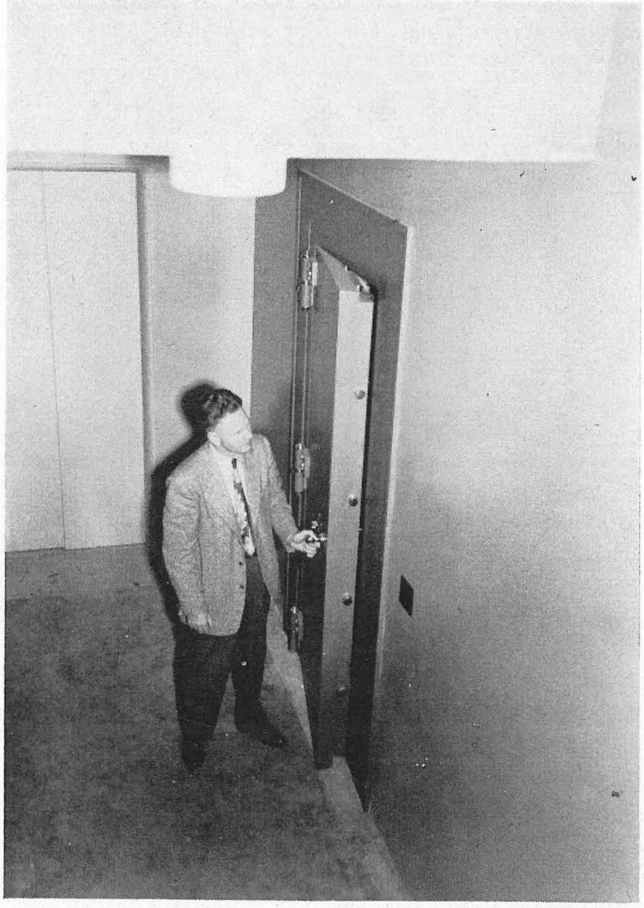


Door to outer vault of Huntington Library's new bomb-resistant structure is solid steel, three inches thick.

BOMB-RESISTANT STRUCTURE

The Huntington Library gets a new building which provides needed stack room along with spaces designed to be bomb-resistant

by ERNEST B. HUGG

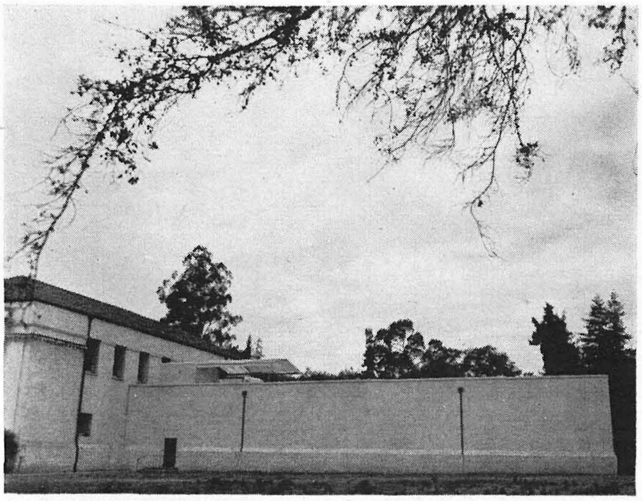
THE BOARD OF TRUSTEES of the Henry E. Huntington Library and Art Gallery has always been keenly aware of its obligation to the public to do its best to protect the rare books, manuscripts, paintings, and other art objects in its custody. During World War II, when air attacks on southern California seemed imminent, some of the more valuable articles were removed to distant places.

When fighting started in Korea the Board was already working on preliminary layouts for a new building which was needed to relieve an acute shortage of book stack space. Since it was now within the realm of possibility that there might be enemy attacks on this country within the next few years, the Board began to consider the construction of a building which would provide the needed stack room *along with* spaces especially designed to be bomb-resistant.

Since there has always been a close relationship between the two institutions, the Board turned to Caltech for assistance in connection with the design and construction of a bomb-resistant structure. Plans and specifications were prepared by Caltech's Buildings and Grounds Department with the assistance of Professor R. R. Martel of the Engineering Department as a consultant.

Preliminary design and cost studies indicated that the addition would be both practical and economical, and the Board's decision to proceed was based on a full understanding that it would be practical to design even a small portion of the building so that the contents would be safe in the event of a direct hit by an atomic bomb or by a heavy super-bomb of the conventional type. In either of these cases the required thickness of reinforced concrete protection would be staggering. Consequently, the building was designed to give various degrees of protection in different portions of the structure.

The building is a reinforced concrete structure approximately 40 feet by 120 feet with a main floor, basement and sub-basement. To allow for future book space it is designed to support two additional stories. The two principal bomb-resistant portions of the building comprise the sub-basement. The inner vault, 12 feet wide by 23 feet long by 12 feet high, with a net usable volume of approximately 3,000 cubic feet, has protection equivalent to ten feet of reinforced concrete on top, bottom and sides. It can be reached only through the outer vault which is 35 feet by 67 feet by 8½ feet high and has a net usable volume of approximately 20,000 cubic feet. This large outer vault has protection equivalent to four feet of reinforced concrete on top, bottom and sides. In each case the unusually thick bottom slab is required because experience has shown that a great



East elevation of the structure shows its relation to the main library building. The roof deck at the left is used as an employees lounge.

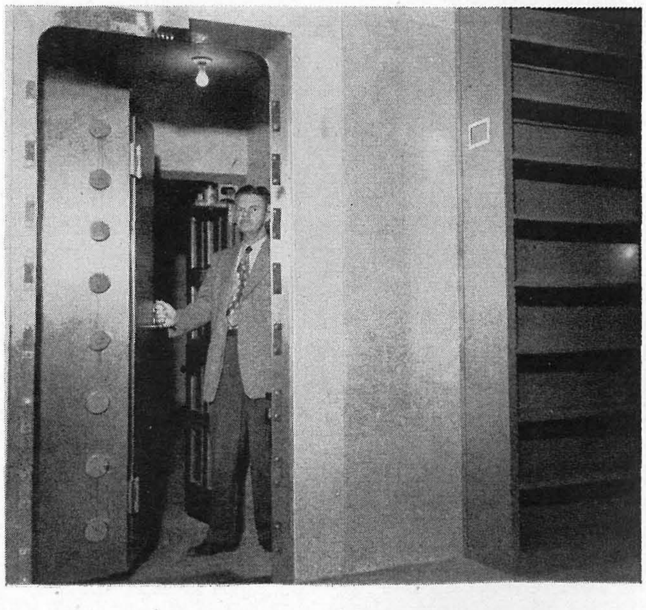
number of bombs follow a path in the earth which resembles a J. This fact makes it imperative that all surfaces, including the bottom, have approximately the same thickness of protection. Otherwise a near miss could easily penetrate to a level below the side wall and turn upward to pierce the bottom slab.

The relatively small inner vault was provided for the storage of the most valuable items. Consequently one additional precaution was taken to protect its contents from damage by flying objects. This was considered necessary because of the fact that when a wall or slab is hit by a projectile, chunks of varying sizes often pop off the opposite side, even though failure of the structural member does not occur. A 1/4 inch steel plate, anchored securely to the concrete, was used to line the interior surfaces of the inner vault to overcome this hazard. This liner plate was welded solid at all intersections and so performs the additional function of insuring against moisture entering the vault.

The opening into the inner vault from the outer vault is protected by a solid steel door 12 inches thick, set in a solid steel frame and recessed eight feet in a reinforced concrete wall nine feet thick. This steel frame is further protected by being welded to three solid steel armor plates surrounding the opening, each of which is four inches thick. These armor plates are in turn securely anchored into the concrete. The total weight of these armor plates alone is about 60,000 pounds.

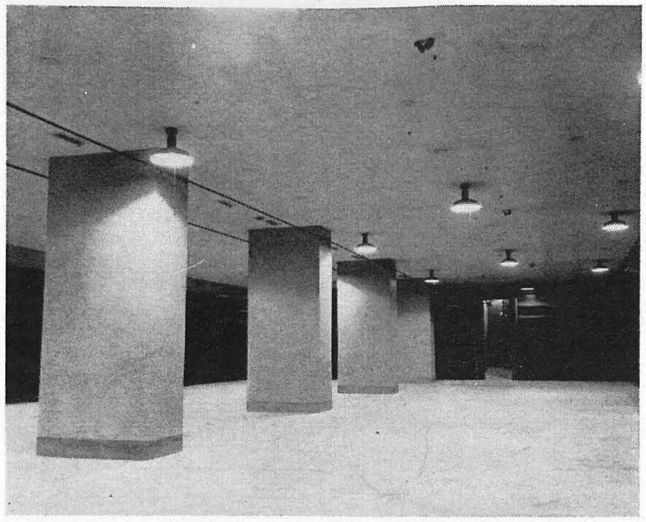
Experience has shown that pour joints form a definite plane of weakness during a bombing attack. It was therefore decided that, even though certain construction difficulties would result, the entire inner vault from the bottom of the eight-foot floor slab to the top of the ten-foot top slab would be cast in an unusually large continuous pour of approximately 1300 cubic yards. Having made this decision, it was apparent that it would be highly desirable to provide a relatively thin base slab to serve simply as a working platform. A steel angle framework was then designed to support the 1/4 inch liner plate and the 60,000 pounds of four-inch thick armor plate until such time as the reinforced steel was placed and the big pour was completed. The liner plate was fabricated as a huge 3,000 cubic foot box (23′x12′x12′) by the structural steel sub-contractor in his own shop, and then transported to the building site.

It was recognized that considerable heat would be generated by the curing of this large mass of concrete. Calculations, however, led to the conclusion that no



Lyle Wright, head of the Library's Reference Department, opens the 12-inch solid steel door to enter the inner vault. The smaller door behind him closes automatically when the carbon dioxide fire extinguishing system goes into operation.

This view down the length of the large outer vault shows (as black dots between the ceiling lights) some of the carbon dioxide fire alarm devices on the ceiling.



special provision for cooling would be required. As there did not seem to be very much information available on heat during curing of structures comparable to this vault, it was decided to insert thermo-couples at various points in the big pour so that the rate of liberation and of dissipation of heat could be studied. The readings taken subsequent to the pour confirmed the conclusion that no artificial cooling was necessary even though three cranes were used and the concrete was deposited at the exceptionally fast rate of 100 cubic yards per hour.

As stated previously, varying degrees of bomb resistance were built into different parts of the building. Most of the attention was given to the two vaults in the sub-basement. However, the basement floor was protected with the equivalent of approximately 18 inches of reinforced concrete and the first floor with 12 inches. Even on the first floor, where the protection is the least, there are no windows and the structural protection is sufficient to withstand the explosion of an atomic bomb directly overhead at about 2,000 feet elevation. This height is mentioned because it is the one that was used for the Hiroshima and the Nagasaki bombs. It was undoubtedly selected as the height that would cause the most widespread damage.

The problem of providing a bomb-resistant structure was also complicated by the necessity of running all of the various service lines to and from each of the spaces. Not even the smallest of the many required conduits, pipes and ducts was allowed to run straight through a protecting concrete member. This precaution was taken to protect against damage from fragments and from the effects of blast. In addition, when relatively large pipes or ducts ran within the structural members and parallel to their length, the members were increased in thickness as required so that the degree of protection would not be lessened.

Every possible precaution has been taken to prevent water damage to the valuable contents. No lines which might contain liquid were run in or through any of the protected areas. For fire protection in the two vault areas, since water systems were not permissible, high pressure type CO_2 extinguishing systems, which would be set off either by rate-of-rise heat actuated detectors or by smoke detectors, were used. In order to be certain that the system as installed would function properly when called upon, complete tests including discharge of the gas were required. Smoke from a smoldering rag on the floor was detected in about five minutes and heat from a pan of gasoline in considerably less time. Upon discharge, a smothering concentration of gas was reached in less than a minute and was held for over an hour.

The Library Board felt that it might be desirable at some future date to have year-round air conditioning, but did not wish to authorize the expense now. Consequently, a ventilating system using washed air was installed, but it was designed so that air conditioning could be installed later with a minimum of revision to the building. Independent control of temperature and humidity was a definite requirement and was provided; however, cooling is limited to the amount that can be obtained from the spray system without exceeding the upper limit of humidification allowed. This severely limits the range over which the desired humidity can be maintained, and explains why the Board feels that year-round air conditioning may sometime be installed.

All of the air passes through two types of filters. Strainer-type cellulose media filters are used to remove most of the suspended matter. Charcoal filters are intended to remove the harmful constituents of smog. In so far as is possible the major portion of the air is recirculated to limit the introduction of dirt and contaminants.

The design and construction were under the supervision of Wesley Hertenstein, '25, Caltech's Superintendent of Buildings and Grounds, with Professor R. R. Martel of the Engineering Department acting as consultant. Detail plans and specifications were prepared in the engineering office of the Buildings and Grounds Department under the direction of the author of this article, Ernest B. Hugg, '29, Assistant Superintendent of the Department. The low bidder, and subsequently the general contractor who constructed the building, was Ray Gerhart, '13.