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ESTIMATING PROCESS DEVELOPMENT MANPOWER REQUIREMENTS

M. C. Leverett

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ESTIMATING PROCESS DEVELOPMENT MANPOWER REQUIREMENTS

Abstract

Rough rules for estimating the manpower required for development work have been derived from Clinton Laboratories experience. For chemical processes, complete development, process design, pilot planting and start up assistance will total about 42 technical man months per process unit. No easy rule is available for pile development, but the total expended and to be expended on the 30,000 KW High Flux pile is 1400 man months, of which one-third is physics and electrical engineering and two-thirds general engineering and metallurgy.

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One of the difficult and recurrent problems of a development laboratory is the estimating of the manpower which will be required for a given program. This problem is made difficult by the fact that ordinary industrial experience is not applicable to our field, and is moreover very imperfectly correlated and reluctantly released outside the company. It is the purpose of this report to record certain rough-and-ready rules for making such estimates, based on the experience, mainly of the Technical Division but partly of others also, at Clinton Laboratories in the last four and one-half years.

1. Chemical Process Manpower

The time, manpower and money required for design and construction of facilities to carry out a chemical operation can be estimated by standard methods once the process design of the proposed operation is complete. The estimation of the time and manpower required for the experimental development, preliminary design and study up to the point of completion of the process design has not, however, been so far reduced to a standard procedure. This section of this report proposes a method of making such estimates.

For present purposes it is assumed that development starts when the proposed process has been carried out in the laboratory on a small (test tube) scale, and that the main features of its chemistry are therefore known.

The first step in making the estimate of manpower required to bring the process to the point of completed process design is to write down a tentative chemical flowsheet for the process. This chemical flowsheet is then elaborated into a tentative equipment flowsheet.

As here used "chemical flowsheet" means a chart on which is written in roughly tabular form all the chemical substances entering or leaving the process at each step, the concentrations of all solutions, the temperatures of all solutions, the reactions which occur, the radioactivity associated with each step, the time required for each step and other data such as agitation requirements, etc. "Equipment Flowsheet", as used here, means a drawing or drawings of the assembled equipment with connecting pipelines, jets, pumps and services. At the beginning of the development of a process neither of these flowsheets can be known with much certainty, but usually they can be made sufficiently certain so as to form the basis of an estimate of manpower required.

The second step is to count up the number of process units in the proposed process, using the flowsheets as a basis. One process unit is defined, for this purpose, as

one chemical transformation, or

one physical transformation, or

one phase separation, or

one special mechanical operation.

Typical examples of process units of each kind are:

Chemical transformations

a. Dissolving metallic slugs in nitric acid. (The purification of the resulting dissolver off gases by scrubbing with sodium hydroxide would constitute a second process unit.)

b. Precipitation and settling of lead-barium sulfate. (But if the operation is repeated several times under essentially identical conditions it is still counted as just one process unit.)

c. Counter-current solvent extraction of a solution with an organic solvent. Each column in series would be counted a separate process unit, because conditions vary from one column to the next.

Physical transformations

a. Evaporation of a solution to reduce its volume. Condensation of the vapor would not be a second process unit, since it is a relatively trivial problem.

Phase Separations

a. Filtration of a solution to remove suspended solids.
b. Centrifugation to remove solids or separate liquids.

Special Mechanical Operations
a. A remote operated filtration for hot solutions.
b. A porous-plate type of reactor.
c. A remotely operated pellet press.
d. In general, any non-standard remotely operated device.

The accompanying table summarizes the experience of the Technical Division in chemical process development work for a number of problems of various degrees of difficulty and urgency. Only two of these projects are complete at present. Two of them were suspended by higher authority before completion. Three of them are at present in progress, and the total effort required for completion is only an estimate based on recent experience. The table shows a wide variability in the quantity "man months per process unit". This would be expected, in view of the crude nature of the quantity, and means that the numbers in the table must be used with great caution. The variation in "man months per process unit" is, in the writer's opinion, about equally attributable to variations in inherent complexity of the processes, variations in urgency of completing the development of the processes and the variable extents to which divisions other than the Technical Division participated in the work. Extensive participation of or review by other divisions seems to slow down the pace of the work in the Technical Division through increasing the number of alternates which must be investigated.

2. Pile Design and Development Manpower (Excluding Metallurgy and Physics)

No rules have yet been formulated for estimating the manpower required for process design and development on piles. The work of the Technical Division on the High Flux pile (estimated now to be 68% complete) has been estimated to require the expenditure of 335 man months of process design time and 280 man months of experimental developmental time, not including metallurgical work in the Technical Division and the work of the Physics Division. This may be summarized as follows:

Process design	335 man months
Experimental Engineering Development	280
Metallurgical Engineering Development	304
Physics	470
Estimated total process design and development for High Flux Pile (Pile only)	1389 man months

The effort put into process design was considerably influenced by the fact that the entire laboratory had to be satisfied with the detailed design of the pile, thus a great many minor changes and re-drawings were necessary. It should be noted that the figures given in this report for the High Flux pile project cover only the work done on this project since August 23, 1946, when the heavy water machine was definitely abandoned. Clearly, some of the work prior to this date was of assistance during the working period covered by the figures. However, no correction of the figures for this fact was made, because it will usually be true that a pile development program is substantially aided by work which has gone before it but is not really a part of it.

The work done on the High Flux pile project is not easily compared with that done on other piles. However, it is believed that comparison among the Clinton graphite pile, the Argonne heavy water pile, the Canadian pile, the Clinton High Flux pile, and the Hanford piles would show that the amount of process design and development effort required generally increases as the design power level increases.

The effort of the Physics Division on the High Flux pile project is estimated by Weinberg at about 35% of the division, which now contains about 73 technical employees. On this basis the Physics Division has put in about 400 man months. It is estimated that the work of the Physics Division on this project is about 85% complete, so that about 470 man months is the total effort required of the division for its participation in the whole 1000 Project.

3. Non-Technical Manpower

All the foregoing figures are for technical personnel. In addition, non-technical personnel are required. In the Technical Division the ratio of non-technical to technical employees will normally be about 0.8. In the Physics Division it is about 0.3.

4. Shop Time

In addition to the non-technical employees of the Technical Division, skilled or semi-skilled employees will be required in the Mechanical Department to build the necessary equipment to carry out the development work. The Technical Division has in the past required about 0.7 shop employee per technical employee. The 0.7 is split about as follows:

Work done on repair orders (less than $500 each)	0.25
Minor projects (labor cost less than $20,000 each)	0.11
Major projects (labor cost more than $20,000 each)	0.34
Total crafts employees per technical employee	0.7

5. Conclusions

In summary it is suggested that the manpower required in chemical development work at Clinton Laboratories for a "normal" development program containing experimental development (laboratory and semi-works), pilot plant, process design and start up assistance phases be estimated as follows:

Phase	Technical Manpower Per Process Unit
Experimental Development	20 technical man months
Pilot Plant	12
Process Design	5
Start up Assistance	5
Total	42

These are average figures and should be adjusted upward or downward to suit the individual case. In some cases pilot planting may be unnecessary, or start up assistance may be dispensed with. In such cases the total manpower required per process unit will be much lower than the above total. Non-technical manpower may be estimated roughly as 0.8 of the technical manpower.

For pile development work a ratio of 2 engineers (or metallurgists) to 1 physicist (or controls engineer) appears to be about right, and the total manpower required for one 30,000 KW pile is about 1400 man months.

The above figures apply only to that amount of effort necessary to bring a development project to a point such that all necessary experimental work has been done, all necessary technical advice has been given, the engineering design work has been done (presumably by others, since engineering design is not included in the above figures) and the installation has been put into operation.

EFFORT EXPENDED & TO BE EXPENDED

MAN MONTHS, PER PROCESS UNIT

Project	Exp'l Dev't	Pilot Plant	Proc. Des.	Start Up	Total	No. Proc Units	% Now Complete
706-D	13.2	None	4.8	6.8	24.8	10	100
Metal Recovery	--	--	--	--	15.7	14	50
Disposal Active Wastes	--	--	--	--	13	1	30
Ra-Be Sources	4.6	0.7	0.9	0.3	6.4	7	100
25 Separation Process	41*	22	10	--	73	11	69
23 Separation Process	20*	3	5	--	28	9	50
Pile Metallurgy	-- 30	--	3.5	--	33.5	9	64
Average	22	10	5		~30**		

* The Chemistry Division participated in this work to the extent of about one-fifth the amount shown with the asterisks. The table thus shows essentially all the chemical development work, regardless of the division in which it is done. It does not include pre-development chemistry, however.

** Note that the average total manpower is not the sum of the averages for the various components since not all components were included in each project.