San Francisco Fire Department Water Supply System

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Every San Franciscan is familiar with the great San Francisco Earthquake of April 18, 1906, and the conflagration which followed, leaving a major portion of the City in ashes. Few people, however, know that most of the damage resulted not from the 'Quake, but from the ensuing fires – the worst fire in the history of the United States. More than 300 water main breaks and over 23,000 broken water services turned the water distribution system into a sieve, and reduced water pressure to the downtown area. Four days later, by the time the fire was finally extinguished on April 21, all of the City's downtown area was destroyed. Twenty-five thousand buildings had burned – 80 per cent of the entire City's property value. It was the sixth time since 1849 that The City had burned to the ground.
The 1906 Earthquake crippled the City's water supplies, and left firefighters literally drafting from sewers in an effort to halt the conflagration, and the people of San Francisco blamed the destruction of the City on the failed water system. Insurance rates soared, and, in some areas, coverage was unobtainable.

In 1908, Marsden Manson, the City Engineer, conducted a study of 250 cities throughout the world to develop plans for a guaranteed water supply system for the sole purpose of fire protection. Exhaustive tests of pipe materials, valves and hydrants were conducted, and many eminent engineers of the period were consulted. All arguments were for a separate fire combat water system and against a private system outside the jurisdiction of the Fire Department.

The solution was the design and construction of the Auxiliary Water Supply System (AWSS) for fire protection – a separate and distinct water supply system for fire protection use only – with the Fire Department solely responsible for its maintenance, operation and development. Adequate volume and pressure were the primary foundations of the many ideas which eventually evolved into the San Francisco AWSS. More water main pressure meant less dependency on the horse- drawn steam fire engines of the era.

The AWSS remains the only high-pressure network of its type in the United States, and was the only public project funded by the citizenry following the Great Earthquake of 1906. The system was developed with a $5.2 million bond issue approved by the people of San Francisco in 1908.

Strongly influenced by the insurance companies of the period, the AWSS is dedicated to the principle that the City will never again be destroyed by fire, at least not for lack of water for fire fighting purposes. It is capable of covering a city block (100,000 square feet) with water to a depth of 25 feet in one day.

Over the years, as the needs of the City have grown, the distribution system has been improved and increased, from an original 72 miles of mains with 889 hydrants, to a 1997 total of 150 miles of 8- to 20-inch diameters mains, with 1,550 special hydrants – for a city of 47 square miles.

Water Storage, Pressure and Elevation

Twin Peaks Reservoir – the backbone of the system – a 10.5- million-gallon storage reservoir located on the City's Twin Peaks Mountains, as originally envisioned by Chief Dennis T. Sullivan in the 1890's, at an elevation of 758 feet. This reservoir, constructed of reinforced-concrete slabs six inches thick, is divided into two equal bays. Normal discharge flows from one bay only. In the event of a sudden break in the pipeline distribution system, only one-half of the capacity would be lost. The reservoir is normally supplied with fresh water by two 750 gallon-per- minute centrifugal pumps drawing from the city's domestic water system. Saltwater has better fire-extinguishing properties, but it is more destructive to fire fighting equipment.

Ashbury Tank – of riveted steel construction on a reinforced-concrete base at an elevation of 495 feet and with a capacity of 500,000 gallons, normally serves elevations above the 150-foot contour. It has gated manifold connections to the Twin Peaks Reservoir, but is only supplied with the higher pressure when required.

Jones Street Tank – of reinforced concrete construction, at an elevation of 369 feet and a capacity of 750,000 gallons, supplies the mains below the 150-foot elevation. This tank is staffed 24 hours per day, and has normally closed, gated manifold connections to the Ashbury distributing system. When required, the reservoirs can be interconnected to provide a total static pressure of 325 psi on the high-value congested downtown districts.

Pump Stations

When the entire fresh water system fails or is depleted, there are two emergency saltwater pumping stations built on the Bay's shores, each with a pumping capacity of 10,000 gpm, which can supplement the water supply with saltwater at a pressure of 300 psi. The stations, built on solid rock, are self-contained, and can operate in the absence of electric power utilizing their own self-contained generators. Originally powered by huge three-story Babcock & Wilcox boilers driving Curtis steam turbines to turn the Byron Jackson centrifugal pumps, technology has dictated a smaller, more modern diesel power source, housed in steel-frame buildings with massive reinforced- concrete walls, to keep the system in service.

Fireboats

When and if the emergency back up pump stations fail, two fireboats (originally the Dennis T. Sullivan and the David Scannell), the Phoenix and the Guardian can make hose connections directly into the AWSS via five special manifolds along the Bay's perimeter. The Phoenix has a pumping capacity of over 9,600 gpm, equal to that of one of the stationary pumping facilities. The Guardian has the largest pumping capacity of any fireboat in the world (24,000 gpm) and is the only fireboat that is outfitted with a 5-1/2-inch monitor tip, capable of pumping 9,000 gpm onto a fire from just one of its monitors.

Distribution Piping

A network of cast iron and special ductile iron distributing pipes in three levels, or zones, with a total length of 150 miles of mains, fitted with 1550 special hydrants, gate valves, and fireboat connections.

Cisterns
In a last-resort, worst-case, drop-dead scenario, a total of 175 independent, underground water cisterns are positioned beneath the intersections, most with a capacity of 75,000 gallons, with some ranging up to 200,000 gallons.

Bay Suction Connections
Thirty-six water suction connections surround the City's waterfront to allow fire engines to draft saltwater from the Bay of San Francisco.

Operation of the System
The mains in the lower zone at the city's base elevations are under a static pressure of 160 psi. If, during the process of a fire in the lower zone, the incident commander needs an increase in pressure above that normally supplied to the lower zone, a radioed command will put Ashbury Tank on the line; gate valves between the two zones will be opened by a tank attendant at Jones Street Tank, and the pressure in the mains at the city's base will increase to 214 pounds per square inch (psi). Should it be necessary to increase the pressure further, another order will place the Twin Peaks Reservoir on the line and increase the static pressure to 328 psi. If for any reason the quantity of water delivered in either zone is not sufficient, the supply can be increased by placing either one or both of the saltwater pumping stations in service.

The original pipe distribution system is constructed of special extra-heavy pit cast iron pipe to meet the effects of earthquake shock, high operating pressures ranging up to 328 psi static, plus water-hammer and the possible use of saltwater. The pipe was cast vertically to permit skimming of impurities. Integrally cast lugs with tie bars, as well as concrete thrust blocks, provide end restraint, to minimize movement.

A special double-beaded lead joint was selected after conducting expulsion and leakage tests at 450 psi on 19 leaded joints with different geometrical configurations. The joint selected has proven its worth over the years, and the combined leakage, evaporation and usage-per-mile of the system are normally considered low by water distribution standards.

During the 1906 earthquake, areas of filled or man-made ground experienced the greatest amount of earth movement. It was therefore decided that a double-spigot pipe with cast sleeves would be used in these areas. This arrangement provides great flexibility, since the possible deflection at the joint is twice as great as that of standard bell and spigot pipe. All intersecting mains, if serving the same zone, were connected with special cast fittings to provide for maximum circulation of water. Gate valves were placed so that any section of main could be shut off without blocking water from the hydrants connected to adjacent sections of the main.

Specially designed dry barrel hydrants were used. The hydrants are equipped with three 3.5-inch male threaded outlets, each of which is independently valved. The main valve at the base of the hydrant incorporates a special pilot valve, which balances water pressure on both sides of the main valve and facilitates opening of the valve under high pressure. The outlets are used to prevent direct connection of hose to the outlets and to require the operator to use a pressure-reducing valve (a Gleeson valve) between the hydrant and the 3-inch hose coupling. The Gleeson valve provides for control of the flow and pressure into the hose, and absorbs any pressure surge which might occur when a valve connected to a hose-line is suddenly opened or closed.

High Tech Flow Controls

In an emergency situation, every second of time can mean lives. No one understands that better than the Fire Department. The AWSS, in conjunction with a new Supervisory Control and Data Acquisition (SCADA) system, can now better ensure that the necessary component for fire combat – water – is available immediately in any situation. The AWSS allows for dynamic routing and rerouting of water throughout the three primary zones of the system via valve sites. The challenge in emergency situations is to determine where the water is needed to operate the valve. This can prove cumbersome and labor-intensive; which is why SCADA was introduced.

Remote Control of Valves

The SCADA system operates on the existing 800 mHz trunked radio system in use city- wide by the Department of Public Works. This existing infrastructure transports data between central control points and Remote Terminal Units (RTUs). These are minicomputers at each valve location, each capable of sending and transmitting information over radio waves to a main control station. The system allows for monitoring and control of a total of 80 main and bypass valves located throughout the City.

The two Central Control Processors (CCPs) are based on a VAX 4000 platform running a software package with a graphic user interface. This is a very user-friendly computer program that simplifies masses of technical jargon into pictures and icons on a television monitor for ease of operation and speed. The two CCPs communicate with each other and the RTUs by radio frequency and also by a back-up telephone wire line connection, providing another level of insurance for system reliability. In addition to the two main computer sites, the system offers four additional satellite control centers located throughout the City to allow rapid decentralized response.

Another unique feature of the SCADA computer system is the provision of control capabilities from either one of the two fireboats that patrol San Francisco Bay. This challenge is met by providing radio link and laptop computers to the fireboats running the same software program. These devices are also carried in the vehicles of the three Fire Department division chiefs. This provides a full range of operational capabilities from many decentralized points – an invaluable asset in the event of a disaster.

Future Needs
Though in operation since 1912, the AWSS still has many integral sub-components, all intended to meet the fire combat needs of a growing City. This fact remains true today even with the recent enhancements. Ancillary work on the system is ongoing, and expansion is anticipated into the next century.

Incorporated into the design of the AWSS is the ability to expand along with the ever- changing needs of the City. The Pacific Board of Fire Underwriters reported to the City Engineer, in 1908, that, once completed, the AWSS would be the best and most up- to-date system of its kind in the world. The system may or may not still warrant this distinction; however, it can be demonstrated that over the years it has served the City well, providing a large concentration of water at the site of a fire in short order, withstanding the many quakes that have shaken the City since 1906 and preventing major conflagrations.

For further information:
San Francisco Fire Department Business number – (415) 558-3200
Fire Prevention - (415) 558-3300
Toy Program - (415) 558-3555
St. Francis Hook & Ladder Co. Museum - (415) 563-4630

Twin Peaks Reservoir at Near-empty Level

Ashbury Tank

Brick Circle Indicating Underground Cistern

Underground Cistern

ST. FRANCIS
FIREBOAT 3
FIRE
FIREBOAT 3
San Francisco Fire Department

Pumping Station No. 2

References

San Francisco Fire Department Auxiliary Water Supply System-Wikipedia

San Francisco Water Supply Systems - SF Fire.org

Library of Congress
San Francisco Fire Department, Pumping Station No. 2, Van Ness Avenue at Bay, San Francisco, San Francisco County, CA

Fireboats of San Francisco

The story behind San Francisco's golden fire hydrant that could

Why Are San Francisco Fire Hydrants Different Colors?

San Francisco's fire hydrants are color-coded. Black-topped hydrants are fed by the Twin Peaks Reservoir, red-topped hydrants are fed by the Ashbury Street tank and blue-topped hydrants are fed by the Jones Street tank.

The white low-pressure hydrants draw on the city's potable water network. Some of these have been around a very long time as indicated by the ball on top of many of them, meant as tethering points for horses.