OIL IS AMMUNITION!

By HALLAN N. MARSH

NOTHING is more vital to winning the war than an adequate supply of petroleum products for all essential purposes. Airplanes, battleships, tanks, submarines, trucks, and cargo vessels might as well be destroyed by the enemy as to be unsupplied with fuel and lubricants. A General of the United States Army declares that oil is the number one military necessity. Two-thirds of the tonnage required to support an expeditionary force is oil! It requires 1,600 gallons of gasoline to fly one heavy bomber from England to Berlin and back. Thousand-plane raids . . . ? And the block busters they drop when they get there, bust the block because they are filled with TNT, made from petroleum! Literally, *oil is ammunition!*

Airplanes and ships and tanks and TNT couldn't be made if workers couldn't get to work. Most of us realize how dependent upon the automobile we are for getting to work. We have found that resort to other forms of transportation isn't a solution, if too many try to do the same thing. Maybe we have overlooked the fact that all of the alternative forms of transportation also depend upon petroleum for lubrication, and most of them for power. Trains, busses, steamers and airliners are powered with petroleum, and even the electricity that moves the streetcars is generated in part by petroleum. Many defense plants are solely dependent upon trucks to bring in material and deliver products.

RATIONING

Gasoline and fuel oil rationing as first applied in the East was necessitated by diversion to direct military use of tankers that formerly hauled 90 per cent of the East's oil from the Gulf Coast. Nation wide rationing was primarily a rubber conservation measure. But if we are to fight an all-out war against Germany now, and conserve a margin with which to defeat Japan next, it appears that gasoline rationing will have to be continued and probably made more stringent, for the sake of saving this vital and irreplaceable natural resource. Why? Let's see how the United States is fixed for liquid ammunition.

Statements and statistics about oil supply seem conflicting and confusing, but the main points are easily grasped. All published figures are estimates, and to some extent a matter of opinion, so there is no use in worrying about minor discrepancies. There are a variety of useful factors that sound similar but which are quite different. Primarily, reserves must be distinguished from the rate at which they can be produced.

RESERVES

Above-ground storage of crude oil in the United States normally amounts to about a quarter billion barrels, which is about a 60-days' supply and may be neglected in long-range considerations.

Underground reserves are commonly estimated at about 20 billion barrels. This term refers to the amount that already has been pretty well located, and which can be recovered by conventional methods of production. It is to be expected that more oil will be discovered from time to time, and that some currently unrecoverable oil will become recoverable as technique improves or prices increase. Thus the 20 billion barrel figure is a minimum.

It should be emphasized that the amount of recoverable reserves depends upon production practice, so that this figure, commonly looked upon as a constant, is really a variable. One of the chief factors affecting the recovery is the rate of production. It appears that high ultimate recovery generally demands low rate of recovery.

Production in the United States for the last three years has been about 1.4 billion barrels per year. Comparing this figure with the reserve figure of 20 billion barrels indicates a 14-years' supply. So, for the duration, why worry?

Productive capacity, or the rate at which reserves can be recovered, has limits independent of the reserves. Each oil well has a "potential" rate at which it can pro-

"Fill 'er up for a trip to Berlin . . . 1,600 gallons!"

Off for Africa (burning 33,000 gallons of oil a day).

duce for a short time. But most wells cannot sustain their potential rate for any length of time. Unfortunately this rate has been measured, optimistically estimated, and quoted, perhaps because it is more tangible than significant.

Recently there has been a growing understanding of the term "reservoir performance." An underground porous reservoir has hydraulic and thermodynamic characteristics that can often be measured with satisfactory engineering accuracy. Oil may be partly displaced from such a reservoir by the expansion of its dissolved gas or of a free gas cap, or by natural water encroachment. The latter is considered most efficient. Low rates of withdrawal tend to permit the gas or water piston to keep up with the oil, thus maintaining pressure. Excessive rates cause fingering of water or gas with consequent by-passing of oil. Hence a study of reservoir performance often establishes a maximum efficient rate for the pool as a whole, which can be prorated back to the individual wells.

Maximum efficient capacity for the United States, according to the Petroleum Industry War Council, will decline from about 1.6 billion barrels in 1943 to 1.5 in 1945, with "minimum essential demands" at 1.5 in 1943 and 1.6 in 1944 and 1945. Thus there will be a small surplus (of capacity, not actual production) this year, and increasing deficits in subsequent war years.

The efficient capacity can be exceeded somewhat for a few months, as an emergency measure, but only at the expense of reduced subsequent capacity and ultimate recovery. Producing at less than the maximum efficient rate tends to build up the productive capacity. Any unnecessary use of petroleum, even at present, subtracts from the reserve and productive capacity for this vital ammunition. In this connection it is significant that stocks of finished gasoline declined over 5 million barrels during a recent month and over 14 million barrels in 12 months.

Even at an efficient rate of production, productive capacity declines naturally. Although the present known reserves are 14 times as great as our annual consumption, it will actually take some 40 years to recover 90 per cent of these reserves. To maintain productive capacity, as well as to maintain a backlog of reserves, it is necessary to keep up the discovery of new reserves.

DISCOVERY

The United States has been aggressive in discovering oil. Since the first oil well was drilled in Pennsylvania in 1859, we have produced nearly twice as much as all the rest of the world combined. This has contributed immeasurably to the prosperity of the country, but it means that there is a lot less oil to be found. Progress in geology and geophysics accelerated discovery during the early thirties, but for the last four years, discoveries have been small. Perhaps this is just a run of bad luck. Perhaps it means that the search has been too successful in the past. Certainly more oil fields will be found, but probably at the expense of more intensive geological work and exploratory drilling.

Published figures are confusing as to whether reserves are being maintained. Estimates of the proven reserves of fields discovered during each year are generally small compared with the year's usage, and in the last four years this ratio has been much smaller than usual. However, the development of a field is rarely completed in the year of discovery, so that extensions and revisions are made in subsequent years.

Adding these revisions, we get figures more nearly resembling those for usage. If these revisions represented only extensions of fields, the situation might not be bad. It is understood, however, that the revisions represent in part more optimistic (and perhaps more realistic) appraisals of fields that are not being extended. This continual reappraisal makes each year's estimate better than preceding ones, but leaves the amount of new discovery questionable. It is the opinion of the Petroleum Administrator for War that "for four years we have been using oil faster than we have been finding new reserves." Many agree with him.

Drilling of exploratory wells is continuing, and new fields are being discovered about as frequently as in the past, but they are smaller. It is easier to find a big field than a small one. Petroleum Administrator Ickes thinks that "the biggest fish have been caught."

Geological work can determine where oil can *not* exist, and where it *may* exist, but only drilling determines where it *is*. It takes an average of eight wildcat wells to locate one new field. New discoveries are therefore the result of intensive effort and great risk of capital. Such wells are ordinarily drilled only with the hope of reward for any success that may be obtained. At the present time oil companies are required to pay more to the government in taxes (gasoline, income, property, and others too numerous to mention) than they can pay in wages, salaries, and dividends combined. However, despite higher taxes, higher labor costs, higher material cost, 50 per cent curtailment of steel allotment, draining of experienced personnel to the armed forces and newer defense industries, and frozen products prices, the industry has been asked to drill 50 per cent more wildcats this year than ever before.

"ENGINEER'S OIL"

It has long been known that with present technique and prices, much oil is left in the ground when wells are economically depleted. The recovery actually ranges from zero, where reservoir rock is found to contain oil but to be of too low permeability to yield it at a commercial rate, to possibly 80 or 90 per cent where oil is fluid and permeability high and the rock is preferentially wet by the displacing water. It is commonly estimated that the average recovery is approximately 30 or 40 per cent. United States recovery to date has been about 27 billion barrels. Adding the 20 billion of recoverable reserves gives 47 billion. If this represents 40 per cent of the total oil discovered, then the discovered oil unrecoverable by present methods is 70 billion barrels! Don Knowlton of the P.A.W. says it is the engineer's job to devise and sell means of recovering as much of this "unrecoverable" oil as possible, and aptly labels it "engineer's oil."

Engineers are alert to this possibility, and much technical progress is being made. Some more tangible progress is being made, but as Mr. Knowlton recognizes, there are legal and political problems, as well as scientific problems.

CALIFORNIA

California is the only oil producing state west of the Rockies. Transportation of oil from other states is not economic at any time, and is not feasible now. Japan has taken the only important sources of oil in the Orient. Therefore California must not only supply the Coast, but must provide the main supply for the United Nations in the Pacific.

California is now producing approximately at its maximum efficient rate of some 780,000 barrels daily, an increase of about 30 per cent over pre-war levels, despite a reduction of some 25 per cent in sale of taxable (civilian) gasoline. Stocks are declining significantly. The increase of industrial and military usage can be inferred. These obligations will undoubtedly increase, and may require further curtailment of unnecessary usage. Certainly no one who understands will complain!

ENEMY POSITION

How are our enemies supplied with liquid ammunition? Of course we have no access to direct and current information, but those whose business it is should be able to make good estimates. Past production has been charted, and there is much indirect evidence on which such charts can be extrapolated. Garfias, Whetzel and Ristori presented an authoritative summary before the A.I.M.E. in New York in February from which the following is extracted:

". . . Japan is now getting at least 33 million barrels a year, which exceeds by 8 million barrels its greatest peacetime yearly consumption. As long as Japan can hold the conquered fields of Dutch East Indies and Burma it will encounter no difficulties as to source of supply. Its greatest problem will be ocean transportation and to some extent refinery equipment.

"The output for 1942 of the European Axis countries and controlled areas is . . . about 112 million barrels or 20 per cent greater than in 1941." (This figure includes synthetic.) ". . . almost 50 per cent of the German supply is now petroleum substitutes.

"Rumanian crude production, which constitutes over 35 per cent of the whole European Axis output, is confined to a small area, definitely known, where continuous bombing could within a short time make effective inroads upon the German oil supply.

"When (German) military operations are passive, small accumulations are possible, but when they are active, shrinkage of reserve stocks could be considerable. . . . Extensive efforts are justified toward the destruction of Axis sources of petroleum supply, wherever they can be found."

Nothing is more vital to a United Nations victory than an adequate supply of oil products for essential

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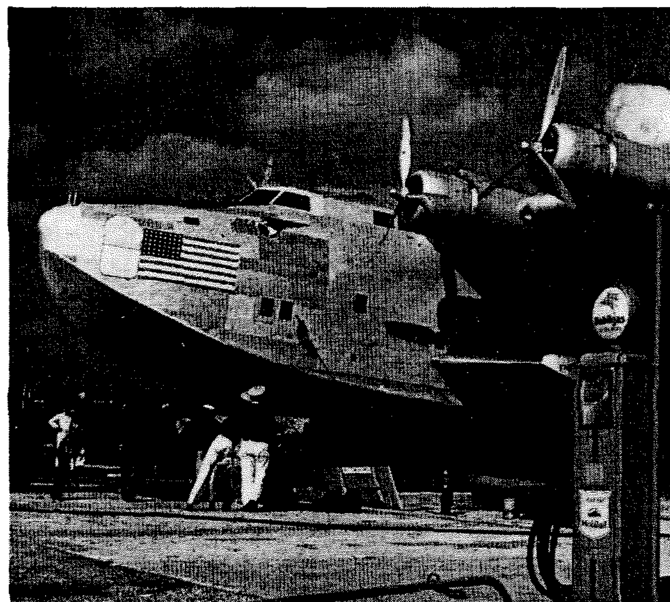
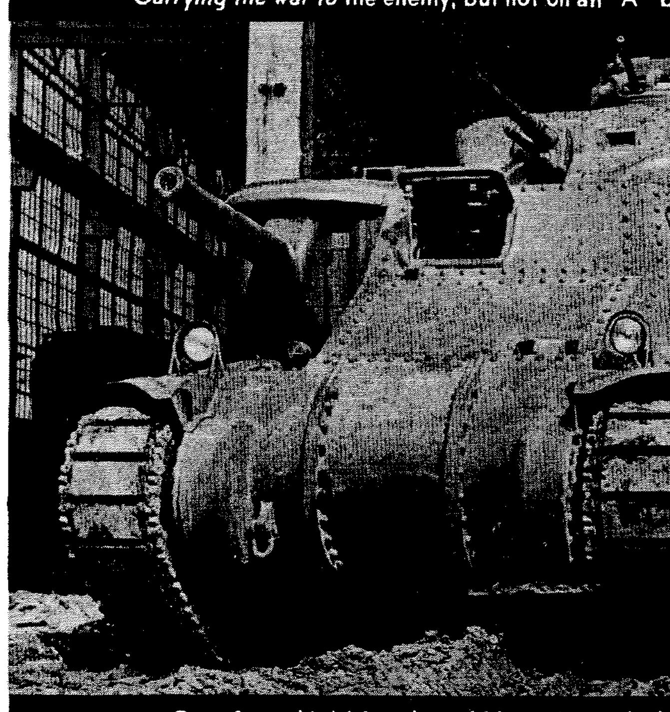


Carrying the war to the enemy, but not on an "A" bo



Out of gas this M-3 tank would be a sitting duck.

MATERIALS TESTING LABORATORY
Begins September 22; 1 evening weekly, 12 weeks.

MATHEMATICAL PROBABILITY, STATISTICS, AND NUMERICAL METHODS FOR WAR WORKERS
Begins forth week in September; meeting place to be arranged; 1 evening weekly, 14 weeks.

METALLOGRAPHY LABORATORY
Begins September 20; 2 evenings weekly, 12 weeks.

MINING METHODS
Begins September 8; 2 evenings weekly, 12 weeks.

PLASTICS, I (Chemistry and Technology)
Begins September 20; 1 evening weekly, 17 weeks.

PLASTICS APPLIED TO AIRCRAFT, I (Chemistry and Technology)
Begins September 21; University High School, 11800 Texas Avenue, West Los Angeles; 1 evening weekly, 17 weeks.

PHYSICAL METALLURGY FOR ENGINEERS
Begins September 21; 2 evenings weekly, 12 weeks.

PRODUCTION DESIGN
Begins September 21; 2 evenings weekly, 12 weeks.

TOOL ENGINEERING—JIGS AND FIXTURES
Begins September 13; 2 evenings weekly, 12 weeks.

Detailed information about any of these courses, together with prerequisites for enrollment, can be secured by writing or telephoning to the WAR TRAINING OFFICE, California Institute of Technology, Pasadena, 4. Students accepted for enrollment are eligible to apply for supplementary gasoline, if this is necessary for class attendance. The Institute will endorse such applications.

MERCHANT MARINE CALLS

The Merchant Marine needs engineering officers to man its growing fleet.

Special concessions have been made in providing a post-graduate course to men holding accredited mechanical and electrical engineering degrees whereby these men may qualify within three or four months to obtain their licenses as Third Assistant Marine Engineers.

Any qualified Caltech alumni may apply for this training by contacting Andrew G. Wilson, Port Representative, Recruitment and Manning Organization, War Shipping Administration, 642 Avalon Boulevard, Wilmington, California.

Oil Is Ammunition!

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purposes. Rationing, originating for other purposes, will probably have to be continued and perhaps made more stringent, to conserve petroleum.

Known recoverable reserves represent 14 years' supply, but productive capacity will be inadequate unless discovery is accelerated. There is hope for the future in improved recovery practice.

California must provide the main supply for the enormous demands of the United Nations in the Pacific. The rest of the United States is a major source for the Atlantic. Japanese and German supplies are small compared to ours, but were greater in 1942 than in 1941.

Axis nations could be greatly handicapped by destruction of part of their oil supply. Our own supply might just as well be destroyed by the enemy as used unwisely.

Oil is ammunition—use it wisely!

THROUGH the far-reaching influence of the California Institute of Technology, Pasadena has taken a place in the world of science which bids fair to spread its fame to all parts of the Universe—not alone in the realm of world conflict but more pleasantly and usefully in the happier achievements of a world at peace.

Engineering and Science Monthly is destined to speak for a great institution to a receptive people, and in so doing the home of that institution—Pasadena—will be further enriched as a center of education and science.

Chamber of Commerce & Civic Association of Pasadena