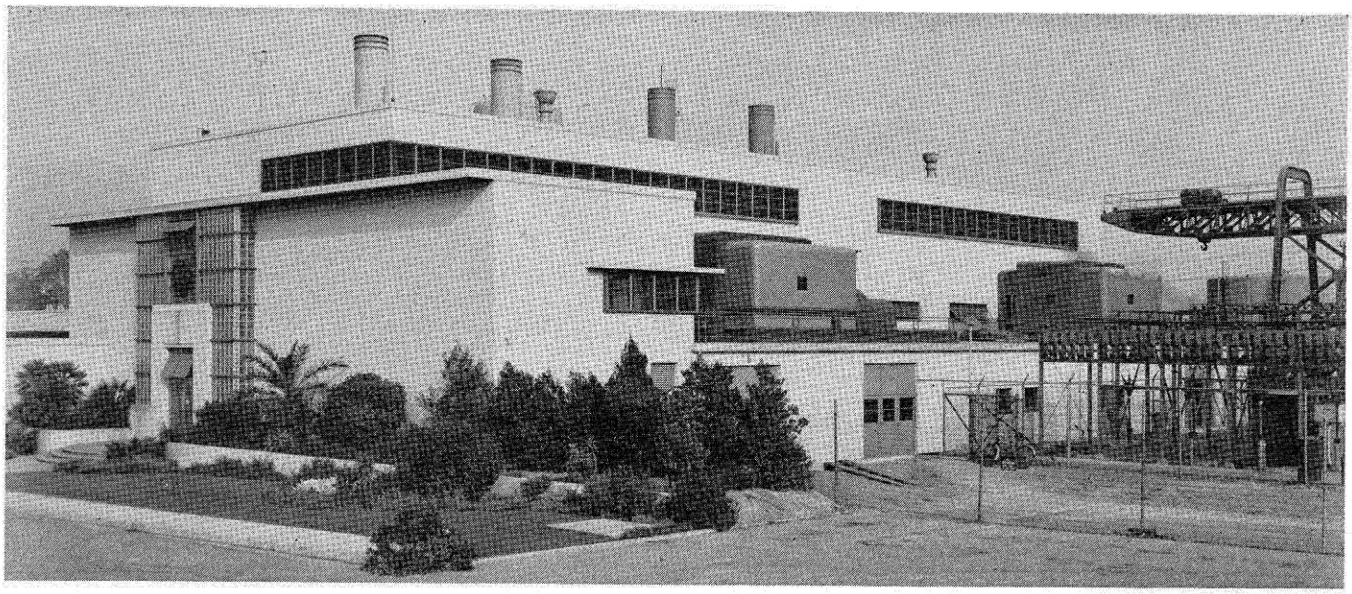

FIG. 1. The Burbank steam plant, a modern semi-outdoor type plant possessing pleasing architectural qualities consistent with economy in design.

WARTIME POWER DEMANDS

By ALAN E. CAPON

THE entire Pacific coast has experienced an unprecedentedly rapid industrial development accelerated by the war. Since in a short article only a small part of this progress can be discussed, it is the purpose here to show the effect produced on the electric facilities in one of the areas wherein the influence of expansion has been keenly felt. The small community of Burbank occupies an area of only 16 square miles, of which approximately 25 per cent cannot be utilized for residential or industrial expansion because of its mountainous character. Although this physical limitation is imposed on the development of the community, few permanent communities have experienced a growth so great as a result of expansion due to production for war. This growth is reflected in the demands on the electric and water utilities which are controlled by the Public Service Department, a branch of city government.

BACKGROUND PRIOR TO PEARL HARBOR

A radical transition has occurred in the type of industrial electric power load served by the Department. Before the war years a portion of the movie industry constituted the principal load, and this, together with a small commercial and residential load, represented quite a low total demand on the system. Commercial airplane manufacture, however, started in this area and was soon transcended by the manufacture of military planes. Even prior to Pearl Harbor a growth in load and population was stimulated by the demand of the Allies for military planes.

The original contractual allotment of firm power from Boulder Dam for Burbank, as determined in 1931, corresponded to a transmission capacity of only 5,194 kilowatts delivered at Receiving Station "B" of the Department of Water and Power of the City of Los Angeles. Later the figure was fixed at 5,109 kilowatts for delivery at the Toluca Switching Station in San Fernando

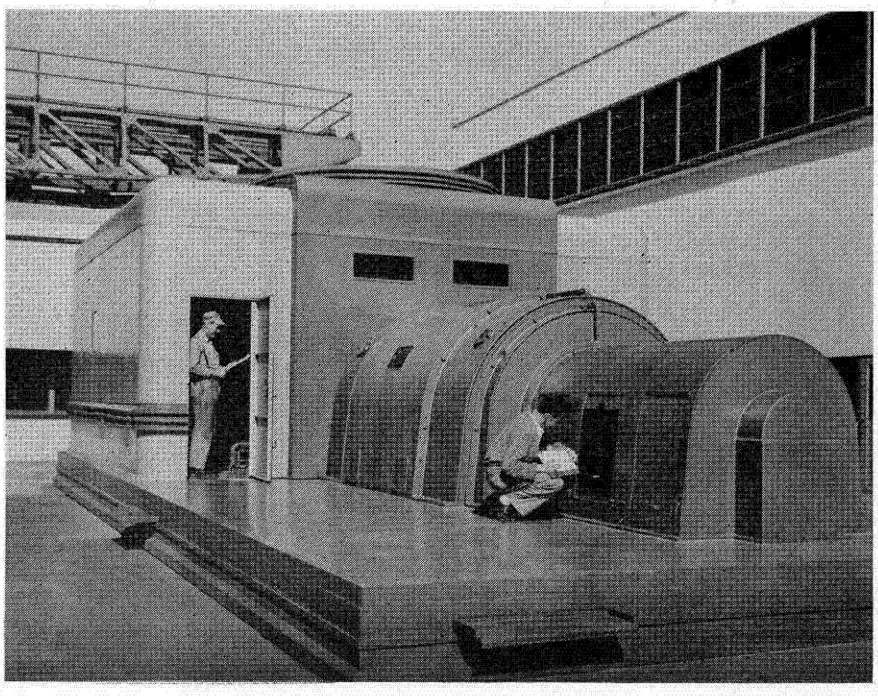

FIG. 2. The turbo-generator units are located on an outdoor deck and enclosed in weatherproof housings but present no serious problem from the standpoint of operation and maintenance.

Valley, where the physical connections between the two systems are actually made. However, preceding the period of the change in frequency from 50 to 60 cycles, power was purchased directly from the Southern California Edison Company and distributed over the municipally owned feeders. A study of the anticipated load growth for the municipality beyond the year 1935 under peacetime conditions, prior even to any consideration of the pressure of war demands, indicated the importance of acquiring an additional power source. It was decided that the installation of a municipally owned steam electric generating power plant to supplement the Boulder Dam supply would be the most economical way of obtaining additional power.

The original intent was to install a plant of standby character planned to operate at a load factor of approximately 50 per cent and designed for a high rate of pick up in the event of failure of the Boulder source. However, since the plant went into service, it has operated a good portion of the time at over 90 per cent load factor, except when operating under oil firing.

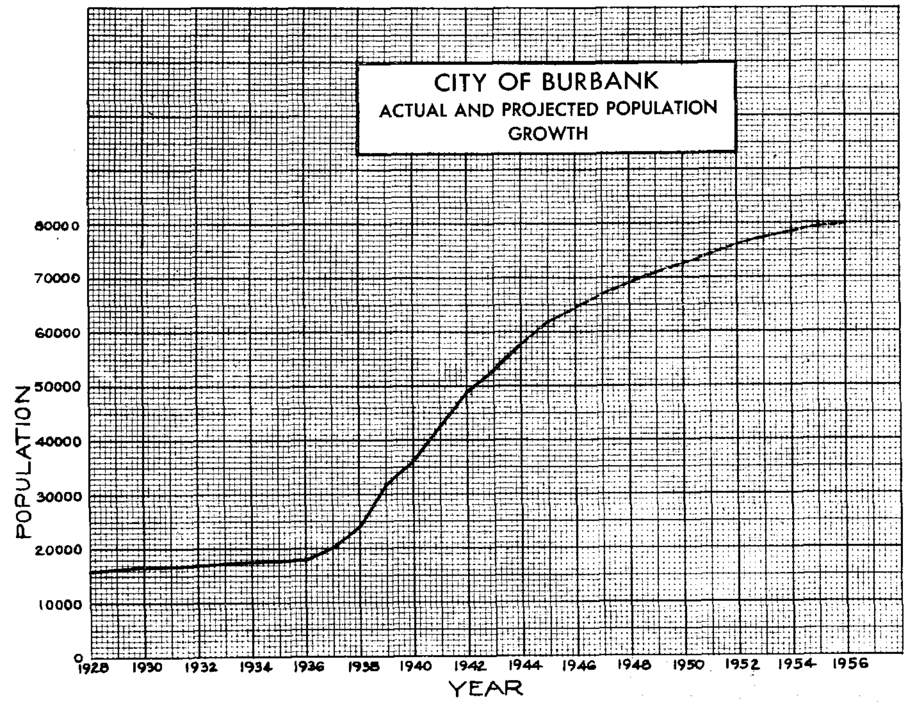

FIG. 3.

A MODERN POWER PLANT

The Burbank plant is one of the first modern, fully automatic, outdoor type steam turbine generator installations, the first outdoor turbine unit having started operation in the adjoining city of Glendale a short time prior to Burbank's installation. The turbo-generator units are located on an outdoor deck (see *Fig. 2*), but the auxiliary and control equipment, firing aisle, and control room are totally enclosed. The superstructure of the building is semi-closed and the steam generators are covered with a canopy roof. This semi-outdoor type of construction resulted in a high saving in building cost which has outweighed the disadvantages attendant thereupon. The use of a cantilever type of travelling gantry crane supported on rails alongside the building permitted a structural design of lighter and lower cost, although the cost of the cantilever type of crane was considerably more than that of the conventional bridge type. The building is supported on steel piles 25 to 30 feet deep with a 30-ton loading value, and the main turbine units are on piles and pile cap structures separated from the remainder of the building. The outdoor turbine-generator presents some problems in operation and maintenance. However, maintenance has been performed in bad weather without any unusual difficulties. One of the features of design in the plant has been the emphasis on automatic control of essential plant facilities, which permits load to be picked up quickly and produces ease of operation. A 100-pound compressed-air system is maintained for control use. Transfer to manual control can be made when desired for any of the automatic operations.

There are two 10,000-kilowatt, 4,500-volt, 0.8 power factor, 3,600-*rpm* turbo-alternators fed by three 120,000-pound-per-hour continuously rated steam generators. Each boiler is capable of handling the full output of one machine, leaving one spare boiler. The first turbo-generating unit was designed for maximum efficiency at 50 per cent of rating, but the trend in system demand required that the second unit be designed for maximum efficiency at 100 per cent load. The steam operating temperature and pressure are 825 degrees Fahrenheit and 625 pounds gauge, respectively. These values were selected as representing the lowest cost based upon an analysis of the relative costs of power production for various temperatures and pressures versus plant amortization. The turbines are of the condensing type, each with an 8,000-square foot capacity main condenser. Cooling water for each condenser is circulated through a mechanical draft, induced type cooling tower. The generator is connected by means of a cable system to the 4,500-volt grounded neutral distribution bus. Generating at the same voltage as the distribution voltage on a grounded neutral system is somewhat unusual for central station installations and presents some problems in protection.

The steam generators are of the water tube integral furnace type, equipped with superheaters and air heaters and combination oil and gas burners. Mechanical draft is obtained by duplex fans both forced and induced on one shaft and driven by two motors, one 75-horsepower and one 300-horsepower, connected in tandem to the fan shaft. The small fan motor will carry the air requirements up to 5,000-kilowatt capacity. Automatic adjustment of loading air requirements is obtained by compressed-air-operated vanes, and transfer of motor drive is obtained automatically by air-pressure switches. There is a small accumulator reserve in the boilers which must maintain steam pressure at the turbine throttle for two and one-half minutes to allow time for the combustion control system to respond to the master controller and bring the boiler furnace conditions into balance with the steam demands. A differential pressure between boiler and turbine is always maintained even when the turbine is taking its full capacity steam, so that sufficient pressure exists to correct for sudden load changes over the period between initial impulse of steam pressure drop and response of automatic control. The

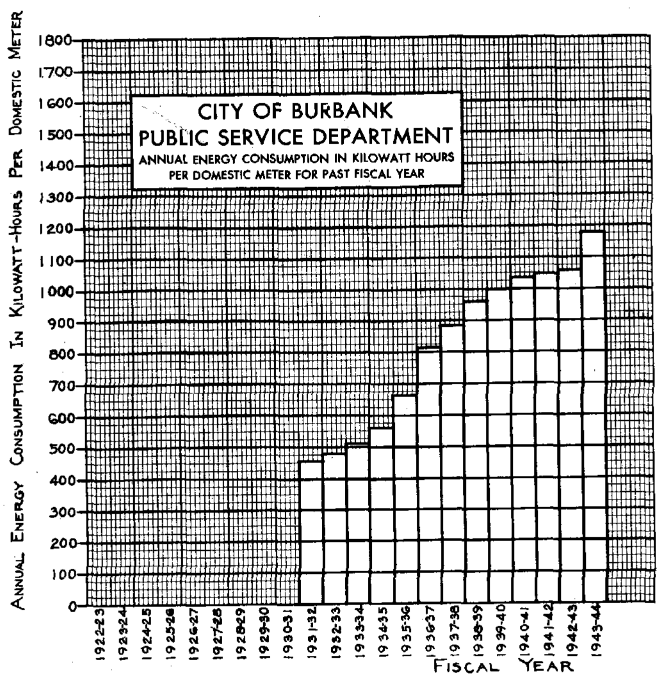

FIG. 4.

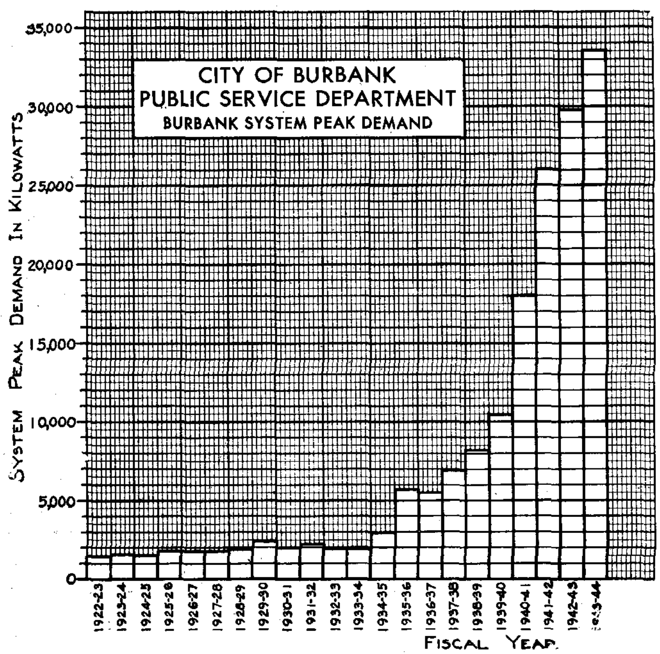

FIG. 5.

feedwater control is operated automatically to provide for changing load simultaneously with the combustion system. Boiler feedwater is conditioned by an elaborate system of softening and treatment to dissolve oxygen and other harmful products. Cooling tower make-up water is softened, and it is further treated with chlorine to prevent the formation of algae in the cooling tower.

All auxiliary drives are electric. Motors up to and including 75-horsepower are 480-volt and higher ratings are 2,500-volt. Each turbine unit with its corresponding boiler and auxiliaries is considered a separate unit functioning independently, although common feedwater and steam headers connecting the three boilers are provided. Flexibility in maintaining continuity of service for the auxiliary equipment is obtained by permitting the transfer of the auxiliary power source for either unit in the event of failure of its normal source. A 750-kilowatt, 3,600-*rpm*, steam-driven house generator capable of coming up to full speed in 19 seconds from a cold start is available in the event of the failure of power source for the plant auxiliaries. This unit will start and pick up load automatically upon drop in voltage on the 2,500-volt auxiliary bus.

The first generating unit was placed in service in October, 1941, and the second unit went into service in July, 1943. A third unit has been proposed, and provision has been made in the plant to permit future expansion to accommodate the additional unit.

EXPANSION DUE TO WAR DEMANDS

After our entry into the war, the system power demands (mostly those required for airplane and parts manufacture) rose tremendously. Industrial expansion in this area was spurred by the advent of war; and the industries were attracted here by low tax rates, low utility rates, and an ample supply of good water. In fact, one of the accomplishments of the Department in 1944 was to further reduce electric power rates. Coincidently with the growth in industrial load came a tremendous increase in population which grew to meet the demand for manpower for the war industries. This increase in population for Burbank is shown in *Fig. 3*. Home building under the sponsorship of the War Housing Authority in permitting the opening of new tracts produced a high rate of increase in added consumers to the system. A peak rate for new domestic meter installations of 332 meters per month was attained. Simultaneously with the increase in the number of residential consumers occurred an increase in the annual energy consumption per domestic consumer, as shown in *Fig. 4*, which was caused essentially during the years before the war by an increase in the number of appliances used in each household and by the installation of electric water heaters and ranges. The sharp increase in energy consumption per domestic meter for the fiscal year 1943-44 is attributed to the lifting of the dimout in the last seven months of that period and by the further curtailment in the consumption of gasoline for private cars, since domestic appliances have been off the market for some time.

The effect of this accelerated growth in industry and population is demonstrated in *Fig. 5*, which shows the rapid rise in the system power requirements, particularly during the past four years to meet the wartime production demands. It is readily seen that with only 5,109 kilowatts allotment from Boulder and 20,000 kilowatts steam generation, the City is obliged to obtain additional power from an outside source to meet the system peak requirements. The municipally owned plant in the adjoining city of Glendale is functioning in a standby capacity on an interchange basis and has contributed to making up the deficit in availability. Fortunately, also, surplus Boulder power becomes available now at a satisfactory rate to the municipality to help out during part of the heavy load period. This surplus hydro power is made available by virtue of the reduction in output of the light metal plants. It is also seen by reference to the system-demand chart that in order to have a true standby power source of reliable and economic character, it would have been necessary to double the present steam generation by installing an additional 20,000 kilowatts of capacity. However, the anticipated postwar trends in power requirements will form the basis of judgment in establishing the size of additional capacity to be installed. Paralleling the rapid rise in system demand requirements, the system kilowatt-hour energy consumption increased approximately 1000 per cent in the past seven years.

As this utility was not in a position to maintain a large investment in capital stock, the expansion had to be met with the idea in mind of avoiding overcapitalization in equipment. Therefore, satisfactory financial arrangements had to be worked out with the expanding industries for handling the power services in order to provide protection in view of the uncertain life of this new war load.

THE PACIFIC SOUTHWEST POWER POOL

The conservation of natural resources in order to divert them to war use became a prime requisite. This meant, of course, that oil and gas fuel had to be used as sparingly as possible for the generation of power, and hydro power had to be developed and utilized to the greatest extent. Steam generation in southern California has lagged behind the development of hydro power, and standby power was lacking in sufficient capacity to maintain a proper balance. As the war industries developed, an impending power shortage became imminent, the condition being made particularly acute by the installation of the metal reduction plants where large blocks of power were used directly for processing. Consequently, several of the utilities in this area realized the need to enlarge upon their steam generation facilities, and forthwith submitted applications to the War Production Board for permission to install additional capacity. Although these applications were tentatively rejected until the postwar period, the need for relief in this area was fully appreciated.

The idea was advanced by the War Production Board under the direction of J. A. Krug, then chief of the Power Branch of the Board, to pool all the power resources in the Pacific Southwest on a cooperative interchange basis. The establishment of such a program was in keeping with the requirements of Limitation Order L-94 of the National Defense Act for curtailment of electric power in the United States. Early in 1942, a thorough survey was made of the available power facilities in southern California. Information concerning current load conditions and load requirements projected through 1944 was tabulated for all systems. As a result of this survey there evolved the formation of the Pacific Southwest Power Interchange Committee and a definite program of action was adopted. The membership of the committee consists of representatives from all the utilities in this area, including the California State Railroad Commission. The power utilities having generating facilities and included in the membership are the Los Angeles Department of Water and Power, the Southern California Edison Company, the California Electric Power Company, the Pasadena Light and Power Department, the Glendale Public Service Department, the Burbank Public Service Department, the San Diego Gas and Electric Company, the Imperial Irrigation District, and the Bureau of Reclamation. Later, representatives of the Metropolitan Water District, because of its interest in the Boulder Dam power allotment, and the Pacific Gas and Electric Company became members of the committee.

The aims of the committee were to insure that maximum use be made of all hydro power to keep the demands upon fuel supply for steam power to a minimum, that the utilities pool their resources for efficient utilization of their combined generating resources, and that additional interconnection facilities be provided to permit maximum interchange of power. It became necessary that all loads be carried with existing generating facilities, and to meet this requirement in some instances new line construction and transformer installations had to be effected to adequately interconnect the systems. In order to put the scheme of interchange on a practical working basis it became necessary to make inter-utility contractual agreements to handle the financing of power interchange, and establish satisfactory rates for energy. Most of these interchange agreements have been completed by now. Furthermore, close operating relations had to be established between the operating departments of the various systems for the proper functioning of the interchange; and maintenance programs had to be co-

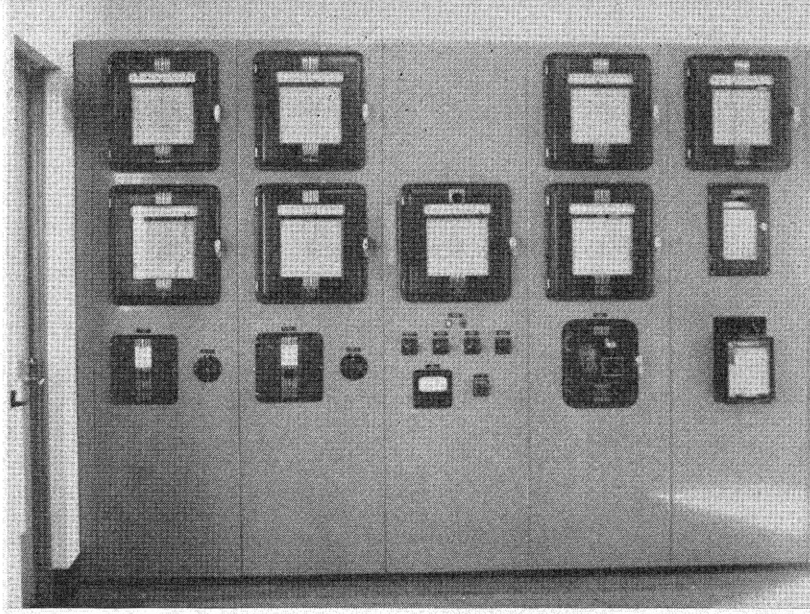

FIG. 7. Telemetering and tie-line load and frequency-control equipment for the Burbank system.

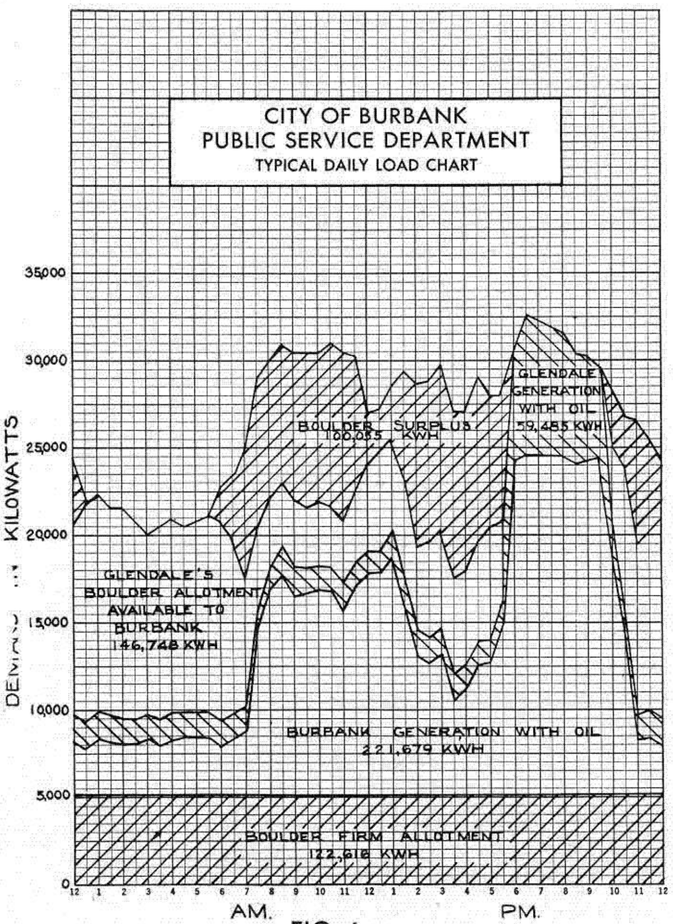

FIG. 6.

ordinated so that cooperative arrangements could be worked out for the shutdown of generating equipment.

The cooperation of the various utilities in working out the interchange program established by the committee has produced very satisfactory results. During the low runoff period in the summer, hydro power must be conserved and stored. This means that steam generation is at maximum capacity then and is usually on gas firing. In the winter and spring when the gas situation becomes critical and no surplus gas is available for generation because of peak consumption for industrial, commercial, and domestic use, hydro power is available for its maximum ultilization. Then oil firing for steam generation has to be used when gas is not available. With the interchange scheme, steam generation with oil firing can be kept to a minimum throughout the year, resulting in maximum conservation of fuel oil.

OPERATING EXPERIENCE WITH THE INTERCHANGE

A practical demonstration of how the interchange of power has worked out between the Cities of Glendale and Burbank and the Water and Power Department of Los Angeles is shown in *Fig. 6.* Although the contribution of the Burbank and Glendale generation to the power pool is small, it is nevertheless important. *Fig. 6* shows an hourly demand chart together with the energy consumption obtained from the various interchange sources for a typical winter day for the Burbank system. The Burbank allotment from Boulder is shown near the bottom of the chart as a flat demand. Next above is the Burbank steam generation with fuel oil firing. On this particular day no gas was available for generation. The narrow band in the third step represents the energy made available to the Burbank system by the Glendale steam plant while burning oil. The fourth step, or the area termed "Glendale's Boulder Allotment Available to Burbank," is that portion of firm power from Boulder Dam for Glendale which it cannot use and which is made available to Burbank at the gas burning rate. Similar to Burbank, Glendale has contracted for a portion of Boulder Dam power for delivery at the Toluca Station of the Department of Water and Power, except that the value of demand was fixed at 18,164 kilowatts. It is seen on the chart that between the hours of 5:30 and 9:30 P.M. for that particular day no quantity of Glendale's apportionment of Boulder power is made available to Burbank. The top area represented by "Boulder Surplus" is that amount of energy released by the City of Los Angeles to Burbank by virtue of surplus hydro generation being available at kilowatt demands varying during different hours of the day. Likewise, between the hours of 5:30 P.M. and 9:30 P.M. there was no surplus available from Los Angeles, and oil-fired generation at maximum output had to be resorted to. All the available power represented by the various sources on the chart totals up to the Burbank system demand in kilowatts as indicated by the top line, and the total of all areas, is the Burbank system consumption of 650,583 kilowatt-hours for that particular day.

OPERATING ECONOMIES

Strict attention is being paid to operating economy of the generating plant. The greatest economy of operation results from firing the boilers with gas. The total cost, including the fixed charges, of operating the plant with gas firing is slightly over 3 mills per kilowatt-hour. This corresponds to approximately 56 per cent of the cost when firing with fuel oil only. Two factors contribute to making firing with oil cost more than gas firing. The rate of fuel cost per kilowatt-hour of plant output is higher for oil and the plant capacity factor is considerably lower when using oil. The cost to Burbank of Boulder power is about 85 per cent of the cost when generating with oil. In addition to a high transmission cost being charged against Boulder power, it is obtained at a relatively low load factor, as it was contracted for at a time when a 50 per cent load factor was considered adequate for the system. These figures for comparative costs are relative only and will vary as fuel oil costs fluctuate. Not only from the standpoint of conservation but also from that of economy, it is highly desirable to generate a minimum with oil and keep the plant operating at a high load factor with gas firing. At times when gas is not made available and it becomes necessary to transfer to oil burning, the transition can be accomplished within a half hour without necessarily dropping load.

The automatic operation of the plant has contributed considerably to the economy of operation. Operating personnel is reduced to four-man shifts, including handling both the steam generating equipment and the electric generating and distribution equipment. Of course, additional personnel for supervision and maintenance is required. Furthermore, load changes can be more closely and capably followed with automatic control. During these times when experienced labor is not readily available the automatic control equipment has been highly desirable.

Since the firm allotment of Boulder power has to be paid for whether used or not, it becomes necessary to use it to the best advantage. The consumption of Boulder energy can be distributed over an annual period so that it is taken in the summer at a low load factor and in the winter at a high load factor. This means that particularly in winter the demand in kilowatts on the 34,500 volt tie lines between the Burbank and the Los Angeles systems is held as close as possible to the maximum available. This is accomplished automatically by a system of tie-line load control incorporating telemetering and control equipment. The transfer of power is metered on the tie lines at a remote location from the steam plant, and the record is transmitted over communication circuits to the recording and control equipment located in the plant. Impulses for regulating the output of the generators are transmitted to the governors, and the generation is varied automatically to maintain a very stable tie-line load transfer. Thus greater utilization of Boulder power is accomplished with the automatic tie-line load control than with manual operation. When operating the plant independently of outside sources, the system frequency may be controlled automatically by the same control equipment. An instantaneous record of total tie-line load, total generation, total system demand, and system frequency is obtained with the telemetering and control equipment shown in *Fig. 7.* The control of tie-line load is important also because at times, when under oil firing, the combined Burbank and Glendale demand from Boulder is taken over the Burbank lines.

CONCLUSION

The postwar aspect presents an imposing problem with relation to the future trend in load requirements. Of necessity, a further change in the character of the industrial load served must be anticipated when production for defense requirements can be reduced as victory approaches. The future trend for the West Coast should not be viewed in a pessimistic manner, as we must expect our high-geared defense industrial program to be converted to peacetime production. The West Coast is in a good position to be able to convert to a peacetime industrial economy, since the labor market and the machinery for industrial development are already here.