

Monthly Review

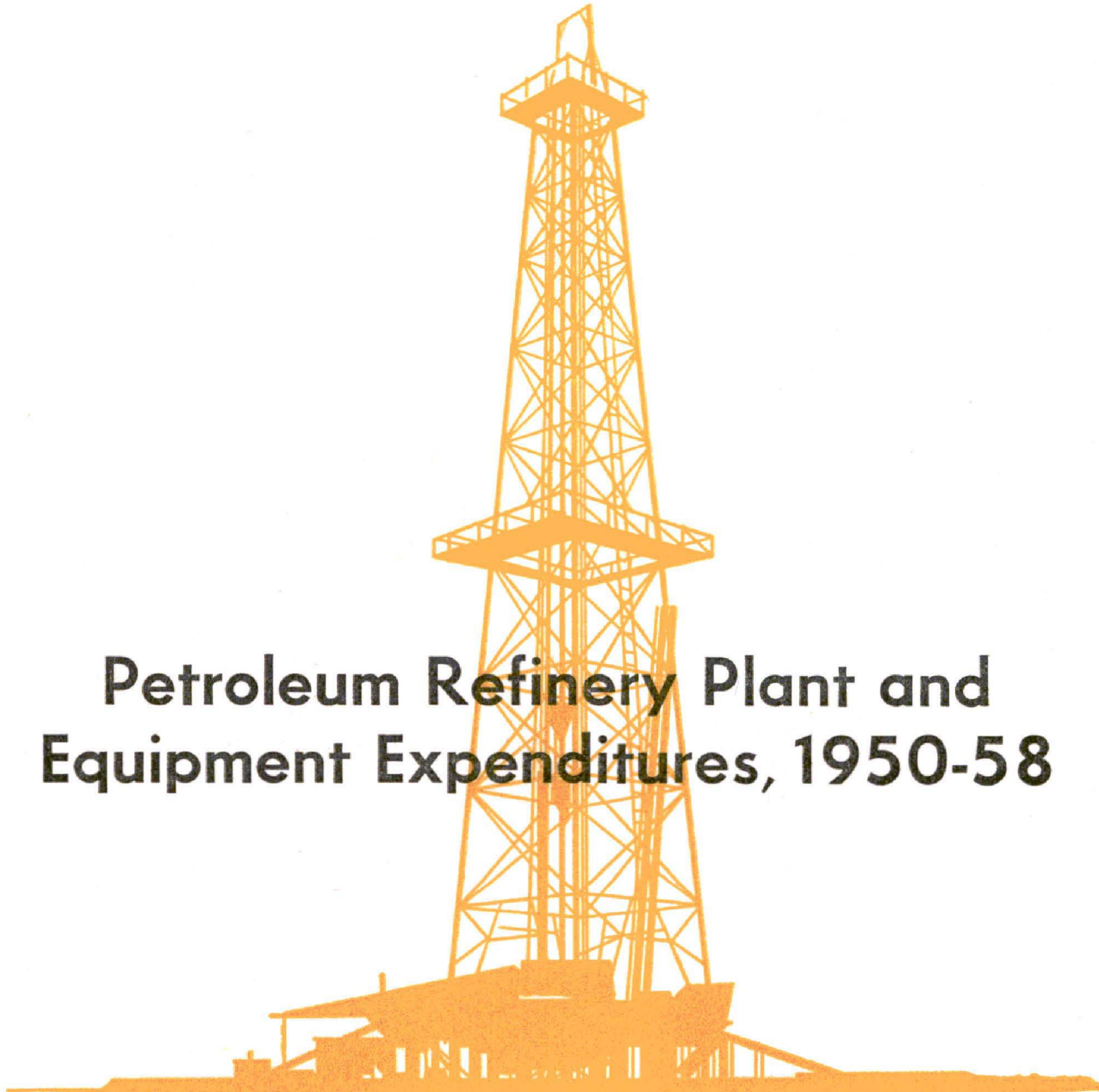


TWELFTH FEDERAL RESERVE DISTRICT

FEDERAL RESERVE BANK OF SAN FRANCISCO

May 1959

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Petroleum Refinery Plant and Equipment Expenditures, 1950-58

EVEN in this age of rocketry the finding, drilling, and processing of oil are ventures which capture the imagination. One need not hold an oil lease to quicken at the sight of a several-hundred-foot-high gusher. Nor need one be overly methodical to stand in awe of the quiet efficiency with which the modern refinery daily processes barrels of oil by the hundreds of thousands. Finally, one need not be a gambler to be impressed with the risk involved when upwards of a million dollars is ventured in drilling a wildcat well which may not even gurgle, much less gush.

In addition to these more dramatic facets of the industry, certain less well-known, but

not necessarily less interesting or important, aspects of the oil industry have captured the interest of economists and students of business in general. Those interested in the pricing process, particularly the relation between cost and price, are intrigued by the problems involved in manufacturing a basic raw material—crude oil—into literally a thousand finished and semi-finished products. Similarly, students of the tax structure find an equally intriguing set of issues concerned with the incentive effects of depletion allowances on domestic and foreign production, or the equity considerations which such tax treatment raises.

But it is perhaps in the field of investment analysis that the oil industry presents some of its most interesting and provocative problems. This is particularly true of petroleum refining. In this industry technological development has been so rapid and so consistent that it gives the appearance of a continuing innovational boom. This persistent technological advance has in turn left its mark on the annual plant and equipment expenditures for refineries. The impact of innovation has been such as to eliminate any notion of a rigidly defined relationship between purchases of plant and equipment and the level or change in refinery output.

Since both capital-saving and capital-using innovations are strong and persistent elements in the refining industry's technological pattern, the capital-to-capacity ratio may be viewed as subject to continuing, offsetting, pressures — the capital-saving innovations constantly working to lower the ratio, the capital-using innovations working to raise the ratio. Although the long-run trend has been an increasing ratio, year-to-year changes have frequently moved against this trend. The direction and magnitude of these changes have produced an investment pattern which seriously challenges the hypothesis that "the" capital-to-capacity ratio tends toward some equilibrium value. Moreover, the apparently volatile and unpredictable nature of these technological changes suggests that the causes are grounded neither in basically cyclical nor secular forces, but are significantly determined by such industry characteristics as the structure of the refining industry, the kind and quantity of competition, the nature of the commodities produced, and the inherent innovational possibilities.

Plant and Equipment Outlays— General Considerations

Plant and equipment expenditures may be distinguished, theoretically, in terms of whether they add new capacity or simply re-

place economically obsolescent facilities. In practice it is often extremely difficult to make this distinction because rarely does the flow of capital spending fall exclusively into either category. A somewhat more detailed classification would distinguish between new facilities that are virtually identical with older capital stock, and equipment that either provides the same output at different real costs or provides qualitatively different products from those produced by older facilities. Again, this apparently clear-cut conceptual distinction is not easily confirmed empirically.

When the new and old plant and equipment are virtually identical, in terms of quality of product and real costs of production at all levels of output, then we say that the new facilities do not change the production function. When, on the other hand, new plant and equipment changes quality, cost, or product mix, we speak of an innovation. In the absence of innovation we should expect fixed capital outlays to manifest a regular, but not necessarily changeless, relation to the level of output and capacity. We would not expect this relationship to be rigidly fixed, of course, because businessmen inevitably will over- or underestimate their capital requirements, or may choose for short periods to respond to increased demand by running plants at greater-than-optimum operating rates. But despite these inevitable irregularities, the capital-output and capital-capacity relationships should tend toward some normal value.

In contrast, an industry possessing a dynamic technology is capable of changing marginal capital coefficients by 50 to 100 percent within a few years. Under these circumstances, an explanation and analysis of the investment pattern requires an understanding, first, of the technological change which conditions the investment process, i.e., inventions and their application; and, second, of the conditions which have encouraged or induced the technological change. Let us look at these conditions in the oil industry.

In the petroleum refining industry there is little doubt that competition, while intense and often bitter, has nevertheless increasingly been manifested in various nonprice forms such as product and process innovation. These innovations have taken the form of changes in the refiner's product mix, improvements in product quality, and reduced processing costs. The pace of such activity has increased substantially in recent years. The petroleum industry employed 17,000 scientific and engineering personnel in 1956, and was spending over \$130 million annually on research and development programs. By 1958 research and development expenditures had climbed to \$259 million, and planned expenditures for 1959 total \$295 million.¹

The impact of these programs has been striking. Over the last forty years technological change has rendered basic refining equipment obsolete on the average of once every five years,² and so fundamental have been the corresponding changes in yields and quality that noninnovating refiners have been forced either to imitate their pioneering rivals or get out of the industry.

Firms have been increasingly forced to match the innovational pace set by the most progressive, with some survivals of this race tending to become specialty plants serving particular product needs or geographic areas. For example, small asphalt plants are "sheltered" against the processing economies of large plants by the heavy transportation costs which a large plant must meet in selling to a geographically widespread market. Similarly, small fuels plants may find their "niche" by selling to nonbrand gasoline jobbers, or by selling nonpremium quality fuels to major refiners for further processing. Nevertheless, the number of small refineries has declined rapidly. Apparently the rapid and costly pace of

technological advance has become an increasingly important factor in this decline.

Petroleum Chemistry and Refining —a Layman's View

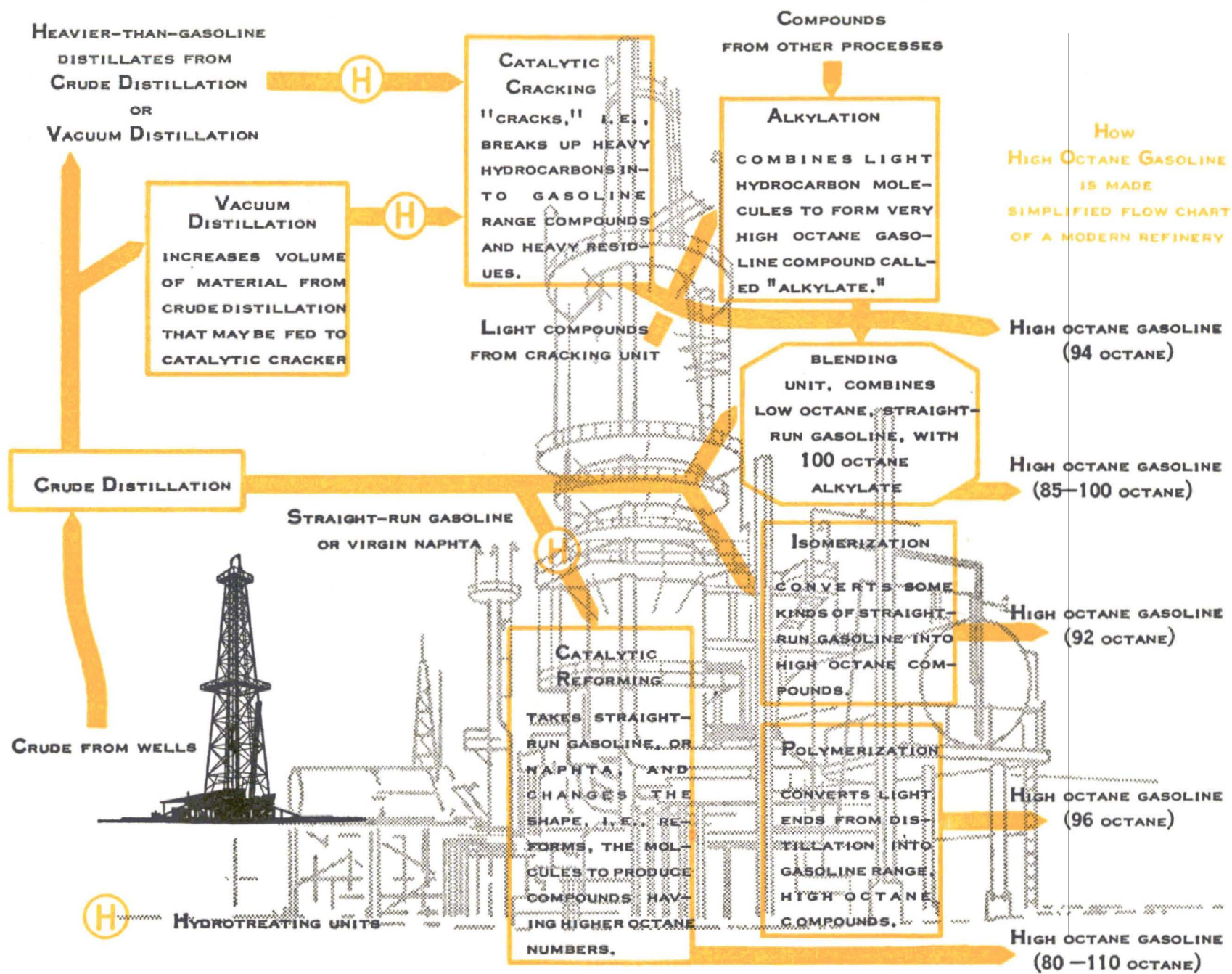
For our purposes the essential technological consideration is that oil refining means converting and transforming a thick black liquid (crude oil) into an indefinite number of products, the most important of which are gasoline, distillate, and residual fuel oils. This transformation is extremely expensive and, though suggestive of magical processes, is actually the commercial translation of well-known principles of organic and physical chemistry. Crude oils are essentially mixtures of carbon and hydrogen compounds. Although the carbon content of almost all crudes is close to 85 percent by weight, and hydrogen constitutes almost all of the remainder, no two crudes (from different fields) are identical. Part of the difference is due to the varying oxygen, nitrogen, and sulfur content, amounting to from less than one-half to almost five percent by weight. But the basic reason is the variation in the molecular size, kinds, and numbers of carbon-hydrogen compounds found in different crudes.

These differences broadly determine the amount of gasoline, kerosene, asphalt, etc., which are yielded by distillation. Fifty years ago the molecular mixture was the ultimate determinant of the refiner's product mix. How much kerosene, fuel oil, or gasoline was produced was a simple function of the kind of crude being processed. Today these differences are largely overcome by special processing equipment, and it will be helpful to consider, however briefly, the principles and techniques of petroleum refining.

The basic refining process is distillation. Before World War I this simple process often constituted the entire refining operation. The coming of the automobile, and more recently of high-compression engines, transformed this "basic" technique into preparation for

¹ United States Bureau of Mines, *Mineral Facts and Problems*, Bulletin 556 (1956), p. 671, and McGraw-Hill Department of Economics (see *Business Week*, April 18, 1959, p. 29).

² W. L. Nelson, "Cracking Equipment Obsolescence," *Oil and Gas Journal*, (September 9, 1957), pp. 123-4.



the more complex cracking and reforming processes. Distillation provides the refiner with relatively fixed amounts of gasoline, light and heavy oils, and a sprinkling of light, even gaseous, products. Historically the changing market for gasoline, distillate, and residual fuels has been reflected in the development of refining processes to rearrange the molecular composition of products in conformance with market requirements. Where once the products of the distillation columns were piped directly to market, the modern refinery subjects these products to an increasingly complex sequence of supplemental processing. Some of the supplemental (in refinery jargon, "downstream") processes convert petroleum gases into automobile or aviation fuel. Others transform thick, almost pitchy, distillate residue into diesel fuels, heating oils, coke, and even gasoline. On the other hand, many of the more recent processing developments have been geared not so much to converting as to improving the quality of refinery products.

Product improvements have not, of course, been confined to developing better gasoline. But gasoline is the refiner's prime product, and most of his product-improving dollars have gone into motor fuel processing. These dollars have developed processes for changing the gravity, sulfur content, vapor pressure, distillation range, and octane rating of gasoline.

Although octane ratings are not the sole index of gasoline quality, they have commanded most of the refining and motoring public's attention. This attention has not been undeserved. From the motorist's point of view, octane improvement is one of the keys to increased engine performance potential. From the standpoint of the refiner it has become increasingly expensive as octanes increase, and consequently productive of a growing number of technologic and economic headaches. Petroleum marketing departments, however, are acutely aware of

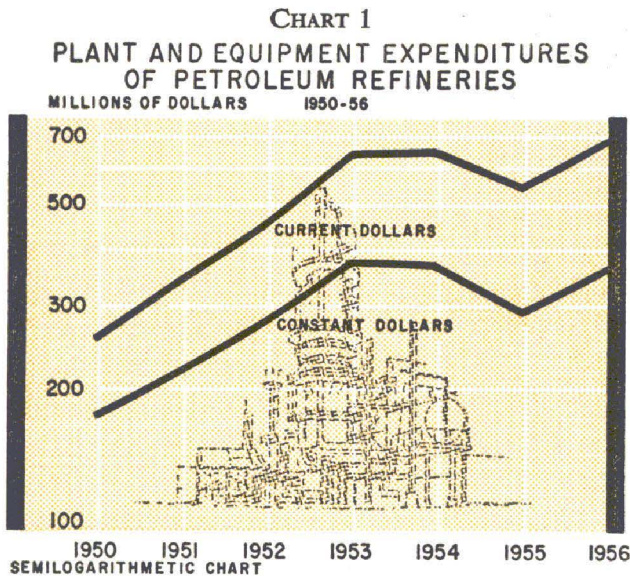
the sales potential of "high" octane gasoline and have spurred the addition of processing capacity which is primarily for product — particularly octane — improvement. Such processes include, in the jargon of the trade: thermal reforming, catalytic reforming, tetraethyl lead addition, desulphurization, and isomerization. Additionally, such processes as polymerization, alkylation, and hydrotreating may be employed to raise the octane rating of the gasoline produced. Alkylation, for example, actually converts nongasoline-type compounds into a gasoline of very high octane rating. Because it converts nongasoline molecules into gasoline-type compounds, it is, strictly speaking, a conversion rather than improvement-type process. But if the high octane gasoline so produced is a necessary blending stock for the manufacture of high octane motor or aviation gasoline, the process is in fact being employed as an improvement device. Similarly, hydrotreating¹ can be primarily employed to change product yields, or to improve product quality. An estimated 70 percent of hydrotreating capacity is employed for product improvement purposes.

Refinery Investment 1950-56²

The introduction or increased utilization of these product improvement processes gave shape to the refining investment pattern of the early and mid-1950's. The pattern was that of boom, and the dimensions of the boom are readily suggested by the Plant and Equipment Expenditure Series in Chart 1. Fixed

¹ Hydrotreating is a generic term covering the use of hydrogen in a wide variety of refining operations including sulfur and nitrogen removal, increasing oxidation stability, color improvement, etc.

² The difficulties of giving empirical content to conceptual relationships are painfully evident in the following section. Although various estimates of capital expenditures are available, only one source provides estimates of plant and equipment expenditures closely conforming to the relationship which we can use in this section. We need estimates of plant and equipment expenditures that count only those outlays which result in *operating* capacity within the calendar year cited. Only the Department of Commerce's *Annual Survey of Manufactures* provides data on this basis, and because refinery construction schedules often extend over two or three years we cannot use capital expenditure for plant and equipment which does not result in operating capacity for one, two, or more years. Unfortunately, the *Surveys of Manufactures* covering 1957 and 1958 are not yet available.



Source: United States Department of Commerce, *Annual Survey of Manufactures*, Constant Dollar Series computed using Nelson's (*Oil and Gas Journal*) Construction Cost Index, 1946 = 100.

capital outlays rose consistently over a five- or six-year period, and culminated in a spending rate in 1956 that was 100 percent (deflated) or 170 percent (current dollar series) over that prevailing in 1950 at the start of the boom.¹

These series bear little resemblance to the crude capacity series in Chart 2. Yet, except for technological change, we should expect a close and continuing similarity, for the one would be the monetary reflection of the

¹ Although identical figures for 1957 are not available, comparable data published by the respective economic departments of the Chase Manhattan Bank and McGraw-Hill Publishing Company indicate the boom actually culminated in 1957, rather than 1956.

TABLE 1

RATIO OF PLANT AND EQUIPMENT EXPENDITURES TO GROSS CAPACITY ADDED

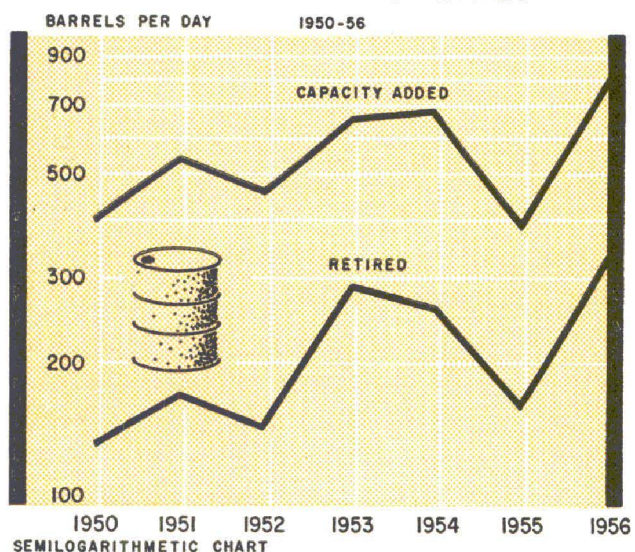
	Expenditures (1946 dollars) [1]	Capacity Added (barrels per day) [2]	Ratio [1]÷[2]
1950	174 million	401 thousand	434
1951	216	539	401
1952	274	451	607
1953	368	651	565
1954	364	673	541
1955	290	374	775
1956	352	818	430
Average			536

Source: United States Department of Commerce, *Survey of Manufactures*, various annual issues, and United States Department of the Interior, Bureau of Mines, Information Circulars 7613, 7646, 7667, 7693, 7724, 7761, and 7815.

other. That is, except for changes in equipment costs or changes in the technique of production, the expenditure series should parallel the series for additions to gross capacity. Instead, after adjusting for cost changes, the expenditure series increases during a year when capacity added "declines" (1952) and declines when gross capacity added increases (1954). In addition to the dissimilarities in turning points, the rates of change in the two series exhibit considerable differences. For example, in 1955 capacity added declined more sharply than did capital expenditure. Table 1 reveals the extent of year-to-year variations in the ratio of plant and equipment expenditures to gross additions to crude (distillation) capacity, from 1950-56.

The sharp changes from year to year pose interesting questions. For example, why is the ratio for 1955 so much higher than that for any other year; and why do the ratios for 1950, 1951, and 1956 stand apart from those for other years? The former ratios range from \$401 to \$434 per barrel of basic capacity, while the latter range from \$540 to \$775 per barrel. The primary explanation appears to be the change in composition of investment,

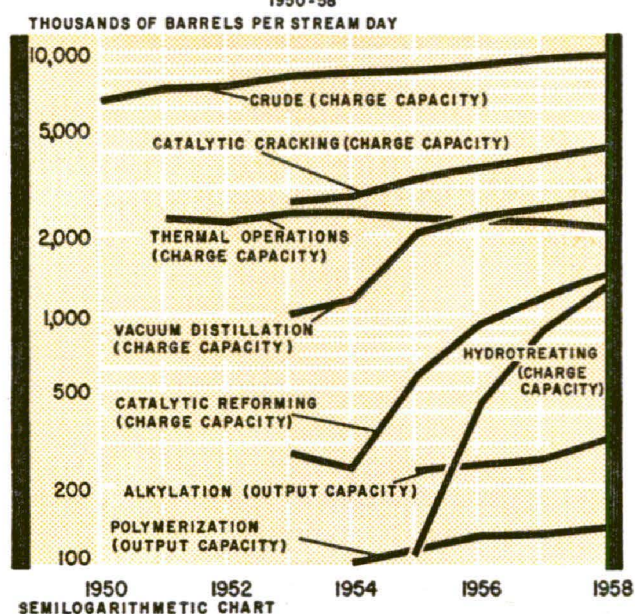
CHART 2
REFINERY GROSS (CRUDE CHARGING) CAPACITY ADDED AND RETIRED



Source: United States Department of the Interior, Bureau of Mines Information Circulars 7613, 7667, 7693, 7724, 7761, and 7815.

as between outlays for basic and supplemental capacity. Between 1953 and 1956 basic crude capacity increased about 11 percent, while supplemental processing capacity increased almost 50 percent. In 1953 there was less than one barrel of supplemental capacity for each barrel of distillation capacity. By 1956 the ratio of supplemental to basic capacity had increased almost 50 percent. Chart 3 illustrates the changing relationship between basic and supplemental processing capacity. Apparently, then, the full explanation for the variable ratio lies in the technological dynamics of a changing market.

CHART 3
PROCESS CAPACITIES - PETROLEUM REFINERIES
1950-58



Note: Stream days are days during which a process is actually in full operation. *Barrels per stream day* represents maximum daily average capacity; it does not allow for necessary shut-down time for routine maintenance, repairs, etc.
Source: *Oil and Gas Journal*, Annual Refining Surveys, 1950-59.

Technological requirements for the changing market

We have referred to the impact of the motor age on refining technique. Where it was once an unmarketable byproduct, the automobile age has made gasoline the refiner's prime product. No longer something to be surreptitiously dumped into nearby streams or mixed with kerosene, gasoline has come to determine the refiner's competitive position;

indeed, it has become basic to his economic survival.

In the 1920's and 1930's competitive position was maintained primarily by introducing thermal cracking and thermal reforming equipment. During the 1940's the conversion to catalytically cracked gasolines began, and this conversion process continued into the 1950's. More recently the trend has been to catalytically reformed gasolines. So swift has been the adoption of new equipment that the typical refinery of 1953 would be hopelessly obsolete in the motor fuels market of 1959.

This is not the first time the refiner has been faced with technological obsolescence. Refining history has been marked by the development and improvement of such processes as continuous distillation, fractionation, cracking, reforming, polymerizing, isomerizing, and hydrotreating. Individually or in combination these advances have undermined the economic position of the refiner who failed to ride with the technological tides.

In the 'twenties and 'thirties the introduction of thermal cracking and reforming profoundly affected refinery yields and product quality. Using the new cracking and reforming equipment, the refiner of the early 1930's doubled his gasoline yields, and at the same time, produced a gasoline of increased octane rating.

Again, in the 1940's the introduction of catalytic processes vastly altered the refining art. During this period, however, little change was effected in gasoline yields. The primary impact of catalytic cracking was to raise the refiner's "middle-of-the-barrel" yields—reducing the relative yield of residual fuels and increasing the yield of distillate fuel oils. Although the trend to catalytic equipment significantly increased octane numbers, yield rather than quality improvement was the primary basis for the trend. The technical superiority of catalytic cracking stemmed primarily from the fact that it enables the re-

finer to reduce the relative yield of low-profit residual oil, increase the yield of middle-distillates, and, at the same time, maintain yields of high quality gasoline.

Although octane improvement from 1920 to 1950 was not negligible (average octane increased from 50 to 84), and although at least a dozen octane improvement processes antedate catalytic reforming, octane improvement was often primarily a valuable byproduct of technical change. The investment boom of the 1950's is the first that can be characterized as reflecting expenditures designed mainly for motor fuels improvement—meaning, primarily, octane improvement. Indeed, the introduction of increasing catalytic reforming capacity, the mainstay of recent octane-improving techniques, has actually tended to reduce gasoline yields. This is in marked contrast to earlier developments when yield and quality improvements were achieved simultaneously.

The impact on yield and octane number is apparent if we compare the performance of three hypothetical refineries whose only differences lie in their respective reforming capacities. To keep our figures simple we shall assume that the basic (crude-throughput) capacity of each refinery is 100,000 barrels per

TABLE 2

THE EFFECT OF REFORMING CAPACITY ON GASOLINE YIELD AND OCTANE NUMBERS

	Plant A	Plant B	Plant C
Gasoline yield (percent of total output, including losses)	59%	56%	52%
Average octane number (including tetraethyl lead)	87	92	98

Source: *Oil and Gas Journal*, (August 16, 1954), pp. 88-91.

day, and that each possesses a catalytic cracking unit of 48,000 barrel capacity. Each refinery is assumed to add an identical amount of tetraethyl lead to its gasoline yield. (Additionally these refineries possess other processing units which need not concern us.)

Plant A will be assumed to have no catalytic reforming unit, while Plants B and C are provided with 10,000 barrel and 27,000 barrel units. How do these differences affect gasoline yield and quality (octane number)?

Immediately apparent is the fact that the considerable octane-generating potential of catalytic reforming involves a significant reduction in gasoline yield, all other things being equal. But a brief glance at refinery yields since the advent of catalytic reforming fails to reveal this declining tendency. Indeed, gasoline yields have increased slightly. Since catalytic reforming capacity has increased enormously it would appear that refiners have offset the yield effects by introducing other process capacity whose basic function is to maintain gasoline yields as quality is improved. The catalytic cracking, vacuum distillation, and hydrotreating capacity involved in maintaining yield while octane number has risen with catalytic reforming is very costly and such expense has come to account for an increasing share of the refiner's equipment dollar.

The impact of these developments is perhaps best shown by comparing the processing capacities of the mythical "representative" refiner of 1954 and 1958. (Note that average plant size grew significantly during these years, from 25,500 to 32,500 barrels per day.)

TABLE 3

PROCESSING CAPACITIES OF "REPRESENTATIVE" REFINERY, 1954 AND 1958

	(Barrels per day)		
	1954	1958	Percent Increase
Crude capacity	25,500	32,500	27.5
Vacuum distillation capacity	3,700	9,800	164.9
Catalytic cracking	8,700	14,300	64.4
Catalytic reforming	765	5,200	579.7
Thermal operations	7,752	7,345	-5.3
Hydrotreating	250 ^e	4,600	1740.0
Alkylation	500 ^e	1,000	100.0
Polymerization	306	500	63.4

^eEstimated.

Source: Computed from *Oil and Gas Journal*, annual refinery surveys.

While the increase in average plant size is partly a reflection of expanding market demand, and partly the result of fuller exploitation of the tremendous economies of scale inherent in petroleum processing plants, the disproportionate increases in nonbasic (i.e., other than crude) capacity are primarily the reflection of other forces. Although all nonbasic capacities increased proportionately more than the 30 percent increase in crude capacity, it is noteworthy that the largest relative gains were registered by catalytic reforming and hydrotreating processes (580 to 1,740 percent). Product improvement thus obviously affects refinery investment.

Unfortunately, it is not possible to determine the precise dollar costs involved in bringing the average 1954 refinery up to representative processing capacities for 1958. As we have noted, a large proportion of the new supplemental capacity was provided by hydrotreating and catalytic reforming equipment. Between 1954 and 1958 fully a dozen new catalytic reforming processes were introduced, and these introductions, coupled with the continuing design improvements in the initial units, significantly altered the capital-to-capacity relationship. The degree of change is suggested by the fact that between 1949 and 1952 the investment requirement per barrel of new catalytic reforming capacity fell over 60 percent. Reinforcing the cost-reducing effects of design improvements, the additions to reforming capacity have been in regions where scale economies are pronounced (2000 to 5000 barrels capacity for reforming units, for example). An additional cost-reducing factor is found in the increase in scale of plant. Estimates provided by McLean and Haigh suggest that the investment costs per barrel of capacity for a 200,000 barrel per day plant are less than half as large as those for a comparable 10,000 barrel refinery.¹ (Table 4)

TABLE 4
EFFECT OF REFINERY SIZE ON INVESTMENT REQUIREMENTS

Refinery size	10,000	30,000	60,000	100,000	200,000
	(Barrels per day)				
Process investment per barrel	610	400	318	275	252
Total investment per barrel ¹	1,300	833	683	610	545

¹ Includes: utilities, offsite facilities, tankage, and docks.
Source: J. G. McLean and R. W. Haigh, *The Growth of Integrated Oil Companies*, (Boston: Harvard University, 1954), pp. 558-567.

In 1954 the *Oil and Gas Journal* estimated that approximately 75 percent of current refinery investment was directed at quality improvements and yield changes. In 1957 the *Petroleum Refiner* estimated that \$150 million of the estimated 1957 plant and equipment expenditure was solely for catalytic reforming units. Another \$30 million was estimated to be for alkylation units. Thus, these processes alone account for almost a quarter of refinery investment. Finally, a leading authority in the field of petroleum technology estimated that at the prevailing levels in 1958 each one point increase in octane number involved an additional industrywide investment of \$330 million.¹

Despite the large number of variables which determine the capital-to-capacity ratio for individual plants, it is possible to make reasonably accurate overall estimates of this relationship. On the assumption that a "modern" refinery is one possessing the same relative processing capacities as the "typical" 1958 refinery (above), and that capital requirements per unit of new capacity are as follows:

- crude and auxiliary—\$1,000/barrel
 - catalytic cracking—\$300/barrel
 - catalytic reforming—\$280/barrel
 - hydrogen treating—\$200/barrel
 - alkylation—\$1,200/barrel
 - polymerization—\$1,000/barrel
- capital investment per barrel of capacity

¹ J. G. McLean and R. W. Haigh, *The Growth of Integrated Oil Companies*, (Boston: Harvard University, 1954), Chapter 20.

¹ Eugene Ayres, *Consumer Bulletin*, (Gulf Oil Corp., Sept. 1958), pp. 29-31.

TABLE 5

**ESTIMATED CONSTRUCTION COSTS
OF MODERN REFINERY IN
SELECTED YEARS**

Year	Estimated cost per barrel of capacity (1950 costs)
1910	\$176
1915	206
1927	240
1935	350
1946	680
1957	920

Source: 1910-46 estimates computed from total cost data in McLean and Haigh, 1957 estimate computed on basis of Curry and Haag capital estimates and assumption that typical refinery possessed basic (crude charging) capacity of 32,500 barrels per day, and the relative processing capacities as given in Table 3.

would be approximately \$1,300.¹ Adjusting to 1950 costs reduces this to \$920/barrel, and enables us to compare this figure with the capital-to-capacity estimates provided by McLean and Haigh. (Table 5)

Although our definition of "modern" refinery is not precisely the one employed by McLean and Haigh (their definition required that the refinery use the most modern processes then available, while our definition requires only that the refinery be "average" with regard to processing equipment), it is clear that refining in the 1950's continues to become more capital-using, i.e., the capital requirement per unit of capacity continues to increase. Thus the postwar refining experience has continued, and perhaps accelerated, the trend established early in the history of refining.

Conclusions

Refinery investment in the postwar period has been, largely, the reflection of two basic and opposing forces. On the one hand, equipment designs have been significantly improved, and process capacities markedly increased. These changes have combined to reduce sharply capital requirements per unit of process capacity *for most individual proc-*

esses. On the other hand, product improvements and yield changes have required the refiner to install increasing amounts of so-called supplemental processing equipment. These additions have markedly offset the cost reductions accruing from design improvements and increased scale economies. The increasing ratio of capital-to-capacity is a measure of the combined effect of these opposing forces.

Since these developments have not been reflected by proportionate changes in refined product prices, and have apparently been accompanied by a reduction in refinery profits (percent return on net assets) the implication is that technological progress has been passed on to the consumer in the form of product improvement.

Gasoline is obviously only one of the refiner's products and octane enhancement is only one of the many product improvements which have been made over the years. Yet even if we limit our analysis to this single index of product quality we can improve our understanding of refinery investment substantially. We can, for example, identify at least two supplemental processes which are solely octane improvement processes. These processes, catalytic reforming and isomerization, account for at least 1.5 million barrels of process capacity added since 1950, and during particular years have amounted to upwards of 100 to 200 percent of the net change in basic (crude charging) capacity. We should also recognize that a substantial proportion of alkylation, hydrotreating, and polymerization capacity installed is directly or indirectly related to octane improvement. The installation of some vacuum distillation capacity is indirectly related to the yield problems caused by increasing the severity of reforming operations.

Four million barrels is probably a conservative figure for the amount of supplemental capacity added since 1950 solely or

¹ Capital investment requirements estimated by S. S. Curry and D. O. Haag, (Universal Oil Products Company), *Petroleum World and Oil*, (October 24, 1957), p. 171.

virtually for octane improvement. The significance of this undoubtedly conservative estimate is best understood by considering that basic crude capacity increased only 4 million barrels between 1950 and 1959.

This would suggest that in the refining industry nonprice competition, in effect, carries over into the investment dimension, and that therefore such investment may be construed largely to reflect the competitive structure of the market. Since this investment is not related primarily to cyclical or long-run changes in output, it requires analysis in terms of rela-

tive strength of capital-saving and capital-using technological change.

In spite of difficulties in the analysis (due to lack of engineering cost data) the evidence of Tables 1 and 5 is clear: the swift adoption of new processes and of improved processes for increased capacity suggests that investment theory must include, at the minimum, some expression of the relationships between capital coefficients, product quality, and capacity, and not assume an easy relationship between capital investment and use of capacity.

Review of Business Conditions

RECOVERY in the country as a whole, which had shown signs of slowing in January and February, picked up momentum in March and developed even greater forward thrust in April. High levels of manufacturing activity lifted the Federal Reserve Board's index of industrial production two points for the third consecutive month, as inventory building in heavy goods industries pushed durable goods production to the boom level of early 1957 and brought increasing pressure to bear on the already high operating rates of the nation's steel mills. Output of large household appliances fell slightly in March but remained, nevertheless, at near record levels, and building materials industries continued to advance as construction activity returned in March to its January high. Automobile assembly increased 100,000 units in April and rose in early May to the highest weekly total in 1959. Nondurable goods production, although failing to advance in March, rose slightly in April to a level about 6 percent above the prerecession high. Petroleum refineries, chemical plants, and paper mills achieved record levels of production; rubber mill output reached a record in March but was held down in April because of strikes at major plants.

Housing starts in April held to the advanced March level and, on the basis of first quarter Federal Housing Administration appraisals completed and contracts awarded, outlays for residential housing and public utilities construction will probably rise further. On the other hand, expenditures on highway construction and industrial building have been less encouraging. Retail sales reached a new peak in March with a 1 percent gain in both durable and nondurable goods. April sales held to the advanced March level (after adjustment for seasonal factors) and were about 9 percent above a year earlier.

Income and employment developments were generally favorable in March, and increasingly so in April. Seasonally adjusted nonfarm employment increased 240,000 in March and 370,000 in April. These, combined with successive lengthenings of the factory workweek, elevated personal income 1 percent in March, followed by a further 1 percent gain in April, to a record annual rate of \$372.7 billion. The latest employment gains have put nonfarm employment within 700,000 of the prerecession high and have brought steadily increasing pressure on the unemployment rate. Though this statistic re-

mains a recalcitrant reminder of the late recession, it becomes less ominous with each passing month. Above 6 percent only three months ago, it dropped in April to 5.3 percent, the lowest rate since December 1957.

Bolstered significantly by the late February and March advances, Gross National Product in the first quarter rose to a seasonally adjusted annual rate of \$467 billion, up \$14 billion from the fourth quarter of 1958 and about 8 percent above the bottom quarter of the recession.

District activity quickens

The Twelfth District's advance in March was even more encouraging than that of the national economy. In contrast to last year's heavy rains, which threw building, farming, and related employment somewhat off balance, this year's mild weather has generally assisted outdoor construction and agricultural activities. Nature's favorable disposition is especially evident in March employment figures, which show District construction employment up almost 4 percent from the month before (after adjustment for normal seasonal factors).

But the District's leap forward in March was not confined to a single industry. Indeed, it appears that the economic tempo extends across the board, with only mining continuing to evidence distressing weaknesses.

Although District manufacturing employment continued to expand in April, the main strength was concentrated in California and Arizona, and was partially offset by losses in the Pacific Northwest. Construction employment gains in California and Arizona also were offset by losses in the Northwest states so that despite the sizable expansion in manufacturing, government, and finance, the increase in nonfarm employment in the Twelfth District was smaller than that experienced in March.

Nevertheless, the size of the combined March-April advance was sufficient to elim-

inate most of the remaining soft spots in the District economy and give promise of new production, sales, income, and employment records in the weeks to come. Nonfarm employment and retail sales, basic indicators of production and consuming activity, already have broken new ground, with the former reaching another record high in April, and the latter continuing to maintain sweeping margins over year-ago levels.

Construction picture promising

District construction employment, already almost 8 percent above the level of February 1958, advanced nearly 4 percent (seasonally adjusted) in March, exceeding the year-ago level by more than 11 percent. With activity going up faster than the roof of a tract house, Western construction should be sustained for some time. The volume of building permits granted in March increased spectacularly, and may have established a record. In California, Federal Housing Administration applications and Veterans' Administration requests for appraisals, also indicators of future activity, were running at nearly twice the 1958 volume in March. Preliminary reports indicate a slight increase in FHA applications during April.

With some striking exceptions, nonresidential building activity apparently is faring less well. In contrast to residential activity, which is advancing on all levels, nonresidential building contract awards are off slightly from the first quarter last year, while heavy engineering construction awards are up 15 percent. Within each of these major categories are also found crosscurrents: despite the overall slight slip in nonresidential building awards, manufacturing building and social and recreational building awards were between 70 and 80 percent above year-ago levels, while, intermixed with the sharp advance in heavy engineering construction awards, contract lettings for utilities were down nearly 10 percent.

Nondurables lead District rise in manufacturing

Judging from employment statistics, which are the most comprehensive available indicators of District industrial and commercial activity, both durable and nondurable goods manufacturing advanced rapidly in March. In contrast to manufacturing nationally, where durable goods gains forced the overall pace, District nondurables registered the stronger gains in March. Although this may reflect, in part, the District's relatively greater growth, much of the March gain in nondurable goods activity stems, as in steel production, from temporary disturbances in the labor market. In canning and processing, for example, part of the large March gains reflected resumption of operations after a shutdown of major retail food markets in Southern California had markedly reduced manufacturers' new orders. There was also a large employment gain in rubber manufacturing as production was stepped up in anticipation of possible shutdowns at major tire manufacturing plants.

Durable goods activity was dominated by sharply advanced operations in steel, machinery, and ordnance industries. District steel mills continued to increase operating rates throughout March and into April as customer demand reflected stockpiling activity. Recent increases in capacity, and a different product mix, have meant that District mills have not felt extreme orders pressure despite the threat of a summer steel strike. Consequently, District operating rates have generally been below the national average. Although individual mills have recently been pushed to near 100 percent rates, apparently even into May District operating rates remained below the 94 to 95 percent levels being maintained nationally.

Other important District metals fared less well. Copper production continued to increase but despite the threat of a copper strike this summer demand was not strong enough

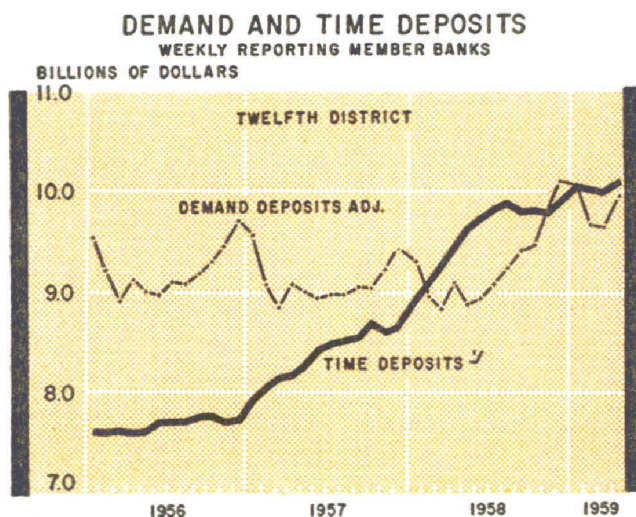
to prevent three April price cuts by custom smelters. Demand for lead and zinc continues to be slack, although a late April increase in lead prices indicated some strengthening.

Rising income and employment stimulate retail sales

Along with the expansion in employment there has been a lengthening of the average workweek and an increase in average hourly earnings. These factors have contributed to the substantial increase in District income—now running almost 10 percent ahead of year-ago levels in several states, according to *Business Week's* newly developed state income series. March department store sales (after seasonal adjustment) remained at about the same level as the previous month's record high. Complete March figures show new auto registrations in California nearly 70 percent above a year ago. Registrations in other District states, as yet incomplete, appear to be running considerably ahead of last year. Automobile sales contributed heavily to the over the year gains in sales by Group I retail stores during March, but sizable increases also were reported for hardware, furniture, and appliance dealers, as well as most soft goods merchants. Preliminary reports indicate department store trade in the Twelfth District increased slightly during April and remained fairly steady into May.

Lumber prices still rising

Reflecting the mounting demand from the national construction industry, fir prices have jumped again. After a slight slip in March, bellwether grade, random-length Douglas fir 2 x 4's climbed to \$80 per thousand board feet in mid-May—up \$8 since mid-April and \$21 above the year-ago level. At the end of the first quarter, trade association reports showed stocks down considerably from a year ago, while second quarter shipments were expected to be 15 percent above those in the comparable year-ago period. By early May



¹ Excluding United States Government time deposits.

orders were running more than 26 percent ahead of production.

According to McGraw-Hill's survey of capital spending plans, District manufacturers' fixed capital outlays will rise over 25 percent in 1959, a markedly sharper expansion than the expected 7 percent national gain. On the basis of particularly impressive increases in paper and pulp, nonferrous metals, machinery, and transportation equipment, the District's share of total plant and equipment spending is expected to rise from 11 to 13 percent of the national total.

Loan demand up

Total loans of weekly reporting banks in the Twelfth District rose \$234 million during April, an amount more than twice as great as the \$101 million increase reported during April 1958. Real estate loans rose \$69 million, commercial and industrial loans \$81 million, and agricultural loans \$19 million, all more than three times the April 1958

gains. Consumer loans (most of the "other" category) increased \$73 million, more than eleven times the April 1958 increase.

United States securities held by the weekly reporting banks in the District decreased \$39 million in April, in contrast to the increase of \$473 million during April 1958. Three-quarters of the current loss was accounted for by a decline in holdings of Treasury notes and United States bonds, although holdings of Treasury bills and certificates of indebtedness also dropped slightly. Holdings of other securities went down \$55 million during April, whereas they rose by \$108 million a year ago. The decline in holdings of United States securities occurred in the face of a \$4 billion new cash offering by the Treasury on April 1, consisting of special bills, notes, and bonds. The shift away from securities has reflected the desire of banks to take advantage of the more profitable business loan opportunities arising as the economy continues to move to higher levels of activity.

During April demand deposits rose \$204 million, while time deposits rose \$118 million. The increase in demand and time deposits during April 1958 was maintained in about the same proportion: demand deposits rose \$257 million, while time deposits rose \$166 million. However, the upward trend of April altered during the first half of May, when demand deposits fell and time deposits rose moderately. At the middle of May demand deposits stood at \$9.8 billion and time deposits at \$10.1 billion, but their respective paths in reaching these levels showed considerable contrast. (See chart)

The following banks have been admitted to membership in the FEDERAL RESERVE SYSTEM:

Pocatello National Bank, Pocatello, Idaho, effective May 14, 1959.

First National Bank of Roseburg, Roseburg, Oregon, effective May 21, 1959.

FEDERAL RESERVE BANK OF SAN FRANCISCO

BUSINESS INDEXES — TWELFTH DISTRICT¹

(1947-49 average = 100)

Year and month	Industrial production (physical volume) ²							Total nonagri-cultural employment	Total mfg employment	Car-loadings (number) ²	Dep't store sales (value) ²	Retail food prices ^{3, 4}	Waterborne foreign trade ⁵	
	Lumber	Petroleum ²		Cement	Steel ²	Copper ²	Electric power						Exports	Imports
		Crude	Refined											
1929	95	87	78	54	...	105	29	...	...	102	30	64	190	124
1933	40	52	50	27	...	17	26	...	...	52	18	42	110	72
1939	71	67	63	56	24	80	40	60	57	77	31	47	163	95
1949	100	99	103	100	97	93	108	99	97	94	98	100	85	121
1950	113	98	103	112	125	115	119	103	105	98	107	100	91	137
1951	113	106	112	128	146	116	136	112	121	100	112	113	186	157
1952	116	107	116	124	139	115	144	118	130	100	120	115	171	200
1953	118	109	122	130	158	113	161	121	137	100	122	113	140	308
1954	116	106	119	132	128	103	172	120	134	96	122	113	131	260
1955	121	106	122	145	154	120	192	127	143	104	132	112	164	308
1956	120	105	129	156	163	131	210	134	152	104	141	114	195	443
1957	107	101	132	149	172	130	224	138	157	96	141	118	230	575
1958	106	94	124	158	141	116	228	137	154	89	142	123	174	537
1958														
March	104	95	119	112	139	125	226	136	153	87	137	123	160	422
April	97	94	119	129	132	120	218	135	151	87	142	125	171	445
May	103	93	124	176	139	106	227	136	151	90	142	124	193	468
June	100	93	123	178	140	101	234	137	153	90	143	124	190	617
July	102	92	127	179	112	79	232	138	153	84	140	124	180	602
August	109	93	128	179	132	91	232	138	155	92	148	123	181	513
September	109	93	129	179	148	119	228	138	155	94	140	123	178	607
October	113	93	130	186	152	132	238	139	156	81	141	123	174	712
November	114	93	127	159	168	139	231	140	158	91	149	124	178	545
December	119	93	124	165	165	129	236	140	159	97	147	123	170	762
1959														
January	120	92	125	161	168 _r	136	238	141	161	98	150	124	237	504
February	118	92	126	142	187 _r	138 _r	...	141	162	93	155	123	153	696
March	115	95	128	171	194 _e	141	...	142	163	97	155	123	...	...

BANKING AND CREDIT STATISTICS — TWELFTH DISTRICT

(amounts in millions of dollars)

Year and month	Condition items of all member banks ⁶				Bank rates on short-term business loans ⁸	Member bank reserves and related items					Bank debits index 31 cities ^{5, 12} (1947-49 = 100) ²
	Loans and discounts	U.S. Gov't securities	Demand deposits adjusted ⁷	Total time deposits		Factors affecting reserves:				Reserves ¹¹	
						Reserve bank credit ⁹	Commer-cial ¹⁰	Treasury ¹⁰	Money in circula-tion ⁹		
1929	2,239	495	1,234	1,790	....	- 34	0	+ 23	- 6	175	42
1933	1,486	720	951	1,609	....	- 2	- 110	+ 150	- 18	185	18
1939	1,967	1,450	1,983	2,267	....	+ 2	- 192	+ 245	+ 31	584	30
1951	7,866	6,463	9,937	6,777	3.66	- 21	-1,582	+1,983	+ 189	2,269	132
1952	8,839	6,619	10,520	7,502	3.95	+ 7	-1,912	+2,265	+ 132	2,514	140
1953	9,220	6,639	10,515	7,997	4.14	- 14	-3,073	+3,158	+ 39	2,551	150
1954	9,418	7,942	11,196	8,699	4.09	+ 2	-2,448	+2,328	- 30	2,505	154
1955	11,124	7,239	11,864	9,120	4.10	+ 38	-2,685	+2,757	+ 100	2,530	172
1956	12,613	6,452	12,169	9,424	4.50	- 52	-3,259	+3,274	- 96	2,654	189
1957	13,178	6,619	11,870	10,679	4.97	+ 31	-4,164	+3,903	- 83	2,686	203
1958	13,812	8,003	12,729	12,077	4.88	- 89	-3,558	+3,645	+ 63	2,658	209
1958											
April	12,979	7,605	11,570	11,406	....	+ 43	- 391	+ 371	- 2	2,574	206
May	12,977	7,546	11,292	11,530	....	+ 11	- 203	+ 154	+ 90	2,456	193
June	13,197	7,632	11,278	11,724	4.81	- 59	- 409	+ 531	+ 22	2,494	212
July	13,142	7,670	11,744	11,779	....	+ 52	- 384	+ 302	+ 4	2,474	211
August	13,356	7,984	11,774	11,817	....	+ 2	+ 15	+ 193	+ 46	2,621	204
September	13,350	7,827	11,860	11,776	4.80	+ 4	- 378	+ 157	- 31	2,451	210
October	13,419	7,846	12,176	11,836	....	+ 0	- 517	+ 726	+ 57	2,612	215
November	13,591	8,026	12,395	11,725	....	+ 48	- 305	+ 398	+ 31	2,727	208
December	13,812	8,003	12,729	12,077	4.95	- 54	- 542	+ 518	- 11	2,658	239
1959											
January	13,897	8,099	12,508	12,037	....	+ 11	- 517	+ 389	- 109	2,656	226
February	14,022	7,735	12,210	12,018	....	+ 9	- 431	+ 386	+ 17	2,602	234
March	14,176	7,436	12,228	12,003	4.97	- 13	- 541	+ 539	+ 4	2,588	240
April	14,768	7,739	12,874	12,301	....	- 9	- 608	+ 635	+ 18	2,606	242

¹ Adjusted for seasonal variation, except where indicated. Except for department store statistics, all indexes are based upon data from outside sources, as follows: lumber, California Redwood Association and U.S. Bureau of the Census; petroleum, cement, and copper, U.S. Bureau of Mines; steel, U.S. Department of Commerce and American Iron and Steel Institute; electric power, Federal Power Commission; nonagricultural and manufacturing employment, U.S. Bureau of Labor Statistics and cooperating state agencies; retail food prices, U.S. Bureau of Labor Statistics; carloadings, various railroads and railroad associations; and foreign trade, U.S. Bureau of the Census. ² Daily average. ³ Not adjusted for seasonal variation. ⁴ Los Angeles, San Francisco, and Seattle indexes combined. ⁵ Commercial cargo only, in physical volume, for Los Angeles, San Francisco, San Diego, Oregon, and Washington customs districts; starting with July 1950, "special category" exports are excluded because of security reasons. ⁶ Annual figures are as of end of year, monthly figures as of last Wednesday in month. ⁷ Demand deposits, excluding interbank and U.S. Gov't deposits, less cash items in process of collection. Monthly data partly estimated. ⁸ Average rates on loans made in five major cities. ⁹ Changes from end of previous month or year. ¹⁰ Minus sign indicates flow of funds out of the District in the case of commercial operations, and excess of receipts over disbursements in the case of Treasury operations. ¹¹ End of year and end of month figures. ¹² Debits to total deposits except interbank prior to 1942. Debits to demand deposits except U.S. Government and interbank deposits from 1942. e—Estimated. r—Revised.