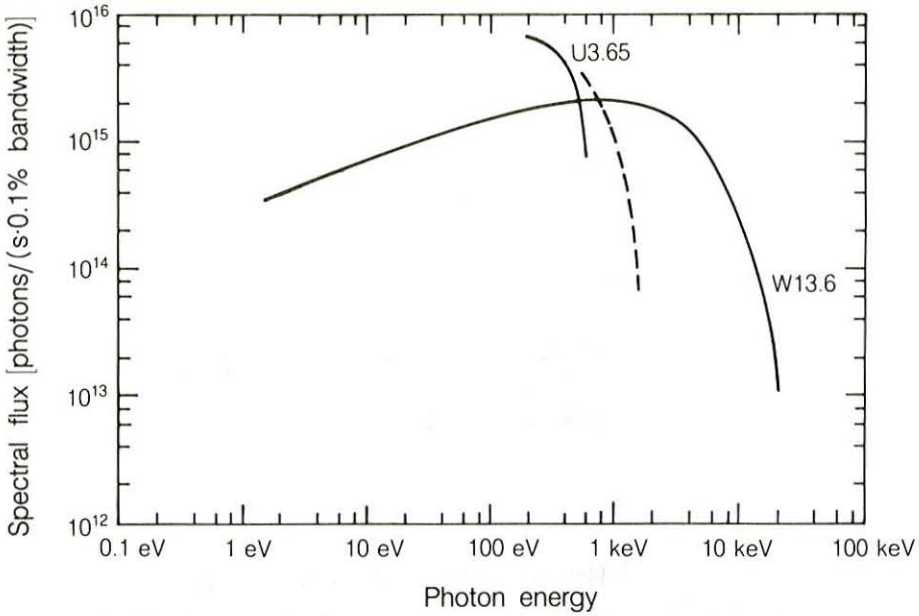


***Figure 4-1. A plot of spectral flux as a function of energy for the undulator and wiggler chosen for the ALS Life Sciences Center. For the wiggler, we assume a 5-mr collection angle. For the undulator, the tuning range is shown for both the fundamental (solid line) and the third harmonic (dashed line).***

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 $\lambda$ 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 U3.65 device has 134 periods, each of length 3.65 cm, to give a total length of 4.9 meters. The output at the fundamental wavelength can be tuned over the range 2.3–6.8 nm and lies within a cone of rms half-angle equal to approximately 0.03 milliradians. By use of the third harmonic, the spectral range 0.75–2.3 nm can 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 3.2 nm (390 eV). In this figure, note the very high output at the third harmonic.

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 $\lambda_u$ is the magnet period in centimeters and $B_0$ is the peak magnetic field in teslas.)

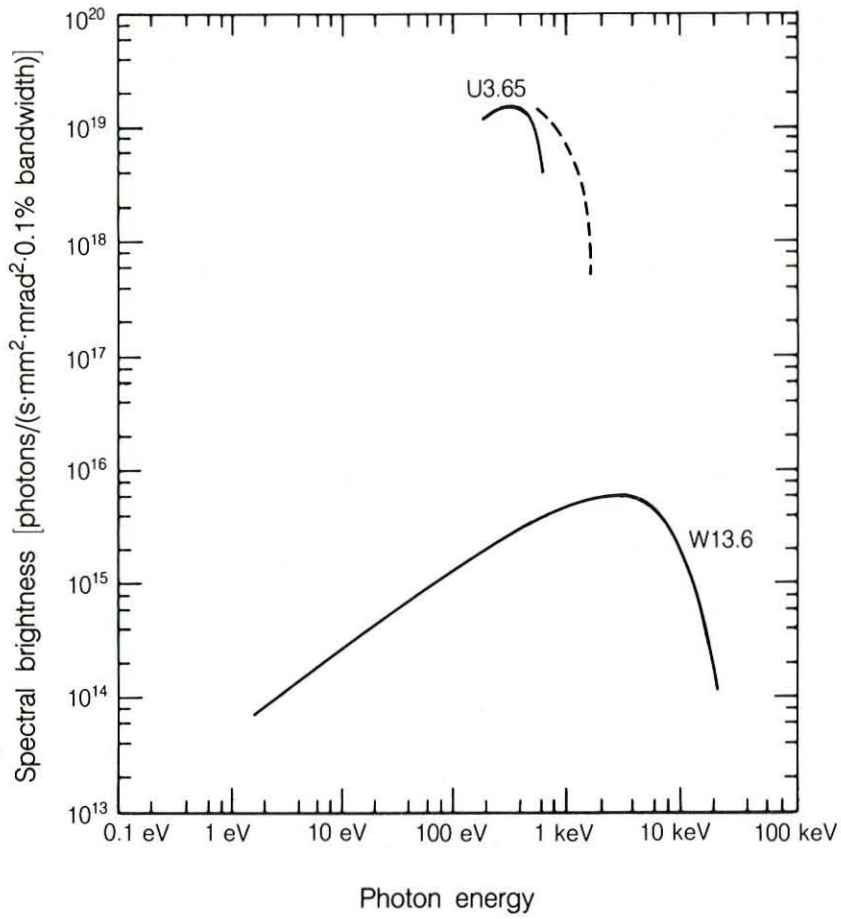


***Figure 4-2. A plot of spectral brightness as a function of energy for the undulator and wiggler chosen for the ALS Life Sciences Center. For the undulator, the tuning range is shown for both the fundamental (solid line) and the third harmonic (dashed line).***

For a given total length of undulator and for a given desired photon energy, it is usually better to choose a higher value of $K$. This is because the spectral flux in the central cone is proportional to $Q_n(K)$, a function that increases (nonlinearly) with $K$. 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. U3.65 was the shortest-period insertion device among those initially 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 U3.65 and (b) wiggler W13.6 with a gap of 1.4 cm. For the undulator, characteristics are given for the fundamental and for additional odd 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. |
| E1(keV) | Photon energy at fundamental frequency. |
| 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)]. |
| GAP(cm) | Magnet gap (pole to pole) of undulators and wigglers. |
| 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. |
| PCOH(W) | Diffraction-limited power with a 1-$\mu$m coherence length. |
| 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 U3.65.*

| E(GeV) | I(Amp) | SIGX(mm) | SIGY(mm) | SIGPX(mr) | SIGPY(mr) | N | LAMBDW(cm) | XLEN(m) |
|---|---|---|---|---|---|---|---|---|
| 1.50 | 0.400 | 0.210 | 0.040 | 0.019 | 0.010 | 134 | 3.65 | 4.9 |

| K | B0(T) | GAP(cm) | El(keV) | PTOT(kW) | PDEN2(W/(mr**2)) | PCEN(W) |
|---|---|---|---|---|---|---|
| 2.10 | 0.62 | 1.40 | 1.83E-01 | 1.06E+00 | 1.78E+03 | 1.80E+01 |

| n | EP(keV) | F(#/s,0.1%BW) | FDEN2 | BRI | PCOH(W) |
|---|---|---|---|---|---|
| 1 | 1.83E-01 | 6.77E+15 | 6.64E+17 | 1.18E+19 | 2.70E-02 |
| 3 | 5.48E-01 | 3.42E+15 | 7.94E+17 | 1.47E+19 | 3.74E-03 |
| 5 | 9.13E-01 | 2.09E+15 | 6.72E+17 | 1.26E+19 | 1.15E-03 |
| 7 | 1.28E+00 | 1.34E+15 | 5.18E+17 | 9.71E+18 | 4.53E-04 |
| 9 | 1.64E+00 | 8.75E+14 | 3.82E+17 | 7.19E+18 | 2.03E-04 |
| 11 | 2.01E+00 | 5.79E+14 | 2.76E+17 | 5.19E+18 | 9.81E-05 |

| K | B0(T) | GAP(cm) | El(keV) | PTOT(kW) | PDEN2(W/(mr**2)) | PCEN(W) |
|---|---|---|---|---|---|---|
| 1.00 | 0.29 | 2.15 | 3.90E-01 | 2.40E-01 | 8.17E+02 | 4.47E+00 |

| n | EP(keV) | F(#/s,0.1%BW) | FDEN2 | BRI | PCOH(W) |
|---|---|---|---|---|---|
| 1 | 3.90E-01 | 4.23E+15 | 7.69E+17 | 1.41E+19 | 7.08E-03 |
| 3 | 1.17E+00 | 6.87E+14 | 2.54E+17 | 4.76E+18 | 2.65E-04 |
| 5 | 1.95E+00 | 1.27E+14 | 5.95E+16 | 1.12E+18 | 2.25E-05 |
| 7 | 2.73E+00 | 2.39E+13 | 1.28E+16 | 2.41E+17 | 2.47E-06 |
| 9 | 3.51E+00 | 4.57E+12 | 2.65E+15 | 5.00E+16 | 3.09E-07 |
| 11 | 4.29E+00 | 8.78E+11 | 5.37E+14 | 1.01E+16 | 4.20E-08 |

| K | B0(T) | GAP(cm) | El(keV) | PTOT(kW) | PDEN2(W/(mr**2)) | PCEN(W) |
|---|---|---|---|---|---|---|
| 0.59 | 0.17 | 2.80 | 4.99E-01 | 8.35E-02 | 4.37E+02 | 2.00E+00 |

| n | EP(keV) | F(#/s,0.1%BW) | FDEN2 | BRI | PCOH(W) |
|---|---|---|---|---|---|
| 1 | 4.99E-01 | 2.10E+15 | 4.57E+17 | 8.45E+18 | 2.59E-03 |
| 3 | 1.50E+00 | 7.43E+13 | 3.11E+16 | 5.84E+17 | 1.99E-05 |
| 5 | 2.49E+00 | 2.88E+12 | 1.49E+15 | 2.81E+16 | 3.45E-07 |
| 7 | 3.49E+00 | 1.14E+11 | 6.58E+13 | 1.24E+15 | 7.78E-09 |
| 9 | 4.49E+00 | 4.53E+09 | 2.80E+12 | 5.30E+13 | 2.01E-10 |
| 11 | 5.48E+00 | 1.81E+08 | 1.17E+11 | 2.22E+12 | 5.62E-12 |

| K | B0(T) | GAP(cm) | El(keV) | PTOT(kW) | PDEN2(W/(mr**2)) | PCEN(W) |
|---|---|---|---|---|---|---|
| 0.36 | 0.11 | 3.55 | 5.50E-01 | 3.11E-02 | 2.09E+02 | 8.92E-01 |

| n | EP(keV) | F(#/s,0.1%BW) | FDEN2 | BRI | PCOH(W) |
|---|---|---|---|---|---|
| 1 | 5.50E-01 | 9.05E+14 | 2.11E+17 | 3.90E+18 | 9.85E-04 |
| 3 | 1.65E+00 | 5.56E+12 | 2.43E+15 | 4.57E+16 | 1.28E-06 |
| 5 | 2.75E+00 | 3.70E+10 | 1.98E+13 | 3.74E+14 | 3.77E-09 |
| 7 | 3.85E+00 | 2.50E+08 | 1.48E+11 | 2.80E+12 | 1.44E-11 |
| 9 | 4.95E+00 | 1.69E+06 | 1.07E+09 | 2.02E+10 | 6.31E-14 |
| 11 | 6.05E+00 | 1.15E+04 | 7.61E+06 | 1.44E+08 | 3.00E-16 |

*Table 4-1b. Wiggler W13.6.*

| E(GeV) | I(Amp) | SIGX(mm) | SIGY(mm) | SIGPX(mr) | SIGPY(mr) | GAP(cm) |
|---|---|---|---|---|---|---|
| 1.50 | 0.400 | 0.210 | 0.040 | 0.019 | 0.010 | 1.40 |

| NPOLE | LAMBDW(cm) | XLEN(m) | B0(T) | ECR(keV) | PTOT(kW) | PDEN2(W/(mr**2)) |
|---|---|---|---|---|---|---|
| 32 | 13.60 | 2.18 | 2.07 | 3.10 | 5.31E+00 | 7.27E+02 |

| EP(keV) | F | FDEN1 | FDEN2 | BRI | PCOH(W) |
|---|---|---|---|---|---|
| 5.000E-03 | 5.878E+14 | 1.176E+14 | 1.529E+13 | 1.754E+14 | 5.353E-04 |
| 1.000E-02 | 7.355E+14 | 1.471E+14 | 2.426E+13 | 2.783E+14 | 2.124E-04 |
| 5.000E-02 | 1.212E+15 | 2.425E+14 | 7.070E+13 | 8.112E+14 | 2.476E-05 |
| 1.000E-01 | 1.477E+15 | 2.953E+14 | 1.116E+14 | 1.281E+15 | 9.771E-06 |
| 5.000E-01 | 2.083E+15 | 4.166E+14 | 3.060E+14 | 3.510E+15 | 1.071E-06 |
| 1.000E+00 | 2.161E+15 | 4.321E+14 | 4.384E+14 | 5.029E+15 | 3.837E-07 |
| 5.000E+00 | 9.720E+14 | 1.944E+14 | 4.541E+14 | 5.202E+15 | 1.588E-08 |
| 1.000E+01 | 2.482E+14 | 4.963E+13 | 1.688E+14 | 1.930E+15 | 1.473E-09 |
| 2.000E+01 | 1.298E+13 | 2.597E+12 | 1.282E+13 | 1.460E+14 | 2.785E-11 |
| 5.000E+01 | 1.218E+09 | 2.437E+08 | 1.935E+09 | 2.179E+10 | 6.650E-16 |
| 1.000E+02 | 1.890E+02 | 3.780E+01 | 3.828E+02 | 4.260E+03 | 3.251E-23 |
| 3.098E+00 | 1.537E+15 | 3.073E+14 | 5.551E+14 | 6.363E+15 | 5.060E-08 |

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

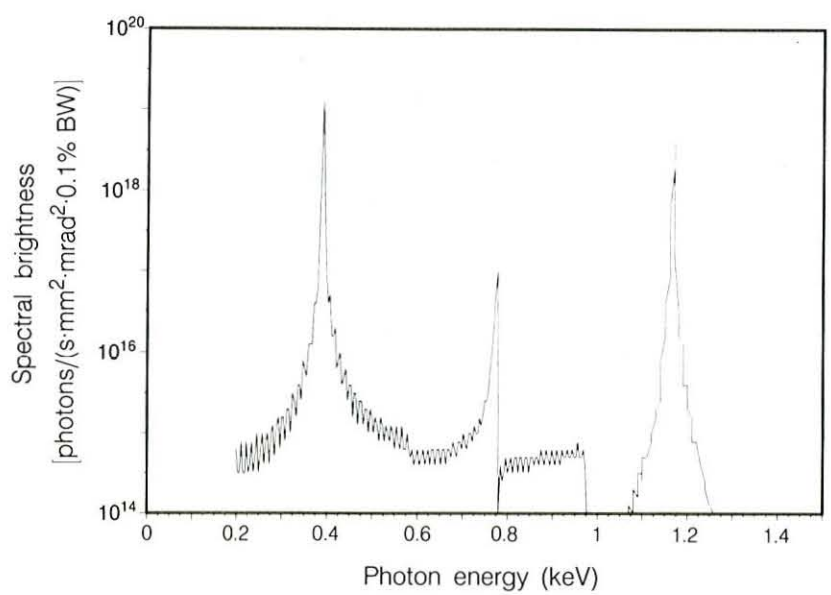


***Figure 4-3. A plot of on-axis spectral brightness from the U3.65 undulator, with the gap set to give a fundamental at 3.2 nm (390 eV).***

relatively wide fan of radiation emerging from the insertion device. Therefore, as a complement to the U3.65 undulator, the Life Sciences Center will include a wiggler of the type first described in the ALS conceptual design report.[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 5-meter 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

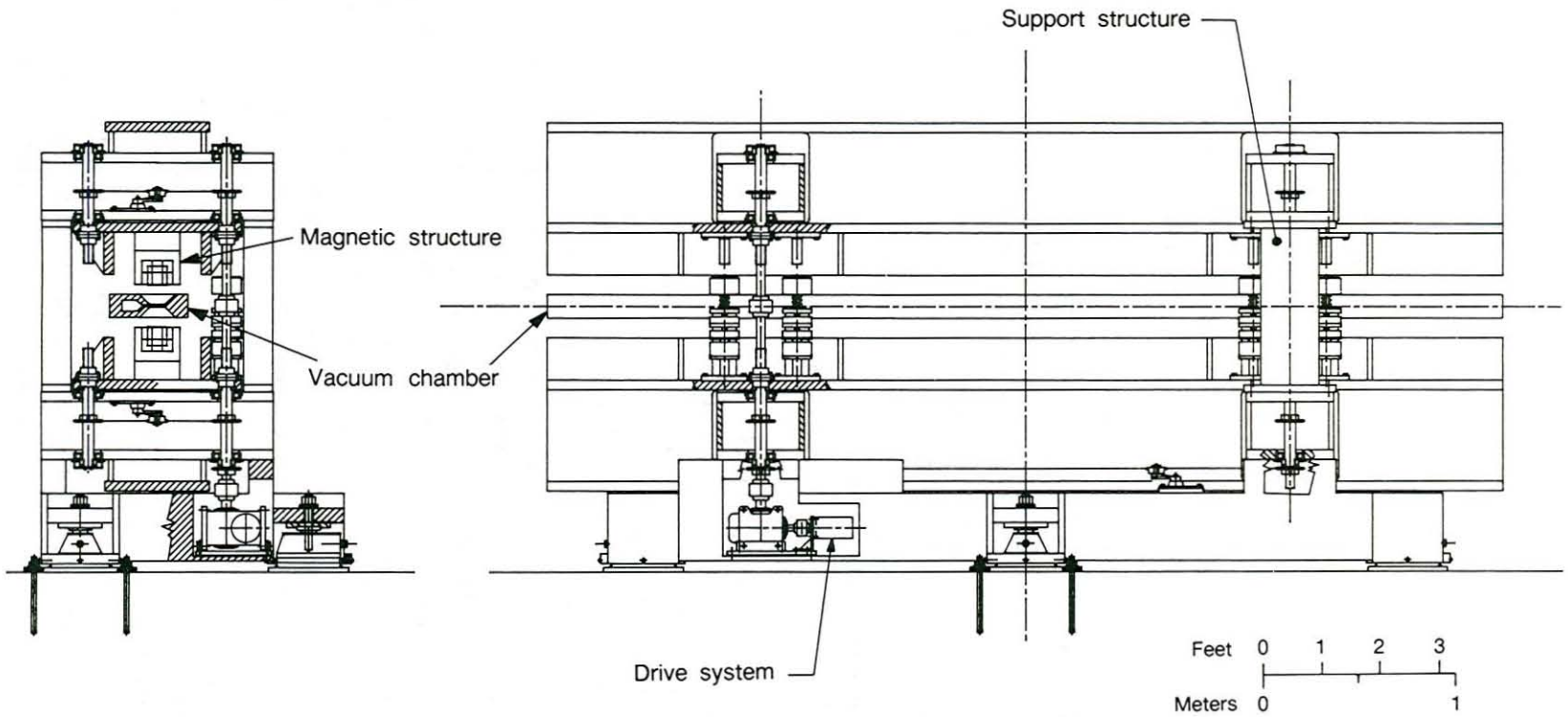


*Figure 4-4. An end view and a side view of a typical ALS insertion device.*

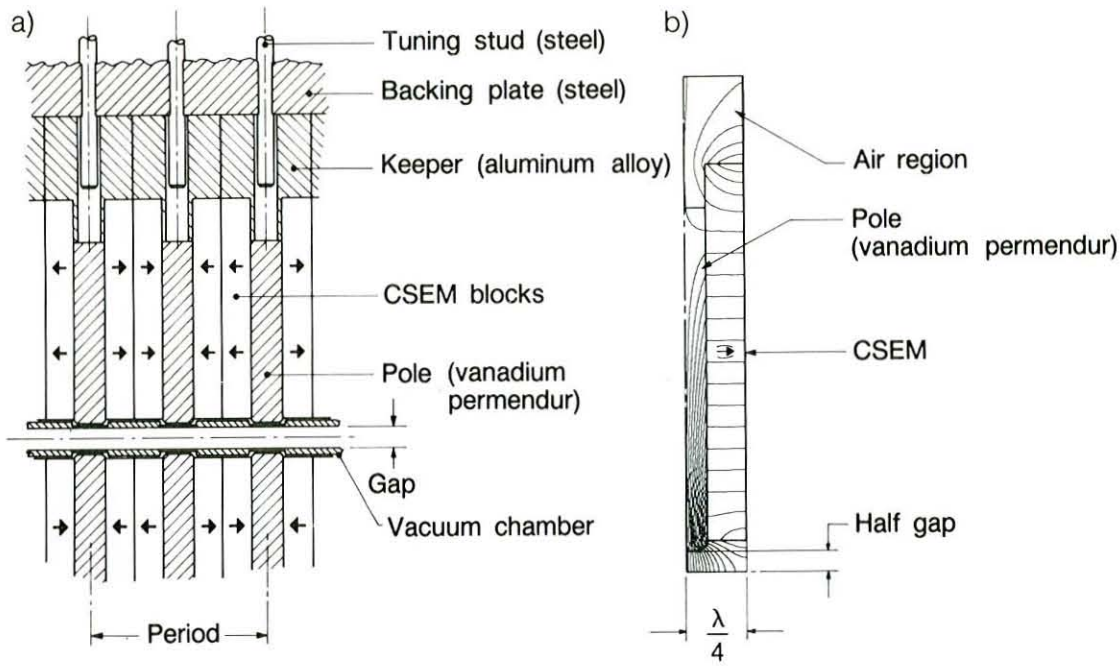


*Figure 4-5. (a) A cross section and (b) a quarter-period magnetic flux plot for a hybrid insertion device. The current-sheet-equivalent material (CSEM) is neodymium-iron.*

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 1.4 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

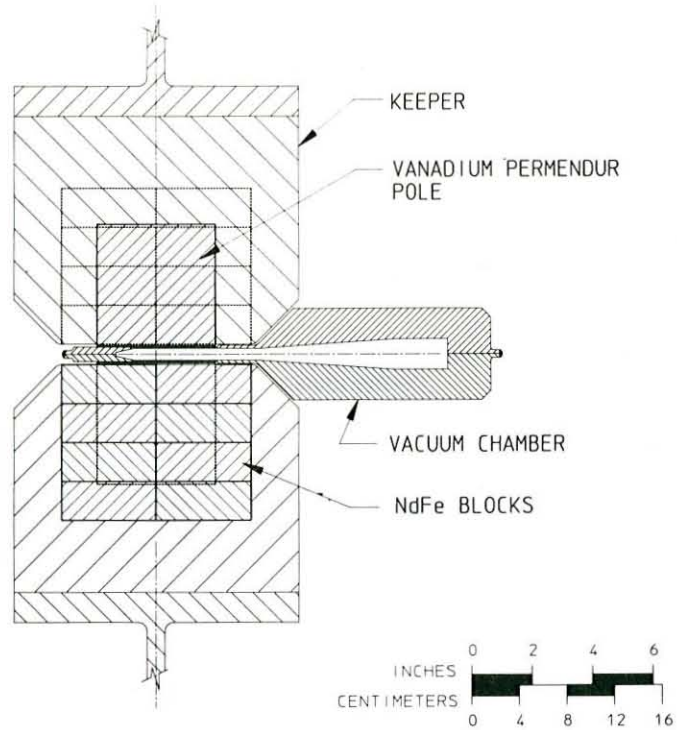


***Figure 4-6. A cross section of wiggler W13.6 with a 1-cm-vertical-aperture vacuum chamber, designed to fit a 1.4-cm gap.***

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. If, at some later time, it is desired to use an imaging (Göttingen-type) microscope, the proposed system could be adapted to this configuration with only a modest effort. 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 close to diffraction limited (single mode) and deliver correspondingly high average coherent power.

The x-ray wavelengths needed in this type of work span the region from about 0.7 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.

***Table 4-2. Descriptive characteristics and capabilities of the Life Sciences Center beamlines and experimental stations.***

| Beam channel name | Floor level | X-ray beam type | Microscope type | Comments |
|---|---|---|---|---|
| U1 | upper | monochromatic | horizontal stage, scanning | some compromise of speed and tunability |
| L1 | lower | monochromatic | vertical stage, scanning | no compromise of the above type |
| L2 | lower | monochromatic | holography, diffraction | |
| L3 | lower | white | none | uncommitted port |

## 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 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

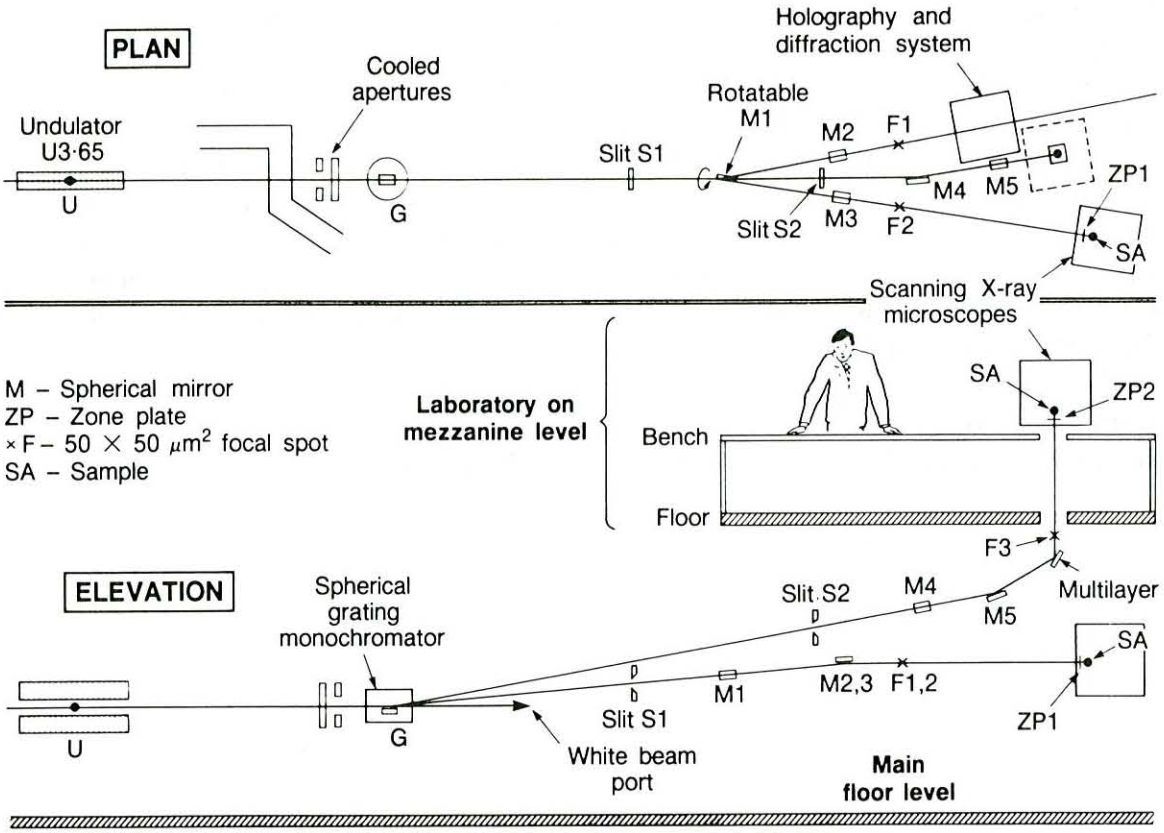


***Figure 4-7. A plan view and an elevation of the beamline designed for undulator U3.65. The distances and angles are distorted for clarity; actual dimensions (in meters) are as follows: UG = 14; GS1 = 5.88; GS2 = 11.48; S1M1 = 1.0; M1M2, M1M3 = 0.9; M3F2, M2F1 = 1.0; F2ZP1 = 2.0; S2M4 = 1.0; M4M5 = 1.27; M5F3 = 1.13; F3ZP2 = 2.88; all the mirrors deflect the beam by 4°. The lower and upper beams emerging from the monochromator are at 4.00° and 5.15° to the horizontal, respectively.***

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.

Wavelength is scanned by simple rotation of the grating, and the depth of focus of the system, utilizing the undulator central cone, is such that it suffers negligible defocusing over its entire operating range of 0.7–7.0 nm. For a sufficiently well-made grating, the resolution is diffraction limited—or source-size limited, which is the same thing for a single-mode source.

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

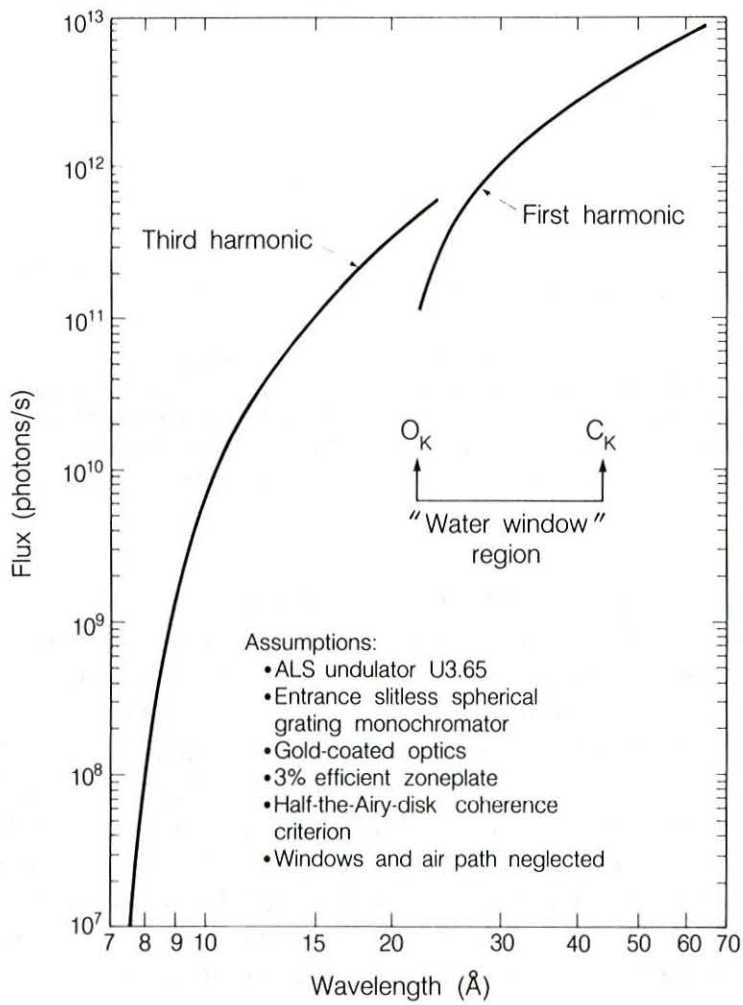


***Figure 4-8. A plot of the undulator beamline output in photons per second onto a zone plate focal spot, for the assumptions indicated in the figure.***

*Table 4-3. Monochromator resolution for the spherical grating design proposed for the U3.65 beamline.*

| Wavelength (nm) | Resolution (nm), lower beam | Resolution (nm), upper beam |
|---|---|---|
| 0.7 | 0.00090 | 0.00112 |
| 1.0 | 0.00093 | 0.00115 |
| 1.5 | 0.00098 | 0.00119 |
| 2.0 | 0.00104 | 0.00123 |
| 3.0 | 0.00114 | 0.00131 |
| 4.0 | 0.00124 | 0.00139 |
| 5.0 | 0.00134 | 0.00147 |
| 6.0 | 0.00144 | 0.00155 |
| 7.0 | 0.00155 | 0.00163 |

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 40 μm, or about 40% of its full width. This would give a wavelength shift of 40% of the resolution function width ($5 \times 10^{-4}$ nm or $\lambda/6000$ at 3.0 nm). Now consider a horizontal shift of one standard deviation (210 μm, or about 40% of the full width). In this case, the affected sample pixels would suffer a displacement of 40% of their width. These are essentially negligible 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 (about 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-nm-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 avoids the need to prepare heavy-atom derivatives and to determine heavy-atom positions. 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 $f'$ 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 for elsewhere. Table 4-5 includes numerical values for these loads. We anticipate that standard water-cooling techniques, similar to those that LBL

*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 x 0.3 |
| Beam area at optical system ($mm^2$) | 28 x 4 |
| Spot size at sample ($mm^2$) | 0.2 x 0.1 |
| Convergence angles at sample ($mr^2$) | 2 x 0.3 |
| X-ray resolving power | $10^{-4}$ |
| X-ray flux at sample at 10 keV (photons/s) | $6 \times 10^{12}$ |
| Useful tuning range, defined as >10% of the flux at 10 keV (keV) | 3–15 |

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 x 0.5 $mm^2$, 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

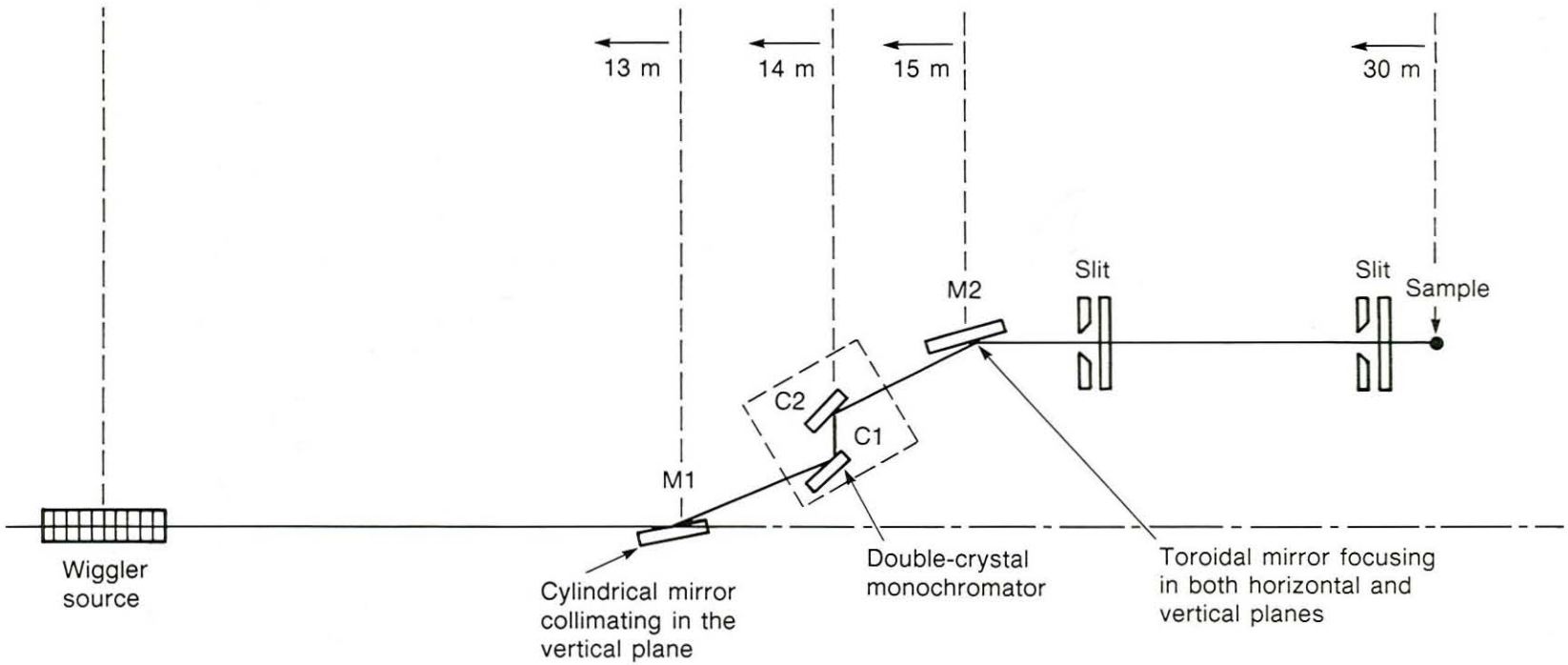


***Figure 4-9. Optical layout for the protein crystallography branch line. The deflection angles, equal to 5 mr, have been exaggerated for clarity. The distances indicated are distances to the source.***

*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)<br>small (second) | small |
| Maximum surface power density ($W/cm^2$) | 1.9 | 59 (first)<br>small (second) | small |

crystal, 0.1 x 0.1 $mm^2$, 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 x 0.5) x (2.5 x 2.5) $mm^2$-$mr^2$, 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 Å 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 Å, 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 μm 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 μm square has already been achieved, and, with improved optics, we expect to achieve a spot size of 1 μm 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 among the appendices.

The Life Sciences Center will be located in existing Buildings 6 and 10, 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 11,100 gross square feet (GSF): 5100 GSF in the ALS building itself (Building 6) and 6000 GSF on the first floor of the contiguous Building 10.

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 second-floor space occupied by the Center. A self-contained 400-GSF modular wet laboratory will be provided as part of the end station on each beamline. The pertinent section of the ALS experimental area in shown in Fig. 5-3.

Space on the second floor 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 second floor 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 second-floor laboratory area. Appropriate HVAC, power, lighting, partitions, integrated communications systems, and other services will be provided as required.

Space on the first floor of Building 10 will be vacated to make way for facilities devoted to the Life Sciences Center. Although no funds will be required to relocate existing occupants, it will be necessary to demolish and strip out existing partitions and to modify existing utilities and services for conversion of the area to life sciences laboratory space. 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 storage. The plan for Building 10 is shown in Fig. 5-5. The exterior siding of Building 10 will be replaced to augment modernization of interior space for the Center. Necessary major maintenance projects on Building 10, including reroofing and upgrading its structural system for seismic safety, will be completed before the Life Sciences Center is funded.

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

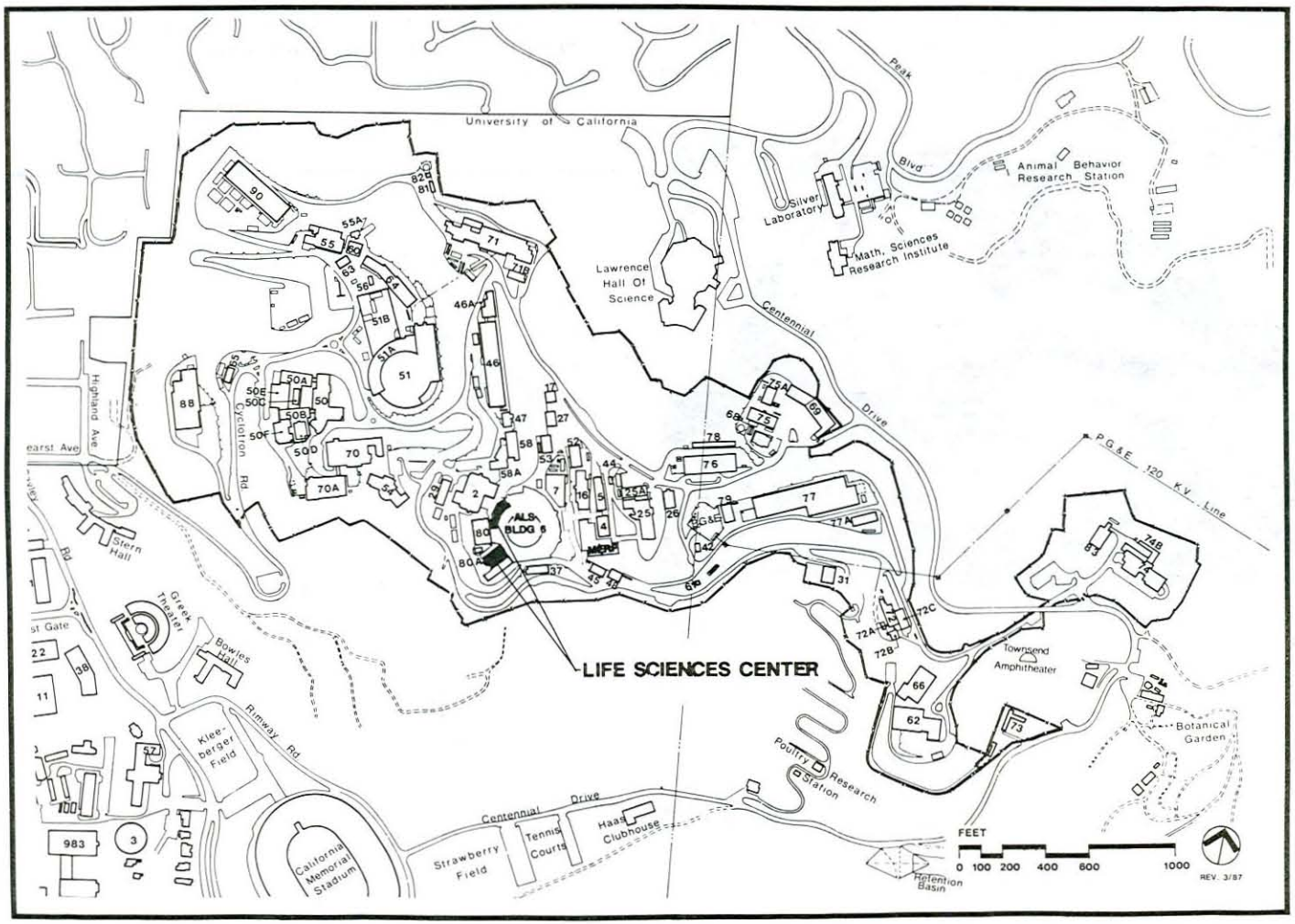



*Figure 5-1. Site plan of the Lawrence Berkeley Laboratory, showing the proposed location of the ALS Life Sciences Center.*

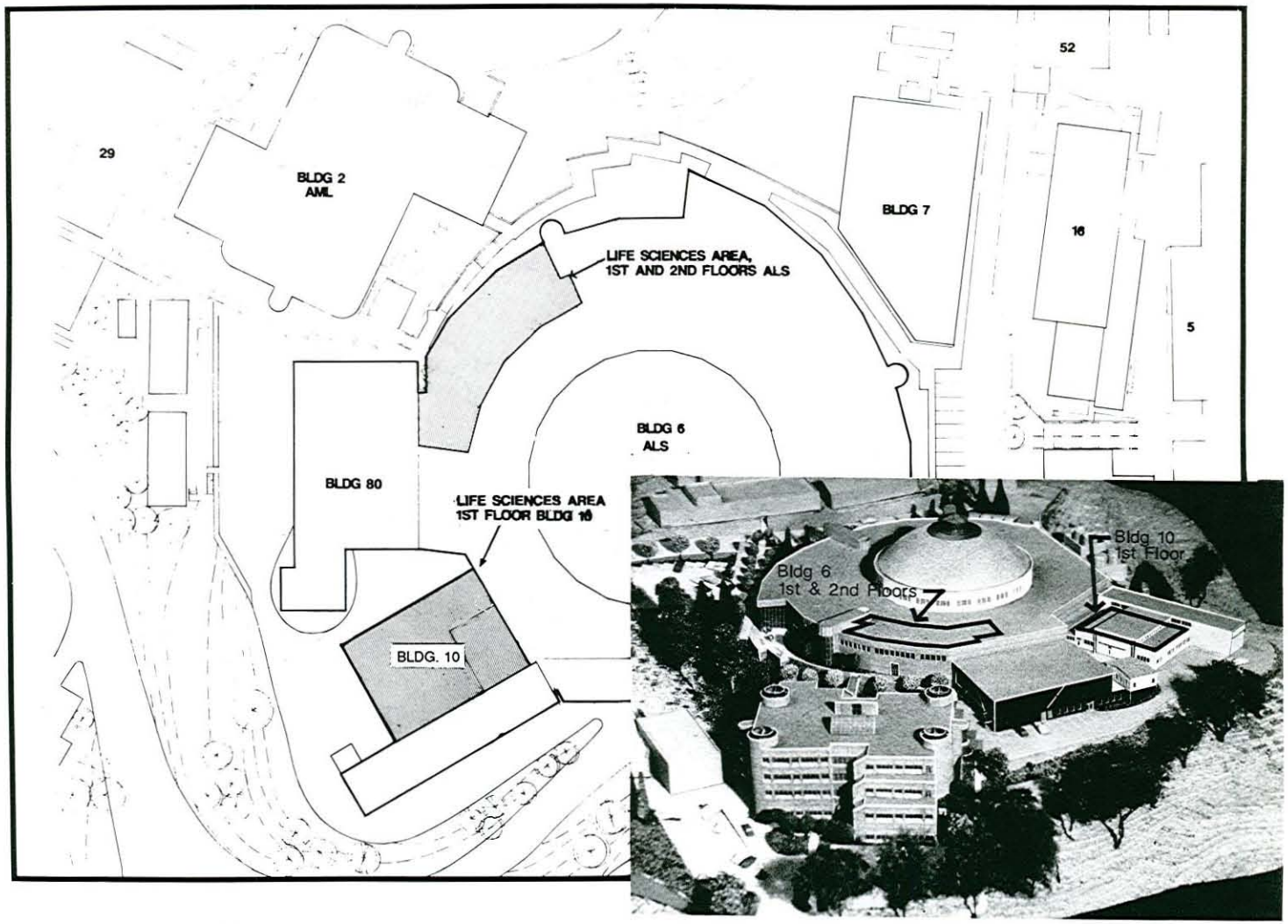



*Figure 5-2. Plan view of the ALS complex, showing the locations of Buildings 6 and 10. Renovation of Building 6 and construction of the ALS are currently under way. The inset shows a photograph of an architect's model of the ALS, again showing the locations of the two affected areas.*

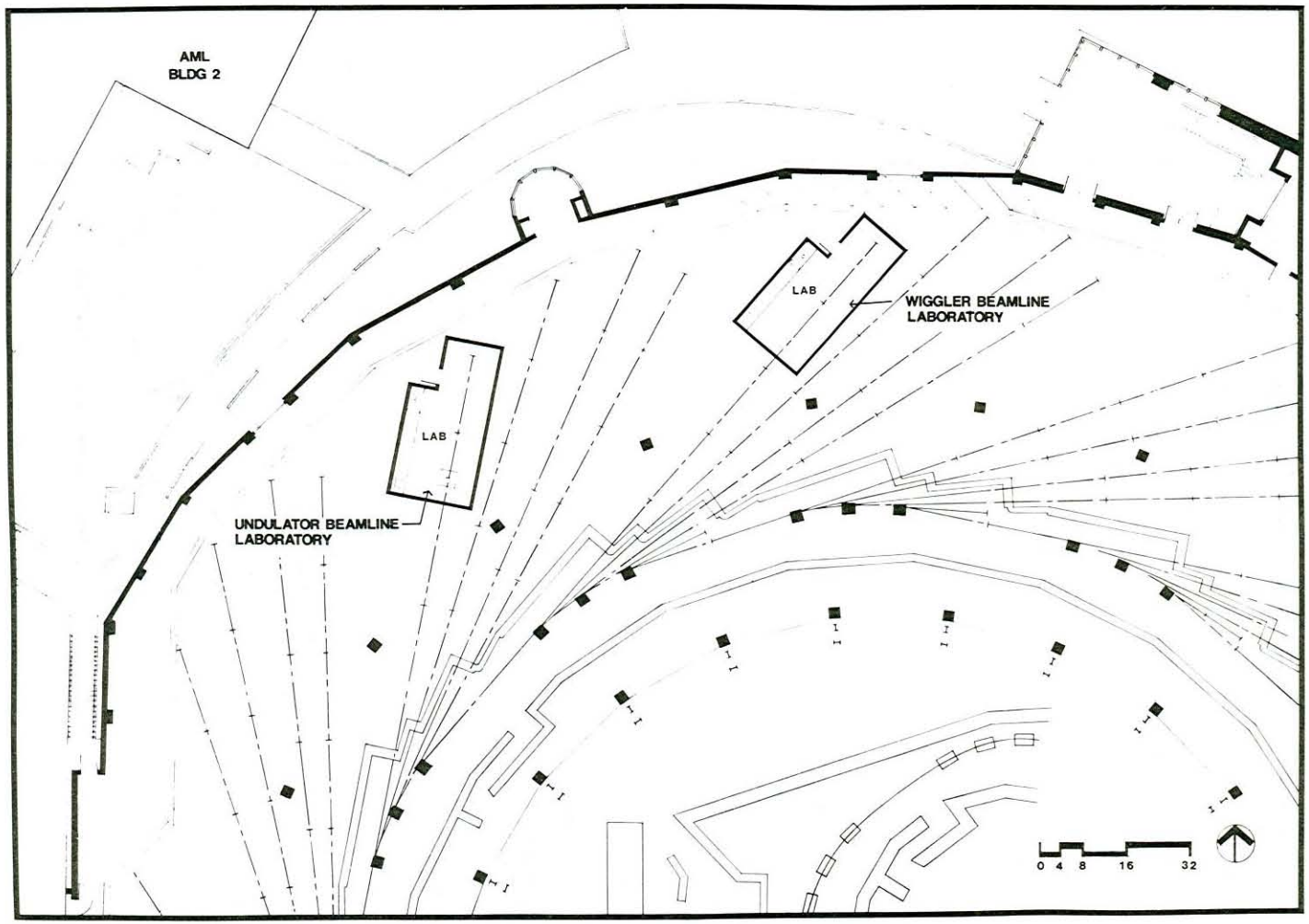



*Figure 5-3. Plan view of a portion of the ALS experimental area in Building 6. Each of the beamline hutches includes a 400-GSF modular wet laboratory.*

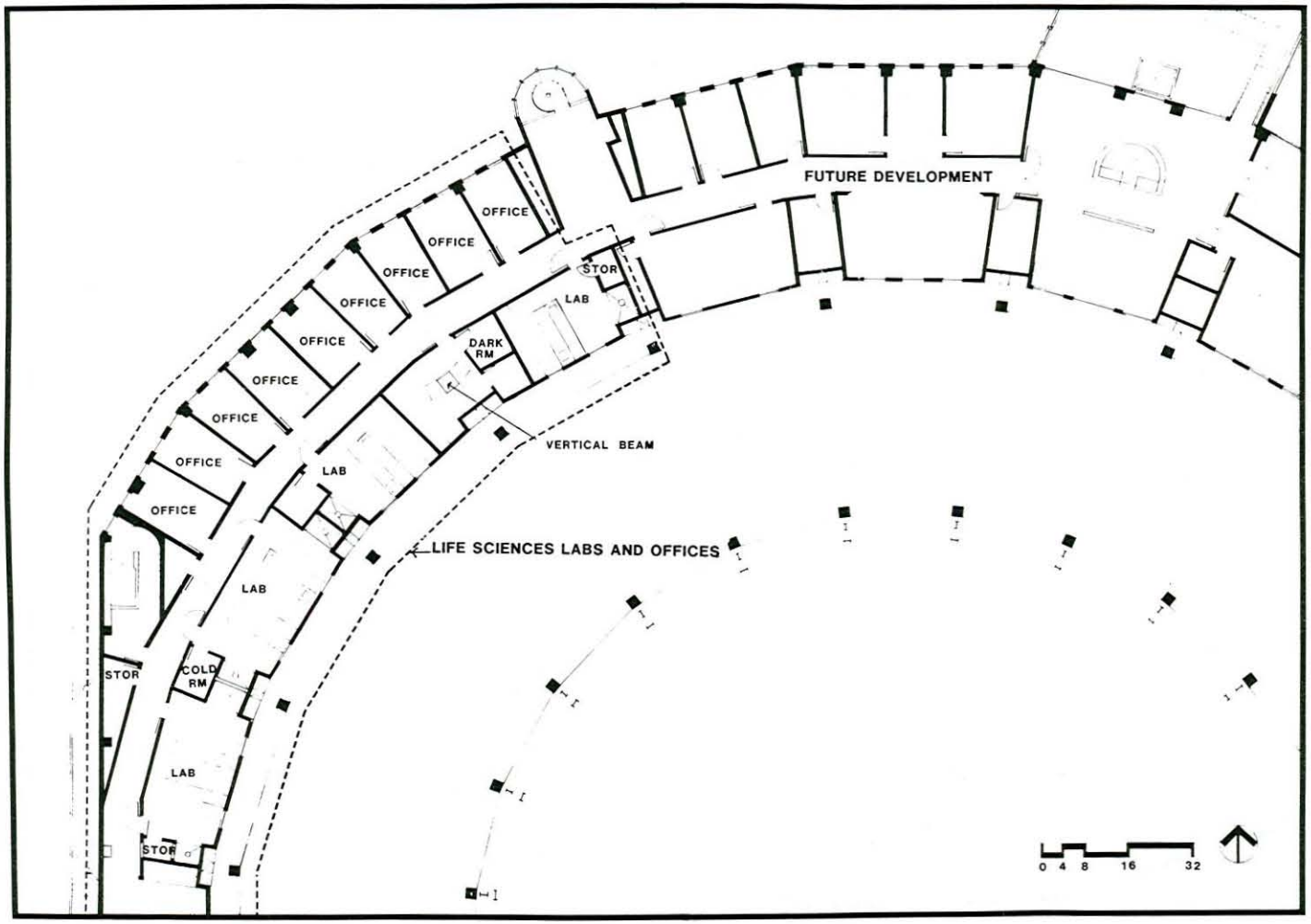



*Figure 5-4. Plan view of a portion of the mezzanine of Building 6. The part within the dashed line is included in the scope of the Life Sciences Center project.*

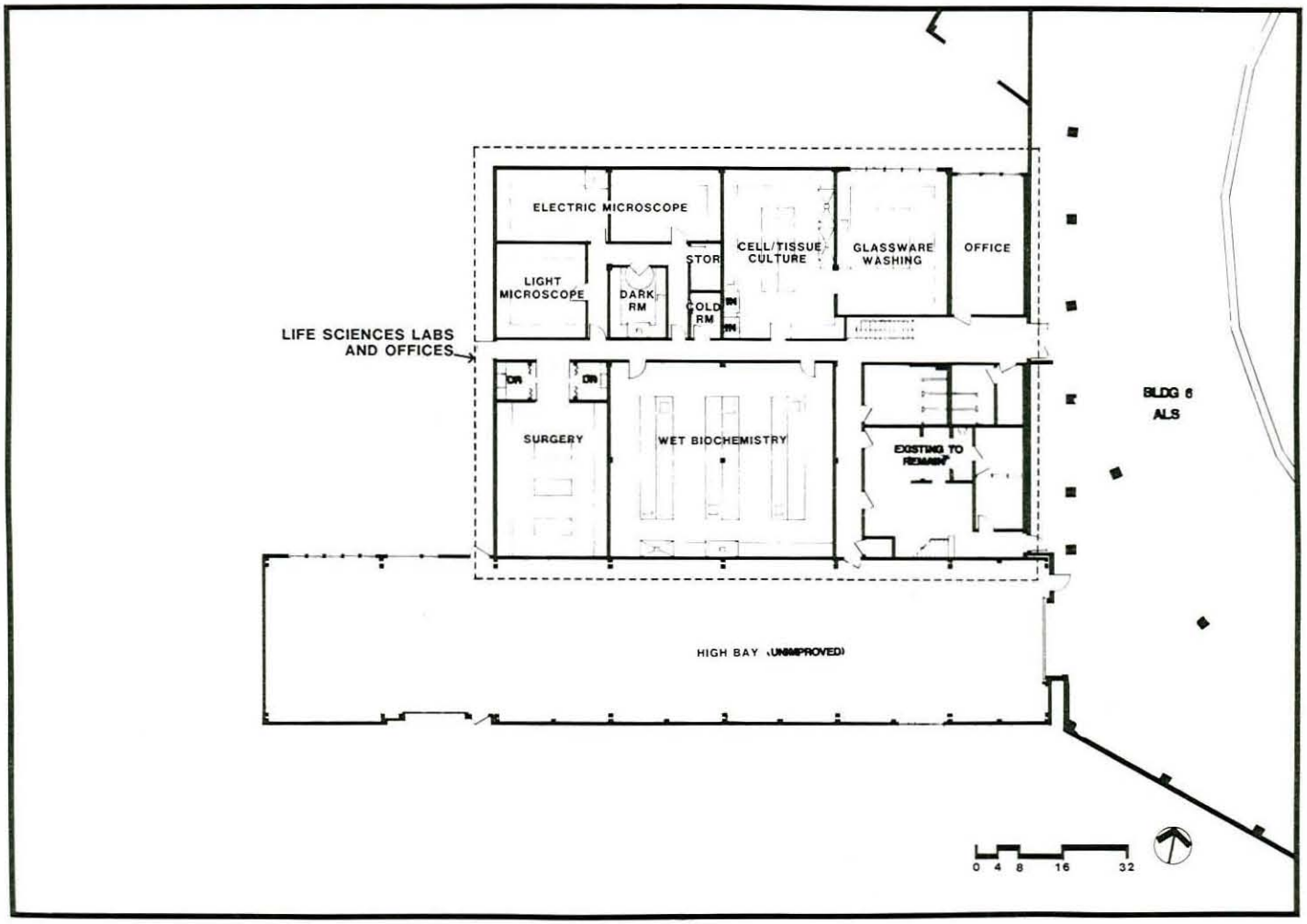



*Figure 5-5. Plan view of the first floor of Building 10.*

***Table 5-1. A summary of net areas, functions, and occupancy of the conventional facilities in Buildings 6 and 10.***

| | Net area (sq. ft.) | | | |
|---|---|---|---|---|
| | Labs | Lab offices | Other | Occupants |
| BUILDING 10 | | | | |
| Biochemistry | 1,475 | | | |
| Microscopy suite | 1,025 | | | |
| Surgery | 560 | | | |
| Cell and tissue culture | 640 | | | |
| Laboratory offices | | 400 | | |
| Glassware, Dishwashing | | | 540 | |
| Cold room | | | 60 | |
| Storage | | | 60 | |
| Subtotal, Bldg 10 | 3,700 | 400 | 660 | 18 |
| BUILDING 6 | | | | |
| *Beamline laboratories* | 800 | | | |
| *Second floor* | | | | |
| Laboratories | 1,990 | | | |
| Laboratory offices | | 1,470 | | |
| Cold rooms | | | 120 | |
| Storage | | | 195 | |
| Subtotal, Bldg 6 | 2,790 | 1,470 | 315 | 14 |
| Total, both buildings | 6,490 | 1,870 | 975 | 32 |

**Total net usable area: 9,335 sq. ft.**

*Gross enclosed areas (sq. ft.)*

| | |
|---|---|
| Building 10: | 6,000 |
| Building 6: | 5,100 |

**Total gross enclosed area: 11,100 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; 11,100 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 1991, 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 FY 1992 and 1993 to ensure efficient commissioning of the insertion devices and beamlines and to lay the organizational groundwork for productive use of the Center as a national user facility.

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.

- 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 1989 dollars, then escalated to obtain the total estimated cost (TEC) of the project. The estimate includes project management and administration, ED&I, and deliverables. Contingencies were estimated separately for special research facilities and management (at 30%) and for conventional facilities (at 20%).

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 $21.5 million cost estimate, in FY 1989 dollars, escalates to $25.4 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.

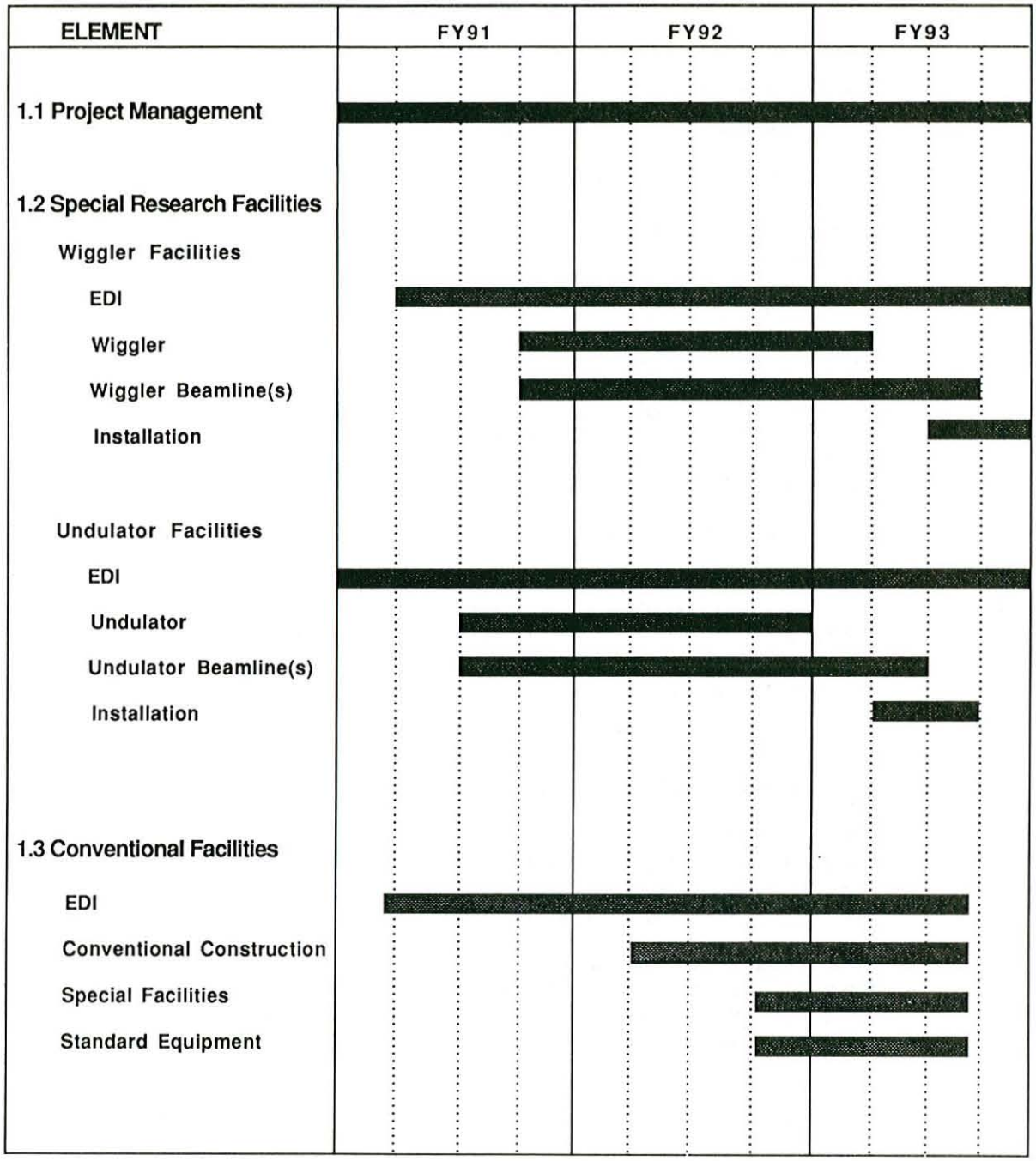



*Figure 6-1. Overall project schedule for the ALS Life Sciences Center.*

***Table 6-1. Summary of the bottom-up cost estimate. All costs are shown in thousands of FY 1989 dollars.***

| | | | | | |
|---|---|---|---|---|---|
| 1. | Life Sciences Center - TEC (all costs shown in FY1989 K$) | | | | 21,500 |
| 1.1. | Project Management & Administration | | | | 695 |
| 1.2. | Special Research Facilities | | | | 11,092 |
| 1.2.1 | Engineering, Design, & Inspection | | | 2,789 | |
| 1.2.1.1 | EDI, Wiggler Facility | | 1,504 | | |
| 1.2.1.1.1 | EDI, Wiggler | 198 | | | |
| 1.2.1.1.2 | EDI, Wiggler Beamline Frontend | 115 | | | |
| 1.2.1.1.3 | EDI, Diffraction Facility | 557 | | | |
| 1.2.1.1.4 | EDI, Spectroscopy/Microprobe Facility | 634 | | | |
| 1.2.1.2 | EDI, Undulator Facility | | 1,285 | | |
| 1.2.1.2.1 | EDI, Undulator | 281 | | | |
| 1.2.1.2.2 | EDI, Undulator Beamline Frontend | 115 | | | |
| 1.2.1.2.3 | EDI, Soft X-ray Imaging Facility | 889 | | | |
| 1.2.2 | Wiggler Facility | | | 4,448 | |
| 1.2.2.1 | Wiggler | | 663 | | |
| 1.2.2.2 | Wiggler Beamline Frontend | | 379 | | |
| 1.2.2.3 | Diffraction Facility | | 1,585 | | |
| 1.2.2.3.1 | Crystallography Branchline | 1,018 | | | |
| 1.2.2.3.2 | Crystallography Station | 432 | | | |
| 1.2.2.3.3 | Small Angle Scattering Station | 135 | | | |
| 1.2.2.4 | Spectroscopy/Microprobe Facility | | 1,821 | | |
| 1.2.2.4.1 | Spectroscopy/Microprobe Branchline | 1,338 | | | |
| 1.2.2.4.2 | Spectroscopy Station | 228 | | | |
| 1.2.2.4.3 | Microprobe Station | 255 | | | |
| 1.2.3 | Undulator Facility | | | 3,855 | |
| 1.2.3.1 | Undulator | | 936 | | |
| 1.2.3.2 | Undulator Beamline Frontend | | 379 | | |
| 1.2.3.3 | Soft X-ray Imaging Facility | | 2,540 | | |
| 1.2.3.3.1 | Main Beamline | 1,115 | | | |
| 1.2.3.3.2 | Main Scanning Microscope Station | 575 | | | |
| 1.2.3.3.4 | R/D Scanning Microscope Station | 470 | | | |
| 1.2.3.3.4 | Diffraction Imaging Station | 380 | | | |

*Table 6-1 continued.*

| | | | | |
|---|---|---|---|---|
| 1.3. | Conventional Facilities | | | 5,157 |
| 1.3.1 | Engineering, Design, & Inspection | | 490 | |
| 1.3.2 | Construction | | 2,935 | |
| 1.3.2.1 | Improvements to Land | 12 | | |
| 1.3.2.2 | Building 10 Improvements | 1,243 | | |
| 1.3.2.3 | Building 6 Improvements | 612 | | |
| 1.3.2.4 | Site Utilities | 71 | | |
| 1.3.2.5 | Special Facilities | 997 | | |
| 1.3.3 | Standard Equipment | | 1,732 | |
| 1.3.3.1 | Biochemistry | 1,034 | | |
| 1.3.3.2 | Microscopy | 105 | | |
| 1.3.3.3 | Cell and Tissue Culture | 135 | | |
| 1.3.3.4 | Surgical Suite | 77 | | |
| 1.3.3.5 | General Support Equipment | 381 | | |
| 1.4. | Contingency | | | 4,556 |
| 1.4.1 | Special Research Facilities & Mgt | | 3,525 | |
| 1.4.2 | Conventional Facilities | | 1,031 | |

***Table 6-2. Project cost summary. All figures are given in thousands of FY 1989 dollars, except the total estimated cost, which is given in thousands of then-year dollars.***

| | | | | |
|---|---|---|---|---|
| 1 | Life Sciences Center (TEC, then-year $) | | | $ 25,400 |
| 1.1 | Project Management & Administration | | 695 | |
| 1.2 | Special Research Facilities | | 11,092 | |
| | 1.2.1 Engineering, Design & Inspection | 2,789 | | |
| | 1.2.2 Wiggler Facility | 4,448 | | |
| | 1.2.3 Undulator Facility | 3,855 | | |
| 1.3 | Conventional Facilities | | 5,157 | |
| | 1.3.1 Engineering, Design & Inspection | 490 | | |
| | 1.3.2 Construction | 2,935 | | |
| | 1.3.3 Standard Equipment | 1,732 | | |
| 1.4 | Contingency | | 4,556 | |
| | 1.4.1 Special Research Facilities and Mgmt | 3,525 | | |
| | 1.4.2 Conventional Facilities | 1,031 | | |
| | Escalation | | 3,900 | |

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

| | FY89 | FY90 | FY91 | FY92 | FY93 | Total |
|---|---|---|---|---|---|---|
| FY 1989 $ | | | 2,732 | 8,651 | 10,117 | 21,500 |
| Inflation (%) | | 4.8 | 5.0 | 5.2 | 5.7 | |
| Escalation factor | 1.000 | 1.048 | 1.100 | 1.158 | 1.224 | |
| Then-year $ | | | 3,006 | 10,015 | 12,379 | 25,400 |

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

| | | | |
|---|---|---|---|
| 1. | Life Sciences Center (TEC) | | $ 25,400 |
| 1.1 | Project Management & Administration | 806 | |
| 1.2 | Special Research Facilities | 13,059 | |
| | 1.2.1 Engineering, Design & Inspection | 3,248 | |
| | 1.2.2 Wiggler Facility | 5,255 | |
| | 1.2.3 Undulator Facility | 4,556 | |
| 1.3 | Conventional Facilities | 6,141 | |
| | 1.3.1 Engineering, Design & Inspection | 558 | |
| | 1.3.2 Construction | 3,492 | |
| | 1.3.3 Standard Equipment | 2,091 | |
| 1.4 | Contingency | 5,394 | |
| | 1.4.1 Special Research Facilities and Mgmt | 4,167 | |
| | 1.4.2 Conventional Facilities | 1,227 | |

*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.*

| | FY91 | FY92 | FY93 | Total |
|---|---|---|---|---|
| 1.1 Project Mgmt. & Administration | 259 | 266 | 281 | 806 |
| 1.2 Special Research Facilities | | | | |
| Wiggler Facility | 990 | 2,779 | 3,245 | 7,014 |
| Undulator Facility | 880 | 2,547 | 2,618 | 6,045 |
| 1.3 Conventional Facilities | 308 | 2,371 | 3,462 | 6,141 |
| 1.4 Contingency | 569 | 2,052 | 2,773 | 5,394 |
| Costs, totals by year | 3,006 | 10,015 | 12,379 | 25,400 |
| Obligations, totals by year | 4,800 | 14,000 | 6,600 | 25,400 |

PUB-5224

# Conceptual Design Report

# ALS - Life Sciences Center

## January 1989

Project Number 91-LBL

Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720
Prepared for U.S. Department of Energy under Contract No. DE-AC03-76SF00098

# SECTION 1

# INTRODUCTION

## Project Description

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

The Life Sciences Center will be located in existing Buildings 6 and 10 within the ALS Complex as shown in the following photograph of the ALS Complex Model. This location provides the Center with direct access to the ALS experimental facilities for optimum integration of associated research and development activities. Figure T-1 shows the location of the proposed Center on the LBL site, while Figure A-1 shows its site location within the ALS Complex.

The Center will occupy a total of 11,100 gross square feet (GSF); 5,100 GSF on the second floor of new ALS Building 6 and 6,000 GSF on the first floor of Building 10 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 ALS Building 6 directly below second floor space occupied by the Center. A self-contained 400 GSF modular wet laboratory will be provided at each beamline end station as shown in Figure A-3.

Space on the second floor 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 Project will fund the cost of improvements necessary to finish and outfit the second floor space for laboratories, cold rooms, offices and ancilliary storage areas as shown in Figure A-4. One branch of one beamline will be reflected vertically from the ALS on the first floor into the second floor laboratory area. Appropriate HVAC, power, lighting, partitions, integrated communication systems, and other services will be provided as required.

Space on the first floor of Building 10 will be vacated to make way for facilities devoted to the Life Sciences Center. Although no cost will be required to relocate existing occupants, it will be necessary to demolish and strip out existing partitions and modify existing utilities and services for conversion of the area to Life Sciences laboratory space, including required HVAC, power, lighting, partitions and integrated communications

systems. 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 in Drawing A-2. The exterior siding of Building 10 will be replaced as shown in Drawing A-5 to augment modernization of interior space for the Center. Recent and planned major maintenance projects at Building 10, including reroofing and upgrading its structural system for seismic safety, will be completed before the Life Sciences Center is funded.

A central feature of the Life Sciences Center will be its well developed biological research laboratories. For broadly-based research in the life sciences to be effectively pursued at the ALS, a variety of different laboratory facilities are required. As noted in the overview: "Biologists, chemists, and materials scientists are all agreed that the forefront science promised by the availablility 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. Amoung 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, and preparing deionized and distilled water, as well as temperature controlled rooms. Visiting scientists will also 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 Life Sciences Center at the ALS must be in close proximity and have direct access to the ALS for optimum integration of associated research and development.

The Light Source Addition to Building 6 is under construction with completion anticipated in FY 1992. Construction of a mezzanine second floor 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 second floor of Building 6. One beamline will be reflected vertically from the first floor experimental area into the second floor laboratory area. No other solution was considered for Life Sciences space in Building 6.

The use of the first floor of existing Building 10 was selected for the additional laboratory space required for the Life Sciences Center because the Building 6 Addition, now under construction, will adjoin Building 10 providing optimum integration of Life Sciences activities in both buildings. LBL's master plan for redevelopment of the old original laboratory (UCLRL) in the vicinity of Building 6 is based upon rehabilitating and using existing buildings in close proximity to the Light Source for laboratories and offices to support ALS research facilities. Existing uses of buildings in this category are to be relocated to more appropriate areas.

An alternative solution to the conversion of the first floor of Building 10 which was considered, was the possibility of adding a third floor to Building 80 which will also adjoin Building 6 when the ALS project is completed. It was determined that the Building 10 scheme was more economical than the Building 80 scheme and the potential for the disruption of ALS research activities by Building 10 construction modifications was less than for Building 80 construction.

In summary, benefits of the use of existing space in Buildings 6 and 10 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.

## 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 plant 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 completed in December 1988.

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

## Method of Performance

### Design

A design program 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 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 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.

# SECTION 2

# PROJECT CRITERIA

## General

This portion of the report describes project design criteria related to conventional facilities construction within Building 10 and the Light Source Addition to Building 6 for the Life Sciences Center at the ALS.

## Conventional Facilities Design Criteria

A. General

1. In compliance with the LBL Long Range Development Plan as amended in 1987 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 10, 14 in 6.

2. Occupancy Classification

   a. ALS Building: B-2

   b. Building 10: B-2

3. Fire Resistivity

   a. ALS Building: One hour at external walls, two hours at adjacent buildings, non combustible construction.

   b. Building 10: Two hours at adjacent ALS, no hour rating and sprinklered otherwise.

4. Schedule of Net Areas, Functions and Occupancy (chart follows).

5. Code Compliance: 1988 Uniform Building Code.

6. Handicapped Requirements: In compliance with ANSI standards.

## Schedule of Net Areas, Functions and Occupancy

| | Net Area - Sq. Ft. | | | |
|---|---|---|---|---|
| BUILDING 10 | Labs | Lab Offices | Other | Occupants |
| **First Floor** | | | | |
| Biochemistry | 1,475 | | | |
| Microscopy Suite | 1,025 | | | |
| Surgery | 560 | | | |
| Cell and Tissue Culture | 640 | | | |
| Laboratory Offices | | 400 | | |
| Glassware, Dishwashing | | | 540 | |
| Cold Room | | | 60 | |
| Storage | | | 60 | |
| Subtotal Bldg 10: | 3,700 | 400 | 660 | 18 |
| **ALS BUILDING** | | | | |
| **First Floor*** | | | | |
| Laboratories-Beam Line: | 800 | | | |
| **Second Floor** | | | | |
| Laboratories | 1,990 | | | |
| Laboratory Offices | | 1,470 | | |
| Cold Rooms | | | 120 | |
| Storage | | | 195 | |
| Subtotal Bldg 6: | 2,790 | 1,470 | 315 | 14 |
| Subtotal All Floors: | 6,490 | 1,870 | 975 | 32 |
| Total Net Usable Area: | 9,335 sq. ft. | | | |
| **Gross Enclosed Areas** | | | | |
| Building 10: | 6,000 sq. ft. | | | |
| Building 6: | 5,100 sq. ft. | | | |
| Total Gross Enclosed: | 11,100 sq. ft. | | | |

* Prefab wet lab enclosures of 400 sq. ft. each at end of beam lines.

C. Civil/Structural

1. Conventional facilities are improvements within existing structures.

2. Existing structures comply with 1985 Uniform Building Code and LBL "Lateral Force (Wind and Earthquake) Design Criteria," July 1, 1985.

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 revised wall layout.

7. Utilities Provided:

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

   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 Communciations System (ICS)
   Closed-circuit intercom
   Local paging system

3. Energy Monitoring and Control System (existing)

4. Fire Alarm and Security:

   Fire call box
   Card key door entry control

## Applicable Codes and Design References

Applicable requirements and recommendations in the following codes and references should 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. 29 CFR Part 1926, Safety and Health Regulations for Construction, Department of Labor

2. 29 CFR 1910, Occupational Safety and Health Standards, Department of Labor

3. National Fire Codes, NFPA

4. National Electrical Safety Code, ANSI C2

5. National Electric Code, NFPA 70 (NEC-1984)

6. NFPA Code No. 101 "Safety to Life from Fire in Buildings and Structures"

7. Safety Code for Building Construction, ANSI A10.2

8. California Administrative Code, Title 8, General Industrial Safety Orders, Construction Safety Orders

9. California Administrative Code, Title 19, Chapter 1; Title 24, Part 2; and Title 24, Part 6, Division T-19

10. Uniform Building Code

11. Uniform Mechanical Code

12. Uniform Fire Code

13. Uniform Plumbing Code

14. Uniform Solar Energy Code (IAMPO)

15. Occupational Safety and Health Act

16. Federal, state, and local air-pollution and water-pollution control regulations

17. The National Energy Act of October 15, 1978

18. AMCA Fan Test Code

19. NBSIR 78-1305A Test Procedures

20. LBL Lateral Force (Wind and Earthquake) Design Criteria, July 1, 1985

B. Design References:

1. Department of Energy General Design Criteria Manual, Order-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. Solar Design Handbooks:

   a. DOE Facilities Solar Design Handbook, January 1978

   b. Passive Solar Design Handbook, draft April 6, 1979 by J.D. Balcomb and B. Anderson

5. NBS Handbook 135, Life Cycle Cost Manual for the Federal Energy Management Program

6. The ASHRAE Handbook and Product Directory:

   a. Applications Volume: 1982
   b. Fundamentals Volume: 1985
   c. Systems Volume: 1984
   d. Equipment Volume: 1983

7. Standards for Natural and Mechanical Ventilating, ASHRAE Standard 62-73 (ANSI B194.1-1977)

8. Energy Conservation in New Building Design, ASHRAE Standard 90-75, August 11, 1975

9. Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) Standards

10. Standards and Codes of the American Society of Mechanical Engineers (ASME)

11. American Water Works Association (AWWA) Standards

12. National Environmental Balancing Bureau (NEBB)

13. American Welding Society Handbook and Standards (AWS)

14. Standards of the American Society for Testing and Materials (ASTM)

15. American National Standard Specifications for Making Buildings and Facilities Accessible and Usable by the Physically Handicapped. ANSI A117.1-1961. REAF-1971

16. Recommended Outdoor Design Temperatures, Northern California Golden Gate Chapter, ASHRAE, November 1977

17. Industrial Ventilation Manual by the American Conference of Industrial Hygienists (ACGIH)

18. Earthquake-Resistive Construction for Mechanical Systems, Light Fixtures, and Ceilings, Ayres & Hayakawa, July 1972

19. Guidelines for Seismic Restraints of Mechanical Systems and Plumbing Piping Systems, SMACNA, October 13, 1982

20. American National Standards Institute (ANSI) Standards

21. National Electrical Manufacturers' Association (NEMA) Standards

22. Institute of Electrical and Electronics Engineers (IEEE) Standards

23. Underwriters' Laboratories, Inc. (UL) Standards and "Product Directories"

24. Factory Mutual Engineering Corp. (FM) Approval Guide and FM Loss Prevention Data

25. Insulated Cable Engineers' Association (ICEA) Standards

26. National Electrical Testing Association (NETA) Standards

27. Illuminating Engineering Society (IES) Lighting Handbook

28. Department of Energy Electrical Safety Criteria for Research and Development Activities, DOE/EV-0051/1, August 1979

29. Standard for Fire Protection of DOE Electronic Computer/Data Processing Systems, Jan 1984 (DOE/EP-0108, Formerly Wash 1245-1). See paragraph 101.4.

30. Department of Labor, Occupational Safety and Health Administration, Design Safety Standards for Electrical Systems, Subpart S 29 CFR 1910 (Federal Register, Vol. 46, No. 11, January 16, 1981)

31. A Building Planning Guide for Communication Wiring, International Business Machines Corp., G320-8059-1, March 1984

32. American Institute of Steel Construction, Manual of Steel Construction, eighth edition

33. American Concrete Institute, ACI Manual of Concrete Practice, Parts 1 through 5, latest edition

34. ANSI/IES RP7 "Practice for Industrial Lighting"

## 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:

A. 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 inspectors. 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 estimate 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 Marshal, the LBL Environmental Health and Safety 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 Chief, EH&S, Plant Management, and the Client is completed at the end of Title I and Title II design. (A sample form follows.)

B. Construction

1. Contract documents are reviewed by LBL's technical staff for compliance with DOE and LBL design criteria.

2. The Construction Inspectors review 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.

3. 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.

4. 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.

5. A Contract Administrator reviews contract documentation for compliance with contract provisions.

6. A Safety Engineer (from The Environmental Health and Safety Department) and the Fire Chief make periodic inspections of construction to assure compliance with codes and regulations.

7. 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.

8. Changes

   a. Reviewed in accordance with UCLBL Construction Subcontracting Manual.

   b. 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.

C. Final Inspection and Acceptance

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

1. Preliminary inspection and list of incomplete work

2. Equipment testing and operational instruction of LBL personnel

3. Final inspection walk-through and punch list

4. Inspection of correctional and completion work (punch list work)

5. Inventory of all operational manuals, instructions, guarantees

6. 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 Chief, EH&S, etc.

7. 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.

D. Project Closeout

1. After final acceptance of the facility, LBL audits all charges to assure that all costs are in proper accounts.

2. LBL sends the cost closing statement to DOE-SAN.

3. Project authorization closed by SAN.

## PROJECT REVIEW AND APPROVAL

_____
Project Title

_____
Job Number | Subcontract No/PB No | Documents Prepared by

☐ PRELIM (TI) ☐ FINAL (TII) ☐ CONSTR COMPLETE (TIII)

☐ SPECIFICATIONS ☐ DRAWINGS

| DESIGN TEAM | SECTION LEADERS | CONSTRUCTION MANAGEMENT |
|---|---|---|
| Arch_____ | Arch _____ | Estimator _____ |
| Civil _____ | Civil _____ | Contract Admin _____ |
| Mech _____ | Mech _____ | Inspection _____ |
| Elec _____ | Elec _____ | Energy _____ |

| | | | |
|---|---|---|---|
| Value Engineering | Date | QA Approval | Date |
| Client | Date | C&M | Date |
| Fire Chief | Date | Structural Review or Memo of Approval Attached | Date |
| Environmental Health & Safety | Date | Project Architect/Engineer | Date |
| Handicap Barriers Review (Compliance w/FPMR 101-19.6) | Date | Plant Engineer | Date |

Distribution: Responsible Section Leader and Contract Administrator.

Sign-Offs (Title I) indicate project is adequately defined to begin Title II work.

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

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

LGC:cw
10/26/88
40b/7745b

SUPPLEMENTARY PROJECT DATA
FACILITY UTILIZATION

Title and Location of Project ALS - Life Sciences Center Project No. 91-LBL

Lawrence Berkeley Laboratory, Berkeley, California

Site-wide Requirements/Assets for CATEGORY 10, Office

Other Projects Affecting this Category: Safety and Support Services Fac, Mech Eng Repl Proj, Phase I, Human Genome 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: | 492,500 | in SF or other unit. |
| B. The total existing assets in this category: | 446,400 | SF, |
| C. Less amount of existing, substandard assets: | 337,200 | SF, |
| D. Equals amount of existing, adequate assets: | 109,200 | SF. |
| E. Existing adequate assets, less total requirement for this category equals excess/(deficiency) of adequate assets: | (383,300) | SF. (D minus A) |

CHANGES TO ASSET LEVELS RESULTING FROM THIS PROJECT:

| | | |
|---|---|---|
| F. The additional assets created in this category by the project: | 2,200 | SF, |
| G. Less assets removed from this category by the project through excessing, demolition, etc.: | 900 | SF, |
| H. Equals net increase/(decrease) of assets in this category due to the project: | 1,300 | SF. (F minus G) |

PROJECTED ASSET STATUS AFTER COMPLETION OF THIS PROJECT:

| | | |
|---|---|---|
| J. Total existing assets, plus net increase/(decrease) of assets in this category due to the project, less total requirement, equal total excess/(deficiency) of assets projected for this category: | (44,800) | SF. (B plus H minus A) |
| I. Existing excess or (deficiency) of adequate assets, plus this project's increases, equal excess or (deficiency) of adequate assets projected for this category: | (381,100) | SF. (E plus F) |

148b/9583b
2/22/89

Figure III-5
Facility Utilization Data

SUPPLEMENTARY PROJECT DATA
FACILITY UTILIZATION

Title and Location of Project ALS - Life Sciences Center — Project No. 91-LBL

Lawrence Berkeley Laboratory, Berkeley, California

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

Other Projects Affecting this Category: Human Genome Laboratory, Biomedical Isotope Facility, 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: | 325,100 | in SF or other unit. |
| B. The total existing assets in this category: | 282,100 | SF, |
| C. Less amount of existing, substandard assets: | 185,200 | SF, |
| D. Equals amount of existing, adequate assets: | 96,900 | SF. |
| E. Existing adequate assets, less total requirement for this category equals excess/(deficiency) of adequate assets: | (228,200) | SF. (D minus A) |

CHANGES TO ASSET LEVELS RESULTING FROM THIS PROJECT:

| | | |
|---|---|---|
| F. The additional assets created in this category by the project: | 7,700 | SF, |
| G. Less assets removed from this category by the project through excessing, demolition, etc.: | 4,800 | SF, |
| H. Equals net increase/(decrease) of assets in this category due to the project: | (2,900) | SF. (F minus G) |

PROJECTED ASSET STATUS AFTER COMPLETION OF THIS PROJECT:

| | | |
|---|---|---|
| J. Total existing assets, plus net increase/(decrease) of assets in this category due to the project, less total requirement, equal total excess/(deficiency) of assets projected for this category: | (40,100) | SF. (B plus H minus A) |
| I. Existing excess or (deficiency) of adequate assets, plus this project's increases, equal excess or (deficiency) of adequate assets projected for this category: | (220,500) | SF. (E plus F) |

148b/9583b
2/22/89

Figure III-5
Facility Utilization Data

# BASIS OF COST ESTIMATES 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 10 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. Mechanical engineering design and energy use estimates were accomplished by Keller and Gannon, Engineers and Architects. Electrical, civil and structural design was prepared by LBL.

Conventional Construction Cost Estimates are dated December 1988 and represent FY 1989 costs. Summary Cost Estimates for Conventional Facilities are included in this section. Detailed cost estimates are included in Section 9. Escalation is based upon "Anticipated Economic Escalation Rates for DOE Construction Projects" updated July 29, 1988 namely, 4.2% in FY 1989, 4.8% in FY 1990, 5.0% in FY 1991, 5.2% in FY 1992 and 5.7% in FY 1993. Escalation rates are compounded from the date of the estimate to the mid-point of construction for "then year" costs.

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.

Cost estimates for scientific equipment in Schedule II, Standard Equipment, are based upon discounted catalog data which has been included in Section 9. A more detailed breakdown of the Standard Equipment summarized in Schedule II is also included in Section 9.

Cost estimate details for that portion of the EDIA associated with Conventional Facilities and Scientific Equipment under Special Facilities are located in Section 9. Both the Summary Estimate shown in this section and the Detailed Cost Estimate in Section 9 have been correlated with the Work Breakdown Structure (WBS).

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

(Amounts in Then-Year $K)

| | |
|---|---|
| Date A-E Work Initiated: | 2nd Qtr. FY91 |
| Date Physical Construction Starts: | 2nd Qtr. FY92 |
| Date Construction Ends: | 3rd Qtr. FY93 |

Financial Schedule, Conventional Facilities Only: (rounded)

| Fiscal Year | Obligations | Costs |
|---|---|---|
| 1991 | $ 490 | $ 360 |
| 1992 | 4,912 | 2,866 |
| 1993 | 1,966 | 4,142 |

Summary of Cost Estimate:

| WBS | | | |
|---|---|---|---|
| 1.3.1 | EDI&A (@ abt 16% of Construction) | | $ 558 |
| 1.3.2 | CONSTRUCTION | | 3,492 |
| | Land Improvements | 13 | |
| | Building 10 Improvements | 1,480 | |
| | Building 6 Improvements | 729 | |
| | Site Utilities | 83 | |
| | Special Facilities (Sch I) | 1,187 | |
| 1.3.3 | STANDARD EQUIPMENT (Sch II) | | 2,091 |
| | | Subtotal | 6,141 |
| | Contingencies at 20% | | 1,227 |
| | Conventional Facilities - Total Est. Cost | | $7,368 |

2-15-89

ALS - LIFE SCIENCES CENTER
CONVENTIONAL FACILITIES
TY$K

## SCHEDULE I

| Special Facilities | Cost |
|---|---|
| Laboratory Furniture and Standard Fume Hoods | |
| Building 10 | 244* |
| Building 6 | 101* |
| Cold Rooms | |
| Building 10 (1) | 18* |
| Building 6 (2) | 36* |
| Laminar Flow Hoods (3) | 43* |
| Scientific Equipment | |
| Digital Scanning Electron Microscope with Analytical Workstation | 310 |
| High Resolution Electron Microscope with Cryoworkstation | 238 |
| Confocal Microscope | 102 |
| Image Analysis Package | 95 |
| TOTAL | 1,187 |

*Included in Construction and A/E Contracts ($442K).

ALS - LIFE SCIENCES CENTER
CONVENTIONAL FACILITIES
TY$K

## SCHEDULE II

| Standard Equipment | | Cost |
|---|---|---|
| Biochemistry | | 1,248 |
| Centrifuges | 293 | |
| Spectrophotometers | 221 | |
| Balances | 71 | |
| Isotope Counters | 50 | |
| Separation Equipment | 258 | |
| General Laboratory Equipment | 355 | |
| Microscopy | | 127 |
| Darkroom Equipment | 63 | |
| General Laboratory Equipment | 64 | |
| Cell and Tissue Culture | | 163 |
| Incubators | 56 | |
| Sterilizer | 45 | |
| General Laboratory Equipment | 62 | |
| Surgical Suite | | 93 |
| Operating Tables, Surgical Instruments, and Special Lighting | 24 | |
| Operating Microscope and Video Equipment | 56 | |
| General Laboratory Equipment | 13 | |
| General Support Equipment | | 460 |
| Computations Equipment | 95 | |
| Dishwasher | 88 | |
| Office Furniture | 48 | |
| Office Equipment | 229 | |
| TOTAL | | 2,091 |

**BA/BO SCHEDULE (TY$K)**
**ALS LIFE SCIENCES CENTER**
**CONVENTIONAL FACILITIES**

| WBS NO. | WBS $K | WBS ELEMENT | TOTAL COST | FY 1991 | FY 1992 | FY 1993 |
|---|---|---|---|---|---|---|
| | | | | 1 2 3 4 | 1 2 3 4 | 1 2 3 4 |
| 1.3.1 | 558 | EDI&A | | | | |
| | | LBL ACTIVITIES | | | | |
| | | Engineering | 139 | 75/75 | 32/32 | 32/32 |
| | | Consultants | 17 | 17/17 | | |
| | | Inspection | 74 | | 38/38 | 36/36 |
| | | A/E ACTIVITIES | | | | |
| | | Title I | 58 | 58/58 | | |
| | | Title II | 159 | 159/159 | | |
| | | Title III | 111 | 111/0 | 0/53 | 0/58 |
| 1.3.2 | 3,492 | CONSTRUCTION | | | | |
| | | Land Improvements | 13 | | 13/13 | |
| | | Bldg 10 Improvements | 1,480 | | 1480/728 | 0/752 |
| | | Bldg 6 Improvements | 729 | | 729/360 | 0/369 |
| | | Site Utilities | 83 | | 83/83 | |
| | | Special Facilities Schedule I | 1,187 | | 1187/564 | 0/623 |
| 1.3.3 | 2,180 | STANDARD EQUIPMENT Schedule II | 2,091 | | 500/500 | 1591/1591 |
| SUBTOTALS | | | 6,141 | 420/309 | 4062/2371 | 1659/3461 |
| CONTINGENCY (20%) | | | 1,227 | 70/52 | 850/495 | 307/680 |
| TOTALS BA/BO | | | 7,368 | 490/360 | 4912/2866 | 1966/4142 |

2-15-89

**BA/BO SCHEDULE (89$K)**
**ALS LIFE SCIENCES CENTER**
**CONVENTIONAL FACILITIES**

| WBS NO. | WBS $K | WBS ELEMENT | TOTAL COST | FY 1991 | FY 1992 | FY 1993 |
|---|---|---|---|---|---|---|
| | | | | 1 2 3 4 | 1 2 3 4 | 1 2 3 4 |
| 1.3.1 | 490 | EDI&A | | | | |
| | | LBL ACTIVITIES Engineering | 120 | 70/70 | 25/25 | 25/25 |
| | | Consultants | 15 | 15/15 | | |
| | | Inspection | 65 | | 33/33 | 32/32 |
| | | A/E ACTIVITIES Title I | 50 | 50/50 | | |
| | | Title II | 145 | 145/145 | | |
| | | Title III | 95 | 95/0 | 0/48 | 0/47 |
| 1.3.2 | 2,935 | CONSTRUCTION | | | | |
| | | Land Improvements | 12 | | 12/12 | |
| | | Bldg 10 Improvements | 1,243 | | 1243/622 | 0/621 |
| | | Bldg 6 Improvements | 612 | | 612/306 | 0/306 |
| | | Site Utilities | 71 | | 71/71 | |
| | | Special Facilities Schedule I | 997 | | 997/499 | 0/498 |
| 1.3.3 | 1,732 | STANDARD EQUIPMENT Schedule II | 1,732 | | 432/432 | 1300/1300 |
| SUBTOTALS | | | 5,157 | 375/280 | 3425/2048 | 1357/2829 |
| CONTINGENCY (20%) | | | 1,031 | 63/47 | 736/428 | 232/556 |
| TOTALS BA/BO | | | 6,188 | 438/327 | 4161/2476 | 1589/3385 |

ALS - LIFE SCIENCES CENTER

OBLIGATIONS AND COSTS SCHEDULE DETAIL
(TY$K)

| DESCRIPTION | TOTAL | 1.100 FY 1991 | | 1.158 FY 1992 | | 1.224 FY 1993 | |
|---|---|---|---|---|---|---|---|
| | | O | C | O | C | O | C |
| LBL Activities | | | | | | | |
| Engineering | 139 | 75 | 75 | 32 | 32 | 32 | 32 |
| Consultants | 17 | 17 | 17 | | | | |
| Inspection | 74 | | | 38 | 38 | 36 | 36 |
| Subtotal | 230 | 92 | 92 | 70 | 70 | 68 | 68 |
| Architect-Engineer | | | | | | | |
| Titles I, II & III | 328 | 328 | 217 | 0 | 53 | 0 | 58 |
| Construction | | | | | | | |
| Land Improvements | 13 | | | 13 | 13 | | |
| Building 10 | 1,480 | | | 1,480 | 728 | 0 | 752 |
| Building 6 | 729 | | | 729 | 360 | 0 | 369 |
| Site Utilities | 83 | | | 83 | 83 | | |
| Special Facilities | 1,187 | | | 1,187 | 564 | 0 | 623 |
| Subtotal | 3,492 | 0 | 0 | 3,492 | 1,748 | 0 | 1,744 |
| Standard Equipment | 2,091 | | | 500 | 500 | 1,591 | 1,591 |
| Subtotal | 6,141 | 420 | 309 | 4,062 | 2,371 | 1,659 | 3,461 |
| Contingency (20%) | 1,227 | 70 | 52 | 850 | 495 | 307 | 680 |
| Total | 7,368 | 490 | 360 | 4,912 | 2,866 | 1,966 | 4,142 |

Above costs have been escalated as follows: 4.8% for FY90; 5.0% for FY91; 5.2% for FY92; and 5.7% for FY93. The compounded factors used to escalate each FY appear at top of columns, above.

ALS - LIFE SCIENCES CENTER

CONTINGENCY ANALYSIS
(TY$K)

| | ESTIMATED COST ($K) | CONTINGENCY (%) | CONTINGENCY ($K) |
|---|---|---|---|
| LBL Activities | | | |
| Engineering | 139 | 15 | 21 |
| Consultants | 17 | 25 | 4 |
| Inspection | 74 | 25 | 18 |
| Architect/Engineer | | | |
| Titles I, II & III | 328 | 18 | 58 |
| Construction Contract | | | |
| Improvements to Land | 13 | 25 | 3 |
| Building 10 | 1,480 | 25 | 370 |
| Building 6 | 729 | 25 | 182 |
| Site Utilities | 83 | 25 | 21 |
| Special Facilities | 1,187 | 20 | 237 |
| Standard Equipment | 2,091 | 15 | 313 |
| Subtotal | 6,141 | | 1,227 |
| Contingency at 20% | 1,227 | | |
| Total | 7,368 | | |

ALS - LIFE SCIENCES CENTER

ESTIMATE SUMMARY DETAIL

Summary by D. Daniels, LBL  Prices by D. Daniels  December 1988

Buildings

| DIV | | | BUILDING 10 | | BUILDING 6 |
|---|---|---|---|---|---|
| 2 | Demolition | | 166,000 | | --- |
| 5 | Metals | | 233,000 | | 6,000 |
| 6 | Carpentry | | 24,000 | | 15,000 |
| 7 | Thermal/Moisture Protection | | 16,000 | | --- |
| 8 | Doors/Windows | | 103,000 | | 20,000 |
| 9 | Finishes | | 154,000 | | 124,000 |
| 10 | Specialties | | 2,000 | | 2,000 |
| 11 | Equipment (Laboratory) | | By Client | | By Client |
| 12 | Furnishings (See Special Facilities/ Standard Equipment) | | --- | | --- |
| 13 | Special Construction (Prefab Lab Modules) | | --- | | 80,000 |
| 15 | Mechanical: Plumbing | | 59,000 | | 66,000 |
| | HVAC | | 127,000 | | 126,000 |
| | Fire Protection | | 4,000 | | 4,000 |
| 16 | Electrical | | 131,000 | | 59,000 |
| | Subtotal | | 1,019,000 | | 502,000 |
| | General Conditions/Mobilize | 7% | 71,330 | 7% | 35,140 |
| | Estimating Contingency | | In Proj.Cont. | | In Proj.Cont. |
| | | | 1,090,330 | | 537,140 |
| | Bond | 2% | 21,810 | 2% | 10,740 |
| | Prime Contractor OH & Fee | 12% | 130,840 | 12% | 64,460 |
| Total Estimated Construction Cost at December 1988 | | | 1,242,980 | | 612,340 |
| Total Escalated Construction Cost | | 19% | 1,480,000 | 19% | 729,000 |

ALS - LIFE SCIENCES CENTER

ESTIMATE SUMMARY DETAIL (CONTINUED)

| Improvements to Land | | Building 10 | | Building 6 | |
|---|---|---|---|---|---|
| Sitework | | 10,000 | | --- | |
| General Conditions/Mobilize | 7% | 700 | | --- | |
| Estimating Contingency | | In Proj.Cont. | | In Proj.Cont. | |
| | | 10,700 | | --- | |
| Bond | 2% | 210 | 2% | --- | |
| Prime Contractor OH & Fee | 12% | 1,280 | 12% | --- | |
| Total Estimated Construction Cost at December 1988 | | 12,190 | | --- | |
| Total Escalated Construction Cost | | 13,000 | | --- | |
| **Site Utilities** | | | | | |
| Mechanical | | 10,000 | | 5,000 | |
| Electrical | | 24,000 | | 19,000 | |
| Subtotal | | 34,000 | | 24,000 | |
| General Conditions/Mobilize | 7% | 2,380 | 7% | 1,680 | |
| Estimating Contingency | | In Proj.Cont. | | In Proj.Cont. | |
| | | 36,380 | | 25,680 | |
| Bond | 2% | 730 | 2% | 510 | |
| Prime Contractor OH & Fee | 12% | 4,370 | 12% | 3,080 | |
| Total Estimated Construction Cost at December 1988 | | 41,480 | | 29,270 | |
| Total Escalated Construction Cost | 17% | 49,000 | 17% | 34,000 | 83,000 |

DOE F 1325.8
(12-84)

United States Government **Department of Energy**

# memorandum

DATE: JUL 29 1988

REPLY TO ATTN OF: MA-221

SUBJECT: Economic Escalation Indices for Department of Energy Construction Projects

TO: Addressees

Attached is the August 1988, update of the economic escalation price change indices for DOE construction projects.

These indices are scheduled to be updated again in February 1989; but, in accordance with the agreement reached at the March 1984 meeting of the Committee for Cost Methods Development, the August 1988 update will be valid for an entire year, unless the February indices vary from these by more than 2 percent.

All questions should be directed to Juan M. Castro, FTS 896-9697.

Robert R. Kemps, Director
Office of Project and
Facilities Management

Attachment

ADDRESSEES

Assistant Secretary, Management and Administration
Assistant Secreary for Nuclear Energy
Assistant Secretary for Fossil Energy
Assistant Secretary, Conservation and Renewable Energy
Assistant Secretary for Defense Programs
Assistant Secretary for Policy, Safety, and Environment
Administrator, Energy Information Administration
Director of Administration
Director of Energy Research
Inspector General
Director of Civilian Radioactive Waste Management
Director of Procurement and Assistance Management
Controller
Managers, DOE Operations Offices

DEPARTMENTAL PRICE CHANGE INDEX

FY 1990 GUIDANCE

ANTICIPATED ECONOMIC ESCALATION RATES

FOR DOE CONSTRUCTION PROJECTS

| FISCAL YEAR | ENERGY RESEARCH AND NUCLEAR | | FOSSIL | | CONSERVATION/SOLAR | | DEFENSE PROGRAMS, EP, & GENERAL CONSTRUCTION | |
|---|---|---|---|---|---|---|---|---|
| | INDEX | % CHANGE | INDEX | % CHANGE | INDEX | % CHANGE | INDEX | % CHANGE |
| 1988 | 1.000 | NA | 1.000 | NA | 1.000 | NA | 1.000 | NA |
| 1989 | 1.042 | 4.2 | 1.043 | 4.3 | 1.039 | 3.9 | 1.043 | 4.3 |
| 1990 | 1.092 | 4.8 | 1.091 | 4.6 | 1.086 | 4.6 | 1.093 | 4.8 |
| 1991 | 1.146 | 5.0 | 1.144 | 4.8 | 1.138 | 4.8 | 1.149 | 5.2 |
| 1992 | 1.205 | 5.2 | 1.203 | 5.2 | 1.195 | 5.0 | 1.214 | 5.6 |
| 1993 | 1.274 | 5.7 | 1.270 | 5.6 | 1.261 | 5.5 | 1.285 | 5.8 |
| 1994 | 1.350 | 6.0 | 1.346 | 5.9 | 1.333 | 5.7 | 1.360 | 5.8 |

Based on the materials and labor data contained in the Energy Supply Planning Model and apppropriate escalation rates forecasted by Data Resources, Incorporated, it would be expected that DOE projects conform to those rates shown above. Should a submission reflect different escalation rates, supporting documentation should specifically delineate assumptions and the methodology used in developing the escalation rates. 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).

AUGUST 1988

| | NUCLEAR ENERGY RESEARCH | FOSSIL | CONSERVATION SOLAR | DEFENSE PROGRAMS & GENERAL CONSTRUCTION |
|---|---|---|---|---|
| 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 | 3.9 | 4.7 | 4.0 | 3.4 |
| 1989 | 4,2 | 4.3 | 3.9 | 4.3 |
| 1990 | 4.8 | 4.6 | 4.6 | 4.8 |
| 1991 | 5.0 | 4.8 | 4.8 | 5.2 |
| 1992 | 5.2 | 5.2 | 5.0 | 5.6 |
| 1993 | 5.7 | 5.6 | 5.5 | 5.8 |
| 1994 | 6.0 | 5.9 | 5.7 | 5.8 |
| 1995 | 6.2 | 6.2 | 5.9 | 6.0 |
| 1996 | 6.4 | 6.3 | 6.1 | 6.0 |
| 1997 | 6.5 | 6.5 | 6.3 | 6.4 |
| 1998 | 6.6 | 6.6 | 6.3 | 6.3 |

## 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, 1991.

Prior to that time LBL will evaluate environmental conditions and prepare recommendations for NEPA documentation for DOE consideration beginning in November 1989 for completion by July 1990. 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 1990 during which time the Design Program necessary for A/E fee negotiations and a Project Management Plan for DOE will also be completed.

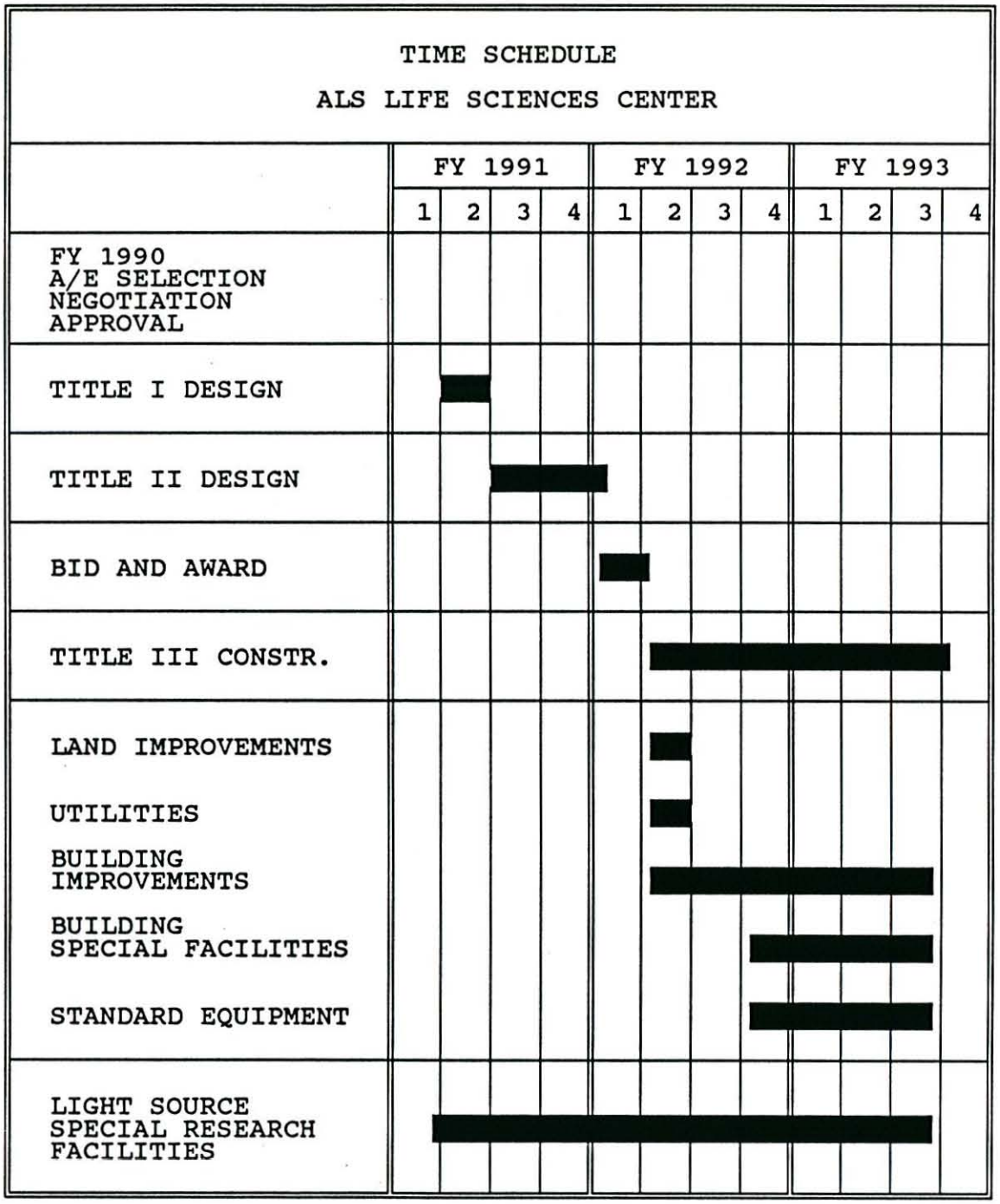
A/E fee negotiations will take place between October 1 and December 1, 1990 contingent upon assurance by DOE-SAN that the project is in the FY 1991 budget.

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.

TIME SCHEDULE

ALS LIFE SCIENCES CENTER



## Method of Performance

Engineering and Design:

LBL will assign a project manager who will be responsible for coordinating efforts of the participants and for reporting status relative to schedule and cost. All subcontractors will be required to prepare and maintain current schedule and budget plans for their work.

Detailed design will be contracted to an Architect-Engineer consultant. Additional technical support will be obtained from consultants, expert in topographical surveying, foundation design, and earthquake engineering.

A design program will be produced by the LBL Plant Engineering Department for direction to the Architect-Engineer and will include project scope and schedule requirements and design criteria for all aspects of the site work, building design, special facilities, and equipment to be included in the construction subcontract documents.

A competent Architect-Engineer firm experienced in this type and size project will be selected, and a lump-sum subcontract will be negotiated and awarded by the University.

Contract administration and inspection of construction will be accomplished by LBL.

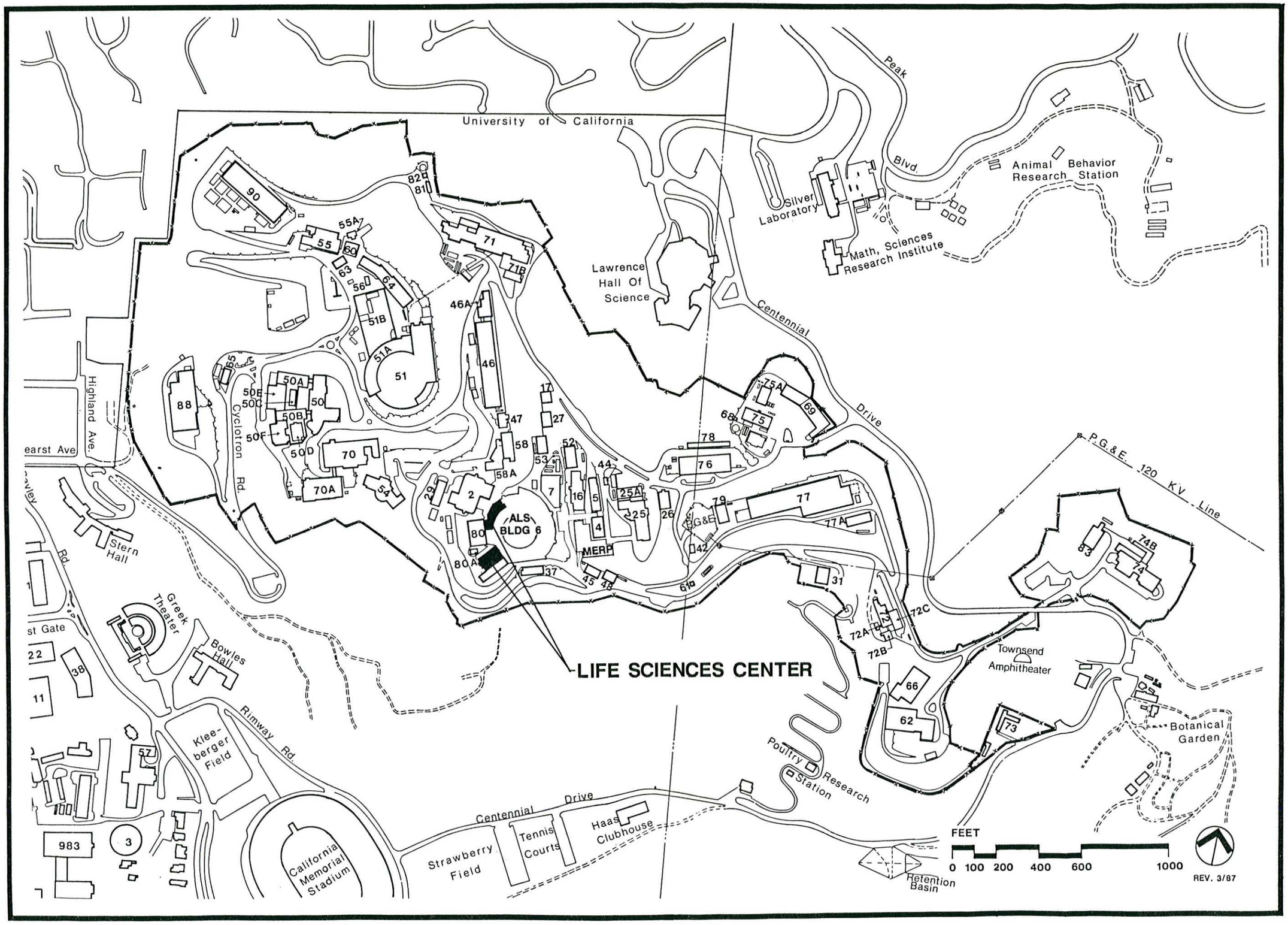
Construction and Procurement:

Construction will be carried out under a lump-sum subcontract awarded after competitive bidding. Some work associated with tie-ins and start-up may be accomplished by LBL crafts to ensure operational continuity. Procurement of standard equipment and some special facilities will be accomplished through competitive procurement.

## SECTION 5

## PROJECT DRAWINGS

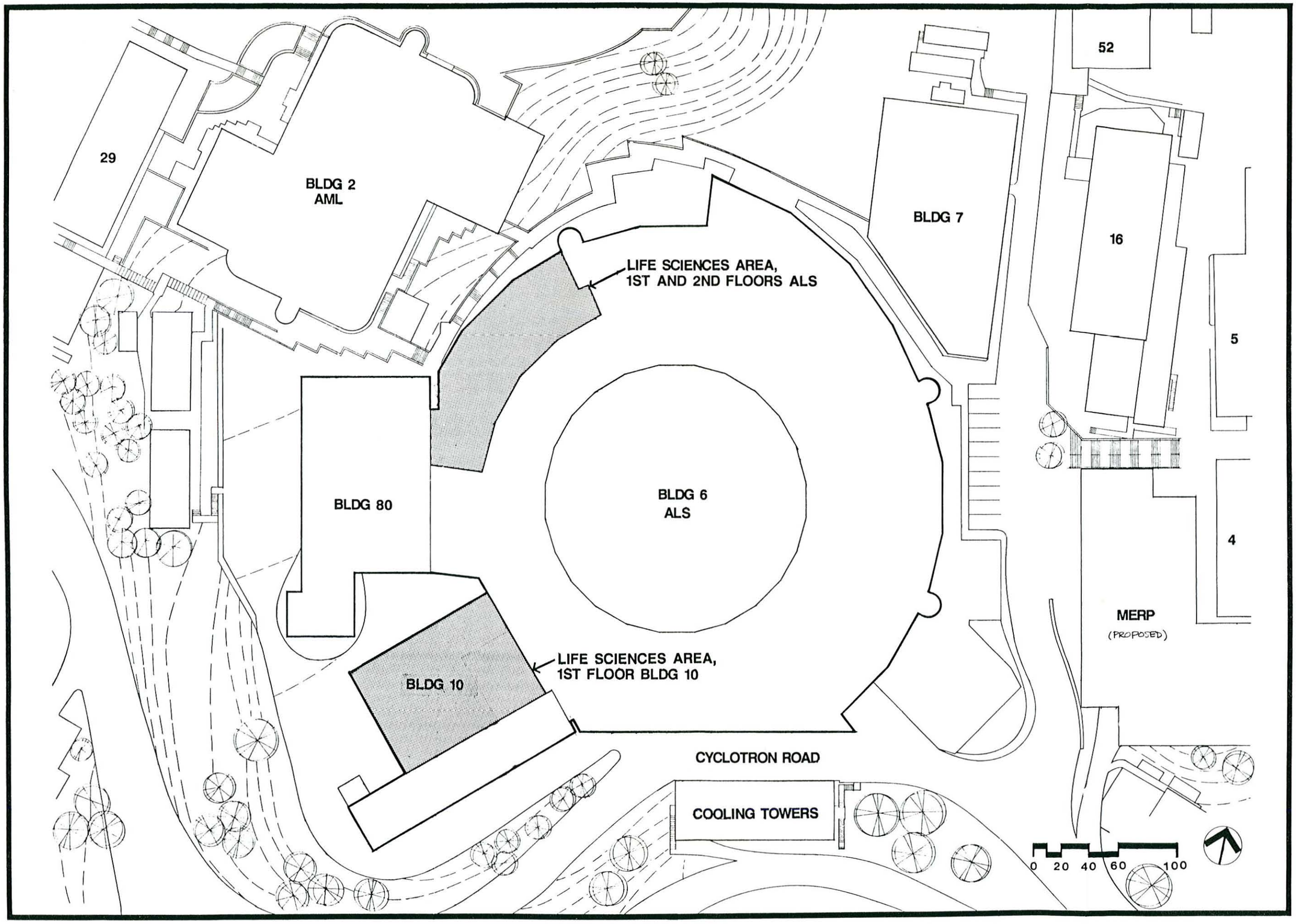
| | |
|---|---|
| T-1 | Location Plan |
| A-1 | Site Plan |
| A-2 | Building 10 - First Floor Plan |
| A-3 | ALS - First Floor Plan |
| A-4 | ALS - Second Floor Plan |
| A-5 | Building 10 Elevations |
| M-1 | Mechanical Floor Plan - First Floor, Building 10 |
| M-2 | Mechanical Floor Plan - First Floor, Building 6 |
| M-3 | Mechanical Floor Plan - Second Floor, Building 6 |
| M-4 | Mechanical Roof Plan - Building 10 |
| M-5 | Airflow Diagrams |
| M-6 | Control Diagram |
| E-1 | Building 6 - Single Line Diagram |
| E-2 | Building 10 - Single Line Diagram |




T-1

LIFE SCIENCES CENTER
**LOCATION PLAN**

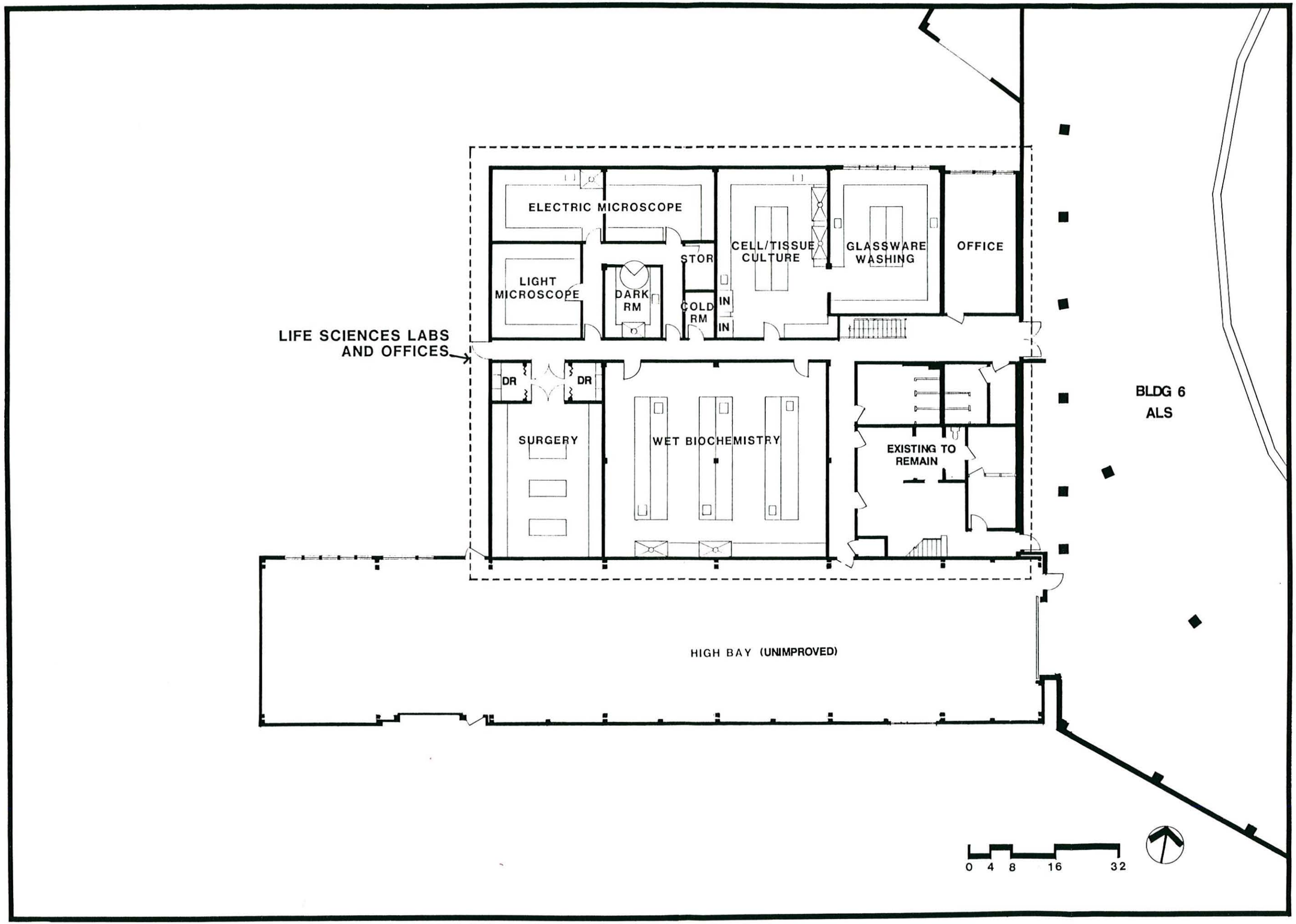
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA




A-1

LIFE SCIENCES CENTER
**SITE PLAN**

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA

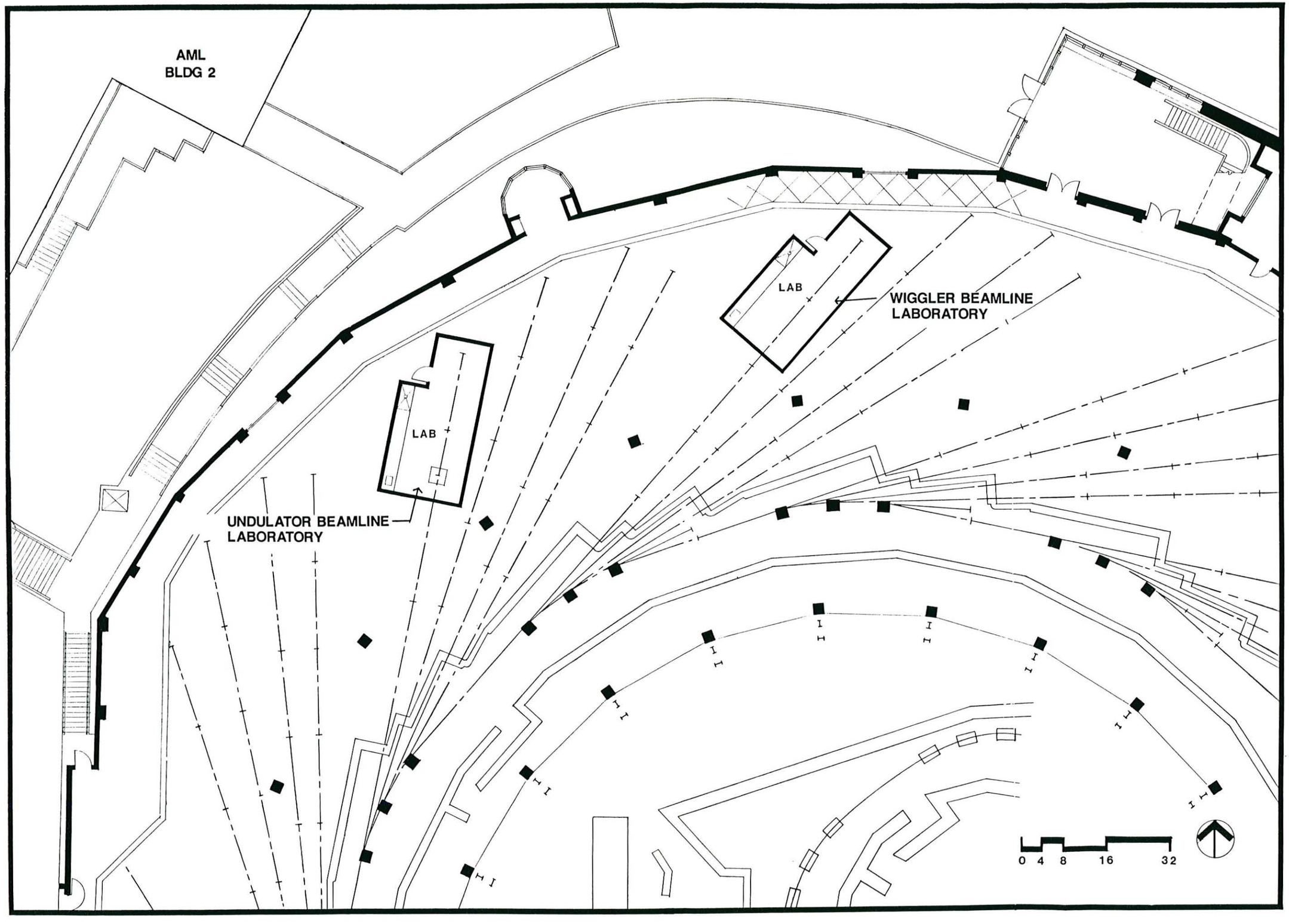



A-2

LIFE SCIENCES CENTER

BUILDING 10 - FIRST FLOOR PLAN

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA

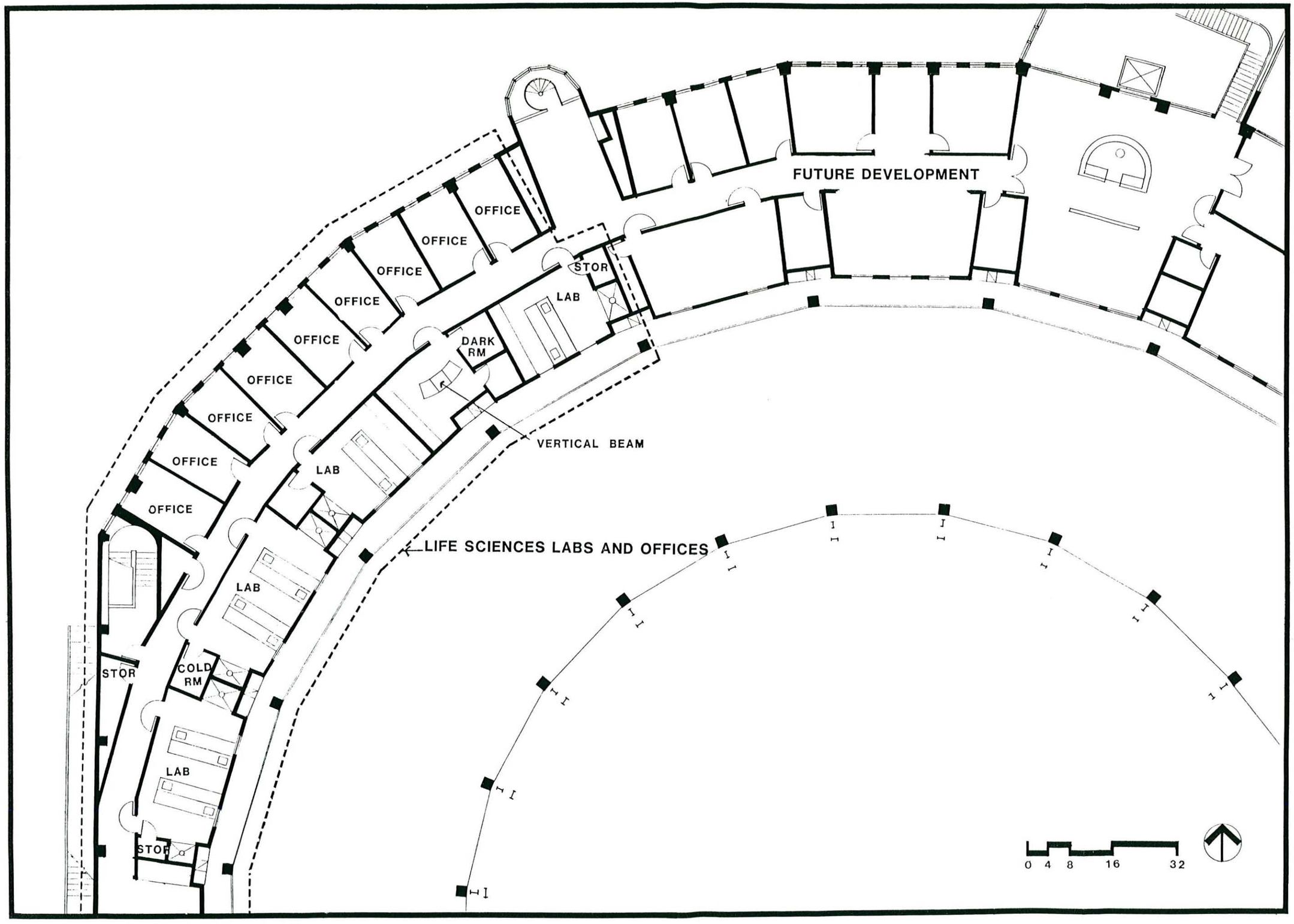



A-3

LIFE SCIENCES CENTER

**ALS - FIRST FLOOR PLAN**

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA

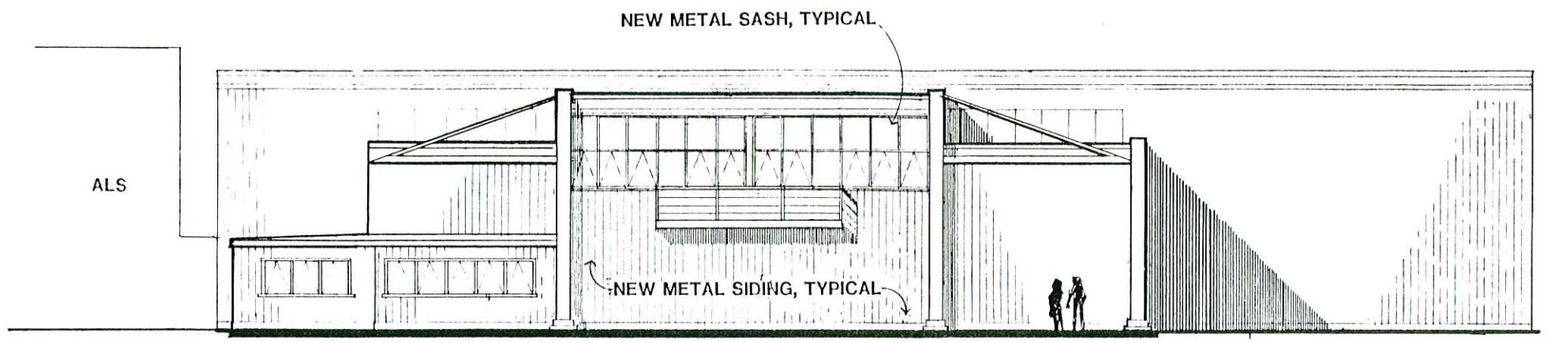



A-4

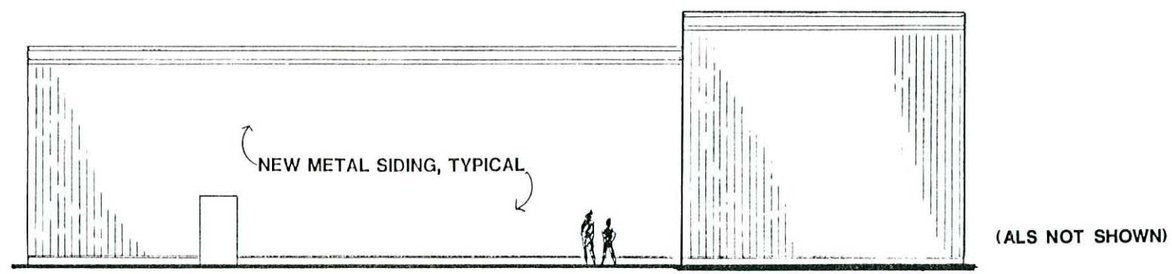
LIFE SCIENCES CENTER

ALS - SECOND FLOOR PLAN

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA

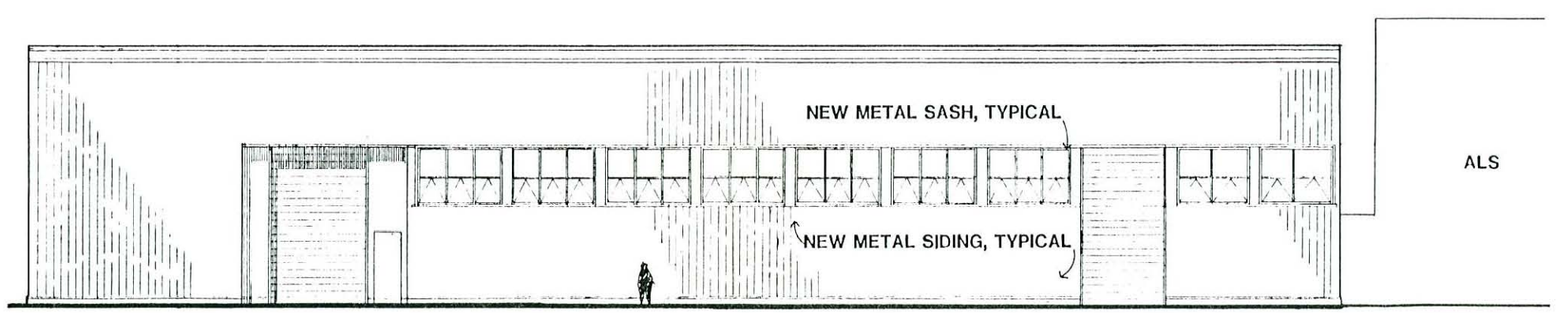



NORTH ELEVATION




(ALS NOT SHOWN)

WEST ELEVATION




SOUTH ELEVATION

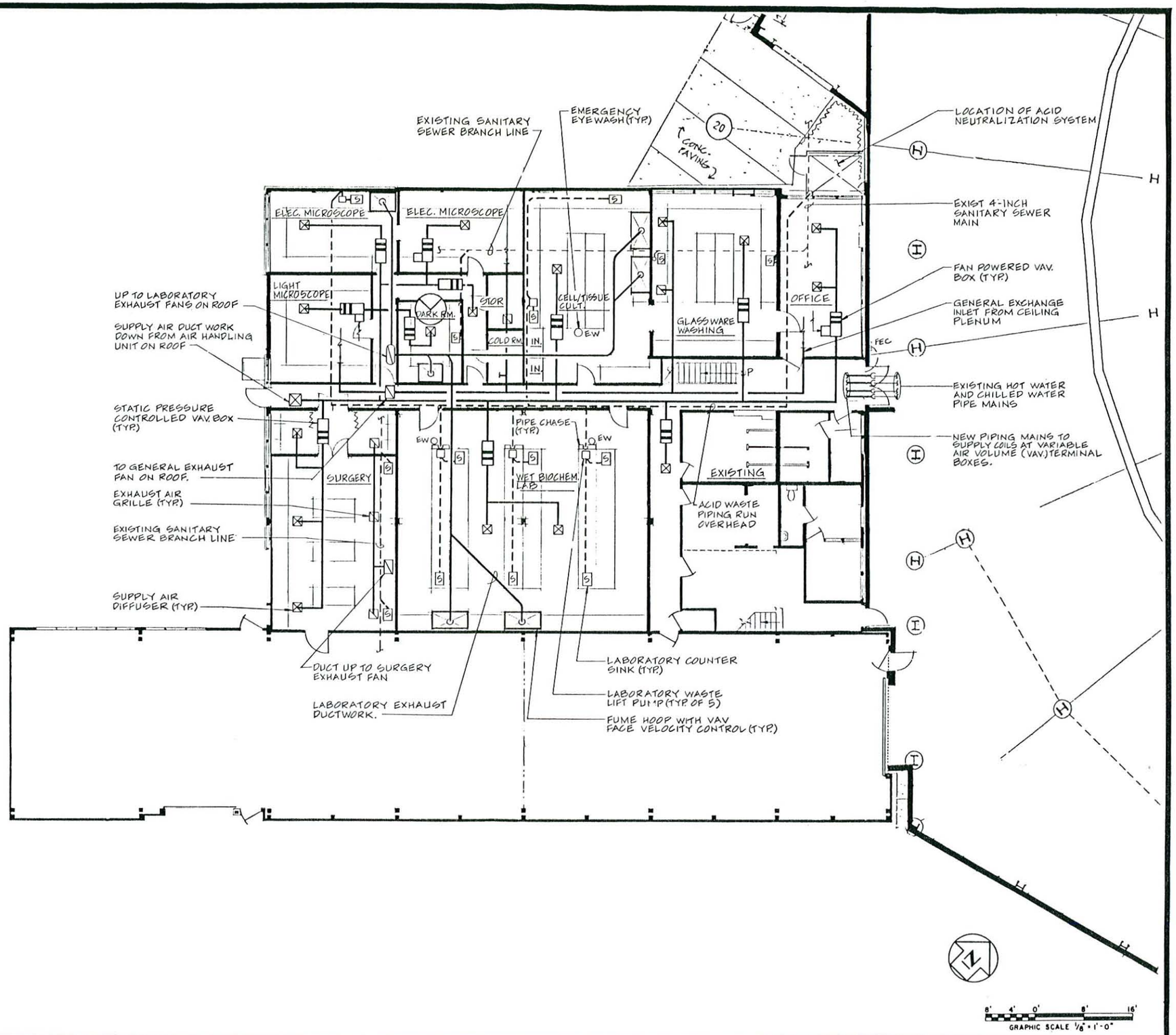
0 4 8 16 32

A -5

LIFE SCIENCES CENTER

BUILDING 10 - ELEVATIONS

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA

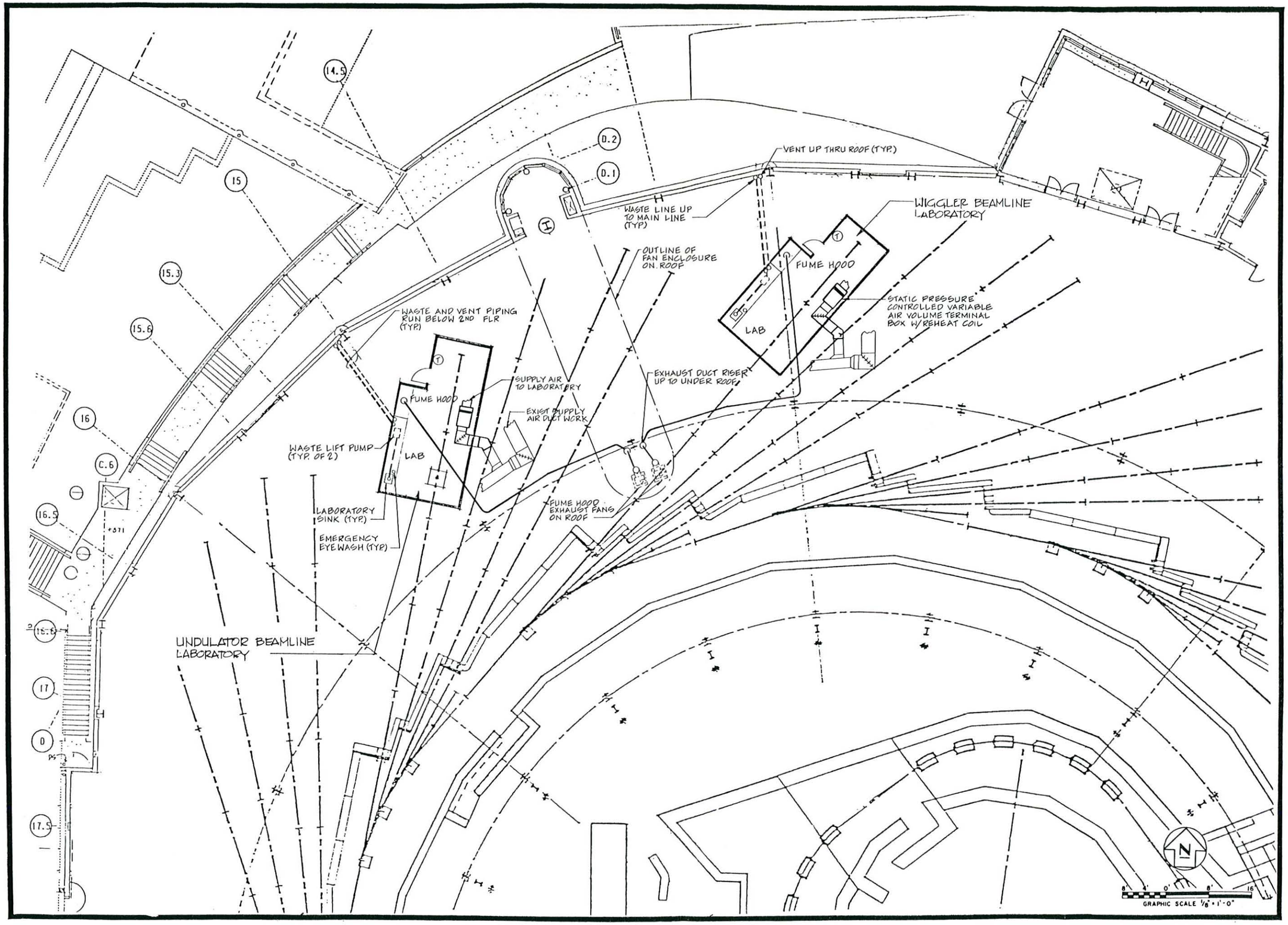



M-1

Life Sciences Center

# MECHANICAL FLOOR PLAN, FIRST FLOOR BUILDING 10

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA

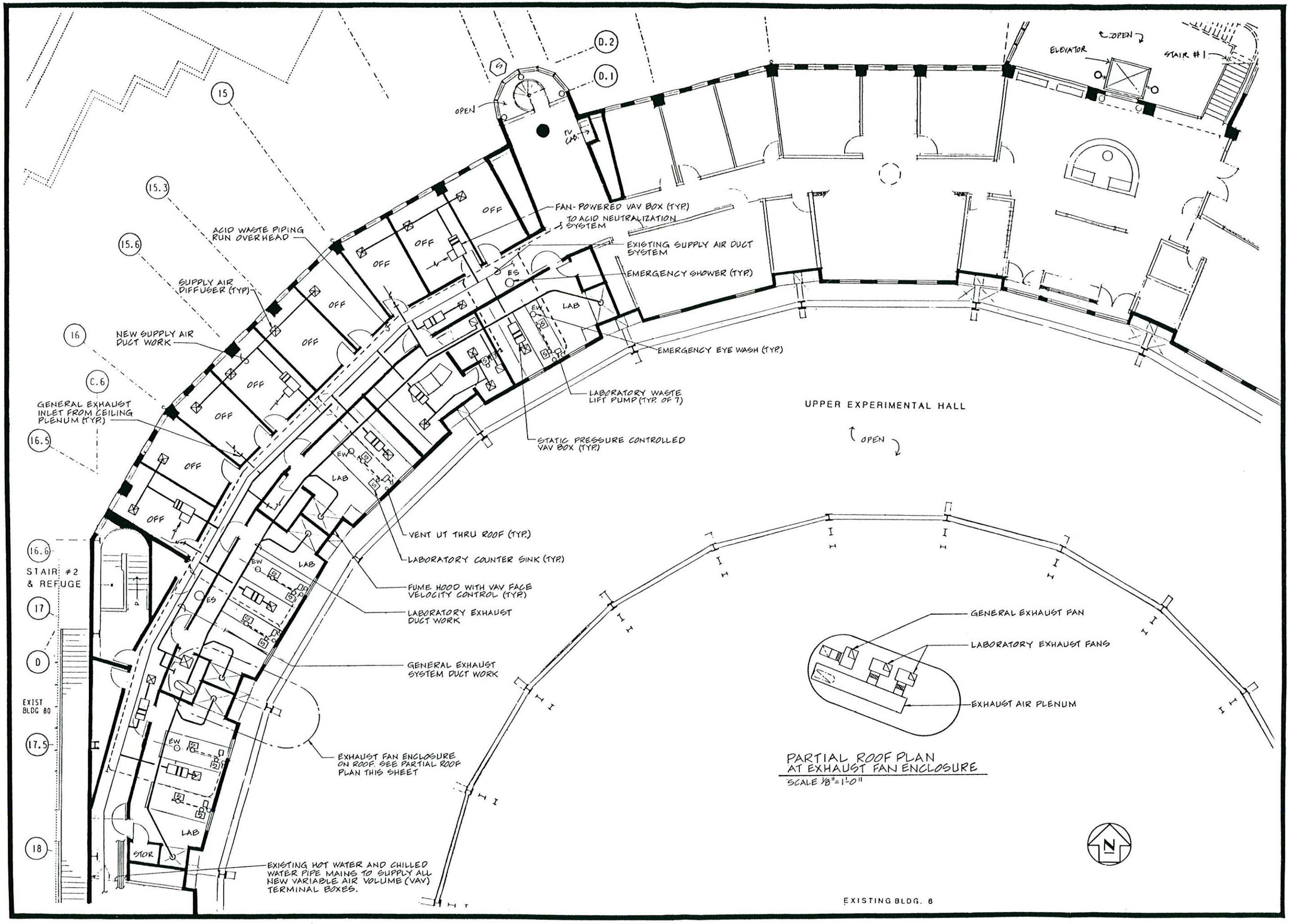


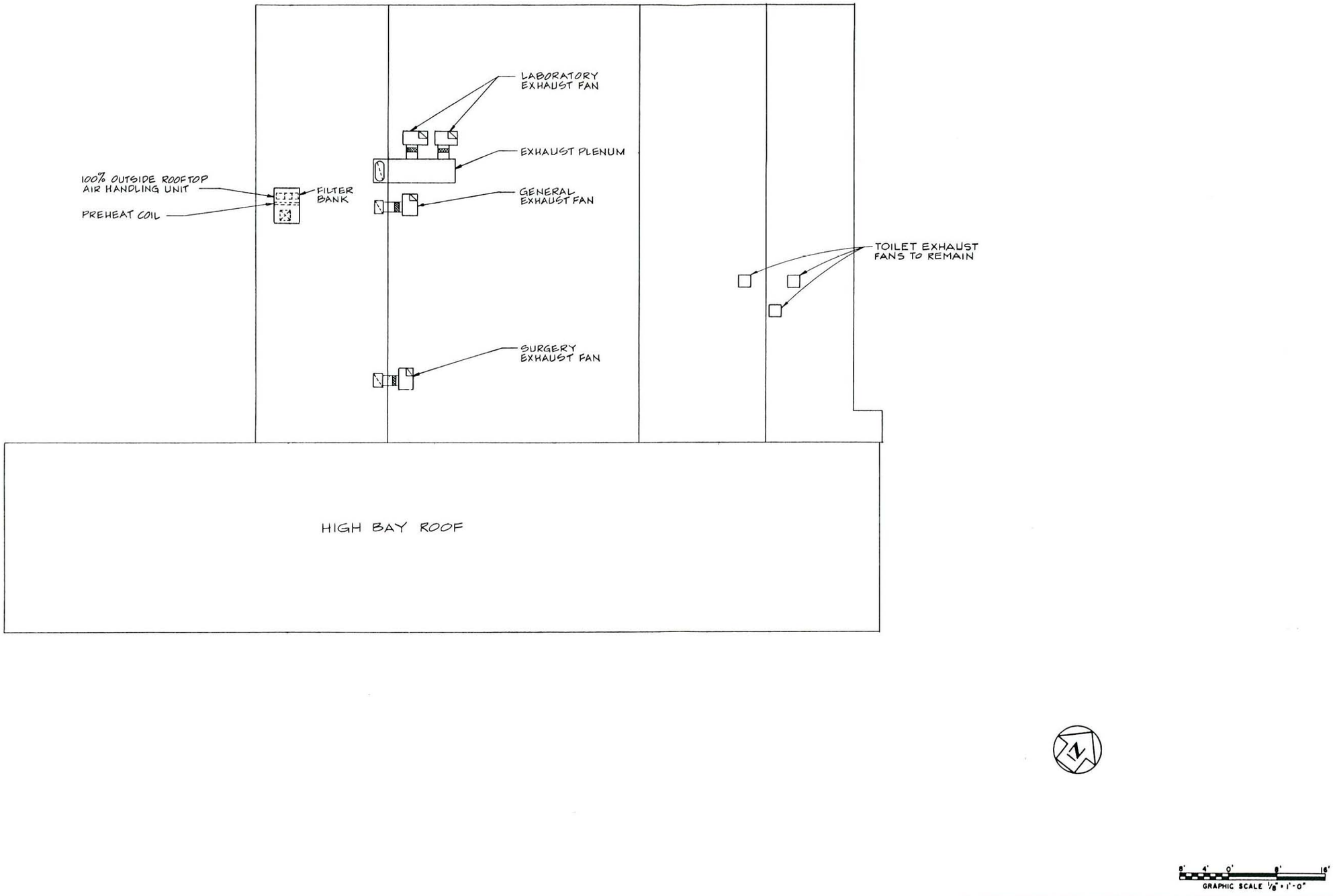

M-2

Life Sciences Center

# MECHANICAL FLOOR PLAN - FIRST FLOOR, BUILDING 6

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA


M-3
Life Sciences Center
MECHANICAL FLOOR PLAN, SECOND FLOOR BUILDING 6
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
D.2
D.1
15
15.3
15.6
16
C.6
16.5
16.6
17
D
17.5
18
OPEN
ELEVATOR
STAIR #1
OFF
FAN-POWERED VAV BOX (TYP.)
TO ACID NEUTRALIZATION SYSTEM
EXISTING SUPPLY AIR DUCT SYSTEM
EMERGENCY SHOWER (TYP.)
ACID WASTE PIPING RUN OVERHEAD
SUPPLY AIR DIFFUSER (TYP)
NEW SUPPLY AIR DUCT WORK
GENERAL EXHAUST INLET FROM CEILING PLENUM (TYP.)
LAB
EMERGENCY EYE WASH (TYP.)
LABORATORY WASTE LIFT PUMP (TYP. OF 7)
UPPER EXPERIMENTAL HALL
STATIC PRESSURE CONTROLLED VAV BOX (TYP.)
VENT UT THRU ROOF (TYP.)
LABORATORY COUNTER SINK (TYP.)
FUME HOOD WITH VAV FACE VELOCITY CONTROL (TYP.)
LABORATORY EXHAUST DUCT WORK
GENERAL EXHAUST SYSTEM DUCT WORK
STAIR #2 & REFUGE
EXIST BLDG 80
EXHAUST FAN ENCLOSURE ON ROOF. SEE PARTIAL ROOF PLAN THIS SHEET
STOR
EXISTING HOT WATER AND CHILLED WATER PIPE MAINS TO SUPPLY ALL NEW VARIABLE AIR VOLUME (VAV) TERMINAL BOXES.
GENERAL EXHAUST FAN
LABORATORY EXHAUST FANS
EXHAUST AIR PLENUM
PARTIAL ROOF PLAN AT EXHAUST FAN ENCLOSURE
SCALE 1/8"=1'-0"
N
EXISTING BLDG. 8

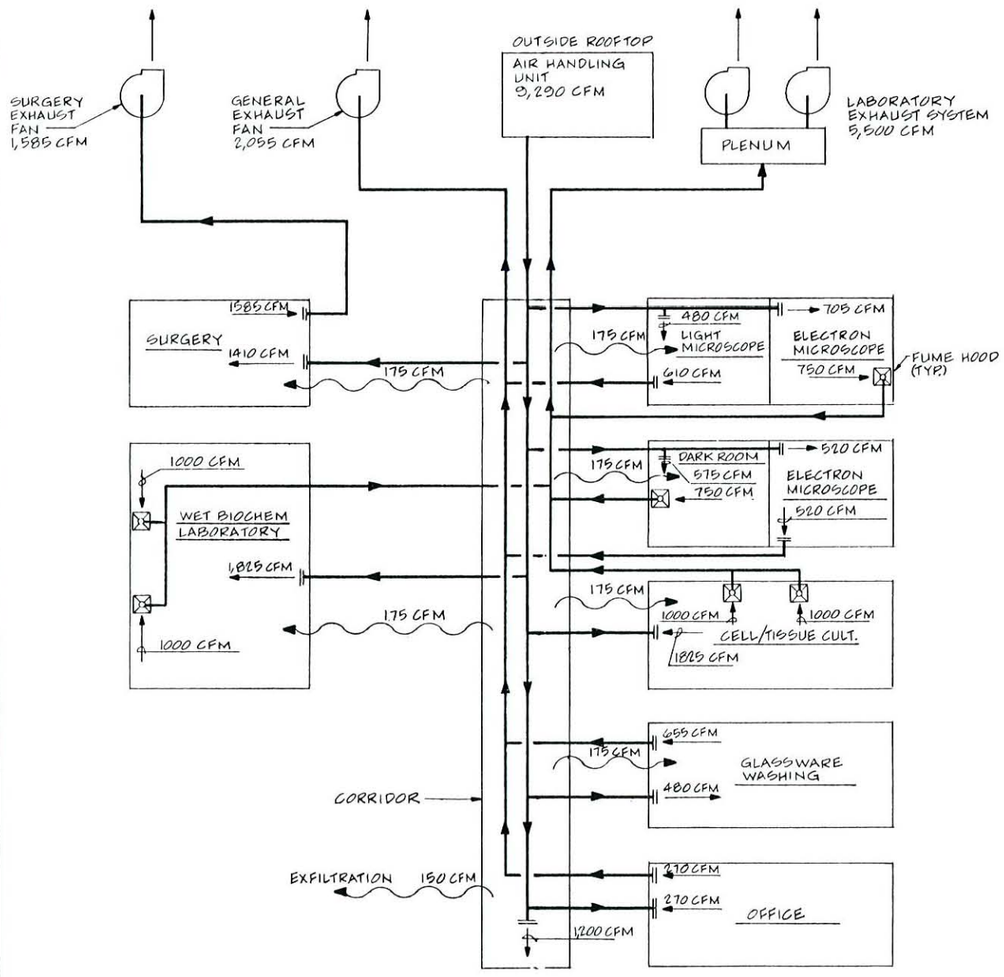



M-4

Life Sciences Center

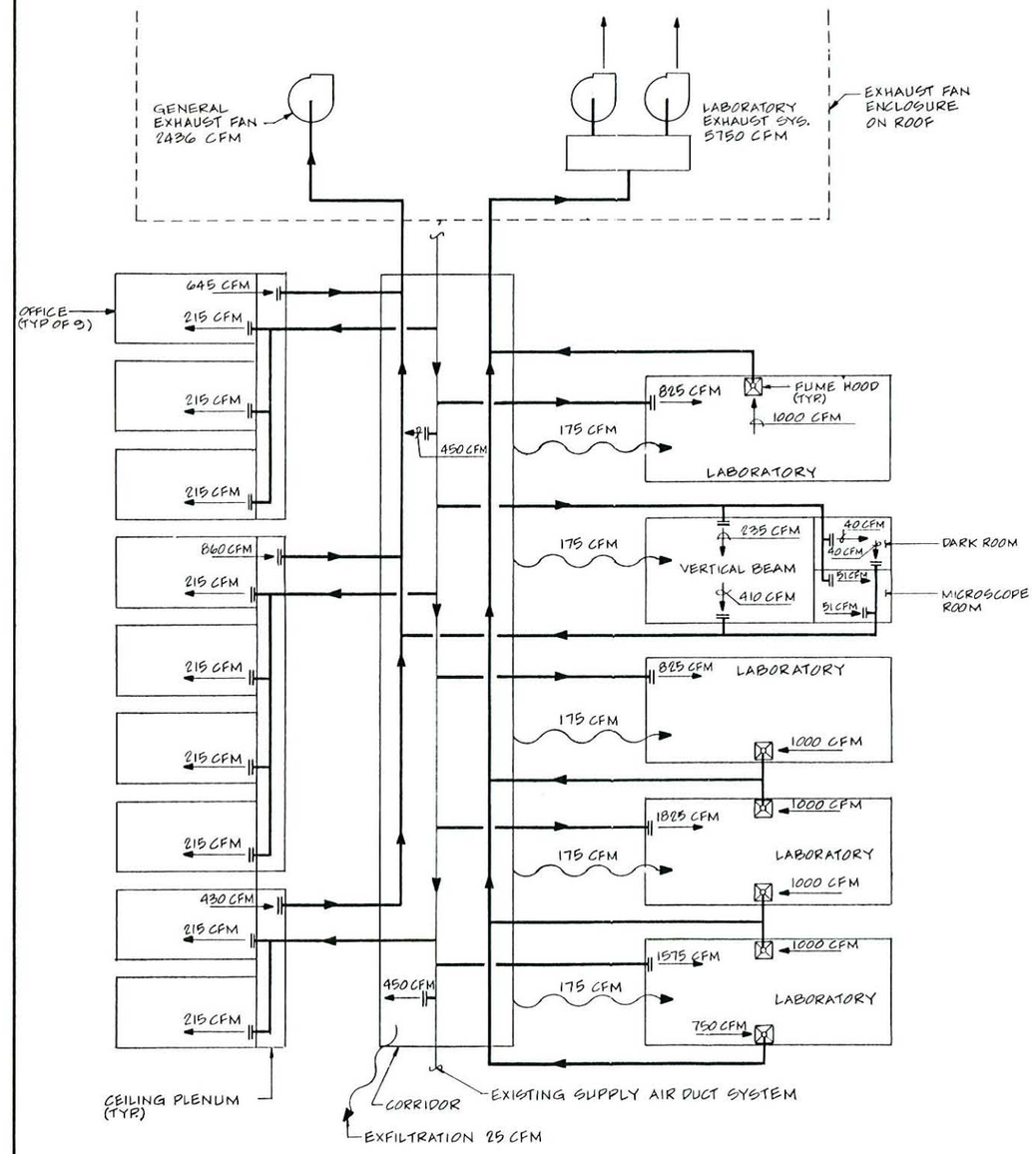
# MECHANICAL ROOF PLAN, BUILDING 10

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA




LIFE SCIENCES CENTER BLDG # 10 - AIR FLOW DIAGRAM

NO SCALE




LIFE SCIENCES CENTER BLDG # 6 - AIR FLOW DIAGRAM

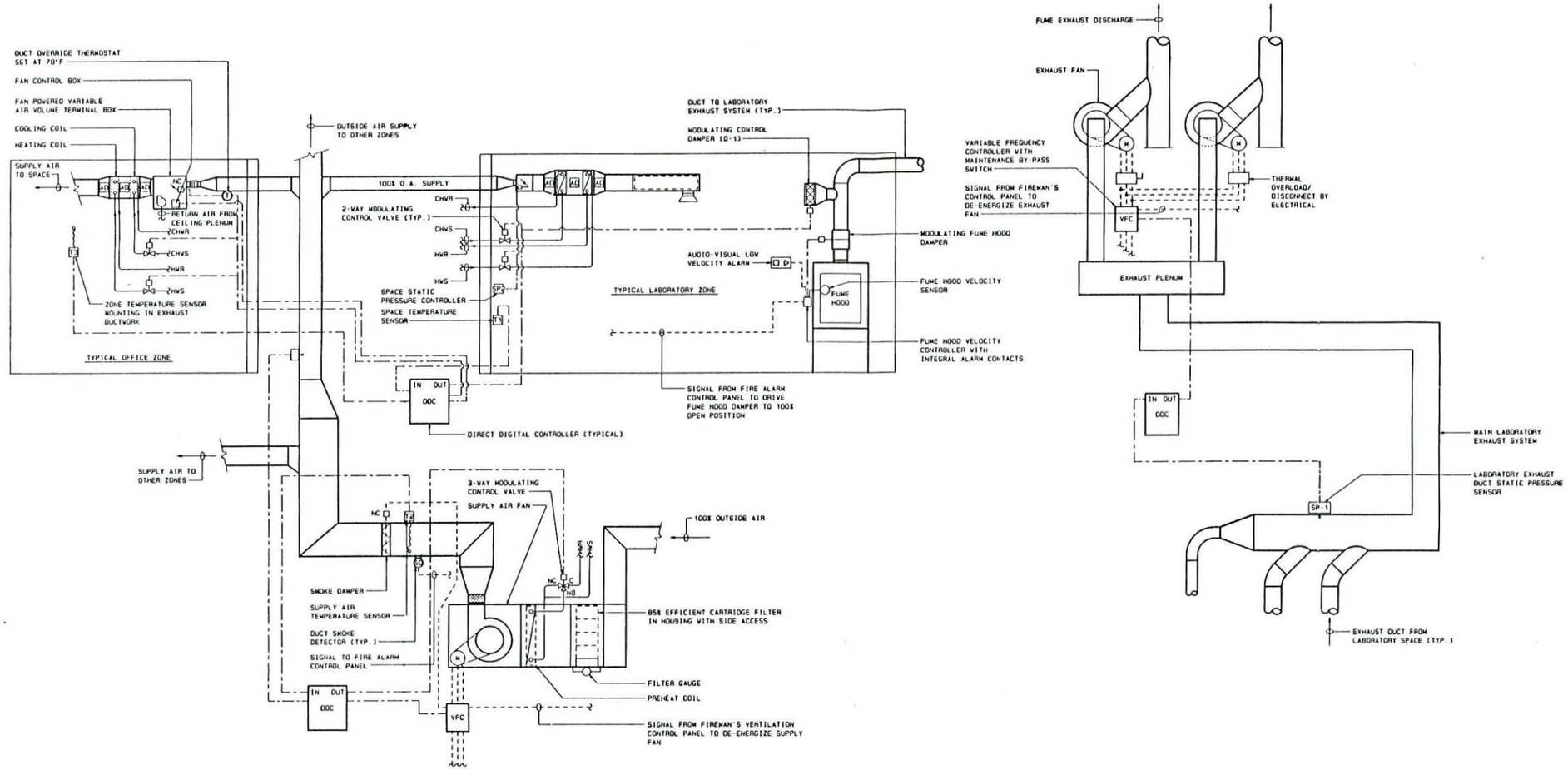
NO SCALE

M-5

Life Sciences Center

# AIRFLOW DIAGRAMS

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA




## 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:

SPARE 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 PRESSSURE 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 78 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:

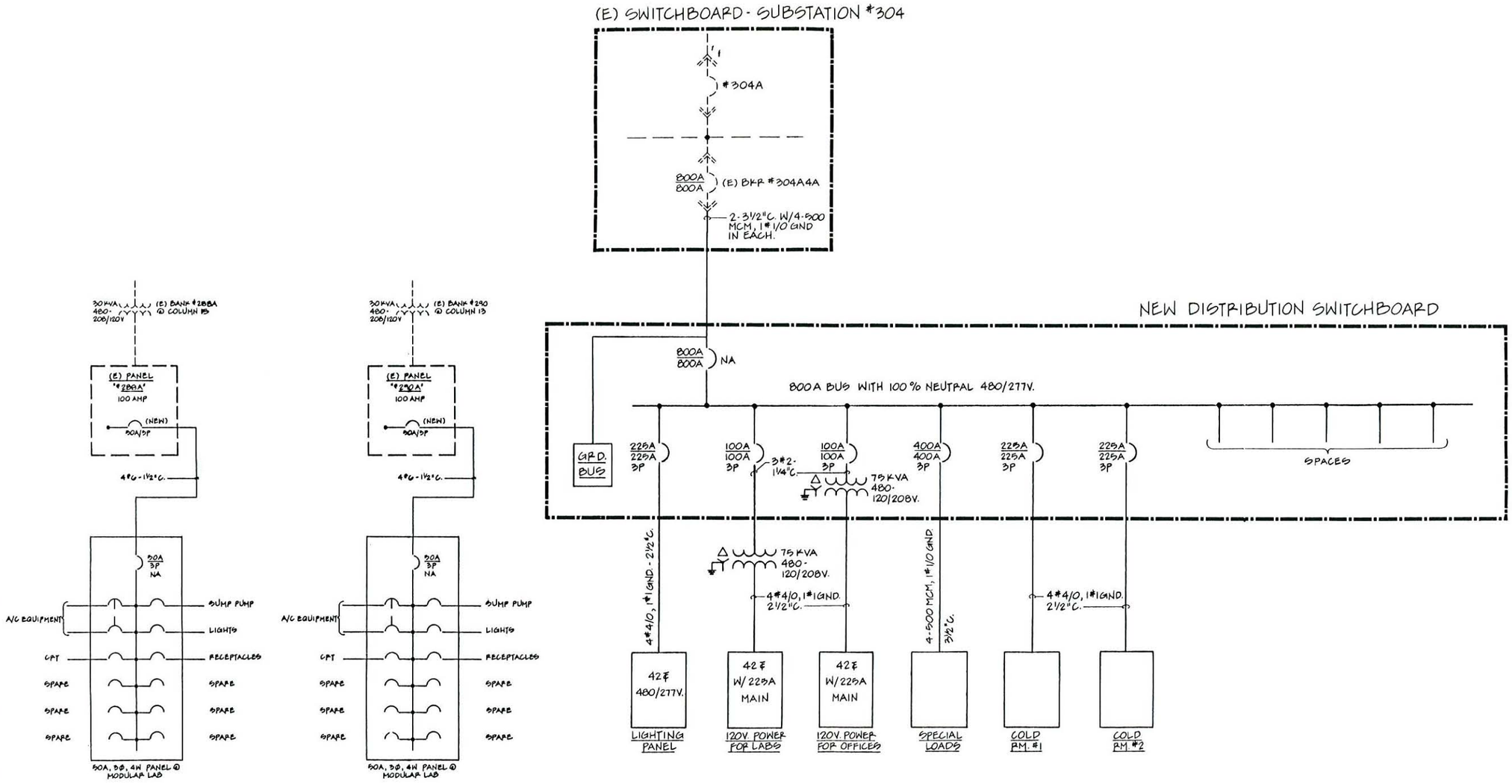
THE FUME HOOD VELOCITY CONTROLLER SHALL BE EQUIPPED WITH AN AUDIO-VISUAL ALARM THAT SHALL BE ACTIVATED WHEN FUME HOOD FACE VELOCITY FALLS BELOW SET POINT. THE AUDIO PORTION OF THE ALARM SHALL BE PROVIDED WITH AN ALARM SILENCE SWITCH. THE SUPPLY FANS SHALL BE INTERLOCKED TO THE FIREMAN'S CONTROL PANEL 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

Life Sciences Center

CONTROL DIAGRAM

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA




MODULAR LAB POWER - 1ST FLOOR

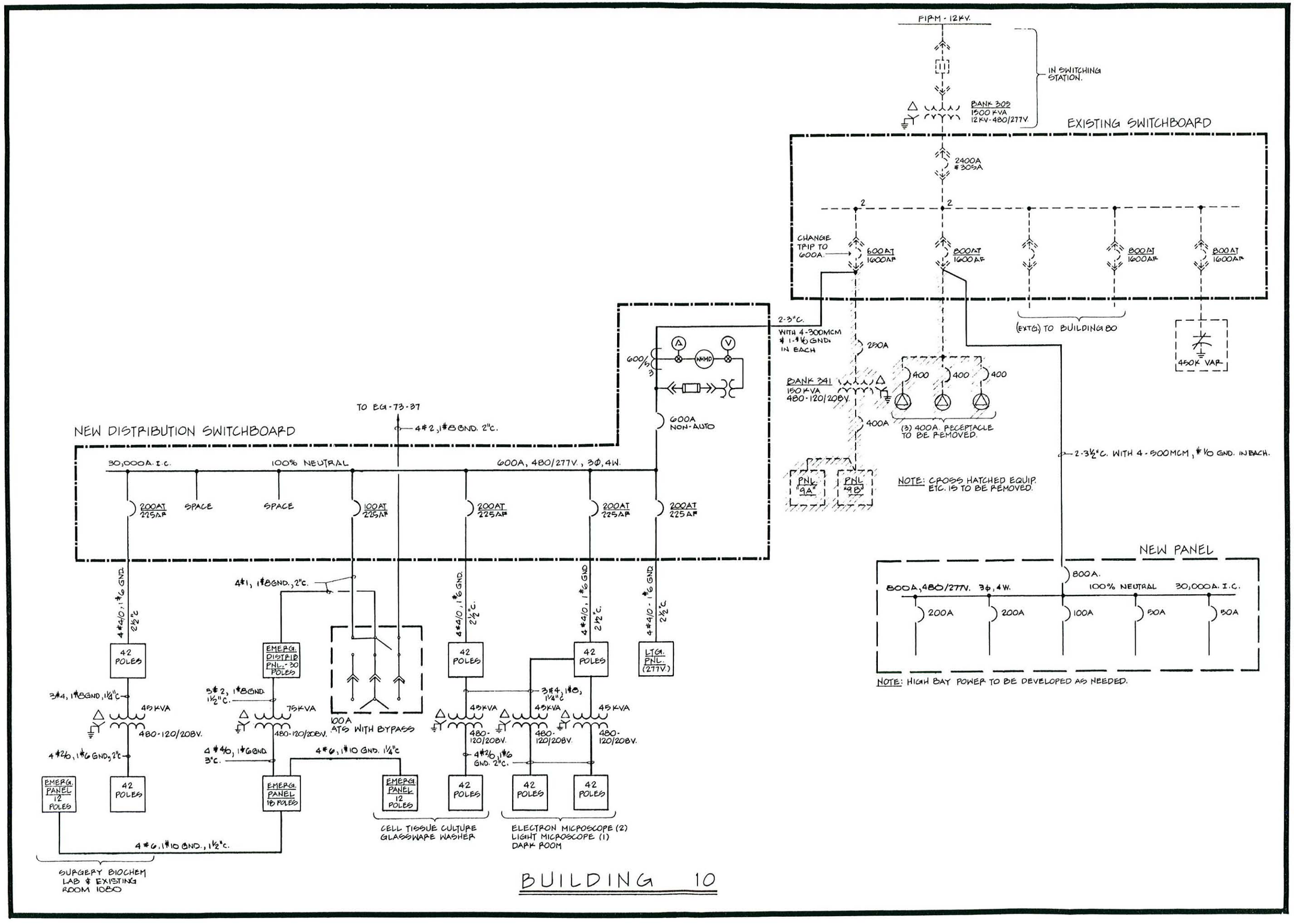
SINGLE LINE DIAGRAM - BUILDING 6 MODIFICATIONS - 2ND FLOOR LABS

E-1

BUILDING 6

SINGLE LINE DIAGRAM

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA




E-2

BUILDING 10

SINGLE LINE DIAGRAM

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA

SECTION 6

OUTLINE SPECIFICATIONS

| | | |
|---|---|---|
| Division 1 | GENERAL REQUIREMENTS | |
| | 01060 | Regulatory Requirements |
| | 01100 | Alternatives |
| | 01200 | Project Meetings |
| | 01300 | Submittals |
| | 01400 | Quality Control |
| | 01510 | Temporary Utilities |
| | 01520 | Construction Aids |
| | 01530 | Barriers |
| | 01580 | Project Sign |
| | 01590 | Field Offices and Sheds |
| Division 2 | SITE WORK | |
| | 02050 | Demolition |
| | 02200 | Earthwork |
| | 02230 | Base Course |
| | 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 |
| | 07410 | Prefabricated Metal Panels |
| | 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 | NOT APPLICABLE | |
| Division 15 | MECHANICAL | |
| | 15101 | 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 |
| | 16300 | Power Transmission |
| | 16320 | Transformers |
| | 16470 | Power Distribution |
| | 16500 | Lighting |
| | 16700 | Communications |
| | 16900 | Controls and Installation |

## SECTION 01060 - REGULATORY REQUIREMENTS

A. Codes and Design References: These codes as listed should be included in the construction specifications; codes and references shall be latest editions except where specifically noted otherwise:

1. Codes:

   a. 29 CFR Part 1926, Safety and Health Regulations for Construction, Department of Labor.

   b. 29 CFR Part 1910, Occupational Safety and Health Standards, Department of Labor.

   c. National FIre Codes, NFPA.

   d. National Electrical Safety Code, ANSI C2.

   e. National Electric Code, NFPA 70-1981.

   f. Code for Safety to Life from Fire in Buildings and Structures, NFPA 101-1976.

   g. Department of Labor, Occupational Safety and Health Administration, Design Safety Standards for Electrical Systems, Subpart S 29 CFR 1910 (Federal Register, Vol. 46, No. 11, January 16, 1981).

   h. Safety Code for Building Construction, ANSI A10.2.

   i. California Administrative Code, Title 8, General Industrial Safety Orders, Construction Safety Orders.

j. California Administrative Code, Title 19, Chapter 1; Title 24, Part 2; Title 24, Part 6; Division T-19.

k. Uniform Building Code.

l. Uniform Mechanical Code.

m. Uniform Fire Code.

n. Uniform Plumbing Code.

o. Occupational Safety and Health Act.

p. Federal, state, and local air-pollution and water-pollution control regulations.

q. Standard for Fire Protection of AEC Electronic Computer/Data Processing Systems 7/73 (Wash 1245-1). (See paragraph 101.04.)

r. The National Energy Act of October 15, 1978.

s. Standards of the American Society for Testing and Materials (ASTM).

t. AMCA Fan Test Code.

u. American National Standards Institute (ANSI) Standards.

v. Uniform Solar Energy Code (IAPMO).

w. NBSIR 78-1305A Test Procedures.

x. American National Standard Specifications for Making Buildings and Facilities Accessible and Usable by the Physically Handicapped ANSI A117.1-1961. REAF-971.

2. Design References:

a. Facilities General Design Criteria Handbook, Order-DOE 6430, 6/10/81.

b. Solar Design Handbooks:

1) DOE Facilities Solar Design Handbook, January 1978.

2) Passive Solar Design Handbook, Draft April 6, 1979 by J.D. Balcomb and B. Anderson.

c. NBS Handbook 135, Life Cycle Cost Manual for the Federal Energy Management Program.

d. The ASHRAE Handbook and Product Directory:

   1) Applications Volume: 1982.

   2) Fundamentals Volume: 1981.

   3) Systems Volume: 1980.

   4) Equipment Volume: 1979

e. Standards for Natural and Mechanical Ventilating, ASHRAE Standard 62-73 (ANSI B194. 1-177).

f. Energy Conservation in New Building Design, ASHRAE Standard 90-75, August 11, 1975.

g. Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) Standards.

h. Standards and Codes of the American Society of Mechanical Engineers (ASME).

i. American Water Works Association (AWWA) Standards.

j. National Environmental Balancing Bureau (NEBB).

k. American Welding Society Handbook and Standards (AWS).

l. National Electric Manufacturers' Standards (NEMA).

m. Recommended Outdoor Design Temperatures, Northern California Golden Gate Chapter, ASHRAE, November 1977.

n. Industrial Ventilation Manual by the American Conference of Industrial Hygienists (ACGIH).

o. Methods of Testing to Determine the Thermal Performance of Solar Collectors, ASHRAE Standard 93-77.

p. Methods of Testing Thermal Storage Devices Based on Thermal Performance, ASHRAE Standard 94-77.

q. University of California Facilities Manual, Part G, "Project Development and Execution," General Conditions, Section G.4.1.

r. Lawrence Berkeley Laboratory Electrical Standard Specification Series BSTE.

s. Underwriters' Laboratories (UL) approved equipment listings and Factory Mutual Engineering Corp. (FM) approved equipment guide.

3. Design Standards:

a. Earthwork:

1) Standard Specification, State of California, Department of Transportation, Division of Highways.

2) ASTM standards for compaction.

b. Concrete:

1) ACI-318 Building Code Requirements for Reinforced Concrete.

2) ACI-347 Recommended Practice for Concrete Formwork.

3) CRSI Manual of Standard Practice.

c. Concrete Reinforcement:

1) ACI-301 Specification for Structural Concrete for Buildings.

2) ACI-315 Manual of Standard Practice for Detailing Reinforced Concrete.

3) ACI-318 Building Code Requirements for Reinforced Concrete.

4) CRSI 59 Recommended Practice for Placing Reinforcing Rods.

5) CRSI 63 Recommended Practice for Placing Bar Supports, Specifications and Nomenclature.

6) ASTM Standards.

7) AWS D12.1 Reinforcing Steel Welding Code.

d. 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.

e. 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 01100 - ALTERNATIVES

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. Soils engineer's services.

B. Testing laboratory's services.

C. Testing agency's services.

SECTION 01510 - TEMPORARY UTILITIES

A. Provide the following temporary utilities as part of the work of this contract:

1. Heat and ventilation.

2. Sanitary facilities.

3. Telephone service.

4. Fire protection.

B. Water will be provided by the owner.

SECTION 01520 - CONSTRUCTION AIDS

A. Provide the following construction aids as part of the work of this contract:

1. Construction elevators and hoists.

2. Temporary enclosures.

3. Swing staging.

4. Scaffolding and platforms.

SECTION 01530 - BARRIERS

A. Fences.

B. Tree and plant protection.

C. Barricades.

SECTION 01580 - PROJECT SIGN

SECTION 01590 - FIELD OFFICES AND SHEDS

A. Field offices and sheds may be specially constructed for the work of this contract, or they may be portable or mobile buildings.

## DIVISION 2 - SITE WORK

### SECTION 02050 - DEMOLITION

A. Remove existing improvements including asphalt paving and miscellaneous structures as required and shown to accommodate new work.

### SECTION 02200 - EARTHWORK

A. Excavation.

B. Backfill.

C. Subsoil compaction.

### SECTION 02230 - BASE COURSE

A. Crushed Rock Under Paving: 3/4 inch size.

### SECTION 02500 - PAVING AND SURFACING

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

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.

SECTION 06100 - ROUGH CARPENTRY

A. Lumber: Douglas fir, construction grade, WCLIB No. 16, S4S; exterior materials and partition sills to be preservative pressure- treated.

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.

SECTION 07210 - BUILDING INSULATION

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

SECTION 07410 - PREFABRICATED METAL PANELS

A. Roof mounted, equipment sight screen as shown.

B. Profiled Siding Panels: 22-gauge G90 galvanized steel; 1-1/2" deep profile on 7" centers; epoxy base coat with baked fluoropolymer coating; INRYCO "M7 Exterior Panel," H.H. ROBERTSON "BRS-36," or equal.

C. Exposed fasteners, sheetmetal flashing, wall caps, and trims shall have finish matching wall panels.

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.

### 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 tiles, typical.

B. Sheet Vinyl: MIPOLAM "220 Series," TARKETT "Multi-Floor," or equal, laboratories and vault.

C. Rubber Base: 4"-high x 1/8" thick rubber base.

## 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.

## SECTION 11650 - LABORATORY FURNITURE

A. Laboratory Furniture

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

## 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 15 - MECHANICAL

SECTION 15010 GENERAL PROVISIONS

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

- o Uniform Mechanical Code 1985
- o Uniform Plumbing Code 1985
- o Uniform Building Code 1985
- o NFPA 13-1987
- o NFPA 72-1987

SECTION 15050 - BASIC MATERIALS AND METHODS

A. Scope: Specifies pipe, fittings, valves, specialities, 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, PVC or CPVC with socket cemented 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 joining for below grade. Indoors above grade use cast-iron service weight piping with bell-and-spigot or hubless joint 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:

a. Below Grade: Class 150-cement lined ductile-iron pipe with mechanical joints and cement-lined ductile-iron fittings.

b. Above Grade: Schedule 40 steel with 175-lb banded cast-iron threaded, or 250-lb 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.

C. Storm Water Systems: Below grade use cast-iron service weight piping with bell-and-spigot joints, from end of down spouts to connection with existing storm drain system. Roof drain leaders; cast-iron service weight piping with bell-and-spigot or hubless joints, or copper DWV tubing.

D. Plumbing Equipment: To include natural gas-fired domestic water heater, domestic hot water in-line recirculation pump and 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 independent 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 connections to the existing energy monitoring and control system (EMCS) 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. Basis for Design:

1. Department of Energy General Design Criteria Manual DOE 6430.1A.

2. Lawrence Berkeley Laboratory - Electrical Standard Specification Series BSTE.

3. Standard for Occupational Safety 29 CFR Part 1910 Subpart S (Design Safety Standards for Electrical Systems).

4. National Electric Code NEC 1987.

B. Work Included:

1. Provide 480V/208Y/120V/480-V transformers.

2. Provide 480V between the new ALS substation and the 480 distribution system.

3. Provide an interior power distribution system for process loads an normal house power.

4. Provide a standby power system.

5. Provide connections to existing telephone, communications, and EMCS systems.

6. Provide a transformer grounding system.

7. Provide power wiring to mechanical equipment.

8. Provide interior lighting.

9. Provide telephone raceways and outlets.

10. Provide fire protection and alarms.

11. Provide paging and intercoms.

12. Provide and Energy Monitoring and Control System.

13. Provide rights-of-way for computer, data, and experimental equipment control.

14. Provide power wiring for major research equipment.

C. Work Excluded:

1. Installation of telephone cables.

2. Final connection to the LBL fire-alarm system.

SECTION 16300 - POWER TRANSMISSION

A. General Scope:

1. Primary electrical feeder to be 480 volts.

2. Tray cables.

3. Copper conductors.

4. Heat-shrinkable splices and terminations.

SECTION 16320 - TRANSFORMERS

A. General Scope:

1. Primary voltage to be 480 volts.

2. 5 primary taps. ± 2.5% each.

3. Indoor dry type.

4. Secondary voltage 280Y/120 volts.

5. Seismic mounting.

6. Energy-efficient construction.

SECTION 16470 - POWER DISTRIBUTION

A. Motor Control Centers:

1. 480 V, 3 phase, 4 wire, 60 Hertz.

2. Copper busses braced to withstand available short circuit current.

3. Plug-in combination circuit breaker starter units.

4. Moter circuit protectors.

5. 120-V control transformer in each plug-in starter.

B. Distribution Panel Boards:

1. Building and Process:

   a. 480 V, 3 phase, 3 wire.

   b. Copper busses braced for available fault current.

   c. Molded-case circuit breakers.

   d. Free standing, front accessible.

2. Lighting Panels:

   a. 480 V/277 V, 3 phase, 4 wire.

   b. Full-size neutral and ground busses.

   c. Copper busses braced for available fault current.

   d. Switch-rated molded-case circuit breakers.

   e. Surface mount.

   f. Door-in-door construction.

3. Power Panels:

   a. 208 V/120 V, 3 phase, 4 wire.

   b. Full-size neutral and ground busses.

   c. Bolt-on circuit breakers.

   d. Copper busses.

SECTION 16500 - LIGHTING

A. Interior Lighting:

1. Office and workstations - 50 fc.

2. Work areas - 30 fc.

3. Nonwork areas and corridors - 10 fc.

4. Provide surface-mounted fluorescent fixtures with acrylic lenses.

5. Provide task lighting where required.

6. Provide 277-V fixtures and ballasts.

7. Provide half-level lighting where practical.

B. Emergency Lighting:

1. Provide exit lights.

2. Provide egress lighting.

SECTION 16700 - COMMUNICATIONS

A. Fire-Alarm and Dectection Circuits:

1. Provide flow switches to indicate sprinkler zone water flow.

2. Provide tamper switches on all sprinkler water valves.

3. Provide alarm signal on sprinkler-water flow to central fire station.

4. Interrupt power to HVAC and electrical equipment upon flow of sprinkler water.

5. Provide heat and smoke detectors in major electronic equipment racks.

6. Provide manual fire-call boxes.

7. Provide building fire-alarm bells.

8. Provide zone annunciation.

9. Ensure compatability with existing LBL fire-alarm system.

10. Provide supervision on all fire-alarm circuits.

B. Telephone System:

1. Provide a telephone equipment room.

2. Provide telephone outlets - 4 -11/16-inch-square boxes with plaster ring.

3. Provide 3/4 inch minimum conduit size.

4. Provide connection to ICS phone system.

C. Public Address:

1. Provide battery-powered amplifiers.

2. Provide surface-mounted speakers.

3. Provide 100% coverage of the area.

4. Provide interconnecting conduit.

5. Provide connection to Laboratory disaster-alert system.

SECTION 16900 - CONTROLS AND INSTRUMENTATION

A. Mechanical Equipment Connections:

1. Provide all power wiring.

2. Provide interconnection for control circuits.

3. Provide motor control centers.

4. Provide connection to Energy Monitoring and Control System.

## 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:

### Building Envelope

As presently planned, the Life Sciences Center facility incorporates reasonably well insulated walls and roof, as well as utilization of double glazed windows. The use of additional wall or roof insulation in conjunction with alternate glazing materials should be studied for cost effectiveness.

In order to minimize direct solar heat gain through the west-facing windows, a glass shading coefficient of 0.50 has been utilized for purposes of analysis. During future design phases, specific tradeoffs of higher and lower glass shading coefficients in conjunction with exterior shading must be analyzed in detail. Several methods of exterior shading should be investigated, including window overhangs, fixed and/or movable louvers, and vertical fins.

### 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 makeup air. The variable air volume terminal boxes serving the laboratory areas 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.

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, 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.

## 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 (OSP's) are mandatory for all potentially-hazardous experiments. The OSP's are reviewed by the Environmental Health and Safety 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.

# SECTION 9

## DETAILED SUPPORTING DATA

EDIA Anaylsis

Basis for Architectural Design

Basis for Mechanical Design

HVAC Load Calculations

Cost Estimate Detail for Conventional Facilities (D. Daniels)

Schedule I - Special Facilities (FY89$K)

Schedule II - Standard Equipment (FY89$K)

Details of Estimate of Scientific Equipment under Schedule I, Special Facilities

Details of Estimates of Scientific Equipment under Schedule II, Standard Equipment

ALS LIFE SCIENCES CENTER
EDIA ANALYSIS (89$K)

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LBL ACTIVITIES

**Engineering**

| | | |
|---|---|---|
| Title I 3 man-months at $6.95K/mo = | | 21 |
| Proj Arch 1 x .4 time x 3 = | 1.2 mm | |
| Proj Team 3 x .2 time x 3 = | 1.8 | |
| Title II 7 mm at $6.95K/mo = | | 49 |
| Proj Arch 1 x .4 x 7 = | 2.8 mm | |
| Proj Team 3 x .2 x 7 = | 4.2 | |
| Title III 7.5 mm at $6.95K/mo = | | 52 |
| Proj Arch 1 x .17 x 16 = | 2.7 | |
| Proj Team 3 x .10 x 16 = | 4.8 | |
| Inspection 9.4 mm at $6.95K/mo = | | 65 |
| Inspectors (combo.) .5 x16 = | 8.0 | |
| Equipment Installn .2 x 7 = | 1.4 | |
| Consultants and Vendors = | | 15 |
| Independent seismic reviews | $ 2K | |
| Independent cost estimates | 4 | |
| Advertisements | 3 | |
| Printing | 6 | |
| | | 202 |

A/E ACTIVITIES

| | |
|---|---|
| 12.5% of designed construction costs ($2,309K) including Special Facilities of $371K | 288 |

---

Total Estimated EDIA $490K

2-15-89

**BASIS FOR ARCHITECTURAL DESIGN**

Exterior Work

Demolition - Building 10

1. Remove existing cement asbestos siding to the wood girts along with wood sash, mullions and jambs.

New Construction - Building 10

1. Install new metal siding applied to the existing 5 ft OC wood girts, same pattern as on adjacent ALS w/o liner and insulation (furnished under Interior Work)

2. Install new metal sash.

Interior Work

Demolition - Building 10

1. Remove all existing partitions as indicated on the drawings including ceilings and floor finishes - laboratory equipment and cabinet work salvaged for re-use.

New Construction - Buildings 10 (1st Floor) and 6 (Second Floor)

1. Exterior wall system at Bldg. 6 (existing) - finished inside and insulated under ALS contract. The interior separating wall (second floor from ALS high bay area) is also in place. New finishes consist of painting at these walls.

2. Exterior wall system at Bldg. 10 - new metal siding plus interior non-combustible metal studs applied over girt faces, insulated, and finished with gypsum board.

3. Interior partitions at Bldgs 10 & 6 - new non-combustible metal studs finished with gypsum board.

4. Ceilings will be suspended in both buildings at a 9 foot height and consist of T-bar system and lay-in accoustical units.

5. Floor finishes - vinyl composition tiles 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. An allowance is made for refinishing the existing toilet rooms in Bulding 10.

8. Building 10 - Modular demountable partitions with pre-wired 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:

| | Summer | Winter |
|---|---|---|
| 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.

| | Summer | Winter |
|---|---|---|
| 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 |

In the follow-on design stages, the finalized building envelope must be reviewed to ensure compliance with the requirements of DOE Manual 6430.1A, ASHRAE 90A-1980, and California Title 24. Actual insulation thicknesses and type of glazing must meet the more stringent requirement established by these documents.

B. HEATING

Heat for both that portion of the Life Science Center to be located on the second floor of Building 6, as well as the first floor of Building 10, 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 531,000 BTU/hour.

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 first floor of Building 10 will be supplied from a new penthouse-type air handling unit located on the roof of Building 10. 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 358,600 BTU/hour.

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. 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. 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 both areas of the Life Science Center. 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 systems will be provided with variable frequency drives, such that the exhaust air quantities can be adjusted as required to maintain a slight positive pressure in the building.

E. MECHANICAL COOLING

Cooling for both that portion of the Life Science Center to be located on the second floor of Building 6, as well as the first floor of Building 10, will be supplied from the existing chilled water system in 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 6430.1, Chapters 5 and 17.

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 floors 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

Keller & Gannon
Engineers-Architects

COMPUTED BY
CHECKED BY
DATE 19
REV. 19

PROJECT
SHEET NO. OF SHEETS

# MECHANICAL CALCULATIONS


| | PAGES |
|---|---|
| DESIGN CRITERIA | 1 - 4 |
| COOLING SUMMARY | 5 - 6 |
| COOLING LOAD CALCULATIONS | 7 - 25 |
| HEATING SUMMARY | 26 - 27 |
| HEATING LOAD CALCULATIONS | 28 - 44 |




FORM 101-1/8

WEATHER DATA:

FROM ASHRAE FUNDAMENTALS, 1985 WEATHER DATA:

| | SUMMER | WINTER |
|---|---|---|
| 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

| | SUMMER | WINTER |
|---|---|---|
| ROOF | .05 BTU/ft²·HR·°F | .05 |
| WALL | .07 " | .07 |
| WINDOWS | .35 " | .31 BTUH/ft²·F° |

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

| | CLTD | LM |
|---|---|---|
| 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

$T_R = 76°F$ INDOOR DESIGN TEMP.

$T_O = 85°F$ OUTDOOR DESIGN TEMP.

THEREFORE THE CORRECTED CLTD SHALL BE (PER ASHRAE)

$$CLTD_{CORR} = [(CLTD + LM) * K + (78 - T_R) + (T_O - 85)$$

$$= (CLTD + LM) * 1.0 + (78 - 76) + (85 - 85)$$

$$= (CLTD + LM) \times 1.0 + 2$$

| | | 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 FACTOR FOR CEILING SPACE VENTILATION
1 = NO VENTILATION

K = 1.0 DARK COLOR

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

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

ROOF $CLTD_{CORR}$ = 37

MAXIMUM SHGF FOR FENSTRATION

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

Keller & Gannon
Engineers-Architects

COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL - LIFE SCIENCES
COOLING SUMMARY

PROJECT 16-199-09
SHEET NO. 5 OF 44 SHEETS

BLDG #10

| ROOM | SUPPLY CFM | OA CFM | BTUH COOLING LOAD |
|---|---|---|---|
| OFFICE | 270 | 30 | 5,350 |
| GLASSWARE | 480 | 480 | 15,030 |
| CELL/TISSUE | 1825 | 1,825 | 30,000 |
| ELECTRON MICR. | 520 | 520 | 16,210 |
| ELECTRON MICR. | 705 | 705 | 22,080 |
| LIGHT MICROSCOPE | 430 | 480 | 15,010 |
| DARK ROOM | 575 | 575 | 7,420 |
| SURGERY | 1,410 | 1,410 | 44,000 |
| WET BIOCHEM | 1825 | 1825 | 39,250 |
| CORRIDOR | 1,200 | 1200 | 14,800 |
| | 9,290 | 9050 | 209,650 |

BLDG #6

| ROOM | SUPPLY CFM | OA CFM | BTUH COOLING LOAD |
|---|---|---|---|
| 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 |
| DARK ROOM | 40 | 40 | 1,270 |
| MICROSCOPE RM. | 51 | 51 | 1,600 |
| LAB | 825 | 825 | 15,800 |
| SUBTOTAL | 3,911 | 2,111 | 82,840 |



FORM 101-1/8

Keller & Gannon
Engineers-Architects

COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL- LIFE SCIENCES
COOLING SUMMARY

PROJECT 16-199-89
SHEET NO. 6 OF 44 SHEETS

BLD #6 CONTINUED

| ROOM | SUPPLY CFM | O.A. CFM | BTUH COOLING LOAD |
|---|---|---|---|
| SUBTOTAL | 3,911 | 2,111 | 82,840 |
| LAB | 1,825 | 1,825 | 27,550 |
| LAB (WEST) | 1,575 | 1,575 | 24,820 |
| CORRIDOR | 900 | 900 | 13,730 |
| BLDG #6 TOTAL | 8211 | 6,411 | 148,940 |



FORM 101-1/8

Keller & Gannon
Engineers-Architects

# COMPUTATION SHEET

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DATE 12-5 1988
REV. 19

LBL - LIFE SCIENCES
COOLING LOAD
OFFICE BLDG 10

PROJECT 16-199-09

SHEET NO. 7 OF 44 SHEETS

Space Used For
Size 14 × 28 = 392 SQ FT × 16 = 6272 CU FT

| ITEM | AREA OR QUANTITY | SUN GAIN OR TEMP. DIFF. | FACTOR | BTU/HOUR |
|---|---|---|---|---|
| **SOLAR GAIN—GLASS** | | | | |
| Glass 45 | SQ FT × 163 | × .42x8 | | 2460 |
| Glass | SQ FT × | × | | |
| Glass | SQ FT × | × | | |
| Glass | SQ FT × | × | | |
| Skylight | SQ FT × | × | | |
| **SOLAR & TRANS. GAIN—WALLS & ROOF** | | | | |
| Wall 180 | SQ FT × 22 | × .07 | | 200 |
| Wall | SQ FT × | × | | |
| Wall | SQ FT × | × | | |
| Wall | SQ FT × | × | | |
| Roof-Sun | SQ FT × | × | | |
| 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 | 2 | PEOPLE × 315 | | 630 |
| Power | .5 w/sf | HP OR KW × | | 670 |
| Lights | 1.0 w/sf | WATTS × 3.4 × | | 1340 |
| Appliances, Etc. | | × | | |
| Additional Heat Gains | | × | | |
| | | SUB TOTAL | | 5300 |
| Storage | SQ FT × | × (– ) | | |
| | | SUB TOTAL | | |
| Safety Factor | 5 % | | | 260 |
| | | ROOM SENSIBLE HEAT | | 5560 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. % | | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | EFFECTIVE ROOM SENSIBLE HEAT | | |
| **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 | | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: 30 | CFM × 9 | F × (1– 0 | BF) × 1.08 | 290 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | GRAND TOTAL HEAT | | 5850 |

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: 2 PEOPLE × 15 CFM/PERSON = 30
SQ FT × CFM/SQ FT =
CFM VENTILATION

INFILTRATION: 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– SF) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP. RISE}$ = $CFM_{OA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{OA}$ = $F_{(RM-OUTLET AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 5850 ROOM SENS. HEAT / 1.08 × 20 F DESIRED DIFF = 270 $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{OA}$ = $CFM_{OA}$ = $CFM_{SA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{OA}$ / CFM†) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + SF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F
FROM PSYCH. CHART: $T_{EDB}$ F, $T_{LDB}$ F

**NOTES**

5,850 BTUH
270 CFM

30 CFM O.A. MINIMUM.

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J C CASE
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DATE 12-5 1988
REV. 19

LBL - LIFE SCIENCES
COOLING LOAD
BLDG 10, GLASSWARE

PROJECT 16-199-09
SHEET NO. 8 OF 44 SHEETS

Space Used For
Size 20 × 27 = 540 SQ FT × 16 = 8640 CU FT

| ITEM | AREA OR QUANTITY | SUN GAIN OR TEMP. DIFF. | FACTOR | BTU/HOUR |
|---|---|---|---|---|
| **SOLAR GAIN—GLASS** | | | | |
| Glass 64 | SQ FT = 163 | × .42 × .8 | | 3510 |
| Glass | SQ FT = | × | | |
| Glass | SQ FT = | × | | |
| Glass | SQ FT = | × | | |
| Skylight | SQ FT = | × | | |
| **SOLAR & TRANS. GAIN—WALLS & ROOF** | | | | |
| Wall 256 | SQ FT = 27 | × .07 | | 280 |
| Wall | SQ FT = | × | | |
| Wall | SQ FT = | × | | |
| Wall | SQ FT = | × | | |
| Roof-Sun | SQ FT = | × | | |
| 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 | 2 | PEOPLE = 315 | | 630 |
| Power | 2.5 w/sf | HP OR KW = 3.413 | | 4610 |
| Lights | 1.0 w/sf | WATTS/1000 = 3.413 | | 1840 |
| Appliances, Etc. | | × | | |
| Additional Heat Gains | | × | | |
| | | SUB TOTAL | | 9870 |
| Storage | SQ FT = | × (– ) | | |
| | | SUB TOTAL | | |
| Safety Factor | 5 % | | | 490 |
| | | ROOM SENSIBLE HEAT | | 10360 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. % | | |
| Outdoor Air | CFM × | F × | SF = 1.08 | |
| | | EFFECTIVE ROOM SENSIBLE HEAT | | |
| **LATENT HEAT** | | | | |
| Infiltration | CFM × | GR/LB × 0.68 | | |
| People | PEOPLE × | | | |
| Steam | LB/HR × 1090 | | | |
| 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 × | SF = 0.68 | |
| | | EFFECTIVE ROOM LATENT HEAT | | |
| | | EFFECTIVE ROOM TOTAL HEAT | | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: 480 | CFM × 9 | F × (1– 0 | SF) × 1.08 | 4670 |
| Latent: | CFM × | GR/LB × (1– | SF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEMIN. & % + PIPE LOSS % | |
| | | GRAND TOTAL HEAT | | 15030 |

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

Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 87 | | | | |
| ROOM (RM) | 76 | | | | |
| DIFFERENCE | 9 | | | | |

**OUTDOOR AIR**

VENTILATION: PEOPLE = CFM/PERSON = ; SQ FT = CFM/SQ FT = ; CFM VENTILATION

INFILTRATION: 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– SF) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / (1.08 × $F_{TEMP. RISE}$) = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / (1.08 × $CFM_{DA}$) = $F_{(RM-OUTLET\ AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 10,360 ROOM SENS. HEAT / (1.08 × 20 F DESIRED DIFF) = 480 $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{DA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{DA}$ / CFM†) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + SF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

15,030 BTUH LOAD

480 CFM O.A.

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J C CASE
CHECKED BY
DATE 12-5 1988
REV. 19

LBL - LIFE SCIENCES
COOLING LOAD
BLDG 10, CELL/TISSUE CULT.

PROJECT 16-199-09

SHEET NO. 9 OF 44 SHEETS

Space Used For
Size 21 × 30 = 630 SQ FT × 16 = 10080 CU FT

| ITEM | AREA OR QUANTITY | SUN GAIN OR TEMP. DIFF. | FACTOR | BTU/HOUR |
|---|---|---|---|---|
| **SOLAR GAIN–GLASS** | | | | |
| Glass 67 | SQ FT × 163 | × .42 × .8 | | 3670 |
| Glass | SQ FT × | × | | |
| Glass | SQ FT × | × | | |
| Glass | SQ FT × | × | | |
| Skylight | SQ FT × | × | | |
| **SOLAR & TRANS. GAIN–WALLS & ROOF** | | | | |
| Wall 269 | SQ FT × 22 | × .07 | | 300 |
| Wall | SQ FT × | × | | |
| Wall | SQ FT × | × | | |
| Wall | SQ FT × | × | | |
| Roof-Sun | SQ FT × | × | | |
| 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 | 4 | PEOPLE × 315 | | 1260 |
| Power | 2.0 W/SF | HP OR KW × 3,413 | | 4300 |
| Lights | 1.0 W/SF | WATTS 3,413 | | 2150 |
| Appliances, Etc. | | × | | |
| Additional Heat Gains | | × | | |
| | | SUB TOTAL | | 11680 |
| Storage | SQ FT × | × (– ) | | |
| | | SUB TOTAL | | |
| Safety Factor | 5 % | | | 580 |
| | | ROOM SENSIBLE HEAT | | 12260 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. % | | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | EFFECTIVE ROOM SENSIBLE HEAT | | |
| **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 | | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: 1825 | CFM × 9 | F × (1– 0 | BF) × 1.08 | 17740 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | GRAND TOTAL HEAT | | 30000 |

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: ____ PEOPLE × ____ CFM/PERSON = ____
____ SQ FT × ____ CFM/SQ FT = ____
CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ ____ F – $T_{ADP}$ ____ F) = ____ F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP. RISE}$ = ____ $CFM_{OA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{OA}$ = ____ $F_{(RM-OUTLET\ AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 12 260 ROOM SENS. HEAT / 1.08 × 20 F DESIRED DIFF = 570 $CFM_{SA}$

BYPASS CFM: ____ $CFM_{SA}$ – ____ $CFM_{OA}$ = ____ $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ ____ F + ($CFM_{OA}$ / $CFM_{SA}$) × ($T_{OA}$ ____ F – $T_{RM}$ ____ F) = $T_{EDB}$ ____ F

LDB: $T_{ADP}$ ____ F + ____ BF × ($T_{EDB}$ ____ F – $T_{ADP}$ ____ F) = $T_{LDB}$ ____ F
FROM PSYCH. CHART: $T_{EWB}$ ____ F, $T_{LWB}$ ____ F

**NOTES**

570 CFM REQUIRED FOR COOLING, HOWEVER HVAC REQUIREMENTS FOR THIS ROOM ARE 2,000 CFM ∴ ROOM REQUIREMENTS ARE 2,000 CFM OA

30,000 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J C CASE
CHECKED BY
DATE 12-5 1988
REV. 19

LBL - LIFE SCIENCE
COOLING LOAD
BLDG #10, ELECTRON MICROSCOPE

PROJECT 16-199-09
SHEET NO. 10 OF 44 SHEETS

Space Used For
Size 20 × 14 = 280 SQ FT × 16 = 4480 CU FT

| ITEM | AREA OR QUANTITY | SUN GAIN OR TEMP. DIFF. | FACTOR | BTU/HOUR |
|---|---|---|---|---|
| **SOLAR GAIN–GLASS** | | | | |
| Glass | 64 SQ FT × | 163 × | .48 × .8 | 4000 |
| Glass | SQ FT × | × | | |
| Glass | SQ FT × | × | | |
| Glass | SQ FT × | × | | |
| Skylight | SQ FT × | × | | |
| **SOLAR & TRANS. GAIN–WALLS & ROOF** | | | | |
| Wall | 256 SQ FT × | 22 × | .07 | 280 |
| Wall | SQ FT × | × | | |
| Wall | SQ FT × | × | | |
| Wall | SQ FT × | × | | |
| Roof-Sun | SQ FT × | × | | |
| 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 | 2 | PEOPLE × | 315 | 630 |
| Power | 5.0 w/SF | ~~HP OR KW~~ × | 3.413 | 4780 |
| Lights | 1.0 w/SF | WATTS × 3.4 × | 3.413 | 960 |
| Appliances, Etc. | | × | | |
| Additional Heat Gains | | × | | |
| | | SUB TOTAL | | 10650 |
| Storage | SQ FT × | × (– ) | | |
| | | SUB TOTAL | | |
| Safety Factor | 5 % | | | 530 |
| | | ROOM SENSIBLE HEAT | | 11180 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. % | | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | EFFECTIVE ROOM SENSIBLE HEAT | | |
| **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 | | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 517 CFM × | 9 F × (1– 0 | BF) × 1.08 | 5030 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | GRAND TOTAL HEAT | | 16210 |

E-5024

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: PEOPLE × CPM/PERSON ×
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 = 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: EFFECTIVE ROOM SENS. HEAT / (1.08 × $T_{TEMP. RISE}$) = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / (1.08 × $CFM_{DA}$) = $F_{(RM-OUTLET\ AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 11180 ROOM SENS. HEAT / (1.08 × 20 F DESIRED DIFF) = 517 $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{SA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{OA}$ / CFM†) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F
FROM PSYCH. CHART: $T_{EDB}$ F, $T_{LDB}$ F

**NOTES**

520 CFM O.A.

16210 BTUH

*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.

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J.C. CASE
CHECKED BY
DATE 12-5 1980
REV. 19

LBL - LIFE SCIENCES
COOLING LOAD
BLDG #10, ELECTRON MICRO.

PROJECT 16-199-09
SHEET NO. 11 OF 44 SHEETS

Space Used For
Size 20 × 14 = 280 SQ FT × 16 = 4480 CU FT

| ITEM | AREA OR QUANTITY | SUN GAIN OR TEMP. DIFF. | FACTOR | BTU/HOUR |
|---|---|---|---|---|
| **SOLAR GAIN—GLASS** | | | | |
| Glass 64 | SQ FT × 163 | | × .48 × .8 | 4000 |
| Glass 45 | SQ FT × 170 | | × .58 × .8 | 3550 |
| Glass | SQ FT × | | × | |
| Glass | SQ FT × | | × | |
| Skylight | SQ FT × | | × | |
| **SOLAR & TRANS. GAIN—WALLS & ROOF** | | | | |
| Wall 256 | SQ FT × 22 | | × .07 | 280 |
| Wall 179 | SQ FT × 34 | | × .07 | 300 |
| Wall | SQ FT × | | × | |
| Wall | SQ FT × | | × | |
| Roof-Sun | SQ FT × | | × | |
| 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 | 2 | PEOPLE × 315 | | 630 |
| Power 5.0 W/SF | | HP OR KW × 3.413 | | 4780 |
| Lights 1.0 W/SF | | WATTS × 3.4 × 3.413 | | 960 |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 14500 |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 730 |
| | | | ROOM SENSIBLE HEAT | 15230 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: 705 CFM × | 9 F × (1– | 0 | BF) × 1.08 | 6850 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 22080 |

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: PEOPLE = CFM/PERSON = ; SQ FT = CFM/SQ FT = ; CFM VENTILATION

INFILTRATION: 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– SF) = ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $T_{TEMP. RISE}$ = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{DA}$ = F (RM–OUTLET AIR)*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 15,230 ROOM SENS. HEAT / 1.08 × 20 F DESIRED DIFF = 705 $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + $CFM_{DA}$ / CFM† × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + SF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F
FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

705 CFM REQUIRED FOR COOLING, HOWEVER HOOD REQUIREMENTS ARE 750 CFM
ROOM REQUIREMENTS ARE:
705 CFM O.A.
22,080 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J. CASE
CHECKED BY
DATE 12-5 1988
REV. 19

LBL-LIFE SCIENCES
COOLING LOAD
BLDG #10, LIGHT MICROSCOPE

PROJECT 16-199-09
SHEET NO. 12 OF 44 SHEETS

Space Used For
Size 16 × 18 = 288 SQ FT × 16 = 4600 CU FT

| ITEM | AREA OR QUANTITY | SUN GAIN OR TEMP. DIFF. | FACTOR | BTU/HOUR |
|---|---|---|---|---|
| **SOLAR GAIN—GLASS** | | | | |
| Glass 58 | SQ FT × 170 | × .58 × .8 | | 4580 |
| Glass | SQ FT × | × | | |
| Glass | SQ FT × | × | | |
| Glass | SQ FT × | × | | |
| Skylight | SQ FT × | × | | |
| **SOLAR & TRANS. GAIN—WALLS & ROOF** | | | | |
| Wall 230 | SQ FT × 34 | × .07 | | 390 |
| Wall | SQ FT × | × | | |
| Wall | SQ FT × | × | | |
| Wall | SQ FT × | × | | |
| Roof-Sun | SQ FT × | × | | |
| 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 3.0 w/sf | HP OR KW × 3,415 | | | 2950 |
| Lights 1.0 w/sf | WATTS × 3.4 × 3,415 | | | 980 |
| Appliances, Etc. | | × | | |
| Additional Heat Gains | | × | | |
| | | SUB TOTAL | | 9850 |
| Storage | SQ FT × | × (– ) | | |
| | | SUB TOTAL | | |
| Safety Factor 5 % | | | | 490 |
| | | ROOM SENSIBLE HEAT | | 10,340 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. % | | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | EFFECTIVE ROOM SENSIBLE HEAT | | |
| **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 | | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: 480 | CFM × 9 | F × (1– 0 | BF) × 1.08 | 4670 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | GRAND TOTAL HEAT | | 15,010 |

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: PEOPLE × CFM/PERSON ×; SQ FT × CFM/SQ FT ×; CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $T_{TEMP. RISE}$ = $CFM_{OA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{OA}$ = F (RM–OUTLET AIR)*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 10,340 ROOM SENS. HEAT / 1.08 × 20 F DESIRED DIFF = 480 $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{OA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{OA}$ / CFM†) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

15,010 BTUH

480 CFM OA

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-5 1988
REV. 19

LBL – LIFE SCIENCES
COOLING LOAD
BLDG #10, DARK ROOM

PROJECT 16-199-09
SHEET NO. 13 OF 44 SHEETS

Space Used For
Size 10 × 13 = 130 SQ FT × 16 = 2080 CU FT

| 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 | SQ FT × | | × | |
| 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 | 7 | PEOPLE × | 315 | 630 |
| Power | 1.5 W/SF | HP OR KW × | | 670 |
| Lights | 1.0 W/SF | WATTS × 3.4 × | | 440 |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 1740 |
| Stolage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 90 |
| | | | ROOM SENSIBLE HEAT | 1830 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 575 CFM × | 9 F × (1– | 0 BF) × 1.08 | 5590 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 7420 |

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: ____ PEOPLE × ____ CFM/PERSON = ____
____ SQ FT × ____ CFM/SQ FT = ____
CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ ____ F – $T_{ADP}$ ____ F) = ____ F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP. RISE}$ = ____ $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{DA}$ = ____ F (RM–OUTLET AIR)*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 1830 ROOM SENS. HEAT / 1.08 × 20 F DESIRED DIFF = 85 $CFM_{SA}$

BYPASS CFM: ____ $CFM_{SA}$ – ____ $CFM_{DA}$ = ____ $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ ____ F + ($CFM_{DA}$ / CFM†) × ($T_{OA}$ ____ F – $T_{RM}$ ____ F) = $T_{EDB}$ ____ F

LDB: $T_{ADP}$ ____ F + ____ BF × ($T_{EDB}$ ____ F – $T_{ADP}$ ____ F) = $T_{LDB}$ ____ F

FROM PSYCH. CHART: $T_{EWB}$ ____ F, $T_{LWB}$ ____ F

**NOTES**

HOOD REQUIREMENTS
575 CFM O.A.
7,420 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-5 1988
REV. 19

LBL - LIFE SCIENCES
COOLING LOAD
BLDG #10, SURGERY

PROJECT 16-199-09
SHEET NO. 14 OF 44 SHEETS

Space Used For
Size 20 × 36 = 720 SQ FT × 16 = 11,520 CU FT

| ITEM | AREA OR QUANTITY | SUN GAIN OR TEMP. DIFF. | FACTOR | BTU/HOUR |
|---|---|---|---|---|
| **SOLAR GAIN—GLASS** | | | | |
| Glass | 115 SQ FT × | 170 × | .58 X .8 | 9070 |
| Glass | SQ FT × | × | | |
| Glass | SQ FT × | × | | |
| Glass | SQ FT × | × | | |
| Skylight | SQ FT × | × | | |
| **SOLAR & TRANS. GAIN—WALLS & ROOF** | | | | |
| Wall | 460 SQ FT × | 34 × | .07 | 780 |
| Wall | SQ FT × | × | | |
| Wall | SQ FT × | × | | |
| Wall | SQ FT × | × | | |
| Roof-Sun | SQ FT × | × | | |
| 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 | 6 | PEOPLE × | 315 | 1890 |
| Power | 2.0 W/SF | HP OR KW × | | 4910 |
| Lights | 5.0 W/SF | 3.4 × | | 12290 |
| Appliances, Etc. | | × | | |
| Additional Heat Gains | | × | | |
| | | SUB TOTAL | | 23940 |
| Storage | SQ FT × | × (– ) | | |
| | | SUB TOTAL | | |
| Safety Factor | 5 % | | | 1450 |
| | | ROOM SENSIBLE HEAT | | 30390 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | EFFECTIVE ROOM SENSIBLE HEAT | | |
| **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 | | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 1400 CFM × | 9 F × (1– | 0 BF) × 1.08 | 13610 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | GRAND TOTAL HEAT | | 44,000 |

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: PEOPLE × CFM/PERSON ×; SQ FT × CFM/SQ FT ×; CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $T_{TEMP. RISE}$ = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{DA}$ = $T_{(RM-OUTLET AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 30390 ROOM SENS. HEAT / 1.08 × 20 F DESIRED DIFF = 1410 $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{DA}$ / CFM†) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

1,410 CFM OA.

44,000 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-5 1980
REV. 19

LBL - LIFE SCIENCES
COOLING LOAD
BLDG #10 WET BIOCHEM. LAB

PROJECT 16·199·09

SHEET NO. 15 OF 44 SHEETS

Space Used For
Size 40 × 36 = 1440 SQ FT × 16 = 23,040 CU FT

| 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 | SQ FT × | | × | |
| 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 | 10 | PEOPLE × 315 | | 3150 |
| Power | 2.5 w/SF | HP OR KW × | | 10810 |
| Lights | 1.0 w/SF | WATTS × 3.4 × | | 4910 |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 18870 |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 940 |
| | | | ROOM SENSIBLE HEAT | 19810 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 1825 CFM × | 9 F × (1– | BF) × 1.08 | 17740 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 37550 |

E-5024

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: ____ PEOPLE × ____ CFM/PERSON = ____
____ SQ FT × ____ CFM/SQ FT = ____
CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ ____ F – $T_{ADP}$ ____ F) = ____ F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / (1.08 × $F_{TEMP. RISE}$) = ____ $CFM_{OA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / (1.08 × $CFM_{OA}$) = ____ $F_{(RM-OUTLET\ AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 19810 ROOM SENS. HEAT / (1.08 × 20 F DESIRED DIFF) = 917 $CFM_{SA}$

BYPASS CFM: ____ $CFM_{SA}$ – ____ $CFM_{OA}$ = ____ $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ ____ F + ($CFM_{OA}$ / CFM†) × ($T_{OA}$ ____ F – $T_{RM}$ ____ F) = $T_{EDB}$ ____ F

LDB: $T_{ADP}$ ____ F + ____ BF × ($T_{EDB}$ ____ F – $T_{ADP}$ ____ F) = $T_{LDB}$ ____ F

FROM PSYCH. CHART: $T_{EWB}$ ____ F, $T_{LWB}$ ____ F

**NOTES**

HOOD REQUIREMENTS ARE
2 × 1000 CFM = 2,000 CFM
∴ ROOM REQUIREMENTS ARE:
1,825 CFM
37,550 BTUH

*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.

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY T CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL - LIFE SCIENCES
COOLING LOAD
BLDG #10, CORRIDOR

PROJECT 16-199-09
SHEET NO. 16 OF 44 SHEETS

Space Used For
Size 6 × 60 = 360 SQ FT × 16 = 5,760 CU FT

| ITEM | AREA OR QUANTITY | SUN GAIN OR TEMP. DIFF. | FACTOR | BTU/HOUR |
|---|---|---|---|---|
| **SOLAR GAIN—GLASS** | | | | |
| Glass | 20 SQ FT × | 170 | × .58 × .8 | 1580 |
| Glass | SQ FT × | | × | |
| Glass | SQ FT × | | × | |
| Glass | SQ FT × | | × | |
| Skylight | SQ FT × | | × | |
| **SOLAR & TRANS. GAIN—WALLS & ROOF** | | | | |
| Wall | 76 SQ FT × | 34 | × .07 | 180 |
| Wall | SQ FT × | | × | |
| Wall | SQ FT × | | × | |
| Wall | SQ FT × | | × | |
| Roof-Sun | SQ FT × | | × | |
| 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 | | PEOPLE × | | |
| Power | — | HP OR KW × | | |
| Lights | 1.0 w/SF | WATTS × 3.4 × | | 1230 |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 2990 |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 150 |
| | | | ROOM SENSIBLE HEAT ■ | 3140 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT ■ | |
| **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 ■ | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 1200 CFM × | 9 | F × (1– 0 BF) × 1.08 | 11660 |
| Latent: | CFM × | GR/LB × | (1– BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT ■ | 14800 |

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: PEOPLE = CFM/PERSON = ; SQ FT = CFM/SQ FT = ; CFM VENTILATION ■

INFILTRATION: 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) = ($T_{RM}$ F – $T_{ADP}$ F) =

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $T_{TEMP. RISE}$ = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{DA}$ = $T_{(RM-OUTLET\ AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 3140 ROOM SENS. HEAT / 1.08 × 20 F DESIRED DIFF = 145 $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{DA}$ / $CFM_{SA}$) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

1200 CFM

14,800 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-5 1988
REV. 19

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

PROJECT 16-199-09

SHEET NO. 17 OF 44 SHEETS

Space Used For
Size 10 × 16 = 160 SQ FT × 14 = 2240 CU FT

| ITEM | AREA OR QUANTITY | SUN GAIN OR TEMP. DIFF. | FACTOR | BTU/HOUR | |
|---|---|---|---|---|---|
| **SOLAR GAIN–GLASS** | | | | | |
| Glass 28 | SQ FT × 163 | | × .42 × .8 | 1 | 530 |
| Glass | SQ FT × | | × | | |
| Glass | SQ FT × | | × | | |
| Glass | SQ FT × | | × | | |
| Skylight | SQ FT × | | × | | |
| **SOLAR & TRANS. GAIN–WALLS & ROOF** | | | | | |
| Wall 112 | SQ FT × 22 | | × .05 | | 120 |
| Wall | SQ FT × | | × | | |
| Wall | SQ FT × | | × | | |
| Wall | SQ FT × | | × | | |
| Roof-Sun 160 | SQ FT × 37 | | × .07 | | 410 |
| 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 | | | PEOPLE × 315 | | 320 |
| Power 400 WATTS, (1 PC) ~~HP OR KW~~ | | | WATTS × 3.4 × 3.413 | 1 | 370 |
| Lights 1.0 W/SF | | | WATTS × 3.4 × | | 550 |
| Appliances, Etc. | | | × | | |
| Additional Heat Gains | | | × | | |
| | | | SUB TOTAL | 4 | 300 |
| Storage | SQ FT × | | × (– ) | | |
| | | | SUB TOTAL | | |
| Safety Factor 5 | | | % | | 210 |
| | | | ROOM SENSIBLE HEAT | 4 | 510 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | | FAN % + H. P. % | | |
| Outdoor Air | CFM × | | F × BF × 1.08 | | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | | |
| **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 | | |
| **OUTDOOR AIR HEAT** | | | | | |
| Sensible: 15 | CFM × 4 | | F × (1– 0 BF) × 1.08 | | 60 |
| Latent: | CFM × | | GR/LB × (1– BF) × 0.68 | | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 4 | 570 |

E-5024

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**

VENTILATION: 1 PEOPLE × 15 CFM/PERSON = 15
SQ FT × CFM/SQ FT =
CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $T_{TEMP. RISE}$ = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{DA}$ = $T_{RM-OUTLET AIR}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 4660 ROOM SENS. HEAT / 1.08 × 20 F DESIRED DIFF = 215 $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + $CFM_{OA}$ / CFM† × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F
FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

215 CFM TOTAL
15 CFM O.A.
4,570 BTUH

*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.

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J C CASE
CHECKED BY
DATE 12-5 1988
REV. 19

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

PROJECT 16-199-09
SHEET NO. 18 OF 44 SHEETS

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

| 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/sf | ~~HP OR KW~~ × 3.413 | | 3920 |
| Lights | 1.0 w/sf | ~~WATTS~~ × 3.413 | | 1570 |
| Appliances, Etc. | | × | | |
| Additional Heat Gains | | × | | |
| | | SUB TOTAL | | 7290 |
| Storage | SQ FT × | × (– ) | | |
| | | SUB TOTAL | | |
| Safety Factor | 5 % | | | 360 |
| | | ROOM SENSIBLE HEAT | | 7650 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | EFFECTIVE ROOM SENSIBLE HEAT | | |
| **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 | | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible | 87.5 CFM × | 9 F × (1– 0 | BF) × 1.08 | 8020 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | GRAND TOTAL HEAT | | 15670 |

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: ____ PEOPLE × ____ CFM/PERSON = ____
____ SQ FT × ____ CFM/SQ FT = ____
CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ ____ F – $T_{ADP}$ ____ F) = ____ F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP. RISE}$ = ____ $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{DA}$ = ____ $F_{(RM-OUTLET\ AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 7650 ROOM SENS. HEAT / 1.08 × 20 F DESIRED DIFF = 355 $CFM_{SA}$

BYPASS CFM: ____ $CFM_{SA}$ – ____ $CFM_{DA}$ = ____ $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ ____ F + ($CFM_{DA}$ / CFM†) × ($T_{OA}$ ____ F – $T_{RM}$ ____ F) = $T_{EDB}$ ____ F

LDB: $T_{ADP}$ ____ F + ____ BF × ($T_{EDB}$ ____ F – $T_{ADP}$ ____ F) = $T_{LDB}$ ____ F

FROM PSYCH. CHART: $T_{EWB}$ ____ F, $T_{LWB}$ ____ F

**NOTES**

HOOD REQUIREMENTS =
1000 CFM ∴
• ROOM REQUIREMENTS =
825 CFM
15,670 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-5 1988
REV. 19

LBL - LIFE SCIENCES
COOLING LOADS
BLDG #6, VERTICAL BEAM

PROJECT 16-199-09
SHEET NO. 19 OF 44 SHEETS

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

| 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 | 272 SQ FT × | 37 | × .05 | 500 |
| 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 | 2 | PEOPLE × | 315 | 630 |
| Power | 3.0 w/sf | HP OR KW × | | 2790 |
| Lights | 1.0 w/sf | WATTS × 3.4 × | | 930 |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 4550 |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 240 |
| | | | ROOM SENSIBLE HEAT | 5090 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 235 CFM × | 9 F × (1– 0 | BF) × 1.08 | 2780 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 7370 |

E-5024

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: ____ PEOPLE × ____ CFM/PERSON = ____
____ SQ FT × ____ CFM/SQ FT = ____
CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ ____ F – $T_{ADP}$ ____ F) = ____ F

DEHUM. CPM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP. RISE}$ = ____ $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{DA}$ = ____ $F_{(RM-OUTLET AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CPM: 5090 ROOM SENS. HEAT / 1.08 × 20 F DESIRED DIFF = 235 $CFM_{SA}$

BYPASS CPM: ____ $CFM_{SA}$ – ____ $CFM_{DA}$ = ____ $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ ____ F + ($CFM_{DA}$ / CFM†) × ($T_{OA}$ ____ F – $T_{RM}$ ____ F) = $T_{EDB}$ ____ F

LDB: $T_{ADP}$ ____ F + ____ BF × ($T_{EDB}$ ____ F – $T_{ADP}$ ____ F) = $T_{LDB}$ ____ F
FROM PSYCH. CHART: $T_{EWB}$ ____ F, $T_{LWB}$ ____ F

**NOTES**

235 CFM O.A.

7370 BTUH

*IF THIS ΔT 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.

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J C CASE
CHECKED BY
DATE 12-6 1988
REV. 19

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

PROJECT 16-199-09

SHEET NO. 20 OF 44 SHEETS

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

| 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 | 60 SQ FT × | 37 | × .05 | 118 |
| 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 | | PEOPLE × | 315 | 320 |
| Power | 1.0 W/SF | HP OR KW × | | 205 |
| Lights | 1.0 W/SF | WATTS × 3.4 × | | 205 |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 840 |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 40 |
| | | | ROOM SENSIBLE HEAT | 880 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | | FAN % + H. P. % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 40 CFM × | 9 | F × (1– 0 BF) × 1.08 | 390 |
| Latent: | CFM × | | GR/LB × (1– BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 1,270 |

| 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: PEOPLE × CFM/PERSON ×
SQ FT × CFM/SQ FT ×
CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP. RISE}$ = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{DA}$ = $F_{(RM-OUTLET AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 880 / 1.08 × 20 F DESIRED DIFF = 40 $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + $CFM_{DA}$ / CFMT × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

40 CFM O.A.

1,270 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J C CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL · LIFE SCIENCES
COOLING LOAD
BLDG #6, MICROSCOPE FAM

PROJECT 16-199-09
SHEET NO. 21 OF 44 SHEETS

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

| 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 | 60 SQ FT × | 37 | × .05 | 116 |
| 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 | 1 PEOPLE × | 315 | | 320 |
| Power | 2.0 w/ft² HP OR KW × | | | 410 |
| Lights | 1.0 w/ft² WATTS × 3.4 × | | | 210 |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 1050 |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 50 |
| | | | ROOM SENSIBLE HEAT | 1100 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | | FAN % + H. P. % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 51 CFM × | 9 F × (1– | 0 BF) × 1.08 | 500 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 1600 |

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: PEOPLE × CFM/PERSON ×; SQ FT × CFM/SQ FT ×; CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) =

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / (1.08 × $F_{TEMP. RISE}$) = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / (1.08 × $CFM_{DA}$) = $F_{(RM-OUTLET\ AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 1100 ROOM SENS. HEAT / (1.08 × 20 F DESIRED DIFF) = 51 $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{OA}$ / $CFM_{SA}$) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

51 CFM O.A.

1,600 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY JC CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL- LIFE SCIENCES
COOLING LOAD
BLDG #G, LAB (15.3)-(16)

PROJECT 16-199-09
SHEET NO. 22 OF 44 SHEETS

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

| 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 | 400 SQ FT = | 37 × | .05 | 740 |
| 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 | 6 | PEOPLE × | 315 | 1890 |
| Power | 2.5 W/ft² | = 3.412 × | | 3410 |
| Lights | 1.0 W/ft² | = 3.415 × | | 1370 |
| Appliances, Etc. | | × | | |
| Additional Heat Gains | | × | | |
| | | SUB TOTAL | | 7410 |
| Storage | SQ FT = | × (– ) | | |
| | | SUB TOTAL | | |
| Safety Factor | 5 % | | | 370 |
| | | ROOM SENSIBLE HEAT | | 7780 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM = | F × | BF = 1.08 | |
| | | EFFECTIVE ROOM SENSIBLE HEAT | | |
| **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 | | |
| **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 | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | GRAND TOTAL HEAT | | 15800 |

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**

VENTILATION: ____ PEOPLE × ____ CFM/PERSON = ____
____ SQ FT × ____ CFM/SQ FT = ____
CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ ____ F – $T_{ADP}$ ____ F) = ____ F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP.\ RISE}$ = ____ $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{DA}$ = ____ $F_{RM-OUTLET\ AIR}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 7780 ROOM SENS. HEAT / 1.08 × 20 F DESIRED DIFF = 360 $CFM_{SA}$

BYPASS CFM: ____ $CFM_{SA}$ – ____ $CFM_{DA}$ = ____ $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ ____ F + ($CFM_{DA}$ / CFM†) × ($T_{OA}$ ____ F – $T_{RM}$ ____ F) = $T_{EDB}$ ____ F

LDB: $T_{ADP}$ ____ F + ____ BF × ($T_{EDB}$ ____ F – $T_{ADP}$ ____ F) = $T_{LDB}$ ____ F
FROM PSYCH. CHART: $T_{EWB}$ ____ F, $T_{LWB}$ ____ F

**NOTES**

HOOD REQUIREMENT ARE:
1,000 CFM
∴
ROOM REQUIREMENTS ARE:
825 CFM O.A
15,800 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL- LIFE SCIENCES
COOLING LOAD
BLDG #6 LAB BTWN (16) + (17)

PROJECT 16-199-09

SHEET NO. 23 OF 44 SHEETS

Space Used For
Size 27 × 20 = 540 SQ FT × 14 = 7560 CU FT

| 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 | 540 SQ FT × | 37 × | .05 | 1000 |
| 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 | 6 | PEOPLE × | 315 | 1890 |
| Power | 2.5 W/ft² | HP OR KW × | 3.413 | 4610 |
| Lights | 1.0 W/ft² | WATTS × | 3.413 | 1840 |
| Appliances, Etc. | | × | | |
| Additional Heat Gains | | × | | |
| | | SUB TOTAL | | 9340 |
| Storage | SQ FT × | × (– ) | | |
| | | SUB TOTAL | | |
| Safety Factor | 5 % | | | 470 |
| | | ROOM SENSIBLE HEAT | | 9810 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. % | | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | EFFECTIVE ROOM SENSIBLE HEAT | | |
| **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 | | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible | 825 CFM × | 9 F × (1– | 0 BF) × 1.08 | 17740 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | GRAND TOTAL HEAT | | 27550 |

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: ____ PEOPLE × ____ CFM/PERSON = ____
____ SQ FT × ____ CFM/SQ FT = ____
CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ ____ F – $T_{ADP}$ ____ F) = ____ F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / (1.08 × $F_{TEMP.\ RISE}$) = ____ $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / (1.08 × $CFM_{DA}$) = ____ F (RM–OUTLET AIR)*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 9810 ROOM SENS. HEAT / (1.08 × 20 F DESIRED DIFF) = 454 $CFM_{SA}$

BYPASS CFM: ____ $CFM_{SA}$ – ____ $CFM_{DA}$ = ____ $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ ____ F + ($CFM_{DA}$ / $CFM_T$) × ($T_{OA}$ ____ F – $T_{RM}$ ____ F) = $T_{EDB}$ ____ F

LDB: $T_{ADP}$ ____ F + ____ BF × ($T_{EDB}$ ____ F – $T_{ADP}$ ____ F) = $T_{LDB}$ ____ F
FROM PSYCH. CHART: $T_{EDB}$ ____ F, $T_{LDB}$ ____ F

**NOTES**

HOOD REQUIREMENTS
2,000 CFM ∴
ROOM REQUIREMENTS ARE:
1,825 CFM
27,550 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1988
REV. 19

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

PROJECT 16-199-09

SHEET NO. 24 OF 44 SHEETS

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

| 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 | 520 SQ FT × | 37 | × .05 | 960 |
| 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 | 6 | PEOPLE = | 315 | 1890 |
| Power | 2.5 w/sf | HP OR KW × | 3.413 | 4440 |
| Lights | 1.0 w/sf | WATTS × | 3.413 | 1770 |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 9000 |
| Storage | SQ FT × | | × (– , ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 450 |
| | | | ROOM SENSIBLE HEAT | 9510 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 1575 CFM × | 9 F × (1– 0 | BF) × 1.08 | 15310 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 24820 |

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: ____ PEOPLE × ____ CFM/PERSON = ____
____ SQ FT × ____ CFM/SQ FT = ____
CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ ____ F – $T_{ADP}$ ____ F) = ____ F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / (1.08 × $F_{TEMP. RISE}$) = ____ $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / (1.08 × $CFM_{DA}$) = ____ F (RM–OUTLET AIR)*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 9510 ROOM SENS. HEAT / (1.08 × 20 F DESIRED DIFF) = 440 $CFM_{SA}$

BYPASS CFM: ____ $CFM_{SA}$ – ____ $CFM_{DA}$ = ____ $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ ____ F + ($CFM_{DA}$ / $CFM_{SF}$) × ($T_{OA}$ ____ F – $T_{RM}$ ____ F) = $T_{EDB}$ ____ F

LDB: $T_{ADP}$ ____ F + ____ BF × ($T_{EDB}$ ____ F – $T_{ADP}$ ____ F) = $T_{LDB}$ ____ F
FROM PSYCH. CHART: $T_{EWB}$ ____ F, $T_{LWB}$ ____ F

**NOTES**

HOOD REQUIREMENTS ARE:
1,750 CFM
ROOM REQUIREMENTS ARE
1,575 CFM
24820 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL - LIFE SCIENCES
COOLING LOAD
BLDG #6 CORRIDOR

PROJECT 16-199-09

SHEET NO. 25 OF 44 SHEETS

Space Used For
Size C × 150 = 900 SQ FT × 14 = 12,600 CU FT

| 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 | 900 SQ FT × | 37 | × .05 | 1670 |
| 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 | PEOPLE × | | | |
| Power | HP OR KW × | | | |
| Lights | 1.0 W/SF | ~~WATTS × 3.4 ×~~ | 3.413 | 3070 |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 4740 |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 240 |
| | | | ROOM SENSIBLE HEAT | 4980 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 900 CFM × | 9 F × (1– | 0 BF) × 1.08 | 8750 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 13,730 |

E-5024

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: PEOPLE × CFM/PERSON ×
SQ FT × CFM/SQ FT ×
CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP. RISE}$ = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{DA}$ = $F_{RM-OUTLET\ AIR}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 4980 ROOM SENS. HEAT / 1.08 × 20 F DESIRED DIFF = 230 $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{DA}$ / CFM†) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F
FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

900 CFM O.A.

13,730 BTUH

*IF THIS ΔT 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.

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers–Architects

COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1986
REV. 19

LBL - LIFE SCIENCES
HEATING LOAD
SUMMARY

PROJECT 16-199-09

SHEET NO. 26 OF 44 SHEETS

BLDG #10

| ROOM | MINIMUM CFM | O.A. CFM | BTUH HEATING LOAD |
|---|---|---|---|
| OFFICE | 140 | 30 | 2,170 |
| GLASSWARE | 240 | 240 | 10,760 |
| CELL/TISSUE | 2,000 | 2,000 | 79,260 |
| ELECTRON MICROSCOPE | 260 | 260 | 11,540 |
| ELECTRON MICROSCOPE | 750 | 750 | 31,600 |
| LIGHT MICROSCOPE | 240 | 240 | 10,620 |
| DARK ROOM | 750 | 750 | 29,160 |
| SURGERY | 705 | 705 | 29,970 |
| WET BIOCHEM | 2,000 | 2,000 | 77,760 |
| | | | 282,840 |



FORM 101-1/8

COMPUTATION SHEET

Keller & Gannon
Engineers-Architects

COMPUTED BY JC CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL- LIFE SCIENCES
HEATING LOAD
SUMMARY

PROJECT 16-199-09

SHEET NO. 27 OF 44 SHEETS

BLDG #6

| ROOM | MINIMUM CFM | O.A. CFM | BTUH HTNG LOAD |
|---|---|---|---|
| OFFICES (9) | 110 (9) | 15 (9) | 1,500 |
| | 990 | 135 | 13,500 |
| LAB (EAST) | 1,000 | 1,000 | 39,750 |
| VERTICAL BEAM | 120 | 120 | 5,130 |
| DARK ROOM | 20 | 20 | 890 |
| MICROSCOPE RM. | 26 | 26 | 1,120 |
| LAB | 1,000 | 1000 | 39,640 |
| LAB | 2,000 | 2,000 | 78,780 |
| LAB (WEST) | 1,750 | 1,750 | 69,030 |
| | 6,906 | 6,051 | 247,890 |



FORM 101-1/8

Keller & Gannon
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J CCASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL - LIFE SCIENCES
HEATING LOAD
BLDG 10, OFFICE

PROJECT 16-199-09
SHEET NO. 28 OF 44 SHEETS

Space Used For
Size 14 × 28 = 392 SQ FT × 16 = 6272 CU FT

| 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 | 180 SQ FT × | 36 × | .07 | 450 |
| Wall | SQ FT × | × | | |
| Wall | SQ FT × | × | | |
| Wall | SQ FT × | × | | |
| Roof-Sun | SQ FT × | × | | |
| Roof-Shaded | SQ FT × | × | | |
| **TRANS. GAIN—EXCEPT WALLS & ROOF** | | | | |
| All Glass | 45 SQ FT × | 36 × | .31 | 500 |
| Partition | SQ FT × | × | | |
| Ceiling | SQ FT × | × | | |
| Floor | SQ FT × | × | | |
| Infiltration | CFM × | × | 1.08 | |
| **INTERNAL HEAT** | | | | |
| People | PEOPLE × | | | |
| Power | HP OR KW × | | | |
| Lights | WATTS × 3.4 × | | | |
| Appliances, Etc. | × | | | |
| Additional Heat Gains | × | | | |
| | | SUB TOTAL | | 950 |
| Storage | SQ FT × | × (– ) | | |
| | | SUB TOTAL | | |
| Safety Factor | ← % | | | 50 |
| | | ROOM SENSIBLE HEAT | | 1,000 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. % | | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | EFFECTIVE ROOM SENSIBLE HEAT | | |
| **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 | | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 30 CFM × | 36 F × (1– 0 | BF) × 1.08 | 1,170 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | GRAND TOTAL HEAT | | 2,170 |

Estimate for — LOCAL TIME / SUN TIME — Peak Load — LOCAL TIME / SUN TIME

Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | – 36 | | | | |

**OUTDOOR AIR**

VENTILATION: 2 PEOPLE × 15 CFM/PERSON = 30
SQ FT × CFM/SQ FT =
CFM VENTILATION

INFILTRATION: 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– DF) × (T_RM – T_ADP) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × F_TEMP. RISE = CFM_OA

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × CFM_OA = F (RM–OUTLET AIR)*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 2170 ROOM SENS. HEAT / 1.08 × 20 F DESIRED DIFF = 100 CFM_SA

BYPASS CFM: CFM_SA – CFM_OA =

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: T_RM F + (CFM_OA / CFM) × (T_OA F – T_RM F) = T_EDB F

LDB: T_ADP F + DF × (T_EDB F – T_ADP F) = T_LDB F
FROM PSYCH. CHART: T_EWB F, T_LWB F

**NOTES**

FROM AC LOAD,
270 CFM, MAXIMUM
TURNDOWN RATIO 50%
∴ 140 CFM
30 OA.
2,170 BTUH

*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

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY JC CASE
CHECKED BY
DATE 12-5 1988
REV. 19

LBL - LIFE SCIENCES
HEATING LOAD
BLDG #10 CLASSWARE

PROJECT 16-199-09

SHEET NO. 29 OF 44 SHEETS

Space Used For
Size 20 × 27 = 540 SQ FT × 16 = 8640 CU FT

| 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 | 256 SQ FT × | 36 | × .07 | 650 |
| Wall | SQ FT × | | × | |
| Wall | SQ FT × | | × | |
| Wall | SQ FT × | | × | |
| Roof-Sun | SQ FT × | | × | |
| Roof-Shaded | SQ FT × | | × | |
| **TRANS. GAIN–EXCEPT WALLS & ROOF** | | | | |
| All Glass | 64 SQ FT × | 36 | × .31 | 710 |
| Partition | SQ FT × | | × | |
| Ceiling | SQ FT × | | × | |
| Floor | SQ FT × | | × | |
| Infiltration | CFM × | | × 1.08 | |
| **INTERNAL HEAT** | | | | |
| People | PEOPLE × | | | |
| Power | HP OR KW × | | | |
| Lights | WATTS × 3.4 × | | | |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | 1360 |
| Safety Factor | 5 % | | | 70 |
| | | | ROOM SENSIBLE HEAT | 1430 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + M. P. | % | |
| Outdoor Air | CFM × | F × | BF = 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 240 CFM × | 36 F × (1– 0 | BF) = 1.08 | 9330 |
| Latent: | CFM × | GR/LB × (1– | BF) = 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 10760 |

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

Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | 36 | | | | |

**OUTDOOR AIR**

VENTILATION: PEOPLE × CFM/PERSON ×; SQ FT × CFM/SQ FT ×; CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) × F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP. RISE}$ = $CFM_{OA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{OA}$ = F (RM–OUTLET AIR)*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: 1430 ROOM SENS. HEAT / 1.08 × 20 F DESIRED DIFF = 66 $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{OA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{OA}$ / CFM†) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

FROM AC LOAD
CFM = 480 MAX
TURNDOWN RATIO 50%
OR 240 CFM

10,760 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J C CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL- LIFE SCIENCES
HEATING LOAD
BLDG #10, CELL/TISSUE CULT.

PROJECT 16-199-09
SHEET NO. 36 OF 44 SHEETS

Space Used For
Size 7.1 × 30 = 630 SQ FT × 16 = 10,080 CU FT

| 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 | 269 SQ FT × | 36 | × .07 | 630 |
| Wall | SQ FT × | | × | |
| Wall | SQ FT × | | × | |
| Wall | SQ FT × | | × | |
| Roof-Sun | SQ FT × | | × | |
| Roof-Shaded | SQ FT × | | × | |
| **TRANS. GAIN—EXCEPT WALLS & ROOF** | | | | |
| All Glass | 67 SQ FT × | 36 | × .31 | 750 |
| Partition | SQ FT × | | × | |
| Ceiling | SQ FT × | | × | |
| Floor | SQ FT × | | × | |
| Infiltration | CFM × | | × 1.08 | |
| **INTERNAL HEAT** | | | | |
| People | PEOPLE × | | | |
| Power | HP OR KW × | | | |
| Lights | WATTS × 3.4 × | | | |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 1430 |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | 70 |
| Safety Factor | 5 % | | | 1500 |
| | | | ROOM SENSIBLE HEAT | |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | | FAN % + H. P. % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 2,000 CFM × | 36 F × (1– 0 | BF) × 1.08 | 77760 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 79 760 |

Estimate for — LOCAL TIME / SUN TIME — Peak Load — LOCAL TIME / SUN TIME

Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | –36 | | | | |

**OUTDOOR AIR**

VENTILATION: PEOPLE × CFM/PERSON ×; SQ FT × CFM/SQ FT ×; CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / (1.08 × $F_{TEMP. RISE}$) = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / (1.08 × $CFM_{DA}$) = F (RM–OUTLET AIR)*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / (1.08 × F DESIRED DIFF) = $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{OA}$ / CFM†) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EDB}$ F, $T_{LDB}$ F

**NOTES**

HEATING REQUIREMENTS
2,000 CFM O.A.
79,760 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J C CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL - LIFE SCIENCES
HEATING LOAD
BLDG 10, ELECTRON MICROSCOPE

PROJECT 16-199-09

SHEET NO. 31 OF 44 SHEETS

Space Used For
Size 20 × 14 = 280 SQ FT × 16 = 4480 CU FT

| 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 | 256 SQ FT × | 36 | × .07 | 650 |
| Wall | SQ FT × | | × | |
| Wall | SQ FT × | | × | |
| Wall | SQ FT × | | × | |
| Roof-Sun | SQ FT × | | × | |
| Roof-Shaded | SQ FT × | | × | |
| **TRANS. GAIN—EXCEPT WALLS & ROOF** | | | | |
| All Glass | 64 SQ FT × | 36 | × .31 | 710 |
| Partition | SQ FT × | | × | |
| Ceiling | SQ FT × | | × | |
| Floor | SQ FT × | | × | |
| Infiltration | CFM × | | × 1.08 | |
| **INTERNAL HEAT** | | | | |
| People | PEOPLE × | | | |
| Power | HP OR KW × | | | |
| Lights | WATTS × 3.4 × | | | |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 1360 |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 70 |
| | | | ROOM SENSIBLE HEAT | 1430 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 260 CFM × | 36 F × (1– .6 | BF) × 1.08 | 10110 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + FUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 11540 |

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

Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | – 36 | | | | |

**OUTDOOR AIR**

VENTILATION: PEOPLE × CFM/PERSON ×; SQ FT × CFM/SQ FT ×; CFM VENTILATION

INFILTRATION: 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– DF) × ($T_{RM}$ F – $T_{ADP}$ F) × F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP. RISE}$ = $CFM_{OA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{OA}$ = F (RM–OUTLET AIR)*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / 1.08 × F DESIRED DIFF = $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{OA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{OA}$ / CFM†) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + DF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

AC LOAD CFM = 520 CFM
MAXIMUM TURNDOWN
RATIO 50%
OR 260 CFM OA
11,540 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J C CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL - LIFE SCIENCES
HEATING LOAD
BLDG 70, ELECTRON MICROSCOPE

PROJECT 16-RT-09
SHEET NO. 32 OF 44 SHEETS

Space Used For
Size 20 × 14 = 280 SQ FT × 16 = 4480 CU FT

| 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 | 435 SQ FT × | 36 | × .07 | 1 | 100 |
| Wall | SQ FT × | | × | | |
| Wall | SQ FT × | | × | | |
| Wall | SQ FT × | | × | | |
| Roof-Sun | SQ FT × | | × | | |
| Roof-Shaded | SQ FT × | | × | | |
| **TRANS. GAIN–EXCEPT WALLS & ROOF** | | | | | |
| All Glass | 109 SQ FT × | 36 | × .31 | 1 | 220 |
| Partition | SQ FT × | | × | | |
| Ceiling | SQ FT × | | × | | |
| Floor | SQ FT × | | × | | |
| Infiltration | CFM × | | × 1.08 | | |
| **INTERNAL HEAT** | | | | | |
| People | PEOPLE × | | | | |
| Power | HP OR KW × | | | | |
| Lights | WATTS × 3.4 × | | | | |
| Appliances, Etc. | | | × | | |
| Additional Heat Gains | | | × | | |
| | | | SUB TOTAL | 2 | 320 |
| Storage | SQ FT × | | × (– ) | | |
| | | | SUB TOTAL | | |
| Safety Factor | 5 % | | | | 120 |
| | | | ROOM SENSIBLE HEAT | 2 | 440 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | | |
| Outdoor Air | CFM × | F × | BF × 1.08 | | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | | |
| **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 | | |
| **OUTDOOR AIR HEAT** | | | | | |
| Sensible: | 750 CFM × | 36 | F × (1– 0 BF) × 1.08 | 29 | 160 |
| Latent: | CFM × | | GR/LB × (1– BF) × 0.68 | | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | | |
| | | | GRAND TOTAL HEAT | 31 | 600 |

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

Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | 36 | | | | |

**OUTDOOR AIR**

VENTILATION: PEOPLE × CFM/PERSON ×; SQ FT × CFM/SQ FT ×; CFM VENTILATION

INFILTRATION: 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) = ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP. RISE}$ = $CFM_{OA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{OA}$ = $F_{(RM-OUTLET\ AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / 1.08 × F DESIRED DIFF = $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{OA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APARATUS**

EDB: $T_{RM}$ F + ($CFM_{OA}$ / CFM) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

750 CFM O.A.

31,600 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL - LIFE SCIENCES
HEATING LOAD
BLDG #10, LIGHT MICROSCOPE

PROJECT 16-199-09

SHEET NO. 33 OF 44 SHEETS

Space Used For
Size 16 × 18 = 288 SQ FT × 16 = 4608 CU FT

| 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 230 | SQ FT × | 36 | × .07 | 580 |
| Wall | SQ FT × | | × | |
| Wall | SQ FT × | | × | |
| Wall | SQ FT × | | × | |
| Roof-Sun | SQ FT × | | × | |
| Roof-Shaded | SQ FT × | | × | |
| **TRANS. GAIN—EXCEPT WALLS & ROOF** | | | | |
| All Glass 58 | SQ FT × | 36 | × .31 | 650 |
| Partition | SQ FT × | | × | |
| Ceiling | SQ FT × | | × | |
| Floor | SQ FT × | | × | |
| Infiltration | CFM × | | × 1.08 | |
| **INTERNAL HEAT** | | | | |
| People | PEOPLE × | | | |
| Power | HP OR KW × | | | |
| Lights | WATTS × 3.4 × | | | |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 1230 |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 60 |
| | | | ROOM SENSIBLE HEAT | 1290 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: 240 | CFM × | 36 | F × (1– .6 BF) × 1.08 | 9330 |
| Latent: | CFM × | | GR/LB × (1– BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 10620 |

Estimate for — LOCAL TIME / SUN TIME
Peak Load — LOCAL TIME / SUN TIME
Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | – 36 | | | | |

**OUTDOOR AIR**

VENTILATION: PEOPLE × CFM/PERSON ×; SQ FT × CFM/SQ FT ×; CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) =

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP. RISE}$ = $CFM_{OA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{OA}$ = $F_{(RM-OUTLET AIR)}$

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / 1.08 × F DESIRED DIFF = $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{OA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{OA}$ / CFM†) × ($T_{OA}$ F – $T_{RM}$ F) × $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) × $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

AC LOAD 480 CFM

MAXIMUM TURNDOWN RATIO

50%, SO CFM = 240

10,620 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY JC CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL - LIFE SCIENCES
HEATING LOAD
BLDG #10, DARK ROOM

PROJECT 16-199-09

SHEET NO. 34 OF 44 SHEETS

Space Used For
Size 10 × 13 = 130 SQ FT × 16 = 2080 CU FT

| 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 | SQ FT × | | × | | | |
| 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 | PEOPLE × | | | | | |
| Power | HP OR KW × | | | | | |
| Lights | WATTS × 3.4 × | | | | | |
| Appliances, Etc. | | | × | | | |
| Additional Heat Gains | | | × | | | |
| | | | SUB TOTAL | | | |
| Storage | SQ FT × | | × (− ) | | | |
| | | | SUB TOTAL | | | |
| Safety Factor | % | | | | | |
| | | | ROOM SENSIBLE HEAT | | | |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | | | |
| Outdoor Air | CFM × | F × | BF × 1.08 | | | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | | | |
| **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 | | | |
| **OUTDOOR AIR HEAT** | | | | | | |
| Sensible: 780 | CFM × 36 | F × (1− 0 | BF) × 1.08 | | 29 | 160 |
| Latent: | CFM × | GR/LB × (1− | BF) × 0.68 | | | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | | | |
| | | | GRAND TOTAL HEAT | | 29 | 160 |

Estimate for — LOCAL TIME / SUN TIME
Peak Load — LOCAL TIME / SUN TIME
Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | − 36 | | | | |

**OUTDOOR AIR**

VENTILATION: PEOPLE × CFM/PERSON ×
SQ FT × CFM/SQ FT ×
CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F − $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / (1.08 × $F_{TEMP. RISE}$) = $CFM_{OA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / (1.08 × $CFM_{OA}$) = $F_{(RM-OUTLET\ AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / (1.08 × F DESIRED DIFF) = $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ − $CFM_{OA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{OA}$ / CFM†) × ($T_{OA}$ F − $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F − $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EDB}$ F, $T_{LDB}$ F

**NOTES**

HOOD REQUIREMENTS
750 CFM O.A.
29,160 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL- LIFE SCIENCES
HEATING LOAD
BLDG #10, SURGERY

PROJECT 16-199-09
SHEET NO. 35 OF 44 SHEETS

Space Used For
Size 20 × 36 = 720 SQ FT × 16 = 11,520 CU FT

| 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 | 460 SQ FT × | 36 | × .07 | 1 | 160 |
| Wall | SQ FT × | | × | | |
| Wall | SQ FT × | | × | | |
| Wall | SQ FT × | | × | | |
| Roof-Sun | SQ FT × | | × | | |
| Roof-Shaded | SQ FT × | | × | | |
| **TRANS. GAIN—EXCEPT WALLS & ROOF** | | | | | |
| All Glass | 115 SQ FT × | 36 | × .31 | 1 | 280 |
| Partition | SQ FT × | | × | | |
| Ceiling | SQ FT × | | × | | |
| Floor | SQ FT × | | × | | |
| Infiltration | CFM × | | × 1.08 | | |
| **INTERNAL HEAT** | | | | | |
| People | PEOPLE × | | | | |
| Power | HP OR KW × | | | | |
| Lights | WATTS × 3.4 × | | | | |
| Appliances, Etc. | | | × | | |
| Additional Heat Gains | | | × | | |
| | | | SUB TOTAL | 2 | 440 |
| Storage | SQ FT × | | × (– ) | | |
| | | | SUB TOTAL | | |
| Safety Factor | 5 % | | | | 120 |
| | | | ROOM SENSIBLE HEAT | 2 | 560 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | | |
| Outdoor Air | CFM × | F × | BF × 1.08 | | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | | |
| **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 | | |
| **OUTDOOR AIR HEAT** | | | | | |
| Sensible: | 705 CFM × | 36 | F × (1– 0 BF) × 1.08 | 27 | 410 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | | |
| | | | GRAND TOTAL HEAT | 29 | 970 |

Estimate for — LOCAL TIME / SUN TIME
Peak Load — LOCAL TIME / SUN TIME
Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | – 36 | | | | |

**OUTDOOR AIR**

VENTILATION: PEOPLE × CFM/PERSON ×; SQ FT × CFM/SQ FT ×; CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP. RISE}$ = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{DA}$ = $F_{(RM-OUTLET AIR)}$

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / 1.08 × F DESIRED DIFF = $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{DA}$ / CFM1) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

FROM AC LOAD CFM = 1,410
MAXIMUM TURNDOWN RATIO
50% ∴ CFM = 705 CFM

29,970 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL - LIFE SCIENCES
HEATING LOAD
BLDG #10, WET BIOCHEM LAB

PROJECT 16-199-09

SHEET NO. 36 OF 44 SHEETS

Space Used For
Size 45 × 36 = 1440 SQ FT × 16 23,040 CU FT

| 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 | SQ FT × | | × | |
| 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 | PEOPLE × | | | |
| Power | HP OR KW × | | | |
| Lights | WATTS × 3.4 × | | | |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | % | | | |
| | | | ROOM SENSIBLE HEAT | |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 2000 CFM × 36 | F × (1– 0 | BF) × 1.08 | 77760 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 77 760 |

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

Hours of Operation

| CONDITIONS | DB | °WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | – 36 | | | | |

**OUTDOOR AIR**

VENTILATION: PEOPLE × CFM/PERSON ×; SQ FT × CFM/SQ FT ×; CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) =

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP. RISE}$ = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{DA}$ = $F_{(RM-OUTLET\ AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / 1.08 × F DESIRED DIFF = $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{OA}$ / CFM*) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

HOOD REQUIREMENTS ARE:
2000 CFM O.A.

77,760 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY: J CASE
CHECKED BY:
DATE: 12-6 1988
REV. 19

LBL - LIFE SCIENCES
HEATING LOAD
BLDG #6, OFFICES (TYPICAL)

PROJECT: 16-199-09

SHEET NO. 37 OF 44 SHEETS

Space Used For:
Size 10 × 16 = 160 SQ FT × 14 = 2240 CU FT

| 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 | 112 SQ FT × | 36 | × .07 | 280 |
| Wall | SQ FT × | | × | |
| Wall | SQ FT × | | × | |
| Wall | SQ FT × | | × | |
| Roof-Sun | 160 SQ FT × | 36 | × .05 | 290 |
| Roof-Shaded | SQ FT × | | × | |
| **TRANS. GAIN–EXCEPT WALLS & ROOF** | | | | |
| All Glass | 28 SQ FT × | 36 | × .31 | 310 |
| Partition | SQ FT × | | × | |
| Ceiling | SQ FT × | | × | |
| Floor | SQ FT × | | × | |
| Infiltration | CFM × | | × 1.08 | |
| **INTERNAL HEAT** | | | | |
| People | PEOPLE × | | | |
| Power | HP OR KW × | | | |
| Lights | WATTS × 3.4 × | | | |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 880 |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 40 |
| | | | ROOM SENSIBLE HEAT | 970 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 15 CFM × | 36 | F × (1– 0 BF) × 1.08 | 580 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 1550 |

Estimate for: LOCAL TIME / SUN TIME — Peak Load: LOCAL TIME / SUN TIME

Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | 36 | | | | |

**OUTDOOR AIR**

VENTILATION: 1 PEOPLE × 15 CFM/PERSON = 15
SQ FT × CFM/SQ FT =
CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / (1.08 × $F_{TEMP. RISE}$) = $CFM_{OA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / (1.08 × $CFM_{OA}$) = $F_{(RM-OUTLET AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / (1.08 × F DESIRED DIFF) = $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{OA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{OA}$ / CFM$_{MT}$) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F
FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

110 CFM TOTAL
15 CFM OA.

1,500 BTUH.

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 19 8
REV. 19

LBL - LIFE SCIENCES
HEATING LOAD
BLDG #6, LAB (EAST)

PROJECT 16-199-09

SHEET NO. 38 OF 44 SHEETS

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

| 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 × | 36 | × .05 | 830 |
| 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 | PEOPLE × | | | |
| Power | HP OR KW × | | | |
| Lights | WATTS × 3.4 × | | | |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 830 |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 40 |
| | | | ROOM SENSIBLE HEAT | 870 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF = 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 1000 CFM × | 36 F × (1– | BF) × 1.08 | 38890 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 39750 |

E-5024

Estimate for — LOCAL TIME / SUN TIME
Peak Load — LOCAL TIME / SUN TIME
Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | – 36 | | | | |

**OUTDOOR AIR**

VENTILATION: PEOPLE = CFM/PERSON = ; SQ FT = CFM/SQ FT = ; CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / (1.08 × $F_{TEMP. RISE}$) = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / (1.08 × $CFM_{DA}$) = F (RM–OUTLET AIR)

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / (1.08 × F DESIRED DIFF) = $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{DA}$ / CFM) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

HOOD REQUIREMENT = 1000 CFM

ROOM REQUIREMENT

1000 CFM

39,750 BTUH

*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.

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL - LIFE SCIENCES
HEATING LOADS
BLDG #6, VERTICAL BEAM

PROJECT 16-199-09
SHEET NO. 31 OF 44 SHEETS

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

| 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 272 | SQ FT × | 36 | × .05 | 490 |
| 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 | PEOPLE × | | | |
| Power | HP OR KW × | | | |
| Lights | WATTS × 3.4 × | | | |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 20 |
| | | | ROOM SENSIBLE HEAT | 510 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | SF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 × | SF × 0.68 | |
| | | | EFFECTIVE ROOM LATENT HEAT | |
| | | | EFFECTIVE ROOM TOTAL HEAT | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: 120 | CFM × 36 | F × (1– 0 | SF) × 1.08 | 4670 |
| Latent: | CFM × | GR/LB × (1– | SF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 5180 |

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

Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | – 36 | | | | |

**OUTDOOR AIR**

VENTILATION: PEOPLE × CFM/PERSON ×; SQ FT × CFM/SQ FT ×; CFM VENTILATION

INFILTRATION: MINGING 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– SF) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $F_{TEMP. RISE}$ = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{DA}$ = $F_{(RM-OUTLET AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / 1.08 × F DESIRED DIFF = $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + $CFM_{DA}$ / CFMT × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + SF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

FROM AC LOAD,
CFM = 235, MAXIMUM
TURNDOWN RATIO 50%
∴ CFM = 120

5,180 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1988
REV. 19

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

PROJECT 16-199-09

SHEET NO. 46 OF 44 SHEETS

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

| 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 | 60 SQ FT × | 36 | × .05 | 110 |
| 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 | PEOPLE × | | | |
| Power | HP OR KW × | | | |
| Lights | WATTS × 3.4 × | | | |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | % | | | |
| | | | ROOM SENSIBLE HEAT | |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 20 CFM × | 36 F × (1– 0 | BF) × 1.08 | 780 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 890 |

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

Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | 36 | | | | |

**OUTDOOR AIR**

VENTILATION: 1 PEOPLE × 15 CFM/PERSON = 15
SQ FT × CFM/SQ FT =
CFM VENTILATION

INFILTRATION: 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) × (T_RM F – T_ADP F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × F_TEMP. RISE = CFM_OA

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × CFM_OA = F_(RM–OUTLET AIR)*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / 1.08 × F DESIRED DIFF = CFM_SA

BYPASS CFM: CFM_SA – CFM_OA = CFM_BA

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: T_RM F + (CFM_OA / CFM_SA) × (T_OA F – T_RM F) = T_EDB F

LDB: T_ADP F + BF × (T_EDB F – T_ADP F) = T_LDB F
FROM PSYCH. CHART: T_EDB F, T_LDB F

**NOTES**

FROM AC LOADS
CFM = 40 MAXIMUM
TURNDOWN 50% ∴
20 CFM
890 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers–Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL - LIFE SCIENCES
HEATING LOADS
BLDG #6, MICROSCOPE RM

PROJECT 16-199-09
SHEET NO. 41 OF 74 SHEETS

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

| 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 | 60 SQ FT × | 36 | × .05 | 110 |
| 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 | PEOPLE × | | | |
| Power | HP OR KW × | | | |
| Lights | WATTS × 3.4 × | | | |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | % | | | |
| | | | ROOM SENSIBLE HEAT | |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 26 CFM × 36 | F × (1– 0 | BF) × 1.08 | 1010 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 1120 |

Estimate for — LOCAL TIME / SUN TIME — Peak Load — LOCAL TIME / SUN TIME

Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | 36 | | | | |

**OUTDOOR AIR**

VENTILATION: PEOPLE × CFM/PERSON ×
SQ FT × CFM/SQ FT ×
CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / (1.08 × $F_{TEMP. RISE}$) = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / (1.08 × $CFM_{DA}$) = F ($T_{RM}$–OUTLET AIR)*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / (1.08 × F DESIRED DIFF) = $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{DA}$ / CFMT) × ($T_{DA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F
FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

FROM AC LOAD, 51 CFM
MAXIMUM TURNDOWN
RATIO, 50% ∴
CFM = 26 CFM

1120 BTUH

*IF THIS ΔT 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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

Keller & Gannon
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL- LIFE SCIENCES
HEATING LOAD
BLDG #6, LAB ETWN (15.3) (16)

PROJECT 16-199-09
SHEET NO. 42 OF 44 SHEETS

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

| 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 | 400 | SQ FT × 36 | × .05 | | | 720 |
| 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 | PEOPLE × | | | | | |
| Power | HP OR KW × | | | | | |
| Lights | WATTS × 3.4 × | | | | | |
| Appliances, Etc. | | | × | | | |
| Additional Heat Gains | | | × | | | |
| | | | SUB TOTAL | | | 720 |
| Storage | SQ FT × | | × (– ) | | | |
| | | | SUB TOTAL | | | |
| Safety Factor | | | % | | | 40 |
| | | | ROOM SENSIBLE HEAT | | | 760 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | | | |
| Outdoor Air | CFM × | F × | BF × 1.08 | | | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | | | |
| **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 | | | |
| **OUTDOOR AIR HEAT** | | | | | | |
| Sensible: | CFM × 36 | F × (1– 0 | BF) × 1.08 | | 38 | 880 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | | | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | | | |
| | | | GRAND TOTAL HEAT | | 39,640 | |

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

Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | – 36 | | | | |

**OUTDOOR AIR**

VENTILATION: ____ PEOPLE × ____ CFM/PERSON × ____; ____ SQ FT × ____ CFM/SQ FT × ____; CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ ____ F – $T_{ADP}$ ____ F) = ____ F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / (1.08 × $F_{TEMP. RISE}$) = ____ $CFM_{OA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / (1.08 × $CFM_{OA}$) = ____ $F_{(RM-OUTLET\ AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / (1.08 × F DESIRED DIFF) = ____ $CFM_{SA}$

BYPASS CFM: ____ $CFM_{SA}$ – ____ $CFM_{OA}$ = ____ $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ ____ F + ($CFM_{OA}$ / $CFM_T$) × ($T_{OA}$ ____ F – $T_{RM}$ ____ F) = $T_{EDB}$ ____ F

LDB: $T_{ADP}$ ____ F + ____ BF × ($T_{EDB}$ ____ F – $T_{ADP}$ ____ F) = $T_{LDB}$ ____ F

FROM PSYCH. CHART: $T_{EWB}$ ____ F, $T_{LWB}$ ____ F

**NOTES**

HOOD REQUIREMENTS

1,000 CFM OA.

39,640 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1988
REV. 19

LBL- LIFE SCIENCES
HEATING LOAD
BLDG #6, LAB BTWN (16) + (17)

PROJECT 16-199-08
SHEET NO. 43 OF 44 SHEETS

Space Used For
Size 27 × 20 = 540 SQ FT × 14 = 7560 CU FT

| 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 | SQ FT × | 36 | × .05 | 990 |
| 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 | PEOPLE × | | | |
| Power | HP OR KW × | | | |
| Lights | WATTS × 3.4 × | | | |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 990 |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | 5 % | | | 50 |
| | | | ROOM SENSIBLE HEAT | 1020 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | FAN % + H. P. | % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 2000 CFM × | 36 F × (1– | 0 BF) × 1.08 | 77760 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + PUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 78780 |

Estimate for — LOCAL TIME / SUN TIME — Peak Load — LOCAL TIME / SUN TIME

Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | – 36 | | | | |

**OUTDOOR AIR**

VENTILATION: PEOPLE × CFM/PERSON ×; SQ FT × CFM/SQ FT ×; CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / (1.08 × $F_{TEMP. RISE}$) = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / (1.08 × $CFM_{DA}$) = $F_{(RM-OUTLET\ AIR)}$*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / (1.08 × F DESIRED DIFF) = $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{BA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{DA}$ / CFMT) × ($T_{OA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

HOOD REQUIREMENTS
2,000 CFM
78,780 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

**Keller & Gannon**
Engineers-Architects

# COMPUTATION SHEET

COMPUTED BY J CASE
CHECKED BY
DATE 12-6 1988
REV. 19

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

PROJECT 16-199-09

SHEET NO. 44 OF 44 SHEETS

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

| 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 | SQ FT × | | × | |
| Roof-Shaded | 520 SQ FT × | 36 | × .05 | 940 |
| **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 | PEOPLE × | | | |
| Power | HP OR KW × | | | |
| Lights | WATTS × 3.4 × | | | |
| Appliances, Etc. | | | × | |
| Additional Heat Gains | | | × | |
| | | | SUB TOTAL | 940 |
| Storage | SQ FT × | | × (– ) | |
| | | | SUB TOTAL | |
| Safety Factor | ← % | | | 50 |
| | | | ROOM SENSIBLE HEAT | 990 |
| SUPPLY DUCT HEAT GAIN | SUPPLY DUCT % + LEAK. LOSS | | FAN % + H. P. % | |
| Outdoor Air | CFM × | F × | BF × 1.08 | |
| | | | EFFECTIVE ROOM SENSIBLE HEAT | |
| **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 | |
| **OUTDOOR AIR HEAT** | | | | |
| Sensible: | 1750 CFM × | 36 F × (1– 0 | BF) × 1.08 | 68,040 |
| Latent: | CFM × | GR/LB × (1– | BF) × 0.68 | |
| RETURN DUCT HEAT GAIN | RETURN DUCT % + LEAK. GAIN | HP % + FUMP | SUB TOTAL DEHUM. & % + PIPE LOSS % | |
| | | | GRAND TOTAL HEAT | 69,030 |

Estimate for — LOCAL TIME / SUN TIME
Peak Load — LOCAL TIME / SUN TIME

Hours of Operation

| CONDITIONS | DB | WB | % RH | DP | GR/LB |
|---|---|---|---|---|---|
| OUTDOOR (OA) | 36 | | | | |
| ROOM (RM) | 72 | | | | |
| DIFFERENCE | – 36 | | | | |

**OUTDOOR AIR**

VENTILATION: PEOPLE × CFM/PERSON ×; SQ FT × CFM/SQ FT ×; CFM VENTILATION

INFILTRATION: 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) × ($T_{RM}$ F – $T_{ADP}$ F) = F

DEHUM. CFM: EFFECTIVE ROOM SENS. HEAT / 1.08 × $T_{TEMP. RISE}$ = $CFM_{DA}$

OUTLET TEMP. DIFF.: ROOM SENS. HEAT / 1.08 × $CFM_{DA}$ = F (RM–OUTLET AIR)*

**SUPPLY AIR QUANTITY**

SUPPLY CFM: ROOM SENS. HEAT / 1.08 × F DESIRED DIFF = $CFM_{SA}$

BYPASS CFM: $CFM_{SA}$ – $CFM_{DA}$ = $CFM_{DA}$

**RESULTING ENT & LVG CONDITIONS AT APPARATUS**

EDB: $T_{RM}$ F + ($CFM_{DA}$ / CFM) × ($T_{DA}$ F – $T_{RM}$ F) = $T_{EDB}$ F

LDB: $T_{ADP}$ F + BF × ($T_{EDB}$ F – $T_{ADP}$ F) = $T_{LDB}$ F

FROM PSYCH. CHART: $T_{EWB}$ F, $T_{LWB}$ F

**NOTES**

HOOD REQUIREMENTS

1,750 CFM

69,030 BTUH

*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.

E-5024

**AIR CONDITIONING LOAD ESTIMATE** (REPRODUCED BY PERMISSION OF CARRIER CORPORATION)

COST ESTIMATE DETAIL

FOR

CONVENTIONAL FACILITIES

PRACTICAL
FORM 518

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER. ESTIMATE NO. C.D.R.
N L.B.L. SHEET NO. 1.
ENGINEER L.B.L. DATE DECEMBER 1988
SUMMARY BY DD PRICES BY DD CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | [redacted] | UNIT PRICE | [redacted] | TOTAL |
|---|---|---|---|---|---|---|---|
| **ESTIMATE SUMMARY** | | | | | | | |
| **BUILDINGS.** | | | | BUILDING 10 | | BUILDING 6 | |
| DIV. 2. DEMOLITION | | | | 166000 | | — | |
| DIV. 5. METALS. | | | | 233000 | | 6000 | |
| DIV. 6. CARPENTRY. | | | | 24000 | | 15000 | |
| DIV. 7. THERMAL & MOISTURE PROTECTION. | | | | 16000 | | — | |
| DIV. 8 DOORS & WINDOWS. | | | | 103000 | | 20000 | |
| DIV. 9. FINISHES. | | | | 154000 | | 124000 | |
| DIV. 10. SPECIALTIES. | | | | 2000 | | 2000 | |
| 11. EQUIPMENT (LABORATORY) | | | | BY CLIENT | | BY CLIENT. | |
| DIV. 12. FURNISHINGS (SEE SPECIAL FACIL / STD. EQUIP.) | | | | — | | — | |
| DIV. 13 SPECIAL CONSTRUCTION (PREFAB LAB. MODULES) | | | | — | | 80000 | |
| DIV. 15. MECHANICAL: PLUMBING | | | | 59000 | | 66000 | |
| H.V.A.C. | | | | 127000 | | 126000 | |
| FIRE PROTECTION. | | | | 4000 | | 4000 | |
| DIV. 16. ELECTRICAL. | | | | 131000 | | 59000 | |
| SUB-TOTAL. | | | | 1019000 | | 502000 | |
| GENERAL CONDITIONS / MOBILIZE. | | | 7% | 71330 | 7% | 35140 | |
| ESTIMATING CONTINGENCY. | | | | IN PROJ. CONT. | | IN PROJ. CONT. | |
| | | | | 1090330 | | 537140 | |
| BOND | | | 2% | 21810 | 2% | 10740 | |
| PRIME CONTRACTOR OH & FEE | | | 12% | 130840 | 12% | 64460 | |
| TOTAL ESTIMATED CONSTRUCTION COST AT DECEMBER 1988 | | | | 1242980 | | 612340 | |
| TOTAL ESCALATED CONSTRUCTION COST | | | 24% | 1542000 | 24% | 760000 | |



FRANK R. WALKER CO., PUBLISHERS, CHICAGO

WESTCAL

RECAPITULATION

PROJECT LIFE SCIENCES CENTER.

LBL.

PROJECT ENGINEER LBL.

ESTIMATE NO. C.D.R.

SHEET NO. 2.

DATE DECEMBER 1988

SUMMARY BY DD. PRICES BY DD CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | | UNIT PRICE | | TOTAL |
|---|---|---|---|---|---|---|---|
| **ESTIMATE SUMMARY. (Cont.)** | | | | | | | |
| **IMPROVEMENTS TO LAND.** | | | | BUILDING 10 | | BUILDING 6 | |
| Sitework SUB-TOTAL | | | | 10000 | | — | |
| GENERAL CONDITIONS/MOBILIZE | | 7% | | 700 | | — | |
| ESTIMATING CONTINGENCY. | | | | IN PROJ. CONT. | | IN PROJ. CONT. | |
| | | | | 10700 | | — | |
| BOND. | | 2% | | 210 | 2% | — | |
| PRIME CONTRACTOR OH & FEE. | | 12% | | 1280 | 12% | — | |
| TOTAL ESTIMATED CONSTRUCTION COST AT DECEMBER 1988 | | | | 12190 | | — | |
| TOTAL ESCALATED CONSTRUCTION COST. | | 23% | | 15000 | | — | |
| **SITE UTILITIES.** | | | | | | | |
| Mechanical. | | | | 10000 | | 5000 | |
| Electrical. | | | | 24000 | | 19000 | |
| SUB-TOTAL | | | | 34000 | | 24000 | |
| GENERAL CONDITIONS/MOBILIZE | | 7% | | 2380 | 7% | 1680 | |
| ESTIMATING CONTINGENCY. | | | | IN PROJ. CONT | | IN PROJ. CONT. | |
| | | | | 36380 | | 25680 | |
| BOND. | | 2% | | 730 | 2% | 510 | |
| PRIME CONTRACTOR OH & FEE | | 12% | | 4370 | 12% | 3080 | |
| TOTAL ESTIMATED CONSTRUCTION COST AT DECEMBER 1988. | | | | 41480 | | 29270 | |
| TOTAL ESCALATED CONSTRUCTION COST. | | 22% | | 50000 | 22% | 36000 | 86000 |



FRANK R. WALKER CO., PUBLISHERS, CHICAGO

PRACTICAL
FORM 518

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER — ESTIMATE NO. C.D.R.

LOCATION BUILDING 10. — SHEET NO. 4.

PROJECT NUMBER LBL + — DATE DECEMBER 1988.

SUMMARY BY DD. — PRICES BY DD. — CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | [redacted] | UNIT PRICE | TOTAL ESTIMATED LABOR COST | TOTAL |
|---|---|---|---|---|---|---|---|
| 1.3.3.1.2 SUBCONTRACT GENERAL CONDITIONS. | | | | | | | |
| SUMMARY DIRECT COST. | | | | 1078000 | | | |
| + GENERAL CONDITIONS. | TO SUMMARY. | | 7% | 75460 | | | |
| | | | | 1153460 | | | |
| 1.3.3.1.3. OVERHEAD PROFIT BOND. | | | | | | | |
| SUB-TOTAL FROM 1.3.3.1.2 | | | | 1153460 | | | |
| + BOND. | | | 2%. | 23070 | | | |
| + PRIME CONTRACTOR OH. & PROFIT. | | | 12% | 138420 | | | |
| | TO SUMMARY. | | | 1614490 | | | |



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PRACTICAL
FORM 518

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER. ESTIMATE NO. C.D.R.

LOCATION BUILDING 10 — 1st FLOOR. SHEET NO. 5

ARCHITECT LBL. DATE DECEMBER 1988.

SUMMARY BY DD PRICES BY DD CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | [redacted] | UNIT PRICE | TOTAL ESTIMATED LABOR COST | TOTAL |
|---|---|---|---|---|---|---|---|
| 1.3.3.2.1.2. INTERNAL DEMOLITION. | | | | | | | |
| Demolish & remove wood stud & drywall partitions | 8450 | S.F. | 1.50 | 12675 | | | |
| Demolish & remove ceilings. | 6000 | S.F. | 1.00 | 6000 | | | |
| Demolish & remove floor finishes & repair surfaces. | 6000 | S.F. | 3.00 | 18000 | | | |
| Demolish & remove wall finishes at exterior wall. | 4732 | S.F. | 1.00 | 4732 | | | |
| Remove single door/frame. | 18 | EA. | 50.00 | 900 | | | |
| Remove 1 storey stair flight | 1 | EA. | 500.00 | 500 | | | |
| Remove electrical equipment. | 6000 | S.F. | 2.00 | 12000 | | | |
| Remove mechanical equipment | 6000 | S.F. | 2.00 | 12000 | | | |
| Remove laboratory cabinets and furniture & store for reuse. | 6000 | S.F. | 1.50 | 9000 | | | |
| Misc. demolition/repairs. | | L.S. | | 5000 | | | |
| Temporary protection. | | L.S | | 1000 | | | |
| Removal of scientific equipt. | | | NOT INCLUDED. | | | | |
| Removal of office furniture & equipment. | | | NOT INCLUDED. | | | | |
| TOTAL TO SUMMARY. | | | | 81807 | | | |

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FORM 518

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER. ESTIMATE NO. C.D.R.

LOCATION BUILDING 10. SHEET NO. 6

ARCHITECT ENGINEER LBL DATE DECEMBER 1988.

SUMMARY BY DD. PRICES BY DD CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | [redacted] | UNIT PRICE | TOTAL ESTIMATED LABOR COST | TOTAL |
|---|---|---|---|---|---|---|---|
| 1.3.3.2.1.3. EXTERIOR SIDING DEMOLITION. | | | | | | | |
| Dismantle, remove structural steel diagonal bracing & re-install on completion of siding work. | 5 | UNITS | 100ea | 5000 | | | |
| Remove existing exterior cement asbestos siding. | 12613 | S.F. | 4ea | 50452 | | | |
| Temporary removal of Electrical equipment and re-installation at completion of siding work. | | L.S. | | 5000 | | | |
| Temporary removal of mecal equipment and re-installation at completion of siding work | | L.S. | | 5000 | | | |
| Temporary removal of gas bottle storage racks and other LBL equipment and re-install at completion of siding work | | L.S. | | 1000 | | | |
| Temporary protection. | | L.S. | | 1000 | | | |
| TOTAL TO SUMMARY. | | | | 67452 | | | |

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PRACTICAL
FORM 518

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER — ESTIMATE NO. C.D.R.

LOCATION BUILDING 10 — SHEET NO. 7.

ARCHITECT ER LBL — DATE DECEMBER 1988.

SUMMARY BY DD — PRICES BY DD — CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | [redacted] | UNIT PRICE | TOTAL ESTIMATED LABOR COST | TOTAL |
|---|---|---|---|---|---|---|---|
| 1.3.3.2.1.4. ROOF DEMOLITION. | | | | | | | |
| Dismantle, remove mech. equipment & re-install at later date | | L.S. | | 5000 | | | |
| Disconnect, remove electr. equipment & re-connect at later date. | | L.S. | | 5000 | | | |
| Cause wood sleeper supports (for roof equipt) & re-install at later date. | 24 | EA | 150.00 | 3600 | | | |
| Strip-off existing B.U. roofing down to existing T.&G. wood & haul to dump. | 14700 | S.F. | 1.00 | 14700 | | | |
| Remove all metal roof flashing | 1300 | LF | 5.00 | 6500 | | | |
| Temporary protection. | | L.S. | | 2000 | | | |
| TOTAL TO SUMMARY. | | | | 36800 | | | |
| 1.3.3.2.1.5. WINDOW DEMOLITION. | | | | | | | |
| Remove wood sash, mullions jambs, glazing & haul to dump | 3210 | SF. | 5.00 | 16050 | | | |
| TOTAL TO SUMMARY. | | | | 16050 | | | |

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FORM 518

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER. ESTIMATE NO. C.D.R.

LOCATION BUILDING 10 SHEET NO. 8.

PROJECT ENGINEER LBL. DATE DECEMBER 1988.

SUMMARY BY DD. PRICES BY DD. CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | [redacted] | UNIT PRICE | TOTAL ESTIMATED LABOR COST | TOTAL |
|---|---|---|---|---|---|---|---|
| 1.3.3.2.3. SITE UTILITIES | | | | | | | |
| Mechanical site utilities | | L.S. | | 10 000 | | | |
| Electrical site utilities. | (See back-up) | | | 24 000 | | | |
| TOTAL TO SUMMARY. | | | | 34 000 | | | |
| 1.3.3.2 d. PAVING/SURFACING | | | | | | | |
| Roads, walks, parking areas | | L.S. | | 10 000 | | | |
| TOTAL TO SUMMARY. | | | | 10 000 | | | |

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FORM 518

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER. ESTIMATE C.D.R.
LOCATION BUILDING 10. SHEET NO. 9.
ARCHITECT LBL. DATE DECEMBER 1988
SUMMARY BY DD. PRICES BY DD. CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | [redacted] | UNIT PRICE | TOTAL ESTIMATED LABOR COST | TOTAL |
|---|---|---|---|---|---|---|---|
| 1.3.3.5.2. METAL SIDING. | | | | | | | |
| New metal profile siding (to match new ALS siding) Secured to wood girts. | 12613 | S.F. | 18¢ | 227034 | | | |
| TOTAL TO SUMMARY. | | | | 227034 | | | |
| 1.3.3.5.3. MISC IRON. | | | | | | | |
| Miscellaneous iron. | 6000 | S.F. | 1¢ | 6000 | | | |
| TOTAL TO SUMMARY. | | | | 6000 | | | |
| 1.3.3.6.1. ROUGH CARPENTRY. | | | | | | | |
| Miscellaneous repairs & modifications to existing wood structure. | 6000 | S.F. | 2¢ | 12000 | | | |
| ~~½" Structural ply diaphragm over existing T&G wood roof deck~~ | ~~14700~~ | ~~S.F.~~ | ~~2¢~~ | ~~29400~~ | | | |
| Misc. rough backs, blocking etc. | 6000 | S.F. | 50¢ | 3000 | | | |
| TOTAL TO SUMMARY. | | | | 15000 | | | |



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PRACTICAL
FORM 518

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER. ESTIMATE NO. C.D.R.

LOCATION BUILDING 10 SHEET NO. 10.

PROJECT ENGINEER LBL DATE DECEMBER 1988.

SUMMARY BY DD. PRICES BY DD. CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | [redacted] | UNIT PRICE | TOTAL ESTIMATED LABOR COST | TOTAL |
|---|---|---|---|---|---|---|---|
| ~~1.3.3.7.1. ROOFING & INSULATION~~ | | | | | | | |
| ~~4 Ply B.U. roofing on 2" rigid insulation~~ | ~~150~~ | ~~SQS~~ | ~~400~~ | ~~60000~~ | | | |
| ~~Misc repair work at roof ladders, equipment etc.~~ | | ~~L.S.~~ | | ~~1500~~ | | | |
| ~~TOTAL TO SUMMARY~~ | | | | ~~61500~~ | | | |
| 1.3.3.7.3. SHEET METAL. | | | | | | | |
| ~~G.S.M. flashings at roof edge and wall abutments.~~ | ~~1300~~ | ~~L.F.~~ | ~~14~~ | ~~18200~~ | | | |
| ~~G.S.M. flashings at Mech. & Elec. roof penetrations~~ | | ~~L.S.~~ | | ~~2500~~ | | | |
| Misc. architectural sheet metal. | | L.S. | | 5000 | | | |
| TOTAL TO SUMMARY. | | | | 5000 | | | |
| 1.3.3.7.6. CAULKING & SEALANTS. | | | | | | | |
| Caulking & sealants | 14700 | S.F. | 35¢ | 5145 | | | |
| TOTAL TO SUMMARY | | | | 5145 | | | |
| 1.3.3.7.2. WALL INSULATION. | | | | | | | |
| insulation at ext. walls | 4730 | SF. | 1¢ | 4730 | | | |
| TOTAL TO SUMMARY. | | | | 4730 | | | |

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PRACTICAL
FORM 518

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER. ESTIMATE NO. C.D.R.

LOCATION BUILDING 10. SHEET NO. 11.

ARCHITECT LBL. DATE DECEMBER 1988

SUMMARY BY DD PRICES BY DD CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | [redacted] | UNIT PRICE | TOTAL ESTIMATED LABOR COST | TOTAL |
|---|---|---|---|---|---|---|---|
| 1.3.3.8.1. METAL DOORS/FRAMES/HARDWARE. | | | | | | | |
| Single glazed alum ext. door/frame/hardware. | 5 | EA. | 1500.00 | 7500 | | | |
| Double ditto ditto. | 1 | EA. | 2500.00 | 2500 | | | |
| Single int. H.M. door/frame & hardware | 10 | EA. | 850.00 | 8500 | | | |
| Double ditto ditto. | 2 | EA | 1600.00 | 3200 | | | |
| Cold room door. | 1 | EA. | | INCL. W/ROOM. | | | |
| TOTAL TO SUMMARY | | | | 21700 | | | |
| 1.3.3.6.2. FINISH CARPENTRY. | | | | | | | |
| Wood stair flights, straight 1-storey height. | 2 | EA. | 3500.00 | 7000 | | | |
| Misc. shelving trim etc. | 6000 | S.F. | 25¢ | 1500 | | | |
| TOTAL TO SUMMARY | | | | 8500 | | | |
| 1.3.3.8.3. METAL SASH/GLASS & GLAZING. | | | | | | | |
| Aluminum sash incl. glazing | 3210 | S.F. | 25.00 | 80250 | | | |
| TOTAL TO SUMMARY. | | | | 80250 | | | |

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PRACTICAL
FORM 518

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER — ESTIMATE C.D.R.

LOCATION BUILDING 10. — SHEET NO. 12.

ARCHITECT LBL. — DATE DECEMBER 1988.

SUMMARY BY DD. — PRICES BY DD. — CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | [redacted] | UNIT PRICE | TOTAL ESTIMATED LABOR COST | TOTAL |
|---|---|---|---|---|---|---|---|
| **1.3.3.9.2. METAL STUDS / GYPSUM BOARD.** | | | | | | | |
| Metal studs at exterior walls & partitions. | 11800 | SF. | 5¢ | 590.00 | | | |
| Gypsum board at ditto | 12130 | SF. | 1¢ | 181.95 | | | |
| TOTAL TO SUMMARY | | | | 771.95 | | | |
| **1.3.3.9.4. ACOUSTICAL TREATMENT.** | | | | | | | |
| Suspended acoustical ceilings. | 6000 | SF. | 5¢ | 300.00 | | | |
| TOTAL TO SUMMARY. | | | | 300.00 | | | |
| **1.3.3.9.5. RESILIENT FLOORING.** | | | | | | | |
| Vinyl composition tile floor. | 6000 | S.F. | 2¢ | 120.00 | | | |
| Base | 1348 | LF | 3¢ | 40.44 | | | |
| TOTAL TO SUMMARY. | | | | 160.44 | | | |
| **1.3.3.9.6. PAINTING & WALL COVERING.** | | | | | | | |
| Paint gypsum board walls. | 12130 | S.F. | 60¢ | 72.78 | | | |
| Paint doors / frames. | 15 | EA. | 30¢ | 4.50 | | | |
| Paint wood stairs. | 2 | EA. | 500¢ | 10.00 | | | |
| Paint finish carpentry. | | L.S. | | 15.00 | | | |
| Misc. touch-up repairs to existing surfaces. | | L.S. | | 20.00 | | | |
| TOTAL TO SUMMARY. | | | | 122.28 | | | |

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PRACTICAL
FORM 518

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER. ESTIMATE NO. C·D·R.

LOCATION BUILDING 10 SHEET NO. 13

PROJECT ENGINEER LBL DATE DECEMBER 1988.

SUMMARY BY DD PRICES BY DD CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | [redacted] | UNIT PRICE | TOTAL ESTIMATED LABOR COST | TOTAL |
|---|---|---|---|---|---|---|---|
| 1.3.3.9.7. REHAB. EXISTING TOILET AREAS | | | | | | | |
| Upgrade existing finishes etc. at existing toilet areas. | 1670 | S.F. | 10.00 | 16700 | | | |
| TOTAL TO SUMMARY. | | | | 16700 | | | |
| 1.3.3.10.1. BUILDING SPECIALTIES | | | | | | | |
| Misc. building specialties. | 6000 | SF. | 25¢ | 1500 | | | |
| TOTAL TO SUMMARY. | | | | 1500 | | | |
| 3.3.12.1. LABORATORY FURNITURE/FUME HOODS. | | | | | | | |
| Base cabinets. | 388 | LF. | 250.00 | 97000 | | | |
| Wall Cabinets | 388 | LF. | 100.00 | 38800 | | | |
| Island Cabinets. | 98 | LF. | 400.00 | 39200 | | | |
| Fume hoods. | 6 | EA. | 5000.00 | 30000 | | | |
| TOTAL TO SUMMARY. | | | | 205000 | | | |
| 1.3.3.13.1. COLD ROOMS | | | | | | | |
| Cold room. (walk-in). | 1 | EA. | 15000.00 | 15000 | | | |
| TOTAL TO SUMMARY. | | | | 15000 | | | |
| 1.3.3.12.2. OFFICE FURNITURE. | | | | | | | |
| Office furniture. | 364 | SF. | 20.00 | 7280 | | | |
| TOTAL TO SUMMARY. | | | | 7280 | | | |



MFD. IN U.S.A. FRANK R. WALKER CO., PUBLISHERS, CHICAGO

# ESTIMATE SHEET

FILE Means - DEMO
S. O. 020-0700 pg 12 ITEM
SHEET [redacted] OF
DATE 4 OCT 88
DRWG. NO.

FOR LIFE SCIENCES CDR.
ITEM TITLE DEMOLITION BLDG 10

| REQUESTED BY | MADE BY | CHECKED BY | APPROVED BY |
|---|---|---|---|
| D. DANIELS | R. BAKER | | |

| DESCRIPTION | UNIT | QUANT. | PRICE | ~~LABOR~~ x 40% | MAT'L | TOTAL |
|---|---|---|---|---|---|---|
| 1. 1200 AMP MAIN SERVICE | EA | 1 | 750 | 1050 | | 1.1K |
| 2. 100 AMP SUB PANELS | EA | 15 | 105 | 147 | | 2.2K |
| 3. 37.5 KVA XFORMER | EA | 1 | 185 | 259 | | .3K |
| 4. FLUOR FIXTURES 150 ea | EA | 150 | 15.70 | 22 | | 3.3K |
| 5. EMT Removal 1/2-1" | LF | 2000 | .70 | .98 | | 2.0K |
| 6. EMT " 2"-3" | LF | 300 | 1.17 | 1.64 | | .5K |
| Recept & Switches | EA | 400 | 1.07 | 1.50 | | .6k |
| 8. DISC. SWITCHES & EQUIP | EA | 20 | 22 | 31 | | .6k |
| 9. Incandescent fixtures | EA | 100 | 8 | 11.20 | | 1.1K |
| 10. Junction boxes | EA | 600 | 3.44 | 4.82 | | 2.9K |
| | | | | | | 14.6K |

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RL-1439

# ESTIMATE SHEET

FILE 88 MEANS SCIENCE TABLE 9.0-117 pg 238
S. O ____ ITEM ____
SHEET 1 OF ____
DATE OCT 4 1988
DRWG. NO. ____

FOR LIFE SCIENCES CDR
ITEM TITLE BLDG 10 IMPROVEMENTS SHEET 2

| REQUESTED BY | MADE BY | CHECKED BY | APPROVED BY |
|---|---|---|---|
| D. DANIELS | R. BAKER | | |

| DESCRIPTION | UNIT | QUANT. | PRICE | ~~LABOR~~ X 40% | MAT'L | TOTAL |
|---|---|---|---|---|---|---|
| 1. NEW 480V & 208V DISTRIBUTION FOR WHOLE BLDG. | SF | 16,263 | 1.26 | 1.76 | | 28.6 K |
| 2. EMERGENCY POWER 480V & 208V FOR WHOLE BLDG | SF | 16,263 | .81 | 1.13 | | 18.4K |
| 3. LIGHTING 1ST FLOOR - 3W/SQFT | SF | 6000 | 2.46 | 3.44 | | 20.6 K |
| 4. OUTLETS, SWITCHES, BOXES | SF | 6000 | .75 | 1.05 | | 6.3K |
| 5. EQUIPMENT CONNECTIONS EXHAUST FANS, HOODS, HVAC & etc | SF | 6000 | .64 | .90 | | 5.4K |
| 6. BASIC MATERIALS GROUNDING, RACEWAYS, PULL BOXES, WIRE | SF | 6000 | 1.97 | 2.76 | | 16.6K |
| 7. FIRE ALARM - WHOLE BLDG SYSTEM 3 - FAN SHUTDOWNS | SF | 16,263 | .48 | .67 | | 10.9K |
| 8. HILL WIDE P.A. SPEAKERS & AMP | SF | 6000 | .39 | .55 | | 3.3K |
| 9. ICS SYSTEM - UNIV. RECEPT 1/200# 6000 ÷ 200 = 30 | EA | 30 | 125 | — | | 3.8K |
| | | 6000 | SF. | $19.00 | | 113.9K |

NOTE: NORMAL POWER, EMERG. POWER AND FIRE ALARM COSTED FOR WHOLE BLDG.

9-69

RL-1439

# ESTIMATE SHEET

FOR LIFE SCIENCES CDR

ITEM TITLE BLDG 6 & 10 SITE UTILITIES

| REQUESTED BY | MADE BY | CHECKED BY | APPROVED BY |
|---|---|---|---|
| D. DANIELS | R. BAKER | | |

FILE
S. O ITEM
SHEET OF
DATE Oct 4 88
DRWG. NO.

| DESCRIPTION | UNIT | QUANT. | PRICE | ~~LABOR~~ X44% | MAT'L | TOTAL |
|---|---|---|---|---|---|---|
| BLDG 6 | | | | | | |
| 1. PROVIDE POWER CABLE FROM SW-A3 TO MEZZANINE 480V @ 400 A MEANS 9.1-310-0320 | LF | 300 | 38.95 | 54.55 | | 16.4K |
| 2. PROVIDE ICS CABLE PAIR 19 Recpt X 2pr X 30% spare = 50 | EA | 50 | 50 | - | | 2.5K |
| | | | | | | 18.9K |
| BLDG 10 | | | | | | |
| 1. PROVIDE NEW 480V & 208V SUBSTATION 300KVA | EA | 1 | 10K | | | 10.0K |
| 2. PROVIDE ICS CABLE FOR BLDG 1st flr = 6000 2nd flr = 5000 11000 ÷ 200 sq ft/person = 55 55 X 1.30 = 71 prs use 100 prs | Pairs | 100 | 50 | | | 5.0K |
| 3. Provide raceway ICS INSIDE BLDG TO ICS ROOM | LF | 100 | 85 | | | 8.5K |
| | | | | | | 23.5K |

9-70

RL-1439

PRACTICAL
FORM 318

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER — ESTIMATE NO. C.D.R.
LOCATION BUILDING 6. — SHEET NO. 17
ARCHITECT LBL — DATE DECEMBER 1988
SUMMARY BY DD — PRICES BY DD. — CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | MATERIAL COST | UNIT PRICE | TOTAL ESTIMATED LABOR COST | TOTAL |
|---|---|---|---|---|---|---|---|
| 1.3.4.1.2 SUBCONTRACT GENERAL CONDITIONS. | | | | | | | |
| SUMMARY DIRECT COST | | | | 556 000 | | | |
| + GENERAL CONDITIONS | TO SUMMARY. | | 7% | 38 920 | | | |
| | | | | 594 920 | | | |
| 1.3.4.1.3 OVERHEAD, PROFIT, BOND. | | | | | | | |
| SUB-TOTAL FROM 1.3.4.1.2 | | | | 594 920 | | | |
| + BOND. | | | 2% | 11 900 | | | |
| + PRIME CONTRACTOR OH. & PROFIT. | | | 12% | 71 390 | | | |
| | TO SUMMARY. | | | 83 290 | | | |
| 1.3.4.2.3. SITE UTILITIES. | | | | | | | |
| Mechanical. (Connections to existing). | | | L.S | 5000 | | | |
| Electrical. (See back-up). | | | | 19 000 | | | |
| | TOTAL TO SUMMARY. | | | 24 000 | | | |

9-71

PRACTICAL
FORM 518

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER. ESTIMATE NO. C.D.R.

LOCATION BUILDING 6. SHEET NO. 18.

PROJECT ENGINEER LBL.. DATE DECEMBER 1988.

SUMMARY BY PRICES BY CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | [redacted] | UNIT PRICE | TOTAL ESTIMATED LABOR COST | TOTAL |
|---|---|---|---|---|---|---|---|
| 1.3.4.5.3. MISC. IRON. | | | | | | | |
| Misc. connections, etc. | 5100 | S.F. | 1¢ | 5100 | | | |
| TOTAL TO SUMMARY. | | | | 5100 | | | |
| 1.3.4.6.1. ROUGH CARPENTRY. | | | | | | | |
| Misc. blocking, rough bucks etc. | 5100 | S.F. | 1¼ | 6375 | | | |
| TOTAL TO SUMMARY | | | | 6375 | | | |
| 1.3.4.6.2. FINISH CARPENTRY | | | | | | | |
| Misc. shelving, trim, small inets. | 5100 | S.F. | 1½ | 7650 | | | |
| TOTAL TO SUMMARY. | | | | 7650 | | | |
| 1.3.4.8.1 METAL DOORS & FRAMES. | | | | | | | |
| Single H.M. door/frame/hardware. | 28 | EA. | 850¢ | 19550 | | | |
| Cold Room door. | 2 | EA. | | INC. IN COLD RMS. | | | |
| TOTAL TO SUMMARY. | | | | 19550 | | | |
| 1.3.4.9.2. METAL STUDS/GYPSUM BOARD | | | | | | | |
| Metal studs at partitions. | 9814 | S.F. | 5¢ | 49070 | | | |
| Gypsum board at ditto. | 12618 | S.F. | 1½ | 18927 | | | |
| TOTAL TO SUMMARY. | | | | 67997 | | | |

9-72

PRACTICAL
FORM 518

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER. ESTIMATE NO. C.D.R.

LOCATION BUILDING 6. SHEET NO. 19.

SUBJECT LBL. DATE DECEMBER 1988.

SUMMARY BY DD. PRICES BY DD. CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | [redacted] | UNIT PRICE | TOTAL ESTIMATED LABOR COST | TOTAL |
|---|---|---|---|---|---|---|---|
| **1.3.4.9.4. ACOUSTIC TREATMENT.** | | | | | | | |
| Suspended acoustical ceilings. | 5100 | S.F. | 5¢ | 255 00 | | | |
| TOTAL TO SUMMARY. | | | | 255 00 | | | |
| **1.3.4.9.5. RESILIENT FLOORING.** | | | | | | | |
| Vinyl composition tile floor. | 5100 | S.F. | 2¢ | 102 00 | | | |
| Bases. | 1737 | LF. | 3¢ | 52 11 | | | |
| TOTAL TO SUMMARY. | | | | 154 11 | | | |
| **1.3.4.9.6. PAINTING & WALL COVERING.** | | | | | | | |
| - gypsum board walls | 15633 | S.F. | 60¢ | 93 80 | | | |
| Paint door & frame. | 25 | EA. | 30¢ | 7 50 | | | |
| Paint finish carpentry. | | L.S. | | 15 00 | | | |
| Misc. touch-up repairs to existing surfaces. | | L.S. | | 15 00 | | | |
| Paint metal stairs. | | L.S. | | 5 00 | | | |
| TOTAL TO SUMMARY. | | | | 136 30 | | | |
| **1.3.4.10.1 SPECIALTIES.** | | | | | | | |
| Signs, notice boards etc. | 5100 | S.F. | 25¢ | 12 75 | | | |
| TOTAL TO SUMMARY. | | | | 12 75 | | | |

9-73

PRACTICAL FORM 518

# RECAPITULATION

PROJECT LIFE SCIENCES CENTER. ESTIMATE NO. C.D.R.

LOCATION BUILDING 6. SHEET NO. 20.

ARCHITECT ENGINEER LBL. DATE DECEMBER 1988.

SUMMARY BY DD PRICES BY DD. CHECKED BY

| DESCRIPTION | QUANTITY | UNIT | UNIT PRICE | [redacted] | UNIT PRICE | TOTAL ESTIMATED LABOR COST | TOTAL |
|---|---|---|---|---|---|---|---|
| 1.3.4.12.1. LABORATORY FURNITURE/FUME HOODS. | | | | | | | |
| Base cabinets. | 60 | LF | 250.00 | 15000 | | | |
| Wall cabinets. | 60 | LF. | 100.00 | 6000 | | | |
| Island cabinets. | 84 | LF. | 400.00 | 33600 | | | |
| Fume hoods. | 6 | EA. | 5000.00 | 30000 | | | |
| TOTAL TO SUMMARY. | | | | 84600 | | | |
| 1.3.4.12.2. OFFICE FURNITURE. | | | | | | | |
| Office furniture. | 1520 | S.F. | 20.00 | 30400 | | | |
| TOTAL TO SUMMARY. | | | | 30400 | | | |
| 1.3.4.13.1. COLD ROOMS. | | | | | | | |
| Cold room. (incl. door). | 2 | EA. | 15000.00 | 30000 | | | |
| TOTAL TO SUMMARY. | | | | 30000 | | | |
| 1.3.4.13.2. MODULAR LABORATORIES. | | | | | | | |
| Architectural/Structural. | 800 | S.F. | 30.00 | 24000 | | | |
| Plumbing. | 800 | S.F. | 30.00 | 24000 | | | |
| H.V.A.C. | 800 | S.F. | 25.00 | 20000 | | | |
| Fire Protection. | 800 | S.F. | 4.00 | 3200 | | | |
| Electrical | 800 | S.F. | 10.00 | 8000 | | | |
| Mech./Elect. utilities. | | | | INCL. IN ABOVE. | | | |
| TOTAL TO SUMMARY. | | | | 79200 | | | |

9-74

# ESTIMATE SHEET

FILE MEANS OFFICE
S. O 9.0-117 ITEM 238
SHEET [redacted] OF
DATE Oct 4 88
DRWG. NO.

FOR LIFE SCIENCES CDR
ITEM TITLE BLDG 6 2ND FLOOR OFFICE IMPROVEMENTS

| REQUESTED BY | MADE BY | CHECKED BY | APPROVED BY |
|---|---|---|---|
| D. DANIELS | R. BAKER | | |

| DESCRIPTION | UNIT | QUANT. | PRICE | ~~LABOR~~ X40% | MAT'L | TOTAL |
|---|---|---|---|---|---|---|
| 1. 208/120V DISTRIBUTION | SF | 2940 | 1.39 | 1.95 | | 5.7K |
| 2. LIGHTING FLUOR 50fc | SF | 2940 | 3.20 | 4.48 | | 13.2K |
| 3. OUTLETS, SWITCHES, BOXES | SF | 2940 | .13 | .18 | | .5K |
| 4. BASIC MATERIALS | SF | 2940 | 2.06 | 2.88 | | 8.5K |
| 5 HILL WIDE P.A. | SF | 2940 | .12 | .17 | | .5K |
| 6 ICS SYSTEM - UNIV RECEPT | EA | 9 | 150 | — | | 1.4K |
| | | SF = | $10.14 | | | 29.8K |

9-75

RL-1439

# ESTIMATE SHEET

FILE MEANS - SCIENCE
S. O 20-117 ITEM
SHEET OF
DATE Oct 4 88
DRWG. NO. —

FOR LIFE SCIENCES CDR
ITEM TITLE BLDG 6 2nd FLOOR LAB IMPROVEMENTS

| REQUESTED BY | MADE BY | CHECKED BY | APPROVED BY |
|---|---|---|---|
| D. DANIELS | R. BAKER | | |

| DESCRIPTION | UNIT | QUANT. | PRICE | ~~LABOR~~ X40% | MAT'L | TOTAL |
|---|---|---|---|---|---|---|
| 1. 480 & 208V DISTRIBUTION | SF | 2160 | 1.26 | 1.76 | | 3.8K |
| 2. LIGHTING - FLUOR | SF | 2160 | 2.46 | 3.44 | | 7.4K |
| 3. OUTLETS, SWITCHES, BOXES | SF | 2160 | .75 | 1.05 | | 2.3K |
| 4. EQUIPMENT CONNECTIONS | SF | 2160 | .64 | .90 | | 1.9K |
| 5. Basic Materials | SF | 2160 | 1.97 | 2.76 | | 6.0K |
| 6 Hill P.A. | SF | 2160 | .39 | .55 | | 1.2K |
| MERG POWER | SF | 2160 | .81 | 1.13 | | 2.4K |
| 8. ICS SYSTEM - UNIV RECEPT 2 per lab X5 = 10 | EA | 10 | 150 | — | | 1.5K |
| | | SF = | $12.27 | | | 26.5K |

9-76

RL-1439

# ESTIMATE SHEET

FILE

S. O ITEM

SHEET OF

DATE Oct 4 88

DRWG. NO.

OR LIFE SCIENCES CDR

ITEM TITLE BLDG 6 & 10 SITE UTILITIES

| REQUESTED BY | MADE BY | CHECKED BY | APPROVED BY |
|---|---|---|---|
| D. DANIELS | R. BAKER | | |

| DESCRIPTION | UNIT | QUANT. | PRICE | X 49% | MAT'L | TOTAL |
|---|---|---|---|---|---|---|
| BLDG 6 | | | | | | |
| 1. PROVIDE POWER CABLE FROM SW-A3 TO MEZZANINE 480V @ 400A MEANS 9.1-310-0320 | LF | 300 | 38.95 | 54.53 | | 16.4K |
| 2. PROVIDE ICS CABLE PAIR 19 Recpt X 2pr X 30% spare = 50 | EA | 50 | 50 | - | | 2.5K |
| | | | | | | 18.9K |
| BLDG 10 | | | | | | |
| 1. PROVIDE NEW 480V $208V SUBSTATION 300KVA | EA | 1 | 10K | | | 10.0K |
| 2. PROVIDE ICS CABLE FOR BLDG 1st flr = 6000 2nd flr = 5000 11000 ÷ 200 sq ft/person = 55 55 X 1.30 = 71 prs use 100 prs | Pairs | 100 | 50 | | | 5.0K |
| 3. Provide raceway ICS INSIDE BLDG TO ICS ROOM | LF | 100 | 85 | | | 8.5K |
| | | | | | | 23.5K |

9-77

RL-1439

Rec'd 12/12/88

24.

Chris Case.

COMPUTATION SHEET

Keller & Gannon
Engineers-Architects

621-1199

| | | |
|---|---|---|
| COMPUTED BY | | PROJECT |
| CHECKED BY | | |
| DATE 19 | | |
| REV. 19 | | SHEET NO. OF SHEETS |

# MECHANICAL COST ESTIMATE

COST BREAKDOWN.

| | BUILDING 6 | BUILDING 10 |
|---|---|---|
| H.V.A.C. EQUIPMENT | 126000 | 127000 |
| PLUMBING | 66000 | 59000 |
| FIRE PROTECTION | 4000 | 3500 |
| | 196000 | 189500 |

9-78

FORM 101-1/8

ESTIMATING SHEET

Keller & Gannon
Engineers-Architects

COMPUTED BY J. Case
CHECKED BY
DATE Dec. 19 88
REV. 19

LBL - LIFE SCIENCES
COST SUMMARY

PROJECT 16-199-09

SHEET NO. 1 OF 4 SHEETS

| ITEM NO. | DESCRIPTION | ESTIMATED QUANTITY | UNIT | UNIT COST | TOTAL COST |
|---|---|---|---|---|---|
| 1 | HVAC Equipment | | | | $253,000 |
| 2 | Plumbing and Process Piping | | | | 125,000 |
| 3 | Fire Protection | | | | 7 500 ~~75,000~~ |
| | Mechanical Total | | | | $385,500 |

9-79

ESTIMATING SHEET

Keller & Gannon
Engineers-Architects

COMPUTED BY J. Case
CHECKED BY
DATE Dec. 19 88
REV. 19

LBL - LIFE SCIENCES
HVAC EQUIPMENT

PROJECT 16-199-09

SHEET NO. 2 OF 4 SHEETS

| ITEM NO. | DESCRIPTION | ESTIMATED QUANTITY | UNIT | UNIT COST | TOTAL COST |
|---|---|---|---|---|---|
| 1 | Rooftop air handling unit with filters, roof curb, preheat coil | 1 | EA | 14,000 | $ 14,000 |
| 2 | Laboratory exhaust fan | 4 | EA | 1,900 | 7,600 |
| 3 | Surgery exhaust fan, Bldg. 10 | 1 | EA | 1,350 | 1,350 |
| 4 | General exhaust fan, Bldg. 10 | 1 | EA | 1,350 | 1,350 |
| 5 | General exhaust fan, Bldg. 6 | 1 | EA | 1,350 | 1,350 |
| 6 | Static pressure controlled VAV box with reheat coil | 23 | EA | 1,000 | 23,000 |
| 7 | Supply diffusers 24" x 24" | 35 | EA | 200 | 7,000 |
| 8 | Exhaust grill 24" x 24" | 8 | EA | 55 | 440 |
| 9 | Supply duct @ 1 lb/sf | 12,360 | LB | 3.25 | 40,170 |
| 10 | General exhaust duct @ .2 lb/sf | 2,472 | LB | 3.25 | 8,034 |
| 11 | Laboratory exhaust duct @ .5 lb/sf | 6,180 | LB | 5.60 | 34,608 |
| 12 | Duct insulation @ .25 sf/sf | 3,090 | SF | 2.10 | 6,489 |
| 13 | Hot water piping w/insul. | 600 | LF | 12 | 7,200 |
| 14 | Chilled water piping w/insul. | 400 | LF | 12 | 4,800 |
| 15 | Seismic bracing | 1 | JOB | LS | 10,000 |
| 16 | Controls | 1 | JOB | LS | 71,000 |
| 17 | Valves and fittings | 1 | JOB | LS | 5,000 |
| 18 | Testing and balancing | 1 | JOB | LS | 10,000 |
| | Subtotal (HVAC) | | | | $253,391 |
| | Total (rounded) | | | | $253,000 |

9-80

ESTIMATING SHEET

Keller & Gannon
Engineers-Architects

COMPUTED BY J. Case
CHECKED BY
DATE Dec. 19 88
REV. 19

LBL - LIFE SCIENCES
PLUMBING AND
PROCESS PIPING

PROJECT 19-199-09

SHEET NO. 3 OF 4 SHEETS

| ITEM NO. | DESCRIPTION | ESTIMATED QUANTITY | UNIT | UNIT COST | TOTAL COST |
|---|---|---|---|---|---|
| 1 | Laboratory counter sink w/ rough-in | 28 | EA | 800 | $ 22,400 |
| 2 | Emergency shower | 2 | EA | 700 | 1,400 |
| 3 | Emergency eyewash | 7 | EA | 300 | 2,100 |
| 4 | Laboratory waste lift pump | 12 | EA | 1,500 | 18,000 |
| 5 | Treated water piping, 4" cu. | 610 | LF | 33 | 20,130 |
| 6 | Low cond. water piping, 4" cu. | 610 | LF | 33 | 20,130 |
| 7 | Natural gas piping, 2" blk. stl. | 305 | LF | 12.15 | 3,705 |
| 8 | Indust. CW, 1-1/2" cu. | 305 | LF | 9.60 | 2,928 |
| 9 | Indust. HW, 1" cu. | 610 | LF | 6.75 | 4,118 |
| 10 | Domestic CW, 1" cu. | 400 | LF | 6.75 | 2,700 |
| 11 | Acid waste piping, 4" p.p. | 400 | LF | 14.35 | 5,740 |
| 12 | Acid neutralization system | 2 | JOB | LS | 10,000 |
| 13 | Vent piping, 2" p.p. | 250 | LF | 10.25 | 2,562 |
| 14 | 100 gal. water heater | 1 | EA | 700 | 700 |
| 15 | Recirc. pump, 10 gpm | 1 | EA | 550 | 550 |
| 16 | Seismic bracing | 1 | JOB | LS | 5,000 |
| 17 | Testing | 1 | JOB | LS | 2,500 |
| | Subtotal (plumbing and process) | | | | $124,663 |
| | Total rounded | | | | $125,000 |

9-81

ESTIMATING SHEET

Keller & Gannon
Engineers-Architects

COMPUTED BY J. Case
CHECKED BY
DATE Dec. 19 88
REV. 19

LBL - LIFE SCIENCES
FIRE PROTECTION

PROJECT 16-199-09

SHEET NO. 4 OF 4 SHEETS

| ITEM NO. | DESCRIPTION | ESTIMATED QUANTITY | UNIT | UNIT COST | TOTAL COST |
|---|---|---|---|---|---|
| 1 | Modification of existing sprinkler system @ 30% of complete system cost | 12,360 | SF | .60 | $7,416 |
| | Subtotal | | | | $7,416 |
| | Total rounded | | | | $7,500 |

9-82

COMPUTATION SHEET

Keller & Gannon
Engineers-Architects

| | | |
|---|---|---|
| COMPUTED BY _____ | _____ | PROJECT _____ |
| CHECKED BY _____ | | _____ |
| DATE _____ 19__ | _____ | _____ |
| REV _____ 19__ | | SHEET NO ____ OF ____ SHEETS |

# MECHANICAL COST ESTIMATE

9-83

FORM 101-1/8

ESTIMATING SHEET

Keller & Gannon
Engineers-Architects

COMPUTED BY J. Case
CHECKED BY
DATE Dec. 19 88
REV 19

LBL - LIFE SCIENCES
COST SUMMARY

PROJECT 16-199-09

SHEET NO 1 OF 4 SHEETS

| ITEM NO | DESCRIPTION | ESTIMATED QUANTITY | UNIT | UNIT COST | TOTAL COST |
|---|---|---|---|---|---|
| 1 | HVAC Equipment | | | | $253,000 |
| 2 | Plumbing and Process Piping | | | | 125,000 |
| 3 | Fire Protection | | | | 7,500 |
| | Mechanical Total | | | | $385,500 |

9-84

ESTIMATING SHEET

Keller & Gannon
Engineers-Architects

COMPUTED BY J. Case
CHECKED BY
DATE Dec. 19 88
REV 19

LBL - LIFE SCIENCES
HVAC EQUIPMENT

PROJECT 16-199-09

SHEET NO 2 OF 4 SHEETS

| ITEM NO | DESCRIPTION | ESTIMATED QUANTITY | UNIT | UNIT COST | TOTAL COST |
|---|---|---|---|---|---|
| 1 | Rooftop air handling unit with filters, roof curb, preheat coil | 1 | EA | 14,000 | $ 14,000 |
| 2 | Laboratory exhaust fan | 4 | EA | 1,900 | 7,600 |
| 3 | Surgery exhaust fan, Bldg. 10 | 1 | EA | 1,350 | 1,350 |
| 4 | General exhaust fan, Bldg. 10 | 1 | EA | 1,350 | 1,350 |
| 5 | General exhaust fan, Bldg. 6 | 1 | EA | 1,350 | 1,350 |
| 6 | Static pressure controlled VAV box with reheat coil | 23 | EA | 1,000 | 23,000 |
| 7 | Supply diffusers 24" x 24" | 35 | EA | 200 | 7,000 |
| 8 | Exhaust grill 24" x 24" | 8 | EA | 55 | 440 |
| 9 | Supply duct @ 1 lb/sf | 12,360 | LB | 3.25 | 40,170 |
| 10 | General exhaust duct @ .2 lb/sf | 2,472 | LB | 3.25 | 8,034 |
| 11 | Laboratory exhaust duct @ .5 lb/sf | 6,180 | LB | 5.60 | 34,608 |
| 12 | Duct insulation @ .25 sf/sf | 3,090 | SF | 2.10 | 6,489 |
| 13 | Hot water piping w/insul. | 600 | LF | 12 | 7,200 |
| 14 | Chilled water piping w/insul. | 400 | LF | 12 | 4,800 |
| 15 | Seismic bracing | 1 | JOB | LS | 10,000 |
| 16 | Controls | 1 | JOB | LS | 71,000 |
| 17 | Valves and fittings | 1 | JOB | LS | 5,000 |
| 18 | Testing and balancing | 1 | JOB | LS | 10,000 |
| | Subtotal (HVAC) | | | | $253,391 |
| | Total (rounded) | | | | $253,000 |

9-85

ESTIMATING SHEET

Keller & Gannon
Engineers-Architects

COMPUTED BY J. Case
CHECKED BY
DATE Dec. 19 88
REV 19

LBL - LIFE SCIENCES
PLUMBING AND
PROCESS PIPING

PROJECT 19-199-09

SHEET NO 3 OF 4 SHEETS

| ITEM NO | DESCRIPTION | ESTIMATED QUANTITY | UNIT | UNIT COST | TOTAL COST |
|---|---|---|---|---|---|
| 1 | Laboratory counter sink w/ rough-in | 28 | EA | 800 | $ 22,400 |
| 2 | Emergency shower | 2 | EA | 700 | 1,400 |
| 3 | Emergency eyewash | 7 | EA | 300 | 2,100 |
| 4 | Laboratory waste lift pump | 12 | EA | 1,500 | 18,000 |
| 5 | Treated water piping, 4" cu. | 610 | LF | 33 | 20,130 |
| 6 | Low cond. water piping, 4" cu. | 610 | LF | 33 | 20,130 |
| 7 | Natural gas piping, 2" blk. stl. | 305 | LF | 12.15 | 3,705 |
| 8 | Indust. CW, 1-1/2" cu. | 305 | LF | 9.60 | 2,928 |
| 9 | Indust. HW, 1" cu. | 610 | LF | 6.75 | 4,118 |
| 10 | Domestic CW, 1" cu. | 400 | LF | 6.75 | 2,700 |
| 11 | Acid waste piping, 4" p.p. | 400 | LF | 14.35 | 5,740 |
| 12 | Acid neutralization system | 2 | JOB | LS | 10,000 |
| 13 | Vent piping, 2" p.p. | 250 | LF | 10.25 | 2,562 |
| 14 | 100 gal. water heater | 1 | EA | 700 | 700 |
| 15 | Recirc. pump, 10 gpm | 1 | EA | 550 | 550 |
| 16 | Seismic bracing | 1 | JOB | LS | 5,000 |
| 17 | Testing | 1 | JOB | LS | 2,500 |
| | Subtotal (plumbing and process) | | | | $124,663 |
| | Total rounded | | | | $125,000 |

9-86

ESTIMATING SHEET

Keller & Gannon
Engineers-Architects

COMPUTED BY J. Case
CHECKED BY
DATE Dec. 19 88
REV 19

LBL - LIFE SCIENCES
FIRE PROTECTION

PROJECT 16-199-09

SHEET NO 4 OF 4 SHEETS

| ITEM NO | DESCRIPTION | ESTIMATED QUANTITY | UNIT | UNIT COST | TOTAL COST |
|---|---|---|---|---|---|
| 1 | Modification of existing sprinkler system @ 30% of complete system cost | 12,360 | SF | .60 | $7,416 |
| | Subtotal | | | | $7,416 |
| | Total rounded | | | | $7,500 |

9-87

ALS - LIFE SCIENCES CENTER
CONVENTIONAL FACILITIES
FY89$K

SCHEDULE I

| Special Facilities | Cost |
|---|---|
| Laboratory Furniture and Standard Fume Hoods | |
| Building 10 | 205* |
| Building 6 | 85* |
| Cold Rooms | |
| Building 10 (1) | 15* |
| Building 6 (2) | 30* |
| Laminar Flow Hoods (3) | 36* |
| Scientific Equipment | |
| Digital Scanning Electron Microscope with Analytical Workstation | 260 |
| High Resolution Electron Microscope with Cryoworkstation | 200 |
| Confocal Microscope | 86 |
| Image Analysis Package | 80 |
| TOTAL | 997 |

*Included in Construction and A/E Contracts ($371K).

ALS - LIFE SCIENCES CENTER
CONVENTIONAL FACILITIES
FY89$K

SCHEDULE II

| Standard Equipment | | Cost |
|---|---|---|
| Biochemistry | | 1,034 |
| Centrifuges | 243 | |
| Spectrophotometers | 183 | |
| Balances | 59 | |
| Isotope Counters | 41 | |
| Separation Equipment | 214 | |
| General Laboratory Equipment | 294 | |
| Microscopy | | 105 |
| Darkroom Equipment | 52 | |
| General Laboratory Equipment | 53 | |
| Cell and Tissue Culture | | 135 |
| Incubators | 46 | |
| Sterilizer | 37 | |
| General Laboratory Equipment | 52 | |
| Surgical Suite | | 77 |
| Operating Tables, Surgical Instruments, and Special Lighting | 19 | |
| Operating Microscope and Video Equipment | 47 | |
| General Laboratory Equipment | 11 | |
| General Support Equipment | | 381 |
| Computations Equipment | 79 | |
| Dishwasher | 73 | |
| Office Furniture | 40 | |
| Office Equipment | 189 | |
| TOTAL | | 1,732 |

DETAILS OF ESTIMATE OF SCIENTIFIC

EQUIPMENT UNDER SCHEDULE I

SPECIAL FACILITIES

IMAGE ANALYSIS PACKAGE
$80K

**Tracor Northern Inc.**

2551 West Beltline Highway
Middleton, Wisconsin 53562-2697
(608) 831-6511 Twx: 910-280-2521

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 |
|---|---|---|---|---|
| | | TN-8502 High Performance Image Analysis Package | | |
| 1 | 1 | TN-8502/BAAC<br>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<br>"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<br>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<br>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<br>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<br>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<br>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 |

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Middleton, Wisconsin 53562-2697
(608) 831-6511 Twx: 910-280-2521

| ITEM | QTY | MODEL NUMBER AND DESCRIPTION | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|
| 8 | 1 | TN-8595-214<br>Small console table (29" x 29" x 30" wide) | 300.00 | 300.00 |
| 9 | 1 | TN-8585-211<br>Installation of a TN-8502 image processor and one operator school credit | 2,000.00 | 2,000.00 |
| 10 | 1 | TN-8510-222<br>2 MByte of additional CPU memory (1 VME slot) | 2,200.00 | 2,200.00 |
| | | | Total | $71,350.00 |

OPTIONAL

A. Objective Aperture Automation

| | | | | |
|---|---|---|---|---|
| A.1 | 1 | TN-8555-221<br>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<br>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 - Addt'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.

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BY: Tan Jelling
Technical Sales Specialist

DIGITAL SCANNING ELECTRON MICROSCOPE
with ANALYTICAL WORKSTATION
$260K

QUOTATION NO.
EBQ801039
Page 1

**Tracor/ Electron Beam Instruments**

3705 FAIRVIEW ROAD
MIDDLETON, WI 53562
(608) 831 6511
FAX (608) 836 7024

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(AB) | 215,000.00 | 215,000.00 |

Digital Scanning Electron Microscope/Analytical Workstation

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

Tracor/ Electron Beam Instruments

| ITEM QTY | MODEL NUMBER AND DESCRIPTION | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|

**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 tranfers 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 $mm^2$ 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

Tracor/ Electron Beam Instruments

| ITEM QTY | MODEL NUMBER AND DESCRIPTION | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|

**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)

Tracor/ Electron Beam Instruments
[illegible] PARVIEW ROAD
MIDDLETON, WI [illegible]
[illegible]

| ITEM | QTY | MODEL NUMBER AND DESCRIPTION | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|
| 2 | 1 | EB-EGM2001<br>Lanthanum hexaboride ($LaB_6$) cathode gun assembly. Requires item number EB-VSM4001 | 1,000.00 | 1,000.00 |
| 3 | 1 | EB-VSM4001<br>20 liters/second ionization pump for gun chamber | 6,000.00 | 6,000.00 |
| 4 | 1 | EB-VSM3002<br>300 liters/second water-cooled turbomolecular vacuum pump (in lieu of standard diffusion pump) | 9,500.00 | 9,500.00 |
| 5 | 1 | EB-SOM1001<br>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<br>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<br>Factory expansion of CPU memory to 5 MByte | 1,550.00 | 1,550.00 |
| 8 | 1 | EB-SWC2001<br>Complex particle sizing with chemical characterization. Requires at least 5 MByte of CPU memory | 4,500.00 | 4,500.00 |
| 9 | 1 | EB-INF1001<br>System installation | 7,500.00 | 7,500.00 |
| | | | Total | $253,150.00 |
| | | | Transportation ~ | 6850.00 |
| | | | | $ 260,000.- |

PAYMENT TERMS: 80% due within 30 days of shipment, balance due upon installation.

- - - - - - - - - -

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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: [signature]

Product Specialist

HIGH RESOLUTION ELECTRON MICROSCOPE
WITH CRYO WORKSTATION
$200K

Carl Zeiss, Inc.

One Zeiss Drive
Thornwood, NY 10594
914 • 747 • 1800

West Germany

October 19, 1988

Quotation #34-180

Jacob Bastacky
Room 116 Donner Lab
Laurence Barkeley 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.
Emergen y 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

9-97

Carl Zeiss, Inc.
One Zeiss Drive
Thornwood, NY 10594
914 • 747 • 1800
West Germany

| | |
|---|---|
| 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 |

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



Cable • ZEISSAG New York Telex • RCA 221834 WU 64 • 6928 Telecopy • 914 • 682 • 8296

Carl Zeiss, Inc.

One Zeiss Drive
Thornwood, NY 10594
914 • 747 • 1800

West Germany

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 3o% 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, exise 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

9-99

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 |
|---|---|---|---|---|
| | | Confocal Tandem Scanning Reflected Light Microscope (TSM) | | |
| 1 | 1 | TN-C1-88001<br>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<br>General purpose scanning disk (includes cartridge) | 6,200.00 | 6,200.00 |
| 3 | 1 | TN-C1-88004<br>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<br>Stage carrier bracket for reflected/transmitted light (accepts condenser carrier for transmitted light option) | 580.00 | 580.00 |
| 5 | 1 | TB-C1-88013<br>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<br>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<br>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 53562-2697
(608) 831-6511 Twx 910-280-2521

| ITEM | QTY | MODEL NUMBER AND DESCRIPTION | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|
| | | Xenon/Mercury EPI Illumination | | |
| 8 | 1 | TB-C1-88024<br>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<br>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<br>200W mercury bulb | 360.00 | 360.00 |
| 11 | 1 | TB-C1-88032<br>150W xenon bulb | 335.00 | 335.00 |
| | | Total | | $59,070.00 |

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<br>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<br>100W power supply (110/115 VAC) for tungsten halogen | 395.00 | 395.00 |
| A.3 | 1 | TB-C1-88128<br>Lamphouse | 610.00 | 610.00 |
| A.4 | 1 | TB-C1-88021<br>Collector lens for tungsten halogen source | 220.00 | 220.00 |
| A.5 | 1 | TB-C1-88022<br>Lampsocket for 100W tungsten halogen bulb | 250.00 | 250.00 |
| A.6 | 1 | TB-C1-88023<br>100W tungsten halogen bulb | 20.00 | 20.00 |
| A.7 | 1 | TB-C1-88035<br>Condenser carrier (fits TB-C1-88008 stage carrier bracket) | 400.00 | 400.00 |

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2551 West Beltline Highway
Middleton, Wisconsin 53562-2697
(608) 831-6511 Twx 910-280-2521



| ITEM | QTY | MODEL NUMBER AND DESCRIPTION | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|
| A.8 | 1 | TB-C1-88037<br>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 | | $4,630.00 |
| B. | | 35mm Format Camera Option | | |
| B.1 | 1 | TB-C1-88071<br>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 |
| B.2 | 1 | TB-C1-88126<br>Auto advance 35mm camera back (use on UFX-II) | 855.00 | 855.00 |
| B.3 | 1 | TB-C1-88083<br>Adapter for auto advance 35mm camera back (use on UFX-II) | 165.00 | 165.00 |
| B.4 | 1 | TN-C1-88087<br>Photo tube and relay lens assembly for Nikon FX series photomicrographic systems (requires photo tube adapter) | 850.00 | 850.00 |
| B.5 | 1 | TN-C1-88088<br>Photo tube adapter for Nikon FX series photomicrographic systems | 195.00 | 195.00 |
| | | Option B Total | | $10,080.00 |
| C. | | Polaroid Format Camera Option | | |
| C.1 | 1 | TB-C1-88072<br>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<br>4"x5" Polaroid film holder (type 52, 53, 55 and 59 films) | 340.00 | 340.00 |
| | | Option C Total | | $8,575.00 |

NOTE: Option C.1 requires TB-C1-88087 relay lens/adapter called out in Option B.4.

SUB TOTAL 82355
TRANSPORTATION ~ 3645
86,000

**Tracor Northern Inc.**
2551 West Beltline Highway
Middleton, Wisconsin 53562-2697
(608) 831-6511 Twx: 910-280-2521

| ITEM | QTY | MODEL NUMBER AND DESCRIPTION | UNIT PRICE | TOTAL PRICE |
|---|---|---|---|---|

- - - - - - - - - -

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BY: Tam Kiling
Technical Sales Specialist

DETAILS OF ESTIMATE OF SCIENTIFIC

EQUIPMENT UNDER SCHEDULE II

STANDARD EQUIPMENT

ALS - LIFE SCIENCES CENTER

Standard Equipment Detail for Schedule II

| | | | |
|---|---|---|---|
| <u>Biochemistry</u> | | | 1,034* |
| Preparative Ultracentrifuge (2) | | 111 | |
| Table Top Ultracentrifuge (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 | | |
| Acessories | 1 | | |
| Tables (4) | 4 | | |
| Isotope Bench Top Liquid Scintillation Counter | | 24 | |
| Isotope Gamma Counter System | | 17 | |
| Separation Equipment | | 214 | |
| Fraction Collectors (6) | 19 | | |
| Chrometography 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 Water Baths (16) | 43 | | |
| Lyophilizer (3) | 39 | | |

ALS - LIFE SCIENCES CENTER

Standard Equipment Detail for Schedule II (continued)

| | | | | |
|---|---|---|---|---|
| General Laboratory Equipment (continued) | | | | |
| Freezers (6) | | 26 | | |
| Sonication Equipment (2) | | 5 | | |
| Mixers, Various | | 9 | | |
| Regular Refrigerators (6) | | 6 | | |
| Special Regrigerators (2) | | 9 | | |
| Ovens (4) | | 13 | | |
| PH, Ion and Voltmeters (12) | | 25 | | |
| Pumps, Various | | 5 | | |
| Safety Equipment | | 5 | | |
| Shakers, Various | | 5 | | |
| Homoginizers (3) | | 9 | | |
| Elemental Chemical Analysis | | 37 | | |
| Flame Photometer | 13 | | | |
| Chloride Titrator | 3 | | | |
| Atomic Absorbtion Photometer | 21 | | | |
| Assorted Lab Glassware, Chemicals, Plasticware, Pipettes, etc | | 29 | | |
| <u>Microscopy</u> | | | | 105 |
| Darkroom Equipment (2) | | | 52 | |
| General Laboratory Equipment | | | 53 | |
| Low Temperature Preparative Facility | | 22 | | |
| Assorted Glassware, Chemicals, Plasticware, Darkroom Supplies and EM Supplies | | 31 | | |
| <u>Cell and Tissue Culture</u> | | | | 135 |
| Incubators (4) | | | 46 | |
| Sterilizer (1) | | | 37 | |
| General Laboratory Equipment | | | 52 | |
| Assorted Glassware, Plasticware, Cell Culture Media and Small Equipment | | | | |

ALS - LIFE SCIENCES CENTER

Standard Equipment Detail for Schedule II (continued)

| | | | |
|---|---|---|---|
| <u>Surgical Suite</u> | | | 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. | | | |
| <u>General Support Equipment</u> | | | 381 |
| Computational Equipment | | 79 | |
| Microvax | 41 | | |
| Computer Workstations (12) | 38 | | |
| Dishwasher | | 73 | |
| Office Furniture | | 40 | |
| Office Equipment | | 189 | |

*5% added to each category for delivery, handling and installation.

**BECKMAN**

AC 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

PAGE 1 OF 2

QUOTATION NO SFR-0239

TO Center for X Ray Optics
Lawerence Berkeley Laboratory
Berkeley, Ca 94720

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 | NET 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 | 52795.80 | 7,100.00 | 5,609.00 |
| 5 | 1 | 348175 | QUICK-SEAL TUBE KIT FOR TYPE 45 Ti | x2 | 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 | 105,591.6 | 7,150.00 | 5,648.50 |
| 8 | 1 | 346457 | TL-100 TABLETOP ULTRACENTRIFUGE | 25,764.00 | 20,560.00 | 18,504.00 |
| 9 | 1 | 349490 | TLA-100.3 FIXED ANGLE ROTOR PACKAGE | 1 only | 3,690.00 | 3,690.00 |
| 10 | 1 | 346134 | TLS-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 | 24047 | 2,450.00 | 1,960.00 |
| 14 | 1 | 346963 | JS-13.1 SWINGING BUCKET ROTOR | x4 | 4,500.00 | 3,600.00 |
| 15 | 1 | 336380 | JS-7.5 SWINGING BUCKET ROTOR | 96188 | 3,900.00 | 3,120.00 |
| 16 | 1 | 349702 | GPR TABLETOP REFRIGERATED CENTRIFUGE | | 4,790.00 | 4,406.80 |
| 17 | 1 | 349830 | GH-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 | 1496.7 | 1,980.00 | 1,623.60 |
| 22 | 1 | 345636 | TYPE 13.2 FIXED ANGLE ROTOR | x2 = 3993.4 | 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/GEL 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 GEL HOLDER | | 520.00 | 442.00 |
| 29 | 1 | 523429 | FILM GEL HOLDER | 29049.34 | 520.00 | 442.00 |
| 30 | 1 | 596077 | GEL SLITS | x2 | 435.00 | 404.50 |
| 31 | 1 | 198649 | GEL CUVETTE | | 176.00 | 139.04 |
| 32 | 1 | 523408 | SIPPER ACCESSORY | 58098.68 | 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 | 874.00 |

- continued -

POSAL FOR ACCEPTANCE WITHIN 60 DAYS OF ABOVE DATE
ENT 30-60 DAYS FROM RECEIPT OF ORDER
F O B Shipping Point

BECKMAN INSTRUMENTS, INC
Signed
Name Bob Cummins, Sales Representative

**BECKMAN**

ADDRESS 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

PAGE 2 OF 2

QUOTATION NO SFR-0239

TO: Center for X Ray Optics
Lawerence Berkeley Laboratory
Berkeley, Ca. 94720

ATTENTION: Dr. Steven Rothman
YOUR REFERENCE NO. 486-4029,4463

PLEASE REFER TO THIS QUOTE NO IN FUTURE CORRESPONDENCE

| ITEM | QTY | PART NO | DESCRIPTION | GSA UNIT PRICE LIST PRICE | GSA NET PRICE DISCOUNTED PRICE |
|---|---|---|---|---|---|
| 38 | 1 | 120640 | MODEL DU 64 SCANNING SPECTROPHOTOMETER | 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 | LS-3801 BENCH TOP LIQUID SCINTILLATION COUNTER | 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 | GAMMA 5500 PC READY PLUS GAMMA COUNTER SYSTEM | 17,200.00 | 15,824.00 |
| 50 | 1 | 239742 | SYSTEM GOLD HPLC | 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 | GENELINE ™ TAFE ELECTROPHORESIS SYSTEM | 6,350.00 | 6,350.00 |
| 54 | 1 | 123000 | MODEL pHI ™ 71 pH METER | 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 |

12036.75 × 3 = 36110.25

22660.00 1 only

1 only

60492.20 × 2 = 120,984.40

2 × 6350 = 12700.00

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. [illegible]

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 Cummins

Name [illegible]

This proposal is made contingent upon the acceptance by Buyer without change or modification of the provisions of this proposal including all insertions on the face hereof and of the terms and conditions of sale on the reverse side hereof unless specifically accepted by Beckman in writing. Contrary or additional terms or conditions or changes in specifications proposed by Buyer's Purchase Order or in any or otherwise shall not bind Beckman. Issuance of Buyer's Purchase Order against this quotation or the acceptance of the products or any part thereof offered hereby shall be deemed an unqualified acceptance of the provisions of this quotation including the terms and conditions of sale on the reverse hereof. Upon the acceptance of this quotation it shall constitute the entire agreement between Buyer and Beckman and shall supersede all prior representations, promises or conditions, written or oral, in connection herewith not expressly included herein.

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FOR CONVENTIONAL FACILITIES
AND SCIENTIFIC EQUIPMENT


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# APPENDIX B

## Project Cost Estimate Details

The cost estimate for the Life Sciences Center was developed in FY1989 dollars, and then escalated to obtain the total estimated cost (TEC). The total cost for the project is $21.50M in FY1989 dollars; in actual year (escalated) dollars for a three year project schedule (FY1991-FY1993) the Total Estimated Cost is $25.40M. The FY1989 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-4. 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-5 through B-12. The "Cost Estimate Detail Listing" data is included in Table B.3, pages B-13 through B-38, and includes the detail cost entry data sheet for each of the lowest WBS levels of the project.

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 an estimate originally developed and reviewed for the July 1986 Conceptual Design Report of the 1-2 Gev Syncrotron Radiation Source (the Advanced Light Source, or ALS). All of this material was recently updated (November 1988) for the ALS project, and is now available directly in FY1989 dollars. 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 10, 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. Conventional Construction costs are dated December 1988 and represent FY1989 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; 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 Architecht/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 project management and special research facilities contingency is approximately 30% overall; the conventional facilities contingency is estimated at 20%.

Table B.1
Cost Estimate Summary

All costs shown in FY1989 K$

| | | | | |
|---|---|---|---|---|
| 1. | Life Sciences Center | | | 21,500 |
| 1.1. | Project Management & Administration | | 695 | |
| 1.2. | Special Research Facilities | | 11,092 | |
| 1.2.1 | Engineering, Design, & Inspection | | 2,789 | |
| 1.2.1.1 | EDI, Wiggler Facility | 1,504 | | |
| 1.2.1.2 | EDI, Undulator Facility | 1,285 | | |
| 1.2.2 | Wiggler Facility | | 4,448 | |
| 1.2.2.1 | Wiggler | 663 | | |
| 1.2.2.2 | Wiggler Beamline Frontend | 379 | | |
| 1.2.2.3 | Diffraction Facility | 1,585 | | |
| 1.2.2.4 | Spectroscopy/Microprobe Facility | 1,821 | | |
| 1.2.3 | Undulator Facility | | 3,855 | |
| 1.2.3.1 | Undulator | 936 | | |
| 1.2.3.2 | Undulator Beamline Frontend | 379 | | |
| 1.2.3.3 | Soft X-ray Imaging Facility | 2,540 | | |
| 1.3. | Conventional Facilities | | 5,157 | |
| 1.3.1 | Engineering, Design, & Inspection | | 490 | |
| 1.3.2 | Construction | | 2,935 | |
| 1.3.2.1 | Improvements to Land | 12 | | |
| 1.3.2.2 | Building 10 Improvements | 1,243 | | |
| 1.3.2.3 | Building 6 Improvements | 612 | | |
| 1.3.2.4 | Site Utilities | 71 | | |
| 1.3.2.5 | Special Facilities | 997 | | |
| 1.3.3 | Standard Equipment | | 1,732 | |
| 1.3.3.1 | Biochemistry | 1,034 | | |
| 1.3.3.2 | Microscopy | 105 | | |
| 1.3.3.3 | Cell and Tissue Culture | 135 | | |
| 1.3.3.4 | Surgical Suite | 77 | | |
| 1.3.3.5 | General Support Equipment | 381 | | |
| 1.4. | Contingency | | 4,556 | |
| 1.4.1 | Special Research Facilities (@30%) | | 3,525 | |
| 1.4.2 | Conventional Facilities (@20%) | | 1,031 | |

# Table B.2

Page No. 1
02/13/89

**Cost Estimate Report**
**Summary of Materials and Labor**
**by Rollup Levels**

| Work Breakdown Structure | Description | Material & Labor Total Cost for Level | | | | |
|---|---|---|---|---|---|---|
| ** * | | | | | | |
| 1 | Life Sciences Center | | | | | 21,500 |
| ** ** | | | | | | |
| 1.1 | Project Management & Administration | | | | 695 | |
| 1.2 | Special Research Facilities | | | | 11,092 | |
| ** *** | | | | | | |
| 1.2.1 | Engineering, Design & Inspection | | | 2,789 | | |
| ** **** | | | | | | |
| 1.2.1.1 | EDI, Wiggler Facility | | 1,504 | | | |
| ** ***** | | | | | | |
| 1.2.1.1.1 | EDI, Wiggler | 198 | | | | |
| 1.2.1.1.2 | EDI, Wiggler Beamline Frontend | 114 | | | | |
| 1.2.1.1.3 | EDI, Diffraction Facility | 557 | | | | |
| 1.2.1.1.4 | EDI, Spectroscopy/Mircroprobe Facility | 634 | | | | |
| ** **** | | | | | | |
| 1.2.1.2 | EDI, Undulator Facility | | 1,285 | | | |
| ** ***** | | | | | | |
| 1.2.1.2.1 | EDI, Undulator | 281 | | | | |
| 1.2.1.2.2 | EDI, Undulator Beamline Frontend | 115 | | | | |
| 1.2.1.2.3 | EDI, Soft X-ray Imaging Facility | 889 | | | | |
| ** *** | | | | | | |
| 1.2.2 | Wiggler Facility | | | 4,447 | | |
| ** **** | | | | | | |
| 1.2.2.1 | Wiggler | | 662 | | | |
| ** ***** | | | | | | |
| 1.2.2.1.1 | Magnetic Structure | 352 | | | | |
| ** ****** | | | | | | |
| 1.2.2.1.1.1 | Magnetic Material | 162 | | | | |
| 1.2.2.1.1.2 | Model Pole | 7 | | | | |
| 1.2.2.1.1.3 | Pole Assemblies | 68 | | | | |
| 1.2.2.1.1.4 | End Pole Assemblies | 18 | | | | |
| 1.2.2.1.1.5 | Backing Beams | 25 | | | | |
| 1.2.2.1.1.6 | Magnet Structure Assembly | 8 | | | | |
| 1.2.2.1.1.7 | Magnetic Measurements | 61 | | | | |
| ** ***** | | | | | | |
| 1.2.2.1.2 | Support & Drive Systems | 108 | | | | |

Cost Estimate Report
Summary of Materials and Labor
by Rollup Levels

| Work Breakdown Structure | Description | Material & Labor Total Cost for Level | | |
|---|---|---|---|---|
| ** ****** | | | | |
| 1.2.2.1.2.1 | Support Structure | 40 | | |
| 1.2.2.1.2.2 | Drive Components | 28 | | |
| 1.2.2.1.2.3 | Drive System Fabrication | 14 | | |
| 1.2.2.1.2.4 | Support-Drive Assembly | 24 | | |
| ** ***** | | | | |
| 1.2.2.1.3 | Vacuum System | | 144 | |
| 1.2.2.1.4 | Electrical | | 33 | |
| 1.2.2.1.5 | Installation | | 24 | |
| ** ****** | | | | |
| 1.2.2.1.5.1 | Mechanical Installation | 23 | | |
| 1.2.2.1.5.2 | Electrical Installation | 0 | | |
| ** **** | | | | |
| 1.2.2.2 | Wiggler Beamline Frontend | | | 378 |
| ** ***** | | | | |
| 1.2.2.2.1 | Front End Components | | 215 | |
| ** ****** | | | | |
| 1.2.2.2.1.1 | Fixed Aperture | 32 | | |
| 1.2.2.2.1.2 | Fast Valve | 20 | | |
| 1.2.2.2.1.3 | Front End Vacuum Sys | 45 | | |
| 1.2.2.2.1.4 | Vacuum Pumping Station | 25 | | |
| 1.2.2.2.1.5 | Personnel Safety Shut. | 55 | | |
| 1.2.2.2.1.6 | Front End Photon Shut. | 36 | | |
| ** ***** | | | | |
| 1.2.2.2.2 | Mechanical Installation | | 93 | |
| 1.2.2.2.3 | Front End Controls | | 45 | |
| 1.2.2.2.4 | Electrical Installation | | 24 | |
| ** **** | | | | |
| 1.2.2.3 | Diffraction Facility | | | 1,584 |
| ** ***** | | | | |
| 1.2.2.3.1 | Crystallography Branchline | | 1,017 | |
| ** ****** | | | | |
| 1.2.2.3.1.1 | Photon Transport Components | 400 | | |
| ** ******* | | | | |
| 1.2.2.3.1.1.1 | Photon BPM | 82 | | |
| 1.2.2.3.1.1.2 | Spherical Mirrors | 177 | | |
| 1.2.2.3.1.1.3 | Branchline Vac Sys | 88 | | |
| 1.2.2.3.1.1.4 | Vacuum Pump Stations | 51 | | |

Cost Estimate Report
Summary of Materials and Labor
by Rollup Levels

| Work Breakdown Structure | Description | Material & Labor Total Cost for Level | | | | |
|---|---|---|---|---|---|---|
| ** ****** | | | | | | |
| 1.2.2.3.1.2 | Monochromator | | 298 | | | 312 |
| ** ******* | | | | | | |
| 1.2.2.3.1.2.1 | High Resolution Double Crystal Monochromator | 298 | 330 | | | |
| ** ****** | | | | | | |
| 1.2.2.3.1.3 | Mechanical Installation | | 103 | | | |
| 1.2.2.3.1.4 | Photon Transport Controls | | 68 | | | |
| 1.2.2.3.1.5 | Monochromator Controls | | 32 | | | |
| 1.2.2.3.1.6 | Electrical Installation | | 43 | | | |
| 1.2.2.3.1.7 | Mechanical & Electrical System Integrati | | 70 | | | |
| ** ***** | | | | | | |
| 1.2.2.3.2 | Crystallography Station | | | 432 | | |
| 1.2.2.3.3 | Small Angle Scattering Station | | | 135 | | |
| ** **** | | | | | | |
| 1.2.2.4 | Spectroscopy/Microprobe Facility | | | | 1,821 | 1912 |
| ** ***** | | | | | | |
| 1.2.2.4.1 | Spectroscopy/Microprobe Branchline | | | 1,338 | | |
| ** ****** | | | | | | |
| 1.2.2.4.1.1 | Photon Transport Components | | 400 | | | |
| ** ******* | | | | | | |
| 1.2.2.4.1.1.1 | Photon BPM | 82 | | | | |
| 1.2.2.4.1.1.2 | Spherical Mirrors | 177 | | | | |
| 1.2.2.4.1.1.3 | Branchline Vac Sys | 88 | | | | |
| 1.2.2.4.1.1.4 | Vacuum Pump Stations | 51 | | | | |
| ** ****** | | | | | | |
| 1.2.2.4.1.2 | Monochromators | | 619 | | | 683 |
| | | | 32 | | | |
| ** ******* | | | 651 | | | |
| 1.2.2.4.1.2.1 | High Resolution Double Crystal Monochromator | 298 | | | | |
| 1.2.2.4.1.2.2 | Pre-Monochromator System (Multilayer) | 320 | | | | |
| ** ****** | | | | | | |
| 1.2.2.4.1.3 | Mechanical Installation | | 103 | | | |
| 1.2.2.4.1.4 | Photon Transport Controls | | 68 | | | |
| 1.2.2.4.1.5 | Monochromator Controls | | 32 | | | |
| 1.2.2.4.1.6 | Electrical Installation | | 43 | | | |
| 1.2.2.4.1.7 | Mechanical & Electrical System Integrati | | 70 | | | |

Cost Estimate Report
Summary of Materials and Labor
by Rollup Levels

| Work Breakdown Structure | Description | Material & Labor Total Cost for Level | | |
|---|---|---|---|---|
| ** ***** | | | | |
| 1.2.2.4.2 | Spectroscopy Station | | 228 | |
| 1.2.2.4.3 | Microprobe Station | | 255 | |
| ** *** | | | | |
| 1.2.3 | Undulator Facility | | | 3,855 |
| ** **** | | | | |
| 1.2.3.1 | Undulator | | | 935 |
| ** ***** | | | | |
| 1.2.3.1.1 | Magnetic Structure | | 625 | |
| ** ****** | | | | |
| 1.2.3.1.1.1 | Magnetic Material | 138 | | |
| 1.2.3.1.1.2 | Model Pole | 7 | | |
| 1.2.3.1.1.3 | Pole Assemblies | 324 | | |
| 1.2.3.1.1.4 | End Pole Assemblies | 18 | | |
| 1.2.3.1.1.5 | Backing Beams | 63 | | |
| 1.2.3.1.1.6 | Magnet Structure Assembly | 11 | | |
| 1.2.3.1.1.7 | Magnetic Measurements | 61 | | |
| ** ***** | | | | |
| 1.2.3.1.2 | Support & Drive Systems | | 108 | |
| ** ****** | | | | |
| 1.2.3.1.2.1 | Support Structure | 40 | | |
| 1.2.3.1.2.2 | Drive Components | 28 | | |
| 1.2.3.1.2.3 | Drive System Fabrication | 14 | | |
| 1.2.3.1.2.4 | Support-Drive Assembly | 24 | | |
| ** ***** | | | | |
| 1.2.3.1.3 | Vacuum System | | 144 | |
| 1.2.3.1.4 | Electrical | | 33 | |
| 1.2.3.1.5 | Installation | | 24 | |
| ** ****** | | | | |
| 1.2.3.1.5.1 | Mechanical Installation | 23 | | |
| 1.2.3.1.5.2 | Electrical Installation | 0 | | |
| ** **** | | | | |
| 1.2.3.2 | Undulator Beamline Front End | | | 378 515 |
| ** ***** | | | | |
| 1.2.3.2.1 | Front End Components | | 215 | |

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Cost Estimate Report
Summary of Materials and Labor
by Rollup Levels

| Work Breakdown Structure | Description | | | Material & Labor Total Cost for Level | | |
|---|---|---|---|---|---|---|
| ** ****** | | | | | | |
| 1.2.3.2.1.1 | Fixed Aperture | | | 32 | | |
| 1.2.3.2.1.2 | Fast Valve | | | 20 | | |
| 1.2.3.2.1.3 | Front End Vacuum Sys | | | 45 | | |
| 1.2.3.2.1.4 | Vacuum Pumping Station | | | 25 | | |
| 1.2.3.2.1.5 | Personnel Safety Shut. | | | 55 | | |
| 1.2.3.2.1.6 | Front End Photon Shut. | | | 36 | | |
| ** ***** | | | | | | |
| 1.2.3.2.2 | Mechanical Installation | | | | 93 | |
| 1.2.3.2.3 | Front End Controls | | | | 45 | |
| 1.2.3.2.4 | Electrical Installation | | | | 24 | |
| ** **** | | | | | | |
| 1.2.3.3 | Soft X-ray Imaging Facility | | | | | 2,540 |
| ** ***** | | | | | | |
| 1.2.3.3.1 | Main Beamline | | | | 1,115 | |
| ** ****** | | | | | | |
| 1.2.3.3.1.1 | Photon Transport Components | | | 455 | | |
| ** ******* | | | | | | |
| 1.2.3.3.1.1.1 | Undulator Pinhole & BPM | 159 | | | | |
| 1.2.3.3.1.1.2 | Undulator Spher. Mirror | 168 | | | | |
| 1.2.3.3.1.1.3 | Branchline Vac Sys | 88 | | | | |
| 1.2.3.3.1.1.4 | Vacuum Pump Stations | 38 | | | | |
| ** ****** | | | | | | |
| 1.2.3.3.1.2 | Monochromator | | | 332 | | |
| ** ******* | | | | | | |
| 1.2.3.3.1.2.1 | Entrance Slit | 62 | | | | |
| 1.2.3.3.1.2.2 | Adjustable Mask | 28 | | | | |
| 1.2.3.3.1.2.3 | Grating Chamber | 131 | | | | |
| 1.2.3.3.1.2.4 | Exit Slit | 71 | | | | |
| 1.2.3.3.1.2.5 | Vacuum Pump Stations | 38 | | | | |
| ** ****** | | | | | | |
| 1.2.3.3.1.3 | Mechanical Installation | | | 99 | | |
| 1.2.3.3.1.4 | Photon Transport Controls | | | 77 | | |
| 1.2.3.3.1.5 | Monochromator Controls | | | 36 | | |
| 1.2.3.3.1.6 | Electrical Installation | | | 43 | | |
| 1.2.3.3.1.7 | Mechanical & Electrical System Integrati | | | 70 | | |
| ** ***** | | | | | | |
| 1.2.3.3.2 | Main Scanning Microscope Station | | | | 575 | |
| 1.2.3.3.3 | R/D Scanning Microscope Station | | | | 470 | |

575

332
36
368

Cost Estimate Report
Summary of Materials and Labor
by Rollup Levels

| Work Breakdown Structure | Description | Material & Labor Total Cost for Level | | | |
|---|---|---|---|---|---|
| 1.2.3.3.4 | Diffraction Imaging Station | 380 | | | |
| ** ** | | | | | |
| 1.3 | Conventional Facilities | | | | 5,157 |
| ** *** | | | | | |
| 1.3.1 | Engineering, Design & Inspection | | | 490 | |
| ** **** | | | | | |
| 1.3.1.1 | LBL Activities | | 200 | | |
| ** ***** | | | | | |
| 1.3.1.1.1 | Engineering | 120 | | | |
| 1.3.1.1.2 | Consultants | 15 | | | |
| 1.3.1.1.3 | Inspection | 65 | | | |
| ** **** | | | | | |
| 1.3.1.2 | A/E Activities | | 290 | | |
| ** ***** | | | | | |
| 1.3.1.2.1 | Title I | 50 | | | |
| 1.3.1.2.2 | Title II | 145 | | | |
| 1.3.1.2.3 | Title III | 95 | | | |
| ** *** | | | | | |
| 1.3.2 | Conventional Construction | | | 2,935 | |
| ** **** | | | | | |
| 1.3.2.1 | Improvements to Land | | 12 | | |
| 1.3.2.2 | Building 10 Improvements | | 1,242 | | |
| ** ***** | | | | | |
| 1.3.2.2.1 | General Requirements | 223 | | | |
| 1.3.2.2.2 | Sitework | 166 | | | |
| 1.3.2.2.3 | Concrete | 0 | | | |
| 1.3.2.2.4 | Masonry | 0 | | | |
| 1.3.2.2.5 | Metals | 233 | | | |
| 1.3.2.2.6 | Carpentry | 24 | | | |
| 1.3.2.2.7 | Thermal and Moisture Protection | 16 | | | |
| 1.3.2.2.8 | Doors, Windows & Glass | 103 | | | |
| 1.3.2.2.9 | Finishes | 154 | | | |
| 1.3.2.2.10 | Specialties | 2 | | | |
| 1.3.2.2.13 | Special Construction | 0 | | | |
| 1.3.2.2.14 | Conveying Systems | 0 | | | |
| 1.3.2.2.15 | Mechanical Work | 190 | | | |
| 1.3.2.2.16 | Electrical Work | 131 | | | |

Cost Estimate Report
Summary of Materials and Labor
by Rollup Levels

| Work Breakdown Structure | Description | | Material & Labor Total Cost for Level | |
|---|---|---|---|---|
| ** **** | | | | |
| 1.3.2.3 | Building 6 Improvements | | | 612 |
| ** ***** | | | | |
| 1.3.2.3.1 | General Requirements | | 110 | |
| 1.3.2.3.2 | Bldg 6 Site Utilities | | 0 | |
| 1.3.2.3.3 | Concrete | | 0 | |
| 1.3.2.3.4 | Masonry | | 0 | |
| 1.3.2.3.5 | Metals | | 6 | |
| 1.3.2.3.6 | Carpentry | | 15 | |
| 1.3.2.3.7 | Thermal and Moisture Protection | | 0 | |
| 1.3.2.3.8 | Doors, Windows & Glass | | 20 | |
| 1.3.2.3.9 | Finishes | | 124 | |
| 1.3.2.3.10 | Specialties | | 2 | |
| 1.3.2.3.13 | Special Construction | | 80 | |
| 1.3.2.3.14 | Conveying Systems | | 0 | |
| 1.3.2.3.15 | Mechanical Work | | 196 | |
| 1.3.2.3.16 | Electrical Work | | 59 | |
| ** **** | | | | |
| 1.3.2.4 | Site Utilities | | | 70 |
| ** ***** | | | | |
| 1.3.2.4.1 | General Requirements | | 12 | |
| 1.3.2.4.15 | Mechanical | | 15 | |
| 1.3.2.4.16 | Electrical | | 43 | |
| ** **** | | | | |
| 1.3.2.5 | Special Facilities | | | 997 |
| ** ***** | | | | |
| 1.3.2.5.1 | Lab Furniture & Standard Fume Hoods | | 290 | |
| 1.3.2.5.2 | Cold Rooms | | 45 | |
| 1.3.2.5.3 | Laminar Flow Hoods (3) | | 36 | |
| 1.3.2.5.4 | Scientific Equipment | | 626 | |
| ** ****** | | | | |
| 1.3.2.5.4.1 | Digital Scanning Elctrn Microscpe w/Workstatn | 260 | | |
| 1.3.2.5.4.2 | HiRes Electron Microscope w/Cryo Workstation | 200 | | |
| 1.3.2.5.4.3 | Confocal Microscope | 86 | | |
| 1.3.2.5.4.4 | Image Analysis Package | 80 | | |
| ** *** | | | | |
| 1.3.3 | Standard Equipment | | | 1,732 |

Cost Estimate Report
Summary of Materials and Labor
by Rollup Levels

| Work Breakdown Structure | Description | Material & Labor Total Cost for Level | | |
|---|---|---|---|---|
| ** **** | | | | |
| 1.3.3.1 | Biochemistry | 1,034 | | |
| 1.3.3.2 | Microscopy | 105 | | |
| 1.3.3.3 | Cell and Tissue Culture | 135 | | |
| 1.3.3.4 | Surgical Suite | 77 | | |
| 1.3.3.5 | General Support Equipment | 381 | | |
| ** ** | | | | |
| 1.4 | Contingency | | | 4,556 |
| ** *** | | | | |
| 1.4.1 | Special Research Facilities and Management | | 3,525 | |
| 1.4.2 | Conventional Facilities | | 1,031 | |

# Table B.3

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Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ** WBS: 1.1 | Project Management & Administration | | | | | | | | | | | | |
| 1 | PROJECT DIRECTOR | | 0 | 0.00 | EU | 0.0 | 1 | 5300.0 | 5300 | AA | 38.44 | 203.7 | 203.7 |
| 2 | CLERICAL SUPPORT | | 0 | 0.00 | | 0.0 | 1 | 5300.0 | 5300 | AA | 38.44 | 203.7 | 203.7 |
| 3 | PROJECT MANAGER | | 0 | 0.00 | | 0.0 | 1 | 2650.0 | 2650 | AA | 38.44 | 101.9 | 101.9 |
| 4 | Proj Conv Fac C.M. | | 0 | 0.00 | | 0.0 | 1 | 2200.0 | 2200 | PEN | 38.50 | 84.7 | 84.7 |
| 5 | SUPPLIES & EXPENSES (18%) | | 1 | 101000.00 | | 101.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 101.0 |
| ** Subtotal ** | | | | | | 101.0 | | | 15450 | | | 594.0 | 695.0 |
| ** WBS: 1.2.1.1.1 | EDI, Wiggler | | | | | | | | | | | | |
| 1 | PRELIM & GENERAL ENGNEERG | | 0 | 0.00 | | 0.0 | 1 | 840.0 | 840 | ME | 54.10 | 45.4 | 45.4 |
| 2 | MAG STRUCTURE ENGINEERING | | 0 | 0.00 | | 0.0 | 1 | 720.0 | 720 | ME | 54.10 | 39.0 | 39.0 |
| 3 | | | 0 | 0.00 | | 0.0 | 1 | 20.0 | 20 | EE | 50.55 | 1.0 | 1.0 |
| 4 | ENGINEERING SUPPORT | | 0 | 0.00 | | 0.0 | 1 | 260.0 | 260 | ME | 54.10 | 14.1 | 14.1 |
| 5 | SUPPORT/DRIVE SYSTEM ENGR | | 0 | 0.00 | | 0.0 | 1 | 280.0 | 280 | ME | 54.10 | 15.1 | 15.1 |
| 6 | | | 0 | 0.00 | | 0.0 | 1 | 70.0 | 70 | EE | 50.55 | 3.5 | 3.5 |
| 7 | VACUUM SYSTEM ENGINEERING | | 0 | 0.00 | | 0.0 | 1 | 220.0 | 220 | ME | 54.10 | 11.9 | 11.9 |
| 8 | ENGR. DURING FABRICATION | | 0 | 0.00 | | 0.0 | 1 | 880.0 | 880 | ME | 54.10 | 47.6 | 47.6 |
| 9 | ENGINEERING SUPPLS & EXP | LOT | 1 | 20650.00 | EU | 20.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.6 |
| ** Subtotal ** | | | | | | 20.6 | | | 3290 | | | 177.7 | 198.3 |
| ** WBS: 1.2.1.1.2 | EDI, Wiggler Beamline Frontend | | | | | | | | | | | | |
| 1 | Mech Engineering | | 0 | 0.00 | EU | 0.0 | 1 | 710.0 | 710 | ME | 54.10 | 38.4 | 38.4 |
| 2 | Mech Design | | 0 | 0.00 | EU | 0.0 | 1 | 620.0 | 620 | MD | 38.60 | 23.9 | 23.9 |
| 3 | Mech Drafting | | 0 | 0.00 | EU | 0.0 | 1 | 440.0 | 440 | MF | 38.60 | 17.0 | 17.0 |
| 4 | Mech Shops (Inspection) | | 0 | 0.00 | EU | 0.0 | 1 | 90.0 | 90 | MS | 36.20 | 3.3 | 3.3 |
| 5 | Mech Tech (Inspection) | | 0 | 0.00 | EU | 0.0 | 1 | 130.0 | 130 | MT | 25.20 | 3.3 | 3.3 |
| 6 | Elec. Engineering | | 0 | 0.00 | EU | 0.0 | 1 | 120.0 | 120 | EE | 50.55 | 6.1 | 6.1 |
| 7 | Elec. Coordination | | 0 | 0.00 | EU | 0.0 | 1 | 120.0 | 120 | EC | 37.15 | 4.5 | 4.5 |
| 8 | Elec Shops (Inspection) | | 0 | 0.00 | EU | 0.0 | 1 | 30.0 | 30 | ES | 29.35 | 0.9 | 0.9 |
| 9 | Supplies & Expenses | | 1 | 17450.00 | EU | 17.4 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 17.4 |
| ** Subtotal ** | | | | | | 17.4 | | | 2260 | | | 97.3 | 114.7 |
| ** WBS: 1.2.1.1.3 | EDI, Diffraction Facility | | | | | | | | | | | | |
| 1 | Total Estimate | | 1 | 557000.00 | | 557.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 557.0 |
| ** Subtotal ** | | | | | | 557.0 | | | 0 | | | 0.0 | 557.0 |
| ** WBS: 1.2.1.1.4 | EDI, Spectroscopy/Mircroprobe Facility | | | | | | | | | | | | |
| 1 | Total Estimate | | 1 | 634000.00 | | 634.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 634.0 |
| ** Subtotal ** | | | | | | 634.0 | | | 0 | | | 0.0 | 634.0 |
| ** WBS: 1.2.1.2.1 | EDI, Undulator | | | | | | | | | | | | |
| 1 | PRELIM & GENERAL ENGNEERG | | 0 | 0.00 | | 0.0 | 1 | 1180.0 | 1180 | ME | 54.10 | 63.8 | 63.8 |
| 2 | MAG STRUCTURE ENGINEERING | | 0 | 0.00 | | 0.0 | 1 | 1030.0 | 1030 | ME | 54.10 | 55.7 | 55.7 |
| 3 | | | 0 | 0.00 | | 0.0 | 1 | 30.0 | 30 | EE | 50.55 | 1.5 | 1.5 |
| 4 | ENGINEERING SUPPORT | | 0 | 0.00 | | 0.0 | 1 | 375.0 | 375 | ME | 54.10 | 20.3 | 20.3 |
| 5 | SUPPORT/DRIVE SYSTEM ENGR | | 0 | 0.00 | | 0.0 | 1 | 400.0 | 400 | ME | 54.10 | 21.6 | 21.6 |
| 6 | | | 0 | 0.00 | | 0.0 | 1 | 90.0 | 90 | EE | 50.55 | 4.5 | 4.5 |
| 7 | VACUUM SYSTEM ENGINEERING | | 0 | 0.00 | | 0.0 | 1 | 310.0 | 310 | ME | 54.10 | 16.8 | 16.8 |
| 8 | ENGR. DURING FABRICATION | | 0 | 0.00 | | 0.0 | 1 | 1250.0 | 1250 | ME | 54.10 | 67.6 | 67.6 |
| 9 | ENGINEERING SUPPLS & EXP | LOT | 1 | 29250.00 | EU | 29.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 29.2 |
| ** Subtotal ** | | | | | | 29.2 | | | 4665 | | | 252.0 | 281.2 |
| ** WBS: 1.2.1.2.2 | EDI, Undulator Beamline Frontend | | | | | | | | | | | | |
| 1 | Mech Engineering | | 0 | 0.00 | EU | 0.0 | 1 | 830.0 | 830 | ME | 54.10 | 44.9 | 44.9 |
| 2 | Mech Design | | 0 | 0.00 | EU | 0.0 | 1 | 730.0 | 730 | MD | 38.60 | 28.2 | 28.2 |
| 3 | Mech Drafting | | 0 | 0.00 | EU | 0.0 | 1 | 20.0 | 20 | MF | 38.60 | 0.8 | 0.8 |
| 4 | Mech Shops (Inspection) | | 0 | 0.00 | EU | 0.0 | 1 | 100.0 | 100 | MS | 36.20 | 3.6 | 3.6 |
| 5 | Mech Tech (Inspection) | | 0 | 0.00 | EU | 0.0 | 1 | 150.0 | 150 | MT | 25.20 | 3.8 | 3.8 |
| 6 | Elec. Engineering | | 0 | 0.00 | EU | 0.0 | 1 | 140.0 | 140 | EE | 50.55 | 7.1 | 7.1 |
| 7 | Elec. Coordination | | 0 | 0.00 | EU | 0.0 | 1 | 140.0 | 140 | EC | 37.15 | 5.2 | 5.2 |

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Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | Elec Shops (Inspection) | | 0 | 0.00 | EU | 0.0 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 1.2 |
| 9 | Supplies & Expenses | | 1 | 20480.00 | EU | 20.5 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.5 |
| ** | Subtotal ** | | | | | 20.5 | | | 2150 | | | 94.7 | 115.2 |
| ** | WBS: 1.2.1.2.3 | EDI, Soft X-ray Imaging Facility | | | | | | | | | | | |
| 1 | Total Estimate | | 1 | 889000.00 | | 889.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 889.0 |
| ** | Subtotal ** | | | | | 889.0 | | | 0 | | | 0.0 | 889.0 |
| ** | WBS: 1.2.2.1.1.1 | Magnetic Material | | | | | | | | | | | |
| 1 | NDFE BLOCKS | CM3 | 67100 | 2.24 | VQ | 150.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 150.3 |
| 2 | MEASUREMENTS/SORTING | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | GAUGES/FIXTURES | LOT | 1 | 112.06 | EU | 0.1 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 2.1 |
| 4 | MOMENT MEAS. PREP | | 0 | 0.00 | | 0.0 | 1 | 20.0 | 20 | EE | 50.55 | 1.0 | 1.0 |
| 5 | MEASUREMENTS | LOT | 1 | 112.06 | EU | 0.1 | 1229 | 0.2 | 221 | EM | 29.35 | 6.5 | 6.6 |
| 6 | SORTING | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | ME | 54.10 | 2.2 | 2.2 |
| ** | Subtotal ** | | | | | 150.5 | | | 361 | | | 11.7 | 162.2 |
| ** | WBS: 1.2.2.1.1.2 | Model Pole | | | | | | | | | | | |
| 1 | MAGNETIC MATERIAL | LOT | 1 | 2241.05 | EU | 2.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.2 |
| 2 | ASSY AND TEST FIXTURE | | 0 | 0.00 | | 0.0 | 1 | 180.0 | 180 | MT | 25.20 | 4.5 | 4.5 |
| 3 | MODEL MAG MEASUREMENTS | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | EM | 29.35 | 1.2 | 1.2 |
| ** | Subtotal ** | | | | | 2.2 | | | 220 | | | 5.7 | 8.0 |
| ** | WBS: 1.2.2.1.1.3 | Pole Assemblies | | | | | | | | | | | |
| 1 | VANADIUM PERMENDUR | CM3 | 22400 | 0.55 | A85 | 12.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 12.3 |
| 2 | KEEPERS | EA | 80 | 303.66 | A82 | 24.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 24.3 |
| 3 | KEEPER INSPECTION | | 0 | 0.00 | | 0.0 | 80 | 0.2 | 20 | MA | 36.20 | 0.7 | 0.7 |
| 4 | CONTAINERS | LOT | 1 | 672.32 | A82 | 0.7 | 80 | 0.2 | 20 | PC | 35.55 | 0.7 | 1.4 |
| 5 | ASSY FIXTURES | LOT | 1 | 224.10 | A82 | 0.2 | 4 | 88.0 | 352 | MM | 36.20 | 12.7 | 13.0 |
| 6 | ASSEMBLY | EA | 80 | 4.66 | A82 | 0.4 | 80 | 5.8 | 464 | MA | 36.20 | 16.8 | 17.2 |
| ** | Subtotal ** | | | | | 37.9 | | | 856 | | | 31.0 | 68.9 |
| ** | WBS: 1.2.2.1.1.4 | End Pole Assemblies | | | | | | | | | | | |
| 1 | END POLE KEEPERS | LOT | 1 | 112.06 | A82 | 0.1 | 4 | 38.0 | 152 | MM | 36.20 | 5.5 | 5.6 |
| 2 | MAG. MAT. BLOCK CUTTING | | 0 | 0.00 | | 0.0 | 16 | 1.0 | 16 | MM | 36.20 | 0.6 | 0.6 |
| 3 | ASSY FIXTURE | | 0 | 0.00 | | 0.0 | 1 | 20.0 | 20 | MM | 36.20 | 0.7 | 0.7 |
| 4 | COILS | LOT | 1 | 112.06 | EU | 0.1 | 4 | 65.0 | 260 | MA | 36.20 | 9.4 | 9.5 |
| 5 | ASSEMBLY | LOT | 1 | 112.06 | EU | 0.1 | 4 | 12.0 | 48 | MA | 36.20 | 1.7 | 1.8 |
| ** | Subtotal ** | | | | | 0.3 | | | 496 | | | 18.0 | 18.3 |
| ** | WBS: 1.2.2.1.1.5 | Backing Beams | | | | | | | | | | | |
| 1 | WF BEAMS | LBS | 2100 | 0.58 | VQ | 1.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.2 |
| 2 | BEAM FABRICATION | | 0 | 0.00 | | 0.0 | 2 | 120.0 | 240 | NC | 55.20 | 13.2 | 13.2 |
| 3 | | | 0 | 0.00 | | 0.0 | 2 | 80.0 | 160 | MM | 36.20 | 5.8 | 5.8 |
| 4 | FIELD CLAMPS | | 0 | 0.00 | | 0.0 | 4 | 4.0 | 16 | MM | 36.20 | 0.6 | 0.6 |
| 5 | FLEXIBLE YOKE | | 0 | 0.00 | | 0.0 | 1 | 16.0 | 16 | MM | 36.20 | 0.6 | 0.6 |
| 6 | SHIMS | LOT | 1 | 112.06 | EU | 0.1 | 1 | 60.0 | 60 | MM | 36.20 | 2.2 | 2.3 |
| 7 | POLE SHIELDS | LOT | 1 | 224.10 | EU | 0.2 | 2 | 16.0 | 32 | PC | 35.55 | 1.1 | 1.4 |
| ** | Subtotal ** | | | | | 1.6 | | | 524 | | | 23.5 | 25.1 |
| ** | WBS: 1.2.2.1.1.6 | Magnet Structure Assembly | | | | | | | | | | | |
| 1 | KEEPER INSTALLATION | LOT | 1 | 224.10 | EU | 0.2 | 70 | 1.2 | 84 | MA | 36.20 | 3.0 | 3.3 |
| 2 | KEEPER INST TOOL | | 0 | 0.00 | | 0.0 | 1 | 16.0 | 16 | MM | 36.20 | 0.6 | 0.6 |
| 3 | KEEPER SHIMMING | | 0 | 0.00 | | 0.0 | 70 | 0.4 | 28 | MA | 36.20 | 1.0 | 1.0 |
| 4 | END POLE COIL COOLING | LOT | 1 | 448.21 | EU | 0.4 | 1 | 80.0 | 80 | MA | 36.20 | 2.9 | 3.3 |
| ** | Subtotal ** | | | | | 0.7 | | | 208 | | | 7.5 | 8.2 |

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Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ** WBS: 1.2.2.1.1.7 | Magnetic Measurements | | | | | | | | | | | | |
| 1 | INITIAL PREPARATION | | 0 | 0.00 | | 0.0 | 1 | 120.0 | 120 | EE | 50.55 | 6.1 | 6.1 |
| 2 | NULL COIL | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 2.0 |
| 3 | GAUGE BLKS/CENT. KEYS | LOT | 1 | 224.10 | A82 | 0.2 | 1 | 63.0 | 63 | MT | 25.20 | 1.6 | 1.8 |
| 4 | MAGNETIC MEASUREMENTS | LOT | 1 | 112.06 | EU | 0.1 | 1 | 755.0 | 755 | EE | 50.55 | 38.2 | 38.3 |
| 5 | | | 0 | 0.00 | | 0.0 | 1 | 321.0 | 321 | EM | 29.35 | 9.4 | 9.4 |
| 6 | | | 0 | 0.00 | | 0.0 | 1 | 174.0 | 174 | MT | 25.20 | 4.4 | 4.4 |
| ** Subtotal ** | | | | | | 0.3 | | | 1513 | | | 61.6 | 62.0 |
| ** WBS: 1.2.2.1.2.1 | Support Structure | | | | | | | | | | | | |
| 1 | BASE ALIGNMENT ASSYS | EA | 3 | 291.33 | CP | 0.9 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.9 |
| 2 | | LOT | 1 | 448.21 | EU | 0.4 | 3 | 20.0 | 60 | MM | 36.20 | 2.2 | 2.6 |
| 3 | BASE FRAME | LOT | 1 | 1120.53 | EU | 1.1 | 1 | 120.0 | 120 | MM | 36.20 | 4.3 | 5.5 |
| 4 | VERTICAL MEMBERS | LBS | 720 | 1.49 | CP | 1.1 | 2 | 40.0 | 80 | MM | 36.20 | 2.9 | 4.0 |
| 5 | | LOT | 1 | 112.06 | EU | 0.1 | 2 | 80.0 | 160 | MS | 36.20 | 5.8 | 5.9 |
| 6 | TOP FRAME | LOT | 1 | 896.42 | EU | 0.9 | 1 | 80.0 | 80 | MM | 36.20 | 2.9 | 3.8 |
| 7 | MAIN FRAME ASSY/ALIGN | LOT | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MA | 36.20 | 7.2 | 7.8 |
| 8 | | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | PP | 35.55 | 2.8 | 2.8 |
| 9 | VACUUM CHAMBER SUPPORTS | LOT | 1 | 224.10 | EU | 0.2 | 1 | 80.0 | 80 | MM | 36.20 | 2.9 | 3.1 |
| 10 | VAC PUMP SUPPORT | LOT | 1 | 112.06 | EU | 0.1 | 1 | 60.0 | 60 | MM | 36.20 | 2.2 | 2.3 |
| 11 | SUPPORTS ASSY | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | MA | 36.20 | 1.4 | 1.4 |
| ** Subtotal ** | | | | | | 5.4 | | | 960 | | | 34.7 | 40.1 |
| ** WBS: 1.2.2.1.2.2 | Drive Components | | | | | | | | | | | | |
| 1 | STEPPER MOTOR | EA | 1 | 1064.50 | CP | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 2 | REDUCER | EA | 1 | 3921.84 | CP | 3.9 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 3.9 |
| 3 | SPROCKETS/CHAIN/COUPLINGS | LOT | 1 | 3189.01 | CP | 3.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 3.2 |
| 4 | BALL SCREW SHAFTS/NUTS | LOT | 1 | 13110.14 | CP | 13.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 13.1 |
| 5 | BEARINGS | LOT | 1 | 3585.68 | CP | 3.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 3.6 |
| 6 | SWITCHES/ADJ. HARDWARE | LOT | 1 | 448.21 | EU | 0.4 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.4 |
| 7 | MISC. HARDWARE | LOT | 1 | 448.21 | EU | 0.4 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.4 |
| 8 | ENCODER | EA | 1 | 2241.05 | EU | 2.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.2 |
| 9 | U JOINTS | LOT | 1 | 526.65 | CP | 0.5 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.5 |
| ** Subtotal ** | | | | | | 28.5 | | | 0 | | | 0.0 | 28.5 |
| ** WBS: 1.2.2.1.2.3 | Drive System Fabrication | | | | | | | | | | | | |
| 1 | DRIVE HARDWARE | LOT | 1 | 336.16 | EU | 0.3 | 1 | 160.0 | 160 | MM | 36.20 | 5.8 | 6.1 |
| 2 | TRANSFER BEAMS | LOT | 1 | 224.10 | EU | 0.2 | 4 | 40.0 | 160 | MM | 36.20 | 5.8 | 6.0 |
| 3 | SAFETY STOPS | | 0 | 0.00 | | 0.0 | 1 | 16.0 | 16 | MM | 36.20 | 0.6 | 0.6 |
| 4 | COVERS/SAFETY GUARDS | LOT | 1 | 336.16 | EU | 0.3 | 1 | 40.0 | 40 | MA | 36.20 | 1.4 | 1.8 |
| ** Subtotal ** | | | | | | 0.9 | | | 376 | | | 13.6 | 14.5 |
| ** WBS: 1.2.2.1.2.4 | Support-Drive Assembly | | | | | | | | | | | | |
| 1 | STRUCTURE/DRIVE ASSY | | 0 | 0.00 | | 0.0 | 1 | 240.0 | 240 | MA | 36.20 | 8.7 | 8.7 |
| 2 | ALIGNMENT | LOT | 1 | 224.10 | EU | 0.2 | 1 | 240.0 | 240 | MA | 36.20 | 8.7 | 8.9 |
| 3 | MAG. STRUCTURE INST. | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | MA | 36.20 | 1.4 | 1.4 |
| 4 | TEST/ALIGNMENT | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | MA | 36.20 | 5.8 | 5.8 |
| ** Subtotal ** | | | | | | 0.2 | | | 680 | | | 24.6 | 24.8 |
| ** WBS: 1.2.2.1.3 | Vacuum System | | | | | | | | | | | | |
| 1 | VACUUM CHAMBER TEST P. | LB | 500 | 2.21 | VQ | 1.1 | 1 | 280.0 | 280 | MS | 36.20 | 10.1 | 11.2 |
| 2 | VACUUM CHAMBER #1 | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | MATERIAL | LB | 4100 | 2.21 | VQ | 9.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 9.1 |
| 4 | FLANGES | LOT | 1 | 1120.53 | EU | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 5 | ANNEALING | EA | 2 | 3809.78 | EU | 7.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 7.6 |
| 6 | FABRICATION | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | NC | 55.20 | 4.4 | 4.4 |
| 7 | | | 0 | 0.00 | | 0.0 | 1 | 720.0 | 720 | MM | 36.20 | 26.1 | 26.1 |
| 8 | ASSY/TEST | | 0 | 0.00 | | 0.0 | 1 | 120.0 | 120 | MA | 36.20 | 4.3 | 4.3 |
| 9 | ASSEMBLY | EA | 1 | 560.26 | EU | 0.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.6 |
| 10 | SYSTEM ASSY | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | MA | 36.20 | 2.9 | 2.9 |
| 11 | UHV BAKEOUT | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | MA | 36.20 | 5.8 | 5.8 |

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Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | ASSEMBLE IN ID | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | MA | 36.20 | 1.4 | 1.4 |
| 13 | TRANSITION SECTIONS | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 14 | INCLUDED IN 1.2.1.3.1 | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 15 | MASKS | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 16 | INCLUDED IN 1.2.1.3.1 | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 17 | PUMPING UNIT | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 18 | INCLUDED IN 1.2.1.3.2 | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 19 | VACUUM CHAMBER #2 | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 20 | MATERIAL | LB | 4100 | 2.21 | VQ | 9.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 9.1 |
| 21 | FLANGES | LOT | 1 | 1120.53 | EU | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 22 | ANNEALING | EA | 2 | 3809.78 | EU | 7.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 7.6 |
| 23 | FABRICATION | | 0 | 0.00 | | 0.0 | 1 | 400.0 | 400 | NC | 55.20 | 22.1 | 22.1 |
| 24 | | | 0 | 0.00 | | 0.0 | 1 | 720.0 | 720 | MM | 36.20 | 26.1 | 26.1 |
| 25 | ASSY/TEST | | 0 | 0.00 | | 0.0 | 1 | 120.0 | 120 | MA | 36.20 | 4.3 | 4.3 |
| ** | Subtotal ** | | | | | 37.3 | | | 2720 | | | 107.6 | 144.9 |
| ** | WBS: 1.2.2.1.4 | Electrical | | | | | | | | | | | |
| 1 | DRIVE CHASSIS | LOT | 1 | 20505.61 | EU | 20.5 | 1 | 80.0 | 80 | ES | 29.35 | 2.3 | 22.9 |
| 2 | END POLE POWER SUPPLIES | LOT | 1 | 7843.68 | EU | 7.8 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 9.0 |
| 3 | CHECKOUT | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 1.2 |
| ** | Subtotal ** | | | | | 28.3 | | | 160 | | | 4.7 | 33.0 |
| ** | WBS: 1.2.2.1.5.1 | Mechanical Installation | | | | | | | | | | | |
| 1 | DEVICE INSTALLATION | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | ICO | 61.60 | 9.9 | 9.9 |
| 2 | COIL COOLING CONNECTING | | 0 | 0.00 | | 0.0 | 1 | 16.0 | 16 | IPL | 61.60 | 1.0 | 1.0 |
| 3 | VACUUM SYSTEM CONNECTING | LOT | 1 | 112.06 | EU | 0.1 | 1 | 40.0 | 40 | IMT | 61.60 | 2.5 | 2.6 |
| 4 | ALIGNMENT | | 0 | 0.00 | | 0.0 | 1 | 120.0 | 120 | IMT | 61.60 | 7.4 | 7.4 |
| 5 | CHECKOUT | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | IMT | 61.60 | 2.5 | 2.5 |
| ** | Subtotal ** | | | | | 0.1 | | | 376 | | | 23.2 | 23.3 |
| ** | WBS: 1.2.2.1.5.2 | Electrical Installation | | | | | | | | | | | |
| 1 | DRIVE SYSTEM INST/CONNECT | | 0 | 0.00 | | 0.0 | 1 | 8.0 | 8 | IEL | 58.20 | 0.5 | 0.5 |
| 2 | POWER SUPPLY INST/CONNECT | | 0 | 0.00 | | 0.0 | 1 | 8.0 | 8 | IEL | 58.20 | 0.5 | 0.5 |
| 3 | | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| ** | Subtotal ** | | | | | 0.0 | | | 16 | | | 0.9 | 0.9 |
| ** | WBS: 1.2.2.2.1.1 | Fixed Aperture | | | | | | | | | | | |
| 1 | Water-cooled absorber | | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.8 |
| 2 | includes copper block, br | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | water-cooling channels/tu | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | UHV mounting ass'y | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Flanges and Bellows | | 4 | 336.16 | EU | 1.3 | 4 | 20.0 | 80 | MS | 36.20 | 2.9 | 4.2 |
| 6 | Mounting and Positioning | | 1 | 560.26 | EU | 0.6 | 1 | 100.0 | 100 | MS | 36.20 | 3.6 | 4.2 |
| 7 | Access flanges for instal | | 2 | 224.10 | EU | 0.4 | 2 | 8.0 | 16 | MS | 36.20 | 0.6 | 1.0 |
| 8 | Water connections | | 1 | 112.06 | EU | 0.1 | 1 | 8.0 | 8 | MT | 25.20 | 0.2 | 0.3 |
| 9 | Assembly & leak check | | 1 | 112.06 | EU | 0.1 | 1 | 120.0 | 120 | MS | 36.20 | 4.3 | 4.5 |
| 10 | Elec. assembly | | 1 | 112.06 | EU | 0.1 | 1 | 20.0 | 20 | ES | 29.35 | 0.6 | 0.7 |
| 11 | Monitoring sensors for | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 12 | position and temperatures | | 1 | 224.10 | EU | 0.2 | 1 | 20.0 | 20 | MS | 36.20 | 0.7 | 0.9 |
| 13 | Misc. hardware | | 1 | 224.10 | EU | 0.2 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 1.7 |
| 14 | Bakeout | | 1 | 224.10 | EU | 0.2 | 1 | 160.0 | 160 | MS | 36.20 | 5.8 | 6.0 |
| 15 | Alignment calibration | | 1 | 112.06 | EU | 0.1 | 1 | 40.0 | 40 | MT | 25.20 | 1.0 | 1.1 |
| ** | Subtotal ** | | | | | 4.0 | | | 804 | | | 28.4 | 32.5 |
| ** | WBS: 1.2.2.2.1.2 | Fast Valve | | | | | | | | | | | |
| 1 | VG Fast Acting Shutter (1 | | 1 | 15239.15 | VQ | 15.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.2 |
| 2 | blades | EA | 2 | 112.06 | VQ | 0.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.2 |
| 3 | Pneumatic system | | 1 | 224.10 | EU | 0.2 | 1 | 16.0 | 16 | MT | 25.20 | 0.4 | 0.6 |
| 4 | Interlock electronics | | 1 | 0.00 | EU | 0.0 | 1 | 16.0 | 16 | ES | 29.35 | 0.5 | 0.5 |
| 5 | Controls | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 6 | spare guides | EA | 2 | 69.47 | VQ | 0.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.1 |

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Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | Assembly/testing | | 1 | 0.00 | EU | 0.0 | 1 | 16.0 | 16 | MT | 25.20 | 0.4 | 0.4 |
| 8 | Bakeout/vac check | | 1 | 112.06 | EU | 0.1 | 1 | 16.0 | 16 | | 0.00 | 0.0 | 0.1 |
| 9 | triggering unit (see cont | | 1 | 0.00 | VQ | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 10 | detection unit (see contr | | 3 | 0.00 | VQ | 0.0 | 3 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 11 | (ion gage & power supply) | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 12 | modification for larger a | | 1 | 3361.58 | EU | 3.4 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 3.4 |
| ** Subtotal ** | | | | | | 19.3 | | | 64 | | | 1.3 | 20.6 |
| ** WBS: 1.2.2.2.1.3 | Front End Vacuum Sys | | | | | | | | | | | | |
| 1 | 400 l/s pumping station | | 1 | 0.00 | | 0.0 | 1 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 2 | Bellows | EA | 1 | 560.26 | CP | 0.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.6 |
| 3 | Bellows flanges & hardwar | | 1 | 840.39 | EU | 0.8 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 2.3 |
| 4 | Shielding wall spool | | 1 | 1120.53 | EU | 1.1 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 2.6 |
| 5 | Vat Series 48 8''valve | EA | 2 | 15239.15 | VQ | 30.5 | 2 | 8.0 | 16 | MT | 25.20 | 0.4 | 30.9 |
| 6 | Valve mounting & connecti | | 2 | 112.06 | EU | 0.2 | 2 | 30.0 | 60 | MS | 36.20 | 2.2 | 2.4 |
| 7 | Bakeout & vac. Check | | 1 | 560.26 | EU | 0.6 | 1 | 160.0 | 160 | MS | 36.20 | 5.8 | 6.4 |
| ** Subtotal ** | | | | | | 33.8 | | | 316 | | | 11.3 | 45.0 |
| ** WBS: 1.2.2.2.1.4 | Vacuum Pumping Station | | | | | | | | | | | | |
| 1 | 400 l/s vac. pump pkg. | EA | 2 | 11468.58 | CP | 22.9 | 2 | 1.0 | 2 | MT | 25.20 | 0.1 | 23.0 |
| 2 | includes ion pump, tsp, c | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | (controller costed with C | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | (Perkin Elmer''Boostivac' | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | TSP spare filaments | SET | 2 | 140.07 | CP | 0.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.3 |
| 6 | Ion gage and power supply | | 0 | 0.00 | | 0.0 | 2 | 1.0 | 2 | MT | 25.20 | 0.1 | 0.1 |
| 7 | (cost included with Contr | | 1 | 0.00 | XX | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 8 | 2 3/4''roughing valve | | 2 | 1226.98 | CP | 2.5 | 2 | 1.0 | 2 | MT | 25.20 | 0.1 | 2.5 |
| ** Subtotal ** | | | | | | 25.7 | | | 6 | | | 0.2 | 25.8 |
| ** WBS: 1.2.2.2.1.5 | Personnel Safety Shut. | | | | | | | | | | | | |
| 1 | Shutter System: | EA | 1 | 0.00 | EU | 0.0 | 1 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 2 | Vac. Chamber | EA | 1 | 4482.10 | EU | 4.5 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 11.7 |
| 3 | Supports | EA | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.8 |
| 4 | Shutters & mechanism | EA | 2 | 2241.05 | EU | 4.5 | 2 | 250.0 | 500 | MS | 36.20 | 18.1 | 22.6 |
| 5 | Temp. monitor | | 2 | 224.10 | EU | 0.4 | 2 | 8.0 | 16 | MT | 25.20 | 0.4 | 0.9 |
| 6 | Assembly & bakeout | EA | 1 | 224.10 | EU | 0.2 | 1 | 120.0 | 120 | MS | 36.20 | 4.3 | 4.6 |
| 7 | Collimating spool | EA | 1 | 1120.53 | EU | 1.1 | 1 | 80.0 | 80 | MS | 36.20 | 2.9 | 4.0 |
| 8 | Lead Shielding & supports | | 1 | 2801.31 | EU | 2.8 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 4.2 |
| ** Subtotal ** | | | | | | 14.1 | | | 1156 | | | 41.7 | 55.8 |
| ** WBS: 1.2.2.2.1.6 | Front End Photon Shut. | | | | | | | | | | | | |
| 1 | Water-cooled absorber | | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.8 |
| 2 | includes copper block, br | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | water-cooling channels/tu | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | UHV mounting ass'y | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Flanges and Bellows | | 4 | 336.16 | EU | 1.3 | 4 | 20.0 | 80 | MS | 36.20 | 2.9 | 4.2 |
| 6 | Mounting and Positioning | | 1 | 1680.79 | EU | 1.7 | 1 | 160.0 | 160 | MS | 36.20 | 5.8 | 7.5 |
| 7 | Access flanges for instal | | 2 | 224.10 | EU | 0.4 | 2 | 8.0 | 16 | MS | 36.20 | 0.6 | 1.0 |
| 8 | Water & pneumatic utiliti | | 1 | 336.16 | EU | 0.3 | 1 | 16.0 | 16 | MT | 25.20 | 0.4 | 0.7 |
| 9 | Assembly & leak check | | 1 | 112.06 | EU | 0.1 | 1 | 120.0 | 120 | MS | 36.20 | 4.3 | 4.5 |
| 10 | Elec. assembly | | 1 | 112.06 | EU | 0.1 | 1 | 20.0 | 20 | ES | 29.35 | 0.6 | 0.7 |
| 11 | Monitoring sensors for | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 12 | position and temperatures | | 1 | 224.10 | EU | 0.2 | 1 | 20.0 | 20 | MS | 36.20 | 0.7 | 0.9 |
| 13 | Misc. hardware | | 1 | 224.10 | EU | 0.2 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 1.7 |
| 14 | Bakeout | | 1 | 224.10 | EU | 0.2 | 1 | 160.0 | 160 | MS | 36.20 | 5.8 | 6.0 |
| 15 | Alignment calibration | | 1 | 112.06 | EU | 0.1 | 1 | 40.0 | 40 | MT | 25.20 | 1.0 | 1.1 |
| ** Subtotal ** | | | | | | 5.4 | | | 872 | | | 30.8 | 36.2 |
| ** WBS: 1.2.2.2.2 | Mechanical Installation | | | | | | | | | | | | |
| 1 | Final Assembly and Bakeou | | 1 | 560.26 | EU | 0.6 | 1 | 320.0 | 320 | MS | 36.20 | 11.6 | 12.1 |
| 2 | includes misc. materials, | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |

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Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | ass'y shop labor (clean r | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | bakeout | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Installation | | 0 | 0.00 | | 0.0 | 1 | 320.0 | 320 | IMT | 61.60 | 19.7 | 19.7 |
| 6 | Survey & Alignment | | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MT | 25.20 | 5.0 | 5.6 |
| 7 | Pneumatic Service | | 1 | 2241.05 | EU | 2.2 | 1 | 80.0 | 80 | IMT | 61.60 | 4.9 | 7.2 |
| 8 | includes copper tubing, f | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | MT | 25.20 | 1.0 | 1.0 |
| 9 | misc. hardware & instrume | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 1.4 |
| 10 | LCW Service | | 1 | 2241.05 | EU | 2.2 | 1 | 80.0 | 80 | IPL | 61.60 | 4.9 | 7.2 |
| 11 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 2.0 |
| 12 | Unistrut & misc hdwre | | 1 | 2241.05 | EU | 2.2 | 1 | 80.0 | 80 | IMT | 61.60 | 4.9 | 7.2 |
| 13 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 1.4 |
| 14 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 40.0 | 40 | MT | 25.20 | 1.0 | 1.0 |
| 15 | Shielding Wall modif. | | 1 | 2241.05 | EU | 2.2 | 1 | 160.0 | 160 | IMT | 61.60 | 9.9 | 12.1 |
| 16 | Lead Safety Shielding | | 1 | 2801.31 | EU | 2.8 | 1 | 40.0 | 40 | MT | 25.20 | 1.0 | 3.8 |
| 17 | '' | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | IMT | 61.60 | 2.5 | 2.5 |
| 18 | Nitrogen - air pressure b | | 1 | 2241.05 | | 2.2 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 4.3 |
| 19 | '' | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | IMT | 61.60 | 4.9 | 4.9 |
| ** Subtotal ** | | | | | | 15.1 | | | 1720 | | | 78.3 | 93.4 |
| ** WBS: 1.2.2.2.3 | | Front End Controls | | | | | | | | | | | |
| 1 | Intelligent Local Control | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 2 | 1 ILC per device plus pro | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | Photon Shutter | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 4 | Isolation Valves | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 5 | Fast Valve | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 6 | Safety Shutter & interloc | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 7 | Water flow switches & int | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 8 | Temp. sensors & interlock | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 9 | ALS system data | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 10 | Vacuum system | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 11 | Cables (see installation) | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 12 | System check & debug | | 1 | 0.00 | EU | 0.0 | 1 | 40.0 | 40 | CP | 50.55 | 2.0 | 2.0 |
| 13 | Vacuum Pump Controller | | 1 | 4229.98 | CP | 4.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 4.2 |
| 14 | Ion Gage & Controller | | 1 | 3986.83 | CP | 4.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 4.0 |
| 15 | Fast Valve Triggering Uni | | 1 | 2498.77 | VQ | 2.5 | 1 | 4.0 | 4 | ES | 29.35 | 0.1 | 2.6 |
| 16 | Fast Valve Detection Unit | | 3 | 3762.72 | CP | 11.3 | 3 | 4.0 | 12 | MT | 25.20 | 0.3 | 11.6 |
| ** Subtotal ** | | | | | | 34.6 | | | 216 | | | 10.5 | 45.1 |
| ** WBS: 1.2.2.2.4 | | Electrical Installation | | | | | | | | | | | |
| 1 | Double Rack,84"x24'' | EA | 1 | 1008.47 | CP | 1.0 | 1 | 8.0 | 8 | ES | 29.35 | 0.2 | 1.2 |
| 2 | BA Panel 3 PH 30A | EA | 1 | 56.03 | CP | 0.1 | 1 | 0.5 | 0 | ES | 29.35 | 0.0 | 0.1 |
| 3 | Breaker Panel | EA | 2 | 182.64 | CP | 0.4 | 2 | 4.0 | 8 | ES | 29.35 | 0.2 | 0.6 |
| 4 | Plug Strip | EA | 2 | 22.41 | EU | 0.0 | 2 | 1.0 | 2 | ES | 29.35 | 0.1 | 0.1 |
| 5 | X-conn Blks & Frame | EA | 1 | 252.12 | CP | 0.3 | 1 | 24.0 | 24 | ES | 29.35 | 0.7 | 1.0 |
| 6 | RLY Blks & Frame | EA | 1 | 549.06 | CP | 0.5 | 1 | 24.0 | 24 | ES | 29.35 | 0.7 | 1.3 |
| 7 | U-panel w/BNC's | EA | 2 | 67.23 | CP | 0.1 | 2 | 2.0 | 4 | ES | 29.35 | 0.1 | 0.3 |
| 8 | Rack Fans | EA | 2 | 56.03 | CP | 0.1 | 2 | 1.0 | 2 | ES | 29.35 | 0.1 | 0.2 |
| 9 | Cables | | 0 | 84.04 | CP | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 10 | Photon Shutter | EA | 5 | 84.04 | CP | 0.4 | 5 | 1.0 | 5 | IEL | 58.20 | 0.3 | 0.7 |
| 11 | Isolation Valves (2) | EA | 8 | 84.04 | CP | 0.7 | 8 | 1.0 | 8 | IEL | 58.20 | 0.5 | 1.1 |
| 12 | Safety Shutter | EA | 6 | 84.04 | CP | 0.5 | 6 | 1.0 | 6 | IEL | 58.20 | 0.3 | 0.9 |
| 13 | ALS system data | EA | 6 | 84.04 | CP | 0.5 | 6 | 1.0 | 6 | IEL | 58.20 | 0.3 | 0.9 |
| 14 | Ion Gages | EA | 4 | 84.04 | CP | 0.3 | 4 | 1.0 | 4 | IEL | 58.20 | 0.2 | 0.6 |
| 15 | Fast Valve | EA | 6 | 84.04 | CP | 0.5 | 6 | 1.0 | 6 | IEL | 58.20 | 0.3 | 0.9 |
| 16 | Beam Position Monitor | EA | 2 | 84.04 | CP | 0.2 | 6 | 1.0 | 6 | IEL | 58.20 | 0.3 | 0.5 |
| 17 | Water Flow switches | EA | 4 | 168.07 | CP | 0.7 | 4 | 0.5 | 2 | ES | 29.35 | 0.1 | 0.7 |
| 18 | Temp. Sensors & Cables | EA | 4 | 112.06 | EU | 0.4 | 4 | 1.0 | 4 | IEL | 58.20 | 0.2 | 0.7 |
| 19 | Temp. Monitor Interlocks | | 1 | 336.16 | EU | 0.3 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 1.5 |
| 20 | Video camera & lens | EA | 1 | 840.39 | CP | 0.8 | 1 | 4.0 | 4 | ES | 29.35 | 0.1 | 1.0 |
| 21 | Video monitor | EA | 1 | 336.16 | CP | 0.3 | 1 | 0.5 | 0 | ES | 29.35 | 0.0 | 0.4 |
| 22 | RG59 COAX camera to monit | | 1 | 56.03 | EU | 0.1 | 1 | 1.0 | 1 | IEL | 58.20 | 0.1 | 0.1 |
| 23 | connectors for video cabl | | 2 | 5.61 | EU | 0.0 | 2 | 0.5 | 1 | ES | 29.35 | 0.0 | 0.0 |
| 24 | Misc Elec. | | 1 | 1120.53 | | 1.1 | 1 | 40.0 | 40 | IEL | 58.20 | 2.3 | 3.4 |
| 25 | Misc. Elec | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 1.2 |

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Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | Thermocouple Monitor & re | | 1 | 560.26 | CP | 0.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.6 |
| 27 | Thermocouple scanner | | 1 | 347.36 | CP | 0.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.3 |
| 28 | Monitor Light Panels | | 5 | 224.10 | CP | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 29 | Key Panel | | 1 | 280.13 | CP | 0.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.3 |
| 30 | Push Button Panel (C2) | | 1 | 224.10 | CP | 0.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.2 |
| 31 | Breaker Panel (P2) | | 1 | 224.10 | CP | 0.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.2 |
| 32 | Monitor Panels Wiring & i | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | ES | 29.35 | 2.3 | 2.3 |
| ** Subtotal ** | | | | | | 12.2 | | | 326 | | | 12.0 | 24.3 |
| ** WBS: 1.2.2.3.1.1.1 | Photon BPM | | | | | | | | | | | | |
| 1 | Knife edge/Heat Absorber | | 4 | 224.10 | EU | 0.9 | 4 | 100.0 | 400 | MS | 36.20 | 14.5 | 15.4 |
| 2 | Knife Edge Mounting | | 4 | 1680.79 | EU | 6.7 | 4 | 200.0 | 800 | MS | 36.20 | 29.0 | 35.7 |
| 3 | Vac. Chamber | | 1 | 3361.58 | EU | 3.4 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 10.6 |
| 4 | Support Stand | | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.8 |
| 5 | Assembly & Bakeout | | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.8 |
| 6 | Alignment Calibration | | 1 | 112.06 | EU | 0.1 | 1 | 200.0 | 200 | MT | 25.20 | 5.0 | 5.2 |
| ** Subtotal ** | | | | | | 12.2 | | | 2000 | | | 70.2 | 82.4 |
| ** WBS: 1.2.2.3.1.1.2 | Spherical Mirrors | | | | | | | | | | | | |
| 1 | Mirror blank & mask | EA | 2 | 1120.53 | EU | 2.2 | 2 | 500.0 | 1000 | MS | 36.20 | 36.2 | 38.4 |
| 2 | (machined, brazed assy, w | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | Polishing | EA | 2 | 13446.30 | EU | 26.9 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 26.9 |
| 4 | (close tolerance spherica | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Optical coating | EA | 2 | 2241.05 | EU | 4.5 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 4.5 |
| 6 | Mirror Mounting | EA | 2 | 2241.05 | EU | 4.5 | 2 | 400.0 | 800 | MS | 36.20 | 29.0 | 33.4 |
| 7 | (machining, welding, etc. | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 8 | Mirror Positioning ( | EA | 2 | 8403.94 | EU | 16.8 | 2 | 200.0 | 400 | MS | 36.20 | 14.5 | 31.3 |
| 9 | (slides, steppers, encode | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 10 | Mirror Assembly & bakeout | | 1 | 560.26 | EU | 0.6 | 2 | 120.0 | 240 | MS | 36.20 | 8.7 | 9.2 |
| 11 | Vacuum Chamber | EA | 1 | 15127.09 | A86 | 15.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.1 |
| 12 | Vac. Chamber bakeout & va | | 1 | 224.10 | A86 | 0.2 | 1 | 160.0 | 160 | MS | 36.20 | 5.8 | 6.0 |
| 13 | vacuum system included se | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 14 | Exit port mask & beam dum | | 1 | 1120.53 | EU | 1.1 | 1 | 100.0 | 100 | MS | 36.20 | 3.6 | 4.7 |
| 15 | Supports & chamber mounti | | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.8 |
| ** Subtotal ** | | | | | | 72.5 | | | 2900 | | | 105.0 | 177.5 |
| ** WBS: 1.2.2.3.1.1.3 | Branchline Vac Sys | | | | | | | | | | | | |
| 1 | Bellows | EA | 4 | 560.26 | CP | 2.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.2 |
| 2 | Bellows hardware: | EA | 4 | 840.39 | EU | 3.4 | 4 | 40.0 | 160 | MS | 36.20 | 5.8 | 9.2 |
| 3 | (flanges,constraints,weld | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | Spools | EA | 4 | 1120.53 | CP | 4.5 | 4 | 4.0 | 16 | MT | 25.20 | 0.4 | 4.9 |
| 5 | Spool mounting & supports | | 4 | 224.10 | EU | 0.9 | 4 | 80.0 | 320 | MS | 36.20 | 11.6 | 12.5 |
| 6 | 6''valve, manual | EA | 2 | 11205.25 | CP | 22.4 | 2 | 2.0 | 4 | MT | 25.20 | 0.1 | 22.5 |
| 7 | 4''valve, manual | EA | 2 | 8403.94 | CP | 16.8 | 2 | 2.0 | 4 | MT | 25.20 | 0.1 | 16.9 |
| 8 | Misc. UHV hardware & asse | | 1 | 5602.63 | EU | 5.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 12.8 |
| 9 | Bakeout & vac check | | 1 | 224.10 | EU | 0.2 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.5 |
| ** Subtotal ** | | | | | | 56.0 | | | 904 | | | 32.5 | 88.5 |
| ** WBS: 1.2.2.3.1.1.4 | Vacuum Pump Stations | | | | | | | | | | | | |
| 1 | 400 l/s vac. pump pkg. | EA | 4 | 11468.58 | CP | 45.9 | 4 | 1.0 | 4 | MT | 25.20 | 0.1 | 46.0 |
| 3 | (controller costed with C | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | (Perkin Elmer''Boostivac' | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | TSP spare filaments | SET | 4 | 140.07 | CP | 0.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.6 |
| 6 | Ion gage and power supply | EA | 4 | 0.00 | VQ | 0.0 | 4 | 1.0 | 4 | MT | 25.20 | 0.1 | 0.1 |
| 7 | (cost included with Contr | | 1 | 0.00 | XX | 0.0 | 0 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 8 | 2 3/4''roughing valve | | 4 | 1226.98 | CP | 4.9 | 4 | 1.0 | 4 | MT | 25.20 | 0.1 | 5.0 |
| ** Subtotal ** | | | | | | 51.3 | | | 12 | | | 0.3 | 51.6 |
| ** WBS: 1.2.2.3.1.2.1 | High Resolution Double Crystal Monochromator | | | | | | | | | | | | |
| 1 | 2-Crystal Mon'r System | TENTH | 10 | 26270.72 | VQ | 262.7 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 262.7 |
| 2 | Support Stamd | | 1 | 2241.05 | EU | 2.2 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 9.5 |

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Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Add'l Vac. Chamber ports | | 1 | 5602.63 | EU | 5.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 5.6 |
| 4 | Shipping | | 1 | 1120.53 | EU | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 5 | Ass'y, Bakeout, Vac. Chec | | 1 | 224.10 | EU | 0.2 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.5 |
| 6 | Alignment & Calibration | | 1 | 224.10 | EU | 0.2 | 1 | 200.0 | 200 | MT | 25.20 | 5.0 | 5.3 |
| 7 | Crystals | EA | 6 | 1120.53 | EU | 6.7 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 6.7 |
| ** | Subtotal ** | | | | | 278.8 | | | 600 | | | 19.5 | 298.4 |
| ** | WBS: 1.2.2.3.1.3 Mechanical Installation | | | | | | | | | | | | |
| 1 | Final Assembly and Bakeou | | 1 | 560.26 | EU | 0.6 | 1 | 400.0 | 400 | MS | 36.20 | 14.5 | 15.0 |
| 2 | includes misc. materials, | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | ass'y shop labor (clean r | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | bakeout | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Installation | | 0 | 0.00 | | 0.0 | 1 | 720.0 | 720 | IMT | 61.60 | 44.4 | 44.4 |
| 6 | Survey & Alignment | | 1 | 560.26 | EU | 0.6 | 1 | 100.0 | 100 | MT | 25.20 | 2.5 | 3.1 |
| 7 | Pneumatic Service | | 1 | 2241.05 | EU | 2.2 | 1 | 80.0 | 80 | IMT | 61.60 | 4.9 | 7.2 |
| 8 | includes copper tubing, f | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | MT | 25.20 | 1.0 | 1.0 |
| 10 | LCW Service | | 1 | 2241.05 | EU | 2.2 | 1 | 80.0 | 80 | IPL | 61.60 | 4.9 | 7.2 |
| 11 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 2.0 |
| 12 | Unistrut & misc. hdwre | | 1 | 3921.84 | EU | 3.9 | 1 | 80.0 | 80 | IMT | 61.60 | 4.9 | 8.8 |
| 13 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 2.0 |
| 14 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 80.0 | 80 | MS | 36.20 | 2.9 | 2.9 |
| 15 | Beam stop lead shielding | | 1 | 3361.58 | EU | 3.4 | 1 | 120.0 | 120 | MS | 36.20 | 4.3 | 7.7 |
| 16 | and shielding enclosure | | 1 | 0.00 | | 0.0 | 1 | 40.0 | 40 | IMT | 61.60 | 2.5 | 2.5 |
| ** | Subtotal ** | | | | | 12.9 | | | 1900 | | | 90.9 | 103.8 |
| ** | WBS: 1.2.2.3.1.4 Photon Transport Controls | | | | | | | | | | | | |
| 1 | Ethernet Controller Board | | 1 | 2241.05 | EU | 2.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.2 |
| 2 | Microcomputer: data stor, | | 1 | 11205.25 | EU | 11.2 | 1 | 40.0 | 40 | CP | 50.55 | 2.0 | 13.2 |
| 3 | Ethernet cable (20 m) | | 1 | 112.06 | EU | 0.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.1 |
| 4 | Ethernet Tranceiver | | 1 | 392.19 | EU | 0.4 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.4 |
| 5 | Intelligent Local Control | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 6 | 1 ILC per device plus pro | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 7 | Mirrors | | 2 | 1568.73 | EU | 3.1 | 2 | 20.0 | 40 | CP | 50.55 | 2.0 | 5.2 |
| 8 | | | 0 | 0.00 | EU | 0.0 | 0 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 9 | Insertion Device | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 10 | ALS system data | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 11 | Beam Position Monitoring | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 12 | B.P.M. Programmable power | | 1 | 1680.79 | EU | 1.7 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.7 |
| 13 | System check & debug | | 1 | 0.00 | EU | 0.0 | 1 | 40.0 | 40 | CP | 50.55 | 2.0 | 2.0 |
| 14 | | | 0 | 0.00 | EU | 0.0 | 0 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 15 | Water flow switches & tem | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | | 0.00 | 0.0 | 1.6 |
| 16 | Cables for controls | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 17 | (see elec installation) | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 18 | Vac. Pump Controllers | | 4 | 4229.98 | CP | 16.9 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 16.9 |
| 19 | Ion Gages & Controllers | | 2 | 3986.83 | CP | 8.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 8.0 |
| 20 | Data Aquisition System (K | | 1 | 6723.15 | CP | 6.7 | 1 | 40.0 | 40 | CP | 50.55 | 2.0 | 8.7 |
| 21 | | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| ** | Subtotal ** | | | | | 56.7 | | | 260 | | | 12.1 | 68.8 |
| ** | WBS: 1.2.2.3.1.5 Monochromator Controls | | | | | | | | | | | | |
| 1 | Intelligent Local Control | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 2 | 1 ILC per device plus pro | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | Monochromator | | 2 | 1568.73 | EU | 3.1 | 2 | 20.0 | 40 | CP | 50.55 | 2.0 | 5.2 |
| 4 | Water flow switches & tem | | 2 | 1568.73 | EU | 3.1 | 2 | 20.0 | 40 | CP | 50.55 | 2.0 | 5.2 |
| 5 | Insertion dev. controls | | 2 | 1568.73 | EU | 3.1 | 2 | 20.0 | 40 | CP | 50.55 | 2.0 | 5.2 |
| 6 | Ent. & exit slits | | 2 | 1568.73 | EU | 3.1 | 2 | 20.0 | 40 | CP | 50.55 | 2.0 | 5.2 |
| 7 | System check & debug | | 0 | 0.00 | EU | 0.0 | 2 | 40.0 | 80 | CP | 50.55 | 4.0 | 4.0 |
| 8 | Ion Gage & controller | | 2 | 3986.83 | CP | 8.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 8.0 |
| ** | Subtotal ** | | | | | 20.5 | | | 240 | | | 12.1 | 32.7 |
| ** | WBS: 1.2.2.3.1.6 Electrical Installation | | | | | | | | | | | | |
| 1 | Double Rack,84"x24'' | EA | 1 | 1008.47 | CP | 1.0 | 1 | 8.0 | 8 | ES | 29.35 | 0.2 | 1.2 |

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| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | BA Panel 3 PH 30A | EA | 1 | 56.03 | CP | 0.1 | 1 | 0.5 | 0 | ES | 29.35 | 0.0 | 0.1 |
| 3 | Breaker Panel | EA | 2 | 182.64 | CP | 0.4 | 2 | 4.0 | 8 | ES | 29.35 | 0.2 | 0.6 |
| 4 | Plug Strip | EA | 2 | 22.41 | EU | 0.0 | 2 | 1.0 | 2 | ES | 29.35 | 0.1 | 0.1 |
| 5 | X-conn Blks & Frame | EA | 1 | 252.12 | CP | 0.3 | 1 | 24.0 | 24 | ES | 29.35 | 0.7 | 1.0 |
| 6 | RLY Blks & Frame | EA | 1 | 549.06 | CP | 0.5 | 1 | 24.0 | 24 | ES | 29.35 | 0.7 | 1.3 |
| 7 | U-panel w/BNC's | EA | 2 | 67.23 | CP | 0.1 | 2 | 2.0 | 4 | ES | 29.35 | 0.1 | 0.3 |
| 8 | Rack Fans | EA | 2 | 56.03 | CP | 0.1 | 2 | 1.0 | 2 | ES | 29.35 | 0.1 | 0.2 |
| 9 | Cables | | 0 | 84.04 | CP | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 10 | Mirrors | EA | 10 | 84.04 | CP | 0.8 | 10 | 1.0 | 10 | IEL | 58.20 | 0.6 | 1.4 |
| 11 | Pinhole | EA | 10 | 84.04 | CP | 0.8 | 10 | 1.0 | 10 | IEL | 58.20 | 0.6 | 1.4 |
| 12 | ALS System Data | EA | 6 | 84.04 | CP | 0.5 | 6 | 1.0 | 6 | IEL | 58.20 | 0.3 | 0.9 |
| 13 | Ion Gages | EA | 6 | 84.04 | CP | 0.5 | 6 | 1.0 | 6 | IEL | 58.20 | 0.3 | 0.9 |
| 14 | Monochromator | EA | 4 | 84.04 | CP | 0.3 | 4 | 1.0 | 4 | IEL | 58.20 | 0.2 | 0.6 |
| 15 | Water Flow switches | EA | 4 | 168.07 | EU | 0.7 | 4 | 0.5 | 2 | ES | 29.35 | 0.1 | 0.7 |
| 16 | Temp. Sensors and Cables | EA | 4 | 112.06 | EU | 0.4 | 4 | 1.0 | 4 | IEL | 58.20 | 0.2 | 0.7 |
| 17 | Temp. Monitor Interlocks | | 1 | 336.16 | EU | 0.3 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 1.5 |
| 18 | Misc Elec. Installation | | 1 | 560.26 | EU | 0.6 | 1 | 40.0 | 40 | IEL | 58.20 | 2.3 | 2.9 |
| 19 | Misc. Elec Assembly | | 1 | 560.26 | EU | 0.6 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 1.7 |
| 20 | Thermocouple Monitor & re | | 1 | 560.26 | CP | 0.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.6 |
| 21 | Thermocouple scanner | | 1 | 347.36 | CP | 0.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.3 |
| 22 | Monitor Lights panel | | 5 | 224.10 | CP | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 23 | Key Panel | | 1 | 280.13 | CP | 0.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.3 |
| 24 | Push Button Panel | | 1 | 224.10 | CP | 0.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.2 |
| 25 | Breaker Panel | | 1 | 224.10 | CP | 0.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.2 |
| 26 | Monitor Panels Wiring & I | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | ES | 29.35 | 2.3 | 2.3 |
| 27 | PLIC (Rad. Safety) | FT | 100 | 11.20 | CP | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 28 | PLIC Camac H.V. P.S. | EA | 1 | 1120.53 | CP | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 29 | PLIC Monitoring card | EA | 1 | 2801.31 | CP | 2.8 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.8 |
| 30 | PLIC - other elec. | | 1 | 3361.58 | CP | 3.4 | 1 | 14.0 | 14 | IEL | 58.20 | 0.8 | 4.2 |
| 31 | PLIC - Installation | FT | 100 | 1.13 | EU | 0.1 | 100 | 0.0 | 3 | IEL | 58.20 | 0.2 | 0.3 |
| 32 | PLIC - Installation | | 1 | 840.39 | | 0.8 | 1 | 8.0 | 8 | IEL | 58.20 | 0.5 | 1.3 |
| 33 | Monochromator System Elec | | 1 | 5602.63 | EU | 5.6 | 1 | 80.0 | 80 | ES | 29.35 | 2.3 | 8.0 |
| 34 | ''(instrumtn, monitors, p | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | IEL | 58.20 | 2.3 | 2.3 |
| ** Subtotal ** | | | | | | 25.8 | | | 459 | | | 17.6 | 43.5 |
| ** WBS: 1.2.2.3.1.7 | Mechanical & Electrical System Integrati | | | | | | | | | | | | |
| 1 | Vac. Roughing System | EA | 1 | 11205.25 | EU | 11.2 | 1 | 20.0 | 20 | MT | 25.20 | 0.5 | 11.7 |
| 2 | portable vacuum system, | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | 'Megasorb''unit | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | (per E. Hoyer) | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Final alignment and calib | | 1 | 560.26 | EU | 0.6 | 1 | 400.0 | 400 | MT | 25.20 | 10.1 | 10.6 |
| 6 | Beam line controls check- | | 1 | 1120.53 | EU | 1.1 | 1 | 400.0 | 400 | MT | 25.20 | 10.1 | 11.2 |
| 7 | (includes instrumentation | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | ES | 29.35 | 4.7 | 4.7 |
| 8 | monitoring & interlocks, | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | IEL | 58.20 | 9.3 | 9.3 |
| 9 | communications, final adj | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | IMT | 61.60 | 9.9 | 9.9 |
| 10 | etc.) | | 0 | 0.00 | | 0.0 | 1 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 11 | Vacuum system check-out | | 1 | 560.26 | EU | 0.6 | 1 | 500.0 | 500 | MT | 25.20 | 12.6 | 13.2 |
| ** Subtotal ** | | | | | | 13.4 | | | 1800 | | | 57.1 | 70.6 |
| ** WBS: 1.2.2.3.2 | Crystallography Station | | | | | | | | | | | | |
| 1 | Huber Goniometer | | 1 | 85000.00 | | 85.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 85.0 |
| 2 | Huber Table w/manipulatn | | 1 | 20000.00 | | 20.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.0 |
| 3 | MicroVAX computer system | | 1 | 40000.00 | | 40.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 40.0 |
| 4 | Data storage & archiving | | 1 | 25000.00 | | 25.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 25.0 |
| 5 | Electronics & interfaces | | 1 | 30000.00 | | 30.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 30.0 |
| 6 | Hutch | | 1 | 25000.00 | | 25.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 25.0 |
| 7 | Image plate scanner | | 1 | 155000.00 | | 155.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 155.0 |
| 8 | Software | | 1 | 52000.00 | | 52.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 52.0 |
| ** Subtotal ** | | | | | | 432.0 | | | 0 | | | 0.0 | 432.0 |
| ** WBS: 1.2.2.3.3 | Small Angle Scattering Station | | | | | | | | | | | | |
| 1 | Scatrng Cell w/envrn ctrl | | 1 | 12000.00 | | 12.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 12.0 |
| 2 | Hi/lo pressure/temp cell | | 1 | 8000.00 | | 8.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 8.0 |

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| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST COST | BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Sample rotation fixture | | 1 | 10000.00 | | 10.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 10.0 |
| 4 | Multiplexing detector | | 1 | 50000.00 | | 50.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 50.0 |
| 5 | Detector electronics | | 1 | 30000.00 | | 30.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 30.0 |
| 6 | Plumbing,windows,vac etc. | | 1 | 25000.00 | | 25.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 25.0 |
| ** | Subtotal ** | | | | | 135.0 | | | 0 | | | 0.0 | 135.0 |
| ** | WBS: 1.2.2.4.1.1.1 | Photon BPM | | | | | | | | | | | |
| 1 | Knife edge/Heat Absorber | | 4 | 224.10 | EU | 0.9 | 4 | 100.0 | 400 | MS | 36.20 | 14.5 | 15.4 |
| 2 | Knife Edge Mounting | | 4 | 1680.79 | EU | 6.7 | 4 | 200.0 | 800 | MS | 36.20 | 29.0 | 35.7 |
| 3 | Vac. Chamber | | 1 | 3361.58 | EU | 3.4 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 10.6 |
| 4 | Support Stand | | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.8 |
| 5 | Assembly & Bakeout | | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.8 |
| 6 | Alignment Calibration | | 1 | 112.06 | EU | 0.1 | 1 | 200.0 | 200 | MT | 25.20 | 5.0 | 5.2 |
| ** | Subtotal ** | | | | | 12.2 | | | 2000 | | | 70.2 | 82.4 |
| ** | WBS: 1.2.2.4.1.1.2 | Spherical Mirrors | | | | | | | | | | | |
| 1 | Mirror blank & mask | EA | 2 | 1120.53 | EU | 2.2 | 2 | 500.0 | 1000 | MS | 36.20 | 36.2 | 38.4 |
| 2 | (machined, brazed assy, w | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | Polishing | EA | 2 | 13446.30 | EU | 26.9 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 26.9 |
| 4 | (close tolerance spherica | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Optical coating | EA | 2 | 2241.05 | EU | 4.5 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 4.5 |
| 6 | Mirror Mounting | EA | 2 | 2241.05 | EU | 4.5 | 2 | 400.0 | 800 | MS | 36.20 | 29.0 | 33.4 |
| 7 | (machining, welding, etc. | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 8 | Mirror Positioning ( | EA | 2 | 8403.94 | EU | 16.8 | 2 | 200.0 | 400 | MS | 36.20 | 14.5 | 31.3 |
| 9 | (slides, steppers, encode | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 10 | Mirror Assembly & bakeout | | 1 | 560.26 | EU | 0.6 | 2 | 120.0 | 240 | MS | 36.20 | 8.7 | 9.2 |
| 11 | Vacuum Chamber | EA | 1 | 15127.09 | A86 | 15.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.1 |
| 12 | Vac. Chamber bakeout & va | | 1 | 224.10 | A86 | 0.2 | 1 | 160.0 | 160 | MS | 36.20 | 5.8 | 6.0 |
| 13 | vacuum system included se | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 14 | Exit port mask & beam dum | | 1 | 1120.53 | EU | 1.1 | 1 | 100.0 | 100 | MS | 36.20 | 3.6 | 4.7 |
| 15 | Supports & chamber mounti | | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.8 |
| ** | Subtotal ** | | | | | 72.5 | | | 2900 | | | 105.0 | 177.5 |
| ** | WBS: 1.2.2.4.1.1.3 | Branchline Vac Sys | | | | | | | | | | | |
| 1 | Bellows | EA | 4 | 560.26 | CP | 2.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.2 |
| 2 | Bellows hardware: | EA | 4 | 840.39 | EU | 3.4 | 4 | 40.0 | 160 | MS | 36.20 | 5.8 | 9.2 |
| 3 | (flanges,constraints,weld | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | Spools | EA | 4 | 1120.53 | CP | 4.5 | 4 | 4.0 | 16 | MT | 25.20 | 0.4 | 4.9 |
| 5 | Spool mounting & supports | | 4 | 224.10 | EU | 0.9 | 4 | 80.0 | 320 | MS | 36.20 | 11.6 | 12.5 |
| 6 | 6''valve, manual | EA | 2 | 11205.25 | CP | 22.4 | 2 | 2.0 | 4 | MT | 25.20 | 0.1 | 22.5 |
| 7 | 4''valve, manual | EA | 2 | 8403.94 | CP | 16.8 | 2 | 2.0 | 4 | MT | 25.20 | 0.1 | 16.9 |
| 8 | Misc. UHV hardware & asse | | 1 | 5602.63 | EU | 5.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 12.8 |
| 9 | Bakeout & vac check | | 1 | 224.10 | EU | 0.2 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.5 |
| ** | Subtotal ** | | | | | 56.0 | | | 904 | | | 32.5 | 88.5 |
| ** | WBS: 1.2.2.4.1.1.4 | Vacuum Pump Stations | | | | | | | | | | | |
| 1 | 400 l/s vac. pump pkg. | EA | 4 | 11468.58 | CP | 45.9 | 4 | 1.0 | 4 | MT | 25.20 | 0.1 | 46.0 |
| 3 | (controller costed with C | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | (Perkin Elmer''Boostivac' | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | TSP spare filaments | SET | 4 | 140.07 | CP | 0.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.6 |
| 6 | Ion gage and power supply | | 0 | 0.00 | | 0.0 | 4 | 1.0 | 4 | MT | 25.20 | 0.1 | 0.1 |
| 7 | (cost included with Contr | | 1 | 0.00 | XX | 0.0 | 0 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 8 | 2 3/4''roughing valve | | 4 | 1226.98 | CP | 4.9 | 4 | 1.0 | 4 | MT | 25.20 | 0.1 | 5.0 |
| ** | Subtotal ** | | | | | 51.3 | | | 12 | | | 0.3 | 51.6 |
| ** | WBS: 1.2.2.4.1.2.1 | High Resolution Double Crystal Monochromator | | | | | | | | | | | |
| 1 | 2-Crystal Mon'r System | TENTH | 10 | 26270.72 | VQ | 262.7 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 262.7 |
| 2 | Support Stamd | | 1 | 2241.05 | EU | 2.2 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 9.5 |
| 3 | Add'l Vac. Chamber ports | | 1 | 5602.63 | EU | 5.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 5.6 |
| 4 | Shipping | | 1 | 1120.53 | EU | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 5 | Ass'y, Bakeout, Vac. Chec | | 1 | 224.10 | EU | 0.2 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.5 |

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| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST COST | BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | Alignment & Calibration | | 1 | 224.10 | EU | 0.2 | 1 | 200.0 | 200 | MT | 25.20 | 5.0 | 5.3 |
| 7 | Crystals | EA | 6 | 1120.53 | EU | 6.7 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 6.7 |
| ** | Subtotal ** | | | | | 278.8 | | | 600 | | | 19.5 | 298.4 |
| ** | WBS: 1.2.2.4.1.2.2 | Pre-Monochromator System (Multilayer) | | | | | | | | | | | |
| 1 | 2-Crystal Mon'r System | TENTH | 10 | 26270.72 | VQ | 262.7 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 262.7 |
| 2 | Support Stamd | | 1 | 2241.05 | EU | 2.2 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 9.5 |
| 3 | Add'l Vac. Chamber ports | | 1 | 5602.63 | EU | 5.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 5.6 |
| 4 | Shipping | | 1 | 1120.53 | EU | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 5 | Ass'y, Bakeout, Vac. Chec | | 1 | 224.10 | EU | 0.2 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.5 |
| 6 | Alignment & Calibration | | 1 | 224.10 | EU | 0.2 | 1 | 200.0 | 200 | MT | 25.20 | 5.0 | 5.3 |
| 7 | Water-cooled Substrates | EA | 3 | 560.26 | EU | 1.7 | 3 | 100.0 | 300 | MS | 36.20 | 10.9 | 12.5 |
| 8 | Un-cooled Substrates | | 3 | 112.06 | EU | 0.3 | 3 | 20.0 | 60 | MS | 36.20 | 2.2 | 2.5 |
| 9 | Substrate polishing | | 6 | 224.10 | EU | 1.3 | 6 | 40.0 | 240 | MT | 25.20 | 6.0 | 7.4 |
| 10 | Multilayer Coating | | 6 | 1120.53 | EU | 6.7 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 6.7 |
| ** | Subtotal ** | | | | | 282.2 | | | 1200 | | | 38.6 | 320.8 |
| ** | WBS: 1.2.2.4.1.3 | Mechanical Installation | | | | | | | | | | | |
| 1 | Final Assembly and Bakeou | | 1 | 560.26 | EU | 0.6 | 1 | 400.0 | 400 | MS | 36.20 | 14.5 | 15.0 |
| 2 | includes misc. materials, | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | ass'y shop labor (clean r | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | bakeout | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Installation | | 0 | 0.00 | | 0.0 | 1 | 720.0 | 720 | IMT | 61.60 | 44.4 | 44.4 |
| 6 | Survey & Alignment | | 1 | 560.26 | EU | 0.6 | 1 | 100.0 | 100 | MT | 25.20 | 2.5 | 3.1 |
| 7 | Pneumatic Service | | 1 | 2241.05 | EU | 2.2 | 1 | 80.0 | 80 | IMT | 61.60 | 4.9 | 7.2 |
| 8 | includes copper tubing, f | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | MT | 25.20 | 1.0 | 1.0 |
| 10 | LCW Service | | 1 | 2241.05 | EU | 2.2 | 1 | 80.0 | 80 | IPL | 61.60 | 4.9 | 7.2 |
| 11 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 2.0 |
| 12 | Unistrut & misc. hdwre | | 1 | 3921.84 | EU | 3.9 | 1 | 80.0 | 80 | IMT | 61.60 | 4.9 | 8.8 |
| 13 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 2.0 |
| 14 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 80.0 | 80 | MS | 36.20 | 2.9 | 2.9 |
| 15 | Beam stop lead shielding | | 1 | 3361.58 | EU | 3.4 | 1 | 120.0 | 120 | MS | 36.20 | 4.3 | 7.7 |
| 16 | and shielding enclosure | | 1 | 0.00 | | 0.0 | 1 | 40.0 | 40 | IMT | 61.60 | 2.5 | 2.5 |
| ** | Subtotal ** | | | | | 12.9 | | | 1900 | | | 90.9 | 103.8 |
| ** | WBS: 1.2.2.4.1.4 | Photon Transport Controls | | | | | | | | | | | |
| 1 | Ethernet Controller Board | | 1 | 2241.05 | EU | 2.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.2 |
| 2 | Microcomputer: data stor, | | 1 | 11205.25 | EU | 11.2 | 1 | 40.0 | 40 | CP | 50.55 | 2.0 | 13.2 |
| 3 | Ethernet cable (20 m) | | 1 | 112.06 | EU | 0.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.1 |
| 4 | Ethernet Tranceiver | | 1 | 392.19 | EU | 0.4 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.4 |
| 5 | Intelligent Local Control | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 6 | 1 ILC per device plus pro | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 7 | Mirrors | | 2 | 1568.73 | EU | 3.1 | 2 | 20.0 | 40 | CP | 50.55 | 2.0 | 5.2 |
| 8 | | | 0 | 0.00 | EU | 0.0 | 0 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 9 | Insertion Device | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 10 | ALS system data | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 11 | Beam Position Monitoring | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 12 | B.P.M. Programmable power | | 1 | 1680.79 | EU | 1.7 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.7 |
| 13 | System check & debug | | 1 | 0.00 | EU | 0.0 | 1 | 40.0 | 40 | CP | 50.55 | 2.0 | 2.0 |
| 14 | | | 0 | 0.00 | EU | 0.0 | 0 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 15 | Water flow switches & tem | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | | 0.00 | 0.0 | 1.6 |
| 16 | Cables for controls | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 17 | (see elec installation) | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 18 | Vac. Pump Controllers | | 4 | 4229.98 | CP | 16.9 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 16.9 |
| 19 | Ion Gages & Controllers | | 2 | 3986.83 | CP | 8.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 8.0 |
| 20 | Data Aquisition System (K | | 1 | 6723.15 | CP | 6.7 | 1 | 40.0 | 40 | CP | 50.55 | 2.0 | 8.7 |
| 21 | | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| ** | Subtotal ** | | | | | 56.7 | | | 260 | | | 12.1 | 68.8 |
| ** | WBS: 1.2.2.4.1.5 | Monochromator Controls | | | | | | | | | | | |
| 1 | Intelligent Local Control | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 2 | 1 ILC per device plus pro | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |

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| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | Monochromator | | 2 | 1568.73 | EU | 3.1 | 2 | 20.0 | 40 | CP | 50.55 | 2.0 | 5.2 |
| 4 | Water flow switches & tem | | 2 | 1568.73 | EU | 3.1 | 2 | 20.0 | 40 | CP | 50.55 | 2.0 | 5.2 |
| 5 | Insertion dev. controls | | 2 | 1568.73 | EU | 3.1 | 2 | 20.0 | 40 | CP | 50.55 | 2.0 | 5.2 |
| 6 | Ent. & exit slits | | 2 | 1568.73 | EU | 3.1 | 2 | 20.0 | 40 | CP | 50.55 | 2.0 | 5.2 |
| 7 | System check & debug | | 0 | 0.00 | | 0.0 | 2 | 40.0 | 80 | CP | 50.55 | 4.0 | 4.0 |
| 8 | Ion Gage & controller | | 2 | 3986.83 | CP | 8.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 8.0 |
| ** | Subtotal ** | | | | | 20.5 | | | 240 | | | 12.1 | 32.7 |
| ** | WBS: 1.2.2.4.1.6 | Electrical Installation | | | | | | | | | | | |
| 1 | Double Rack,84"x24'' | EA | 1 | 1008.47 | CP | 1.0 | 1 | 8.0 | 8 | ES | 29.35 | 0.2 | 1.2 |
| 2 | BA Panel 3 PH 30A | EA | 1 | 56.03 | CP | 0.1 | 1 | 0.5 | 0 | ES | 29.35 | 0.0 | 0.1 |
| 3 | Breaker Panel | EA | 2 | 182.64 | CP | 0.4 | 2 | 4.0 | 8 | ES | 29.35 | 0.2 | 0.6 |
| 4 | Plug Strip | EA | 2 | 22.41 | EU | 0.0 | 2 | 1.0 | 2 | ES | 29.35 | 0.1 | 0.1 |
| 5 | X-conn Blks & Frame | EA | 1 | 252.12 | CP | 0.3 | 1 | 24.0 | 24 | ES | 29.35 | 0.7 | 1.0 |
| 6 | RLY Blks & Frame | EA | 1 | 549.06 | CP | 0.5 | 1 | 24.0 | 24 | ES | 29.35 | 0.7 | 1.3 |
| 7 | U-panel w/BNC's | EA | 2 | 67.23 | CP | 0.1 | 2 | 2.0 | 4 | ES | 29.35 | 0.1 | 0.3 |
| 8 | Rack Fans | EA | 2 | 56.03 | CP | 0.1 | 2 | 1.0 | 2 | ES | 29.35 | 0.1 | 0.2 |
| 9 | Cables | | 0 | 84.04 | CP | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 10 | Mirrors | EA | 10 | 84.04 | CP | 0.8 | 10 | 1.0 | 10 | IEL | 58.20 | 0.6 | 1.4 |
| 11 | Pinhole | EA | 10 | 84.04 | CP | 0.8 | 10 | 1.0 | 10 | IEL | 58.20 | 0.6 | 1.4 |
| 12 | ALS System Data | EA | 6 | 84.04 | CP | 0.5 | 6 | 1.0 | 6 | IEL | 58.20 | 0.3 | 0.9 |
| 13 | Ion Gages | EA | 6 | 84.04 | CP | 0.5 | 6 | 1.0 | 6 | IEL | 58.20 | 0.3 | 0.9 |
| 14 | Monochromator | EA | 4 | 84.04 | CP | 0.3 | 4 | 1.0 | 4 | IEL | 58.20 | 0.2 | 0.6 |
| 15 | Water Flow switches | EA | 4 | 168.07 | EU | 0.7 | 4 | 0.5 | 2 | ES | 29.35 | 0.1 | 0.7 |
| 16 | Temp. Sensors and Cables | EA | 4 | 112.06 | EU | 0.4 | 4 | 1.0 | 4 | IEL | 58.20 | 0.2 | 0.7 |
| 17 | Temp. Monitor Interlocks | | 1 | 336.16 | EU | 0.3 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 1.5 |
| 18 | Misc Elec. Installation | | 1 | 560.26 | EU | 0.6 | 1 | 40.0 | 40 | IEL | 58.20 | 2.3 | 2.9 |
| 19 | Misc. Elec Assembly | | 1 | 560.26 | EU | 0.6 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 1.7 |
| 20 | Thermocouple Monitor & re | | 1 | 560.26 | CP | 0.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.6 |
| 21 | Thermocouple scanner | | 1 | 347.36 | CP | 0.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.3 |
| 22 | Monitor Lights panel | | 5 | 224.10 | CP | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 23 | Key Panel | | 1 | 280.13 | CP | 0.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.3 |
| 24 | Push Button Panel | | 1 | 224.10 | CP | 0.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.2 |
| 25 | Breaker Panel | | 1 | 224.10 | CP | 0.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.2 |
| 26 | Monitor Panels Wiring & I | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | ES | 29.35 | 2.3 | 2.3 |
| 27 | PLIC (Rad. Safety) | FT | 100 | 11.20 | CP | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 28 | PLIC Camac H.V. P.S. | EA | 1 | 1120.53 | CP | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 29 | PLIC Monitoring card | EA | 1 | 2801.31 | CP | 2.8 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.8 |
| 30 | PLIC - other elec. | | 1 | 3361.58 | CP | 3.4 | 1 | 14.0 | 14 | IEL | 58.20 | 0.8 | 4.2 |
| 31 | PLIC - Installation | FT | 100 | 1.13 | EU | 0.1 | 100 | 0.0 | 3 | IEL | 58.20 | 0.2 | 0.3 |
| 32 | PLIC - Installation | | 1 | 840.39 | | 0.8 | 1 | 8.0 | 8 | IEL | 58.20 | 0.5 | 1.3 |
| 33 | Monochromator System Elec | | 1 | 5602.63 | EU | 5.6 | 1 | 80.0 | 80 | ES | 29.35 | 2.3 | 8.0 |
| 34 | ''(instrumtn, monitors, p | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | IEL | 58.20 | 2.3 | 2.3 |
| ** | Subtotal ** | | | | | 25.8 | | | 459 | | | 17.6 | 43.5 |
| ** | WBS: 1.2.2.4.1.7 | Mechanical & Electrical System Integrati | | | | | | | | | | | |
| 1 | Vac. Roughing System | EA | 1 | 11205.25 | EU | 11.2 | 1 | 20.0 | 20 | MT | 25.20 | 0.5 | 11.7 |
| 2 | portable vacuum system, | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | 'Megasorb''unit | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | (per E. Hoyer) | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Final alignment and calib | | 1 | 560.26 | EU | 0.6 | 1 | 400.0 | 400 | MT | 25.20 | 10.1 | 10.6 |
| 6 | Beam line controls check- | | 1 | 1120.53 | EU | 1.1 | 1 | 400.0 | 400 | MT | 25.20 | 10.1 | 11.2 |
| 7 | (includes instrumentation | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | ES | 29.35 | 4.7 | 4.7 |
| 8 | monitoring & interlocks, | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | IEL | 58.20 | 9.3 | 9.3 |
| 9 | communications, final adj | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | IMT | 61.60 | 9.9 | 9.9 |
| 10 | etc.) | | 0 | 0.00 | | 0.0 | 1 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 11 | Vacuum system check-out | | 1 | 560.26 | EU | 0.6 | 1 | 500.0 | 500 | MT | 25.20 | 12.6 | 13.2 |
| ** | Subtotal ** | | | | | 13.4 | | | 1800 | | | 57.1 | 70.6 |
| ** | WBS: 1.2.2.4.2 | Spectroscopy Station | | | | | | | | | | | |
| 1 | Detectors: misc. equip | | 1 | 35000.00 | | 35.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 35.0 |
| 2 | MicroVAX computer system | | 1 | 40000.00 | | 40.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 40.0 |
| 3 | Electrometers & interface | | 1 | 15000.00 | | 15.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.0 |

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| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | Electonic cntrls & intrfc | | 1 | 30000.00 | | 30.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 30.0 |
| 5 | Fluorescence detector | | 1 | 10000.00 | | 10.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 10.0 |
| 6 | Software | | 1 | 10000.00 | | 10.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 10.0 |
| 7 | Sample cells and mounts | | 1 | 18000.00 | | 18.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 18.0 |
| 8 | Hutch (special lrge type) | | 1 | 30000.00 | | 30.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 30.0 |
| 9 | Mech sys for exp intrchng | | 1 | 40000.00 | | 40.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 40.0 |
| ** | Subtotal ** | | | | | 228.0 | | | 0 | | | 0.0 | 228.0 |
| ** | WBS: 1.2.2.4.3 | Microprobe Station | | | | | | | | | | | |
| 1 | Kirkpatrick-Baez substrat | | 1 | 25000.00 | | 25.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 25.0 |
| 2 | Multilayer coatings | | 1 | 30000.00 | | 30.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 30.0 |
| 3 | Mirror mounting, alignmnt | | 1 | 50000.00 | | 50.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 50.0 |
| 4 | Sample mountings w/cntrl | | 1 | 10000.00 | | 10.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 10.0 |
| 5 | Piezoelectric scanning | | 1 | 30000.00 | | 30.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 30.0 |
| 6 | Computer system | | 1 | 40000.00 | | 40.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 40.0 |
| 7 | Electronic cntrls/intrfcs | | 1 | 30000.00 | | 30.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 30.0 |
| 8 | SiLi detector/cryo system | | 1 | 15000.00 | | 15.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.0 |
| 9 | Part cst:shared image sys | | 1 | 25000.00 | | 25.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 25.0 |
| ** | Subtotal ** | | | | | 255.0 | | | 0 | | | 0.0 | 255.0 |
| ** | WBS: 1.2.3.1.1.1 | Magnetic Material | | | | | | | | | | | |
| 1 | NDFE BLOCKS | CM3 | 47100 | 2.24 | VQ | 105.5 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 105.5 |
| 2 | MEASUREMENTS/SORTING | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | GAUGES/FIXTURES | LOT | 1 | 112.06 | EU | 0.1 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 2.1 |
| 4 | MOMENT MEAS. PREP | | 0 | 0.00 | | 0.0 | 1 | 20.0 | 20 | EE | 50.55 | 1.0 | 1.0 |
| 5 | MEASUREMENTS | LOT | 1 | 112.06 | EU | 0.1 | 5146 | 0.2 | 926 | EM | 29.35 | 27.2 | 27.3 |
| 6 | SORTING | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | ME | 54.10 | 2.2 | 2.2 |
| ** | Subtotal ** | | | | | 105.7 | | | 1066 | | | 32.4 | 138.1 |
| ** | WBS: 1.2.3.1.1.2 | Model Pole | | | | | | | | | | | |
| 1 | MAGNETIC MATERIAL | LOT | 1 | 2241.05 | EU | 2.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.2 |
| 2 | ASSY AND TEST FIXTURE | | 0 | 0.00 | | 0.0 | 1 | 180.0 | 180 | MT | 25.20 | 4.5 | 4.5 |
| 3 | MODEL MAG MEASUREMENTS | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | EM | 29.35 | 1.2 | 1.2 |
| ** | Subtotal ** | | | | | 2.2 | | | 220 | | | 5.7 | 8.0 |
| ** | WBS: 1.2.3.1.1.3 | Pole Assemblies | | | | | | | | | | | |
| 1 | VANADIUM PERMENDUR | CM3 | 16900 | 0.55 | A85 | 9.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 9.3 |
| 2 | KEEPERS | EA | 562 | 303.66 | A82 | 170.7 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 170.7 |
| 3 | KEEPER INSPECTION | | 0 | 0.00 | | 0.0 | 562 | 0.2 | 140 | MA | 36.20 | 5.1 | 5.1 |
| 4 | CONTAINERS | LOT | 1 | 672.32 | A82 | 0.7 | 562 | 0.2 | 140 | PC | 35.55 | 5.0 | 5.7 |
| 5 | ASSY FIXTURES | LOT | 1 | 224.10 | A82 | 0.2 | 4 | 88.0 | 352 | MM | 36.20 | 12.7 | 13.0 |
| 6 | ASSEMBLY | EA | 562 | 4.66 | A82 | 2.6 | 562 | 5.8 | 3260 | MA | 36.20 | 118.0 | 120.6 |
| ** | Subtotal ** | | | | | 183.5 | | | 3893 | | | 140.8 | 324.3 |
| ** | WBS: 1.2.3.1.1.4 | End Pole Assemblies | | | | | | | | | | | |
| 1 | END POLE KEEPERS | LOT | 1 | 112.06 | A82 | 0.1 | 4 | 38.0 | 152 | MM | 36.20 | 5.5 | 5.6 |
| 2 | MAG. MAT. BLOCK CUTTING | | 0 | 0.00 | | 0.0 | 16 | 1.0 | 16 | MM | 36.20 | 0.6 | 0.6 |
| 3 | ASSY FIXTURE | | 0 | 0.00 | | 0.0 | 1 | 20.0 | 20 | MM | 36.20 | 0.7 | 0.7 |
| 4 | COILS | LOT | 1 | 112.06 | EU | 0.1 | 4 | 65.0 | 260 | MA | 36.20 | 9.4 | 9.5 |
| 5 | ASSEMBLY | LOT | 1 | 112.06 | EU | 0.1 | 4 | 12.0 | 48 | MA | 36.20 | 1.7 | 1.8 |
| ** | Subtotal ** | | | | | 0.3 | | | 496 | | | 18.0 | 18.3 |
| ** | WBS: 1.2.3.1.1.5 | Backing Beams | | | | | | | | | | | |
| 1 | WF BEAMS | LBS | 4200 | 0.58 | VQ | 2.4 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.4 |
| 1 | KEEPER INSTALLATION | LOT | 1 | 224.10 | EU | 0.2 | 542 | 1.2 | 650 | MA | 36.20 | 23.5 | 23.8 |
| 2 | KEEPER INST TOOL | | 0 | 0.00 | | 0.0 | 1 | 16.0 | 16 | MM | 36.20 | 0.6 | 0.6 |
| 2 | BEAM FABRICATION | | 0 | 0.00 | | 0.0 | 2 | 240.0 | 480 | NC | 55.20 | 26.5 | 26.5 |
| 3 | | | 0 | 0.00 | | 0.0 | 2 | 80.0 | 160 | MM | 36.20 | 5.8 | 5.8 |
| 4 | FIELD CLAMPS | | 0 | 0.00 | | 0.0 | 4 | 4.0 | 16 | MM | 36.20 | 0.6 | 0.6 |
| 5 | FLEXIBLE YOKE | | 0 | 0.00 | | 0.0 | 1 | 16.0 | 16 | MM | 36.20 | 0.6 | 0.6 |

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| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | SHIMS | LOT | 1 | 112.06 | EU | 0.1 | 1 | 60.0 | 60 | MM | 36.20 | 2.2 | 2.3 |
| 7 | POLE SHIELDS | LOT | 1 | 224.10 | EU | 0.2 | 2 | 16.0 | 32 | PC | 35.55 | 1.1 | 1.4 |
| ** Subtotal ** | | | | | | 3.0 | | | 1430 | | | 60.9 | 63.9 |
| ** WBS: 1.2.3.1.1.6 | Magnet Structure Assembly | | | | | | | | | | | | |
| 3 | KEEPER SHIMMING | | 0 | 0.00 | | 0.0 | 542 | 0.4 | 217 | MA | 36.20 | 7.8 | 7.8 |
| 4 | END POLE COIL COOLING | LOT | 1 | 448.21 | EU | 0.4 | 1 | 80.0 | 80 | MA | 36.20 | 2.9 | 3.3 |
| ** Subtotal ** | | | | | | 0.4 | | | 297 | | | 10.7 | 11.2 |
| ** WBS: 1.2.3.1.1.7 | Magnetic Measurements | | | | | | | | | | | | |
| 1 | INITIAL PREPARATION | | 0 | 0.00 | | 0.0 | 1 | 120.0 | 120 | EE | 50.55 | 6.1 | 6.1 |
| 2 | NULL COIL | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 2.0 |
| 3 | GAUGE BLKS/CENT. KEYS | LOT | 1 | 224.10 | A82 | 0.2 | 1 | 63.0 | 63 | MT | 25.20 | 1.6 | 1.8 |
| 4 | MAGNETIC MEASUREMENTS | LOT | 1 | 112.06 | EU | 0.1 | 1 | 755.0 | 755 | EE | 50.55 | 38.2 | 38.3 |
| 5 | | | 0 | 0.00 | | 0.0 | 1 | 321.0 | 321 | EM | 29.35 | 9.4 | 9.4 |
| 6 | | | 0 | 0.00 | | 0.0 | 1 | 174.0 | 174 | MT | 25.20 | 4.4 | 4.4 |
| ** Subtotal ** | | | | | | 0.3 | | | 1513 | | | 61.6 | 62.0 |
| ** WBS: 1.2.3.1.2.1 | Support Structure | | | | | | | | | | | | |
| 1 | BASE ALIGNMENT ASSYS | EA | 3 | 291.33 | CP | 0.9 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.9 |
| 2 | | LOT | 1 | 448.21 | EU | 0.4 | 3 | 20.0 | 60 | MM | 36.20 | 2.2 | 2.6 |
| 3 | BASE FRAME | LOT | 1 | 1120.53 | EU | 1.1 | 1 | 120.0 | 120 | MM | 36.20 | 4.3 | 5.5 |
| 4 | VERTICAL MEMBERS | LBS | 720 | 1.49 | CP | 1.1 | 2 | 40.0 | 80 | MM | 36.20 | 2.9 | 4.0 |
| 5 | | LOT | 1 | 112.06 | EU | 0.1 | 2 | 80.0 | 160 | MS | 36.20 | 5.8 | 5.9 |
| 6 | TOP FRAME | LOT | 1 | 896.42 | EU | 0.9 | 1 | 80.0 | 80 | MM | 36.20 | 2.9 | 3.8 |
| 7 | MAIN FRAME ASSY/ALIGN | LOT | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MA | 36.20 | 7.2 | 7.8 |
| 8 | | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | PP | 35.55 | 2.8 | 2.8 |
| 9 | VACUUM CHAMBER SUPPORTS | LOT | 1 | 224.10 | EU | 0.2 | 1 | 80.0 | 80 | MM | 36.20 | 2.9 | 3.1 |
| 10 | VAC PUMP SUPPORT | LOT | 1 | 112.06 | EU | 0.1 | 1 | 60.0 | 60 | MM | 36.20 | 2.2 | 2.3 |
| 11 | SUPPORTS ASSY | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | MA | 36.20 | 1.4 | 1.4 |
| ** Subtotal ** | | | | | | 5.4 | | | 960 | | | 34.7 | 40.1 |
| ** WBS: 1.2.3.1.2.2 | Drive Components | | | | | | | | | | | | |
| 1 | STEPPER MOTOR | EA | 1 | 1064.50 | CP | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 2 | REDUCER | EA | 1 | 3921.84 | CP | 3.9 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 3.9 |
| 3 | SPROCKETS/CHAIN/COUPLINGS | LOT | 1 | 3189.01 | CP | 3.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 3.2 |
| 4 | BALL SCREW SHAFTS/NUTS | LOT | 1 | 13110.14 | CP | 13.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 13.1 |
| 5 | BEARINGS | LOT | 1 | 3585.68 | CP | 3.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 3.6 |
| 6 | SWITCHES/ADJ. HARDWARE | LOT | 1 | 448.21 | EU | 0.4 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.4 |
| 7 | MISC. HARDWARE | LOT | 1 | 448.21 | EU | 0.4 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.4 |
| 8 | ENCODER | EA | 1 | 2241.05 | EU | 2.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.2 |
| 9 | U JOINTS | LOT | 1 | 526.65 | CP | 0.5 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.5 |
| ** Subtotal ** | | | | | | 28.5 | | | 0 | | | 0.0 | 28.5 |
| ** WBS: 1.2.3.1.2.3 | Drive System Fabrication | | | | | | | | | | | | |
| 1 | DRIVE HARDWARE | LOT | 1 | 336.16 | EU | 0.3 | 1 | 160.0 | 160 | MM | 36.20 | 5.8 | 6.1 |
| 2 | TRANSFER BEAMS | LOT | 1 | 224.10 | EU | 0.2 | 4 | 40.0 | 160 | MM | 36.20 | 5.8 | 6.0 |
| 3 | SAFETY STOPS | | 0 | 0.00 | | 0.0 | 1 | 16.0 | 16 | MM | 36.20 | 0.6 | 0.6 |
| 4 | COVERS/SAFETY GUARDS | LOT | 1 | 336.16 | EU | 0.3 | 1 | 40.0 | 40 | MA | 36.20 | 1.4 | 1.8 |
| ** Subtotal ** | | | | | | 0.9 | | | 376 | | | 13.6 | 14.5 |
| ** WBS: 1.2.3.1.2.4 | Support-Drive Assembly | | | | | | | | | | | | |
| 1 | STRUCTURE/DRIVE ASSY | | 0 | 0.00 | | 0.0 | 1 | 240.0 | 240 | MA | 36.20 | 8.7 | 8.7 |
| 2 | ALIGNMENT | LOT | 1 | 224.10 | EU | 0.2 | 1 | 240.0 | 240 | MA | 36.20 | 8.7 | 8.9 |
| 3 | MAG. STRUCTURE INST. | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | MA | 36.20 | 1.4 | 1.4 |
| 4 | TEST/ALIGNMENT | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | MA | 36.20 | 5.8 | 5.8 |
| ** Subtotal ** | | | | | | 0.2 | | | 680 | | | 24.6 | 24.8 |

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| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ** WBS: 1.2.3.1.3 | Vacuum System | | | | | | | | | | | | |
| 1 | VACUUM CHAMBER TEST P. | LB | 500 | 2.21 | VQ | 1.1 | 1 | 280.0 | 280 | MS | 36.20 | 10.1 | 11.2 |
| 2 | VACUUM CHAMBER #1 | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | MATERIAL | LB | 4100 | 2.21 | VQ | 9.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 9.1 |
| 4 | FLANGES | LOT | 1 | 1120.53 | EU | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 5 | ANNEALING | EA | 2 | 3809.78 | EU | 7.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 7.6 |
| 6 | FABRICATION | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | NC | 55.20 | 4.4 | 4.4 |
| 7 | | | 0 | 0.00 | | 0.0 | 1 | 720.0 | 720 | MM | 36.20 | 26.1 | 26.1 |
| 8 | ASSY/TEST | | 0 | 0.00 | | 0.0 | 1 | 120.0 | 120 | MA | 36.20 | 4.3 | 4.3 |
| 9 | ASSEMBLY | EA | 1 | 560.26 | EU | 0.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.6 |
| 10 | SYSTEM ASSY | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | MA | 36.20 | 2.9 | 2.9 |
| 11 | UHV BAKEOUT | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | MA | 36.20 | 5.8 | 5.8 |
| 12 | ASSEMBLE IN ID | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | MA | 36.20 | 1.4 | 1.4 |
| 13 | TRANSITION SECTIONS | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 14 | INCLUDED IN 1.2.1.3.1 | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 15 | MASKS | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 16 | INCLUDED IN 1.2.1.3.1 | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 17 | PUMPING UNIT | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 18 | INCLUDED IN 1.2.1.3.2 | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 19 | VACUUM CHAMBER #2 | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 20 | MATERIAL | LB | 4100 | 2.21 | VQ | 9.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 9.1 |
| 21 | FLANGES | LOT | 1 | 1120.53 | EU | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 22 | ANNEALING | EA | 2 | 3809.78 | EU | 7.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 7.6 |
| 23 | FABRICATION | | 0 | 0.00 | | 0.0 | 1 | 400.0 | 400 | NC | 55.20 | 22.1 | 22.1 |
| 24 | | | 0 | 0.00 | | 0.0 | 1 | 720.0 | 720 | MM | 36.20 | 26.1 | 26.1 |
| 25 | ASSY/TEST | | 0 | 0.00 | | 0.0 | 1 | 120.0 | 120 | MA | 36.20 | 4.3 | 4.3 |
| ** Subtotal ** | | | | | | 37.3 | | | 2720 | | | 107.6 | 144.9 |
| ** WBS: 1.2.3.1.4 | Electrical | | | | | | | | | | | | |
| 1 | DRIVE CHASSIS | LOT | 1 | 20505.61 | EU | 20.5 | 1 | 80.0 | 80 | ES | 29.35 | 2.3 | 22.9 |
| 2 | END POLE POWER SUPPLIES | LOT | 1 | 7843.68 | EU | 7.8 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 9.0 |
| 3 | CHECKOUT | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 1.2 |
| ** Subtotal ** | | | | | | 28.3 | | | 160 | | | 4.7 | 33.0 |
| ** WBS: 1.2.3.1.5.1 | Mechanical Installation | | | | | | | | | | | | |
| 1 | DEVICE INSTALLATION | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | ICO | 61.60 | 9.9 | 9.9 |
| 2 | COIL COOLING CONNECTING | | 0 | 0.00 | | 0.0 | 1 | 16.0 | 16 | IPL | 61.60 | 1.0 | 1.0 |
| 3 | VACUUM SYSTEM CONNECTING | LOT | 1 | 112.06 | EU | 0.1 | 1 | 40.0 | 40 | IMT | 61.60 | 2.5 | 2.6 |
| 4 | ALIGNMENT | | 0 | 0.00 | | 0.0 | 1 | 120.0 | 120 | IMT | 61.60 | 7.4 | 7.4 |
| 5 | CHECKOUT | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | IMT | 61.60 | 2.5 | 2.5 |
| ** Subtotal ** | | | | | | 0.1 | | | 376 | | | 23.2 | 23.3 |
| ** WBS: 1.2.3.1.5.2 | Electrical Installation | | | | | | | | | | | | |
| 1 | DRIVE SYSTEM INST/CONNECT | | 0 | 0.00 | | 0.0 | 1 | 8.0 | 8 | IEL | 58.20 | 0.5 | 0.5 |
| 2 | POWER SUPPLY INST/CONNECT | | 0 | 0.00 | | 0.0 | 1 | 8.0 | 8 | IEL | 58.20 | 0.5 | 0.5 |
| 3 | | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| ** Subtotal ** | | | | | | 0.0 | | | 16 | | | 0.9 | 0.9 |
| ** WBS: 1.2.3.2.1.1 | Fixed Aperture | | | | | | | | | | | | |
| 1 | Water-cooled absorber | | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.8 |
| 2 | includes copper block, br | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | water-cooling channels/tu | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | UHV mounting ass'y | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Flanges and Bellows | | 4 | 336.16 | EU | 1.3 | 4 | 20.0 | 80 | MS | 36.20 | 2.9 | 4.2 |
| 6 | Mounting and Positioning | | 1 | 560.26 | EU | 0.6 | 1 | 100.0 | 100 | MS | 36.20 | 3.6 | 4.2 |
| 7 | Access flanges for instal | | 2 | 224.10 | EU | 0.4 | 2 | 8.0 | 16 | MS | 36.20 | 0.6 | 1.0 |
| 8 | Water connections | | 1 | 112.06 | EU | 0.1 | 1 | 8.0 | 8 | MT | 25.20 | 0.2 | 0.3 |
| 9 | Assembly & leak check | | 1 | 112.06 | EU | 0.1 | 1 | 120.0 | 120 | MS | 36.20 | 4.3 | 4.5 |
| 10 | Elec. assembly | | 1 | 112.06 | EU | 0.1 | 1 | 20.0 | 20 | ES | 29.35 | 0.6 | 0.7 |
| 11 | Monitoring sensors for | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 12 | position and temperatures | | 1 | 224.10 | EU | 0.2 | 1 | 20.0 | 20 | MS | 36.20 | 0.7 | 0.9 |
| 13 | Misc. hardware | | 1 | 224.10 | EU | 0.2 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 1.7 |

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| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | Bakeout | | 1 | 224.10 | EU | 0.2 | 1 | 160.0 | 160 | MS | 36.20 | 5.8 | 6.0 |
| 15 | Alignment calibration | | 1 | 112.06 | EU | 0.1 | 1 | 40.0 | 40 | MT | 25.20 | 1.0 | 1.1 |
| ** | Subtotal ** | | | | | 4.0 | | | 804 | | | 28.4 | 32.5 |
| ** | WBS: 1.2.3.2.1.2 | Fast Valve | | | | | | | | | | | |
| 1 | VG Fast Acting Shutter (1 | | 1 | 15239.15 | VQ | 15.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.2 |
| 2 | blades | EA | 2 | 112.06 | VQ | 0.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.2 |
| 3 | Pneumatic system | | 1 | 224.10 | EU | 0.2 | 1 | 16.0 | 16 | MT | 25.20 | 0.4 | 0.6 |
| 4 | Interlock electronics | | 1 | 0.00 | EU | 0.0 | 1 | 16.0 | 16 | ES | 29.35 | 0.5 | 0.5 |
| 5 | Controls | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 6 | spare guides | EA | 2 | 69.47 | VQ | 0.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.1 |
| 7 | Assembly/testing | | 1 | 0.00 | EU | 0.0 | 1 | 16.0 | 16 | MT | 25.20 | 0.4 | 0.4 |
| 8 | Bakeout/vac check | | 1 | 112.06 | EU | 0.1 | 1 | 16.0 | 16 | | 0.00 | 0.0 | 0.1 |
| 9 | triggering unit (see cont | | 1 | 0.00 | VQ | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 10 | detection unit (see contr | | 3 | 0.00 | VQ | 0.0 | 3 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 11 | (ion gage & power supply) | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 12 | modification for larger a | | 1 | 3361.58 | EU | 3.4 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 3.4 |
| ** | Subtotal ** | | | | | 19.3 | | | 64 | | | 1.3 | 20.6 |
| ** | WBS: 1.2.3.2.1.3 | Front End Vacuum Sys | | | | | | | | | | | |
| 1 | 400 l/s pumping station | | 1 | 0.00 | | 0.0 | 1 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 2 | Bellows | EA | 1 | 560.26 | CP | 0.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.6 |
| 3 | Bellows flanges & hardwar | | 1 | 840.39 | EU | 0.8 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 2.3 |
| 4 | Shielding wall spool | | 1 | 1120.53 | EU | 1.1 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 2.6 |
| 5 | Vat Series 48 8''valve | EA | 2 | 15239.15 | VQ | 30.5 | 2 | 8.0 | 16 | MT | 25.20 | 0.4 | 30.9 |
| 6 | Valve mounting & connecti | | 2 | 112.06 | EU | 0.2 | 2 | 30.0 | 60 | MS | 36.20 | 2.2 | 2.4 |
| 7 | Bakeout & vac. Check | | 1 | 560.26 | EU | 0.6 | 1 | 160.0 | 160 | MS | 36.20 | 5.8 | 6.4 |
| ** | Subtotal ** | | | | | 33.8 | | | 316 | | | 11.3 | 45.0 |
| ** | WBS: 1.2.3.2.1.4 | Vacuum Pumping Station | | | | | | | | | | | |
| 1 | 400 l/s vac. pump pkg. | EA | 2 | 11468.58 | CP | 22.9 | 2 | 1.0 | 2 | MT | 25.20 | 0.1 | 23.0 |
| 2 | includes ion pump, tsp, c | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | (controller costed with C | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | (Perkin Elmer''Boostivac' | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | TSP spare filaments | SET | 2 | 140.07 | CP | 0.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.3 |
| 6 | Ion gage and power supply | | 0 | 0.00 | | 0.0 | 2 | 1.0 | 2 | MT | 25.20 | 0.1 | 0.1 |
| 7 | (cost included with Contr | | 1 | 0.00 | XX | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 8 | 2 3/4''roughing valve | | 2 | 1226.98 | CP | 2.5 | 2 | 1.0 | 2 | MT | 25.20 | 0.1 | 2.5 |
| ** | Subtotal ** | | | | | 25.7 | | | 6 | | | 0.2 | 25.8 |
| ** | WBS: 1.2.3.2.1.5 | Personnel Safety Shut. | | | | | | | | | | | |
| 1 | Shutter System: | EA | 1 | 0.00 | EU | 0.0 | 1 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 2 | Vac. Chamber | EA | 1 | 4482.10 | EU | 4.5 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 11.7 |
| 3 | Supports | EA | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.8 |
| 4 | Shutters & mechanism | EA | 2 | 2241.05 | EU | 4.5 | 2 | 250.0 | 500 | MS | 36.20 | 18.1 | 22.6 |
| 5 | Temp. monitor | | 2 | 224.10 | EU | 0.4 | 2 | 8.0 | 16 | MT | 25.20 | 0.4 | 0.9 |
| 6 | Assembly & bakeout | EA | 1 | 224.10 | EU | 0.2 | 1 | 120.0 | 120 | MS | 36.20 | 4.3 | 4.6 |
| 7 | Collimating spool | EA | 1 | 1120.53 | EU | 1.1 | 1 | 80.0 | 80 | MS | 36.20 | 2.9 | 4.0 |
| 8 | Lead Shielding & supports | | 1 | 2801.31 | EU | 2.8 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 4.2 |
| ** | Subtotal ** | | | | | 14.1 | | | 1156 | | | 41.7 | 55.8 |
| ** | WBS: 1.2.3.2.1.6 | Front End Photon Shut. | | | | | | | | | | | |
| 1 | Water-cooled absorber | | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.8 |
| 2 | includes copper block, br | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | water-cooling channels/tu | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | UHV mounting ass'y | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Flanges and Bellows | | 4 | 336.16 | EU | 1.3 | 4 | 20.0 | 80 | MS | 36.20 | 2.9 | 4.2 |
| 6 | Mounting and Positioning | | 1 | 1680.79 | EU | 1.7 | 1 | 160.0 | 160 | MS | 36.20 | 5.8 | 7.5 |
| 7 | Access flanges for instal | | 2 | 224.10 | EU | 0.4 | 2 | 8.0 | 16 | MS | 36.20 | 0.6 | 1.0 |
| 8 | Water & pneumatic utiliti | | 1 | 336.16 | EU | 0.3 | 1 | 16.0 | 16 | MT | 25.20 | 0.4 | 0.7 |
| 9 | Assembly & leak check | | 1 | 112.06 | EU | 0.1 | 1 | 120.0 | 120 | MS | 36.20 | 4.3 | 4.5 |

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| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Elec. assembly | | 1 | 112.06 | EU | 0.1 | 1 | 20.0 | 20 | ES | 29.35 | 0.6 | 0.7 |
| 11 | Monitoring sensors for | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 12 | position and temperatures | | 1 | 224.10 | EU | 0.2 | 1 | 20.0 | 20 | MS | 36.20 | 0.7 | 0.9 |
| 13 | Misc. hardware | | 1 | 224.10 | EU | 0.2 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 1.7 |
| 14 | Bakeout | | 1 | 224.10 | EU | 0.2 | 1 | 160.0 | 160 | MS | 36.20 | 5.8 | 6.0 |
| 15 | Alignment calibration | | 1 | 112.06 | EU | 0.1 | 1 | 40.0 | 40 | MT | 25.20 | 1.0 | 1.1 |
| ** Subtotal ** | | | | | | 5.4 | | | 872 | | | 30.8 | 36.2 |
| ** WBS: 1.2.3.2.2 | Mechanical Installation | | | | | | | | | | | | |
| 1 | Final Assembly and Bakeou | | 1 | 560.26 | EU | 0.6 | 1 | 320.0 | 320 | MS | 36.20 | 11.6 | 12.1 |
| 2 | includes misc. materials, | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | ass'y shop labor (clean r | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | bakeout | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Installation | | 0 | 0.00 | | 0.0 | 1 | 320.0 | 320 | IMT | 61.60 | 19.7 | 19.7 |
| 6 | Survey & Alignment | | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MT | 25.20 | 5.0 | 5.6 |
| 7 | Pneumatic Service | | 1 | 2241.05 | EU | 2.2 | 1 | 80.0 | 80 | IMT | 61.60 | 4.9 | 7.2 |
| 8 | includes copper tubing, f | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | MT | 25.20 | 1.0 | 1.0 |
| 9 | misc. hardware & instrume | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 1.4 |
| 10 | LCW Service | | 1 | 2241.05 | EU | 2.2 | 1 | 80.0 | 80 | IPL | 61.60 | 4.9 | 7.2 |
| 11 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 2.0 |
| 12 | Unistrut & misc hdwre | | 1 | 2241.05 | EU | 2.2 | 1 | 80.0 | 80 | IMT | 61.60 | 4.9 | 7.2 |
| 13 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 1.4 |
| 14 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 40.0 | 40 | MT | 25.20 | 1.0 | 1.0 |
| 15 | Shielding Wall modif. | | 1 | 2241.05 | EU | 2.2 | 1 | 160.0 | 160 | IMT | 61.60 | 9.9 | 12.1 |
| 16 | Lead Safety Shielding | | 1 | 2801.31 | EU | 2.8 | 1 | 40.0 | 40 | MT | 25.20 | 1.0 | 3.8 |
| 17 | '' | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | IMT | 61.60 | 2.5 | 2.5 |
| 18 | Nitrogen - air pressure b | | 1 | 2241.05 | | 2.2 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 4.3 |
| 19 | '' | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | IMT | 61.60 | 4.9 | 4.9 |
| ** Subtotal ** | | | | | | 15.1 | | | 1720 | | | 78.3 | 93.4 |
| ** WBS: 1.2.3.2.3 | Front End Controls | | | | | | | | | | | | |
| 1 | Intelligent Local Control | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 2 | 1 ILC per device plus pro | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | Photon Shutter | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 4 | Isolation Valves | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 5 | Fast Valve | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 6 | Safety Shutter & interloc | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 7 | Water flow switches & int | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 8 | Temp. sensors & interlock | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 9 | ALS system data | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 10 | Vacuum system | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 11 | Cables (see installation) | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 12 | System check & debug | | 1 | 0.00 | EU | 0.0 | 1 | 40.0 | 40 | CP | 50.55 | 2.0 | 2.0 |
| 13 | Vacuum Pump Controller | | 1 | 4229.98 | CP | 4.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 4.2 |
| 14 | Ion Gage & Controller | | 1 | 3986.83 | CP | 4.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 4.0 |
| 15 | Fast Valve Triggering Uni | | 1 | 2498.77 | VQ | 2.5 | 1 | 4.0 | 4 | ES | 29.35 | 0.1 | 2.6 |
| 16 | Fast Valve Detection Unit | | 3 | 3762.72 | CP | 11.3 | 3 | 4.0 | 12 | MT | 25.20 | 0.3 | 11.6 |
| ** Subtotal ** | | | | | | 34.6 | | | 216 | | | 10.5 | 45.1 |
| ** WBS: 1.2.3.2.4 | Electrical Installation | | | | | | | | | | | | |
| 1 | Double Rack,84"x24'' | EA | 1 | 1008.47 | CP | 1.0 | 1 | 8.0 | 8 | ES | 29.35 | 0.2 | 1.2 |
| 2 | BA Panel 3 PH 30A | EA | 1 | 56.03 | CP | 0.1 | 1 | 0.5 | 0 | ES | 29.35 | 0.0 | 0.1 |
| 3 | Breaker Panel | EA | 2 | 182.64 | CP | 0.4 | 2 | 4.0 | 8 | ES | 29.35 | 0.2 | 0.6 |
| 4 | Plug Strip | EA | 2 | 22.41 | EU | 0.0 | 2 | 1.0 | 2 | ES | 29.35 | 0.1 | 0.1 |
| 5 | X-conn Blks & Frame | EA | 1 | 252.12 | CP | 0.3 | 1 | 24.0 | 24 | ES | 29.35 | 0.7 | 1.0 |
| 6 | RLY Blks & Frame | EA | 1 | 549.06 | CP | 0.5 | 1 | 24.0 | 24 | ES | 29.35 | 0.7 | 1.3 |
| 7 | U-panel w/BNC's | EA | 2 | 67.23 | CP | 0.1 | 2 | 2.0 | 4 | ES | 29.35 | 0.1 | 0.3 |
| 8 | Rack Fans | EA | 2 | 56.03 | CP | 0.1 | 2 | 1.0 | 2 | ES | 29.35 | 0.1 | 0.2 |
| 9 | Cables | | 0 | 84.04 | CP | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 10 | Photon Shutter | EA | 5 | 84.04 | CP | 0.4 | 5 | 1.0 | 5 | IEL | 58.20 | 0.3 | 0.7 |
| 11 | Isolation Valves (2) | EA | 8 | 84.04 | CP | 0.7 | 8 | 1.0 | 8 | IEL | 58.20 | 0.5 | 1.1 |
| 12 | Safety Shutter | EA | 6 | 84.04 | CP | 0.5 | 6 | 1.0 | 6 | IEL | 58.20 | 0.3 | 0.9 |
| 13 | ALS system data | EA | 6 | 84.04 | CP | 0.5 | 6 | 1.0 | 6 | IEL | 58.20 | 0.3 | 0.9 |

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| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | Ion Gages | EA | 4 | 84.04 | CP | 0.3 | 4 | 1.0 | 4 | IEL | 58.20 | 0.2 | 0.6 |
| 15 | Fast Valve | EA | 6 | 84.04 | CP | 0.5 | 6 | 1.0 | 6 | IEL | 58.20 | 0.3 | 0.9 |
| 16 | Beam Position Monitor | EA | 2 | 84.04 | CP | 0.2 | 6 | 1.0 | 6 | IEL | 58.20 | 0.3 | 0.5 |
| 17 | Water Flow switches | EA | 4 | 168.07 | CP | 0.7 | 4 | 0.5 | 2 | ES | 29.35 | 0.1 | 0.7 |
| 18 | Temp. Sensors & Cables | EA | 4 | 112.06 | EU | 0.4 | 4 | 1.0 | 4 | IEL | 58.20 | 0.2 | 0.7 |
| 19 | Temp. Monitor Interlocks | | 1 | 336.16 | EU | 0.3 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 1.5 |
| 20 | Video camera & lens | EA | 1 | 840.39 | CP | 0.8 | 1 | 4.0 | 4 | ES | 29.35 | 0.1 | 1.0 |
| 21 | Video monitor | EA | 1 | 336.16 | CP | 0.3 | 1 | 0.5 | 0 | ES | 29.35 | 0.0 | 0.4 |
| 22 | RG59 COAX camera to monit | | 1 | 56.03 | EU | 0.1 | 1 | 1.0 | 1 | IEL | 58.20 | 0.1 | 0.1 |
| 23 | connectors for video cabl | | 2 | 5.61 | EU | 0.0 | 2 | 0.5 | 1 | ES | 29.35 | 0.0 | 0.0 |
| 24 | Misc Elec. | | 1 | 1120.53 | | 1.1 | 1 | 40.0 | 40 | IEL | 58.20 | 2.3 | 3.4 |
| 25 | Misc. Elec | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 1.2 |
| 26 | Thermocouple Monitor & re | | 1 | 560.26 | CP | 0.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.6 |
| 27 | Thermocouple scanner | | 1 | 347.36 | CP | 0.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.3 |
| 28 | Monitor Light Panels | | 5 | 224.10 | CP | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 29 | Key Panel | | 1 | 280.13 | CP | 0.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.3 |
| 30 | Push Button Panel (C2) | | 1 | 224.10 | CP | 0.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.2 |
| 31 | Breaker Panel (P2) | | 1 | 224.10 | CP | 0.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.2 |
| 32 | Monitor Panels Wiring & i | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | ES | 29.35 | 2.3 | 2.3 |
| ** Subtotal ** | | | | | | 12.2 | | | 326 | | | 12.0 | 24.3 |
| ** WBS: 1.2.3.3.1.1.1 | Undulator Pinhole & BPM | | | | | | | | | | | | |
| 1 | Knife-edge/Heat Absorber | EA | 4 | 560.26 | EU | 2.2 | 4 | 200.0 | 800 | MS | 36.20 | 29.0 | 31.2 |
| 2 | Knife-edge Mounting | EA | 4 | 1680.79 | EU | 6.7 | 4 | 200.0 | 800 | MS | 36.20 | 29.0 | 35.7 |
| 3 | (bellows, water-cooling, | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | elec. isolation, flange m | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Positioning Mechanism | EA | 4 | 4482.10 | EU | 17.9 | 4 | 200.0 | 800 | MS | 36.20 | 29.0 | 46.9 |
| 6 | Vac. Chamber | EA | 1 | 3361.58 | EU | 3.4 | 1 | 300.0 | 300 | MS | 36.20 | 10.9 | 14.2 |
| 7 | Support stand | EA | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.8 |
| 8 | (incl. kinematic mounting | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 9 | 400 l/s pumping (included | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 10 | Assembly & bakeout | | 4 | 112.06 | EU | 0.4 | 4 | 100.0 | 400 | MS | 36.20 | 14.5 | 14.9 |
| 11 | Alignment calibration | | 1 | 112.06 | EU | 0.1 | 1 | 200.0 | 200 | MT | 25.20 | 5.0 | 5.2 |
| 12 | Misc. hardware for B.P M. | | 1 | 560.26 | EU | 0.6 | 1 | 80.0 | 80 | MS | 36.20 | 2.9 | 3.5 |
| ** Subtotal ** | | | | | | 31.9 | | | 3580 | | | 127.4 | 159.3 |
| ** WBS: 1.2.3.3.1.1.2 | Undulator Spher. Mirror | | | | | | | | | | | | |
| 1 | Mirror blank & mask | EA | 2 | 1120.53 | EU | 2.2 | 2 | 500.0 | 1000 | MS | 36.20 | 36.2 | 38.4 |
| 2 | (machined, brazed assy, w | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | Polishing | EA | 2 | 10084.73 | VQ | 20.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.2 |
| 4 | (close tolerance spherica | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Optical coating | EA | 2 | 1120.53 | EU | 2.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.2 |
| 6 | Mirror Mounting | EA | 2 | 2241.05 | EU | 4.5 | 2 | 400.0 | 800 | MS | 36.20 | 29.0 | 33.4 |
| 7 | (machining, welding, etc. | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 8 | Mirror Positioning (in | EA | 2 | 8403.94 | EU | 16.8 | 2 | 200.0 | 400 | MS | 36.20 | 14.5 | 31.3 |
| 9 | (slides, steppers, encode | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 10 | Mirror Assembly & bakeout | | 1 | 560.26 | EU | 0.6 | 2 | 120.0 | 240 | MS | 36.20 | 8.7 | 9.2 |
| 11 | Vacuum Chamber | EA | 1 | 15127.09 | A86 | 15.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.1 |
| 12 | Vac. Chamber bakeout & va | | 1 | 224.10 | A86 | 0.2 | 1 | 160.0 | 160 | MS | 36.20 | 5.8 | 6.0 |
| 13 | vacuum system included se | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 14 | Exit port mask & beam dum | | 1 | 1120.53 | EU | 1.1 | 1 | 100.0 | 100 | MS | 36.20 | 3.6 | 4.7 |
| 15 | Supports & chamber mounti | | 1 | 560.26 | EU | 0.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.8 |
| ** Subtotal ** | | | | | | 63.5 | | | 2900 | | | 105.0 | 168.5 |
| ** WBS: 1.2.3.3.1.1.3 | Branchline Vac Sys | | | | | | | | | | | | |
| 1 | Bellows | EA | 4 | 560.26 | CP | 2.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.2 |
| 2 | Bellows hardware: | EA | 4 | 840.39 | EU | 3.4 | 4 | 40.0 | 160 | MS | 36.20 | 5.8 | 9.2 |
| 3 | (flanges,constraints,weld | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | Spools | EA | 4 | 1120.53 | CP | 4.5 | 4 | 4.0 | 16 | MT | 25.20 | 0.4 | 4.9 |
| 5 | Spool mounting & supports | | 4 | 224.10 | EU | 0.9 | 4 | 80.0 | 320 | MS | 36.20 | 11.6 | 12.5 |
| 6 | 6''valve, manual | EA | 2 | 11205.25 | CP | 22.4 | 2 | 2.0 | 4 | MT | 25.20 | 0.1 | 22.5 |
| 7 | 4''valve, manual | EA | 2 | 8403.94 | CP | 16.8 | 2 | 2.0 | 4 | MT | 25.20 | 0.1 | 16.9 |
| 8 | Misc. UHV hardware & asse | | 1 | 5602.63 | EU | 5.6 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 12.8 |

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Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | Bakeout & vac check | | 1 | 224.10 | EU | 0.2 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.5 |
| ** | Subtotal ** | | | | | 56.0 | | | 904 | | | 32.5 | 88.5 |
| ** | WBS: 1.2.3.3.1.1.4 | Vacuum Pump Stations | | | | | | | | | | | |
| 1 | 400 l/s vac. pump pkg. | EA | 3 | 11468.58 | CP | 34.4 | 3 | 1.0 | 3 | MT | 25.20 | 0.1 | 34.5 |
| 2 | includes ion pump, tsp, c | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | (controller costed with C | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | (Perkin Elmer''Boostivac' | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | TSP spare filaments | SET | 3 | 140.07 | CP | 0.4 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.4 |
| 6 | Ion gage and power supply | | 0 | 0.00 | | 0.0 | 3 | 1.0 | 3 | MT | 25.20 | 0.1 | 0.1 |
| 7 | (cost included with Contr | | 1 | 0.00 | XX | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 8 | 2 3/4''roughing valve | | 3 | 1226.98 | CP | 3.7 | 3 | 1.0 | 3 | MT | 25.20 | 0.1 | 3.8 |
| ** | Subtotal ** | | | | | 38.5 | | | 9 | | | 0.2 | 38.7 |
| ** | WBS: 1.2.3.3.1.2.1 | Entrance Slit | | | | | | | | | | | |
| 1 | Blade Mechanism | | 1 | 1120.53 | EU | 1.1 | 1 | 100.0 | 100 | MS | 36.20 | 3.6 | 4.7 |
| 2 | Blade Actuation | | 1 | 2801.31 | EU | 2.8 | 1 | 80.0 | 80 | MS | 36.20 | 2.9 | 5.7 |
| 3 | Z-travel mechanism | | 1 | 1120.53 | EU | 1.1 | 1 | 100.0 | 100 | MS | 36.20 | 3.6 | 4.7 |
| 4 | Z-travel actuation | | 1 | 5602.63 | EU | 5.6 | 1 | 80.0 | 80 | MS | 36.20 | 2.9 | 8.5 |
| 5 | Vacuum chamber | | 1 | 560.26 | EU | 0.6 | 1 | 160.0 | 160 | MS | 36.20 | 5.8 | 6.4 |
| 6 | Vacuum Bellows | | 2 | 7843.68 | EU | 15.7 | 2 | 40.0 | 80 | MS | 36.20 | 2.9 | 18.6 |
| 7 | Vac. Pump & gaging (separ | | 1 | 0.00 | EU | 0.0 | 1 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 8 | Ass'y & bakeout | | 1 | 224.10 | EU | 0.2 | 1 | 120.0 | 120 | MS | 36.20 | 4.3 | 4.6 |
| 9 | Support Stand | | 1 | 560.26 | EU | 0.6 | 1 | 180.0 | 180 | MS | 36.20 | 6.5 | 7.1 |
| 10 | Alignment Calibration | | 1 | 0.00 | EU | 0.0 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 2.0 |
| ** | Subtotal ** | | | | | 27.7 | | | 980 | | | 34.6 | 62.3 |
| ** | WBS: 1.2.3.3.1.2.2 | Adjustable Mask | | | | | | | | | | | |
| 1 | Blade Mechanism | | 4 | 1680.79 | EU | 6.7 | 4 | 80.0 | 320 | MS | 36.20 | 11.6 | 18.3 |
| 2 | Vacuum Housing | | 1 | 1344.63 | CP | 1.3 | 1 | 100.0 | 100 | MS | 36.20 | 3.6 | 5.0 |
| 3 | Assembly and Bakeout | | 1 | 224.10 | EU | 0.2 | 1 | 120.0 | 120 | MS | 36.20 | 4.3 | 4.6 |
| 4 | Alignment calibration | | 1 | 0.00 | EU | 0.0 | 1 | 40.0 | 40 | MT | 25.20 | 1.0 | 1.0 |
| ** | Subtotal ** | | | | | 8.3 | | | 580 | | | 20.6 | 28.8 |
| ** | WBS: 1.2.3.3.1.2.3 | Grating Chamber | | | | | | | | | | | |
| 1 | Grating Blank | | 3 | 560.26 | EU | 1.7 | 3 | 100.0 | 300 | MS | 36.20 | 10.9 | 12.5 |
| 2 | Gratings - figuring | SET | 1 | 30058.08 | VQ | 30.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 30.1 |
| 3 | Gratings - ion etching | SET | 1 | 21934.28 | VQ | 21.9 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 21.9 |
| 4 | Grating Mounting | EA | 1 | 1680.79 | EU | 1.7 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 8.9 |
| 5 | Vacuum Chamber | | 1 | 6723.15 | EU | 6.7 | 1 | 500.0 | 500 | MS | 36.20 | 18.1 | 24.8 |
| 6 | Support Stand | | 1 | 6723.15 | EU | 6.7 | 1 | 80.0 | 80 | MS | 36.20 | 2.9 | 9.6 |
| 7 | Vac Pump & gaging (separa | | 0 | 0.00 | EU | 0.0 | 0 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 8 | Assembly and bakeout | | 1 | 224.10 | EU | 0.2 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 7.5 |
| 9 | Alignment calibration | | 1 | 224.10 | EU | 0.2 | 1 | 200.0 | 200 | MT | 25.20 | 5.0 | 5.3 |
| 10 | Grationg Scan Mechanism | | 1 | 3921.84 | EU | 3.9 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 11.2 |
| ** | Subtotal ** | | | | | 73.2 | | | 1680 | | | 58.6 | 131.8 |
| ** | WBS: 1.2.3.3.1.2.4 | Exit Slit | | | | | | | | | | | |
| 1 | Blade Mechanism | | 1 | 1120.53 | EU | 1.1 | 1 | 100.0 | 100 | MS | 36.20 | 3.6 | 4.7 |
| 2 | Blade Actuation | | 1 | 2801.31 | EU | 2.8 | 1 | 80.0 | 80 | MS | 36.20 | 2.9 | 5.7 |
| 3 | Z-travel mechanism | | 1 | 1120.53 | EU | 1.1 | 1 | 100.0 | 100 | MS | 36.20 | 3.6 | 4.7 |
| 4 | Z-travel actuation | | 1 | 5602.63 | EU | 5.6 | 1 | 80.0 | 80 | MS | 36.20 | 2.9 | 8.5 |
| 5 | Vacuum chamber | | 1 | 1120.53 | EU | 1.1 | 1 | 200.0 | 200 | MS | 36.20 | 7.2 | 8.4 |
| 6 | Vacuum Bellows | | 2 | 11205.25 | EU | 22.4 | 2 | 40.0 | 80 | MS | 36.20 | 2.9 | 25.3 |
| 7 | Vac. Pump & gaging (separ | | 0 | 0.00 | EU | 0.0 | 0 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 8 | Ass'y & bakeout | | 1 | 224.10 | EU | 0.2 | 1 | 120.0 | 120 | MS | 36.20 | 4.3 | 4.6 |
| 9 | Support Stand | | 1 | 560.26 | EU | 0.6 | 1 | 180.0 | 180 | MS | 36.20 | 6.5 | 7.1 |
| 10 | Alignment calibration | | 0 | 0.00 | EU | 0.0 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 2.0 |
| ** | Subtotal ** | | | | | 35.0 | | | 1020 | | | 36.0 | 71.0 |

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| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ** WBS: 1.2.3.3.1.2.5 | Vacuum Pump Stations | | | | | | | | | | | | |
| 1 | 400 l/s vac. pump pkg. | EA | 3 | 11468.58 | CP | 34.4 | 3 | 1.0 | 3 | MT | 25.20 | 0.1 | 34.5 |
| 2 | includes ion pump, tsp, c | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | (controller costed with C | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | (Perkin Elmer''Boostivac' | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | TSP spare filaments | SET | 3 | 140.07 | CP | 0.4 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.4 |
| 6 | Ion gage and power supply | | 0 | 0.00 | | 0.0 | 3 | 1.0 | 3 | MT | 25.20 | 0.1 | 0.1 |
| 7 | (cost included with Contr | | 1 | 0.00 | XX | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 8 | 2 3/4''roughing valve | | 3 | 1226.98 | CP | 3.7 | 3 | 1.0 | 3 | MT | 25.20 | 0.1 | 3.8 |
| ** Subtotal ** | | | | | | 38.5 | | | 9 | | | 0.2 | 38.7 |
| ** WBS: 1.2.3.3.1.3 | Mechanical Installation | | | | | | | | | | | | |
| 1 | Final Assembly and Bakeou | | 1 | 560.26 | EU | 0.6 | 1 | 320.0 | 320 | MS | 36.20 | 11.6 | 12.1 |
| 2 | includes misc. materials, | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | ass'y shop labor (clean r | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | bakeout | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Installation | | 0 | 0.00 | | 0.0 | 1 | 640.0 | 640 | IMT | 61.60 | 39.4 | 39.4 |
| 6 | Survey & Alignment | | 1 | 560.26 | EU | 0.6 | 1 | 300.0 | 300 | MT | 25.20 | 7.6 | 8.1 |
| 7 | Pneumatic Service | | 1 | 2241.05 | EU | 2.2 | 1 | 80.0 | 80 | IMT | 61.60 | 4.9 | 7.2 |
| 8 | includes copper tubing, f | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | MT | 25.20 | 1.0 | 1.0 |
| 9 | misc. hardware & instrume | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | MS | 36.20 | 1.4 | 1.4 |
| 10 | LCW Service | | 1 | 2241.05 | EU | 2.2 | 1 | 80.0 | 80 | IPL | 61.60 | 4.9 | 7.2 |
| 11 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 2.0 |
| 12 | Unistrut & misc. hdwre | | 1 | 3921.84 | EU | 3.9 | 1 | 80.0 | 80 | IMT | 61.60 | 4.9 | 8.8 |
| 13 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 80.0 | 80 | MT | 25.20 | 2.0 | 2.0 |
| 14 | '' | | 1 | 0.00 | EU | 0.0 | 1 | 80.0 | 80 | MS | 36.20 | 2.9 | 2.9 |
| 15 | Beam stop lead shielding | | 1 | 2801.31 | EU | 2.8 | 1 | 80.0 | 80 | MS | 36.20 | 2.9 | 5.7 |
| 16 | and shielding enclosure | | 1 | 0.00 | | 0.0 | 1 | 20.0 | 20 | IMT | 61.60 | 1.2 | 1.2 |
| ** Subtotal ** | | | | | | 12.3 | | | 1920 | | | 86.9 | 99.2 |
| ** WBS: 1.2.3.3.1.4 | Photon Transport Controls | | | | | | | | | | | | |
| 1 | Ethernet Controller Board | | 1 | 2241.05 | EU | 2.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.2 |
| 2 | Microcomputer: data stor, | | 1 | 11205.25 | EU | 11.2 | 1 | 40.0 | 40 | CP | 50.55 | 2.0 | 13.2 |
| 3 | Ethernet cable (20 m) | | 1 | 112.06 | EU | 0.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.1 |
| 4 | Ethernet Tranceiver | | 1 | 392.19 | EU | 0.4 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.4 |
| 5 | Intelligent Local Control | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 6 | 1 ILC per device plus pro | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 7 | Mirrors | | 2 | 1568.73 | EU | 3.1 | 2 | 20.0 | 40 | CP | 50.55 | 2.0 | 5.2 |
| 8 | Pinhole (H & V variable s | | 2 | 1568.73 | EU | 3.1 | 2 | 20.0 | 40 | CP | 50.55 | 2.0 | 5.2 |
| 9 | Insertion Device | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 10 | ALS system data | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 11 | Beam Position Monitoring | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 12 | B.P.M. Programmable power | | 1 | 1680.79 | EU | 1.7 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.7 |
| 13 | System check & debug | | 1 | 0.00 | EU | 0.0 | 1 | 40.0 | 40 | CP | 50.55 | 2.0 | 2.0 |
| 14 | B.P.M. Drive electronics | | 1 | 2801.31 | EU | 2.8 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 4.0 |
| 15 | Water flow switches & tem | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | | 0.00 | 0.0 | 1.6 |
| 16 | Cables for controls | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 17 | (see elec installation) | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 18 | Vac. Pum Controllers | | 3 | 4229.98 | CP | 12.7 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 12.7 |
| 19 | Ion Gages & Controllers | | 3 | 3986.83 | CP | 12.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 12.0 |
| 20 | Data Aquisition System (K | | 1 | 6723.15 | CP | 6.7 | 1 | 40.0 | 40 | CP | 50.55 | 2.0 | 8.7 |
| 21 | | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| ** Subtotal ** | | | | | | 62.4 | | | 340 | | | 15.3 | 77.7 |
| ** WBS: 1.2.3.3.1.5 | Monochromator Controls | | | | | | | | | | | | |
| 1 | Intelligent Local Control | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 2 | 1 ILC per device plus pro | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | Monochromator | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 4 | Water flow switches & tem | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 5 | Insertion dev. controls | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 6 | Ent. & exit slits | | 1 | 1568.73 | EU | 1.6 | 1 | 20.0 | 20 | CP | 50.55 | 1.0 | 2.6 |
| 7 | System check & debug | | 1 | 0.00 | EU | 0.0 | 1 | 40.0 | 40 | CP | 50.55 | 2.0 | 2.0 |
| 8 | Ion Gage & controller | | 3 | 3986.83 | CP | 12.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 12.0 |

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Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST | COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | Vacuum Pump controller | | 3 | 4229.98 | CP | 12.7 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 12.7 |
| ** | Subtotal ** | | | | | 30.9 | | | 120 | | | 6.1 | 37.0 |
| ** | WBS: 1.2.3.3.1.6 | Electrical Installation | | | | | | | | | | | |
| 1 | Double Rack,84"x24'' | EA | 1 | 1008.47 | CP | 1.0 | 1 | 8.0 | 8 | ES | 29.35 | 0.2 | 1.2 |
| 2 | BA Panel 3 PH 30A | EA | 1 | 56.03 | CP | 0.1 | 1 | 0.5 | 0 | ES | 29.35 | 0.0 | 0.1 |
| 3 | Breaker Panel | EA | 2 | 182.64 | CP | 0.4 | 2 | 4.0 | 8 | ES | 29.35 | 0.2 | 0.6 |
| 4 | Plug Strip | EA | 2 | 22.41 | EU | 0.0 | 2 | 1.0 | 2 | ES | 29.35 | 0.1 | 0.1 |
| 5 | X-conn Blks & Frame | EA | 1 | 252.12 | CP | 0.3 | 1 | 24.0 | 24 | ES | 29.35 | 0.7 | 1.0 |
| 6 | RLY Blks & Frame | EA | 1 | 549.06 | CP | 0.5 | 1 | 24.0 | 24 | ES | 29.35 | 0.7 | 1.3 |
| 7 | U-panel w/BNC's | EA | 2 | 67.23 | CP | 0.1 | 2 | 2.0 | 4 | ES | 29.35 | 0.1 | 0.3 |
| 8 | Rack Fans | EA | 2 | 56.03 | CP | 0.1 | 2 | 1.0 | 2 | ES | 29.35 | 0.1 | 0.2 |
| 9 | Cables | | 0 | 84.04 | CP | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 10 | Mirrors | EA | 10 | 84.04 | CP | 0.8 | 10 | 1.0 | 10 | IEL | 58.20 | 0.6 | 1.4 |
| 11 | Pinhole | EA | 10 | 84.04 | CP | 0.8 | 10 | 1.0 | 10 | IEL | 58.20 | 0.6 | 1.4 |
| 12 | ALS System Data | EA | 6 | 84.04 | CP | 0.5 | 6 | 1.0 | 6 | IEL | 58.20 | 0.3 | 0.9 |
| 13 | Ion Gages | EA | 6 | 84.04 | CP | 0.5 | 6 | 1.0 | 6 | IEL | 58.20 | 0.3 | 0.9 |
| 14 | Monochromator | EA | 4 | 84.04 | CP | 0.3 | 4 | 1.0 | 4 | IEL | 58.20 | 0.2 | 0.6 |
| 15 | Water Flow switches | EA | 4 | 168.07 | EU | 0.7 | 4 | 0.5 | 2 | ES | 29.35 | 0.1 | 0.7 |
| 16 | Temp. Sensors and Cables | EA | 4 | 112.06 | EU | 0.4 | 4 | 1.0 | 4 | IEL | 58.20 | 0.2 | 0.7 |
| 17 | Temp. Monitor Interlocks | | 1 | 336.16 | EU | 0.3 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 1.5 |
| 18 | Misc Elec. Installation | | 1 | 560.26 | EU | 0.6 | 1 | 40.0 | 40 | IEL | 58.20 | 2.3 | 2.9 |
| 19 | Misc. Elec Assembly | | 1 | 560.26 | EU | 0.6 | 1 | 40.0 | 40 | ES | 29.35 | 1.2 | 1.7 |
| 20 | Thermocouple Monitor & re | | 1 | 560.26 | CP | 0.6 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.6 |
| 21 | Thermocouple scanner | | 1 | 347.36 | CP | 0.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.3 |
| 22 | Monitor Lights panel | | 5 | 224.10 | CP | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 23 | Key Panel | | 1 | 280.13 | CP | 0.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.3 |
| 24 | Push Button Panel | | 1 | 224.10 | CP | 0.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.2 |
| 25 | Breaker Panel | | 1 | 224.10 | CP | 0.2 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.2 |
| 26 | Monitor Panels Wiring & I | | 0 | 0.00 | | 0.0 | 1 | 80.0 | 80 | ES | 29.35 | 2.3 | 2.3 |
| 27 | PLIC (Rad. Safety) | FT | 100 | 11.20 | CP | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 28 | PLIC Camac H.V. P.S. | EA | 1 | 1120.53 | CP | 1.1 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1.1 |
| 29 | PLIC Monitoring card | EA | 1 | 2801.31 | CP | 2.8 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.8 |
| 30 | PLIC - other elec. | | 1 | 3361.58 | CP | 3.4 | 1 | 14.0 | 14 | IEL | 58.20 | 0.8 | 4.2 |
| 31 | PLIC - Installation | FT | 100 | 1.13 | EU | 0.1 | 100 | 0.0 | 3 | IEL | 58.20 | 0.2 | 0.3 |
| 32 | PLIC - Installation | | 1 | 840.39 | | 0.8 | 1 | 8.0 | 8 | IEL | 58.20 | 0.5 | 1.3 |
| 33 | Monochromator System Elec | | 1 | 5602.63 | EU | 5.6 | 1 | 80.0 | 80 | ES | 29.35 | 2.3 | 8.0 |
| 34 | ''(instrumtn, monitors, p | | 0 | 0.00 | | 0.0 | 1 | 40.0 | 40 | IEL | 58.20 | 2.3 | 2.3 |
| ** | Subtotal ** | | | | | 25.8 | | | 459 | | | 17.6 | 43.5 |
| ** | WBS: 1.2.3.3.1.7 | Mechanical & Electrical System Integrati | | | | | | | | | | | |
| 1 | Vac. Roughing System | EA | 1 | 11205.25 | EU | 11.2 | 1 | 20.0 | 20 | MT | 25.20 | 0.5 | 11.7 |
| 2 | portable vacuum system, | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 3 | 'Megasorb''unit | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 4 | (per E. Hoyer) | | 0 | 0.00 | | 0.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 0.0 |
| 5 | Final alignment and calib | | 1 | 560.26 | EU | 0.6 | 1 | 400.0 | 400 | MT | 25.20 | 10.1 | 10.6 |
| 6 | Beam line controls check- | | 1 | 1120.53 | EU | 1.1 | 1 | 400.0 | 400 | MT | 25.20 | 10.1 | 11.2 |
| 7 | (includes instrumentation | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | ES | 29.35 | 4.7 | 4.7 |
| 8 | monitoring & interlocks, | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | IEL | 58.20 | 9.3 | 9.3 |
| 9 | communications, final adj | | 0 | 0.00 | | 0.0 | 1 | 160.0 | 160 | IMT | 61.60 | 9.9 | 9.9 |
| 10 | etc.) | | 0 | 0.00 | | 0.0 | 1 | 0.0 | 0 | XX | 0.00 | 0.0 | 0.0 |
| 11 | Vacuum system check-out | | 1 | 560.26 | EU | 0.6 | 1 | 500.0 | 500 | MT | 25.20 | 12.6 | 13.2 |
| ** | Subtotal ** | | | | | 13.4 | | | 1800 | | | 57.1 | 70.6 |
| ** | WBS: 1.2.3.3.2 | Main Scanning Microscope Station | | | | | | | | | | | |
| 1 | Sperical Mirrors | | 2 | 10000.00 | | 20.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.0 |
| 2 | Mirror mount/steer system | | 2 | 25000.00 | | 50.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 50.0 |
| 3 | Multilayer substates/ctng | | 1 | 50000.00 | | 50.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 50.0 |
| 4 | M'layer mountng/steering | | 1 | 25000.00 | | 25.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 25.0 |
| 5 | Part cost:support structr | | 1 | 30000.00 | | 30.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 30.0 |
| 6 | Building modifications | | 1 | 20000.00 | | 20.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.0 |
| 7 | Smpl stage/environ cntrl | | 1 | 10000.00 | | 10.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 10.0 |
| 8 | Smpl trgttng microscp sys | | 1 | 20000.00 | | 20.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.0 |

Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | White lite interferometer | | 1 | 5000.00 | 5.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 5.0 |
| 10 | Piezoelctrc scan motion | | 1 | 20000.00 | 20.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.0 |
| 11 | Position meas intrfrmtr | | 1 | 15000.00 | 15.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.0 |
| 12 | Interferometer electronic | | 1 | 5000.00 | 5.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 5.0 |
| 13 | Computing sys & interfacs | | 1 | 40000.00 | 40.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 40.0 |
| 14 | Part cost:image system | | 1 | 25000.00 | 25.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 25.0 |
| 15 | Granite table | | 1 | 15000.00 | 15.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.0 |
| 16 | Microfab:zone plts/wndws | | 1 | 65000.00 | 65.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 65.0 |
| 17 | Software & controls | | 1 | 75000.00 | 75.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 75.0 |
| 18 | Vacuum hardware | | 1 | 60000.00 | 60.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 60.0 |
| 19 | Electronics & interfaces | | 1 | 25000.00 | 25.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 25.0 |
| ** | Subtotal ** | | | | 575.0 | | | 0 | | | 0.0 | 575.0 |
| ** | WBS: 1.2.3.3.3 | R/D Scanning Microscope Station | | | | | | | | | | |
| 1 | Spherical mirrors | | 2 | 10000.00 | 20.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.0 |
| 2 | Mirror mount/steer system | | 2 | 25000.00 | 50.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 50.0 |
| 3 | Part cost:supprt structur | | 1 | 30000.00 | 30.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 30.0 |
| 4 | Smpl stage/environ cntrl | | 1 | 20000.00 | 20.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.0 |
| 5 | Smpl targttng micrscp sys | | 1 | 20000.00 | 20.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.0 |
| 6 | White lite intrfrmtr focs | | 1 | 5000.00 | 5.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 5.0 |
| 7 | Piezoelctrc scan system | | 1 | 20000.00 | 20.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.0 |
| 8 | Position meas intrfrmtr | | 1 | 15000.00 | 15.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.0 |
| 9 | Interferometer electrnics | | 1 | 5000.00 | 5.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 5.0 |
| 10 | Computing sys & interfacs | | 1 | 40000.00 | 40.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 40.0 |
| 11 | Part cost:image dsply sys | | 1 | 25000.00 | 25.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 25.0 |
| 12 | Granite table | | 1 | 15000.00 | 15.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.0 |
| 13 | Microfab:zone plts/wndws | | 1 | 100000.00 | 100.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 100.0 |
| 14 | Software and controls | | 1 | 20000.00 | 20.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.0 |
| 15 | Vacuum hardware | | 1 | 60000.00 | 60.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 60.0 |
| 16 | Electronics & interfaces | | 1 | 25000.00 | 25.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 25.0 |
| ** | Subtotal ** | | | | 470.0 | | | 0 | | | 0.0 | 470.0 |
| ** | WBS: 1.2.3.3.4 | Diffraction Imaging Station | | | | | | | | | | |
| 1 | Spherical mirrors | | 2 | 10000.00 | 20.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.0 |
| 2 | Mirror mount/steer system | | 2 | 30000.00 | 60.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 60.0 |
| 3 | Part cost:support strctur | | 1 | 30000.00 | 30.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 30.0 |
| 4 | Smpl stage/environ cntrl | | 1 | 20000.00 | 20.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.0 |
| 5 | Smpl trgttng microscp sys | | 1 | 20000.00 | 20.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.0 |
| 6 | Computing sys & interfcs | | 1 | 40000.00 | 40.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 40.0 |
| 7 | Part cost:image dsply sys | | 1 | 25000.00 | 25.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 25.0 |
| 8 | Granite table | | 1 | 15000.00 | 15.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.0 |
| 9 | Microfab:zone plts/windws | | 1 | 50000.00 | 50.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 50.0 |
| 10 | CCD detector & interfaces | | 1 | 40000.00 | 40.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 40.0 |
| 11 | Vacuum hardware | | 1 | 60000.00 | 60.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 60.0 |
| ** | Subtotal ** | | | | 380.0 | | | 0 | | | 0.0 | 380.0 |
| ** | WBS: 1.3.1.1.1 | Engineering | | | | | | | | | | |
| 1 | Engineering | | 1 | 120000.00 | 120.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 120.0 |
| ** | Subtotal ** | | | | 120.0 | | | 0 | | | 0.0 | 120.0 |
| ** | WBS: 1.3.1.1.2 | Consultants | | | | | | | | | | |
| 1 | Consultants | | 1 | 15000.00 | 15.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.0 |
| ** | Subtotal ** | | | | 15.0 | | | 0 | | | 0.0 | 15.0 |
| ** | WBS: 1.3.1.1.3 | Inspection | | | | | | | | | | |
| 1 | Inspection | | 1 | 65000.00 | 65.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 65.0 |
| ** | Subtotal ** | | | | 65.0 | | | 0 | | | 0.0 | 65.0 |
| ** | WBS: 1.3.1.2.1 | Title I | | | | | | | | | | |
| 1 | Title I | | 1 | 50000.00 | 50.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 50.0 |

Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ** Subtotal ** | | | | | 50.0 | | | 0 | | | 0.0 | 50.0 |
| ** WBS: 1.3.1.2.2 | | Title II | | | | | | | | | | |
| 1 | Title II | | 1 | 145000.00 | 145.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 145.0 |
| ** Subtotal ** | | | | | 145.0 | | | 0 | | | 0.0 | 145.0 |
| ** WBS: 1.3.1.2.3 | | Title III | | | | | | | | | | |
| 1 | Title III | | 1 | 95000.00 | 95.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 95.0 |
| ** Subtotal ** | | | | | 95.0 | | | 0 | | | 0.0 | 95.0 |
| ** 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 | 12.2 |
| ** WBS: 1.3.2.2.1 | | General Requirements | | | | | | | | | | |
| 1 | General Requirements | | 1 | 223980.00 | 224.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 224.0 |
| ** Subtotal ** | | | | | 224.0 | | | 0 | | | 0.0 | 224.0 |
| ** WBS: 1.3.2.2.2 | | Sitework | | | | | | | | | | |
| 1 | Sitework | | 1 | 166000.00 | 166.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 166.0 |
| ** Subtotal ** | | | | | 166.0 | | | 0 | | | 0.0 | 166.0 |
| ** WBS: 1.3.2.2.5 | | Metals | | | | | | | | | | |
| 1 | Metals | | 1 | 233000.00 | 233.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 233.0 |
| ** Subtotal ** | | | | | 233.0 | | | 0 | | | 0.0 | 233.0 |
| ** WBS: 1.3.2.2.6 | | Carpentry | | | | | | | | | | |
| 1 | Rough Carpentry | | 1 | 15000.00 | 15.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.0 |
| 2 | Finish Carpentry | | 1 | 9000.00 | 9.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 9.0 |
| ** Subtotal ** | | | | | 24.0 | | | 0 | | | 0.0 | 24.0 |
| ** WBS: 1.3.2.2.7 | | Thermal and Moisture Protection | | | | | | | | | | |
| 1 | Wall Insulation | | 1 | 5000.00 | 5.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 5.0 |
| 2 | Sheet Metal | | 1 | 5000.00 | 5.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 5.0 |
| 3 | Caulking and Sealants | | 1 | 6000.00 | 6.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 6.0 |
| ** Subtotal ** | | | | | 16.0 | | | 0 | | | 0.0 | 16.0 |
| ** WBS: 1.3.2.2.8 | | Doors, Windows & Glass | | | | | | | | | | |
| 1 | Metal Doors/Frames/Hrdwre | | 1 | 22000.00 | 22.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 22.0 |
| 2 | Metal Sash/Glass/Glazing | | 1 | 81000.00 | 81.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 81.0 |
| ** Subtotal ** | | | | | 103.0 | | | 0 | | | 0.0 | 103.0 |
| ** WBS: 1.3.2.2.9 | | Finishes | | | | | | | | | | |
| 1 | Metal Studs/Gypsum Board | | 1 | 78000.00 | 78.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 78.0 |
| 2 | Accoustic Treatment | | 1 | 30000.00 | 30.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 30.0 |
| 3 | Resilient Flooring | | 1 | 16000.00 | 16.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 16.0 |
| 4 | Painting and Wall Coverng | | 1 | 13000.00 | 13.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 13.0 |
| 5 | Rehab Existng Toilet Area | | 1 | 17000.00 | 17.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 17.0 |
| ** Subtotal ** | | | | | 154.0 | | | 0 | | | 0.0 | 154.0 |
| ** WBS: 1.3.2.2.10 | | Specialties | | | | | | | | | | |
| 1 | Specialties | | 1 | 2000.00 | 2.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.0 |

Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ** Subtotal ** | | | | | 2.0 | | | 0 | | | 0.0 | 2.0 |
| ** WBS: 1.3.2.2.15 | | Mechanical Work | | | | | | | | | | |
| 1 | Plumbing | | 1 | 59000.00 | 59.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 59.0 |
| 2 | HVAC | | 1 | 127000.00 | 127.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 127.0 |
| 3 | Fire Protection Systems | | 1 | 4000.00 | 4.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 4.0 |
| ** Subtotal ** | | | | | 190.0 | | | 0 | | | 0.0 | 190.0 |
| ** WBS: 1.3.2.2.16 | | Electrical Work | | | | | | | | | | |
| 1 | Basic Material & Methods | | 1 | 17000.00 | 17.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 17.0 |
| 2 | Power Transmission | | 1 | 29000.00 | 29.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 29.0 |
| 3 | Service & Distribution | | 1 | 12000.00 | 12.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 12.0 |
| 4 | Lighting | | 1 | 21000.00 | 21.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 21.0 |
| 5 | Special Systems | | 1 | 4000.00 | 4.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 4.0 |
| 6 | Communications | | 1 | 14000.00 | 14.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 14.0 |
| 7 | Emergency Power | | 1 | 19000.00 | 19.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 19.0 |
| 8 | Demolition | | 1 | 15000.00 | 15.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.0 |
| ** Subtotal ** | | | | | 131.0 | | | 0 | | | 0.0 | 131.0 |
| ** WBS: 1.3.2.3.1 | | General Requirements | | | | | | | | | | |
| 1 | General Requirements | | 1 | 110340.00 | 110.3 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 110.3 |
| ** Subtotal ** | | | | | 110.3 | | | 0 | | | 0.0 | 110.3 |
| ** WBS: 1.3.2.3.5 | | Metals | | | | | | | | | | |
| 1 | Metals | | 1 | 6000.00 | 6.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 6.0 |
| ** Subtotal ** | | | | | 6.0 | | | 0 | | | 0.0 | 6.0 |
| ** WBS: 1.3.2.3.6 | | Carpentry | | | | | | | | | | |
| 1 | Rough Carpentry | | 1 | 7000.00 | 7.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 7.0 |
| 2 | Finish Carpentry | | 1 | 8000.00 | 8.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 8.0 |
| ** Subtotal ** | | | | | 15.0 | | | 0 | | | 0.0 | 15.0 |
| ** WBS: 1.3.2.3.8 | | Doors, Windows & Glass | | | | | | | | | | |
| 1 | Metal Doors & Frames | | 1 | 20000.00 | 20.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 20.0 |
| ** Subtotal ** | | | | | 20.0 | | | 0 | | | 0.0 | 20.0 |
| ** WBS: 1.3.2.3.9 | | Finishes | | | | | | | | | | |
| 1 | Gypsum Wall Board,Taping | | 1 | 68000.00 | 68.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 68.0 |
| 2 | Accoustic Treatment | | 1 | 26000.00 | 26.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 26.0 |
| 3 | Resilient Flooring | | 1 | 16000.00 | 16.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 16.0 |
| 4 | Painting and Wall Coverng | | 1 | 14000.00 | 14.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 14.0 |
| ** Subtotal ** | | | | | 124.0 | | | 0 | | | 0.0 | 124.0 |
| ** WBS: 1.3.2.3.10 | | Specialties | | | | | | | | | | |
| 1 | Specialties | | 1 | 2000.00 | 2.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.0 |
| ** Subtotal ** | | | | | 2.0 | | | 0 | | | 0.0 | 2.0 |
| ** WBS: 1.3.2.3.13 | | Special Construction | | | | | | | | | | |
| 1 | Prefab Lab Modules | | 1 | 80000.00 | 80.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 80.0 |
| ** Subtotal ** | | | | | 80.0 | | | 0 | | | 0.0 | 80.0 |
| ** WBS: 1.3.2.3.15 | | Mechanical Work | | | | | | | | | | |
| 1 | Plumbing & Process Piping | | 1 | 66000.00 | 66.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 66.0 |
| 2 | HVAC | | 1 | 126000.00 | 126.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 126.0 |
| 3 | Fire Protection Systems | | 1 | 4000.00 | 4.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 4.0 |

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Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ** Subtotal ** | | | | | 196.0 | | | 0 | | | 0.0 | 196.0 |
| ** WBS: 1.3.2.3.16 | | Electrical Work | | | | | | | | | | |
| 1 | Basic Material & Methods | | 1 | 15000.00 | 15.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.0 |
| 2 | Power Transmission | | 1 | 10000.00 | 10.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 10.0 |
| 3 | Service & Distribution | | 1 | 5000.00 | 5.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 5.0 |
| 4 | Lighting | | 1 | 21000.00 | 21.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 21.0 |
| 5 | Special Systems | | 1 | 3000.00 | 3.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 3.0 |
| 6 | Communications | | 1 | 2000.00 | 2.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 2.0 |
| 7 | Emergency Power | | 1 | 3000.00 | 3.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 3.0 |
| ** Subtotal ** | | | | | 59.0 | | | 0 | | | 0.0 | 59.0 |
| ** WBS: 1.3.2.4.1 | | General Requirements | | | | | | | | | | |
| 1 | General requirements | | 1 | 12750.00 | 12.8 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 12.8 |
| ** Subtotal ** | | | | | 12.8 | | | 0 | | | 0.0 | 12.8 |
| ** WBS: 1.3.2.4.15 | | Mechanical | | | | | | | | | | |
| 1 | Mechanical | | 1 | 15000.00 | 15.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.0 |
| ** Subtotal ** | | | | | 15.0 | | | 0 | | | 0.0 | 15.0 |
| ** WBS: 1.3.2.4.16 | | Electrical | | | | | | | | | | |
| 1 | Electrical | | 1 | 43000.00 | 43.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 43.0 |
| ** Subtotal ** | | | | | 43.0 | | | 0 | | | 0.0 | 43.0 |
| ** WBS: 1.3.2.5.1 | | Lab Furniture & Standard Fume Hoods | | | | | | | | | | |
| 1 | Building 10 | | 1 | 205000.00 | 205.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 205.0 |
| 2 | Building 6 | | 1 | 85000.00 | 85.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 85.0 |
| ** Subtotal ** | | | | | 290.0 | | | 0 | | | 0.0 | 290.0 |
| ** WBS: 1.3.2.5.2 | | Cold Rooms | | | | | | | | | | |
| 1 | Building 10 | | 1 | 15000.00 | 15.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 15.0 |
| 2 | Building 6 | | 2 | 15000.00 | 30.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 30.0 |
| ** Subtotal ** | | | | | 45.0 | | | 0 | | | 0.0 | 45.0 |
| ** WBS: 1.3.2.5.3 | | Laminar Flow Hoods (3) | | | | | | | | | | |
| 1 | Hoods | | 3 | 12000.00 | 36.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 36.0 |
| ** Subtotal ** | | | | | 36.0 | | | 0 | | | 0.0 | 36.0 |
| ** WBS: 1.3.2.5.4.1 | | Digital Scanning Elctrn Microscpe w/Workstatn | | | | | | | | | | |
| 1 | Microscope | | 1 | 260000.00 | 260.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 260.0 |
| ** Subtotal ** | | | | | 260.0 | | | 0 | | | 0.0 | 260.0 |
| ** WBS: 1.3.2.5.4.2 | | HiRes Electron Microscope w/Cryo Workstation | | | | | | | | | | |
| 1 | Microscope | | 1 | 200000.00 | 200.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 200.0 |
| ** Subtotal ** | | | | | 200.0 | | | 0 | | | 0.0 | 200.0 |
| ** WBS: 1.3.2.5.4.3 | | Confocal Microscope | | | | | | | | | | |
| 1 | Microscope | | 1 | 86000.00 | 86.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 86.0 |
| ** Subtotal ** | | | | | 86.0 | | | 0 | | | 0.0 | 86.0 |
| ** WBS: 1.3.2.5.4.4 | | Image Analysis Package | | | | | | | | | | |
| 1 | Package | | 1 | 80000.00 | 80.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 80.0 |
| ** Subtotal ** | | | | | 80.0 | | | 0 | | | 0.0 | 80.0 |

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Technical Components Cost Estimate

| ITM NBR | ITM DESCRIPTION | UNIT MEAS | NBR UNITS | UNIT COST COST BASIS | TOTAL ISC K$ | LBR UNTS | HRS/ UNIT | TOTAL HRS | CRAFT CODE | CRAFT RATE | TOTAL LABOR K$ | ISC + LABOR K$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ** WBS: 1.3.3.1 | | Biochemistry | | | | | | | | | | |
| 1 | Centrufuges | | 1 | 243000.00 | 243.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 243.0 |
| 2 | Spectrophotometers | | 1 | 183000.00 | 183.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 183.0 |
| 3 | Balances | | 1 | 59000.00 | 59.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 59.0 |
| 4 | Isotope counters | | 1 | 41000.00 | 41.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 41.0 |
| 5 | Separation equipment | | 1 | 214000.00 | 214.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 214.0 |
| 6 | General lab equipment | | 1 | 294000.00 | 294.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 294.0 |
| ** Subtotal ** | | | | | 1034.0 | | | 0 | | | 0.0 | 1034.0 |
| ** WBS: 1.3.3.2 | | Microscopy | | | | | | | | | | |
| 1 | Darkroom equipment | | 1 | 52000.00 | 52.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 52.0 |
| 2 | General lab equipment | | 1 | 53000.00 | 53.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 53.0 |
| ** Subtotal ** | | | | | 105.0 | | | 0 | | | 0.0 | 105.0 |
| ** WBS: 1.3.3.3 | | Cell and Tissue Culture | | | | | | | | | | |
| 1 | Incubators | | 1 | 46000.00 | 46.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 46.0 |
| 2 | Sterilizer | | 1 | 37000.00 | 37.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 37.0 |
| 3 | General lab equipment | | 1 | 52000.00 | 52.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 52.0 |
| ** Subtotal ** | | | | | 135.0 | | | 0 | | | 0.0 | 135.0 |
| ** WBS: 1.3.3.4 | | Surgical Suite | | | | | | | | | | |
| 1 | Tables, instrumts,lightng | | 1 | 19000.00 | 19.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 19.0 |
| 2 | Microscope & video equip | | 1 | 47000.00 | 47.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 47.0 |
| 3 | General lab equipment | | 1 | 11000.00 | 11.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 11.0 |
| ** Subtotal ** | | | | | 77.0 | | | 0 | | | 0.0 | 77.0 |
| ** WBS: 1.3.3.5 | | General Support Equipment | | | | | | | | | | |
| 1 | Computational equipment | | 1 | 79000.00 | 79.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 79.0 |
| 2 | Dishwasher | | 1 | 73000.00 | 73.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 73.0 |
| 3 | Office furniture | | 1 | 40000.00 | 40.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 40.0 |
| 4 | Office equipment | | 1 | 189000.00 | 189.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 189.0 |
| ** Subtotal ** | | | | | 381.0 | | | 0 | | | 0.0 | 381.0 |
| ** WBS: 1.4.1 | | Special Research Facilities and Management | | | | | | | | | | |
| 1 | Special Research Facility | | 1 | 3320000.00 | 3320.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 3320.0 |
| 2 | Project Mgmt & Admin | | 1 | 205000.00 | 205.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 205.0 |
| ** Subtotal ** | | | | | 3525.0 | | | 0 | | | 0.0 | 3525.0 |
| ** WBS: 1.4.2 | | Conventional Facilities | | | | | | | | | | |
| 1 | Conventional Facilities | | 1 | 1031000.00 | 1031.0 | 0 | 0.0 | 0 | | 0.00 | 0.0 | 1031.0 |
| ** Subtotal ** | | | | | 1031.0 | | | 0 | | | 0.0 | 1031.0 |
| *** Total *** | | | | | 17476.4 | | | 102096 | | | 4023.9 | 21500.3 |

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