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METALLURGICAL PROJECT

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REPORT FOR MONTH ENDING SEPTEMBER 26, 1943

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A. INTRODUCTION

Emphasis this month has been on the homogeneous slurry pile and on the experimental heterogeneous P-9 pile. A 750,000 KW homogeneous pile can be built with 16 heat exchangers (2000 3/8" tubes 10 ft. long) with an external hold-up of 9-10 tons of P-9. The requirements of an experimental program have been outlined in some detail as to problems, personnel, space, equipment and power. Considerable thought has been given to separation processes. Design, detailing and procurement of equipment for an experimental P-9 pile is progressing rapidly. Work is continuing on the general problem of shielding and on the construction of a model of the 50,000 P-9 heterogeneous pile.

SECRET

B. ABSTRACT

Process Group

A 750,000 KW homogeneous pile has been analyzed to provide a practical heat exchanger and pumping system for a minimum of P-9.

A survey has been started which shows that P-9 utilization increases with power extractions from a single pile, up to 3 to 6 x 10^6 k.w. and then falls off.

Studies show that 8000 k.w./ton of P-9 may be realized without pumps (thermal syphon) as contrasted with 10,000 with pumps, in pile dissipation sizes of the order of 600,000 k.w.

Studies have been started to outline a program to investigate the problems in connection with separation of the oxide from P-9 slurries.

Application Group

An experimental program is formulated to allow a preliminary design of a production unit.

A survey of methods for 1000 k.w. removal from an experimental heterogeneous pile is presented.

The status of aluminum welding of chemical process vessels is covered.

SECTION C

PROCESS GROUP - J. H. Chapin, Group Leader

Summary and Conclusions

A detailed investigation of the P-9 utilization (kw/ton P-9) as effected by the arrangement and size of heat exchangers in the external cooling system indicates that practical requirements for a 750,000 kw pile are:

1.) 16 heat exchangers, 2000 3/8" tubes 12' long
2.) 96,000 g.p.m. cooling water
3.) 9.4 tons P-9 in external system
4.) 20-25 lbs./sq.in. pressure drop

Rather formal calculations on the utilization of P-9 indicate that utilizations of 50,000 kw/ton and power outputs of 3,000,000 to 5,000,000 kw are theoretically the optimum or maximum values, with total requirements of P-9 in the neighborhood of 100 tons. These calculations point to the desirability of requesting the fabrication of heat exchangers containing twice as many tubes as manufactured at present.

Removal of heat from a 600,000 kw pile by thermal convection can permit utilizations of 8000 kw/ton with proper elevation of heat exchangers. This figure is to be compared with a utilization of 10,600 kw/ton obtained with pump circulation.

A preliminary survey of methods of separating the solids from P-9 in a slurry indicates that evaporation to dryness, distillation with a third component, settling and centrifuging appear the most promising methods. Considerable study will be required before more can be said.

The attack on the general problem of shielding has been broken down into 1) materials employed 2) construction 3) effect of inhomogeneities and 4) induced radioactivity effects. Two types of shields are under consideration: 1) single unit of construction acting as a combined thermal and biological shield and 2) two units each performing its own function. The work has not reached a point where definite results can be reported.

I P-9 Utilization in Homogeneous Pile (J. T. Weills, F. R. Ward)

A CE report, entitled "P-9 Utilization In The Slurry Pile Cooling System" is being completed. This report is a preliminary investigation of the heat transfer and P-9 utilization problems involved in the cooling system of a 40 ton homogeneous pile.

In this report, two general types of exchangers have been considered, i.e., spiral plate and single-pass, floating head tubular exchangers. In the latter type, only 1/4" - 3/8" - 5/8" tubes were considered.

Calculations for various exchanger arrangements and sizes have been made to determine:-

1.) P-9 hold-up in the external cooling system.

2.) Total power that can be removed.

3.) Number of exchangers and amounts of cooling water required for various power outputs.

In general, arrangements were made for the purpose of using a minimum amount of P-9 rather than attaining the optimum utilization of P-9.

Data and recommendations used were those supplied by the Andale and Schutte-Koerting companies (see CE-865-Ward and Thompson). The following pertinent conclusions have been reached:

1.) The use of spiral plate exchangers is impractical, this type requiring 5 - 6 times the P-9 required by tubular exchangers for a 750,000 kw pile.

2.) Vertical exchangers arranged symmetrically about the pile with an equal number of exchangers per row give the best P-9 utilization and the most compact arrangement.

3.) In order to remove a large amount of power with a minimum expenditure of P-9 in the cooling system, it is necessary to have:-

a.) Highest permissible slurry velocities in the tubes
b.) Maximum tube lengths allowable
c.) Low outlet cooling water temperatures
d.) Two cooling water streams on the shell side

4.) The larger the tube size in the exchanger -

a.) The fewer the number of exchangers required for a given heat load.

b.) The greater the amount of D_2O required in the cooling system for a given heat load.

c.) The lower will be the pressure drop on the shell side.

5.) For a 750,000 kw pile

a.) 1 row of 16 exchangers with 1' 2" exchanger - pile clearances,

b.) 9.4 tons D_2O in the cooling system,

c.) 96,000 g.p.m. cooling water total, and

d.) 2000 - 3/8" O.D. - 16 BWG - 12 foot long tubes

appear to be the most satisfactory arrangement in so far as P-9 economy, cooling water economy, stainless steel economy and construction economy are concerned.

6.) The maximum pressure drop likely to be encountered in the external pile system is of the order of 20-23 lbs./sq.in. on the tube side. Minimum drop is of the order of 2.0 lbs./sq. in.

Another type of exchanger, the Votator, is under consideration. Although information available at present is incomplete, present indications are that this type will be even less satisfactory from a P-9 economy point of view than the spiral plate type.

Further calculations are being made to determine:-

1.) Effect of increasing tube-spacing on P-9 utilization.

2.) Effect of increasing number of tubes on P-9 utilization

3.) Amounts of 18 - 8 stainless steel required per ton D_2O for given heat loads

4.) Effect of using elliptical shaped bundles and shells on P-9 utilization.

Calculations are also being made to determine the feasibility of submerging tube bundles in a flume, using diverted river water as the cooling medium.

II Natural Maximum Size of a Homogeneous Pile (J. R. Huffman)

On the assumption that mechanical difficulties and complexities do not restrict the number of heat exchangers which can be connected to the pile, an investigation is under way to determine the maximum utilization of P-9 obtainable. In a layout where heat exchangers are located as close to the pile as possible, such a maximum will be reached when the increment of power removal by a heat exchanger becomes smaller than the increment of external hold-up necessary to feed and operate the exchanger. Since tube size and the number of tubes per heat exchanger effect the heat removal and the hold-up in tubes, heads, lines and pumps more than tube length and fluid velocity, only these variables have been investigated.

Because a clear presentation of the subject requires considerable discussion of layouts, methods of calculations, etc., a special report is being prepared. The following table presents briefly the order of magnitudes being obtained:-

Tube Size	No. Tubes	KW/ton	KW	No. heat exchangers
1/4"	1615*	46,500	3,750,000	225
1/4"	3230	55,000	5,000,000	150
3/8"	1850*	50,500	4,500,000	114
3/8"	3700	44,000	5,000,000	163
5/8"	1800*	26,500	2,500,000	30
5/8"	3600	27,500	4,400,000	26

* Maximum number in present commercial design.

While it is improbable that any effort will be made to reach the power levels possible, these figures furnish information as to the direction in which any improvements in design should tend. For instance, it appears highly desirable to approach manufacturers for tube bundles in heat exchangers of twice the size of those at present fabricated, particularly in the 1/4" tube size. On the basis of utilization of P-9, heat exchangers employing 5/8" tubes do not compare favorably with those having 1/4" or 3/8" tubes.

These calculations suggest the use of extreme numbers of heat exchangers far beyond the number that can be physically connected to the pile. Future work is planned to correlate these maximum size calculations with practical and physically possible layout limitations.

III Thermal Syphon for Heat Removal (J. J. Goett)

The possibility of the use of a thermal syphon as a means of circulation for the removal of heat from P-9 piles has been investigated. The assumption has been made that the temperature within the pile would be constant along its length and that in the slurry pile this temperature is 120° C.

Thermal syphon has been found to be a possibility only where there is a large temperature range. Thus for the homogeneous pile, with a maximum temperature of 70° C., its use has been found inadvisable.

Thermal syphon has been considered both as the primary means of circulation and as a standby for pump failure.

Two cases have been considered:

1.) 40 - 1615 1/4" 16 ga tube 10' long heat exchangers

2.) 28 - 1800 5/8" 10 ga tube 10' long heat exchangers

The attached graph gives the results obtained. Case 1 shows, that in the standard arrangement of heat exchangers, the power under thermal syphon will be 3000 kw per exchanger; compared to 20,000 kw under the pumping system. Elevating the exchangers above the pile to gain a greater head by thermal syphon will give a maximum utilization 4250 kw/ton at a 50 foot elevation, with an individual exchanger power of 8000 kw.

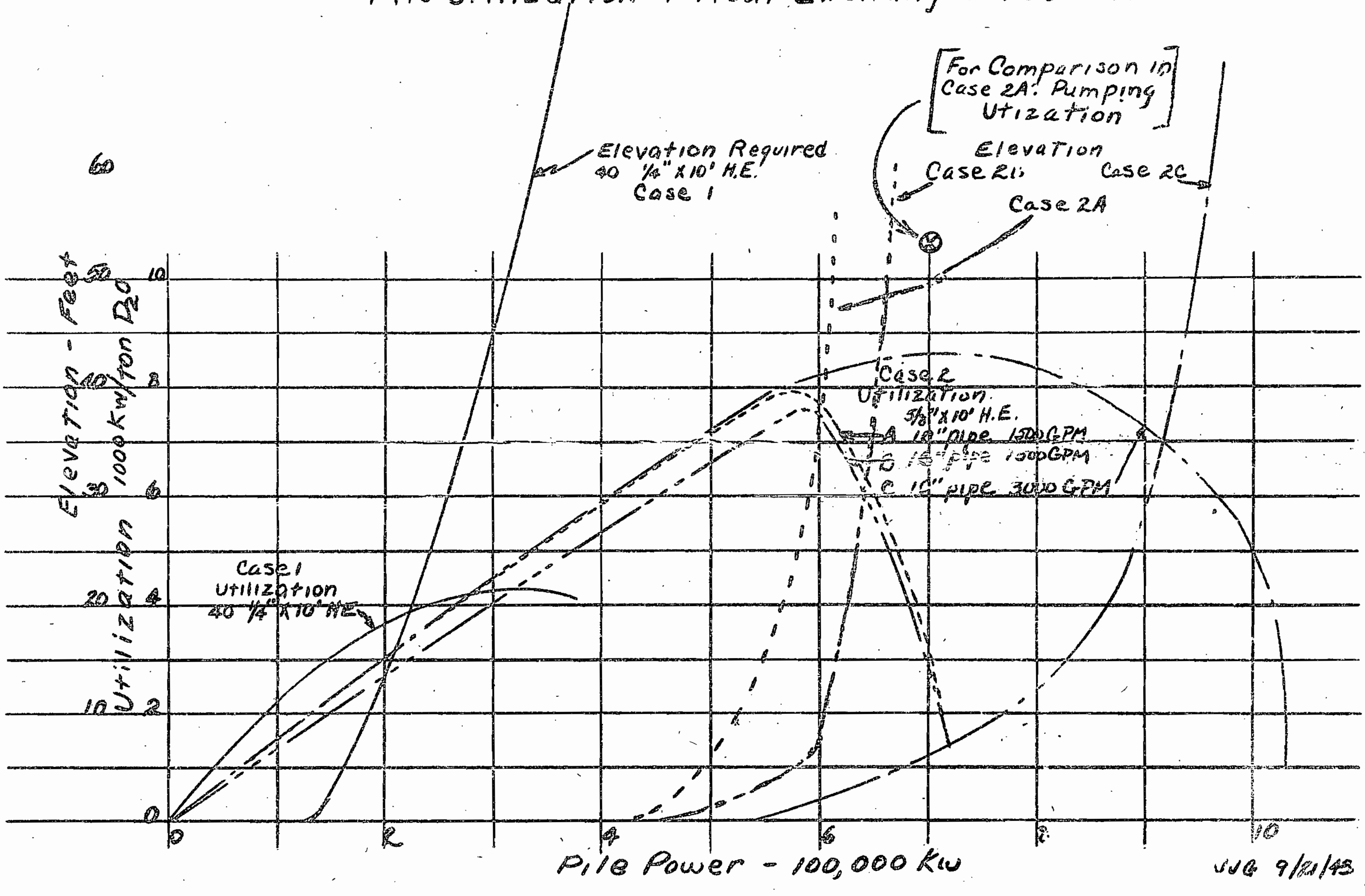
Case 2 has been subdivided into three cases. Case 2A describes the action of a 5/8" exchanger with a 10" pipe connection to the pile and 1500 g.p.m. of cooling water flowing. In the standard position the power of the exchanger will be 17,000 kw as compared with 25,600 kw under pumping conditions. Maximum utilization by elevation of the exchanger is 8000 kw/ton at an elevation of 5 feet above the standard position for all 28 exchangers. Individual exchanger power is 20,500 kw. This maximum utilization may be compared with that of the pumping system which has a value of 10,600 kw/ton.

Case 2B uses the 5/8" exchanger with 16" pipe lines in order to cut down the required head. Utilization is reduced, however.

Case 2C is similar to 2A, using twice as much cooling water. In the standard position an exchanger will deliver 20,200 kw. Maximum utilization of 8,600 kw/ton D_2O occurs at 15 foot elevation, with an individual exchanger power of 29,000 kw. No comparable case has been considered by the group working on heat exchangers and the pumping system.

Considering the simplicity of thermal syphon as compared with the pumping system, it might be advisable to further investigate its use since it would give longer pile life than that promised by pumps.

THERMAL SYPHON
Pile Utilization + Heat Exchanger Position



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IV Separation of Slurry (J. H. Chapin, J. R. Huffman)

The separation of the slurry particles from the P-9 in a homogeneous pile plant presents problems of a different type than those encountered in heterogeneous pile designs. The problem consists of the separation of the solid particles from P-9 in about 6 tons of slurry per day, returning the P-9 to the pile system with substantially no loss, as quickly as possible and delivering the solids to storage in suitable form for ageing and chemical processing. Since it is highly probable and desirable that the process plant at W handle the separation of the product an by-products, the raw material from the homogeneous pile should be delivered in a form and of a quality fixed by its design and operation.

Some major problems which must be considered are:

1.) The P-9 should be returned to the system sufficiently pure from any added or formed corrosion agents or contaminants. Due to radioactivity, the fission products should be confined to as small an equipment coverage as possible. Similarly only very small amounts of slurry, if any, should be present in the recycling P-9 stream.

2.) If possible, valves and moving parts should be eliminated or reduced to the absolute minimum to prevent losses of P-9, product or fission products, as well as from a maintenance point of view.

3.) Evolution of heat from the slurry during separation, handling and storage must be considered.

4.) Control and instrumentation by remote operations will present a number of problems. For instance, to handle a distillation system, liquid level controls in tanks, measurement of rates, etc., add complexities to this method which may well be the determining factors in selection.

A preliminary survey and general discussion of the various methods suggested seems to narrow the field to the following general methods, or some suitable combination of them. Two step processes will probably be most desirable, i.e., to return substantially all the P-9 in the first step and to recover the remainder in a second step. This system would reduce the hold-up of P-9 materially.

1. Evaporation. Evaporation to dryness on a cooled surface followed by flushing out with water, solution in acid or storage as a solid mass.

Advantages: simplest, P-9 purified from non-volatiles, no added contaminants, destruction of hydrates.

Disadvantages: handles hot dry solids; may be a batchwise operation, possible solution difficulties, may have losses of P-9, product and fission product in vapors.

Distillation. Use of a second immiscible liquid to strip P-9 off and deliver solids in a fluid medium. Involves a concentration step, a stripping step and a reclaiming step.

Advantages: no dry solids at any time, easier cooling and handling, purifies P-9.

Disadvantages: Complexity, required more design, requires more shielding.

3. Centrifuging. Use of continuous solid basket centrifuge with a second immiscible fluid to carry solids. Involves a concentrating step (no second fluid), a stripping step and a final purifying distillation to remove last solvent from P-9.

Advantages: no dry solids, may have less hold-up.

Disadvantages: moving parts, experiments needed, no purification of P-9, relatively complex, some particles in recycling stream of P-9.

4. Settling. Settling of substantially all particles with aid of coagulating agent, followed by a step for final removal of P-9, such as evaporation.

Advantages: simplicity, probably serve as a first step in any process.

Disadvantages: no purification of P-9, high hold-up, added contaminants, recycle of some particles.

5. Filtration. Filtration to remove most of P-9. No developments on succeeding steps.

Advantages: no dry solid handling.

Disadvantages: removal of cake, difficulty of filtering fine particles, requires second process step, cooling, no purification of P-9.

6. Molten Salt. Addition of salt to slurry prior to evaporation to serve as absorber of heat evolved.

Advantages: cooling easier, destroys hydrates.

Disadvantages: added contaminant, later solution difficulties, possibly requires added processing to prepare material for chemical separation. Handling of high temperature fluids.

V Shielding (G. F. Quinn, L. B. Thompson)

The engineering section of the special group studying the shielding of the heterogeneous P-9 pile has been concerned with the structural and constructional problems of the various types of shield, meeting the requirements of the theoretical section with regard to the clearances around and inside the tubes, and the removal of the heat developed. From the constructionsl viewpoint, there are two general types of shield which have been considered to date. Type I consists of a single unit of construction fulfilling the capacities of both the thermal and biological shields, while Type II consists of two units to perform those functions, as in the "W" shield.

Type I - Because of structural reasons, the shields of the single-unit type have been designed as follows: the shielding material is sandwiched between two steel plates of thicknesses sufficient to support the structure when freely supported around the edges. These plates which may be either square or round are connected by steel pipes (through which pass the aluminum tubes) making the two act as a single beam. The two thick plates also serve as shields; the one nearer the pile functioning as a heat shield while the outside one provides the last part of the required γ ray shield. In between the two plates is located the main body of shielding material consisting of a more or less homogeneous arrangement of dense and hydrogenous substances, e.g., iron or lead, shot and water, iron plates with alternate layers of masonite (or water), special concrete. Alternatives to the intermediate plates in the plate-masonite type have been considered.

Type II - Work on the type of shield embodying the principle of separate thermal and biological shields has begun recently. The heat shield may be composed of overlapping cast iron blocks supported by cross beams between each row of tubes. The biological shield will probably be supported in the same way, but little has as yet been done on this design.

The possibility that all the heat developed in the end shields may be removed by conduction into the pile cooling water (as in the W plant) is being investigated. Small clearances at points where the tubes pass through the shield will not only assist in the heat removal problem, but will also be imperative to block the escaping radiation. The problem of diminishing the sizes of the gaps and weakly absorbing regions in and around the aluminum tubes is being considered. A related problem is that of blocking the inner aluminum tubes sufficiently so that the piping connections do not become dangerously radioactive.

SECTION D

APPLICATION GROUP - J. R. Huffman, Group Leader

Summary and Conclusions

Estimates for an engineering experimental program for the design of a homogeneous slurry pile are:

Added personnel	- 21 men	(\$60,000/yr)
Equipment	-	\$115,000
Floor Space	-	5000 sq. ft.
Power	-	900 kw.

Comparative heat exchanger costs for removing heat from recirculated P-9 in an experimental 1000 kw pile are presented. The cases considered are: (1) air cooler, (2) evaporative air cooler (3) and liquid-liquid heat exchanger. Data on pump costs are also given. Since relative costs are approximately equal, space requirements, procurement and flexibility will be determining.

Information on aluminum welding obtained from a manufacturer of chemical process equipment indicates no trouble can be anticipated from joints made by flame welding either by oxy-acetylene or oxy-hydrogen techniques.

I <u>Engineering Experimental Program For Homogeneous Pile</u> (J. H. Chapin, J. R. Huffman)

In a memorandum to H. D. Smyth (LM-212 MUC-HCV), an experimental program is proposed to obtain data necessary for the engineering design and development of P-9 homogeneous slurry piles. Many of the problems are of such a nature that a rather full and well-oriented experimental program needs to be planned and initiated at the earliest proper moment if the data can be expected to fit any practical time schedule of design.

The main topics requiring investigation are outlined briefly below. No attempt is made to include the physical or radio-chemical experiments which will be required.

1. <u>Erosion</u>

   a. Tests on standard commercial heat exchangers and on modified designs.

   b. Tests on pipes, fittings, valves.

   c. Tests on several commercial slurry pumps, and on modified designs.

   d. Overall lifetime of pumps under no maintenance conditions.

2. <u>Separation</u> of solids from P-9.

3. <u>Recombination</u> of P-9 gases.

4. <u>Preparation</u> of slurry

Assuming that floor space and general facilities are available, the program is estimated to require:

Added personnel	- 21 men	($60,000)
Equipment	-	$115,000
Floor space	-	5000 sq. ft.
Power	-	900 kw.

At the present time detailed layouts, equipment lists and test procedures are being compiled.

It is to be emphasized that this covers the experimental requirement only and that other additional personnel and space will also be required for evaluating the data and translating it into practical designs.

II Heat Removal From Experimental Heterogeneous Pile (J. J. Goett)

In anticipation of the possibility of the construction of an experimental P-9 pile, the problem of an external cooling system has been investigated. P-9 has been considered as the internal pile coolant, circulated externally by means of a pump through various types of heat exchangers; (1) air cooled exchanger, (2) evaporative air cooled exchanger and (3) a liquid-liquid exchanger. The requirements have been set by preliminary estimate to be 1000 kw power removed from 200 g.p.m. circulation at a maximum temperature of 70° C.

1. The air cooled exchanger system would require 6 - 24" x 144" 6 row cooling coils, using 70,000 CFM of 95° F. maximum temp. air. The coils would have aluminum tubes, headers and fins. The cost of the unit installed is estimated at $8000. Total power to drive the unit is 17.5 H.P. Hold-up of P-9 is 11.cu.ft.

2. The evaporative cooler in a single unit would measure 14' x 5' x 11' high and require 20,000 CFM of air at a maximum wet bulb temperature of 75° F. The water spray system would circulate 100 g.p.m. requiring at full load a maximum water makeup of 4 g.p.m. P-9 head through the exchanger would be 33 feet. The complete unit, installed with temperature controls for freezing weather, is estimated at $9000. Power requirements exclusive of P-9 circulation is 6 H.P. Hold-up of P-9 is 8 cu. ft.

3. The liquid-liquid system would require a heat exchanger and water cooling tower. The exchanger has been estimated as a single pass tube and shell type, consisting of 230, 3/8" 16 ga tubes, 9 feet long. Overall dimensions may be considered as 10' x 18" diameter. Cost installed would be approximately $3000. P-9 hold-up would amount to about 2 cu. ft. The water cooling tower, handling 500 g.p.m. at a cold temperature of 90° F. would measure 15' x 13' x 25' and cost $4000 installed. The make-up water requirements would be about 9.5 g.p.m. Power for the unit would run to about 20-25 H.P.

The possibility exists that the temperature range 50° C. - 70° C. may be too high for the internal pile cooling requirements. To reduce the range to 30° C. - 50° C. eliminates the dry air cooler as a possibility. The evaporative type would require two of the units previously described, connected in P-9 series in order to remove 500 kw. The liquid-liquid system would be inadequate with a water cooling tower and would require refrigeration. Installation and operating costs have been estimated as $30,000 and $6.00 per hour respectively on a conservative estimate for the refrigeration unit alone.

The pump to be used in the system of P-9 circulation has been considered as a Wilfley-type A.C. - pump. The advantages of its use lie in its unique construction, eliminating the stuffing-box, and reducing leakage to a few cubic centimeters per shutdown. The cost of a unit to pump 200 g.p.m. against a 50 ft. head is $485 in the 18-8 stainless steel construction. Power requirements will be 5 H.P. P-9 hold-up has been estimated as approximately one gallon. Such a pump is now on order (Physics Division) and will be experimentally investigated.

III Heterogeneous P-9 Pile Model

As time permitted, the erection of a wood model of the piping system for the 460 rod, light water cooled P-9 heterogeneous pile has progressed to about ninety percent completion (410 Eckhart).

In general, very little time has been spent on heterogeneous pile design during this month.

IV Aluminum Welding (J. T. Weills)

In a recent consultation with a representative of a company with years of experience in the fabrication of aluminum equipment for the chemical industry, several important considerations in the welding of aluminum were given.

Trimmed sheet is often used in lieu of welding rod to assure exact alloy composition.

Arc welding is sometimes used for welds of structural importance only. For vessels, where the weld must act as a seal also, flame welding is used, oxy-acetylene being more common today than oxy-hydrogen, mainly because of the greater availability of acetylene.

Examination of typical flame welds shows that the oxy-acetylene flame gives a pitted weld surface while the oxy-hydrogen does not. Ends of samples of both types of flame weld, just rough saw cut, show no occluded slag and no pits when viewed with the unaided eye.

In butt welds in general both sides of the joint are welded. After one side has been welded, the inner part of the joint is chipped to remove any slag which would be occluded when the middle of the joint is sealed by the weld on the other side. This technique can be used readily on sheet as thin as 3/16 of an inch. One-eighth inch sheet joints can be so prepared, but with some difficulty.

Additional points in butt welding are: (1) below 3/16 inch thickness, the sheet ends are not bevelled, (2) below 1/8 inch sheet, the ends to be joined are bent 90 degrees so that the sheets are parallel at the ends; the two ends are then placed flush and melted together;(this does not leave a protruding ridge), (3) in butt welding, two sizes of sheet, it is recommended that 1/8 inch be welding to 3/16 inch, 3/16 inch to 1/4 inch, etc.; larger differences at these thicknesses result in difficulty in controlling temperatures at the weld.

In vessel fabrication, corner welds are not used at all for thin sheets; a sheet, or plate, to be joined at, say, a right angle to the end of another is bent 90 degrees near the edge on about a 1 1/4 inch radius so that the sheets meet to form a butt joint.

Further considerations in welding aluminum in vessel fabrication are: (1) aluminum pieces to be welded must be positioned; (field welds are not satisfactory), (2) one weld can be crossed by another, (3) one of the easiest types of weld is that described above for welding very thin sheets, i.e., welding two or more ends which are parallel and flush.