REPORT OF THE NATIONAL PETROLEUM COUNCIL COMMITTEE ON OIL AND GAS EXPLORATION DRILLING AND PRODUCTION REQUIREMENTS

HEADQUARTERS OFFICE

601 COMMONWEALTH BUILDING

1625 K. STREET, N. W.

WASHINGTON 6, D. C.

TELEPHONE: EXECUTIVE 3:5167

DECEMBER 1953

F I N A L R E P O R T

NATIONAL PETROLEUM COUNCIL COMMITTEE ON OIL AND GAS EXPLORATION, DRILLING AND PRODUCTION REQUIREMENTS

December 3, 1953

I N D E X

NATIONAL PETROLEUM COUNCIL

COMMITTEE ON OIL AND GAS EXPLORATORY AND DEVELOPMENT REQUIREMENTS

Paul Endacott Chairman	Phillips Petroleum Company	Bartlesville, Oklahoma
Hines H. Baker	Humble Oil & Refining Co.	Houston, Texas
F. W. Brigance	Rowan Drilling Company	Fort Worth, Texas
Russell B. Brown	Ind. Pet. Assoc. of America	Washington, D. C.
M. D. Bryant	Texas Ind. Producers & Royalty Owners Assoc.	San Angelo, Texas
J. P. Coleman	McCarty and Coleman	Wichita Falls, Texas
Robert H. Colley	The Atlantic Refining Company	Philadelphia, Pa.
Stuart M. Crocker	The Columbia Gas Sys., Inc.	New York 17, N. Y.
E. DeGolyer	DeGolyer and MacNaughton	Dallas 1, Texas
J. C. Donnell, II	The Ohio Oil Company	Findlay, Ohio
Stark Fox	Oil Producers Agency of California	Los Angeles, Calif.
Hial B. Gernert	Trigood Oil Company	Casper, Wyoming
George J. Hanks	South Penn Oil Company	Bradford, Pennsylvania
A. Jacobsen	Amerada Petroleum Corporation	New York 5, New York
Mason B. Jones	The S. M. Jones Company	Toledo, Ohio
Paul Kayser	El Paso Natural Gas Company	El Paso, Texas
Richard Gray Lawton	Lawton Oil Corporation	Magnolia, Arkansas
J. Sayles Leach	The Texas Company	New York 17, N. Y.
Charlton H. Lyons	Texas-Eastern Building	Shreveport, Louisiana
L. F. McCollum	Continental Oil Company	Houston 1, Texas
R. W. McDowell	Mid-Continent Petroleum Corporation	Tulsa, Oklahoma
N. C. McGowen	United Gas Corporation	Shreveport 92, Louisiana
William T. Payne	Big Chief Drilling Company	Oklahoma City 2, Okla.
Frank M. Porter	American Petroleum Institute	New York 20, New York
J. French Robinson	Consolidated Natural Gas Company	New York 20, New York
Reese H. Taylor	Union Oil Company of California	Los Angeles 17, Calif.
W. W. Vandeveer	National City Bank Building	Cleveland 14, Ohio
John H. White	Hewitt Oil Company	Charleston, S. C.
C. H. Wright	Sunray Oil Corporation	Tulsa 2, Oklahoma
Robert N. Sears Secretary	Phillips Petroleum Company	Bartlesville, Oklahoma

COORDINATING AND OTHER COMMITTEE MEMBERSHIP

COORDINATING COMMITTEE

Chairman - Paul Endacott	Phillips Petroleum Company, Bartlesville, Okla.
Exploration - J. C. Donnell II	The Ohio Oil Company, Findlay, Ohio
Drilling - William T. Payne	Big Chief Drilling Co., Oklahoma City, Okla.
Production - C. H. Wright	Sunray Oil Corporation, Tulsa, Oklahoma
Manpower - W. W. Vandeveer	627 National City Bank Bldg., Cleveland, Ohio
Materials - Russell B. Brown	Independent Pet. Assoc. of America, Washington, D.C.
Secretary - Robert N. Sears	Phillips Petroleum Co., Bartlesville, Oklahoma

MATERIALS COMMITTEE

Chairman - Russell B. Brown	Ind. Pet. Assoc. of America, Washington, D. C.
Secretary - Minor Jameson	Ind. Pet. Assoc. of America, Washington, D. C.
N. G. Dumbros	The Ohio Oil Company, Findlay, Ohio
Brad Mills	American Assoc. of Oil Well Drilling Contractors
R. E. Foss	Sunray Oil Corporation, Tulsa, Oklahoma
Mercer Parks	Humble Oil and Refining Co., Houston, Texas

MANPOWER COMMITTEE

Chairman - W. W. Vandeveer	627 National City Bank Bldg., Cleveland, Ohio
Secretary - Ralph K. Hoitsma	The Standard Oil Company (Ohio), Cleveland, Ohio
R. E. Foss	Sunray Oil Corporation, Tulsa, Oklahoma
N. G. Dumbros	The Ohio Oil Company, Findlay, Ohio
Brad Mills	Amer. Assoc. of Oil Well Drilling Contractors Dallas, Texas

EXPLORATION SUBCOMMITTEE

J. C. Donnell II - Chairman	The Ohio Oil Company, Findlay, Ohio
N. G. Dumbros - Secretary	The Ohio Oil Company, Findlay, Ohio
D. V. Carter	Magnolia Petroleum Co., Dallas 1, Texas
Morgan Davis	Humble Oil & Refg. Co., Houston, Texas
W. J. Gillingham	Schlumberger Well Surveying Corp., Houston, Texas
C. D. Hogue	Humble Oil & Refining Co., New Orleans, La.
Ralph K. Hoitsma	The Standard Oil Co. (Ohio), Cleveland, Ohio
Frank A. Morgan	Richfield Oil Corp., Los Angeles, California
E. E. Pyles	Jergins Oil Co., Long Beach, California
E. E. Roth	The Columbia Gas Sys. Ser. Corp., New York, N. Y.
Rubel, A. C.	Union Oil Co. of California, Los Angeles, Calif.
B. B. Weatherby	Amerada Petroleum Corp., Tulsa, Oklahoma
Westby, Gerald H.	Seismograph Service Corp., Tulsa, Oklahoma

DRILLING SUBCOMMITTEE

Wm. T. Payne - Chairman	Big Chief Drilling Co., Oklahoma City, Okla.
F. W. Brigance - Vice Chairman	Rowan Drilling Co., Ft. Worth, Texas
A. W. Thompson	Thompson-Carr, Inc., Houston, Texas
R. W. Wire	Loffland Bros. Co., Tulsa, Oklahoma
Jack H. Abernathy	Big Chief Drilling Co., Oklahoma City, Okla.

PRODUCTION SUBCOMMITTEE

C. H. Wright - Chairman	Sunray Oil Corporation, Tulsa, Oklahoma
R. E. Foss - Vice Chairman	Sunray Oil Corporation, Tulsa, Oklahoma
L. W. Chasteen	Union Oil Co. of Calif., Los Angeles, Calif.
Mercer H. Parks	Humble Oil & Refining Co., Houston, Texas
R. W. Shannon, Jr.	Pioneer Oil Company, Denver, Colorado
A. W. McKinney	The National Supply Co., Pittsburgh, Pa.
A. E. Pierce	Mid-Continent Petroleum Corp., Tulsa, Okla.
E. W. Webb	Continental Oil Company, Houston, Texas
Burton W. Whitely	Sohio Petroleum Company, Oklahoma City, Okla.

UNITED STATES
DEPARTMENT OF THE INTERIOR
PETROLEUM ADMINISTRATION FOR DEFENSE
Washington 25, D. C.

C
O
P
Y

February 24, 1953

Mr. Walter S. Hallanan
Chairman, National Petroleum Council
1625 K Street, N. W.
Washington, D. C.

Dear Mr. Hallanan:

Studies carried on by the Petroleum Administration for Defense of petroleum requirements in event of an all-out war indicate that continuous drilling of a substantial number of wells would be required year by year throughout the war period. Obviously, to drill a substantial number of wells year by year, the petroleum industry must be assured of minimum requirements of manpower, equipment and materials.

Information and data as to the minimum requirements are complex and extensive. However, for security planning, the Government should have sound information and data on the requirements for all phases of oil and gas exploration and development such as:

Geological and Geophysical

Leasing

Exploratory or Wildcat Drilling

Development Drilling

Producing

Services (well logging, cementing, gun perforating, drilling mud, etc.)

In view of the importance of this information to the Government for analyzing potential requirements for national security and defense, a comprehensive study of the requirements set out above would be in the national interest. For the purpose of such a study, well drilling rates of the year 1952 and 10% above the year 1952 should be assumed.

Therefore, I request that the National Petroleum Council undertake to make this study and to submit reports thereon with such recommendations as the National Petroleum Council deems appropriate.

Sincerely yours,

/s/ J. Ed Warren
J. Ed Warren
Deputy Administrator

REPORT OF THE AGENDA COMMITTEE

OF THE

NATIONAL PETROLEUM COUNCIL

February 25, 1953

Under date of February 24, 1953, Mr. J. Ed Warren, Deputy Administrator of the Petroleum Administration for Defense, addressed a letter (copy of which is attached herewith) to Mr. Walter S. Hallanan, Chairman of the National Petroleum Council, requesting that a committee be appointed to make a study as to the minimum requirements of manpower, equipment and materials for all phases of oil and gas exploration and development such as:

Geological and Geophysical
Leasing
Exploratory or Wildcat Drilling
Development Drilling
Producing
Services (well logging, cementing, gun perforating, drilling mud, etc.)

For the purpose of such a study Mr. Warren indicated in his letter that well drilling rates of the year 1952 and 10% above the year 1952 should be assumed.

As provided in the Articles of Organization of the Council, this letter was considered at a meeting of the Agenda Committee on February 25, 1953 in Washington, D. C., at which meeting it was unanimously agreed to recommend to the Council the appointment of a committee to make a study as requested by Mr. Warren and that the committee report to the Council as soon as practicable with such recommendations within the scope of study as outlined in the request, as the committee deems appropriate.

Respectfully submitted,

A. Jacobsen, Chairman
Agenda Committee

NATIONAL PETROLEUM COUNCIL
Suite 601, 1625 K Street N.W.
Washington 6, D. C.

March 12, 1953

Mr. Paul Endacott
President, Phillips Petroleum Company
Phillips Building
Bartlesville, Oklahoma

Dear Mr. Endacott:

I am pleased to appoint you chairman of the National Petroleum Council's Committee on Oil and Gas Exploratory and Development Requirements.

The Agenda Committee, acting on the request of the Deputy Administrator for the Petroleum Administration for Defense, dated February 24, 1953, in its report of February 25, 1953 unanimously adopted by the Council on February 26, recommended that the Council make a study as to the minimum requirements of manpower, equipment and materials for all phases of oil and gas exploration and development, and that for the purpose of such a study well drilling rates of the year 1952 and 10% above the year 1952 should be assumed. The report also stated that the Committee should report to the Council as soon as practicable with such recommendations within the scope of study, as outlined in the request, as the committee deems appropriate.

There is enclosed for your information a copy of the Agenda Committee report including Mr. J. Ed Warren's letter of request, together with a copy of the membership list of the Committee. Each member of the Committee has been informed of his appointment as per the attached sample letter.

You will no doubt want to name necessary subcommittees and a secretary, who in addition to such other duties as you may assign to him, should supply the Secretary of the Council with brief minutes of all meetings of your committee and subcommittees, which minutes should include an attendance record of all present at the meetings.

I greatly appreciate your undertaking this important assignment. Jim Brown has informed me of your acceptance.

Sincerely,

(Signed) Walter S Hallanan

Walter S. Hallanan
Chairman

S U M M A R Y

NATURE OF REPORT

The production of crude oil and gas can be maintained on a continuous or expanding basis for any period of time only if declining and depleted wells are replaced with new wells. For this reason the Petroleum Administration for Defense has recognized the necessity of, and advocated, continuous activity in the exploration, drilling, and production operations of the oil and gas industry, both in time of peace and war. The supply of oil during a war period will be directly affected by the amount of exploration and drilling carried on. Any reduction in exploration or drilling will result in reduced productive capacity.

To drill the necessary number of wells the petroleum industry must be assured of receiving minimum requirements of materials, equipment and manpower in the search for oil and gas and its subsequent development. This study therefore covers the materials, equipment and manpower requirements for exploration, drilling and production, as well as the requirements for related services which fall within these three branches of the petroleum industry. This report was designed to have pertinent information immediately available to the military and others should an emergency arise.

To establish a basic period from which to make comparisons, the committee was directed to use well drilling rates of the year 1952 and 10% above the year 1952. If the materials and manpower requirements in this report are used in the future, to be realistic they should be brought up to date in light of conditions and prevailing methods employed at that time.

MATERIALS

1. Steel mill products used by the exploration, drilling and production branches of the petroleum industry in 1952, based on categories claimed by the Petroleum Administration for Defense, amounted to 3,191,000 short tons. This does not include all of the steel used by these branches of the industry, but does take into account the specialized uses. Not included above are the numerous items which are generally used throughout all industry, but are nontheless essential to the petroleum industry. There are so many industries supplying these various fabricated steel products to the petroleum industry that these items could not be segregated and shown separately.

2. Oil country tubular goods requirements for use in oil and gas wells represented 2,106,000 short tons of steel, or approximately 66% of the total claimed by PAD for the exploration, drilling and production branches of the industry in 1952.

3. An analysis of oil country tubular goods indicated that 11.3 tons of steel was required for each 1,000 feet drilled in 1952. This factor compares closely with the results of previous studies. With greater average well depths, the factor of 11.3 tons of oil country tubular goods per 1,000 feet drilled will probably increase in the future.

4. In 1952, there were 2,642 rotary rigs and approximately 1,500 cable tool rigs in operation. In round numbers 3,000 rotary rigs and 1,500 cable tool rigs would be required for a 10% increase in operations above the 1952 level. It is anticipated that all of the increase in drilling activity will be accomplished with rotary rigs. Overall requirements for related drilling materials would increase at least 10%.

5. To maintain uninterrupted drilling activity at the 1952 level would require replacement of approximately 450 rotary rigs annually.

6. To maintain production from the 464,000 producing oil wells and the 66,000 natural gas wells in the United States requires a constant flow of maintenance

and repair requipment. There are thousands of items of material and equipment required in exploration, drilling and production. Whether used in large or small volumes, each is an operating necessity, and the lack of one seemingly insignificant item may shut down an exploration, drilling or production operation.

7. Although many metal products are an absolute necessity, alloys are critical to the operation of certain oil field equipment. Substitutions for alloys made during World War II resulted in increased total tonnages of steel used, slowed down operations, and lowered oil production rates.

8. Many items of relatively small volume are utilized in seismograph operations. These items are the type usually in critically short supply during emergencies. Equipment of this nature is not used exclusively by the petroleum industry and is mostly available through general supply sources.

MANPOWER

9. Total manpower required in 1952 for exploration, drilling and production was 311,000 with production of oil and gas accounting for approximately 56% of the total. At a rate of 10% greater activity, manpower requirements would be approximately 332,000.

10. Even to maintain the 1952 drilling rate of 46,000 wells, it will be necessary for the industry to operate 650 seismograph and 100 gravity meter crews every month throughout each year, approximately the number of crews operating during 1952.

11. Of the 42,000 persons in exploration activities in 1952, 11,000 were geologists and geophysicists and 4,000 were scouts and landmen.

12. Studies of trained manpower available for exploration activities indicate the oil industry will need geologists and geophysicists in greater numbers than are being graduated by our educational institutions.

13. Approximately 95,000 persons were employed in drilling activities in 1952. The petroleum industry cannot again afford to lose its drilling manpower in time of war as occurred in World War II due to improper draft classification of drilling personnel.

14. Since the petroleum industry is more highly technical and mechanized than most industries, it has a high percentage of young scientists and engineers who are either subject to the draft or hold reserve commissions. This very rapid penetration of technology into the petroleum industry has come about in relatively recent years. It is essential that the scientifically trained manpower be retained in time of emergency if oil demands are to be met.

15. The magnitude of operations performed by the individual employee in the petroleum industry is high due to advanced technology and the relatively great utilization of machinery and equipment. The importance of each single employee is therefore magnified.

16. Approximately 165,000 persons were engaged in production operations of the 464,000 active oil wells in 1952. The number of producing oil wells is increasing approximately 3% per year.

17. Of the 165,000 in producing operations, approximately 136,000 persons were engaged in direct producing activities in 1952, while 3,000 persons were required in supervisory and technical development work and 26,000 persons provided the necessary services and supplies for producing wells.

18. An additional 9,000 employees were used in 1952 to produce natural gas from the 66,000 operating gas wells in the country.

GENERAL

19. The materials and manpower requirements covered in this study represent all phases of exploration, drilling and production, to and including the lease

tanks for crude oil and the separators for natural gas produced with crude. For natural gas produced as such the requirements include gas production and field gathering.

20. The finding and development of reserves capable of sustaining necessary productive capacity must be achieved well in advance of any production from reserves which may be discovered. Any curtailment in exploration activity or wildcat drilling will subsequently diminish development and eventually reduce both productive capacity and production. The necessity for exploratory (wildcat) drilling is illustrated by the fact that one of every ten wells in 1940 was exploratory, while in 1952 one out of every four wells was a wildcat.

21. During an emergency a continuous exploration and drilling program must be maintained or even increased because of the serious consequences which would be suffered from the lack of oil if a short war were assumed and a more extended emergency occurred.

22. Finding new oil and gas reserves can be expected to become increasingly difficult since the areas to be explored are generally more inaccessible and the producing formations will be found at greater depths. Therefore, as exploratory activities rise, ever increasing quantities of materials and greater manpower must be devoted to these operations. To indicate the increasing importance of exploratory activities, for every single seismograph crew utilized in 1940, the industry used almost four in 1952.

23. Although requirements of materials and manpower were figured at the 1952 rate and 10% above, in the future use of these figures, adjustments must be made to fit the conditions that will exist at that time.

24. As exploration, drilling and production become increasingly difficult, manpower and materials for research will play a larger role in finding, developing and increasing the recovery of oil.

25. An increasingly important and necessary part of the exploration, drilling and production branches of the industry are the many service and supply companies which furnish specialized tools, equipment and supplies, as well as highly trained personnel.

INTRODUCTION - MATERIALS AND MANPOWER

The assignment given the committee was to study the minimum requirements of materials and manpower for all phases of oil and gas exploration and development. The study, therefore, has two main divisions - Materials (which includes equipment) and Manpower. Each of these divisions includes sections for exploration, drilling and production, covering the major activities of the petroleum industry up through the storage of crude oil in the lease tanks and the separation of associated gas at the well, and the production and gathering of natural gas. These activities relate to the finding and development of both crude oil and natural gas reserves, but do not cover natural gasoline liquids extraction nor the transmission of gas. The survey of materials and manpower requirements was confined to the activities of the petroleum industry within the United States.

Shown below is a list tabulating the principal activities performed within the scope of exploration, drilling and production.

PRINCIPAL ACTIVITIES INCLUDED IN THE EXPLORATION, DRILLING AND PRODUCTION OF OIL AND GAS

EXPLORATION

Geology
Geophysics
Core Drilling
Scouting
Leasing
Offshore Location Surveying
Aerial Photography and Map making
Administration, Research, etc.

DRILLING

Rig Hauling
Rig Building
Rotary Drilling
Cable Drilling
Slim Hole Drilling
Directional Drilling and Surveying
Casing Crew Operations
Mud Servicing
Fishing Tool Service
Repair and Maintenance Operations
Administration, Engineering, Research, etc.

PRODUCTION

Production Operations (Well & Lease Equipment)
Roustabout and Maintenance Operations
Work-over Operations
Acidizing
Gun Perforating
Formation Fracturing Operations
Cementing
Marine Construction and Transportation
Electric Logging
Dip Meter Surveying
Formation Shooting
Tank Building
Subsurface Testing
Repair and Maintenance Operations
Administration, Engineering, Research, Accounting, etc.

The extent of material and manpower needs from supply and service organizations for exploration, drilling and production operations is indicated in the sections of this report which deal with specific requirement data. Generally speaking, manpower and materials requirements of supply and service organizations dealing exclusively with petroleum operations in the three activities previously indicated, have been included. However, manpower and materials used by industries serving the petroleum industry and other industries as well were not included in this study.

The present study is based on the actual rate of exploration, drilling and production in 1952, and at a rate 10% higher. The Petroleum Administration for Defense advised that in the event of an all-out war, petroleum requirements would be such that continuous drilling of a substantial number of wells would be required each year throughout the entire war period. Such a program contrasts with the policy during World War II when drilling was sharply curtailed by government restrictions. The importance of assuring adequate materials and manpower in the future, therefore, is apparent.

The need to maintain or expand petroleum exploration, drilling and producing activities is emphasized by the continuing growth in demand for petroleum. The following tables and charts indicate the expansion that has occurred in United States oil demand compared to productive capacity. There is a direct relationship between the drilling program and productive capacity. During the past few years the drilling program was barely able to keep productive capacity at a level sufficient to meet the increasing demands. (See Chart I)

COMPARISON OF U. S. PETROLEUM DEMAND AND PRODUCTIVE CAPACITY

Year	U. S. Petroleum Demand (In Thous. B/D)	Productive Capacity (In Thous. B/D)
1940	3,981	4,945
1941	4,369	4,935
1942	4,293	4,920
1943	4,579	4,905
1944	5,134	4,890
1945	5,358	4,875
1946	5,331	5,230
1947	5,902	5,590
1948	6,143	5,950
1949	6,130	6,460
1950	6,812	6,980
1951	7,463	7,500
1952	7,717	7,950

The increased volumes of oil country tubular goods required and the number of wells drilled are directly related and are shown in the accompanying table. Preceding drilling with its resulting requirements for steel was the necessary exploratory activity, representing the initial phase of any program aimed at maintaining or increasing reserves and productive capacity.

COMPARISON OF OIL COUNTRY TUBULAR GOODS,
NEW WELL COMPLETIONS AND EXPLORATORY WELLS DRILLED IN THE U.S.

	Oil Country Tubular Goods Thous.Tons	New Well Completions				
		Oil	Gas	Dry	Service	Total
1940	956	19,843	2,265	7,053	1,988	31,149
1941	985	19,590	3,279	7,280	2,361	32,510
1942	426	11,082	2,685	5,962	2,261	21,990
1943	633	9,963	2,314	6,364	1,708	20,349
1944	1,048	13,556	3,024	7,153	2,053	25,786
1945	1,040	14,097	3,039	7,346	2,167	26,649
1946	1,018	16,294	3,355	8,496	2,085	30,230
1947	1,280	17,896	3,437	9,751	2,063	33,147
1948	1,612	22,543	2,966	11,939	2,029	39,477
1949	1,318	21,793	3,121	12,898	1,150	38,962
1950	1,834	24,240	3,015	14,918	1,134	43,307
1951	1,990	23,876	3,198	17,497	1,425	45,996
1952	2,106	23,638	3,166	17,759	1,322	45,885

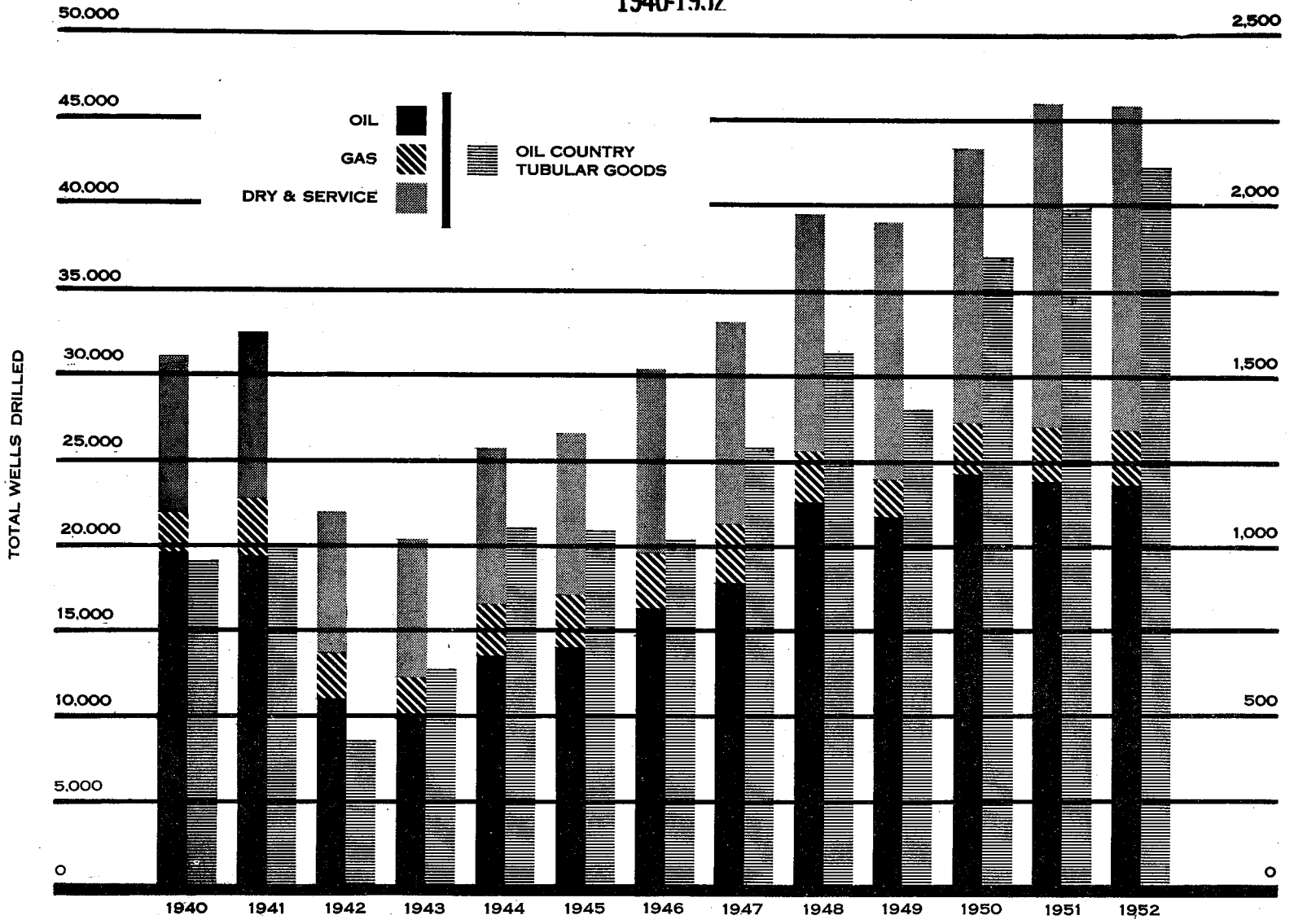
Source: Oil Country Tubular Goods - American Iron & Steel Institute. (1948-1952 adjusted for additional supplies from conversion, imports, second hand, etc.)
New Well Completions - World Oil

The comparison between demand and productive capacity and the relationship existing between wells drilled and the supply of oil country tubular goods are shown in Charts I and II on the following page. When drilling was reduced during the war years, productive capacity was reduced below the demand. Whenever drilling is restricted, productive capacity declines rapidly.

In the past, drilling has also been restricted by the supply of oil country tubular goods, which in turns limits the number of wells drilled. This is indicated in Chart II on the following page. From 1948 through 1952, in addition to the regular supply of oil country tubular goods, conversion pipe, imports, second-hand pipe and line pipe were all used in an attempt to meet the total requirements for oil country tubular goods. It is important to note in Chart II that although the number of wells drilled in 1951 exceeded those drilled in 1950, and in 1952 wells drilled were approximately the same as in 1951, fewer oil wells were obtained in each succeeding year after 1950. This illustrates the point that oil is becoming more difficult to find, and generally speaking, it will be necessary to drill deeper each year and more materials and manpower will be required to find each barrel of oil. Off shore operations, from which a great volume of our future petroleum may come, offer a good example of the increased difficulties and added requirements to be expected in the future.

The number of exploratory wells (known as "wildcats") has been increasing at a faster rate than development or producing activities. This is shown in the following table.

TOTAL U. S. WELL COMPLETIONS AND SUPPLY OF OIL COUNTRY TUBULAR GOODS 1940-1952



SOURCE: OIL COUNTRY TUBULAR GOODS, AMERICAN IRON & STEEL INSTITUTE. NEW WELL COMPLETIONS, WORLD OIL.

TOTAL WELLS DRILLED COMPARED TO EXPLORATORY WELLS IN THE UNITED STATES

	Total Wells Completed	Exploratory (Wildcat) Wells Drilled	Exploratory Wells as a Percentage of Total Wells
1940	31,149	3,165	10.2%
1941	32,510	3,697	11.4
1942	21,990	3,176	14.4
1943	20,349	3,631	17.8
1944	25,786	4,325	16.8
1945	26,649	4,510	16.9
1946	30,230	4,947	16.4
1947	33,147	5,874	17.7
1948	39,477	7,197	18.2
1949	38,962	7,721	19.8
1950	43,307	8,997	20.8
1951	45,996	10,952	23.8
1952	45,885	11,066	24.1

Source: World Oil

It follows that to find and develop the reserves capable of sustaining productive capacity in relation to demand, exploratory efforts must be expanded currently and also during periods of emergency demand. Since increased emergency demand begins abruptly, a backlog of new locations must be built up if the necessary development is to take place. New reserves can be found only by drilling exploratory wells. Only one exploratory well in nine finds petroleum reserves capable of adding to productive capacity. Suitable well locations can be found only by advance exploration work. In order to provide such locations, a continuous supply of materials and skilled manpower are absolutely necessary in geophysical and geological operations, as well as in the other functions of oil and gas exploration.

As previously pointed out, a substantial level of development drilling in time of emergency must be utilized in order to make discovered reserves available for use. Development drilling, although it does not pose the high degree of increased difficulty in operation of exploratory drilling, requires much larger total quantities of material, equipment and manpower. These requirements vary approximately in relation to the amount of drilling.

The drilling of wells does not end their need for material, equipment and manpower. Wells must be serviced, maintained, and repaired in order to continue production. At the close of 1952 there were approximately 464,000 oil wells producing or contributing to the production of petroleum in the United States.[1] Production operations, lasting over many years, require replacement items for equipment worn out or destroyed by normal processes. The expanded efforts to increase recovery in older producing areas require additional supplies of material and equipment. In a period of emergency the processes for stimulating production, such as secondary recovery methods now in use, must be supplied with adequate quantities of the materials they need, and also be assured of adequate manpower.

As previously stated, estimates of material and manpower requirements have been based on the level of operations for 1952. During that year there was a total of 7,958 crew months of seismograph activity, an average of 2,642 rotary rigs were in operation, and 45,885[2] wells and 184,600,000[2] feet of hole were drilled. On December 31, 1952, 464,000 wells were producing oil and approximately 66,000 wells were producing gas. Production of crude oil and natural gas liquids averaged 6,868,000 barrels daily in the United States during the year 1952.

A level of operations 10% above that of 1952 would require an increase in the quantities of materials, equipment and manpower of approximately the same magnitude. It is pointed out, however, that the relative amounts of exploratory and development drilling, together with the specific physical conditions associated with such drilling, will cause variations which must be re-calculated for any future emergency. In addition, the number and depth of new wells required to maintain productive capacity at the same volume as in 1952 will probably be entirely different at some future time. These, and related problems must be re-evaluated as conditions change.

[1] Oil and Gas Journal
[2] From "World Oil"

Further, in any future national emergency, new methods or added emphasis to existing methods, such as secondary recovery and off shore development, must be taken into consideration in determining the actual requirements for materials and manpower existing at that time.

While not specifically included in the Committee assignment, it should be noted that the assurance of a proper economic climate is a prerequisite to full and efficient use of materials and manpower.

It is estimated that a total manpower force of 311,000 was required for the exploration, drilling and production activities of the oil and gas industry during 1952. The total manpower requirement was made up of the following number of employees for each of the major divisions: exploration, 42,000; drilling, 95,000; production, 174,000. If activities were carried on at a rate 10% higher than 1952, the total manpower requirements would increase to 332,000. A more detailed summary, with general classifications for each of these major divisions, is included in the discussion of manpower for each of these divisions.

REPORT ON MATERIALS REQUIREMENTS

MATERIALS REQUIREMENTS - PROBLEMS AND DISCUSSION

Material requirements span the needs from initial exploration activities through development drilling to and including the producing operations of oil and the gathering of gas. No requirements have been estimated for the processing and transportation of gas.

Materials and equipment for exploration, drilling and producing operations are obtained by the petroleum industry as follows:

(1) Directly from the steel mill or distributor of mill products.

(2) Through manufacturers or fabricators who specialize in oil field equipment.

(3) From the manufacturers of general industrial equipment.

Supplies from the first two categories were claimed during the Korean emergency for the petroleum industry by the Petroleum Administration for Defense. It is possible, therefore, to estimate with some accuracy quantities of basic materials for the drilling and production branches of the petroleum industry from these two sources. Material and equipment for petroleum exploration, drilling and production from manufacturers of general industrial equipment cannot be estimated quantitatively from any available source of information, inasmuch as a tremendous number of distributing firms and more than 12,000 petroleum operators are involved. It is possible, however, to supply detailed lists of specific items used and to make estimates of the correct degree of magnitude covering some of the major categories.

Appendix Table I lists most of the important categories of materials and equipment used in exploration, drilling and production operations, and indicates whether the material and equipment comes directly to the operator from the manufacturer, through a petroleum industry manufacturer or through a manufacturer of general industrial equipment. Although items coming to the petroleum industry from the

manufacturers of general industrial equipment were not claimed for the industry by the Petroleum Administration for Defense, they number in the thousands. Some of them cost thousands of dollars, and others only a few cents, but many are an operating necessity and the lack of one small item can cause a delay or a diminished rate of production. For instance, at one time during World War II, the exploration branch of the industry found it almost impossible to obtain B batteries without which a great amount of work, involving many exploratory units and hundreds of men was delayed. Drilling operations have likewise been held up for items as relatively insignificant as spark plugs.

The basic framework of material and equipment needs for exploration, drilling and production operations is steel and steel products. To these numerous steel items must be added thousands of products which require other materials used separately or in combination with steel. Since steel is the backbone of materials and equipment requirements for exploration, drilling and production operations, the following table has been prepared to summarize the estimated requirements for steel and mill products claimed by the Petroleum Administration for Defense, based on the 1952 level of industry operations:

STEEL MILL PRODUCT REQUIREMENTS FOR UNITED STATES OIL AND GAS EXPLORATION, DRILLING AND PRODUCTION BASED ON 1952 LEVEL OF OPERATIONS
(In Short Tons)

	Requirement for 1952 Level of Operations		
	Direct to Oil Industry	Through Mfgrs. of Oil Field Machinery and Equipment	Total
Oil Country Tubular Goods (Casing, Tubing & Drill Pipe)	2,106,000	-	2,106,000
Other Tubular Goods (Line Pipe & Mechanical Tubing)	250,000	75,000	325,000
Structural Shapes	6,000	89,000	95,000
Sheet, Strip and Plate	13,000	260,000	273,000
Bars and Bar Shapes	2,000	309,000	311,000
Rods, Wire, Wire Products and other Mill Forms and Products	13,000	68,000	81,000
Total Mill Products	2,390,000	801,000	3,191,000

Petroleum Administration for Defense allocations did not furnish the total amount shown. The steel covered by the above table is used in material and equipment delivered to the industry from the two sources previously defined, namely:

(1) Direct shipment of mill products; and

(2) Indirect through manufacturers of oil field machinery and equipment.

In addition to these requirements, substantial quantities of steel are needed for the manufacture of products coming to the petroleum industry through manufacturers of general industrial equipment. The quantities are no doubt considerable, inasmuch as the list of items is large, as indicated by Appendix Table I.

The foregoing estimate for 1952 requirements of oil country tubular goods was based on a factor of 11.3 tons per thousand feet of hole drilled. Following is an analysis of the oil country tubular goods requirements for the first half of 1952 showing the derivation of this factor. It is based on reported statistics of American Iron and Steel Institute, combined with the best estimates available on other quantities of oil country tubular goods or substitutes available to the industry.

ANALYSIS OF OIL COUNTRY TUBULAR GOODS
First Half 1952

Mill Shipments	Tons
Total	769,000
Less Exports	80,000
For Domestic Use	689,000
Other Oil Country Goods	
Imported Pipe	75,000
Inventory Withdrawals	125,000
Unreported Mill Pipe, Rejects, Line Pipe Used as Oil Country and Abnormal Use of Second-hand Pipe	195,000
Total Other	395,000
Grand Total	1,084,000
Tons per 1000 Ft. Drilled/1	11.3 /2

/1 Based on 95.9 million feet drilled, per World Oil.
/2 The factor may be compared with the following:
Factor Used in NPC Report of September 26, 1950 (For Year 1951) . . . . . 11.2 tons per 1000 ft. drilled.
Factor Determined by NPC Study of July 29, 1952 (For 4th Quarter 1951 . . . . . 11.3 tons per 1000 ft. drilled.

The factor of 11.3 tons of oil country tubular goods per 1,000 feet of hole drilled is considered to be accurate, inasmuch as it can be substantiated historically by experience as far back as the period from 1935 to 1941, which is substantially the immediately pre-World War II period of use. The relationship of oil country tubular goods to footage drilled is shown in the following table:

TOTAL U.S. FOOTAGE DRILLED AND SUPPLY OF OIL COUNTRY TUBULAR GOODS

Year	Oil Country[1] Tubular Goods (Thous. of Tons)	New Footage[2] Drilled (Millions of Feet)	Tons of Oil Country Tubular Goods per Thous. Feet of Hole Drilled
1935	723	67.8	10.7
1936	1,095	81.0	13.5
1937	1,358	104.7	13.0
1938	979	90.6	10.8
1939	989	85.5	11.6
1940	956	96.2	9.9
1941	985	99.3	9.9
1942	426	67.9	6.3
1943	633	62.0	10.2
1944	1,048	84.4	12.4
1945	1,040	93.0	11.2
1946	1,018	101.1	10.1
1947	1,280	112.8	11.4
1948	1,612	136.7	11.8
1949	1,318	137.6	9.6
1950	1,834	159.8	11.5
1951	1,990	176.8	11.3
1952	2,106	186.4	11.3

(1) Source: American Iron & Steel Institute. After 1947 total adjusted for use from conversions, imports, second-hand, etc.
(2) World Oil.

It is pointed out, however, that the factor is an overall average for the industry and is not applicable to individual operations or areas. Deeper wells require substantially more than 11.3 tons per thousand feet of hole drilled, and as average depths of drilling increase, the average factor may become larger, increasing the industry's total requirement for oil country tubular goods. There has been a steady increase in the depth of wells drilled. The average depth of wells drilled increased from 3,200 feet per well in 1942 to 4,100 feet per well in 1952.

In connection with oil country tubular goods, it is pointed out that in any future emergency immediate consideration should be given to mill rolling patterns for size and quality of oil country tubular goods, since the proper pattern of manufacture is imperative for maximum efficient utilization of the available steel tonnage. In this connection, reference is made to the previous study of oil country tubular goods by sizes and weights, submitted by the NPC on July 29, 1952.

In the tabulation of steel mill products required for exploration, drilling and production, the quantities of steel other than oil country tubular goods were estimated from historical relationships to oil country tubular goods. These relationships have been established by experience data from the Petroleum Administration for War and the Petroleum Administration for Defense. This portion of steel is delivered to the industry principally through the manufacturers of oil field equipment and machinery.

Based on 1952 allocations of Petroleum Administration for Defense, requirements for steel mill products in 1952 included stainless steel products in the magnitude of 3,500 tons per year.

In addition to steel, there are a number of other basic materials which are required by the industry in substantial quantities. Some idea of the magnitude of such requirements may be obtained from the Petroleum Administration for Defense allocations for the first half of 1952. Based on these allocations, the level of 1952 operations in exploration, drilling and production required copper in the magnitude of 900,000 pounds, copper base alloy in the magnitude of 3,000,000 pounds, copper wire mill products, 2,200,000 pounds, copper and copper base alloy foundry products, 4,600,000 pounds. Aluminum in various forms totaling some 3,500,000 pounds was indicated as required for the level of activity.

Critical also are various alloying elements. Petroleum Administration for Defense allocations again indicate the magnitude of the needs. For the year 1952,

nickel, for instance, was required in the magnitude of 5,000,000 pounds, cobalt 65,000 pounds, tungsten 55,000 pounds, molybnemum, 1,900,000 pounds and chromium, 5,500,000 pounds. These alloying elements are critical to the manufacture of items such as shafting, gearing, drill pipe, tool joints, sucker rods, bits, drill collars and N-80 and other superior grades of tubular goods. The quantities stated take into consideration the use of substitutes, many of which were tried during both World War II and the recent emergency. The quantities, therefore, have been reduced below normal requirements.

Other materials critical to the industry, and often difficult to obtain, are items like quebracho and other chemicals required for which no adequate substitutes have been available. In addition, forgings and castings, both for oil field manufacturers and for those in the general industrial field, are important. According to experience in past emergencies, some of the major critical components furnished by general industrial equipment manufacturers for exploration, drilling and production operations, are internal combustion engines, compressors, general purpose pumps, speed changers, switch gears, anti-friction bearings, rotary chain, tractors and other construction equipment.

Attention is directed to the fact that exploration, drilling and production requirements cover a very broad field of specialized items which vary, for example, from field photographic supplies, mapping equipment, boats and barges which service marsh and off-shore operations for all three categories to business machines in offices. In this connection reference is made again to Appendix Table I which lists many of the principal items required, their place of use, and the source from which they are delivered to the petroleum industry.

The following discussions cover the special phases of equipment and material requirements for exploration, drilling and production which have not been touched upon in the foregoing general statement.

EXPLORATION

The development and producing operations of the petroleum industry must be preceded by exploratory activity. The exploration branch of the industry provides the backlog of drilling locations which permits the industry to carry on future development and production.

The materials requirements for the exploration branch of the industry, as contained in this report, are based on the 1952 exploration program, during which year there were approximately 46,000 total well completions. It should be recognized that there is an important time element involved, since only adequate exploration activities make possible the drilling programs for several years in the future. While the estimated materials requirements are based on the 1952 level of exploration, it is emphasized that this exploration program is applicable only to the relatively near future as a support for a 46,000 well completion program. Exploratory efforts during recent years have increased at a faster rate than either drilling or development operations. As oil deposits become increasingly difficult to locate, it is probable that the exploration program required to support the 1952 level of drilling activity will increase steadily with resulting increases in the quantity of materials and changes in the type of materials needed for exploration.

As a basis for the calculation of 1952 materials requirements, a detailed study was made of the various phases of exploration activity. During the year 1952 there was a total of 7,958 crew-months of seismograph activity, 965 crew-months of gravity meter operations, 57 crew-months of aeromagnetometer work, and 63 crew-months of ground magnetometer exploration. The record of this activity for seismograph and gravity meter crews during the years 1947-1952 inclusive, is shown in the following tabulations:

ACTIVE SEISMOGRAPH CREWS IN THE UNITED STATES

(Shown in Crew-months)

	1947	1948	1949	1950	1951	1952
Jan.	390	448	510	418	483	589
Feb.	390	439	510	417	502	619
Mar.	405	458	513	423	506	628
Apr.	403	473	511	431	524	647
May	416	485	507	447	525	651
June	414	494	487	447	540	667
July	428	490	484	442	554	680
Aug.	427	517	458	458	555	693
Sept.	433	498	447	470	573	702
Oct.	438	507	445	468	587	710
Nov.	434	515	505	477	600	687
Dec.	432	505	427	467	592	685
Total	5,010	5,829	5,804	5,365	6,541	7,958

ACTIVE GRAVIMETER CREWS IN THE UNITED STATES

(Shown in Crew-months)

	1947	1948	1949	1950	1951	1952
Jan.	126	98	125	64	60	82
Feb.	127	98	120	59	61	82
Mar.	125	100	112	52	63	71
Apr.	123	102	104	53	62	82
May	121	106	97	54	61	80
June	126	110	90	48	66	79
July	123	116	86	48	64	84
Aug.	118	118	83	55	67	87
Sept.	119	122	80	50	72	81
Oct.	114	127	77	60	77	80
Nov.	109	129	73	61	83	80
Dec.	109	129	70	58	80	77
Total	1,440	1,355	1,117	662	816	965

Source: "Geophysical Activity in 1952" - E. A. Eckhardt. Data in crew-months taken from chart except for 1952 for which actual figures are available.

Based on this recent experience, it is estimated that 172 crew-months of seismograph work and 21 crew-months of gravity work per 1000 wells drilled represent the current requirements to support a drilling program equal to that carried on during the year 1952. These dominant methods of geophysical exploration require materials for 651 seismograph crews (which in 1952 were divided as follows: 553 land; 33 marsh; 33 shallow water; and 32 offshore), and 96 gravity meter crews (which in 1952 operated as follows: 76 land; 6 marsh; 6 shallow water; and 8 offshore). The great bulk of the materials for exploration are required to permit the operation of geophysical crews since geological materials requirements are relatively small except for automobiles. A sample survey of a few companies indicates that about 10,000 automobiles are needed for the work of the industry's scouts, landmen and geologists alone.

A wide variety of equipment and materials is needed by the geological and geophysical branches in order to conduct the industry's exploration activities. Due partly to the fact that a large portion of these materials and equipment does not reach the industry through fabricators and suppliers of oil field machinery, previous studies of materials requirements for the petroleum industry have reflected only a small part of the materials and equipment used in oil and gas exploration. This study, therefore, includes a detailed analysis of the materials and equipment requirements for the more important geophysical operations. Since such activity is now vital to future development and production, and may well become even more significant with the passage of time, it was felt both desirable and important to set out in detail the materials requirements for seismograph and gravity meter crews.

Attached to this report as Appendix Tables II and II is a detailed list of the major items of materials and equipment required for annual replacement, as well as maintenance, repair and operating supplies for seismic and gravity meter operations. An indication of the wide variety and magnitude of the materials needed is shown by referring to a few of the many requirements listed in these appendix

tables. For example, the maintenance, repair and operating supplies required by 651 seismic field parties during one year include 260 million feet of cap wire, about 36 million feet of insulated wire for recording cables, and more than three-quarters of a million dollars worth of resistors, transformers, and other miscellaneous electrical and electronic components. Attention is particularly called to dynamite, the requirements for which amounted to 26,040 tons in 1952. Annual replacements for these 651 seismic parties include almost 4,000 pounds of nickel-iron transformer sheets, about 13,000 pounds of plastic insulating materials, approximately 2500 pounds of brass screws and fittings, and more than 250 sets of two-way radio communication equipment. Appendix Table II C contains a list of the many other items including the equipment and materials for rotary shot-hole drills, mud pumps, and all the variety of items required in connection with such activity. As in the case of seismic operations, Appendix Table III sets out the important material requirements for the 96 gravity meter crews operating in 1952.

In addition to the materials and equipment requirements shown in Appendix Tables II and III, seismic and gravity field parties need a variety of marine equipment such as boats, outboard motors, barges, marsh buggies, helicopters, underwater meters, and cranes.

Geological aerial photography and mapping activities cannot be carried on without many items of photographic equipment, chemicals, and specialized office and laboratory supplies. Core drilling operations involve the use of such materials and equipment as trucks, power units, pumping units, pipe, bits, drilling cable, water lines, and water tanks. Aeromagnetic and ground magnetometer operations cannot be conducted without adequate aviation and automotive equipment and supplies as well as photographic materials and electronic components.

The materials requirements for exploration activities covered in this section of the report, Including Appendix Tables II and III, are based on the 1952 level of operations as specified in the assignment for this study. In order to

support a 10% increased level of exploration operations, generally speaking it would be necessary to increase the various phases of activities, such as the number of seismic and gravity meter crew-months proportionately with a resulting increase in the volume of materials needed. As pointed out above, however, an even larger increase in exploration activities may be necessary in order to furnish the locations required to accomplish an increase of 10% in total well completions above the actual completion rate during the year 1952. In the event that it becomes necessary in the future to determine material requirements for oil and gas exploration, a review should be made of the situation at that particular time when greater activity and enlarged requirement for materials may exist, including significant changes in the type and character of equipment and supplies resulting from advancements in exploration methods and technology.

DRILLING

Exploration activities as discussed above provide the locations to support development operations. The material requirements for drilling oil and gas wells have been analyzed in relation to the 1952 rate of approximately 46,000 total well completions and a 10% increase in these activities.

It is important to recall that the drilling branch of the oil producing industry was subjected to severe shortages of materials which disrupted and curtailed operations during World War II. In order to continue the 1952 rate of drilling, or increase this rate in the event of any future emergency, provision must be made for an adequate supply of the proper materials and equipment.

In the Appendix of this report Table I lists in detail the important items of materials and equipment required for oil and gas drilling operations. The volume and quantity of these many items of equipment and materials is related to the number of drilling rigs in operation.

The following table shows the average number of rotary drilling rigs in operation each month during the period 1942-1952, inclusive.

MONTHLY AVERAGE OF ROTARY RIGS ACTUALLY RUNNING IN UNITED STATES AND CANADA

Month	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952
Jan.	787	729	1327	1738	1696	1548	1980	2090	2021	2244	2945
Feb.	756	773	1356	1714	1521	1594	1919	2021	1972	2169	2885
Mar.	720	810	1399	1700	1449	1618	1912	2085	2031	2287	2872
Apr.	750	829	1452	1715	1501	1633	2070	2130	2091	2442	2917
May	789	869	1517	1790	1479	1686	2189	2181	2145	2578	3007
June	795	935	1599	1743	1511	1806	2251	2109	2277	2647	2964
July	861	1036	1665	1730	1515	1896	2302	2027	2295	2740	2658
Aug.	833	1105	1710	1730	1552	1947	2348	2022	2304	2867	2505
Sept.	789	1156	1754	1756	1639	1978	2335	2001	2297	2937	2585
Oct.	788	1231	1808	1762	1683	2044	2372	2039	2438	3040	2709
Nov.	788	1293	1849	1796	1674	2056	2437	2197	2500	3088	2835
Dec.	816	1353	1800	1760	1700	2008	2385	2247	2481	3137	2896
Average	788	1009	1603	1744	1576	1817	2208	2096	2238	2683	2816
LESS: Rigs in Canada	*	*	*	30	19	35	50	74	88	132	174
Rigs in U.S.	788	1009	1603	1714	1557	1782	2158	2022	2150	2551	2642

*No data available; unquestionably number of rigs running in Canada in war years was relatively few.

It will be noted from the above table that an average of 2642 rotary rigs were operating in the United States during 1952. In addition to these rotary rigs thereare a substantial number of cable tool rigs in the United States. The total number of cable tools in 1952 is estimated as follows:

CABLE TOOLS IN UNITED STATES

New York	175
Pennsylvania	375
West Virginia	200
Ohio	210
Indiana	50
Kentucky	100
Kansas	110
Oklahoma	180
Illinois	75
Michigan	110
Rocky Mountains	150
New Mexico	75
Texas	100
TOTAL	1,910

Of the above total cable tools it is estimated that about 1500 rigs were in operation on the average during the year 1952. In total, therefore, 1500 cable tool rigs and an average of 2642 rotary rigs were required for the completion of approximately 46,000 wells during 1952.

As previously pointed out, the operation of rotary and cable tool rigs requires a wide variety of equipment items and a substantial quantity of materials. For example, the total 1952 well completions required an estimated 590,000 tons of bentonite, 712,000 tons of barites, 36,000 tons of quebracho.

In order to maintain the 1952 level of drilling operations it is estimated that there would be a minimum requirement of 453 new rotary rigs for replacement of obsolete, inefficient, unusable equipment. A total of 2930 new engines are needed yearly for the continued operation of 2642 rotary rigs and 1500 cable tool rigs.

Among the important material and equipment requirements for the maintenance of the 1952 level of drilling activity are 18,750 tons of high alloy steel drill collars and 84,000 tons of steel for rock bits. In connection with the requirement for rock bits it should be noted that the steel needs to contain about 3.5% nickel. The use of inferior alloy steel for such purposes, as was tried for a period during World War II, would probably now reduce efficiency by as much as 50% due to the greatly increased weight carried and the severity of present day drilling operations.

Other important material requirements for conducting rotary and cable tool operations at the 1952 level include approximately 1,000 air compressors and 6,000 sets of brake lining blocks. In addition, there is a need for an estimated 750,000 feet of hose (largely metallic and flexible hose of 1" or smaller diameter), and 11,200,000 feet or 23,000 tons of line pipe, which on a footage basis is divided approximately 8% under 2", 52% 2" and 2-1/2", and 40% 3" to 6". The line pipe requires a total of 2,100,000 fittings (nipples, tees, ells, unions, plugs, and bushings) of various sizes ranging from 1/8" to 10-3/4", representing a total of 3,000 tons of steel. Additional equipment requirements include 115,000 valves from 1/8" to 10", an estimated 25,000 tons of wire line, most of which is 1-1/8" or 1-1/4" line and approximately 95,000 tons of drill pipe in 1952. The drill pipe requirements by size and grades for the 1952 level of drilling and 10% above this level are estimated as follows:

ANNUAL DRILL PIPE REQUIREMENTS
Tons per Year

Size	1952		1952 + 10%	
	Grade D	Grade E and Better	Grade D	Grade E and Better
2-7/8"	370	438	420	498
3-1/2"	5,832	8,899	6,627	10,113
4 "	2,994	4,096	3,402	4,655
4-1/2"	32,995	36,767	37,494	41,776
5 "	168	1,621	191	1,842
5-1/2"	368	772	418	877
6-5/8"*	0	0	0	0
Total	42,727	52,593	48,552	59,861

*No requirements indicated on survey. (NOTE: It is generally considered to be mandatory to use Grade E drill pipe when drilling below 9,000'.)

The operation of 2642 rotary rigs and 1500 cable tool rigs requires an estimated 1,690,000 pounds of rubber per year and approximately 1800 tons of high manganese steel roller chains.

In order to accomplish a 10% increase in total well completions over the 1952 level, it is estimated that cable tool rigs would continue at approximately the same rate, but that it would be necessary to operate an average of about 3,000 rotary rigs as compared with the 2,642 average for the year 1952. Because of the relatively greater quantity of materials needed for rotary rig operations as compared with the cable tool drilling, the quantity of materials and equipment needed to accomplish this 10% increase in the level of drilling activities would be somewhat greater than a 10% increase in the quantities of equipment and materials listed above.

PRODUCTION

For purposes of determining material requirements for producing operations in this study, production needs were defined as those items of material and equipment required after drilling operations had been completed.

The major item of materials and equipment in this phase of the industry's activities, both from the standpoint of quantity and critical nature, is steel tubular goods (casing and tubing). The estimated requirements for these tubular goods have been shown in a previous section of this report. It should be emphasized, however, that an adequate supply of casing and tubing of the proper sizes, weights and grades is a basic necessity to the maintenance of necessary oil and gas production and the required expansion of petroleum supply.

In the event of national emergency and material shortages, one important consideration is the possibility of utilizing substitute materials. While at times this may be necessary, it is important to recognize that such practices have not always resulted in any real conservation or efficient utilization of available materials. As an example, shortages in the past have resulted in the use of carbon-manganese sucker rods in wells which had been or would have been equipped with nickel alloy rods. Since the lower grade rods had a shorter life than the nickel alloy rods, a higher rate of replacement was needed and more material was used eventually as a result of this substitution. This in turn delayed producing operations.

The completion of producing oil and gas wells requires substantial quantities of materials, including many items of equipment supplied by both manufacturers of oil field machinery as well as fabricators of industrial equipment. During the year 1952, well completions totaled 45,885, of which 23,638 were producing oil wells and 3,166 were producing gas wells, the remainder being dry holes and service wells. Among the more important items of equipment needed for the completion of these producing wells are:

Casing - Oil and Gas Well
Cement
Compressors - Air and Gas
Engines
Instruments - Well Logging, Surveying, Radio Activity Log, Electric Log, Temperature Log, Caliper Survey, Well Inclination, Fluid Level Indicator, Gun Perforation, etc.
Motors - Electric
Pipe - Line
Pumps - Tubing & Rod Inserts
Rods - Sucker and Pull
Separators - Gas, Oil and Water
Tanks - Steel
Units - Oil Well Pumping
Valves - All Types
Well Head Equipment

In addition to the material requirements for newly completed wells, materials and equipment are needed for the maintenance and repair of all producing wells, which averaged 463,637 during 1952, according to the Oil and Gas Journal.[1] Of the total producing oil wells, 88% were reported as operating by pumping or other means of artificial lift. The repair and maintenance of these wells, which include more than 300,000 wells in the stripper category, according to the survey conducted by the Interstate Oil Compact Commission, involve a substantial requirement of such items of material and equipment as:

Engines
Motors - Electric
Pipe - Line
Pumps - Tubing and Rod Insert
Rods - Sucker and Pull
Tanks - Steel
Treaters - Crude Oil Emulsion
Units - Oil Well Pumping
Units - Oil Well Servicing
Valves - All types.

During 1952, according to estimates by the Oil and Gas Journal, a total of 25,550 wells required the installation of artificial lift equipment. There is a continuing need for the installation of sucker rod pumping equipment, hydraulic subsurface equipment, plunger lift, gas lift, and electrical submersible pumps as

[1] The "Oil and Gas Journal" well figures do not agree with "World Oil" well figures principally because "World Oil" included input wells in its totals.

thousands of flowing wells are added each year to the wells producing by artificial lift.

A survey of oil field equipment manufacturers indicated that approximately 18,500 pumping units (sucker rod type) were delivered during 1952, 22% of which were in the API sizes 6 to 16, 33% in the API sizes 25-57, 34% in the API sizes 80-160, and 11% in the API sizes 228-640. This same survey also showed that 1952 deliveries of all sizes and grades of sucker rods totaled about 64 million feet. For the same year it is estimated that approximately 500 hydraulic sub-surface units and 150 hydraulic surface power units were delivered. In addition to the deliveries of these items of equipment and material, equipment was salvaged and inventories were reduced as a result of shortages in the availability of new equipment.

Other critical items for production operations include the acids and chemicals used by the industry in treating and completing wells. As in the case of other materials and equipment, substitutions have been used during periods of shortages but, again, this practice has not always resulted in either conservation of materials or efficient operating methods.

As in the case of exploration and drilling, producing activities require many items of equipment that are delivered to the petroleum industry by fabricators and manufacturers not identified as suppliers of oil field machinery and equipment. In order to maintain the 1952 level of producing operations, or to increase this level by 10%, it is necessary that the industry obtain adequate supplies of such equipment as electric motors, switch gears, copper wire, internal combustion engines and general industrial pumps. Steel plate is required for both the installation and replacement of tankage, including separators and treaters. The industry's producing operations can be disrupted or reduced in efficiency by the shortage of any one of an almost countless number of such items of general equipment, including such items as heavy duty trucks and trailers designed for special service in oil producing activities.

REPORT ON MANPOWER REQUIREMENTS

MANPOWER REQUIREMENTS - PROBLEMS AND DISCUSSION

As pointed out in the summary, the total estimated manpower required in exploration, drilling and production totaled 311,000 in 1952. This was made up of 42,000 employees in exploration, 95,000 in drilling and 165,000 in oil production and 9,000 in gas production.

In determining manpower requirements for 1952 plus 10%, it was concluded that exploration and drilling requirements in general are in direct ratio to the rate of activity in these operations. On the other hand, manpower requirements for production are only indirectly related to the number of wells drilled and are more closely related to the number of producing wells in operation. The total number of producing oil and gas wells increased approximately 3% per year during the past five years. The maintenance of drilling activity at the 1952 rate of approximately 46,000 wells would result in the completion of about 23,650 new oil wells and 3,150 new gas wells. However, these wells are partially offset by the abandonment of many stripper wells. It has been estimated that on an annual 46,000 well completion basis there will be a net increase of approximately 13,000 in the total number of producing wells, based on operations as they are today. This number of added wells would increase manpower requirements for production by about 4,000 each year, even though exploration and drilling manpower might possibly remain constant.

A drilling program 10% higher than 1952 would result in an increased manpower requirement of 10% for exploration, or slightly more than 4,,000. Drilling would increase by a little more than 9,000 employees. A 10% increase in drilling activity does not necessarily increase the manpower requirements for production operations a like amount. Allowing for service wells and dry holes, a 10% increase in the 1952 drilling rate would result in an increase of approximately 0.6% in the total number of producing wells. This figure applies only to the 10% additional wells above the 1952 rate, and not to any increase in total producing wells as a result

of the 46,000 well program. It is estimated that manpower requirements for production would increase about 7,000 in oil production and 1,000 in natural gas production. The total additional annual manpower requirements for a 10% increased drilling program over the 1952 rate would necessitate an additional 21,000, or a grand total of 332,000 employees.

The increasing complexity of all phases of exploration, drilling and production are such that the need for scientifically trained and experienced personnel is increasing and will continue to increase in the future. While some jobs in all these activities can be performed with relatively inexperienced personnel, the nature of the work, in drilling for instance, where heavy and expensive machinery is required, is such that either more men will be required or fewer wells will be drilled as inexperienced personnel are substituted.

Attention is called to the problem of military reserves who are employees of the oil industry. A large group of experienced men, particularly in the technical phases, are members of the reserve forces. The withdrawal of even a limited number of these personnel would have a serious and detrimental effect on operations. Additionally, the petroleum industry, because it has been expanding rapidly, has a large proportion of young people. Many of these are also in the reserves. Generally, those who are not would be subject to the draft. While this younger group, because of limited experience, may not be as important to the operations of the petroleum industry as the older employees, it would be essential to retain at least the scientifically trained among this younger group. As compared to other industries, the oil industry has one of the highest ratios of investment per employee due to an unusually high degree of mechanization and technology. This results in a relatively low number of employees as related to the size of the industry. To an industry already low in total manpower, each employee thus becomes more vital.

During 1952 most of the oil industry operated on a 40 hour week. Drilling was an exception, however, and operated largely on a 56 hour week. Geological and geophysical operations are not based on a fixed number of hours, since traveling and weather conditions play an important part in these operations.

A breakdown of the numbers of personnel in the skilled, semi-skilled and unskilled classifications has not been attempted. Neither has an attempt been made in this study to determine the number of male and female employees. A previous report to the National Petroleum Council dated January 26, 1950, however, showed about 6% females in exploration, drilling and production work. Except for jobs in both field and headquarters offices, women are rarely used. The nature of the jobs in the oil fields is such that women are not able to perform the work.

In making this study it became evident that there are variations in the classifications of personnel doing similar work within the many companies in the industry. For example, in production one company may call a man a Chief Engineer, another company may call him Engineer or Superintendent, etc. Further, there are many more classifications of jobs than are shown in the tabulations. The total numbers of people given in this report, however, include the total manpower of these three phases of the industry. A more complete breakdown of the job classifications for these activities of the oil industry can be found in the Dictionary of Occupation Titles prepared by the U. S. Employment Service and published by the Department of Labor.

No attempt has been made in this study to estimate the manpower required by manufacturing companies producing equipment and materials used in the three activities of the industry covered. A great number of personnel are employeed by these companies in the fabrication of a vast number of items used in the oil and gas industry. However, their output is also used by many other industries as well. Two notable examples are manufacturers of tubular goods and automotive equipment.

It is suggested that the National Petroleum Council or some other industry group utilize the facilities of trade associations and professional societies and maintain an active file of the critical manpower needs of the various segments of the petroleum industry. It is also suggested that the Bureau of Labor Statistics as well as other Federal government agencies concerned with manpower problems, such as the National Research Council, be advised of these estimates. The experience gained in this study in developing and working with sources of manpower information will be invaluable in setting up patterns of manpower requirements and in working with Federal agencies to develop deferment policies and procedures in the event of an emergency.

EXPLORATION

As explained in the section on materials, exploration activities in 1952 reached record high levels. Future exploration activities must increase more rapidly than drilling operations in order to meet petroleum requirements. An indication of probably future increase in exploration activities is clearly shown from the sharply increased upward trend of past geophysical activity.

AVERAGE ANNUAL NUMBER OF SEISMOGRAPH CREWS OPERATING IN THE UNITED STATES

1940	180	1947	417
1941	179	1948	486
1942	223	1949	484
1943	249	1950	447
1944	295	1951	545
1945	337	1952	663
1946	363		

Source: "Geophysical Activity in 1952" - E. A. Eckhardt.

Due to the anticipated increase in exploratory activities, the estimates which have been prepared for manpower, as in the case of material, can only be used in the immediate future. With the passage of time it will be necessary to recompute manpower requirements for the exploration phase of the industry in the light of the then existing situation. The estimates presented herein should be used merely as a guide, and in case of another emergency a group should be set up to bring the estimates in this study up to date.

Any group which may undertake to determine exploration manpower requirements in the future should for assistance contact certain organizations that have participated in this study on manpower. In addition to the membership of the committee and the oil producing companies, this should include:

1. For Leasing Activities -
   The National Oil Scouts & Landmen's Association

2. For Data on Geologists -
   The American Association of Petroleum Geologists

3. For Geophysical Information -
   The Society of Exploration Geophysicists.

Following is a summary of the estimated total manpower requirements for exploration:

		1952	1952 + 10%
Leasing Activities			
Scouts	1,240		
Land & Titlemen	2,760		
Total		4,000	
Geology			
Geologists & Geophysicists	11,000		
Aerial Photography & Mapmaking	800		
Core Drilling	400		
Total		12,200	
Geophysics (Except for geophysicists included above)			
Seismograph	11,850		
Gravity Meter	800		
Magnetometer	200		
Total		12,850	
Offshore Location Devices(Gulf Coast Only)		280	
Administrative, Clerical, Stenographic, draftsmen, etc. (n.e.c.)		12,670	
GRAND TOTAL EXPLORATION		42,000	*46,200

(*Shown as 46,000 in Summary and discussion.)

As shown above, the manpower requirements for leasing activities total 4,000. With the competitive nature of the oil industry, these men are essential, for without them neither exploration nor drilling could proceed, as land holdings in the United States are usually in small sized parcels and mostly privately owned. The activities of this group are needed to obtain the leases under which drilling and production can proceed. The number of lease brokers whose function closely approximates that of scouts and landmen was not determined in this study.

It is estimated that in 1952 11,000 geologists and geophysicists were employed within the industry. This estimate is based on data obtained from the American Association of Petroleum Geologists and the Society of Exploration Geophysicists. These professional societies estimated that there were 11,600 petroleum geologists of all categories in the United States at the end of 1952.

On the basis of past studies it was determined that about 600 of these petroleum geologists are only indirectly connected with oil exploration, since they are employed by educational institutions and Federal and State government agencies. Of the remaining 11,000, a small number, probably not more than 250, have attained positions of executive authority in various petroleum organizations. Still others are engaged in research work and/or provide technical assistance to the drilling and production departments, but the entire 11,000 may be considered as essential to the exploration program which was conducted in 1952. Actually, the petroleum industry needs many more geologists and geophysicists than are becoming available from our educational institutions. They are the key personnel in the prospecting for oil, and are essential if exploration activities must continue to expand to make adequate supplies of petroleum available.

One of the tools of exploration is the core drill. This equipment is generally used to drill to depths ranging from 300 to 1,900 feet in order to obtain geological information. During 1952 there was an average of 27 core drills in operation, requiring 400 men. It is probable that in the future there will be an increase not only in the number of core drilling operations but also in the ratio that this activity bears to total exploration activities.

The exploration phase of the industry requires a large assortment of maps. In recent years aerial photography has been employed in order to obtain many of these maps, and one of the principal organizations engaged in this activity was contacted in order to obtain some measure of the scope of such operations. On the basis of this contact it has been estimated that approximately 800 employees are engaged in this type of work. Since this is a relatively new form of activity and conditions will undoubtedly change, it is recommended that in any future emergency a thorough survey be conducted for reliable data on aerial photography.

Geophysical methods such as seismograph and gravimeter are being used more and more in the exploration for petroleum. This is indicated in the table on Page 27 in the Material section of this report. The most important single method of geophysical operation involves the use of the seismograph. On the basis of a 15% sample of the 1952 crews, including both contract seismograph organizations and oil company operations, it has been estimated that 11,850 employees were engaged in all phases of this activity in 1952, including central offices, field parties, shops and laboratories. This figure does not include, however, the seismologists and geophysicists shown under Geology on the preceding table. Among the 11,850 employees are included about 450 physicists, electrical engineers and other scientifically trained personnel who work in geological laboratories and are essential to exploration activities. Also included are such classifications as computers, surveyors, shooters, observers, shot hole drillers and helpers of various types. Shown in addition are master mechanics, welders, clerks, technicians, and many other classifications. Geophysical operations required the direct services of about 320 draftsmen, but this figure does not include the much larger number of draftsmen used in other exploration activities.

The second most important type of geophysical exploration utilizes the gravity meter as a tool. There were about 800 people engaged in the use of the gravity meter in 1952, excluding the executives and geophysicists.

Another tool used for geophysical exploration is the magnetometer. This instrument is used for ground survey work and also to cover large areas by airplane. The aerial magnetometer and ground magnetometer activities in 1952 required approximately 200 people.

With the growing interest in the oil and gas possibilities of the continental shelf, it has become necessary to utilize radio location devices, one of which is called LORAC. Based on 14 shore networks witn an average of three offshore units per network, a total of 280 men were required. With an increase of offshore

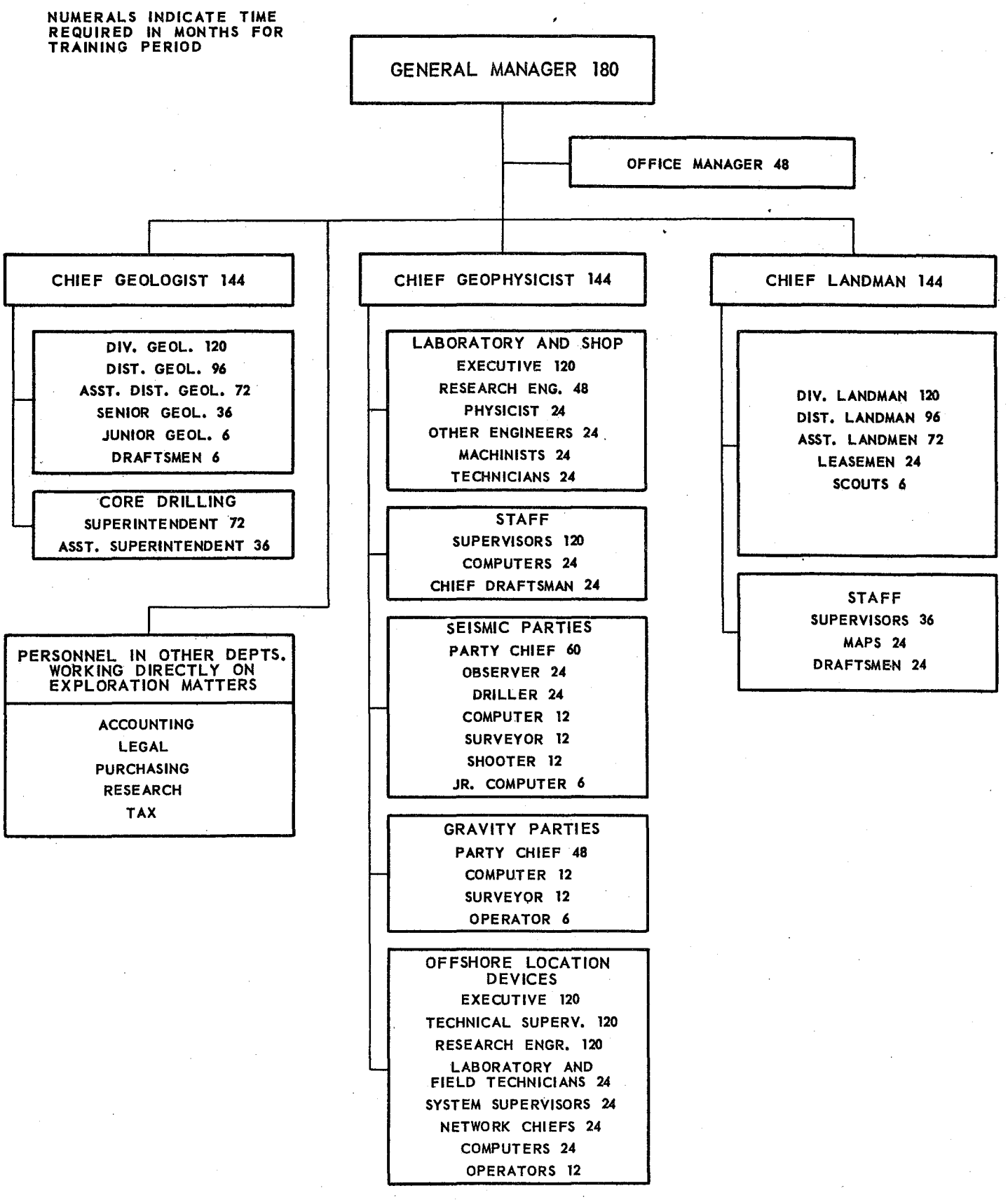
explorations as anticipated, personnel requirements would increase proportionately.

In addition to the personnel which have been enumerated in the foregoing paragraph, it was estimated that approximately 12,670 people would be needed for the administrative, clerical, stenographic, drafting and other personnel requirements not classified elsewhere, to support the activities of the key personnel of exploration. It should be made clear that this estimate does not include such personnel for the geophysical activities, since they have been included with geophysics above. Basically the 12,670 mentioned herein would supplement the geologists, scouts and landmen.

It was estimated that with an increase of 10% over 1952 in geological and geophysical activity, the requirement for exploration personnel would increase 10%, or approximately 4,000, increasing the total manpower in exploration work to 46,000. In using this report as a basis for computing manpower requirements at some future time, it should be kept in mind that personnel requirements for exploration will change with time as new technical developments are made, and as the industry enters into newer areas of exploration.

The chart on training time for key personnel on the following page should be look upon only as a guide and a measure of current requirements. It is conceivable that additional categories will be needed in the future, and the requirements in terms of education and training may become more stringent. In case of an emergency, military and defense authorities should give proper consideration to the needs for petroleum, and not handicap the industry in its search for new oil and gas reserves by depleting key exploratory personnel through calling them into military service.

MINIMUM MANPOWER CLASSIFICATIONS AND TRAINING TIMES NECESSARY FOR EXPLORATION OPERATIONS



DRILLING

At the beginning of World War II, the essentiality of drilling crewmen was not properly established. As a result, the draft status of men working in the drilling industry was not comparable to the draft status of men working in war plants.

It was not until the middle of the war that the industry was able to obtain proper deferment of drilling crewmen. This delay resulted in the loss of a high percentage of skilled drilling crewmen to other war industries -- a loss from which full recovery was never made during the war period. This war-time experience should point up the importance of workmen in the drilling industry. They must be regarded as most essential in war and also in periods of defense preparation if the industry is to meet its responsibilities during emergencies.

During the past ten years average well depths in the United States have increased about 80 feet annually. In any future emergency the data contained in this report should be adjusted, if at that time average well depths drilled are materially different from 4,100 feet, the average for 1952.

The following information was compiled by the staff of the American Association of Oilwell Drilling Contractors, Dallas, Texas, and is based on surveys of industry sources.

Rotary Rig Manpower Requirements

Historically, in Mid-Continent areas, drilling crews have worked on a 56-hour work week basis. Taking into account absences, illnesses, "float" between jobs, and delays incident to moving a rig from one location to another, it is calculated that the men required per rig per day in the Mid-Continent area are as follows:

	Men per Rig
Toolpushers	1.0
Drillers	4.0
Derrickmen	4.0
Enginemen or Firemen	3.0
Floormen	8.0
Superintendents, Engineers, Warehousemen, Truck Drivers, Welders, Mechanics	2.0
Subtotal - Mid-Continent Area	22.0
Adjustment in Manpower Required for Other Areas	2.2
National Average of Manpower Required per Rig	24.2

In explanation of the foregoing adjustment, many drilling crews in California and on the Gulf Coast (especially crews employed on "off-shore" jobs) have been operating for several years on approximately a 42-hour work week, and the industry trend is definitely toward a shorter average work week. It has therefore been estimated that the national average manpower requirement is 24.2 men per rig crew, 10% higher than the Mid-Continent averages. From the above calculations, and with 2,642 rotary rigs in operation, the total manpower required for rotary rigs is approximately 64,000. Following is a table showing a breakdown of this figure by jobs:

Rotary Rigs	
Toolpushers	2,905
Drillers	11,625
Derrickmen	11,625
Enginemen	8,720
Floormen	23,250
Superintendent & Misc.	5,815
Total	63,940

Cable Tool Rig Manpower Requirements

The estimate for cable tool requirements is based on the following manpower for each rig:

	Men per Rig
Drillers	3.5
Tool Dressers	3.5
Toolpusher	0.5
Misc. Skilled Help	0.5
Total	8.0

In the foregoing table, allowance is made for one extra driller for each two cable tool rigs as a relief or swing man, by listing 3.5 drillers per rig. The same provision applies to tool dressers. This allotment, it is believed, is sufficient to cover absences, illnesses, etc. The estimate of 0.5 toolpusher per cable tool rig is based on the fact that only about half of the rigs have toolpushers acting as such. On the remainder of the rigs the driller working on the daylight tour (8 A.M. to 4 P.M.) acts as toolpusher. Miscellaneous skilled help consists of firemen on steam operated rigs, truck drivers and supervision.

The total manpower requirements for cable tool drilling, based on the foregoing analysis, is shown in the following table:

Cable Tools	
Drillers	5,250
Tool Dressers	5,250
Tool Pushers	750
Misc. Skilled	750
	12,000

Other Manpower Requirements

Not included in the above rotary and cable tool lists is the clerical and administrative help required by the industry. Among these are such classifications as accountants, attorneys, clerks, stenographers and other office personnel. A recent survey shows that in this miscellaneous category there is an average of 1.5 persons employed per rotary rig and 0.75 person per cable tool rig, or a total of about 5,300.

Another group essential to the drilling industry is that which provides special non-continuous services on a fee basis. This group supplies drilling mud and mud engineering services, fishing tool service, casing crew services, rig building, mechanical and machinist services, drilling industry trucking, and various smaller specialized services. It should be pointed out here that the rig-moving truck driver has a considerably different responsibility from that of an "over the road" truck driver. He operates a specially designed truck and must be able to winch, load, haul, unload, and rig-up extremely heavy, expensive equipment items.

He must know the sequence in which each part of the rig and equipment is to be loaded in order that assembly at the delivery point may proceed efficiently; he uses heavy gin poles, equivalent to work done by a crane operator, and assembles equipment in a manner similar to work done by the rigger in the construction industry.

Some larger operators employ men in certain of the foregoing classifications sufficient to handle a portion of their work requirements while most smaller operators depend entirely on outside specialists for these jobs. In either event such services are essential to the drilling industry and must be maintained.

The total estimated manpower required in miscellaneous drilling services is 14,000. These figures were determined by actual surveys made in connection with this study. Shown below is a breakdown of these miscellaneous services:

Miscellaneous Services	
Drilling Mud	1,900
Fishing & Directional	400
Casing Crews	800
Mechanics	1,600
Rig Builders	300
Rig Hauling	9,000
	14,000

Based on industry surveys made for this report and all the foregoing calculations, a summary of the manpower requirements for the drilling activity as estimated for 1952 and 1952 plus 10% is shown below:

	1952	1952 + 10%
Rotary Rigs	64,000	72,600
Cable Tools	12,000	12,000
Administrative & Clerical	5,300	5,820
Misc. Services	14,000	14,000
	95,300*	104,420*

(* Shown as 95,000 and 104,000 respectively in Summary and Discussion)

It will be noted in the above table that cable tools, administrative and clerical and miscellaneous services are the same for 1952 and 1952 + 10%. It has been estimated that under emergency conditions no increase in these categories will be needed to take care of the higher drilling rate.

Training Manpower for the Drilling Industry

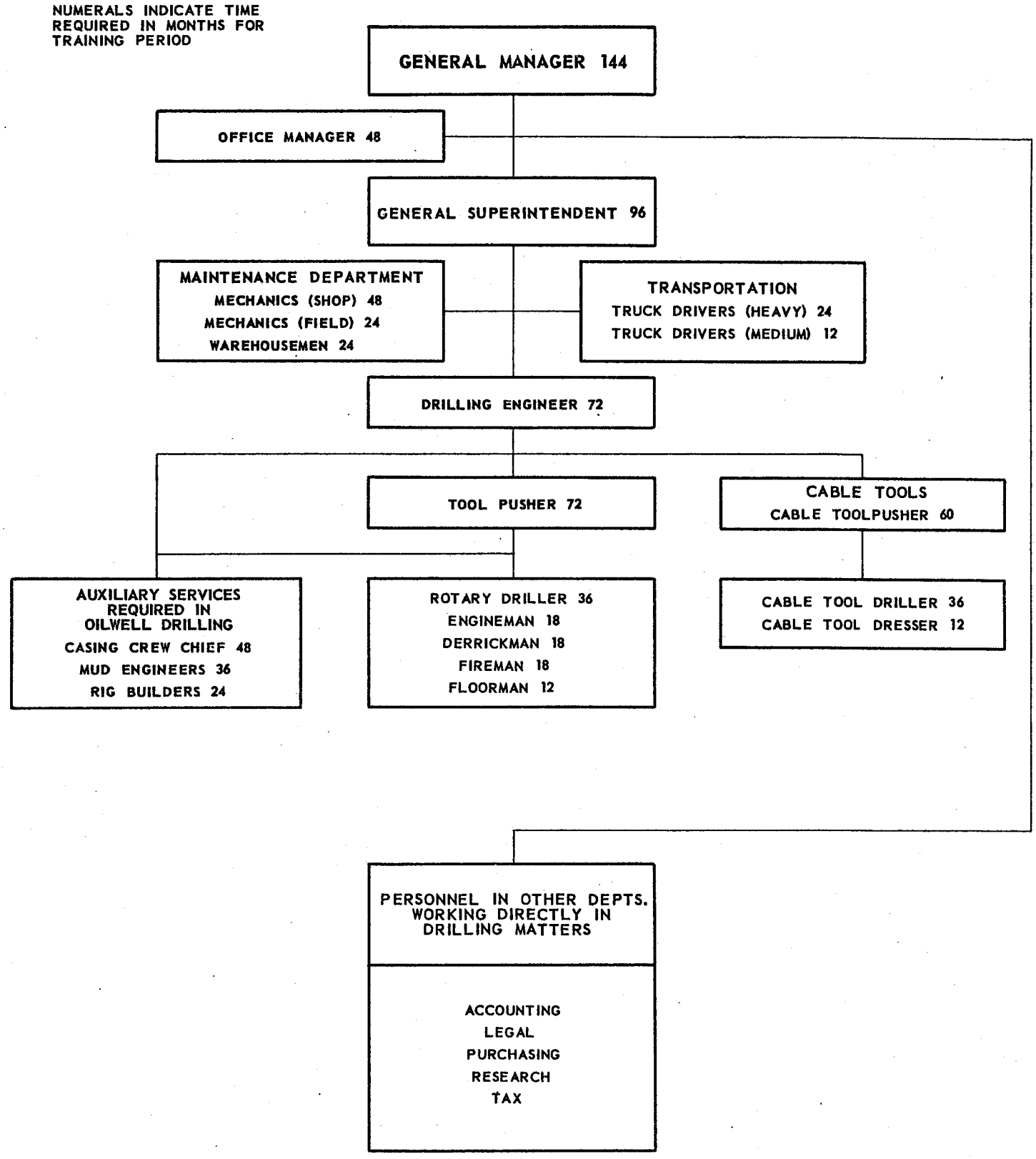
Because of the vagaries of the earth's crust drilling oil wells is an art rather than an exact science. However, the skills used in this art are based upon the sciences of civil engineering, mechanical engineering, steam and gas engineering, geology, hydraulics, chemistry, and much common sense. The selection of personnel, from management to floormen, is not what could be described as simply routine. Each individual's background, education, training, and experience must be carefully checked and evaluated before he can be placed in a position of operations responsibility.

A driller, when on duty, is responsible for a rig (rotary) that is worth $100,000 to $1,000,000, depending on its size, and also for the well that is being drilled, which may be worth, at any given time, from $20,000 to $500,000 or more. A toolpusher is responsible to the drilling superintendent for the rig and the work and services of all drillers and their crews. The drilling superintendent is responsible to top management for all of the toolpushers, drillers, crewmen, and rigs in a given area.

A cable tool driller has the same responsibilities as the rotary driller, although the cost of a cable tool rig is much less than a rotary rig. On a cable tool rig the tool dresser and/or his helper functions in the dual capacity of keeping the bits sharp and true, acting as firemen or enginemen, and generally assisting the driller.

An organization chart showing the training time necessary for the various jobs in the drilling activity is shown on the page which follows.

MINIMUM MANPOWER CLASSIFICATIONS AND TRAINING TIMES NECESSARY FOR DRILLING OPERATIONS



PRODUCTION

When a well has been drilled to the oil or gas producing formations, completion and operation of the well becomes the responsibility of the production division. A technical team consisting of the superintendent, production foreman, petroleum and reservoir engineer, studies the problem. Data on the formation's thickness, porosity, permeability, and extent are analyzed to determine the best method of completion. This team with its knowledge and experience may decide on the open hole method, or they may decide upon selective perforating, formation fracturing, acidizing, glycering shooting, or a combination of these. The petroleum and reservoir engineers are especially vital at this state and also throughout the production life of the well and the entire oil field. Their determinations affect the ultimate recovery of oil or gas from the formation. Should improper methods be used to any extent the productive capacity and ultimate recovery of reserves may suffer.

In addition to the actual completion of the well in the producing formation, there is also the surface completion, which includes the installation of the "Christmas Tree", the making of various pipe connections with tanks, gas lines, gas separators and the setting and connecting of the pumping unit or other artificial lifting devices as needed. These duties are also the responsibility of the production technical group. Once the well has been completed and the connections made to the receiving equipment, the lease foremen and pumpers take over its actual operation. The pumper produces the amount of oil permitted under state allowables, and delivers the crude oil to the pipeline. This requires him to be familiar with gauging methods, temperature and gravity readings, and allowances to be made for Basic Sediment and Water. He is also responsible for keeping the lease clean and the removal of fire hazards. Comparable operations are also performed for gas wells. Roustabouts are used to perform the general work about the wells such as maintaining connections, making minor repairs and changing installations as they may be needed. These

roustabouts function under the general direction of the lease foreman.

In case of serious trouble the well service superintendent takes charge. Trouble which develops on the surface with pumps, connections or other equipment is handled by roving mechanics who also take care of preventive maintenance. Trouble which develops with the well itself is handled by a well servicing group.

When an area has been produced until secondary recovery methods are needed, the same manpower as discussed above performs the work. The technical people plan the new servicing wells needed according to the pattern of development for the operation. Recycling projects and pressure maintenance are also the responsibility of these same technical people.

With the trend to deeper wells the problems of production multiply and the need for increased technical knowledge increases far more rapidly than the proportional increase in well depth.

No determination was made in this study of the manpower requirements for production research. A large part of this activity has been carried on by the technical people who have other responsibilities. However, this work is becoming increasingly important, both in the laboratory and in the fields, and more and more people will be required in this activity as time goes on.

It goes without saying, therefore, that the production function must be performed adequately, and the substitution of inexperienced personnel, particularly in the technical groups, or a reduction in total manpower will have an immediate effect and possibly a permanent effect on the amount of oil produced.

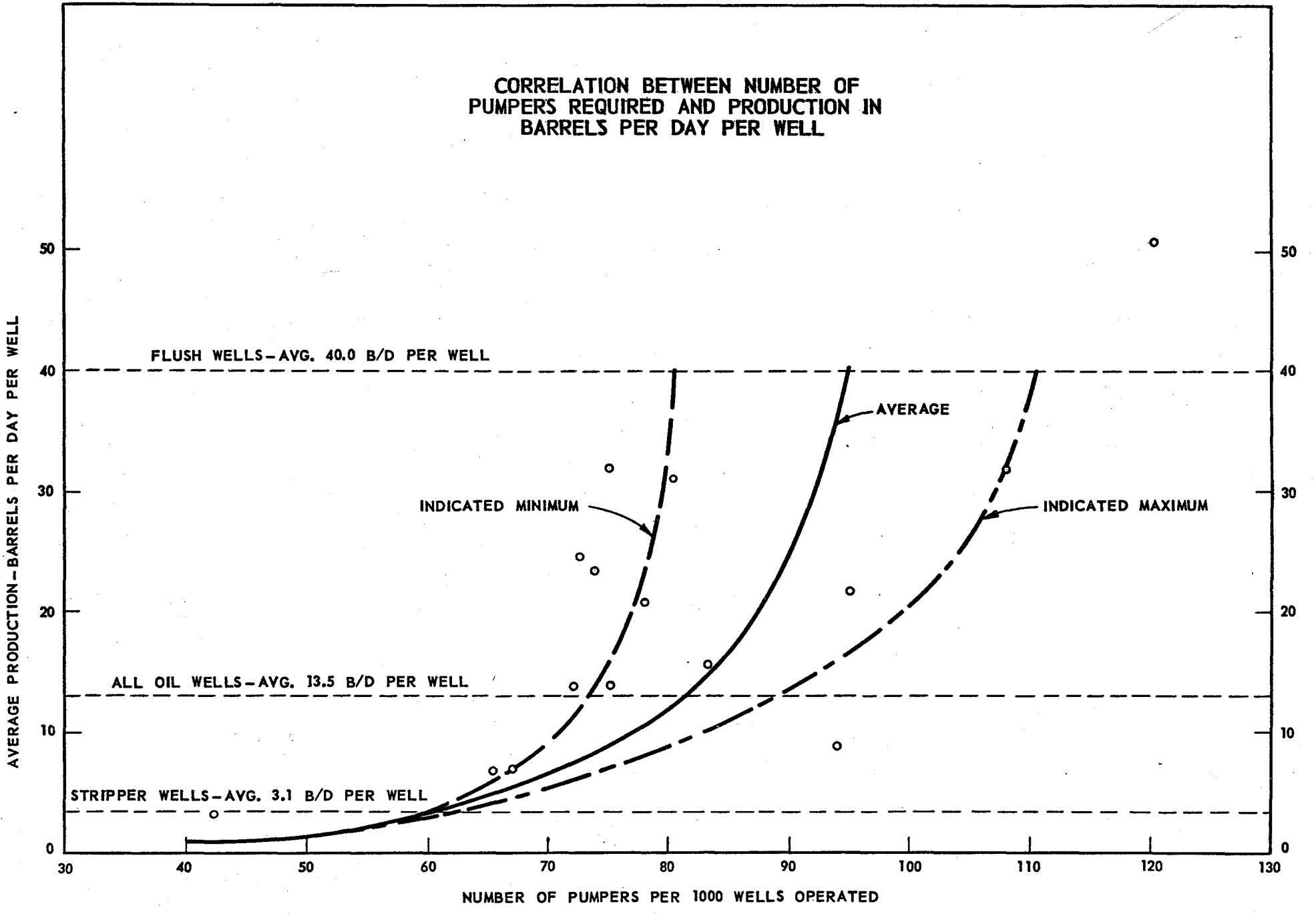
The following table summarizes the estimated manpower requirements for the production activities:

Production of Oil and Associated Gas	1952	1952 plus 10%
Pumpers	33,000	
Roustabouts	36,000	
Supervisory & Technical	27,000	
Supervisory & Technical (Develop.)	3,000	
Clerical & Administrative	20,000	
Legal, Tax, Accounting, Purchasing	20,000	
Related Services (Cementing, etc.)	13,000	
Supply Services	13,000	
Total Production - Oil	165,000	172,000
Production, Gathering and Maintenance of Natural Gas	9,000	10,000

The manpower requirements of the oil production phase of the industry were determined from an analysis of a spot survey of a number of company operations. This analysis showed that the total estimated number of oil field employees for production could be based on the number of pumpers, as shown from the curves on the following page. The curves indicate the number of pumpers required for each thousand wells at various rates of daily production.

Production manpower figures were based on 463,637 producing oil wells in 1952, reported by the "Oil and Gas Journal". These figures were used instead of "World Oil" figures because the "Oil and Gas Journal" adjusted downward the total producing wells for the input wells in secondary recovery operations.

Stripper wells were studied first, and the National Stripper Well Survey for 1952 shows 332,058 such wells. These wells averaged 3.1 barrels per day. From the curve, 60 pumpers per thousand wells, or approximately 20,000 men would be required for strippers. The remaining 131,579 wells average 40 barrels per day and require 95 pumpers per thousand wells, or approximately 13,000, making a total of 33,000 pumpers. The survey further shows a ratio of 1.1 roustabouts per pumper, for a total of approximately 36,000. This figure also includes contract oil servicing and maintenance crews. Supervisory and technical personnel are divided into two groups. It was found there were 58 such personnel directly connected to


CORRELATION BETWEEN NUMBER OF PUMPERS REQUIRED AND PRODUCTION IN BARRELS PER DAY PER WELL
FLUSH WELLS – AVG. 40.0 B/D PER WELL
ALL OIL WELLS – AVG. 13.5 B/D PER WELL
STRIPPER WELLS – AVG. 3.1 B/D PER WELL
AVERAGE
INDICATED MINIMUM
INDICATED MAXIMUM
AVERAGE PRODUCTION – BARRELS PER DAY PER WELL
NUMBER OF PUMPERS PER 1000 WELLS OPERATED
0
10
20
30
40
50
30
40
50
60
70
80
90
100
110
120
130

producing operations per thousand producing wells, for a total of approximately 27,000. There were also 0.93 supervisory and technical men whose duties were directly related to developmental drilling operations per thousand wells drilled (45,885-10,571 wildcats = 35,314), for a total of about 3,300.

Field clerical and main office service groups such as legal, tax, purchasing, and accounting, as surveyed, are related to the 30,000 supervisory and technical personnel in the ratio of 1-1/3 to 1, making a total of approximately 40,000, which is divided about equally between field clerical and main office.

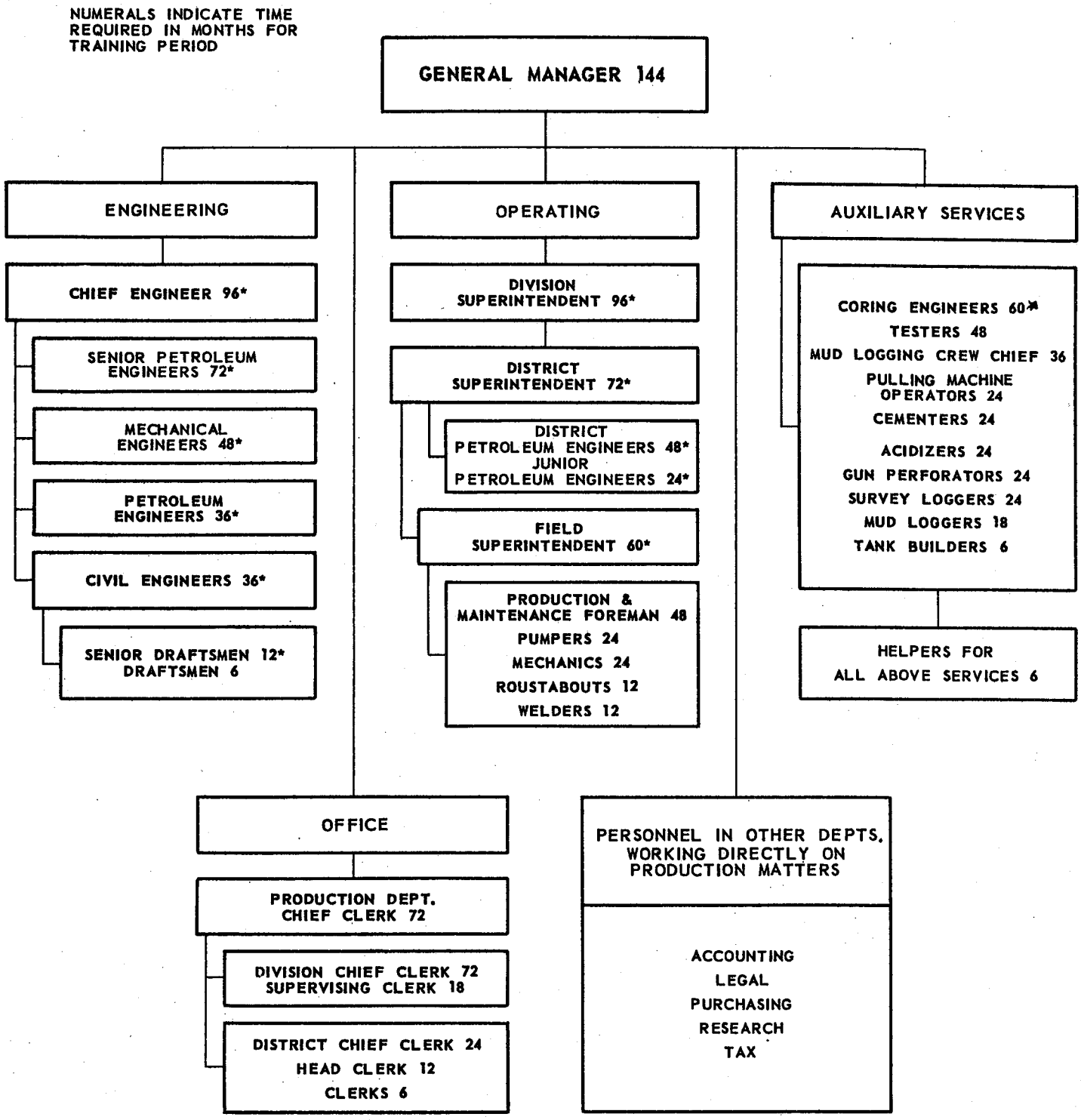
Manpower requirements for natural gas production, gathering and maintenance of gas producing facilities were estimated to be approximately 9,175 in 1952. Gas must be gathered when produced and this was considered part of the function of production in the study. Manpower requirements were based on approximately 66,000 producing gas wells in the United States at the close of 1952. A 10% increase in the 1952 rate of operations would require approximately 825 additional employees, or a total of 10,000 concerned with natural gas production and gathering.

Manpower requirements for the related oil and gas production services, such as cementing, perforating, electric logging, hydrafracing, directional survey, and others as determined by the same spot survey mentioned above, totaled 13,000. Requirements for this group will vary in almost direct proportion to drilling activity, as will work-over well repair personnel. Supply company requirements are based on a survey which shows 1,000 field stores using 13 employees per store for a total of 13,000.

A 10% increase in drilling activity would add an estimated 2,676 new producing wells, or 0.58% of 463,637. This factor was applied to pumpers, roustabouts, production technical and supervisory people, and supply services. Related services would increase 10%, as would developmental supervisory and technical personnel. Clerical and administrative, legal, etc. would increase at a ratio of 1.33 to supervisory and technical.

The training times for production personnel are shown on the organization chart on the following page. When used in the future this chart should serve as a guide only, due to many variations in titles among the oil companies, as well as due to changing conditions brought about by the development of new methods and operations in new areas.

MINIMUM MANPOWER CLASSIFICATIONS AND TRAINING TIMES NECESSARY FOR PRODUCTION OPERATIONS



* IN ADDITION TO ENGINEERING DEGREE

APPENDIX

TABLE I

LIST OF MAJOR ITEMS OF EQUIPMENT AND MATERIALS
USED IN PETROLEUM EXPLORATION, DRILLING, & PRODUCTION OPERATIONS

Item	Material Passing Direct to Operator (PAD acted as Claimant Agcy.)	Material Passing Thru Manufacturers of: Oil Field Mach. & Equipment	Material Passing Thru Manufacturers of: General Indust. Equipment	Material Used In: Explor-ation	Material Used In: Dril-ling	Material Used In: Produc-tion
ACID-Cresylic		X			X	X
ACID-Hydrochloric			X	X	X	X
ACID-Phosphoric			X	X	X	
ADHESIVES			X	X	X	X
AIRPLANES & PARTS			X	X	X	X
ALIDADES			X	X		
ANTI-FREEZE COMPOUND			X	X	X	X
AUTOMOBILES & PARTS			X	X	X	X
BABBITT			X	X	X	X
BALLS & SEATS		X				X
BARIUM SULFATE		X			X	X
BATTERIES-Dry Cell			X	X	X	X
"B"			X	X	X	X
"C"			X	X	X	X
Storage			X	X	X	X
Auto			X	X	X	X
BEARINGS-Anti-friction			X	X	X	X
-Sleeve			X	X	X	X
BELTING-Transmission			X			X
BELTS- V-Type			X	X	X	X
BENTONITE		X			X	X
BITS-Core drilling		X		X	X	
Diamond core			X	X	X	
Fishtail		X		X	X	X
Rock (roller)		X		X	X	X
Rockcutter blades		X		X	X	X
All Other bits		X		X	X	X
BLASTING CAPS, etc.			X	X		X
BLOCKS-Tubing		X				X
BOATS-Offshore operations			X	X	X	X
BODIES-Truck (special)			X	X	X	X
BOILERS-Oil field			X		X	
BOLTS-Alloy steel		X			X	X
BOMBS-Pressure test		X				X
BOXES-Stuffing		X				X
BRASS & BRONZE						
Bushings, castings,						
rod, tubing			X	X	X	X
valves & fittings			X	X	X	X
BUILDINGS-Section steel			X	X	X	X
BULBS-Electric light			X	X	X	X

Table I(Cont'd)

Item	Direct to Operator (PAD acted as Claimant Agcy.)	Oil Field Mach. & Equipment	General Indust. Equip.	Material Used In: Explor- ation	Dril- ling	Produc- tion
CABLE-Electric			X	X	X	X
CAPACITORS			X			X
CARBIDE			X		X	X
CASING-Oil & Gas Well	X				X	X
Shot hole-Steel Sheet		X	X	X	X	X
CEMENT	X			X	X	X
CENTRALIZERS-Casing & Tubing		X			X	X
CHAIN-Forged steel			X	X	X	X
Roller			X	X	X	X
CHEMICALS-Emulsion treating			X			X
-Photographic						
Hypo			X	X	X	X
Developer			X	X	X	X
Drilling Mud (X-37)			X	X	X	X
CHOKES-Adjustable & Positive		X				X
Bottom hole		X				X
CLAMPS-Casing		X			X	X
Collar leak		X			X	X
Parallel tubing		X				X
Polished rod		X				X
Wire line			X	X	X	X
CLUTCHES & PARTS-Air & conventional			X	X	X	X
COLLARS-Cementing		X			X	X
Drill		X			X	
COMPONENTS-Miscl.						
Elect. & Electronic			X	X	X	X
COMPOUNDS & CHEMICALS						
Water treatment			X	X	X	X
COMPRESSORS-Air & Gas			X	X	X	X
CONTROLS-Elect. motor			X		X	X
Engine safety			X		X	X
Hydraulic			X		X	X
CONVERTERS-Torque			X		X	X
COOLERS-Engine			X		X	X
COPPER ALLOYS			X	X	X	X
CORDAGE-Manila, Sisal & Jute			X	X	X	X
COUPLINGS-Casing,Tubing & P.L.		X		X	X	X
Flexible			X	X	X	X
Hydraulic			X		X	X
Sucker rod		X				X
CUPS-Pump piston			X	X	X	X
Valve & seating		X				X
DERRICKS-Steel		X			X	X
DIAMONDS-Industrial			X	X	X	
DIES-Tongs			X	X	X	X
DOZERS			X		X	X
DRILLS-Twist			X	X	X	X
DYNAMITE-(High Velocity)			X	X		X
DYNAMOMETERS-Polished rods & Pull rod		X				X

Table I Cont'd

Item	Direct to Operator (PAD acted as Claimant Agcy.)	Oil Field Mach. & Equipment	General Indust. Equip.	Material Used In: Explor-ation	Dril-ling	Produc-tion
ELECTRODES-Welding			X	X	X	X
ELEVATORS-Casing,Tubing & Sucker rod		X			X	X
ENGINES-Air cooler			X	X	X	X
Gas,Gaso,Diesel & Parts			X	X	X	X
EQUIPMENT-Construction			X	X	X	X
EXCHANGES-Heat			X		X	X
EXTINGUISHERS & PROTECTION EQUIP.-Fire			X	X	X	X
FANS-Electric			X		X	X
FEEDERS-Chemical		X	X		X	X
FENCE-Steel wire			X			X
FILTERS-Air(for compressors & engines)			X		X	X
Oil			X	X	X	X
Water			X		X	X
FIRST AID EQUIPMENT			X	X	X	X
FITTINGS-Cast iron, Steel, Malleable			X	X	X	X
FLAGGING (Paper or Cloth)			X	X		
FLASHLIGHTS			X	X	X	X
FLOODLIGHTS			X	X	X	X
FORMALDEHYDE			X			X
FORMICASHEET (Fiber)			X	X	X	X
FUSES-Electric switch			X	X	X	X
GASKETS-Cork, Leather, Metallic, Ring, Rubber, Sheet			X	X	X	X
GAUGES-Liquid level, Pressure, Vacuum, Temperature			X		X	X
GENERATORS-Electric			X	X	X	X
Steam			X		X	X
GRADERS-Road			X		X	X
HATS-Protective			X	X	X	X
HEADS-Casing & Tubing		X				X
HOISTS-Chain			X	X	X	X
HOOKS-Chain			X	X	X	X
HOOKS-Rod & Tubing		X				X
HOSE-Air, Steam, Water, Oil Gasoline, Fire			X	X	X	X
INHIBITORS-Corrosion			X		X	X
Paraffin			X			X
INJECTORS-Chemical			X		X	X
INSTRUMENTS-Well logging, Surveying, Radio-activity log, Electric log, Temperature log, Caliper Survey, Well inclination, Fluid level indicator		X			X	X
INSULATION-Electric cable			X	X	X	X

Table I (Cont'd)

Item	Direct to Operator (PAD acted as Claimant Agcy.)	Oil Field Mach. & Equipment	General Indust. Equip.	Material Used In: Explor- ation	Dril- ling	Produc- tion
JACKS - Pumping		X				X
JOINTS- Tool		X		X	X	X
KNOCK-OUTS - Water		X				X
LABORATORY EQUIPMENT			X	X	X	X
LIFTS-Gas		X				X
LINING-Brake (Fiber)			X	X	X	X
LUBRICATION-Force Feed			X		X	X
MAGNETOS			X	X	X	X
MASTS-Drilling		X			X	X
MANIFOLDS-Well Control		X			X	X
MATERIALS-Hard Surfacing			X	X	X	X
METALS-Hard Surfacing		X			X	X
METERS-Electric			X		X	X
METERS-Flow (gas, oil, water)			X		X	X
MOTORS-Electric			X		X	X
MUD-Drilling		X		X	X	X
NAILS			X	X	X	X
NIPPLES-Casing & Tubing		X			X	X
NIPPLES-Swaged		X			X	X
OIL-Lubricating			X	X	X	X
Lubricating Additives			X	X	X	X
O-Rings - Rubber			X	X	X	X
OVERSHOTS		X			X	X
OXIDIZING AGENT (Ammonium Nitrate base: Nitramon or Vibronite)			X	X		
OXYGEN			X	X	X	X
PACKERS-Anchor, Control, Formation squeeze, Formation testing, etc.		X			X	X
PACKING-Fiber Composition, Metallic, Plastic, Rubber			X	X	X	X
PAINT			X	X	X	X
PAPER-Photographic			X	X	X	X
PARTS-Truck repair			X	X	X	X
PERFORATORS-Casing & Tubing, Gun & Jet		X			X	X
PIPE-Drill	X			X	X	X
Line	X			X	X	X
PISTONS-Pump		X	X	X	X	X
PISTONS & VALVES-Slush pump (rubber inserts)		X	X	X	X	X
PLANTS-Elect. lighting			X	X	X	X
POWER-Pumping, Geared & Bandwheel		X				X
PREVENTERS-Blowout		X			X	X
PRIMA-Cord			X	X		X
PRIMMERS or BOOSTERS			X	X		
PROTECTORS-Casing & Tubing Thread		X			X	X
PUMPS-Rotary, Centrifugal & Reciprocating		X	X	X	X	X
Tubing & Rod insert		X				X

Table I (Cont'd)

Item	Direct to Operator (PAD acted as Claimant Agcy.)	Oil Field Mach. & Equipment	General Indust. Equip.	Material Used In: Explor- ation	Dril- ling	Produc- tion
QUEBRACHO			X		X	X
RADIO EQUIPMENT & PARTS			X	X	X	X
RECORDERS - Level, Pressure, Vacuum, Temperature, etc.			X		X	X
REDUCERS - Geared			X	X	X	X
REGULATORS - Liquid, Pressure, Temperature, Voltage, etc.			X		X	X
RIGS - Drilling (complete)		X			X	
RINGS- Pistons			X	X	X	X
RODS- Pistons & Pump		X	X	X	X	X
Polished		X				X
Sucker & Pull		X				X
ROOFING-Asphalt, Asbestos & Galvanized Sheet			X		X	X
ROPE - Wire			X	X	X	X
RUBBER - Natural & Synthetic			X	X	X	X
RUBBERS - Stuffing box		X			X	X
Swab		X			X	X
SEALS - Mechanical shaft, Oil & Grease			X	X	X	X
SEPARATORS - Gas, Oil & Water		X				X
SHEAVES - Rope & V-belt			X	X	X	X
SHOES - Casing Cementing		X			X	X
SLIPS - Tubing		X			X	X
SODA - Caustic			X	X	X	X
SODIUM & POTASSIUM CHROMATE			X	X	X	X
SOLDER			X	X	X	X
SPARK PLUGS			X	X	X	X
SPIDERS - Casing & Tubing		X			X	X
SPRAYERS - Paint & Chemical			X	X	X	X
SPRINGS - Tong, Pull back			X		X	X
Pump valve		X	X	X	X	X
SPROCKET -Chain			X	X	X	X
STAIRWAYS - Steel		X	X		X	X
STOCKS & DIES			X	X	X	X
SURVEYING EQUIPMENT			X	X	X	X
SWABS		X			X	X
SWITCHGEAR - Electrical			X	X	X	X
TACHOMETERS			X		X	X
TANKS - Steel		X	X		X	X
TANNIN & TANNIC ACID			X		X	X
TAPE - Friction & Rubber			X	X	X	X
TAPE - Measuring, steel			X	X	X	X
TAPS & DIES - Threading			X	X	X	X
THERMOMETERS			X	X	X	X
THERMOSTATS			X		X	X
TIGHTENERS - Belt & Chain		X	X		X	X
TIN			X	X	X	X
TIRES & TUBES			X	X	X	X
TONGS - Casing & Tubing		X			X	X
TOOLS - Blacksmith & Hand			X	X	X	X

Table I (Cont'd)

Item	Direct to Operator (PAD acted as Claimant Agcy.)	Oil Field Mach. & Equipment	General Indust. Equip.	Material Used in: Explor- ation	Dril- ling	Produc- tion
TOOLS - Machine			X	X	X	X
TOWERS - Radio			X	X	X	X
TRACTORS			X		X	X
TRAILERS - Truck & Auto			X	X	X	X
TRANSFORMERS - Electric			X		X	X
TREATERS - Crude Oil Emulsion		X				X
TRUCKS			X	X	X	X
TUBES - Vacuum			X	X	X	X
TUBULAR GOODS	X	X		X	X	X
TYPEWRITERS & OFFICE MACHINES			X	X	X	X
UNITS - Oil Well pumping		X				X
UNITS - Oil Well servicing		X			X	X
VALVES			X	X	X	X
WAGONS - Crawler Type			X	X	X	X
WALKWAYS - Steel		X	X		X	X
WASHERS (Fiber)			X	X	X	X
WEIGHT INDICATORS		X			X	X
WELDERS - Electric			X	X	X	X
WELDING CABLES & SUPPLIES			X	X	X	X
WINCHES, WINDLASSES, & CAPSTANS			X	X	X	X
WINCHES - Hand & Power			X		X	X
WIPERS - Rubber (for casing, tubing, & sucker rods)		X			X	X
WIRE - Aluminum, copper, & steel			X	X	X	X
WIRE - Cap (attached to caps)			X	X		X
- Insulated (for recording cables)			X	X		
WRENCHES			X	X	X	X

TABLE II-A

MATERIALS REQUIREMENTS FOR SEISMIC OPERATIONS

Annual Maintenance, Repair & Operating Supplies Required
To Operate 651 Seismic Field Parties (Based on 1952 Operations)

Flagging (paper or cloth)	72,240	rolls (14,448,000')
Alidade	32	
Blasting Caps, electric	27,000,000	
Cap Wire (attached to caps)	260,400,000'	(2-conductor)
Primers or Boosters	23,345,030	
Dynamite (high-velocity)	26,040	T
Oxidizing Agent (Amonium-Nitrate base: Nitramon or Vibronite)	25,000	T
Prima-Cord	976,500'	
Blasters	32	
Photographic Paper	238,380	rolls (47,676,000'; 4" to 12" width)
Photographic Chemicals:		
Hypo	252,090	cans) 5 qts. of solution per can
Developer	252,090	cans)
Vacuum Tubes	58,590	
Insulated Wire (for recording cables)	35,805,000'	(single-conductor, 20 to 24 ga.)
Batteries: "B"	16,275	
"C"	29,295	
6-v. auto	61,621	
Misc. Electrical & Electronic Components	$ 846,300	(resistors, transformers, etc.)
Drilling Mud	125,180	sacks (6,259 T)
Drilling Mud Chemicals (X-37)	34,140	qts..
Steel Wire Rope	180,600'	
Fuel, Diesel & Gasoline	51,260,000	gals.
Oil, Lubricating	511,990	gals.
Casing, Shot Hole (steel sheet)	11,702,400'	(11,703 T)
Tubular Goods (2-5/8" drill pipe)	68,280'	(205 T)
Tool Joints	13,656	(48 T)
Bits: Rock (roller)	25,036	)
Fishtail	12,518	) Total 295 Tons
Rockcutter Blades	25,036	sets)

TABLE II-B

MATERIALS REQUIREMENTS FOR SEISMIC OPERATIONS (Cont.)

Automotive Equipment Required For Operation of 651 Seismic Field Parties (Based on 1952 Operations)

Vehicle	Total	Annual Replacements (4-Yr. Life)
Truck, 2½ T., 4-wheel drive	1,248	312
Truck, 2½ T., 2-wheel drive	1,248	312
Truck, 1½ T., 4-wheel drive	506	127
Truck, 1½ T., 2-wheel drive	506	127
Pickup, ½ or 3/4 T., 2-wheel drive	678	178
Pickup, ½ or 3/4 T., 4-wheel drive	126	32
Carryall, 1 T., 2-wheel drive	651	163
Sedan	868	217

Annual Parts Required For Automotive Equipment	
Engine, complete	2,937
Crankshaft	2,857
Axle	6,831
Differential	2,857
Transmission or Transfer Case	3,424
Tires, Truck	32,844
Tires, Car, Pickup, Carryall	6,338
Power Takeoff	2,276
Other Misc. Parts	$2,030,000

TABLE II-C

Basic Materials & Components for Construction of 651 Sets of Seismic Field Equipment, (Based on 1952 operations)

	Total	Annual Replacements (5-Yr. Life)
Carbon Steel:		
Sheet	1,400 T.	280 T.
Plate	573 T.	115 T.
Structural	407 T.	81 T.
Tubular	464 T.	93 T.
Bar	138 T.	28 T.
Stainless Steel, nickel-bearing	114 T.	23 T.
Aluminum (alloys)	138 T.	28 T.
Copper (wire)	46 T.	9.2 T.
Nickel-Iron Magnet Steel	32,550 lbs.	6,510 lbs.
Nickel-Iron Transformer Sheets	19,530 lbs.	3,906 lbs.
Plastic Insulating Materials	65,100 lbs.	13,020 lbs.
Tin-Lead Alloys (solder)	13,020 lbs.	2,504 lbs.
Beryllium-Copper alloy	3,255 lbs.	651 lbs.
Brass (Misc. screws & fittings)	13,020 lbs.	2,504 lbs.
Optical Components (lenses, mirrors, etc.; 19,530 units)	$97,650	$19,530
Electronic & Electrical Components (vacuum tubes, transformers, etc., 2,864,400 units)	$1,953,000	$390,600
Two-Way Radio Communication Equipment (1,302 sets)	$ 651,000	$130,200
Winches, Power, bumper	3,750	375 (10 Yr. Life)

TABLE II-D

MATERIALS REQUIREMENTS FOR SEISMIC OPERATIONS (Contd)

Rotary Shot Hole Drills, Complete, Required for Operation of 651 Seismic Field Parties (Based on 1952 Operations)

	Total	Annual Replacement (5-Yr. Life)
Truck-Mounted, heavy	829	166
Truck-Mounted, light	277	56
Portable, heavy	66	13
Portable, light	66	13

Basic Materials Required for Production of Above-Listed Rotary Shot Hole Drills

	Total	Annual Replacement (5-Yr. Life)
Portable, heavy:		
Carbon Steel, structural	28,600 lb.	5,720 lb.
Carbon Steel, tubular	105,105 lb.	21,021 lb.
Misc. Alloy Steels	21,450 lb.	4,290 lb.
10-HP Engine, stationary, gasoline	66	66 (1 Yr. Life)
Portable, light:		
Aluminum (alloys)	78,650 lb.	15,730 lb.
Misc. Alloy Steels	14,300 lb.	2,860 lb.
10-HP engine, stationary, gasoline	66	66 (1 Yr. Life)
Truck-Mounted, Heavy:		
Alloy Steels:		
Castings	129.5 T.	25.9 T.
Bar	358.5 T.	71.7 T.
Carbon Steel:		
Castings	1,301.5 T.	260.3 T.
Bar Stock	236.5 T.	47.3 T.
Tubular	431.5 T.	86.3 T.
Structural	398.5 T.	79.7 T.
Plate	167.0 T.	33.4 T.
Sheet	228.5 T.	45.7 T.
Sprockets & Chain	135.5 T.	27.1 T.
Bearings	65.0 T.	13.0 T.
Clutches	170.0 T.	34.0 T.
Wire Rope	25.0 T.	5.0 T.
Pump		
Reciprocating (746)	869.5 T.	173.9 T.
Centrifugal (83)	19.0 T.	3.8 T.
Air Compressor (83)	100.0 T.	20.0 T.
Truck-Mounted, Light:		
Alloy Steels:		
Castings	14.0 T.	2.8 T.
Bar Stock	21.5 T.	4.3 T.
Carbon Steel:		
Castings	48.5 T.	9.7 T.
Bar Stock	21.0 T.	4.2 T.
Tubular	46.5 T.	9.3 T.
Structural	39.0 T.	7.8 T.
Plate	28.0 T.	5.6 T.

TABLE II-D (Contd)

MATERIALS REQUIREMENTS FOR SEISMIC OPERATIONS (Contd)

Basic Materials Required for Production of Rotary Shot Hole Drills (Contd).

Sprockets & Chain	10.5 T.	2.1 T.
Bearings	6.5 T.	1.3 T.
Clutches	7.5 T.	1.5 T.
Wire Rope	3.5 T.	0.7 T.
Misc. Parts (bolts, nuts, etc.)	35.0 T.	7.0 T.
Pump:		
Reciprocating (249)	184.0 T.	36.8 T.
Centrifugal (28)	4.5 T.	0.9 T.

Annual Parts Requirements for Rotary Shot Hole Drills

Chain, various types & sizes	25,400'
Flex couplers, various types & sizes	1,270
Clutches, various types & sizes	2,540
Sprockets, various types & sizes	3,175
Bearings, various types & sizes	12,700
Transmissions, various types & sizes	953
Misc. other parts	$ 158,750

Annual Parts Requirements for Mud Pumps Mounted on Drills

Reciprocating Pumps	
Liners & Glands	8,144 sets
Pistons	9,162
Piston Rods	10,180
Valves & Seats	18,833
Inserts	28,504
Bull Gear & Pinion Shaft	127
Misc. Other Parts	$ 101,800
Centrifugal Pumps	
Impellers	504
Wear Plates	252
Back Casings	126
Shafts	252
Shaft Packings	2,520
Misc. Other Parts	$ 37,800

TABLE III

MATERIALS REQUIREMENTS FOR GRAVITYMETER OPERATIONS

Annual Maintenance, Repair & Operating Supplies
Required for 96 Gravity Field Parties(Based on 1952 operations)

Transit	5
Flagging, paper or cloth	4,400 rolls (880,000 ft.)
Batteries, 6v., auto	576
Gravity Meter Parts	$ 4,800
Fuel, Diesel & Gasoline	3,790,000 gals.
Lubricating Oil	43,180 gals.
Steel Wire Rope	8,800 ft.

Special Materials to Equip Gravity Crews

	Total	Annual Replacements
Gravity Meter	96	None (Life indefinite)
Transit	220	22 (10 yr. life)
Aluminum Tubing (tripods)	3,400 lbs.	1,134 lbs. (3 yr. life)
Winches, bumper	156	16 (10 yr. life)

Vehicles for Gravity Crews

	Total	Annual Replacements
Pickup, ½ T., 2-wheel drive	44	11
Pickup, ½ T., 4-wheel drive	44	11
Jeep or ½ T., 4-w.d. pickup	176	44
Sedan	115	29
Carryall, 1 T.	20	5

Annual Parts for Automotive Vehicles (Gravity Crews)

Engine, complete	246
Crankshaft	164
Axle	328
Differential	164
Transmission or Transfer Case	164
Tires	1,188
Misc. Other Parts	$123,000