consisted of a uniform slab 18 to 22 inches thick. The thickness of this slab corresponded to the separations found by the stratascope study in December 1949.

After failure of the roofstone in the test room, the roofstone in the Underground Quarry was reexamined closely. Eight NX-size diamond-drill holes were drilled at selected intervals (see fig. 18). Examination of these holes with the stratascope showed no parting or separation in the Underground Quarry roofstone below the 8-foot level. A high safety factor still exists for the roofstone in the 60-foot spans used in the Underground Quarry.

In addition to seismic and subsidence information obtained from test-room studies, measurements to determine absolute pressures in mine structures have been made. One means of obtaining these measurements is to calculate stress by means of strain relief. The procedure followed is to bond an electric strain gage to a pillar surface and obtain a zero reading with a strain indicator. After a zero reading is made, a section is cored around the strain gage and removed, the resulting change in strain being recorded. These data are then correlated with laboratory data, and the original stress can be calculated.

A method employing the basic principle of sonic velocity change with applied stress also has been investigated. Initial velocity measurements were taken in pillar D-7 in the Underground Quarry in June 1950. These measurements were repeated in July 1951, and a new series was made in pillar D-9. No laboratory data to correlate the change in velocity with changes in stress have been gathered.

Estimated Cost for Commercial Mining

In November 1950, the Oil-Shale Mining Branch made a cost estimate for mining, crushing, and conveying 19,200 tons of oil shale daily to a processing plant, with a daily production of 11,700 barrels of crude shale oil. This proposal, which was summarized in the 1950 Annual Report, was prepared for the Oil-Shale Raw Materials Subgroup of the National Petroleum Council Committee on Synthetic Liquid Fuels. During the past year, certain revisions were made in the proposal through escalating cost items to the January 1, 1951, level.

This revised estimate is a proposal for mining 19,200 tons of oil shale per calendar day from one of a number of possible sites in the Rifle-DeBeque area of Western Colorado. In this area the Mahogany ledge outcrops along a nearly vertical escarpment facing the Colorado River. The site chosen has an area of 1.4 square miles, the Mahogany ledge is 72 feet thick, and the average grade is 30 gallons of shale oil per ton. Within this area roughly 140 million tons of shale can be mined from the Mahogany ledge by underground methods, with allowances made for mining losses. This tonnage will supply a 11,700-barrel-a-day plant for 20 years.

The 72-foot Mahogany ledge, as considered in this estimate, would be mined from two levels dividing it into two minable sections, each assaying 30 gallons of oil per ton of shale. The top level will be 38 feet high and will be advanced horizontally under the roofstone. The roofstone will be supported by 60-foot-square pillars spaced 60 feet apart and staggered in one direction.

The bottom level will be 34 feet high and will closely follow the top-level advance. By using a two-level method, it is possible to supply the processing plant with shale of uniform grade from either or both levels of the mine.

The Bureau, in conforming its estimate to the January 1, 1951, cost data, obtained new quotations on major equipment and revised other costs to reflect prices then existing.

The original Bureau estimate in November 1950 based mine labor rates on those prevailing in the Rifle area at that time. It was realized that these rates would be subject to change. In the revised report, the Bureau used information supplied by the Department of Labor in its Hours and Earnings Industry Report for December 1950. To calculate an average rate, the weekly earnings for all types of mineral production were averaged for December and divided by a 40-hour week to reduce it to an hourly basis. The rate obtained in this manner and used in the revised estimate for all labor classifications except supervisory is $1.81 per hour. A rate of $2.50 per hour was assumed for all hourly basis supervisory employees.

The estimated total cost of mining, crushing, and conveying the shale to the retort stockpile is 47.63 cents a ton. This estimate includes management, depreciation, and taxes but not depletion, interest on investment, profit, or expenditures or off-site facilities.

Tables 3 and 4 show the estimated capital cost of developing the mine and the estimated operating cost.

TABLE 3. - Capital cost for preparing an oil-shale mine to produce, crush, and convey 19,200 tons per calendar day

Item	Amount
Excavations	$ 468,000
Installations	2,132,000
Start-up expense 1/	173,000
Subtotal	$2,773,000
Mining equipment	2,085,000
Warehouse stock 2/	125,000
Subtotal	$4,983,000
Contingencies at 10 percent	498,000
Total	$5,481,000

1/ Start-up expense - normal labor costs for first 90 days with production at half capacity. This amounts to 20 cents per ton additional cost for first 864,000 tons.

2/ Warehouse stock - 90 days operating, maintenance, and repair supplies; 2 weeks explosive supplies; and 30 days research supplies. Warehouse stock is not depreciable.

TABLE 4. - Operating costs for mining, crushing, and conveying 19,200 tons of oil shale per calendar day

	Cost per day	Cost per ton
Labor:		
Underground	$1,555	$0.0810
Maintenance, service, and surface	1,347	.0702
Supervision, engineering, and administration	416	.0217
Labor benefits 1/	593	.0309
Supplies:		
Operating	3,040	.1583
Maintenance and repair	439	.0229
Depreciation:		
Mining equipment	1,034	.0539
Installation, excavation, and development	411	.0214
Contingency at 10 percent of capital investment 2/	143	.0074
Taxes:		
Ad valorem tax on 50 percent of capital investment at $21.51 per $1,000	166	.0086
Total cost	$9,144	$ .4763

1/ Based on 19-percent labor benefits for all employees except supervisory, engineering, and administrative on which a 10-percent rate applies.

2/ Contingency on capital expenditures depreciated at average rate for equipment, installation, excavation, and development.

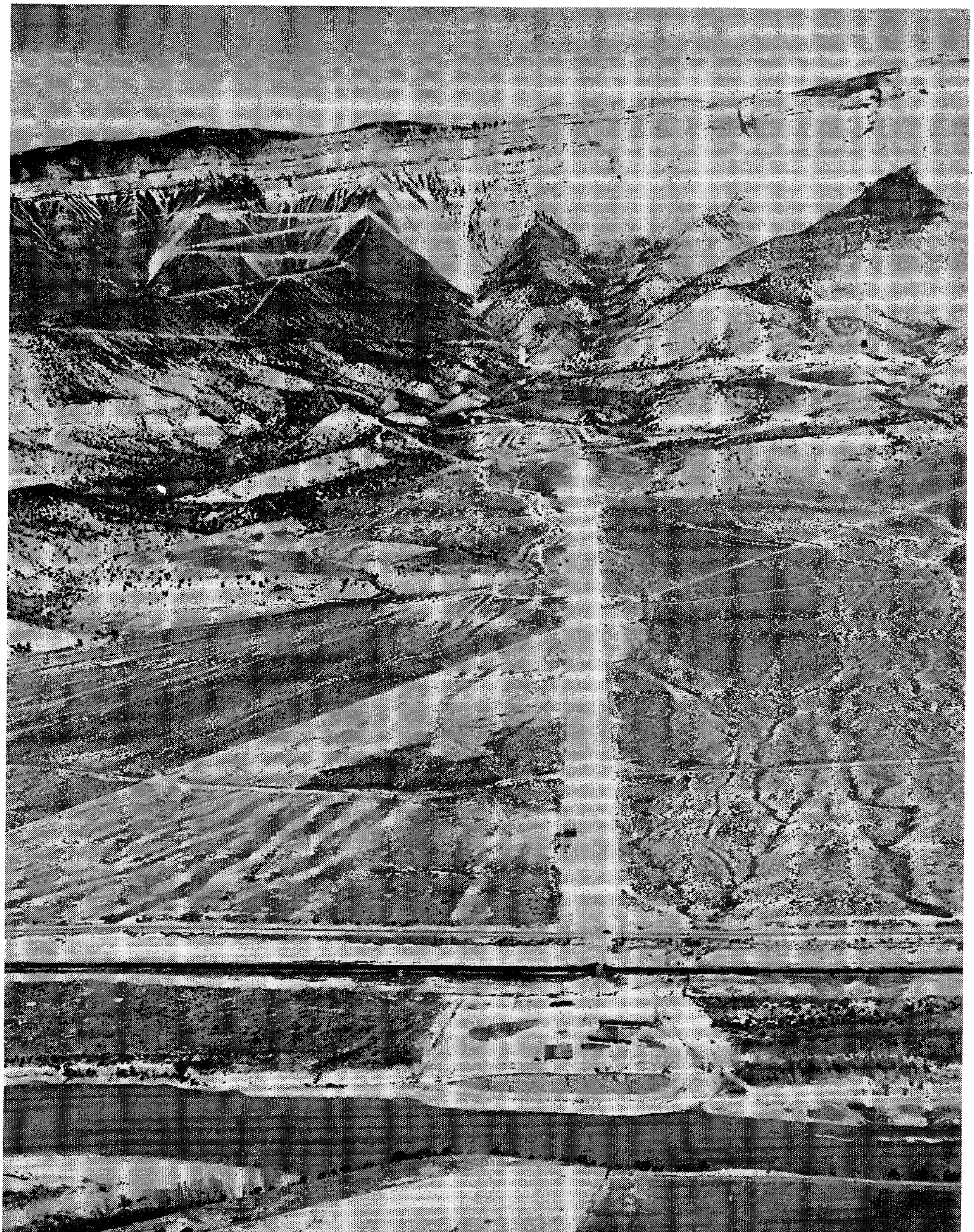

Figure 19. - Oil-Shale Demonstration Plant project.

PROCESSING, OIL-SHALE DEMONSTRATION PLANT, RIFLE, COLO.

The prime responsibility of the Oil-Shale Demonstration Branch is to develop processes and equipment for making liquid fuels from oil shale at costs low enough that the products can be sold for prices comparable to those of the corresponding petroleum fuels.

Although hundreds of processes have been patented, extensive engineering studies and preliminary cost evaluations, coupled with research and development work in the laboratories of the Oil-Shale Petroleum and Experiment Station, Laramie, Wyo., have narrowed the processes having commercial possibilities to relatively few. The technical feasibility and relative merits of these few are determined by pilot-plant studies at Rifle, Colo. Detailed cost estimates, based on pilot-plant data, then can be made to complete the evaluation and selection of processes at this stage. Improvements are usually devised before larger-scale studies are made. Finally, retorting and refining processes and equipment are proved on a demonstration-plant scale, and technical and cost data are obtained that can be projected to industry-scale designs.

The information developed in this manner is being made available to industry for use in designing commercial oil-shale plants.

Authorized by the Synthetic Liquid Fuels Act of 1944, construction of the Oil-Shale Demonstration Plant (see fig. 20) was begun in 1945. Oil was first produced in that plant in May 1947, and the demonstration refinery started operating in July 1949. In 1950 the gas-combustion retort was invented and developed on a pilot-plant scale, while the experimental refinery demonstrated that thermal refining techniques - particularly viscosity breaking, recycle cracking, and coking combined with chemical treating of naphtha and light gas-oil distillates - were readily adaptable to shale oil.

In 1951, studies on the gas-combustion pilot plant were continued and a demonstration-scale plant of this type was designed and construction begun. Operation of the demonstration refinery was continued, with emphasis on ascertaining optimum operating conditions for processes that had previously been found suitable for shale-oil refining and on new techniques, especially thermal reforming of shale naphtha. Also, plans were made for adding a Suspensoid catalytic cracking unit and a catalytic naphtha treater. Rapid accumulation of information and improvement in mining and processing techniques made it possible to prepare a new, more complete cost estimate based on producing shale oil in Colorado, piping it to the west coast, and refining it in that area.

Pilot-Plant Activities

The pilot-plant test program initiated last year on the gas-combustion retort[1] was continued, and several improvements in the process have been made. One of the highlights of the test program was a 4-day evaluation run to establish the operability and performance of the process on 30-gallon-per-ton shale.

1/ Synthetic Liquid Fuels, Annual Report of the Secretary of the Interior for 1950, Part II - Oil from Oil Shale: Bureau of Mines Rept. of Investigations 4771, 1951, 88 pp.

Other engineering development work included designing and beginning fabrication of a larger gas-combustion pilot plant, completion of the experimental program on the gas-flow retort, and inauguration of a study of refining processes and problems on a pilot-plant scale (see fig. 21).

Gas-Combustion Process

With the shale flowing by gravity, the gas-combustion process utilizes countercurrent heat exchange between the shale and the retorting gas. An important advantage of the process is the low temperatures of the streams leaving the retort. Thus, disposal of the spent shale presents no special handling problems, and no coolers are needed to recover the product oil.

Description of Pilot Plant

The gas-combustion pilot plant has a throughput range of 4 to 10 tons a day and consists of a retorting vessel with an auxiliary gas-handling and liquid-recovery system. Figure 22 is a flow diagram of the process. The retort vessel (fig. 23) is cylindrical and refractory-lined, with an inside diameter of 20 inches and an effective shale-bed height of 12 feet. Crushed shale is charged intermittently to the retort through a lock hopper and flows continuously by gravity through the retort. A rotating-disk feeder at the bottom provides a support for the column of shale and causes it to move uniformly downward through the retort. The disk feeder is entirely enclosed, and by discharging the spent shale to a closed receiver through a slide valve, gas and air leakage is prevented.

The down-flowing shale is processed by a rising stream of gas. Recycle gas is injected into the bottom of the retort at a predetermined rate. As the gas flows upward, it removes the sensible heat of the spent shale, allowing the spent shale to be discharged at a low temperature. The heat-exchange zone is approximately 3 feet in height.

Just below the center of the retort and immediately above the heat-exchange zone is a gas-air mixing device - a vertical pipe with an air-cooled conical shale deflector above; it provides a shale-free channel through which a relatively large portion of the preheated recycle gas passes, owing to the lower resistance of the mixing chamber to gas flow as compared with that of the shale bed. Air is introduced into the channel and mixes with the disengaged portion of the recycle gas. Combustion of the gas-air mixture takes place immediately after it leaves the mixer and is controllable by varying the recycle-gas:air ratio. Some of the residual organic matter on retorted shale serves as fuel also, but for the most part the preheated gas burns in the controlled supply of oxygen in preference to the solid matter.

As the stream of hot combustion gases travels upward, its heat is transferred to the shale, causing retorting of the shale in a section immediately above the combustion zone and cooling of the gas stream to about 150° F. in the uppermost zone of the retort. In this cooling zone the oil vapors are condensed in the form of minute droplets of liquid which remain suspended in the gas stream as a mist. The combined height of the combustion, retorting, and product cooling zones is about 7 feet.

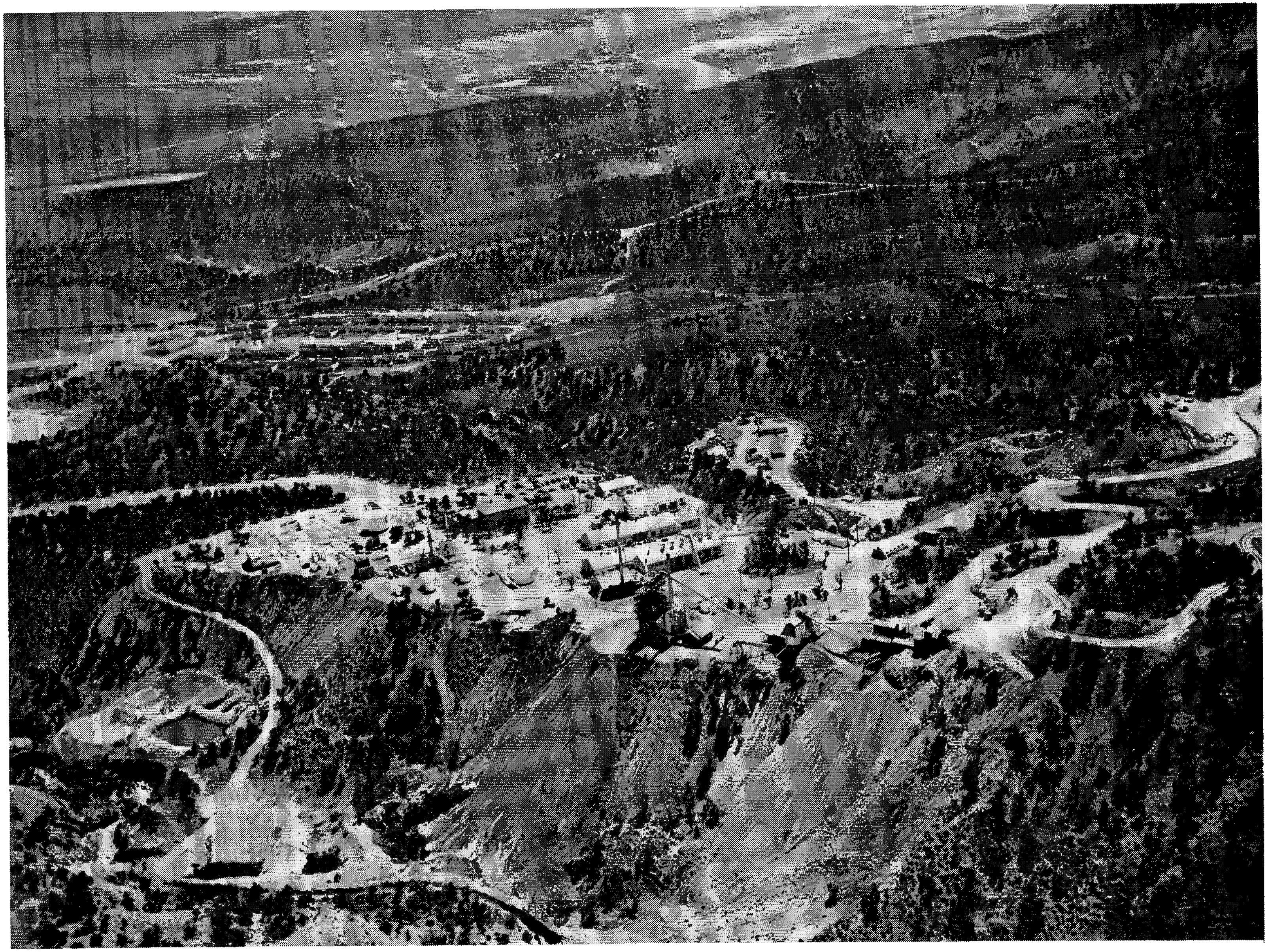

Figure 20. - Plant area, with residential area in background.

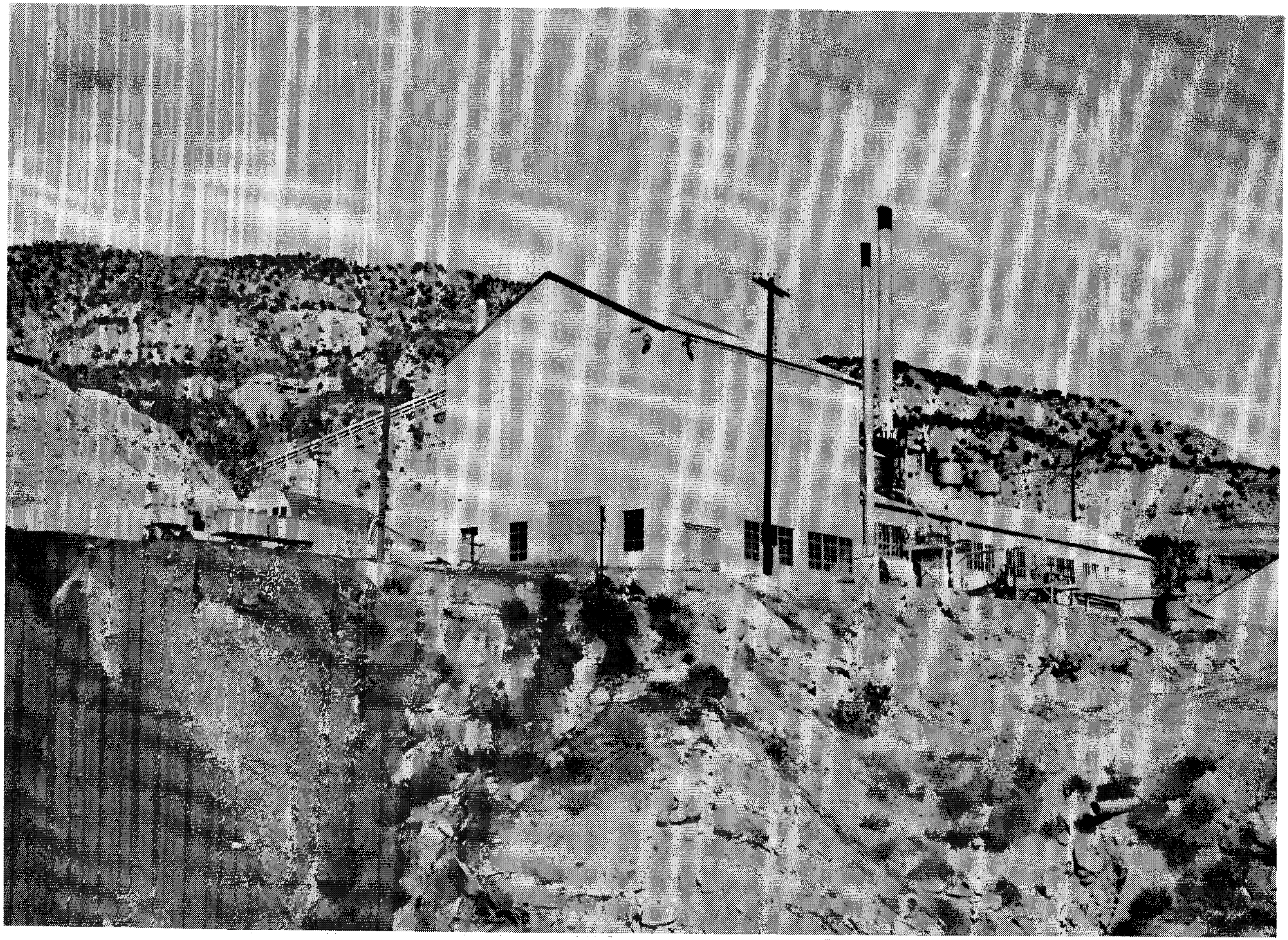

Figure 21. - Pilot-plant area, showing spent-shale disposal pile and spent-shale cars, new building addition (taller part), and original pilot-plant building.

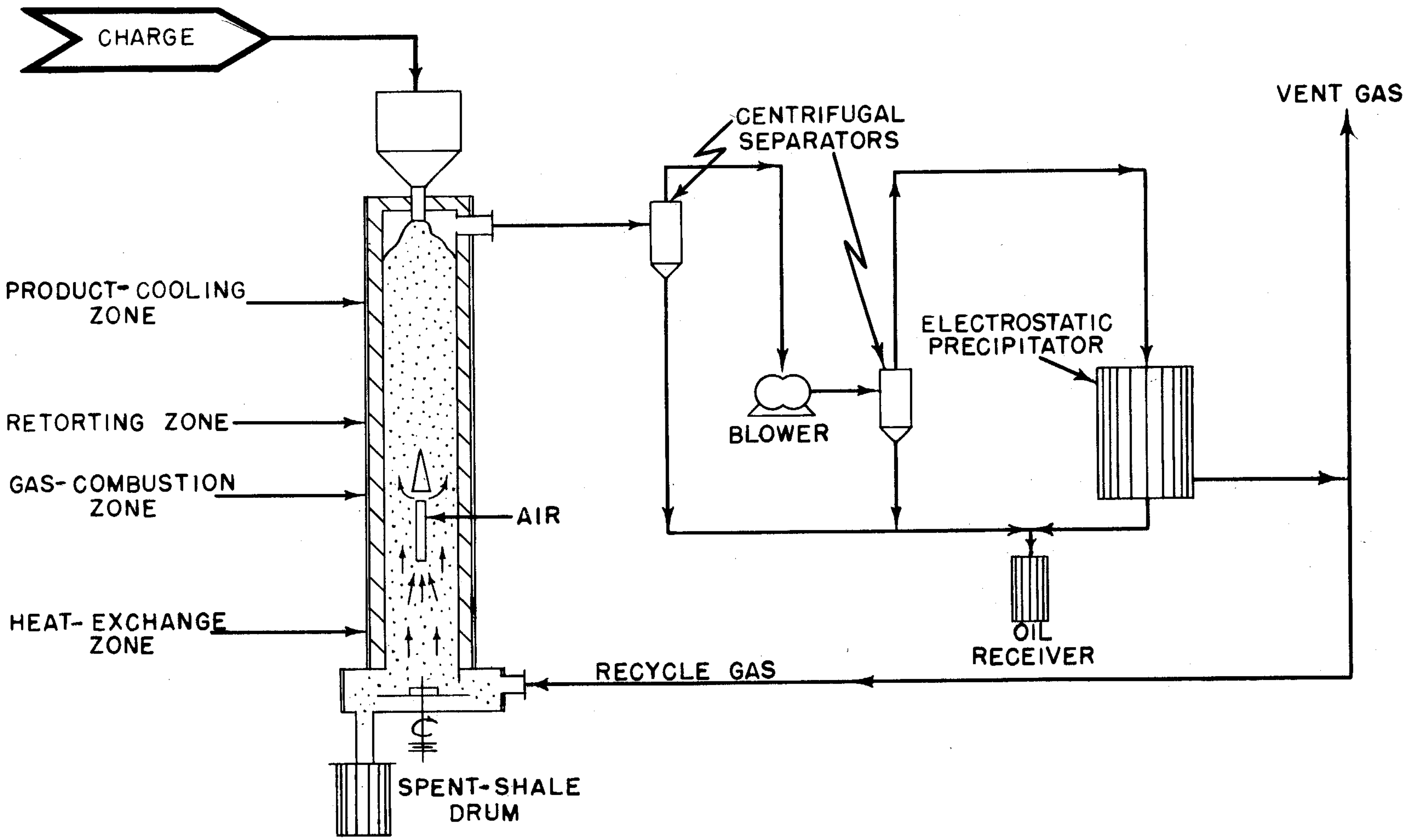

Figure 22. - Flow diagram of Gas-Combustion pilot plant for retorting oil shale.

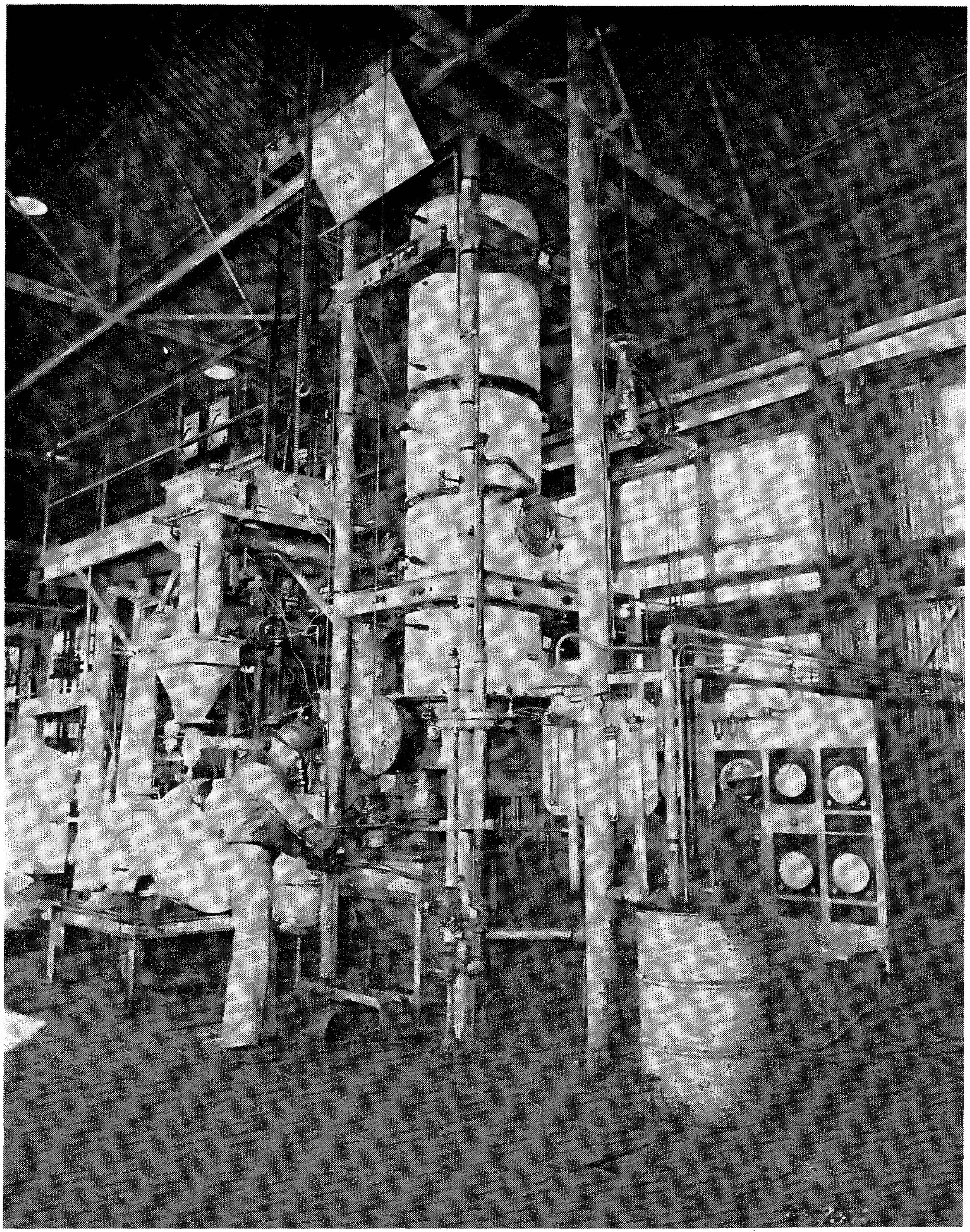

Figure 23. - Gas-combustion pilot plant.