Ninth Annual

Dominion - Provincial Coal Research Conference

August 30th - September 1st, 1957

PROCEEDINGS

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Research Council of Alberta
87th Avenue and 114th Street
Edmonton, Alberta

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NINTH ANNUAL DOMINION-PROVINCIAL COAL RESEARCH CONFERENCE

August 30th - September 1st, 1957

THEME - THE ROLE OF COAL IN CANADA'S ECONOMY

Conference Committee:

W. A. Lang, Chairman
W. C. Whittaker
S. C. Mifflen
M. G. Goudge
A. Ignatieff
W. E. Uren, Member ex officio

Research Council of Alberta
87th Avenue and 114th Street
Edmonton, Alberta

Foreword

Dr. Clarence A. Seyler, dean of British coal scientists, some years ago characterized coal research by saying that to report upon it is like trying to get off a fast-moving bus that refuses to stop or even slow down. But this bon mot, no matter how apt, contains only half the problem that faces us. The other half — the greater and more serious half — arises from the fact that modern coal research has become a discipline in its own right, and that its ramifications are now so vast that specialists in its various branches are finding it increasingly difficult to communicate with each other in terms that they, or the intelligent layman, can understand. The geologist, chemist, physicist, combustion engineer, mining expert, plant designer and economist, while often constrained to co-operate on a particular project, will yet each have their own special field of interest, their own narrow area of competence, and their own jargon. Faced with this seeming or actual confusion, the coal operator or industrialist upon whom devolves the responsibility for applying research findings, may well feel inclined to throw up his hands.

It is in order to prevent this sterilization of research and to publicize the results of scientific investigation that the Dominion-Provincial coal research conferences and the coal research committee were set up in 1948. The committee is charged with the task of maintaining proper liaison between the various Canadian agencies engaged in coal research; and the primary function of the annual research conference is to inform coal operators and others interested in the economic exploitation of coal of what is being done to provide new scientific and technical foundations for the industry. A second function, and one whose importance is perhaps still not fully realized, is to enable the researcher to obtain the coal operator's reaction to current research and to gather from him suggestions about spheres in which an expanded research effort is required.

The Ninth Dominion-Provincial Coal Research Conference, which was held in Edmonton on August 30 and 31, 1957, and the detailed proceedings of which are contained in this volume, appears by common consent of all participants to have largely fulfilled these objectives. Under the general theme "The Role of Coal in Canada's Economy", eight individual papers have attempted to present the organization and significance of research on coal and to broadly survey progress in a few selected fields. Discussions following each paper served to focus particular areas of interest. And several eminently valuable suggestions for future research activities were made both in the papers and in the business meeting of the conference.

In view of the range of topics dealt with by the conference, this preface cannot possibly attempt a detailed consideration of the many points that emerged from the sessions. Several major problems, however, which affect the industry as a whole, might usefully be commented on. They are the questions of research organization, current research trends and fields requiring more intensive study.

The forms in which individual research institutions (or laboratories) are set up are beyond our province here; while they were examined in Dr. Grace's paper to the conference, they are primarily the responsibility of research directors and management boards. But the conference was rightly concerned over matters of liaison between the several coal research agencies in this country, over communication between research laboratory and industrial interests, and over dissemination of research findings among interested lay parties. The work of the coal research committee and of the annual conferences has undoubtedly gone far to lessen these problems; but it would be unrealistic to think that they have been wholly resolved, or indeed, that they can be resolved from one day to the next. They are clearly matters that must be kept under continuous review. Consideration might perhaps be given to somewhat enlarging the coal research committee by the inclusion of a few specialists (e.g. as co-opted, corresponding members without voting rights), and to endowing it with limited funds in order to enable it to issue an annual publication on the lines of the British Coal Board's annual "Summary of Research Work". Similarly, some thought might be given to the possibility of annual or semi-annual specialist meetings of Canadian coal research workers. The desirability of such meetings was stressed by at least two speakers at the business meeting of the conference.

With respect to current research, there is every indication that the Canadian coal industry is now fully aware of the need for, and long-term value of, fundamental studies. Such studies are accepted as vital if the industry is to regain, and maintain, a high level of prosperity in the years to come. The Ninth Conference was, however, implicitly and explicitly concerned about some unbalance between basic and applied research and repeatedly stressed the need for an expansion of engineering and design studies. Mr. Gordon's paper, for example, emphasises the urgency of extending investigations into various phases of mine operation and coal-getting; Mr. Mitchell referred to metallurgical problems that require examination in connection with the new coal-fired combustion appliances; and both Dr. Christie and Mr. Cass-Beggs pointed to the need for operational research and economic studies in connection with new coal-burning thermal power stations. Problems of transport of coal and the possibilities of pipeline transport were touched upon in Mr. Whittaker's paper.

It is undoubtedly legitimate to think that several of these matters lie more within the province of industrial establishments than of government-sponsored or university laboratories. Improvements in coal-getting machinery, conveyor systems, underground locomotives and roof supports (looked for by Mr. Gordon) are perhaps good examples of topics that ought be left to the manufacturers of these products. Many of the improvements that can reasonably be expected are already largely protected by privately- or corporation-owned patent rights, and it is a safe assumption that the long-established manufacturer will have greater know-how, and therefore greater chances of success, than a small group of engineers working in a more academic environment and endowed with fewer material resources. But there are, without question, many spheres in which the research worker must not divorce himself from acute "practical" problems. Systematic combustion studies, investigations into coal grindability, an examination of behaviour of coal during transport and storage, metallurgical research of the type referred to by Mr. Mitchell, and new forms of coal beneficiation procedures are all aspects of the general coal utilization problem with which the research worker is peculiarly qualified to deal, and that would often go by default if he were not to concern himself with them.

Canadian coal research organizations (as well as institutions in the United States and in Europe) seem to have accepted this thesis. As research facilities in this country have expanded, research has expanded, and several of the problems pointed up during the Ninth Conference are now under active study both by the Fuels Laboratory of the Federal Department of Mines and Technical Surveys, and by the Provincial research councils. But the range of studies under way is so large, and the organizations in which they are being carried out are so numerous and so widely scattered, that the responsibility devolving upon the Canadian coal research committee and on the annual coal research conference is increasing at an accelerating pace. The committee and conference are now more than ever before the major clearing house through which research can be brought to fruition in industrial application. It was the hope of the program committee of the Ninth Conference to contribute to this.

Summary of Technical Program,
THE ROLE OF COAL IN CANADA'S ECONOMY

Chairman's Remarks

It is my pleasure on behalf of the planning committee to welcome you to the Ninth Dominion-Provincial Coal Research Conference. I am sure also that Dr. Grace, Director of the Research Council, would wish me to express Council's pleasure in having this meeting held at the Research Council of Alberta. A formal welcome will be extended on behalf of the Province and the Research Council at the banquet this evening by the Hon. Gordon E. Taylor, Minister of Highways, Minister of Telephones, and Chairman of the Research Council of Alberta.

Since some of you may not be fully aware of just what the Dominion-Provincial Coal Research Conference is or what it attempts to do, I thought it advisable to briefly outline the formation of this conference, and its aims and aspirations.

At the Fifth Annual Conference of Provincial Mines Ministers held at Jasper National Park in September, 1948, the need for greater co-operation between Dominion and Provincial organizations, and the coal industry was stressed. As a result of this suggestion, the Ministers of Mines approved a resolution which, in part, reads as follows:

> "Realizing the need for closer liaison and co-ordination of the work of these organizations (Dominion and Provincial government research institutions, and the coal industry) in order to avoid duplication of effort and to ensure the greatest benefits to the Canadian economy, it is suggested:
>
> (1) That Dominion and Provincial authorities dealing with research should establish a co-ordinating committee to review the work which had been done and to consider on a broad basis a policy with respect to research; and
>
> (2) That the committee consider how the results of research done in Canada and elsewhere can be made available to those whom it will benefit.

At the same conference, the Ministers approved recommendations that had been submitted by the coal industry concerning a coal policy for Canada, and coal sales acts, both for those provinces producing and selling coal, and for those provinces receiving coal. They further approved and named a Standing Committee on Coal. The duties of this committee would be to investigate all matters dealing with production and sale of coal. The findings of the policy committee were to be presented to the Provincial Ministers of Mines who would in turn take up these matters with the Federal Government.

You will see that two ideas were developed at the Fifth Provincial Mines Ministers' Conference:

(1) the need for a research committee,

(2) the formation of a standing committee on coal policy.

The next development of interest was a meeting of senior government and research officials called by Mr. Uren, Chairman of the Dominion Coal Board. This meeting was held in the Board Room of the Dominion Coal Board, Ottawa, December 6 - 8, 1948 and was followed by meetings with members of the Coal Board on December 8 - 10.

The minutes of the Coal Research Meeting read, in part, as follows:

"The delegates were welcomed by the Chairman of the Dominion Coal Board who in a short address, outlined the background of the meeting and set out the task as:

(1) Consideration of the work presently carried on under provincial jurisdiction on all matters having to do with the more efficient production and utilization of coal.

(2) The development of methods for the co-ordination of such work and the creation of plans for the future whereby the individual projects can be correlated one with another.

(3) The building up of the spirit and means of co-operation in this important work that will produce the greatest benefits to each body individually and to Canada as a whole."

Meetings of this group were held in Ottawa in 1948, 1950, 1951, 1952 and 1953. Members of the Standing Coal Policy Committee of the Provincial Mines Ministers met at the same time.

An innovation in 1954 was that the Dominion-Provincial Coal Research Conference met immediately prior to the Provincial Ministers of Mines' Conference and in the same locale. This procedure was followed in 1955 and 1956. This year, the locale has been changed but many of the delegates will be proceeding to the Ministers of Mines' Conference in Vancouver. At the meeting held at Lake Louise in 1956, a program committee was set up. The committee met in Ottawa in April of this year. We trust that the program which was worked out there will prove of interest and be mutually beneficial. It is likely consideration will be given at the Business Meeting on Saturday evening, as to whether the conference is fulfilling the purpose for which it was constituted, and also what should be the pattern for the future.

The Objectives Of A Research Program

by

N. H. Grace

Director of Research, Research Council of Alberta,

Edmonton, Alberta.

The Planning Committee for the Ninth Dominion-Provincial Coal Research Conference has aptly chosen "The role of coal in Canada's economy" as the broad subject for its deliberations in Edmonton on this occasion. It is my privilege to discuss "The objectives of a research program", under the theme "Research as a necessary tool to improved developments".

Representation at this Conference is made up of three groups, namely, representatives of industry, of government, and research personnel. Approaching this subject of "objectives for a research program" imposes something of a challenge under the circumstances. Obviously, each group represented here will tend to look somewhat differently at research of itself and also will possibly have a varying appreciation of objectives. However, the fact that this is the Ninth Dominion-Provincial Coal Conference indicates quite clearly that this group of industrialists, government people, and research personnel have been working together in the past and have found common ground. It is our hope as we develop this subject that we may stand on ground which most can accept, as common and vital in sound research development.

Lest there may be any misunderstanding, I want to make two points perfectly clear. First, as the title of the whole program indicates, coal has been vital in Canada's economy and I, for one, feel that there is every indication that coal is and will continue to be of vital importance for a long time to come in the future. In the second place, I hope you can go with me in accepting the theme of this morning's session, namely, that research is a necessary tool to "improved development". This is a proposition which hardly needs discussion; however, there may be some "doubting Thomases" and they will be referred to a recent publication, namely, the 1956 edition of the Industrial Research Laboratories of the United States, a list prepared by the National Research Council, Washington, D. C. This gives 4834 research and development laboratories operated by 4060 companies. A sizable number of these companies were not operating research programs ten years ago, and a majority of them were not doing so fifteen years ago. As for the programs that did exist then, most have grown so fast, that today they can hardly be recognized. This reference surely indicates the importance of effective research and development programs in our rapidly developing North American industry.

Natural resources are only developed through the application of capital, management, labour, and technical skills which in their combined efforts produce a needed, available, and saleable product or products. Canada is in an almost unique position in its availability of a variety of high quality coals and a great quantity of them. An article entitled "Outlook and Research Possibilities for Bituminous Coal" published by the United States Department of Interior in May 1956 speaks as follows under the heading "Total Energy Requirements of the Future":

"The unprecedented and continuing growth of our population, the tremendously accelerating demand for electric power and a heavy expansion of our industrial economy, indicate that demands for energy will reach phenomenol proportions within the next twenty-five years. Although there are some differences in the estimates of various experts as to the magnitude and timing of successive new peaks in total energy demand, these estimates fall within the range that indicates an increase of about 25,000 to 30,000 trillion B.t.u. over the present energy demand in the next twenty years,or approaching a two-thirds increase.

"The principal interests with respect to coal in these forecasts are:

1. The extent to which it will participate in the increased energy demand and,

2. When will the increasing demand begin to manifest itself in terms of substantial and sustained increases in coal production and utilization.

"The answers to both questions lie primarily in the extent to which the coal industry will be prepared to assume the greatest share of the expanded energy market, as distinguished from having to accept the residual demand that cannot be supplied by other energy sources.

"Each major facet of coal technology — production, transportation, and utilization — will require early planning and action on an unprecedented scale if the objective is to be met. Coal producers, transporters, and users alike will have to participate if the nation is to get the greatest value from one of its largest natural sources of energy."

This quotation and the detailed statistical studies on which it is based, as well as many others, make it abundantly clear that research and development in the domain of coal can accomplish much. Achievement can be expected to be directly related to the quality and magnitude of the research and development effort which is applied. Gentlemen, one of the important aspects of any research and development program is a challenging, yet reasonable, objective. Here today we surely face, in coal research, a great and yet reasonable research and development challenge.

Perhaps at this point it should be made quite clear that the purpose of our discussion is to deal with <u>objectives of a research program</u>, not the detailed and specific objectives in regard to research on coal. We are well aware of the many laboratories working in North America, Great Britain, Europe and elsewhere on coal and coal problems. One thing these programs all seem to stress at this time is work on the occurrence, properties and constitution of coal. Coal is undoubtedly the largest store of fossil organic substance, but its utilization lags. Scientific and technological advances suggest that it might best be used, not as a fuel but as a chemical raw material. The foregoing is apparently part of the drive behind many of the research programs which are being drawn to the attention of all workers in this field.

I wonder if any of you have read the popular book by Cameron Hawley in which through his main character, Cash McCall, a rather shrewd observation is made regarding research and development. Cash is an amazing dealer in businesses, buying and selling at just the right times. Cash is talking with one of the bright young men in his employ and speaks as follows: "Research is fashionable now — it's the thing to do — build a big beautiful laboratory and fill up with Ph.D.'s. Theoretically, it has to pay off. In a lot of cases it hasn't — and there will be more where it doesn't. I can buy a dozen companies right now that have poured too much down the research rat hole......

"The trouble usually isn't in the lab; it's up on top, as I see it, that's the most common weakness in general management today. You can walk into company after company — surely you have seen it yourself — and find good financial management, good production management, good sales management, everything under tight control until you hit research. Then it's a wing and a prayer."

Gentlemen, what of the management of research and development? By management, I refer in this complex field of coal investigation, to the working together of the various interests which must come together, work together, and, of course, <u>above all</u> plan together. These groups obviously are, industry and government — the two bodies who through mutual interest, public interest and from a variety of reasons are mutually responsible for the organization, development and management of research. The whole research program must of necessity have an intelligent, able, effective management. Let us be quite clear at this point, I am not referring to individuals. Reference is, however, being made to the mutual planning by the various parties interested in diverse aspects of the great industry, on which research and development is to be made. I like to look at this group as representative of the effective management which is needed to attain a first-class coal research program.

When the research and development program involves industry and government, there are obviously several problems to be faced and surmounted in achieving the effective integration of the best kind of program. The industrial representatives must, of course, be sympathetic with the attitude of the government scientists on the one hand, and yet the government scientists can profit much by the factual dollars-and-cents attitude of the industrialist, and a blending of these two interests is a "must be", a major objective, in the development of an effective research program. I do not hesitate to stress this point. The scientist in the laboratory can profit greatly from the industrialist, and the industrialist must not hesitate to be frankly critical. Before leaving the important subject of research management, the type of research and development we are considering today, in the final essence, will have to be through a committee. Let us bear one final point in mind, namely, a committee is vitally needed in the initial planning of a program, in assessing the relative merits and priorities which should be afforded individual projects. It has, further, a great responsibility in the sympathetic, yet critical, periodic evaluation of the developing program. The committee must not hesitate to effect changes in detailed objectives, dropping certain projects and taking on new projects as these courses of action are indicated. However, in the final essence, it must be realized that research per se can never be directed by a committee. True research can only arise through the superior intellect of the individual worker.

For example, in coal we have a challenging domain for profitable research. We see that both industry and government, the bodies providing financial sponsorship for research and development, must get together, keep together, and work together closer than they ever have before through the planning and data-collecting stages of the research programs. Bearing in mind the intricate series of detailed problems which exist, it is highly important that some thought be given to what is meant by research and what kinds of research we should undertake to make our program truly effective. Doubtless you have all been wearied by many definitions of fundamental, basic and applied research, and I shall not attempt any mere repetition of these. Furnas in Research and Industry suggests that the possible objectives of industrial research are:

1. To improve the quality of products,
2. To develop new materials, processes or devices for existing or new markets,
3. To develop new uses for existing materials, processes or devices,
4. To cut costs,
5. To abate dangers or nuisances,
6. To prevent or cure troubles of production or use,
7. To assist in standardization,
8. To improve customer and public relations.

These are valid and are generally quoted as objectives of research and development, but most of them are not stated in terms that imply the nature of the need. However, on careful examination, I think we will find that the above list pretty well covers the broad field in regard to coal investigations.

I personally have been interested by W. L. Swager's classification of two types of research. These are spoken of by him as follows: Intellect-oriented research is that technical endeavour usually considered basic or fundamental research, which is motivated by a man's curiosity. It is obvious that the control of this kind of research begins with, and ends with, the selection of the man. Once he is selected and provided with equipment, assistants and a research environment, there is no external control. Then there is need-oriented research and development, which on the other hand, is that technical effort of interest to most of us where our goals and motives are new products, new markets, lower costs, improved quality, and the like. The planning and control of need-oriented research and development are inextricably entwined in the assessing of needs and the economics of satisfying them. We thus have Swager's intellect-oriented and need-oriented comprehensive classification and a detailed list such as that of Furnas. It is obviously the responsibility of management to assess the field to be covered and organize the most effective program.

Reams have been written on the setting of criteria for research and development. Management has found, to its sorrow, that standard control and evaluation procedures are not readily applicable to research and development programs. Efforts must be made to find new procedures by which appropriate priorities may be accorded to individual projects and by which, from time to time, they can be effectively evaluated, individually and relatively. Consequently, management must always be aware of the need for full thought and consideration in this matter of weighing of projects before they are commenced, and following them afterwards, while they are in operation. Efforts have been made to produce mathematical expressions which are of some assistance in this matter. Personally, I feel that in the domains of applied investigations such efforts have a reasonable likelihood of success.

Recently, in an article in Business Week, a formula developed by American Alcolac is given.

$$\frac{\text{Chances of Technical Success} \times \text{Chances of Commercial Success} \times \text{Annual Volume} \times \left(\frac{\text{Price-}}{\text{Cost}}\right) \times \sqrt{\text{Life}}}{\text{Total Costs}} = \text{Project Number}$$

President Blinoff of American Alcolac discusses several examples in which this particular formulation has been a real help to his company, in evaluating a project; the application of the formula has actually saved the company money in certain cases, and helped them to go ahead and profit in other instances. Possibly some thought should be given to these efforts at evaluation. However, it is my own feeling that if management is conscious of all such attempts to evaluate the applied programs, it will at least be helpful and lead to a more effectively critical spirit. When it comes into the domain of the more fundamental or basic kind of investigation, I feel that there is little hope for any simple mathematical formulation. Such, at the best, may lead one astray as often as it will be of assistance. There, management must combine an element of reasonable common sense with necessary vision, and encourage the investigators working in such fields.

We are now in the position where our objectives in regard to effective management and selection of individual projects have been stated. What follows? Next comes the vitally important matter of staff selection and project organization — the choosing of the right kind of training, combined with the right kind of intellect and personality to work on the particular problem or group of problems. Modern science is becoming extremely complicated; in a number of cases it is found that not one scientific talent, but a group of such are required for the development of a particular project. If only one scientific talent is needed, the choice is much simpler — a highly trained splendid intellect is usually the goal of the research director though for many jobs a good average man with the right kind of encouragement is able to do a commendable job.

Where a variety of scientific disciplines are needed for the development of an individual project, there indeed management is faced with a series of problems and decisions, and it must be a major objective in the planning of research that these decisions be made in such a way that the work will be given every chance to develop as effectively and as rapidly as possible. Let me illustrate some of the problems which are encountered at this stage of the development of a research program. Let us say that one requires for a particular project, engineers, several kinds of chemists, a microbiologist, microscopists,and so forth. If there are several such complicated projects requiring immediate action from their high priority rating, how should a laboratory arrange its staff? Should there be organization along the lines of disciplines? Namely, would you put engineers together, chemists together and so forth, and work from such groups, or would you set up a project group which should combine all the needed scientific and technical skills for the development of the project in hand. Let us examine some of the problems to be faced in making the right decision under these circumstances.

There is a strong tendency for laboratories to become organized functionally, chemists with chemists, engineers together and so on into permanent specialists groups; the consequences of this process, for morale and productivity, are hard to assess. There is some evidence that this has a depressing effect on creativity, enthusiasm, inter-personal and inter-group co-operation. The principle of putting like specialists together is quite in accord with professional organization traditions, and has many advantages such as the ease of comparing individuals, one against the other; it facilitates observance of such matters as the submission of technical reports, and other rules and regulations. Moreover, it permits each man to be employed at the work he likes best and allows him to develop as a professional specialist. It usually provides him with secure status in the organization, and a clearly defined path of advancement. It makes for good communication between the laboratory and other parts of the organization, and is helpful for reliability in budgetary forecasts. However, such functional organization has its disadvantages. Among these may be mentioned resistance to crossing specialists' boundaries and co-operating with other groups; a tendency to work on ever more-specialized problems of ever decreasing significance; lack of creativity and responsiveness to challenge — a scientist becomes a specialist in knowing what cannot be done, and is afraid to venture into unfamiliar fields. Recent studies have suggested that in a functional organization such association may be detrimental, that the ratings of research and development from such groups fall off directly with the length of time members have been associated with one another.

The alternative to functional organization is organization by _ad hoc_ project teams, with specialists from various fields as members so that each team is equipped to solve a particular complex problem requiring knowledge from several disciplines. The project-team approach has an immediate and obvious advantage over the functional approach. The team members' energies and interests are all concentrated on a single complex problem. Such teams often turn out to be enthusiastic, creative and dramatically successful. Unfortunately, organization by this method presents serious administrative and personnel problems. Such project-teams tend to perpetuate themselves and become specialist groups. There is often strong resistance to project termination and transfer to new groups. As team-members, such workers do not achieve the same degree of specialized knowledge the laboratory requires to keep abreast of advancing technology, and the project may tend to rely a bit too much on its own resources and is not too ready to consult the literature or other specialists. Inter-group jealousies are often developed. Too much depends upon the leadership and technical competence of the team supervisors. Men with the necessary quality for such leadership are rare, the path of promotion is not clear, and supervisors have to evaluate representatives of several disciplines, and may lack the knowledge to do this objectively. Project termination causes insecurity. This whole problem is discussed by Herbert A. Shepherd in the Nine Dilemmas in Industrial Research, published in the Administrative Science Quarterly of Cornell University, December 1956. Shepherd concludes his discussion at this point, which I have quoted above fairly extensively, as follows:

"In most laboratories some combination of functional organization and ad hoc team organization is used. Each appears to have its advantages and disadvantages from the point of view of administration, productivity, creativity, and satisfaction in work. Choosing the most appropriate combination of functional and project modes of organization is not the only organizational problem in the laboratory, however, nor does the solution automatically take care of all human relations problems."

The importance of selection of the right kind of group leadership cannot be overemphasized. Many studies have been made of this matter and a variety of reports all stress the great importance of the group leaders' personal qualities. He must be interpreter of the group needs and achievements to higher levels of management, and act as interpreter of management requirements to his group. He must protect the group from demands and pressures which he believes will adversely affect it. He is a source of technical guidance and judgment, of inspiration and stimulation. He must co-ordinate the ideas and resources of his group. Studies of Shepherd and his associates show the successful research group-leader to be a more active social being, than the unsuccessful group leader. He has many friends in the laboratory, centres his social life around the laboratory. Studies by Stein suggest that the successful research group-leader has certain charismatic attributes. Subordinates tend to identify with him and model themselves on his pattern. All of these observations point in the same direction — the effective research group-leader is a creative, dynamic, enthusiastic person who relates easily to others. Such men are said to be rare among engineers and scientists. Thus, as a major objective in its research organization, management has to decide on the particular make-up of its project groups and pay especial care to the selection of group-leaders and supporting staff.

The development and maintenance of the right kind of relationship between the professional and non-professional workers presents a problem, and it must be a major objective of management that this difficulty is resolved as fully as possible. Many professionals regard participation in activities involving the drafting board, hardware and glassware as somewhat degrading, or as they put it, "an uneconomical use of professional time". This attitude does not endear them to the non-professional workers. Given this attitude, any sign of incompetence in these matters on the part of the engineer wins him the enmity of non-professional personnel. Such enmities appear to flourish in functionally organized laboratories, where inter-personal difficulties can quickly develop into inter-group conflicts. In project organizations, on the other hand, there often develops an intense loyalty between the professional and non-professional members of the team. The professional sometimes regards himself as teacher and protector, the non-professional as student and apprentice.

Much has been written on the importance of the social factors in research and development performance. Studies of the research atmosphere and the question of contacts of individual on individual is of outstanding importance. It appears that many scientists may benefit from (a) close colleagues who represent a variety of values, experiences, and disciplines, and (b) supervisors who avoid both isolation and domination, and who provide frequent stimulation combined with autonomy of action. Thus, there must ever be efforts made to develop, foster and encourage the right kind of research atmosphere, if the work is to be done in the way it should, if morale is to be maintained, and creativity and productivity maintained at the highest possible level.

Obviously there must be effective communication in the whole question of project development, and that is a problem which goes back to individuals who are working in the projects involved. The impact of personal relations is of unquestioned importance in this connection.

Nothing has been said up to this point on the research plant, and this, I think, is the appropriate juncture at which the importance of research facilities should be mentioned. Obviously, a well-designed research building is needed, and if there are to be applied investigations in coal conducted, a suitable pilot plant is also a physical necessity. These needs must be supplemented with the right kind of heavy and modern equipment. However, let us remember that buildings and the equipment by themselves, and of themselves, are simply a means to an end. Research and development will proceed or fall as it is organized and, in particular, in accordance with the type and qualities of the staff selected to conduct it. Certainly, no one expects individuals to make "bricks without straw" and likewise scientific and developmental advances will be retarded unless supply is made of the necessary modern adjuncts. But there are far too many laboratories provided with highly specialized equipment, and yet producing very little. The important thing is the human intellect which is dedicated to the application of all modern instrumentation to the particular project in view. In the last analyses research and development depend on human thought, effective mental action is what is required and what must be applied.

You may wonder why nothing has been said up to this point on the matter of research financing. It is important that a program of research and development receive adequate budgetary support. This is an obvious objective, but if the broad field of investigation is really challenging and, if in this case, industry and government get together, and really work together, there is no doubt in my mind but that the needed funds will continue to be made available providing programs of research and development are carefully conceived, consciensciously and ably developed, and then critically evaluated, terminated, modified, enlarged or continued, in line with the need and the opportunity.

The Organization And Co-ordination Of Coal Research in Canada And Remarks On The Principal Projects Of The Fuels Division. *

by

D. S. Montgomery
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Department of Mines and Technical Surveys.

The organization and co-ordination of coal research in Canada is a matter of considerable importance, not only to the coal industry in its present situation, but to help this industry to anticipate as well as to meet the demands of the future.

The co-ordination of coal research within a given organization, and for that matter between different organizations, is not as simple as might be supposed due to factors which tend to disperse the activities of the research organization, making it extremely difficult to have strength in every sector. This gives rise to the need for co-ordinating activities of the various agencies conducting coal research.

In the narrow sense coal research refers to research on the nature of the coal substance itself. However, any organization which has as its major objective assistance to the coal industry discovers that it must encompass a very wide territory, making use of specialists in many fields. This situation arises from the fact that reductions in the cost of using coal must come from small reductions all along the route from mining to final use.

Even if we confine ourselves for the moment to the field of coal chemistry, which must provide the basis for entirely new uses of coal, it has been very ably demonstrated by the English and the Dutch that the structure of coal is so complicated that the co-ordination and co-operation of experts in many fields is an essential requirement for rapid progress. In fact, every modern technique for elucidating the structure of organic

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substances is required. This means that the efforts of specialists in such different fields of scientific enquiry as X-ray diffraction, nuclear magnetic resonance, organic chemistry, and physical chemistry, must be co-ordinated to synthesize a picture of the coal substance. One of the essential requirements for co-ordination is a medium for the exchange of information and a desire on the part of the experts to express the results of their research in terms that are understood by those working in related fields.

The interests of the coal operators vary in some degree, but cover a much wider territory than that of the coal substance itself. For example, associated with mining there are often regional and structural geological problems which if clarified would assist the mining engineer in conducting the mining operation. There are, of course, a host of problems associated with the selection of the most suitable mining methods in a given area, and the cheapest mode of transport, not to mention problems in the field of coal cleaning, storage, disposal of the fines and so on. To these must be added the interests of the consumer which are directed toward selecting and developing the most suitable apparatus for using coal. However, the point to be emphasized is that a Canadian organization which attempts to cover every field is apt to be weak in every sector. As is well known, the art in establishing a research program lies in keeping the research effort properly balanced, which involves selecting those projects where effort must be concentrated and deciding what projects may be safely postponed. It is in this area where the co-ordination between the various research agencies would be important in deciding on the projects requiring emphasis, and the co-operation and suggestions of the coal operators would be of great value.

During the prewar era both the Province of Alberta and the

Federal Government were interested in the classification and characterization of coals, in an attempt to evaluate the material resources of the country. This brought about close co-operation through work on A.S.T.M. committees associated with coal classification. Probably the most significant recent development in co-ordination between the various coal laboratories is that six of them have agreed to co-operate in exchanging samples on a monthly basis to ensure analytical uniformity across the country, and to guarantee the operators accuracy in the measurement of the calorific value of fuels. Periodic exchanges are also made with the United States Bureau of Mines to ensure continent-wide uniformity.

In the postwar era the interests associated with coal have spread far beyond classification. Much more attention is being devoted to chemistry, petrography, and the utilization of coal. This more extensive coverage requires better co-ordination. To illustrate the extent of this expansion, the Geological Survey of Canada maintains a Coal Research Laboratory in accommodation provided by the Nova Scotia Department of Mines. Here research on the petrographic composition of coal is undertaken by Dr. Hacquebard on both Eastern and Western Canadian coals. A joint project is now being undertaken between the Geological Survey of Canada and the Fuels Division of the Mines Branch, to study the relation of the petrographic constituents to the coking properties of Sydney coals. The Nova Scotia Research Foundation, in addition to aiding the Coal Research Laboratory in Sydney, also supports chemical work done at Mount Allison University by Dr. C. A. Cuthbertson on the oxidation and ozonization of coal. For the past few years the Nova Scotia Research Foundation has awarded postgraduate scholarships to Maritime students who wish to carry out research on Nova Scotia coals at the Massachusetts Institute of Technology. This research has been devoted for the most part to the study of the coking and plastic properties of Nova Scotia coals using differential thermal analysis.

In Western Canada the growth of the Research Council of Alberta since 1943 has been most impressive and encouraging. This institution is to be congratulated on building up a fine technical organization. Projects have been undertaken in both the fields of basic and applied research on coal. These projects include research on analytical methods, paleobotany, organic chemistry of humic acids, physical structure of coal as revealed by X-ray diffraction, and differential thermal analysis. On the applied side, fluidized carbonization, briquetting, grindability and combustion are being studied in some detail.

One evident outcome of the diversity of topics studied in coal research is that it becomes impossible for one person to speak authoritatively on every aspect of such work, and opportunities should be provided for those engaged in similar work to have periodic discussions.

The organizational framework designed to facilitate the co-ordination of Canadian coal research has grown up along slightly different lines in various parts of the country. The development of the natural resources is a provincial responsibility, but in the early days before the provinces established organizations of their own to undertake research on fuels a central agency was developed in Ottawa to evaluate the properties of the fuel resources discovered by the Geological Survey of Canada.

In Nova Scotia, research projects associated with coal are co-ordinated through the Advisory Coal Committee of the Nova Scotia Research Foundation. Any work done by the Federal Government in the province is reviewed by this committee and very helpful recommendations are received concerning the best method of proceeding with a given project. Sometimes as many as three or four agencies are involved, such as the Nova Scotia

Research Foundation, the Nova Scotia Department of Mines, and various branches of the Department of Mines and Technical Surveys.

In the western provinces no counterpart of this committee exists although in Alberta close co-operation in certain areas is possible by virtue of the fact that a representative of the Mines Branch is located in the building of the Research Council of Alberta. The Fuels Division recognizes the importance of co-operating with other agencies as well as the necessity of regional work to bring about more effective aid to the industry, and the work would be intensified if the funds and manpower were available.

Lastly it is the feeling of the Fuels Division that the co-ordination between the various research agencies as well as among those interested in coal might be improved by consultation prior to Commonwealth conferences so that Canada's views may be expressed in a unified and authoritative manner.

Remarks on the Principal Projects of the Fuels Division During 1956-57.

The Fuels Division has recognized the great economic pressure which is being exerted on the coal operators by the abundant supplies of liquid fuels in Western Canada. In an effort to do work which would be of more or less immediate benefit to the coal industry, the Fuels Division has attempted to concentrate upon projects in the field of applied coal research, particularly in those areas which are thought to give rise to large bulk uses of coal. This concept is responsible for the Division's active interest in the metallurgical uses of coal. Cyclone smelting has been studied for some years and an application for United States patent is being made to cover certain phases of this work. Research is being conducted on the rate of reduction of iron ore in carbon monoxide and hydrogen atmospheres to supply information which may form the basis for a rational design of a pulverized-coal-fired smelting unit. The kinetics of the reduction of hematite to both magnetite and iron are being studied. It is felt that there may be some application for a process capable of reducing hematite to magnetite, to enable low-grade ores to be concentrated magnetically.

In an effort to provide an alternative to the rapid conversion of the railways to diesel locomotives, a coal-fired gas turbine engine operating on the Mordell cycle was studied at McGill University with a view to securing basic information on the suitability of this type of cycle. A detailed report of the results of this investigation is now being prepared. Briefly, to achieve the efficiencies of the diesel engine the heat exchangers in the Mordell cycle have to be operated at high temperatures. This creates severe metallurgical problems which have not yet been solved.

In the area of mining research the Division has been conducting studies in coal mines of Eastern and Western Canada into problems of ground stress that restrict mining operations at depth. At Springhill, Nova Scotia, observations are being made into strata deformations associated with full seam long-wall extraction. In addition, stress changes within the solid rock and coal seams have been investigated with special bore hole load cells. Similar observations were carried out in Western Canadian coal mines to observe the effects of strata stress associated with room and pillar methods of extraction. The Dominion Observatory and the Nova Scotia Research Foundation are co-operating in such investigations by conducting seismic studies at Springhill, N. S. This study has indicated a recognizable association between the frequency of occurrence of ground tremors and the rate of coal extraction, but due to the absence of bump occurrences during the observation period, no relation has been established between the pattern of seismic activity and bump phenomena.

The data obtained from use of bore hole instruments require considerable computational work to determine the magnitude and direction of the principal stresses. The Burroughs E101 Computor has been a very useful aid in completing the work. While such calculations provide information on the stresses within the load cell, they require further interpretation in terms of stress within the enclosing medium, either rock or coal. The Mining Engineering Department of the Nova Scotia Technical College, Halifax, is conducting research to establish the necessary correction factors.

It may be recalled that electrical resistivity measurements at Canmore were made in bore holes drilled into the coal seam. The large fluctuations in resistivity values in certain zones seemed to be associated with subsequent outbursts. In order to study the effect of occluded gases on such values, measurements were made in Ottawa of the resistivity of blocks of Canmore coal under pressures of up to 1,000 pounds per square inch of carbon dioxide as well as methane. It was shown that the action of these gases under pressure did bring about some decrease in resistivity, but not of the order of magnitude observed in Canmore. It was concluded that small changes in moisture content were responsible for the low resistivities observed. This year, in addition to making resistivity measurements, gas samples from the boreholes are being taken as well as samples of coal in order to study a possible relationship between the composition of the gas contained in different zones of the coal seams and the tendency of such zones to outburst. The moisture content is also being determined. The pattern that seems to be emerging is that there are dry and slightly moist areas in the coal, and that at the boundary between these zones considerable quantities of gas exist with the tendency to outburst substantially increased.

In relation to coking, about three years ago the Fuels Division began to undertake some work to secure a more intimate knowledge of the coking coals of Western Canada under light overburden. The first step was to find a suitable test to evaluate coals quickly. The Gieseler plasticity test was chosen because it was being used by a steel plant in the western United States. This test was not found to be convenient for the rapid assessment of a large number of coals, and indeed it was found to be difficult to secure reproducible results with this apparatus even in the hands of a skilled operator. Consequently, there was some doubt as to the value of this test as the sole criterion for blending coking coals. For this reason it was felt that the A.S.T.M. swelling test was a more rapid means of evaluating coking coals, including the variations that occur within a given seam. As specific examples of what has been done, an area in a mountain strip mine was sampled for variation in coking properties, and at two western underground mines samples were taken sectionally through the entire seam thickness. Wide variations in the swelling properties were found. It would seem that for the production of desirable grades of coke, selective mining or preparation would be required.

Another field of interest to the Fuels Division concerns the storage of coal. The high sulphur content coals in New Brunswick are notoriously difficult to store so that spontaneous ignition will not occur. A pile of this type of coal was carefully laid down employing a technique recommended by the Fuels Division with thermocouples at numerous points to study the rate of increase in temperature. As yet, no sign of heating has taken place and the indications are that this storage technique will be successful.

Considerable effort has been expended to develop a ring analysis system for determining the structure of hydrocarbons in coal tar pitches and bitumen. The purpose of this research is to provide a means to follow changes in hydrocarbon structure resulting from various thermal and chemical treatments. It is felt that this ring analysis system can play a role in coal chemistry analogous to the role of accurate bearings in navigation. The system developed, though it requires a modern high speed computer, is relatively accurate and appears to have a promising future in the chemistry of hydrocarbons.

As the aluminium industry demands considerable quantities of hard coal tar pitch for the manufacture of electrodes, a number of these pitches have been studied to determine the qualities that are necessary to produce the best electrodes. Infra-red spectroscopy and ring analysis are being applied to this problem. So far it has been shown that the electrode compressive strength can be predicted from the infra-red absorption spectrum with considerable success. The research on coal tar pitch provides an excellent opportunity to develop research tools suitable for tackling the more difficult problems associated with the determination of the structure of coal.

A matter of frequent concern to coal operators is coal dust explosibility. The apparatus required for determining the minimum ignition temperature and the relative explosibility has been constructed. A Hartman apparatus to measure the pressures due to dust explosions and to evaluate the minimum energy required to ignite a dust cloud is under construction.

The production of synthetic liquid fuels from coals by the Bergius process has never been commercially attractive in Canada. Last year a laboratory was planned to investigate a new approach to this problem which involves the use of intense gamma radiation and catalysts. This laboratory has been essentially completed and investigations in this new area of coal research will be undertaken shortly to see if coal will play a new and unexpected role in the atomic age.

A Coal Operator's Thoughts on How Research Can Help the Industry.

by

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Broadly speaking, research can help the coal industry to reduce its inherent hazards, to cheapen production costs and to market an improved product.

To the operator pure research and research in design are practically synonomous in meaning. Into the former category, as one sees it at this time, fall the problems of safety and utilization, while into the latter falls the broad problem of machine design. Frequently, pure research and research in design are closely allied and inter-dependent.

Today, many consumers of coal call for a product of more or less uniform size and with a minimum of fines. The percentage of coal consumed which falls into this category is quite large. It, therefore, falls on the operator to produce from his colliery as large a percentage of round coal as it is possible to get. There are on the market today a number of machines which can produce coal almost continuously in large tonnages, but almost invariably these machines produce a high percentage of fine coal. Efforts which have been made to date to increase the percentage of large coal produced by continuous mining machines have not been very successful. Much research is required to improve machine design to the point where a maximum tonnage of large coal can be produced continuously. This is entirely a matter of applied design.

As long as coal-getting machines, as we know them, are used, it is essential to the industry that such machines should be capable of being operated with a minimum of labour and that repair costs of the machine should be kept to a minimum. The matter of cheap operation is one of design research, while the problem of low maintenance cost is one of pure research into a choice of materials and coupled again with design research.

Once the coal has been broken from the face it has to be brought to the surface by one means or another. During the past 25 years the development of conveyors and even of mine cars has greatly improved. Through research, belt manufacturers have greatly improved their product, both in strength and in reliability. There is, however, room for much improvement in belt conveying systems, for in almost all installations underground there is the constant danger of fire being started unless the whole installation is kept under a more or less constant inspection. Probably the cable belt conveyor is nearer perfect for underground work than any other belt conveyor yet produced. This particular type of conveyor has been developed only after many years of research.

Where belts cannot be used and conveyors of the general flight type have to be installed a considerable breakage of the product occurs. The power required to drive such a conveyor is comparatively great and maintenance costs relatively high. Research into conveying systems is required in order to produce a conveyor which is essentially safe, which can handle the product without breakage, which requires a minimum of power, and which has a reasonably low maintenance cost.

In recent years mine cars have been greatly improved, both in size and in free-running ability. The development of such cars has lessened transport costs but further research is required to develop a mine car which is free-running, of large capacity, of light tare, and of sufficient ruggedness to avoid heavy maintenance charges. The problem is a combination of pure and applied research.

Today, an increasing number of locomotives of many types are used in underground roadways where the grade is reasonably flat. Locomotives have many advantages over rope haulage and conveyors because of flexibility. Many of these locomotives, both Diesel and electric, are reasonably efficient but further research is required to improve their reliability and cost of maintenance.

Research into roof support in recent years has produced improved roof bolts, improved yielding steel supports for roadways constructed through moving ground where rigid supports are rapidly distorted and rendered useless, and has produced improved yielding supports for longwall work. Research which has been done on methods of roof support to this time has greatly improved colliery performance, but still further research is required to improve such products as are now available. Where heavy supports are used for securing the roof of longwall faces, their weight is objectionable because the supports have to be frequently moved. Research is necessary to produce metal props of a yielding design strong enough to do the work required of them, yet light enough to be readily handled.

Fine coal, much of it in the form of very fine dust, which is objectionable to the average consumer but which is made by our present mining methods, creates one of the great hazards of underground coal mining. Today, it is impossible to effectively lay the dust made and thrown into the mine atmosphere. Much research is required to determine means of completely laying fine dust in the immediate areas in which it is made, in order to reduce to a minimum the hazards it creates.

Research is required into the means of detecting various mine gases, automatically, quickly and at the position in which a sample is taken. It is essential that the apparatus designed to do the work should be unfailingly accurate. Several machines are marketed today for the detection of methane and carbon monoxide. Much further research is required to produce machines which are completely reliable for the detection of these gases and which will produce readings readily and accurately.

Continuous research into means of improving lighting underground has been carried on since the production of the Davy lamp. This has resulted in very much improved lighting underground. However, the introduction of mechanical mining calls for illumination of working faces in a manner which is not yet possible. Much additional research is required to produce the complete lighting of working faces which modern working methods demand.

In most collieries roadways lengthen daily and over the course of a number of years distances from the surface to the working faces become unreasonably long. Where roadways cannot be cut off by new openings from the surface, as is the case in submarine workings, the travel time of men to their work becomes a serious burden on the industry. As much as 20% of the working shift may be taken up in travel time. Research is required into methods of safely transporting men from the surface to the working faces at high rates of speed, in order to minimize the loss of time presently taken by means of transport now available. This is one of the most serious problems facing large collieries which have been in operation for many years, for it creates an economic problem of real magnitude.

Research into all the matters already mentioned is required from the point of view of safely producing coal at as low a cost as possible. Research which has already been done and applied has produced many benefits to the industry. Much more is still needed. Some such research is comparatively simple while in other cases the research is of a highly technical nature.

In preparation plants research is required to improve the efficiency of the operations in order to provide the consumer with the exact type of coal he requires. Research is required too in the briquetting of the finer coals so that a product suitable for the market may be made from one which today is frequently undesirable.

In the utilization of coal, combustion engineers through research have improved to a very marked degree the efficiency of the larger coal-burning units. Research will further increase the efficiencies of such units.

Comparatively little research, however, has been done on coal-burning units used for domestic heating. A very large potential market for coal for this use has been lost to other fuels merely because of the inconveniences experienced in the use of coal burned in small domestic units. Since the use of coal in such units today depends on convenience rather than on economy, research is required to develop a domestic unit for the burning of coal, which is completely automatic, both in the supplying of coal to it and in the removing of the resulting ashes. There are on the market today furnaces which do this reasonably well, but much research is required to make these units completely satisfactory in all details. There is, however, one point which must be overcome in the making of coal completely convenient for domestic use, particularly in localities where the range of temperature varies widely in a 24-hour period. This is the 'hold-fire' feature. At present, in order to hold fire, even the best-designed coal furnaces must produce some unnecessary heat unless the fire is to be allowed to go out and to be rekindled. Much research is required to develop a unit which will hold fire with the production of practically no heat or which can be automatically rekindled if the fire goes out altogether. Until research has overcome this particular feature coal cannot be considered as convenient as some other fuels for domestic heating purposes.

Coal burned as a solid fuel wastes many products of considerable value. Research into the cheap gasification of coal at the pit head is of extreme importance. This research is probably a long-range one, but one of extreme importance where the cost of coal production is likely to increase materially during the coming years. It is only through the recovery of some of the by-products of value lost when coal is burned as a solid fuel that high-cost producing collieries may remain economic. The cost of gasification, as we know it today, is excessive and research into a much cheaper and more efficient process is required.

Much of the research on coal, particularly the pure research of a highly technical nature, has been hampered by lack of sufficient funds to properly carry on the work. Were even a small part of the amounts spent on atomic research in recent years devoted to research on coal, its mining and its utilization, the industry would be of much more importance to the nation than it is today.

What's New And What's Needed In The Mining, Preparation, Transportation And Marketing of Coal

by

W. C. Whittaker, Managing Director,
The Coal Operators' Association of Western Canada

This talk was to have been given by an Engineer from Britain, but due to the illness of Mr. Ignatieff, the necessary arrangements were not made and Mr. Lang has asked me to substitute.

What I have to say will consist mainly of a general review of the problems facing the industry and what is being done about these problems elsewhere, principally in the United States.

I will also take the liberty of going somewhat further afield than the title suggests, since I feel that one should not consider the technical aspects alone without giving some consideration as to the factors behind these technical needs and improvements.

Now as to the present situation in the coal industry of Canada.

In the West we are surrounded by cheap fuel oil, cheaper natural gas and face the ultimate dieselization of the railways. The 1957 railway tonnage to the end of June was just 50% of that of 1956 and one-sixth of that of ten years ago — all of this with only the beginnings of industrialization in the area we serve.

In the East the industry must contend with imported fuel oil and residuals, the dieselization of the railways, the advent of natural gas in the Montreal area within the next year or two, and the unknown factors of the seaway.

An industry facing a tough competitive situation such as this, needs primarily, substantially lower costs. In our case, this can only result through substantially higher output/man-shift since most other costs are largely beyond our control.

Unfortunately at this time, lower production costs are not entirely the answer. In heavy industrial coals — perhaps Yes. In the small industrial, commercial and domestic markets, lower costs alone will not solve our problems. We face the same situation here as elsewhere — where automatic or so-called automatic fuels are available in quantity, price is generally the minor consideration, with convenience and automatic features generally governing the final choice.

However, to come back to what is needed.

Our situation, with some modifications, is similar to that of the United States five years ago. They experienced at that time the same competitive situation but now appear to have turned the corner, although they still face stiffest competition from fuel oil and natural gas.

In the production field, it appears therefore that we require a substantially higher output/man-shift in order to reduce costs and thus meet competition of other fuels, particularly in the industrial market which is most responsive to price changes.

In the matter of coal preparation, we require:
1. Greater efficiency in cleaning with consequent better product and recovery;
2. Plants which will operate with a minimum of manpower and with lower power and maintenance costs;
3. Increased bin, mine car or other storage capacity so that preparation plants can maintain a greater throughput per manshift with consequently less power wastage and maintenance.

In the transportation field, we require,

Within the mines:
1. Larger and more flexible haulage units;
2. Better transportation for mechanized operations from the face to the mine car by means of extensible belts and other types of conveyors.

Outside the mines,
1. Lower railway transportation costs, both on short and long hauls, particularly on industrial coals;
2. Lower rates for industrial coal which comes into competition with pipeline gas and fuel oil, and special rates for large scale shipments of export coal.
3. A good bulk loading terminal for export coal at Vancouver.

In the marketing field, we require:

1. A wider variety of low cost, easily obtainable automatic burning equipment, backed by an efficient, well-advertised and easily obtainable installation, repair and maintenance service.
2. The strengthening of the industry's position —
   (a) by joint sales;
   (b) by effective and adequate advertising and market promotion to keep constantly before the public the lower cost and general efficiency of coal, particularly in the domestic, commercial and industrial fields.
   (c) Well organized technical service organizations.
3. Research in the development of equipment and in marketing techniques on a co-operative basis — our producing units are too small to do these things effectively on anything but an industry-wide basis.

In the management field,

With the added pressures for lower costs and efficient planning, we will require more than ever, capable and experienced engineers and managers. At the same time, the manpower problem will become more accentuated and skilled miners and experienced mechanics, electricians and supervisors will be at a premium.

In the field of government activities, we require,

1. Protection against unfair natural gas competition and that of imported fuel oil and residual oils;
2. The continuance of the subvention policy on a flexible basis to meet the changing competition of imported fuels;
3. Assistance to underground mined coal used for electric power production at or near the pithead;
4. A change in government policy so that coal for use in federal buildings and institutions can be purchased on the same kind of long-term type contract as is now available to natural gas;
5. Promotion of better understanding in government circles, particularly among the elected representatives, of the importance of coal in the economy of the nation and of the greatly increased need for coal in the energy picture of the future.

The foregoing are some of the main factors of need in the industry today. Now, what is new in the industry?

Production

The United States underground output per man-shift has increased from 6.4 to 8.5 tons over the last 5 years. By 1960 it is predicted that it will average 12 tons per man-shift and strip production, 25 tons per man-shift. In Canada our underground production has increased in the last five years from 2.5 tons to about 2.8 tons, or an increase of about 10%.

Alberta underground production in the same period has increased from 3.7 tons to slightly over 4 tons per man-shift.

These increases are not impressive, and there is much room for improvement. With our much less favorable mining conditions, we cannot of course hope to attain the same production levels as in the United States. Necessity, however, will force us to do considerably better in the next five years than we have done in the last five.

The improvements in the United States output/man-shift have resulted mainly from:

1. The scrapping of high-cost mines and the opening of new low-cost operations;
2. By mergers of smaller companies into larger units with attendant savings in management, engineering, sales, etc.
3. The larger size of companies has enabled the financing of the capital necessary for creating new facilities and for buying new equipment.

The improvement in production techniques is said to have resulted from:

1. The increased use of the continuous miner;
2. Wider use of roof bolting (it is stated 35% of the 1956 bituminous tonnage in United States was recovered under bolted roof);
3. Faster and higher capacity haulage;
4. Better equipment for difficult mining conditions;
5. Maintenance programs to cut down breakdown time to a minimum;
6. Better recruitment and training of personnel for engineering and maintenance;
7. Incentives to encourage greater effort and less absenteeism;
8. More safety training for all engaged in the production cycle;
9. Added research in the production methods and techniques.

At the Coal Show in Cleveland in May of this year, I was impressed with the great variety of continuous miners and other loading equipment ranging from a huge machine with a cutting head about 8 feet in height and 10 feet in width and weighing some 35 tons, to a small twin-auger miner which appeared to be mounted on the front of a Goodman Shortwall. Surely within this range of equipment we should be able to find something which is suited or can be adapted to the needs of our western pitching seams.

Incidentally, the General Manager and the Superintendent of the North West Improvement Company were at the Show and told us that they were using Joy Continuous Miners with good success at their Roslyn, Washington operations — driving rooms up the pitch and drawing pillars on the retreat using a pocketting system. This operation was written up in the August 1956 issue of Coal Age, but I understand that the operating results have improved very considerably since that time. In addition, I believe the output/man-shift for the whole operation is considerably better than the average for our own pitching seams.

In our own area, the Crow's Nest Pass Coal Company in co-operation with the Ingersoll Rand Company, are developing a continuous miner called, I believe, the "Gardner Borecat". This machine has been designed especially for use in pitching seams and, I am told, has now had most of the bugs worked out of it and shows considerable promise. This equipment will likely be available on the market in the not too distant future.

I was also interested to see at the Coal Show the advances in conveyor belt design, both in the extensible features and the ability to change directions with one section of the belt loading onto another.

I note also in the trade magazines that there is beginning to be a wider use of rope-driven conveyor belts where the traction is taken care of by wire rope or other means with the belt function being limited to carrying the material. This results in:

1. Conveyors which can be built to almost unlimited length while at the same time using light-weight and inexpensive belting;
2. Conveyors which can handle material on the forward as well as on the return strand;
3. Conveyors which can handle bulk material around vertical and horizontal curves.

In this connection I believe that the Dominion Coal Company was the pioneer in Canada of the rope-driven belt in the Rock Slope at Old Sydney Collieries.

Apropos of the foregoing —

New mines in the Pittsburgh seam in the eastern United States have recently been engineered to produce 20 to 25 tons per man-shift.

An official of a large corporation told me recently that he thought roof bolting had provided the biggest single advance to his company in recent years. He also stated that automatic loading and moving of cars had saved his company a great deal of money.

Another operator stated that the new extensible belts had been responsible for a great increase in the productivity of the continuous miner.

In the strip field the trend is to bigger shovels and bigger transportation and drilling units. During the Coal Board's visit to one operation in eastern Ohio in May of this year, we saw one 65-yard shovel and four 45-yard shovels at one operation with the large shovel handling 120 feet of overburden. This company had also just put into service a fleet of thirty 60-ton drop-bottom trucks on the coal haul from the pits to the preparation plant.

All of these things point to the fact that large companies with ample financial resources and large coal reserves can do things necessary to improve efficiency, which are usually not within reach of smaller companies. In spite of this, we do know that in our own smaller way, the same sort of things can be done and should be done. We should all perhaps take another hard look at this factor.

Unfortunately we are in a vicious circle. It takes a good deal of courage under present conditions in both Western and Eastern Canada to make the large capital investment necessary to modernize an old mine or to open a new one in the face of fast-disappearing markets. And yet, if the improvements necessary to reduce cost are not made, it will be difficult to remain in competition with lower cost operations and with other fuels.

What's New in the Preparation Field

There is a great variety of preparation equipment available in the form of jigs, cones, cyclones, tables, dense media separators, etc. There are also available a number of good dryers of various types as well as other ancillary equipment. All of this equipment will do an excellent job on the work for which it was designed. What I think most important is:

1. That the proper choice be made for the type of coal to be treated, and
2. After the equipment is installed, that the equipment be properly maintained and carefully operated to get the best performance that it is capable of producing.

I think it a common failing that after the newness has worn off, coal preparation equipment is often neglected and inadequately maintained with consequent lowered efficiency and recovery.

In the future, a good deal of our production may be sold to utilities and other industrial applications where uniform quality and low-cost per 1,000 pounds of steam raised may be more important than fancy preparations involving low ash and large refuse losses.

On the whole, I feel that the coal preparation problem is well in hand. It needs, however, to be constantly studied so that the best selection of equipment can be made and the best operating efficiencies maintained.

What's Needed in the Transportation Field

The Ohio Coal Pipeline. Most of you know something of the 108 mile coal pipeline which Pitt-Consol has built from Georgetown to Cleveland, Ohio. This was designed to carry 1,200,000 tons per annum of minus 14-mesh coal from the mine to the Cleveland Electric Illuminating Company's Eastlake plant. Pitt-Consol has long felt that it was paying too much in railway freight and this pipeline, if the economics work out as expected, will be only the first of a number of such lines.

The rail rate from Georgetown to Cleveland is about $3.30 per ton. Experimental work has indicated that the pipeline can carry coal for at least $1.00 per ton less. As a result, after some five years of study and experimentation, the pipeline was built at a cost of $12.5 million. The line commenced operations in February of this year. Shortly afterward it ran into operational difficulties due to the fact that the feed was not being ground and screened to specification. As a result, it has been shut down until recently pending the solution of the screening problem. Recent news reports indicate that the line is about ready to operate again and that September should see some substantial tonnages of coal moving.

If the actual operation of the line proves successful and the economics work out as expected, it is likely that a further pipeline will be built in the near future from the same general area to the Chesapeake Bay on the Atlantic seaboard, about 400 miles distant. In this area there are numerous electric generating stations which could use the large amount of powdered fuel required to make a pipeline of this kind feasible.

At the moment there seems little likelihood of pipelining Canadian coal in either the East or West. However, if the Pitt-Consol experiment works out well there is no telling what the ultimate developments will be.

By-Products from Coal

One of the most frequently asked questions about the coal industry is "What is being done about producing by-products from coal?" Many people seem to think that the future of the industry lies in this development and that perhaps the coal industry has not made the most of its opportunities in this regard.

First of all, it should be pointed out that despite many years of experimentation and research, no presently economic method has yet been devised which will completely convert coal to liquid and gaseous products. High temperature carbonization has for many years produced large tonnages of metallurgical and other types of coke as the primary product plus coal tars and coal gas as the secondary or by-products. These coal tars are the source material of hundreds of chemicals today. However, the amount of coke which can be sold and the market which can be found for the coal tar products are the limiting factors. Moreover, a balance in the sales of the respective products must be achieved if the process is to be an economic one.

We have within this area at Michel, B.C., a modern coking plant which produces coke as a primary material and substantial quantities of coal tar, which is available to the chemical trade. So far, however, the principal use made of this material is as a wood preservative in the form of creosote.

Literally thousands of low-temperature carbonization processes have been developed over many years, but extremely few have attained economic success. However, within the past few years there have been several notable developments, and one of these, the Cresap development of Pitt-Consol, points up the tremendous problems involved, particularly in:

(a) The large amount of capital required per ton of coal throughput;
(b) The need for constant large-scale market for the resultant char;
(c) The vast amounts of chemical products which must be disposed of concurrently with the rest of the operation.

These problems are very clearly illustrated in a paper presented recently by Mr. Joseph Pursglove, Vice-President, Research and Development, Pitt-Consol, before the American Coke and Coal Chemical Institute, White Sulphur Springs, October 23rd, 1956. The following excerpts will provide probably as complete an answer as can be given as to the present status and limitations in the production of by-products from coal:

"One of our initial projects was devoted to the gasification of our large reserves of high-volatile Pittsburgh seam caking coals using the fluidized solid techniques developed by the oil industry for fluid catalytic cracking. Our partner in this venture was Standard Oil Company of New Jersey. The over-all concept here was to find a very high-capacity continuous method of converting Pittsburgh seam coal into a gas suitable for synthesis into liquid fuels.

"We proved to both of our satisfaction that 'synthesis gases' could be produced by this method using oxygen and steam as the fluidizing medium. But this process, by its very definition of its term of development, was only economically attractive when huge quantities of 'synthesis gases' were required for large synthetic liquid fuel plants. Such plants would cost multiples of millions of dollars and the economics of the world petroleum business toward the end of this development had been re-arranged by the opening up of the vast new oil fields of the Middle East.

"In other words, the commercialization of a straight synthetic liquid fuels process was not at hand in 1950, so we decided to put the pilot plant reports on the shelf for future reference and continued work in the lab on radical improvements in gasification techniques. We are still at it. At the same time we turned to more near-term possibilities. As of today we know of no method or process for converting coal completely into liquid fuels only, that is economically attractive under today's conditions in the U.S.A. However, the tremendous growth in the use of liquid fuels all over the world and the conflict in the Middle East suggests that we should be prepared to move when the time is right, and we believe we will be in the position to do so.

"In 1948 we began work on the application of this same technique to low-temperature carbonization through the knowledge we were then deriving from working with fluidized solid techniques in the gasification process. Up to the present, this development, along with the organic chemical work on the coal liquids produced has occupied the greater part of our efforts, time and money. Almost eight full years have passed. Our one other sizeable project was the development of cross-country pipelining of coal which I'll tell you about briefly later.

"These years of work are culminating in the coal processing developments you have probably read about at Cresap, West Virginia, 8 miles south of Moundsville, on the Ohio River. I want to tell you something about these developments because you will then know where we stand today in regard to commercialization.

"We have learned through our continuous economic analysis of our coal processing research that commercially it must be done on a very large scale to be attractive economically. In the case of low temperature carbonization we must also have a large power station adjacent to our plant that can burn coal and/or our char residue with equal economy under the boilers. We believed last year that if we had both these factors in hand, that is a large power station as well as one that could burn char, we would be ready to go ahead with our first commercial plant.

"About this time the large new aluminum developments projected on the Ohio River of Kaiser, Olin-Mathieson and Revere, materialized. We knew that they would create a new demand for about 900,000 kw. One such plan that evolved from this big projected power demand consisted of an entirely new power station now under construction at Cresap, West Virginia. This site is on top of a large tract of coal which our company controls. The whole tract contains close to a billion tons of mineable Pittsburgh seam coal that faces the Ohio River frontage for some 16 miles. This new station is being designed so that it will burn coal and/or char The station is planned for an ultimate capacity of 1,350,000 kw.

"With the 675,000 kw. Kammer station being built to burn our char, we had the foundation laid for our own developments. First, an entirely new mine is being opened up. It will have a productive capacity of 3,000,000 tons a year and can be expanded to 5,000,000 tons as the Kammer station grows. Coal will be delivered directly by belt from the mine slope into the 450,000 ton stockpile of the power station. Our low temperature carbonization plant, or char maker will be located between the stockpile and the boilers. Coal moving in a direct line from the mine to stockpile to boilers can be intercepted and passed through the char makers. Char is then put back into the former coal stream and then moves along through the bunkers and feeders and into the cyclone burners.

"The liquids removed from the coal, approximately 26 to 30 gallons per ton of coal treated, are then moved through a whole train of liquid processing, refining, purifying and manufacturing steps in order to make products that,

1. have qualities that permit them to fit into late 1958 and 1959 markets;
2. that will go into markets of large enough size to absorb such a volume production at one geographical location; and
3. that the overall estimated price realized for these products in the 1958-1959 markets will make the $30 million dollar investment in the plant and working capital an attractive one.

"We have spent a very sizeable amount of all our money invested in low temperature carbonization research on the organic chemistry of the liquids we would produce, and the searching for and development of the marketing outlets we had to have. We thereby have hoped to avoid making the mistake of so many developers and promoters of low temperature carbonization processes.

"This type of coal processing must be done on a large scale to be attractive and the major outlets for the liquid products must be large volume outlets. We will have to dispose of about 50 to 60 million gallons of refined liquids a year. Five million gallons, or about 45 million pounds of material is a lot of stuff in the chemical industry, as you all well know, but it's less than 10% of our output.

"The lighter ends, approximately 15% of our total, will be distilled out first and processed on a parallel course with that produced from petroleum cresylate streams we now handle at Newark.

"The intermediate materials consisting of 35 to 40% of the total will be split into a number of products:

1. Highly effective wood preservatives;
2. Road tar components;
3. A feedstock for carbon black plants.

"We are currently working on commercial arrangements for the disposal through regular marketing channels of 1. and 2. above and expect to be in the carbon black business with a partner or partners by building a modern furnace black plant at Cresap site. The carbon black plant we envisage will make approximately 50 to 60 million pounds per year of abrasion blacks.

"The heavy bottoms will be fed to a coker producing a green coke. This green pitch coke will be mixed with green petroleum coke from Sohio's new Toledo and existing Lima refineries. These mixtures will be calcined at a new plant being built at Cresap by Mountaineer Carbon Company. This is a jointly owned corporation put together for the purpose of building and operating the calcining plant, and marketing the electrode carbons produced.

"No doubt further processing equipment of one kind or another will be added to the plans before the whole complex is in operation. We are thinking of producing resins and several different derivatives of the acids.

"No one has ever had such quantities of these materials 'under one roof' so to speak, so the possibilities here of large-scale further processing are almost unlimited. We invite chemical processors to consider us as new large-scale suppliers so that they, along with us, can look down new chemical-processing vistas."

Markets

In the United States, the National Coal Association has re-organized its sales and promotion arm under the name of the "Bituminous Coal Institute", and a similar organization has been formed by the Canadian Commercial Dock Operators, which is not unlike our own Western Coal Utilization Council.

Bituminous Coal Institute plans an all-out attack on the four main trouble spots in industry selling. These are:

1. Inadequate engineering aid;
2. Inadequate market research;
3. Lack of co-ordination among existing marketing groups;
4. Weak public relations and advertising.

It is the Association's opinion that what is needed most for success is:

1. Total co-operation of all within the industry, including wholesalers and retailers;
2. Firm support from the railways, the equipment manufacturers and other allied interests.

The main objectives are:

1. To reduce and minimize the heavy loss to competitive fuels;
2. To get a bigger share in the new business that is constantly developing; and
3. To convert gas and oil burning plants to coal.

Bituminous Coal Institute will seek to integrate the work of existing marketing agencies. It feels that coal's toughest problem and one of its prime opportunities is in the market which falls between the strictly household consumer and the big industrial outlet. This market, which includes small and medium sized industrial plants, commercial buildings, schools, apartment houses, etc., will be the initial target of B.C.I.'s program.

To solve competitive problems and develop the full potential of the commercial market, B.C.I. aims to,

1. Give engineering assistance to existing and potential coal users, architects, consulting engineers, etc., through field representatives.
2. Develop sound engineering data, designs, recommendations and general information on modern coal burning installations.
3. Undertake market research that will define who are coals existing and potential customers and where they are.
4. It will seek to integrate the work of existing group marketing agencies that are unable, because of limited jurisdiction or function, to fill the vacuum of service needed by the total industry.

Government Activities

Earlier, I mentioned something about the industry's contacts with government and I would like to comment briefly on this matter.

Natural Gas Competition. Within the next year the industry will begin to feel the effects of the several large natural gas pipelines which are now being built. If the United States natural gas experience is repeated, the gas lines in their early stages, prior to the full build-up of their markets, will dump gas at less than their full cost of operation into the large industrial jobs to maintain their load factor, particularly until large volume United States markets become available. The rates for domestic consumers, which are not particularly sensitive to price, will be raised to compensate for the low price of this interruptible gas.

Interruptible gas in large quantities will be sold for the time being at any price necessary to capture a volume market and coal will thus be driven out of long established markets until such time as the gas can upgrade its markets and operate at high load factor.

I think you will agree that this is unfair competition and that the coal industry is entitled to some protection in this regard. The only remedy is by government control which would prohibit gas being sold at less than the full cost of its production and transportation.

There have been several bills introduced recently into the United States House of Representatives which would require this prohibition. These have received very considerable support and may achieve success in the near future. I believe that the Canadian coal industry should continue to press for similar legislation.

Transportation Subventions. Transportation subventions have been available to the Canadian coal industry for more than 30 years. Despite the criticisms that have been aimed at them and their administration from time to time, I believe you will agree that they have been very worthwhile, that the subvention policy has been flexible and realistic, particularly in recent years, and has met the changing conditions in the industry reasonably well. A case in point is the new Order in Council providing additional assistance up to $2.25 per gross ton on coal exported to the Orient. A similar sort of assistance has been available in the last year or two to the eastern mines on shipments to Europe.

Coal export to Canada and Overseas accounted for 13.0% of the bituminous coal production of the United States in 1956. While our export shipments to date have been small, this is a business which could grow to substantial proportions and which could be most valuable in the transition period the industry is now passing through.

Thermal Power. Until about five years ago little was heard of thermal power in Canada. Just a year or two ago the newspapers and the popular press had atomic power taking over immediately and the use of coal for firing steam boilers was shortly to become a thing of the past. However, we now find that such is not to be the case.

It has been announced recently that Ontario Hydro is to spend $500,000,000 in the next eleven years on coal-fired steam generating plants. In addition, Manitoba, which has hitherto been practically 100% hydro, is building two steam generating plants to be fired by either Saskatchewan lignite or natural gas. The Saskatchewan Power Corporation is also building new steam plants at Estevan and Saskatoon, which will burn large tonnages of Saskatchewan and Alberta coal; and Alberta in the past few years has seen three new steam generating plants built, the two larger of which will be ultimately based on coal.

Even the B.C. Electric Company, in a province completely dominated by hydro to date, has now come to the conclusion that it will require a large steam power plant in the Vancouver area within the next five years, the choice of fuel being between Alberta coal, residual fuel oil or Peace River natural gas.

Nova Scotia and New Brunswick require additional steam generated power. In the Maritime Provinces the Federal Government, as the result of surveys and investigations initiated by the Dominion Coal Board, are assisting in integrating present power facilities with the aim of providing cheaper power in this area to attract industry and to burn more Maritime coal closer to the mines. It is felt that money spent now in such development will ultimately reduce the amount of money necessary for transportation subventions required to move Maritime coal up into the St. Lawrence area.

A parallel opportunity exists in the West and it is suggested that the federal and provincial governments might well give thought to subsidizing in a modest way underground coal used in power production in southern Alberta for a limited period of say ten years, so as to enable it to compete with natural gas during the period of pipeline load build-up. This might be a cheap and effective method of assistance for the next few years.

Government Purchasing Policy. Within the past year western coal producers lost a sizeable contract to natural gas in a large government establishment, with the gas company using its differential pricing policy to gain this contract. In this instance, the government has committed itself to take natural gas from this one company at a fixed price over a period of years. The coal producers offered to enter a similar contract but were advised that this was not possible under present buying policy.

At another large government establishment, the writer was told that any trouble that had been experienced with coal had resulted from the fact that the supply contracts were for a period of one year only, and that the contract had to go to the lowest bidder in every case, even though the alternate coal, while meeting specifications, might not suit the needs of the plants — thus the plant staff have had to adjust their operations each year to a different fuel. This makes coal a "sitting duck" for natural gas competition and has been responsible for the loss of a considerable number of contracts.

I believe the industry should make a united effort to have policy changed so that coal can have the same opportunities as competing fuels.

Finally, I think you will agree that there exists a great need to educate the public, and in particular, the legislators, on the importance of coal in the economy of the nation. I think we should never let the opportunity pass by of acquainting them of what is going on in such developments as just announced by Ontario Hydro. So many people have been so glamorized by the constant flood of propaganda regarding natural gas and atomic power that they have already reached the conclusion that coal is of no further importance in the future of this country.

This is a job for the industry as a whole, both East and West, and should be tackled without delay. We have plenty of ammunition if we will but use it.

Summary of Trial Data on Borecut Continuous Miner

by

H. H. Gardner

General Manager
Crow's Nest Pass Coal Company Limited

Mr. Whittaker has requested that I report on our experiences with the above machine. It is a pleasure to be able to state that our trials have been most encouraging. The unit, a prototype model, has required some expected changes and revision. Obviously, we can expect much better, more consistent results with the next model.

The Borecut Miner grew out of a desire to design a simple, relatively low-cost continuous miner for pitch-seam coal mining. It was realized that such a machine must cut entries to any required shape, when driving on strike, regardless of seam pitch, and preferrably be able to cut to heights of at least 14 feet. Other requisites were: a machine capable of loading loose coal or loose rock, as it is often necessary to do rock brushing in our entry driving, and ability to lift entry timber into place. Recent trials have amply confirmed that these requirements have been realized.

Canadian Ingersoll-Rand Company Limited have undertaken the mechanical development and have rights to manufacture; patents have been applied for. The prototype machine was designed under their orders by Mr. Henry Harlos, consulting mechanical engineer of Vancouver. The Crow's Nest Pass Coal Company Limited of Fernie, B. C., have supplied mining and shop facilities for testing. Mr. H. H. Gardner, General Manager of the above coal company, is the inventor. During trials to August 31st, the machine worked 142 production shifts over five months, driving 990 feet of entry, erecting 199 sets, mining 11,640 tons of coal and loading out

41 cars of brushed rock.

The machine is essentially a hollow rotating drive unit or barrel, 23" inside diameter, housed in fixed frame and bearings. This frame is carried on a transverse horizontal shaft at the rear, and two vertical hydraulic pistons at each front corner. To the front of the barrel is attached a funnel-shaped cutter head, 15 feet long and enlarged to four feet diameter at the cutting end, with cutter bits on rim set to cut a $2\frac{1}{2}$" kerf. The hydraulic pistons can lift the cutter rim to over 14 feet high. Within the barrel and funnel are spiral flights which convey broken coal to a bridge conveyor attached to the rear of the machine. The whole assembly is carried on crawler tracks which allow complete maneuverability.

The Borecut is powered by a 75 h.p. double-end explosion-proof electric motor operating on 550 volt alternating current. One motor shaft rotates the barrel, to give a 400-foot-per-minute cutter bit speed, through a fluid coupling, clutch, planetary reducing gear, and pinion chain drive. The other shaft drives four hydraulic pumps by means of direct gearing. One pump serves to lift the barrel, one drives the bridge conveyor which in turn delivers to a loading conveyor, and each large volume-control pump supplies power to a crawler track. The machine is controlled by an operator who sits just ahead of the right crawler track, 12 feet from cutter ring.

The operation is most simple and direct. The funnel is placed below the roof on the right side of the face and advanced about 3 feet; then the machine is retreated, barrel and funnel dropped 4 feet and advanced 6 feet; the machine is again retreated, the barrel and funnel dropped to the floor and advanced 6 feet. Thus the right rib is cut and a width of 4 feet of coal from roof to floor has been loaded into cars. The cutter ring is then again placed at the roof 4 or 5 feet to the left and another 4 feet of coal is removed and loaded into cars. This is continued until the entire round has been removed. The coal core breaks down in large lumps, passes through the barrel to the bridge conveyor, then to the loading conveyor and into our large 10-ton cars. Allowing for car changes, forty to fifty tons of coal are loaded per hour.

When the round is completed, a small saddle is placed on the funnel — steel or timber collar placed therein — and lifted into required place by the Borecut. Miners then place legs under the collar, slab set, and wedge securely. The loading conveyor is then pulled ahead 5 feet by the machine, and the face is ready for another loading cycle.

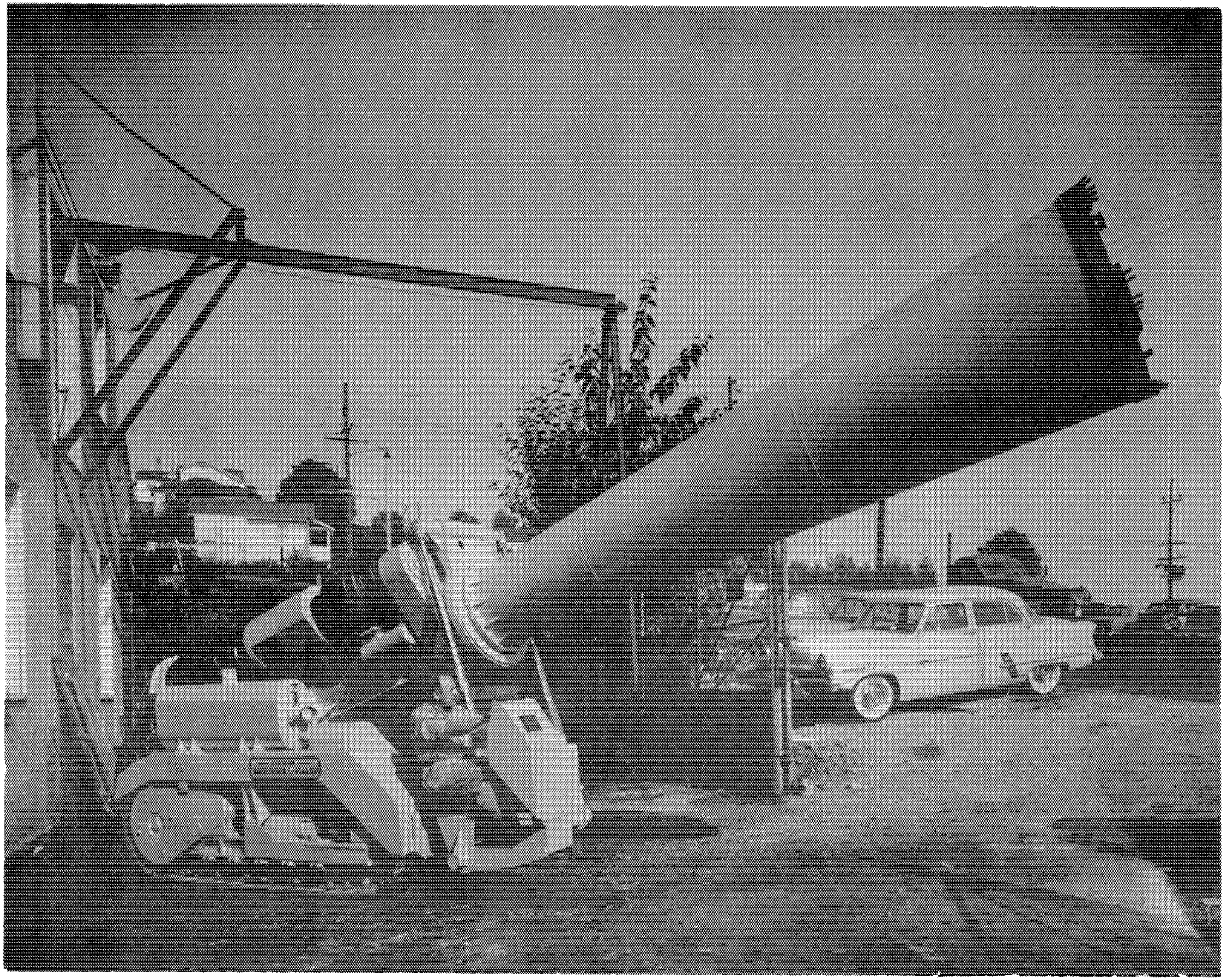
While in service, the machine has continually loaded out two rounds or better each shift, and erected sets each round, for an average tonnage of about 100 tons, with a four-man crew. Recently, with the machine in coal 12 feet high, five consecutive shifts advanced fifteen rounds, erected fifteen sets, and loaded 700 tons of coal.

The present machine is 26 feet long, 7 feet wide, $5\frac{1}{2}$ feet high and weighs $11\frac{1}{2}$ tons. The design of the next model is well underway; it will be 25 feet long, 6 feet wide, less than 4 feet high, and weigh somewhat less. By changing funnels of varying lengths on the new model, it will be possible to work seams from 4 feet to 16 feet high with one model or drive unit.

Field trials are continuing, with encouraging results. Experience to date has fully established the soundness of the mining and conveying principles incorporated in the basic design. These principles make the Borecut different in most respects from more "conventional" types of continuous mining machines, and permit its application as a continuous miner in coal and other soft formations, or as a general purpose loading machine for virtually all materials, including hard rock.

In our mining operations, it is performing as no other available machine could, mining from the solid at any and all points on faces up to 16 feet high and 18 feet wide, loading out loose coal and rock, installing steel and timber collars, scaling high roof, and providing a mobile, easily-maneuvered platform for roof bolting.

It is our belief that this machine will find a wide range of application in the hard-rock mining and materials-handling fields, as well as in coal mining.



BORECUT CONTINUOUS MINER

What's New and What's Needed in The Utilization of Coal, Combustion Phases *

by

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Introduction

The greatest single use for coal is as a fuel to burn on grates or in a furnace to generate heat for space heating, for producing steam, or for process purposes. Although it has been in use for centuries (the first official record of coal mining dates from 852 A.D.), our knowledge of coal is meagre. It is true that we have laboratory procedures to analyse it, but the determinations (hardly indices) are empirical and they do not always measure the properties of the coal sample. Instead, they indicate behaviour under fixed conditions. This is unfortunate because coal is rarely, if ever, burned under the same conditions as those chosen for the laboratory analyses.

A single coal possesses eight principal chemical and physical characteristics, each of which has a profound influence on its handling and burning. When it is considered that there is a wide range of quality within the 13 grades of the 4 ranks, it is little wonder that burning coal successfully is as much an art as it is a science. Not only are combustion reactions complex, but in addition there is the further complication of the influence of the environment or conditions under which coal is burned.

* Published with permission of the Director, Mines Branch, Department of Mines and Technical Surveys, Ottawa.

Scientists everywhere are conscious of this lack of knowledge of coal; consequently, long-term fundamental research is being undertaken in order to obtain a more complete understanding of its physical and chemical make-up. There are several such research projects in many countries, and they appear to indicate a trend to the long-term fundamental type of studies.

The engineer, however, cannot wait for the scientist to unscramble the unknown. In any event, there is every possibility that we will have to continue to accept the coal structure as nature has provided it, whether we know what it is like or not. The engineer's urgency emanates from the modern demand for automation which for obvious reasons has made oil and gas fuels popular. This popularity has caused coal to lose ground in some of its traditional markets, and although consumption remained steady between 1948 and 1955, its share dropped from 74.9 per cent to 54.9 of all industrial fuel energy consumed in Canada. Coal is losing ground in still greater proportion in the domestic heating market.

The pressure of this situation together with coal's inherent complexity bears heavily on the engineer. However, with dogged persistence and ingenuity he has produced new coal-burning equipment which in certain classes equals any available for competitive fuels and in other classes approaches equality but not popularity.

Next to the transportation market, the domestic heating market is probably the most difficult for coal to compete in and by virtue of being one of the most lucrative markets in Canada, it will be discussed first.

Domestic Stokers and Furnaces

Post War Competition

A multiplicity of building codes, regulations restricting or controlling manufacture and installation of heating equipment, and a complicated system of inspection have created an unfortunate confusion. In the eyes of the coal industry this has contributed to unfair competition by permitting the installation of inadequate domestic heating systems using competitive fuels. As competition increased the situation gradually became more adverse and caused reaction from the consumer and reputable contractor.

One outcome has been the inauguration of a bonded heating scheme on a national scale by the National Warm Air Association. Another has been a request by this Association to the Ontario government to institute controls to curb the activities of its member contractors. However, there is no reason to anticipate any help to coal in the domestic market. Actually, it is suggested that the industry should watch all schemes carefully to ensure that they do not infringe on the freedoms of the consumer or further jeopardize the future of coal.

The coal industry had no effective means of coping with either the competition described above or the popularity of oil-burning equipment. Automatic coal-burning equipment has been the underfeed stoker which could not be trimmed to compete in price, and also, could not provide the popular features demanded. As oil and gas became increasingly popular, stoker manufacturers added innovations to their equipment but it was a case of too little and too late.

Trends in Underfeed Stoker - Furnace Development

The innovations and refinements to underfeed stokers, in themselves, have been important contributions to automatic coal burning and deserve some explanation although they have not made this class of equipment popular.

The self-cleaning grate is the first important improvement and is illustrated by the Kirk Stoker. Cleaning a stoker fire by hand is a chore which the householder should not be expected to do, and with this type of equipment there is little or no need for attention to the fire, even with high ash coals.

Ash removal with the self-cleaning grate is the next natural improvement and is illustrated by the Electric Furnace Man conversion stoker. With proper planning, it is conceivable that the ash containers could be located outside of the house. Dust from the handling of ashes in the home has been a major complaint, and it can be eliminated with this refinement.

Coal conveyors or automatic coal feed from the coal bin to the fire is another step toward complete automation. This apparatus is available for all classes of coal-burning equipment, but for domestic purposes the worm conveyor is used extensively. It can be designed to convey coal in any direction and around an obstacle.

Overfire air is required by the high volatile bituminous coals to prevent smoke and can be provided as in the Iron Fireman B R series stoker.

Automatic ignition is an attractive and popular refinement and was incorporated in the Campbell stoker.

The integral stoker and furnace is the final improvement which most manufacturers have used to glamorize both the stoker and furnace. There are now many models of neat compact automatic coal-fired furnaces.

Limitations of the Underfeed Stoker

For domestic purposes this class of equipment, while flexible and rugged, has failed to attract any important degree of popularity. The complication and bulk of the machinery which is required for automatic operation, together with high cost, are sufficient reasons for its lack of popularity; and so, there must be something new to compete with the popularity of oil and gas heating equipment.

Dosco Downdraft Stoker

The Dosco downdraft stoker is one of the newer types of apparatus to be developed. It was designed specifically for highly caking, low ash fusion coals and appears to provide all of the theoretical requirements to burn such coals successfully. During the heating season of 1956-57 it underwent large-scale comparative tests with oil-burning furnaces, but authoritative reports have not been completed as yet.

Cross-feed Stoker

The average householder is interested in a saving in most items of overhead expense, but so far as the heating bill is concerned it seems that popular appeal of the heating equipment has an overriding influence. For the equipment to be popular it must be small, compact and simple and the new cross-feed stoker appears to possess these features more than any other stoker known.

This type of stoker is naturally suited to the free-burning, non-caking coals; consequently, it was first adopted for burning anthracite. There are many makes and models of furnaces incorporating such stokers but the Herco furnace is the only one of Canadian design and manufacture. This is an integral stoker furnace which is attractive in appearance and has popular features.

The cross-feed stoker was recently developed to burn bituminous coal by Dallas Engineers Incorporated and has been made an integral part of the furnace known as the Coal-O-Matic furnace. It was tested and improved in the laboratories of Bituminous Coal Research (B.C.R.) at Columbus, Ohio. Some 50 units were tested in private homes with success during the heating season of 1956-57. Recently it was learned that Eastern

Car Company, Trenton, a subsidiary of the Dominion Steel and Coal Company has undertaken to manufacture this equipment in Canada.

The simplicity, compactness and lower cost of this class of furnace are attractive features which should, with proper timing of advertising, approach the popularity of oil and gas equipment. Then, with the advantage of lower fuel cost, coal may have new hope of competing in the domestic market.

Commercial Stokers and Boilers

Coal's New Competitive Position

The commercial and small industrial class of consumer is probably the next most vulnerable to competitive fuels and is one of the most important markets left to the Canadian coal industry. The outlook for coal deteriorated rapidly with the introduction of the packaged oil and gas or multi-fuel boiler. This equipment became so popular that some well-known manufacturers confined their production to the packaged boiler.

The loss of market for coal as a result of the popularity of the packaged boiler was a matter of serious concern to the coal industry, but the situation has much improved. Competitive coal equipment is now available and with consumer realization from experience that competitive fuels are costly the coal prospects have become much brighter. However, in order to capitalize on developments, competent engineers should give thorough and vigorous attention to the class of consumer mentioned.

Stoker Trends

Underfeed Stoker - The underfeed stoker is traditionally a commercial class of equipment. It has been developed to a high degree to suit many of the variations in coal properties and, as in the case of the domestic stoker, can be equipped easily with all of the modern refinements. With automatic controls and ash and coal conveying equipment, it can complement the commercial and small industrial boiler plant. In the small sizes, 35 to 150 horsepower, it has little competition but in the medium sizes from 150 horsepower to industrial steam generators of 100,000 lbs. of steam per hour, there is need for automatic self-cleaning grates.

Self-Cleaning Vibrating Stoker - Recently, entirely new designs of self-cleaning grates have been introduced in Europe and the United States. These are the vibrating cross-feed type of grate which, at first, seemed best suited to non-agglomerating, high-ash fusion coals. Consequently, one of the first to appear in the United States was an anthracite burner which Losch built into what can be considered a packaged coal-fired hot-water boiler; although it has limitations of capacity and of coal selections. It features a flat inclined water-cooled grate which vibrates to feed coal from a hopper and to move ash to the end of the grate as the coal burns. A conversion stoker for steam boilers of about 25 to 200 horsepower was built to fill an important need in the commercial market.

The simplicity, compactness and self-cleaning features of this grate were soon recognized as the essential features of a burner for a packaged boiler. However, to be successful it had to be capable of burning a wide range of coals. Such a grate known as the Schuetelrost was developed in Germany and it was introduced in the United States by the American Engineering Company under the trade name of Vibra Grate. This is a hopper-fed water-cooled grate mounted on inclined furnace water wall tubes which vibrate as one assembly. Water cooling minimizes the slagging of low-fusion ash, thereby making it possible to burn heavy caking coals without difficulty.

The Babcock and Wilcox Company markets the self-cleaning Detroit stoker in Canada which consists of bars mounted in a shingle fashion with alternate rows reciprocating to move ash from beneath the fire bed. This is hopper-fed and air-cooled and is available for boilers in the range of about 150 to 2,500 horsepower (5,000 to 75,000 lbs. of steam per hour).

Another new self-cleaning stoker is an air-cooled, flat, horizontal hopper-fed oscillating grate manufactured by the Riley Stoker Company. Air is zoned under the grate and its operation can be compared with the chain grate except that it has a star feeder in the hopper at the gate. Normally, this grate oscillates for 1 to 8 seconds in periods of 30 seconds and the off time can be adjusted to suit the required burning rate. It has the advantage of being shop-assembled and, being flat, it can be water-cooled. Currently, this unit is available in sizes from 2,000 lbs. to 20,000 lbs. of steam per hour (about 65 to 650 horsepower). If water-cooling is desired, a supply of water separate from the boiler circulation is used, and to avoid waste it can be drained to a hot well with boiler feed water.

There is a second Riley self-cleaning stoker and as in the case of the previous oscillating stoker, it is flat and horizontal but has spreader coal feed. Actually, the oscillating grate has been used as a substitute for the more expensive self-cleaning travelling grate. This seems to be a natural application.

Recently, the Fire Jet and Hoffman vibrating type of stoker appeared on the market to add to the availability of much needed simple, compact, flexible and self-cleaning stokers in the commercial and small industrial class. These stokers, in themselves have given an important boost to coal and, moreover, they have made possible one of the most promising equipment advances we have seen, the packaged coal-fired boiler.

Packaged Coal-Fired Boilers

Superior Packaged Boiler - Late in 1955 the Superior Combustion Industries Inc., built the first packaged coal-fired boiler. It is a completely shop-assembled and shop-tested unit with a capacity of 12,000 lbs. of steam per hour. A Riley oscillating air-cooled grate with spreader firing was selected to provide high burning rates (in order of 600,000 B.t.u. per hr. with bituminous coal) in a minimum of space. This design is available in a size ranging of from 10,000 to 22,500 lbs. of steam per hour (about 325 to 750 horsepower).

Springfield Packaged Boiler - The Springfield Boiler Company, Springfield, Illinois, also produces a coal-fired packaged unit which uses either the Detroit agitating grate or the Hoffman air-cooled vibrating grate with spreader coal feed. This is similar to the Superior boiler and design for about the same size range. The first two to be manufactured have a steaming capacity of 35,000 lbs. per hour with a furnace heat release of 50,000 B.t.u. per cu. ft. per hour. These have been successful in continuous service and have been capable of overloads up to 45,000 lbs. of steam per hour.

Foster Wheeler Packaged Boiler - The Foster Wheeler Company designed a coal-fired packaged boiler using a conventional spreader stoker in the same size range as the previous boilers. Although the combination was reported to be too expensive to be competitive, its development is evidence of the company's interest in this class of equipment.

B.C.R. Packaged Boiler - Having discussed the work of individual companies in this field, it will be of interest to review the work by B.C.R., an industry supported organization.

In 1955 B.C.R. demonstrated the feasibility of designing an automatic packaged type of coal-fired boiler as a result of experiments with a water-cooled vibrating grate. Experiments with a Riley air-cooled grate showed limitations by comparison with the water-cooled version. Although modifications were made to reduce these limitations, the water-cooled grate was incorporated in the final designs which cover a range of boilers from 1,500 to 20,000 lbs. of steam per hour (about 50 to 650 horsepower).

The first four units are now being manufactured through an exclusive arrangement by the International Boiler Works Company, East Stroudsburg, Pennsylvania. The design incorporates an inclined pulsating water-cooled grate with positive coal feed. It is substantially smaller than the conventional stoker-boiler plants, which, together with a patented B.C.R. automatic control system, makes it competitive with equivalent oil-burning equipment.

Steam Plant Consulting Service

Although the vibrating grate and packaged boilers will provide a degree of flexibility not previously possible, there still remains the need for competent engineering consulting services. Mr. Earl Payne, a consulting engineer in the United States, started to promote the idea of such a service in 1951. At the time, his idea was rather advanced or radical in that he proposed offering designs of a complete packaged coal-burning plant to consultants and consumers. Since that time, he has prepared plans and the Bituminous Coal Institute recently has undertaken to actively promote the scheme.

Bituminous Coal Institute, U. S. A.

This well-known institute has just completed a reorganization in which 18 fuel and equipment engineers are located in 14 districts in the United States to work with equipment manufacturers, consulting firms, architects, retail coal dealers and consumers. In promoting the use of coal and to combat the competition from other fuels, B.C.I. is utilizing to the fullest extent the package plans and specifications which Earl Payne developed earlier. These may be improved and enlarged by B.C.I. and will be widely available for plants of many sizes. However, the first series of plans are for plant sizes common to most commercial heating plants, ranging from 25 to 500 horsepower with one and two boilers. Sizing of the boiler is not considered as important as the proper design of the over-all plant, including boiler room ventilation, coal bin, coal and ash conveying, stoker, overfire air and automatic controls.

Bituminous Coal Institute of Canada

The Canadian Commercial Coal Dock Operators Association, Toronto, have recognized, for the past few years, the need for a consulting service to those in the professions and industry who are concerned with steam power and heat generation. This organization followed the activities of the Western Coal Utilization Council, and at the beginning of this year established Bituminous Coal Institute of Canada, with Mr. John G. Hall as Executive Vice-President. The activities of the organization are patterned after those of B.C.I. in the United States, and it presently provides services in the Province of Ontario. The Institute has stated, however, that it co-operates gladly with other sections of Canada on this important national program.

Large Industrial Stokers and Boilers

Spreader Stoker

The underfeed stoker was unable to keep pace with the rapidly advancing steaming capacities of boilers. This limitation together with the high cost of the multiple retort stoker resulted in wide acceptance of the spreader stoker. Stationary grates were used at first but the demand for a self-cleaning grate soon resulted in the adaptation of the travelling type of grate. This self-cleaning grate is expensive and when the simple vibrating grate was introduced it was quickly recognized as a relatively inexpensive substitute. Now, the spreader stoker with a self-cleaning vibrating grate is available for boilers ranging from 5,000 to 100,000 lbs. of steam per hour. As previously stated, this grate can be water-cooled to make it less selective regarding coal characteristics.

Chain Grate

The conventional chain grate was recently improved by the Babcock Wilcox Company. To be more accurate it should be said that the furnace designed for the chain grate has been improved and simplified. The modification is the removal of the front ignition arch and the introduction of air jets aimed through the front wall and downward onto the raw coal as it passes the gate. In principle, the air jet causes furnace flame to curl back to the raw coal, thus igniting it. This is called "jet ignition" and is reputed to improve the burning of strongly caking coals.

Pulverized Coal Firing

The Combustion Engineering Company, and also the Riley Stoker Company, introduced directional burners to improve the flexibility not only of operation of pulverized-coal fired boilers, but also of coal selection. These are well-known refinements of a conventional burning system and need no further comment.

Cyclone Furnace

With dry bottom pulverized-coal fired boilers there is the nuisance of fly ash which requires the application of efficient dust-collecting equipment. Incidentally, dust collecting in some form is something that all coal-burning installations should have. However, in such large boilers as are pulverized-fired, this becomes a major factor. Wet bottom furnaces reduced this requirement somewhat, but the Babcock Wilcox Company introduced the cyclone furnace to reduce it to a minimum.

This is a hollow, horizontal water-cooled cylinder which burns coal crushed to minus 1/8th inch thus eliminating pulverizers and associated equipment. By removing 80 to 85 per cent of ash it minimizes the fly ash or dust-collecting problem. It has other advantages but has the limitation of requiring coal with an ash having a fusion temperature of 2500°F. or lower, and a viscosity of 250 poises at slag temperatures below 2600°F.

Turbo Furnace

The fly ash problem associated with pulverized-coal fired boilers in the larger sizes was the principal reason for the development of the Turbo Furnace by the Riley Stoker Company. This is a very attractive development which may prove to be one of the most important in the field of large utility or central station steam generators. The first two units, one having a capacity of 175,000 lbs. of steam per hour and the other 285,000 lbs. of steam per hour, were built just two years ago. Since then 19 have been sold, the smallest having a capacity of 500,000 lbs. of steam per hour and the largest 1,550,000 lbs. of steam per hour. This has been reported to be an unprecedented acceptance of a new boiler and burning system. It incorporates a new design of furnace in which directional-flame pulverized-coal burners are located in the front and rear walls and inclined downward into a slag pot at the bottom. The flames impinge on each other on the furnace bottom. This produces extreme turbulence and a high-temperature zone. The ash slags in the pot and is drained intermittently.

The flame so fills the relatively small refactory bottom that it is forced up into the centre of the radiant furnace without impinging on any of the walls. Consequently, the small amount of ash carried over cools before reaching the superheater tubes, and it was found that there was no need for soot blowers in this region.

The bottom temperature can be varied to suit the coals, and the highest required has been from 2800° to 3000°F. with special fuel (petroleum coke). Combustion efficiency is high as evidenced by 16 to 17 per cent CO_2 in the products of combustion and 4.7 per cent combustibles in dust collector fly ash without reinjection of fly ash. Under similar conditions the conventional furnace operates at 12.8 per cent CO_2 with 25.65 per cent combustibles in dust collector fly ash.

Petroleum coke was reported to have been burned successfully for the first time in this equipment. To do so, the Riley Atrita pulverizer was modified so as to increase velocity of the coke particles without changing the rotational speed. In actual operation, the petroleum coke has been pulverized to 70 per cent through 200-mesh, with over 90 per cent through 100-mesh, and a trace on 50-mesh.

Transportation Market

The complete dieselization of the railways within the next four to eight years under plans reported in the newspapers, end a market which has been important to Canadian coals. It is unfortunate that as yet there is no competitive coal-burning engine. The coal-fired gas turbine has not materialized, although Alco Products Inc. in the United States is developing a one-million-dollar prototype, using the direct-fired open-cycle gas turbine.

Under present conditions, there appears to be need for work on a suitable portable coal-gasifier or for new concepts, if it is expected to get coal back into this market.

Other Phases

There has been a trend toward improved grate materials and grate designs. Alloys are available which reduce the growth and oxidation characteristics of cast iron and provide longer life.

Laminated steels are available for coal bunkers with a corrosion resistant surface inside and mild steel outside. Acid resistant paints and fibre glass coatings can be applied to coal bunker surfaces, and there is room for further improvement.

Summary

The most important advances in the utilization of coal by combustion in the conventional applications have been discussed. Definite progress has been made in equipment to increase the efficiency of coal burning and to broaden the use of coal. The new equipment justifies intensive testing and further refinement to improve or widen its application. In order to capitalize on these developments, a vigorous engineering consulting service to the consumer is needed.

Engineering development has been hampered by a lack of knowledge of the physical and chemical make-up of coal. It is important that we have a better understanding of the mechanism by or through which coal cokes and becomes plastic in the process of ignition; of the mechanism of ash slagging on boiler surfaces; of the mechanism of corrosion by ash or slag; of the factors influencing grindability; of the processes of ignition and combustion; and of the influences of coal structure on reactivity.

There is some need for research on metals for use in stokers, coal bunkers, coal and ash conveying equipment. Improved corrosion and erosion resistant materials are needed for application to metal surfaces. Many valuable contributions could be made to coal utilization by engineering research on fly ash disposal, coal drying in bunkers or in the steam plant using flue gases, flue gas scrubbing, carbonization, gasification and similar related investigations.

What's New and What's Needed: — Chemical Aspects

by

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Ever since the turn of the century, and the establishment of coal science as a "legitimate" field of research, coal chemists have cherished a vision — the large-scale use of coal, not primarily as a fuel but as a chemical source material. Coal, they were quick to point out again and again, is after all the cheapest and most abundant form of available carbon; and carbon, in one form or another, dominates our very existence. Yet, it is only during the past few years that this chemists' dream has begun to move perceptibly nearer realization. By the 1940's, despite the classic work of Bergius, Franz Fischer and Tropsch, talk about chemicals from coal had degenerated into a series of distinctly hollow clichés; in the 1950's, it has regained some respectability and acquired a definite rationale. The stimulus which has brought about this change lies, I think, not so much in the introduction of new experimental techniques into coal research as in the reorientation of this research during the opening years of the present decade. For the first time, I think, chemical investigations on coal are being conducted in a properly mapped-out terrain.

At the risk of being accused of exercising hindsight, I venture to suggest that the principal obstacle to earlier progress in the chemical utilization of coal has been of the chemists' own making. The knowledge that a "normal" coal contains no more than about 5% hydrogen led them to become obsessed with the notion that coal is basically deficient in hydrogen; and this obsession, far more than any pressing industrial demands, caused them to channel all practical (and much academic) chemical research into hydrogenation and gasification reactions. The alternative possibilities, which were fundamentally as obvious 40 years ago as they are today, were largely ignored. To say this, is not to belittle hydrogenation and gasification work. The experience gained by operating these processes in large-scale demonstration units is invaluable, and there can be little doubt that hydrogenation and gasification reactions will play an important role in future developments. As a matter of fact, only two years ago a very extensive oil-from-coal plant, the world's largest so far, has been completed in South Africa, and others (destined for the Central African Federation and Southern Rhodesia in particular) are on the drawing boards or under actual construction. I shall return to these matters later. For the moment, I wish only to suggest that the concentration on hydrogenation and gasification to the virtual exclusion of all else has been a major factor in retarding the development of other processes even though some of these potential alternatives seem, prima facie, to be economically much more attractive. I have in mind, for instance, various coal carbonization processes whose operation in flexible and integrated installations may well be less dependent than Fischer-Tropsch syntheses on a fluctuating chemical market, and whose commercial success does not hinge so critically upon the development of new outlets.

Let me enlarge upon this statement in order to illustrate why carbonization, hitherto solely regarded as a means of satisfying the immense industrial demands for coke and gas, is now considered as a possible chemical coal utilization process.

When coal is carbonized in any conventional plant by conventional procedures, chemical by-products (amounting to perhaps 10 - 12 gallons per ton) are, admittedly, relatively insignificant. But this very meagre yield does not tell the full story. Stoichiometric calculations indicate that theoretically possible maximum yields of liquid by-products would lie in the neighbourhood of 140 - 150 gallons per ton and that the distribution of hydrogen among the many carbonization products should be amenable to direct control and variation. It is not, of course, suggested that these theoretical yields will ever be completely attainable: what is stoichiometrically possible will always be in excess of what is chemically possible; and the stoichiometric limits may also have to be somewhat scaled down in the face of known constitutional differences that prevail as between coals of different rank. But it is not unreasonable to hope that it will be possible to approach, say, 50 - 60 per cent of the stoichiometric limits and thereby to reach yields of 80 - 100 gallons per ton of coal carbonized. That this is not a vain hope, a sort of sham carrot held out to research sponsors and new recruits to coal research, is in fact indicated by several preliminary observations: there is increasing evidence that the mechanism of coal pyrolysis can be controlled and modified both by changes in carbonization procedure and by catalysts (or reagents functioning not unlike catalysts).

This new emphasis placed on an investigation of coal carbonization is, I think, one of the most exciting recent developments; and it opens the way to a most rewarding field of research. It will of course require much time and effort to bring the laboratory work (which is itself still in the very early stages) to a point at which transfer to the pilot plant becomes desirable. And before this happens, a detailed assessment of coal carbonization as a chemical coal utilization scheme is clearly impossible. In the meantime, however, we have here a very real challenge to the ingenuity of the chemist, and, in my view, a particular challenge to Canadian coal chemists: proper coal carbonization, to which a chemical development would always be an adjunct, is likely to play a vital role in the Canadian power-generation picture; and, equally important in some respects, carbonization research seems, at least at this stage, capable of being prosecuted with quite modest means.

A by-product of the increasing preoccupation of coal scientists with the fundamentals of coal carbonization is, incidentally, a gradually more complete understanding of the difference between coking and non-coking coals. Systematic chemical studies are now rapidly approaching the point at which a synthesis between the various, and frequently mutually exclusive, working hypotheses of the past may become possible, and at which coke manufacture may cease to be an "art" and enter the realm of technology.

Similarly, the "new coal chemistry" has taken some very important strides towards a solution of the vexing but more general problem of coal constitution. Coal chemists are still uncertain about the detailed structure of the coal "molecule": on the basis of available evidence (which is mainly derived from X-ray diffraction studies and infrared spectroscopy) we cannot, for example, unequivocally decide whether it contains a polynuclear system of fused aromatic rings, or single benzene rings linked by naphthenic structures or aliphatic chains. At this stage, we can only presume in favour of the first alternative. But on the other hand, some very important discoveries contributing to knowledge about the coal "molecule" have been made since 1952. A very ingenious theoretical framework which limits the choice of possible structures has been developed by a Dutch school of workers. For the first time, we can consider that we possess definite knowledge about peripheral groups, i.e. about functional groups disposed around the fringes of the coal "molecule". We are beginning to obtain reliable information about the distribution of oxygen in coal and about the role of oxygen in determining the pattern of physical and chemical behaviour of coal. And we are coming closer to understanding the mechanism of coal extraction and the nature of solvent extracts. All this, I think, is bound to have profound repercussions on coal utilization generally and on the chemical utilization of coal in particular. To cite but one example: using information about peripheral groupings in the coal molecule, coal chemists are already beginning to think in terms of reactions that were not even considered 5 years ago. Mild hydrogenation with lithium in ethylene diamine is a case in point.

At the same time, the gathering momentum of current chemical research on coal is likely to re-focus attention on such matters as industrial solvent extraction of coal and the oxidation of coal to complex acids. Perhaps because research fashions, like ladies' clothes, tend to run in cycles, these topics (which were under active study in the forties) have rather slipped back into obscurity. With respect to coal oxidation, the problem is, I think, largely one of finding markets for the products; given these, the process could even now be operated without serious difficulty. Yet, if our optimism about the contribution of coal oxidation and solvent extraction to chemical industry must, for the time being, be tempered, we have good reasons for at least allowing these processes to figure in our thinking. Both are likely to become more prominent as basic laboratory-scale chemical research develops. For instance, it does not seem unrealistic to suppose that a closer understanding of the structure of the coal "molecule" will suggest ways and means of carrying out oxidation and solvent extraction as specific reactions rather than as "random processes". And if this appreciation of the present position is correct, both techniques may find interesting and commercially important applications.

I am conscious that everything I have said so far about chemical developments in the field of coal utilization relates to laboratory work, and that most is still either highly speculative or at best in the very early stages of investigation. Nothing that I have said so far, then, is likely to satisfy the "practical" man. However, to the question "what's new in chemical coal research?", what I have attempted to outline seems to me the most exciting, and in the long run the most significant, answer. And by indicating some rewarding fields of research, it obviously kills two birds with one stone by providing an answer to "what's needed?".

On the purely "practical" side of new chemical work, the only significant item that I can mention is the South African SASOL oil-from-coal plant to which I have already briefly referred earlier. Located some 50 miles south of Johannesburg, this plant demonstrates what is possible under certain conditions. The installation is designed to gasify about 7,500 tons per day in Lurgi generators and to convert the resultant CO/H mixture into gasoline, diesel oil, fuel oil, industrial solvents, paraffin waxes and creosote in a Kellogg synthesis plant and a smaller (German) Arge unit. (The quantities of the various products anticipated to be obtained from the synthesis reactors are listed in the accompanying table.) Gasoline itself will be produced at a cost of ca. 16.3¢ per imp. gal. and will therefore, at the refinery selling price of about 25¢ per gallon, yield a profit of over 8.5¢. It is noteworthy that no provision has in this calculation been made for revenue accruing from the sale of refinery by-products (such as diesel oil, paraffin wax, liquid petroleum gas, etc.). But South African conditions, which make the SASOL installation such a remunerative undertaking, are not likely to be easily reproduced on this continent. While SASOL's own mine employs a labour force of about 390 (350 Africans and 40 European staff members) and the very latest types of mechanical equipment (with an output of about 20 tons per man-day), total mining costs are still held to about 70¢ per ton. I must leave it to the economists to determine what conditions must be satisfied and on what scale an operation must be carried out if a SASOL-like venture is to flourish in this country. On balance, I am inclined to think that the only real economies possible in North American gasification work lie in improved catalysts (particularly in the development of catalysts that will not trigger conversion of CO into CO_2), in still higher throughput rates, and simplification of reactor designs. But all these are matters that do not, and ought not, fall within the scope of Canadian coal research work.

Planned SASOL Production

A. Refinery Products:

Gasoline	4 300 bbl/day
Diesel oil	335 bbl/day
Fuel oil	180 bbl/day
Paraffin waxes (m.p.=105-240°F)	18 000 tons/year
Liquified Petroleum gas	720 gal/day
Pitch and tar road primers	2 685 gal/day

B. Chemical Products:

Ethanol	4 000 000 gal/yr
Propanol	2 000 000 gal/yr
Butanol	525 000 gal/yr
Acetone	210 000 gal/yr
Methyl Ethyl Ketone	260 000 gal/yr
Mixed Solvents	60 000 gal/yr
Benzene	500 000 gal/yr
Toluene	280 000 gal/yr
Xylene and Solvent Naphtha	500 000 gal/yr
Creosote Wood Preservative	1 000 000 gal/yr
Crude Phenols	6 000 tons/yr
Ammonium Sulphate	35 000 tons/yr

The Role of Thermal Power and The Place of Coal In Canada's Energy Program

by

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The first electrical services in many Canadian communities were provided by small steam-driven engine generator sets. The successful development of electrical transmission systems led to the utilization of water power at more or less distant sites. Electrical energy was supplied from such sources in greater amounts and at less cost than from the earlier steam plants. The development of domestic electrical appliances and the extension of services to villages, outlying homes and farms added loads at such rates that most low-cost hydro sites within economic transmission distances of loads have been developed. Remaining hydro sites either require large investments per unit of capacity or are in remote locations. Hence consideration is being given to thermal power plants to supplement available hydro energy.

Steam plants have been added to some hydro-electrical systems to provide for seasonal low-water flows. In other cases thermal plants are planned to carry system peak loads. Recently the economic co-ordination of thermal and hydro plants has received serious study and some interesting results have been achieved.

Thermal plants may be of several types, dependent upon available fuels. Where ample low-cost coal is available, this serves as fuel in steam power plants. Where there are oil refineries or where transported fuel oil is available, this product may be competitive in over-all cost with coal. Natural gas is burned in some plants, but this can be regarded as a passing phase, as natural gas is a premium fuel and, when provided an adequate market, it will sell for domestic and industrial uses at relatively higher prices than coal or fuel oil. Atomic energy reactors may replace fuel furnaces in future thermal plants.

Another form of thermal plant, the gas turbine, is being added in Canadian plants. It burns either natural gas or fuel oil, as no successful coal-burning gas turbine is at present available. There appears to be ample justification for the assumption that the prices of these fuels will advance in the future. While the gas turbine appears to have a place for peak-load service, the uncertainties of first cost and future fuel costs have retarded its extended use.

Recent studies of Canadian system developments indicate that thermal plants, largely in the form of steam plants, supplied with fuel or atomic generating equipment will be installed to an increasing extent in future extensions. It is estimated that 1,300,000 kw. of thermal capacity is now in operation on Canadian utility systems; equipment totalling about 1,600,000 kw. is said to be under construction or on order; and some 1,500,000 kw. of additional plant are under consideration. If allowance is made for the time required to design, purchase and install this added equipment, it appears that about 4,600,000 kw. of thermal plant will be available by 1965. System demands can be assumed to double every ten years. Hence beyond 1965 the capacity of thermal plants will increase with great rapidity as the growing loads of many systems must be carried by new thermal plants. It is thus possible that 20,000,000 kw. of thermal plant will be in service by 1975.

Among the principal problems confronting Canadian engineers, are those connected with the planning and design of these additional thermal plants and their co-ordination with the hydro plants to produce electrical services at lowest cost to customers. Canadian engineers have designed many outstanding hydro plants and it is now fitting that they should undertake the planning and design of these new thermal plants.

A most important factor in planning is the early choice of sites for future plants and the purchase of such property at once, even though it may not be built upon for some years. Otherwise it has been the general experience that industries or domestic homes have occupied all desirable sites. Utilities in the United States are experiencing great difficulties in securing desirable sites. Plants must frequently be located at considerable distances from load centres as a result of this lack of foresight in securing future sites during earlier years.

Co-ordination of hydro and steam plants is best secured when each is operated to secure maximum dollar efficiency for the system. Hydro run-of-river plants, with no water storage facilities, must be assigned base loads to secure maximum use of the river flow. The balance of load which includes peak loads must then be carried by hydro plants having water storage and by interconnected thermal plants. Such thermal plants may operate on a daily one or two shift basis and at variable loads, this operation leads to high operating costs. The economics of the installation of capacity at run-of-river plants to utilize the secondary flow during spring and fall high river flows is a problem at each individual site. Such added capacity can be provided for in the original design at comparatively low cost. It will generally be found economical to develop this secondary energy at a later date due to increasing fuel costs of interconnected thermal plants.

When hydro dams provide for considerable water storage, a different situation exists. During high river flows, the plant should be operated to prevent, if possible, any waste of water over the spillway, and consequently would carry the base load of the system. The thermal plants would carry the remainder of the load, and may operate on a one or two shift basis and at variable loads, as for the run-of-river system. At times other than during high water flows, the base load would be assigned to the thermal plant which would then be operated at its best economy of both fuel and labor. The remaining loads, including the peak load would be carried by draw-down of the storage ponds by shift operation of the hydro units. Large peak load capacity could be made available generally at lower first cost than by any other means, by adding more units at the hydro plant for draw-down operation each day. The pond level could be restored during non-operating hours. In the case of a pond or lake with seasonal storage, its available kilowatt-hours could be fully utilized by adjusting the load on the thermal plant.

Seasonal conditions in Canada are such that the thermal stations under these conditions would operate for a major portion of the year at high load factor and therefore high efficiency. This is often justification for the installation of large, high pressure and high efficiency steam plants on systems with water storage.

Pumped storage plants have been built in Europe to provide for peak loads. Energy from run-of-river or other plants can be used in off-peak hours to pump water from a river or lake to a high-level storage pond from which it can be delivered through high head turbines to carry later peak loads. There are situations in Canada where pumped storage may be economically utilized by using either run-of-river flow or pumping by energy from thermal plants with low-cost incremental fuel rates. Since it appears desirable to operate atomic energy plants at full output at all times, studies should be made of the possibilities of pumped storage plants on the various electrical systems to use the off-peak energy from the atomic energy plants.

The impending addition of large thermal plants to hydro systems is justification for engineering reappraisals of all hydro plants now developed or to be developed, to determine whether additional capacity could be added and storage with draw-down provided at economical cost for peak-load operation. Experience has indicated that the incremental cost of such plant additions may be much less than the investment in equivalent capacity in new hydro or thermal stations. The possibilities of pumped storage should be reviewed at the same time, with increasing fuel costs in mind.

The place of atomic energy in power development is still under study. Power plants of several systems based on the use of enriched uranium ore are under design and construction in the United States. The first cost of these plants is said to be high, due in a large measure, to the development costs of such radically new plants. True operating costs are not known yet. The price to be charged for the enriched uranium is controlled by the United States government which will credit the user for plutonium and other by-products of atomic fission. The operating staffs of these early plants will be larger than in later developments as much experimentation is still to be done. Consequently total operating costs of these early plants will be high.

The atomic reactor will replace the fuel-burning furnace only. Contemplated steam pressures are relatively low and unless some separate fuel-fired equipment is added, the thermal performance will be poor due to lack of high pressure and superheat. Satisfactory means have not been developed for the disposal of large quantities of radio-active waste materials from these American plants. The Calder Hall plant in Great Britain uses raw uranium which is less costly than the enriched product employed in the United States. It has been proposed to use raw uranium in a Canadian plant which is said to differ in design from Calder Hall.

Many problems connected with the use of atomic energy remain to be solved. Cost data must be gathered both on first and operating expenses. The useful life of plants must be learned. Experience must be gained on means to handle radio-active materials. Several years must elapse before these factors are known sufficiently to justify the extended use of atomic energy plants. Some consider that such plants will not be in general use before 1970. There is also the possibility that some one will learn how to use low-cost hydrogen or other elements in the reactor in place of expensive uranium.

The first cost of an atomic energy plant is high as compared to thermal stations. The lower rates of capital charges in government-owned systems would justify the addition of atomic energy plants on such systems before their use by the privately-owned utilities.

In the meantime, the performance of fuel-fired plants will be improved by the use of higher steam pressures and temperatures, by combination of gas turbines and steam generators, and by other means. Hence plans for extensions to utility systems during the next decade will probably be based in new hydro and fuel-fired generating plants. Extensions now in contemplation in general consist of such plants. However, coal will meet increasing competition as the supply of heat to boilers from natural gas, fuel oil, and later from atomic fission.

The preceding paragraphs have presented in general terms, the place of thermal plants on Canada's power systems. Consider next the probable use of coal in the several provinces.

Newfoundland has considerable developed and undeveloped water power but has found it necessary to add a steam stand-by plant at St. Johns, due to drought and winter freeze-up. It is proposed to burn fuel oil in this plant. Labrador appears to have ample water power for its future needs, except in the far north where thermal plants are under consideration. Coal abounds in the Arctic islands and may form a future source of fuel supply.

Prince Edward Island has a comparatively small electrical demand. The Charlottetown steam plant depends on fuel from outside sources. No large increase in energy demand is anticipated.

The power situation in New Brunswick and Nova Scotia is unsatisfactory. While hydro energy could be made available in New Brunswick by development of storage on the headwaters of the St. John river in Quebec and the State of Maine, small steam plants furnish the major energy supplies. Coal-burning plants supplemented by small hydro developments serve four major power systems in Nova Scotia. It is claimed that the cost of electrical energy in both provinces is high.

A thin seam of low-grade coal with deep overburden is strip-mined to supply small plants at Grand Lake, Chatham and St. John. Since the efficiencies of these plants is relatively low, the fuel costs per kilowatt-hour are high.

In Nova Scotia the Springhill coal mines have reached considerable depths. Mines on Cape Breton are now being worked several miles under the ocean floor. Such operations result in high coal cost so that fuel oil has become competitive with coal in much of the province. Small steam plants are in operation at Maccan, Stellarton and Sydney, with some larger more modern units in the Halifax station.

As pointed out in a discussion at the Winnipeg conference in 1954, the most promising solution appears to be in the formation of a power pool which would combine the hydro resources of New Brunswick and upper Maine, with the steam stations and transmission lines of the two provinces. This would permit the addition of large highly efficient steam units, in combination with hydro plants supplied by regulated river flow and controlled storage for future power supplies. Such an integrated system with a simplified transmission system should lead to minimum power costs for that area. These provinces need low cost electrical energy to encourage mining and industrial developments, but it is questionable whether coal prices can be reduced below present values.

Quebec has ample hydro energy to meet its needs for some time and may even supply some energy to neighboring areas. Industries are developing rapidly in the province, which will require much fuel. While some will be supplied with fuel oil, coal from Nova Scotia and from the United States will be the principal fuel. The price of coal from Lake Erie ports will decrease when the coal forms return cargoes for ore boats using the seaway. The long cold weather season at Montreal would seem to justify the installation of a central steam-heating system with by-product electrical energy.

Ontario has no coal deposits in production. The development and distribution of electrical energy is controlled by the Hydro-Electric Power Commission of Ontario. The hydro resources in the southern section are approaching complete economic development. The remaining hydro sites lie in the northern section, at great distances from loads. Two large steam stations at Toronto and Windsor are operated on a shift basis to carry system loads in excess of available hydro. Some pumped storage has been provided at Queenston, but, on account of the scenic value of Niagara Falls, Lake Erie cannot be used as a storage pond. It may be possible to have Lake Ontario serve to some extent as storage for the seaway power plant, particularly during the closed season for navigation, which coincides with heavy winter peak loads. A study of other hydro plants, large and small, may disclose locations where water storage and peaking capacity are possible. Such developments would permit greater and more economical use of the large steam plants. Interconnections with utilities in the United States has resulted in the availability of stand-by reserves, a better co-ordination of hydro and thermal plants and cost savings to all participating parties.

Coal for the steam plants comes from the United States. Objections have been raised to this purchase of coal, as money leaves Canada. At the present moment, these foreign purchases tend to lessen the premium on the Canadian dollar, which premium is deplored by such exporting industries as paper, minerals, iron ore, etc.

Future system additions in Ontario will probably consist of more coal-burning steam plants, followed later by those using atomic energy.

The system of the Hydro Commission in Western Ontario has only hydro plants. Some undeveloped sites are still available. Loads are growing rapidly on this system as a result of mining and other developments. The addition of a steam stand-by plant at Lakehead has been temporarily postponed by an interconnection with the Manitoba system, which provides for emergency reserve and some use of the new Manitoba steam stations.

The hydro energy in the Winnipeg river in southern Manitoba is fully developed, and steam plants are under design and construction at Brandon and Selkirk, which will use Saskatchewan lignite as principal fuel. The development of hydro in the north to serve the Winnipeg area is not economic at present owing to the long transmission distance. Hence load increases in the immediate future will probably be carried by additions to the steam plants.

Hydro is being developed in northern Manitoba to serve the new nickel mines and other developments. While much hydro is available in the north, it is beyond economic transmission distance to Winnipeg.

Saskatchewan lacks hydro in the southern section which is served by steam plants at Regina, Moose Jaw, Saskatoon, and Prince Albert, and by a number of diesel plants. The government has an extensive transmission system over the province. Natural gas from recent discoveries now supplements coal at certain of the steam plants. Larger steam turbines are being installed at Saskatoon and in a new station adjacent to the large lignite deposits at Estevan. The future electrical needs of the province will probably be supplied by fuel-burning power plants until the northern areas are more fully developed. While the abundant lignite is not a high-grade fuel, it can be easily recovered and provides a cheap fuel source to near-by steam plants.

Alberta has immense resources of coal, petroleum and natural gas. The Rocky Mountains provide sites for many small and medium sized hydro plants. Winter freeze-up lessens run-off from the mountains and this has led to the building of dams to form storage lakes in the mountains which can regulate winter flows. Hydro plants with such storage are particularly suited for peak load operation. Such water storage will be extended, for cities and towns on the lower rivers will require greater quantities of water from regulated river flow for domestic supplies in winter. The storage dams may even be financed jointly by the public utilities and the municipalities needing water. Calgary Power Limited has eleven hydro plants in service and others under consideration.

Steam plants have been built at Medicine Hat, Lethbridge, Sentinel, Forestburg, Drumheller, Edmonton and Wabamun. The Edmonton and Medicine Hat plants burn natural gas. Gas turbines are in operation at Vermilion and are being added at Edmonton and Lethbridge. It has been the experience in the United States that the price of natural gas continuously increases as soon as the long distance pipe lines are completed, and this will probably be the experience in Alberta. With abundant supplies of low-cost coal, it is a reasonable assumption that Alberta's rapidly increasing electrical demands will ultimately be supplied by coal-burning plants supplemented by hydro energy. The various systems are inter-connected so that future joint operation for energy production at minimum cost can be accomplished by the formation of a power pool.

British Columbia has large undeveloped coal deposits together with large resources of potential water power. The electrical demands of the mainland and Vancouver Island are being supplied by hydro. Gas turbines for peak load services are being added at Vancouver city and on the Island. Pending developments of hydro on the upper Columbia river and on the Fraser river will probably provide for future load increases, although coal-fired plants may be added later for stand-by and peak load services.

This review presents the situation as regards thermal power plants in the several provinces. It appears that Canadian coal production is approaching a minimum amount at the moment. Markets are still being lost to competitive fuels. Coal costs may be reduced by increased use of automatic mining machines, by improved coal preparation processes or by decreased transportation rates. Steam plants such as Estevan and Wabamun are being placed adjacent to the coal deposits. Large steam plants require assured supplies of coal secured either by contracts with large mines or by ownership of the coal deposit. Unless coal costs become too high as compared with atomic energy or other fuels, the inevitable increase of capacity of thermal power plants will lead to steadily increasing demands for coal.

Based on present indications, markets will continue to be lost to Maritime coal for a few years and consumption will then slowly increase. Much more coal from United States will be imported into Ontario and Quebec. Coal consumption in the Prairie Provinces will increase rapidly but will be confined to local areas. Coal fields in British Columbia may be untouched for a few years.

Assessment of Costs For Power Generation and Transportation

by

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The analysis of the cost of generating and transmitting electric power involves so many variables that it is difficult to approach the problem of finding the conditions for the most economical generation in general terms. Obviously each power system presents its own problems such as the location of fuel and load centres; fuel costs, freight rates and transmission costs. However, certain general relationships can be established and conclusions can be drawn for a typical though hypothetical set of conditions.

For given fuel costs, wage rates and interest rates, the cost of generation depends upon three important factors namely: the size of the individual plant, the load factor in effect on the system as viewed from the plant, and the capacity it is necessary to hold in reserve for emergency conditions. In the design of a given system, consisting of several generating plants interconnected by a transmission system, these factors can be varied to a considerable degree for any particular plant and the only meaningful evaluation of costs must be for the system as a whole. Generally speaking any system will already contain a variety of plants of varying sizes more or less unsuitably adapted to present needs, and the most usual problem arises out of the need to plan additional generating capacity.

Assuming that wage rates, interest rates and fuel costs are held constant (although the effect of variations in these factors will be examined later), it can be shown that there is a very significant reduction in generating cost as the size of unit increases. The graph of Figure 1 is taken from the experience of the Saskatchewan Power Corporation and shows a rapid decrease in cost for plants on the order of a few thousand kilowatts with a less rapid but continuously decreasing cost for larger sizes. Between the 5,000 kw. to 10,000 kw. range and the range over 100,000 kw. there is a better than 2 to 1 spread in generating cost. This factor is one of the primary reasons for interconnecting scattered loads to a common generating station of large capacity, rather than supplying each town or city separately with a small plant of appropriate size. When the constituents of the generating costs are examined (Figure 1), it is apparent that each factor is higher for the smaller plant although the change in labour costs is much the most significant, the operating personnel being by no means multiplied in the ratio of capacity as the plant size increases. In making a comparison of costs it is necessary either to assume a fixed plant size or to make assumptions as to the typical sizes that would be encountered in the various situations examined.

For the purpose of the curves of Figure 1, each plant has been assumed to operate on 50% load factor with 25% of its capacity in reserve at the time of peak load. These are not very realistic figures for an interconnected system where the most economical plants would normally be the more highly loaded.

However, for comparative purposes, Figure 1 shows the trend of increasing efficiency for the larger plants with a constant fuel cost based on the cost of Alberta coal at Saskatoon or equivalent oil and gas prices. The capital costs associated with larger units also decrease due to the reduced amount of labour and materials involved per kilowatt. The relative significance of the cost factors indicated are greatly influenced by local conditions as to fuel prices, wage rates and interest rates.

Load factor is defined as the ratio of the average load to the peak demand and as viewed from the plant, would include the losses in the transmission and distribution systems. This factor is not infrequently below 40% in rural and small-town (primarily domestic) systems, and rarely over 55% unless there are exceptional industrial loads in continuous operation. The capacity of the plant or plants must be capable of meeting the maximum or peak demand, which occurs only once in the year (perhaps just before Christmas), and so for a large part of the time much of the equipment is idle. The effect of low load factor is thus to increase the capital cost of the station for a given energy output. Conversely, high load factor increases the relative significance of fuel costs in the total cost. The influence of load factor on generating cost is illustrated in Figure 2. In each case it is assumed that 25% of the capacity is held in reserve, that is the 100% load factor case still only utilizes 75% of the plant capacity. Thus while Figure 2 shows the relative effect, an individual plant in a system could still be operated at lower cost, if no reserve capacity were held in that particular plant.

The plant capacity that must be held in reserve for contingencies also varies greatly with the size of plant. A small plant may consist of three units of equal size, one of which must be held in reserve, giving say 35% spare capacity. A larger plant of four units might require only 25% spare capacity while much larger stations (or interconnected systems) might approach a reserve capacity of only 15%. The curve in Figure 3 gives this effect; the effect of plant size is illustrated for three hypothetical systems. The first case assumes sixteen separate small plants that might be encountered in a group of towns and small cities, but which, since they are not interconnected, must each carry a great deal of spare capacity. The first stage of integration assumes the development of four plants to sizes between 30 mw. and 75 mw. interconnected to supply the same load and requiring 25% spare capacity. Finally, the alternative is one larger plant supplying the whole system with resulting savings both by virtue of its increased size and as a result of reduced spare capacity. The broken heavy line, in Figure 3, thus represents the most typical trend of generating costs for a supply to a given area for a given load supplied by small, medium and large plants as integration proceeds.

If in practice the transition from a number of small plants to a few large ones were made over a period of years, the increasing load would lead not to one large plant of equivalent size to the group of small ones (as assumed in Figure 3) but to perhaps two or three large ones.

The economies secured in generating costs by such integration must however support the cost of interconnection. This would usually be the case in the development of a typical system, even supposing the basic elements of generating costs, fuel, wages and interest rates remained fixed. However, the process of interconnection provides the opportunity for locating plants at the most economical positions for the cheapest fuel and the greatest load. An examination of these factors leads to closer scrutiny of the elements of generating cost and of the cost of moving power either as fuel or as electrical energy.

The cost elements in generating a kilowatt-hour of electrical energy (which are indicated in Figure 1) can be broken down into two main categories: those which are fixed or dependent only on the size of the plant or the peak demand it is required to supply, and those which are variable and increase in proportion to the amount of energy generated. The breakdown for the sizes of plants considered is given in Table 3. *

* These represent approximately the experience of the Saskatchewan Power Corporation with appropriate revision to current prices.

Fixed costs include primarily the capital costs of interest charges and depreciation on the whole plant investment. For this purpose 6% has been used as a combined sinking fund and interest charge which does not vary much for interest rates between 3-1/2% and 5%. A life of 35 years is taken, at the end of which time it is assumed that the original investment will have been completely retired.

While fuel costs are almost entirely variable costs, some fuel is used even when there is no load on the station so some part of it is regarded as fixed. Similarly, part of the operating labour, maintenance and administration cost is fixed. The fixed costs are thus assumed to be:

Interest and depreciation	100%
Labour costs	65%
Administration costs	65%
Maintenance	50%
Fuel	5%

The remaining parts of these costs are the variable costs and are apportioned per kwh. generated.

It is possible to calculate the generating cost for a given plant by assigning to it the appropriate kilowatt load including the reserve capacity and the kilowatt-hours of energy produced. Where several plants are interconnected the spare capacity will be assigned to the plant which has the highest cost per kwh. The maximum amount of energy will be assigned to the plant with the lowest variable cost. The system load will in fact be divided between base load plants operating at high load factor and generating as much of the energy as possible, and peak load plants which will be in operation mainly over peak periods and will generate little energy. The peak load plants will be those with high variable costs.

In a new or expanding system it will frequently be possible to design a plant for peaking purposes, when the aim would be to secure the minimum fixed costs and accept high variable or energy costs, while a plant for base load use would aim primarily at low variable costs. Thus fuel cost is not important in peaking plants but fundamental to a base load plant.

From these considerations it is evident that a base load plant will tend to be located at the source of minimum cost fuel while the peaking plant may be at the load centre, in or close to a major city.

However, the cost of transporting the energy, whether as fuel or electricity is fundamental in the analysis of such a system. Transportation of fuel or electricity involves either coal by road or rail; gas or oil by pipeline; or electric power over high voltage transmission lines. The comparative costs involve the fixed and variable factors corresponding approximately to capital charges and operating costs and are therefore sensitive to load factor.

It is necessary to distinguish between energy transportation as such, and the movement of fuel which is to be used for the production of electricity at the load centre. In this case the comparison to be made must be on the basis of kilowatt-hours and the cost to be determined for coal, for example, is the cost for the amount of coal to generate one kwh. Thus the efficiency of conversion is involved and must be known or assumed for the particular case. In the case of transportation of fuels there is a negligible loss, but where electrical energy is transmitted there is a significant loss to be evaluated and included in the cost.

Railway freight rates tend to be more a historical accident than a reasoned cost structure, and so it is difficult to state the true cost of transporting the coal required to generate a kilowatt-hour. It is a vague function of distance but also, in Western Canada, depends on the direction.

For example, lignite coal can be taken from Estevan in a northwesterly direction 143 miles to Regina or 303 miles to Saskatoon for 15 cents and 9 cents respectively per million B.t.u. per 100 miles. Drumheller subbituminous coal, however, can be moved in an easterly direction to Regina (434 miles) or Saskatoon (315 miles) for 6 cents and 7 cents respectively per million B.t.u. per 100 miles. In these examples the cost varies from 6 cents per million B.t.u. per 100 miles, to 15 cents with a mean of say 10 cents per million B.t.u. per 100 miles or 1.0 mills per million B.t.u. per mile. It is interesting to note that railway freight rates do not take into account the load factor, and so the cost of moving coal to operate a peak load station mainly in winter would be no more than the cost for a base load station with high load factor. Gas by pipeline and electricity by transmission line would show decidedly higher costs for peak load transmission.

Examination of the zone rates in operation for the Trans-Canada Pipe Lines Company reveals at least one estimate of large scale transmission costs for natural gas. Based on the spread between Regina and Montreal, the cost per million B.t.u. per 100 miles is approximately 22 mills at 50% load factor, 18 at 75% and 16 at 90% load factor. There is considerable variation in these figures over different sections of the line. The figures quoted, however, show that the cost of moving coal by rail is some five times that of moving gas by large pipeline. Transmission costs for a much smaller pipeline, such as those used by the Saskatchewan Power Corporation, are consistent with these, being of the order of 0.2 mills per million B.t.u. per mile, at high load factor.

If the efficiency of conversion of gas or coal to electrical energy is taken to be 12,500 B.t.u. per kwh., the above figures represent the following transportation rates (mills per kwh. per 100 miles):

	90% L.F.	75% L.F.	50% L.F.
Gas	0.2	0.22	0.28
Coal	1.25	1.25	1.25

For comparison with these figures the cost of electrical transmission can be determined from Saskatchewan Power Corporation experience and design figures. Based on 138 kv. wood pole construction for 60 mw. with 10% loss, 120 miles from Estevan to Regina, the cost is (mills per kwh. per 100 miles):

90% L.F.	75% L.F.	50% L.F.	15% L.F.
0.39	0.59	0.59	1.43

It thus appears that the transmission of electrical energy is distinctly more economical than the transportation of the coal necessary to produce it at all but the lowest load factors, though not as low in cost as the movement of natural gas where this fuel is used.

In the case of the Saskatchewan Power Corporation plants at Saskatoon and Estevan, each of comparable efficiency and operating cost, save for the cost of fuel, there is a difference of 18 cents per million B.t.u. between the fuel price at Saskatoon (28 cents) and at Estevan (10 cents). This represents approximately 2.2 mills per kwh. difference in the generating cost. At high load factor with a transmission cost of approximately 0.5 mills per kwh. per 100 miles, it is possible to move this energy more than 400 miles and break even on the operation. This would easily allow of the movement of this base load power to Saskatoon (300 miles from Estevan), and it would be a satisfactory procedure (if other physical conditions permitted it), provided there were a peaking plant at Saskatoon.

Coal-burning steam turbine plants normally require an immense amount of cooling water for the condensers. This water is often not easily available at the mine, and part of the potential saving in transportation cost is lost in moving the coal to the water or providing a water supply at the mine. Recent developments in completely air-cooled steam turbine generating sets appear likely to solve this problem at only very moderate increase in plant cost.

It would be somewhat unusual to transmit gas over a considerable distance to serve a power-plant load alone. It is much more probable that the gas would be in use for general distribution and surplus gas only would be used in the plant. However, should the opportunity arise it might be noted that the spread of some 10 cents per million B.t.u. between the gathered gas price and the coal price at the load centres in Saskatchewan (or 1.25 mills per kwh.) would justify a pipeline of over 600 miles to supply the plant alone. That this procedure is not adopted is due to a recognition of the value of gas as a domestic and industrial fuel and the acceptance of a prior claim for these loads to the presently limited reserves of natural gas.

The cost of transmitting oil of moderate viscosity by pipeline is comparable to that of transmitting natural gas on a B.t.u. basis, but the price of oil (crude or refined) is rarely competitive with coal at the load centre and so need not be considered in this case. The residue oil from refinery operations is sold competitively with local coal, but is too viscous for effective transportation by pipeline over any significant distance.

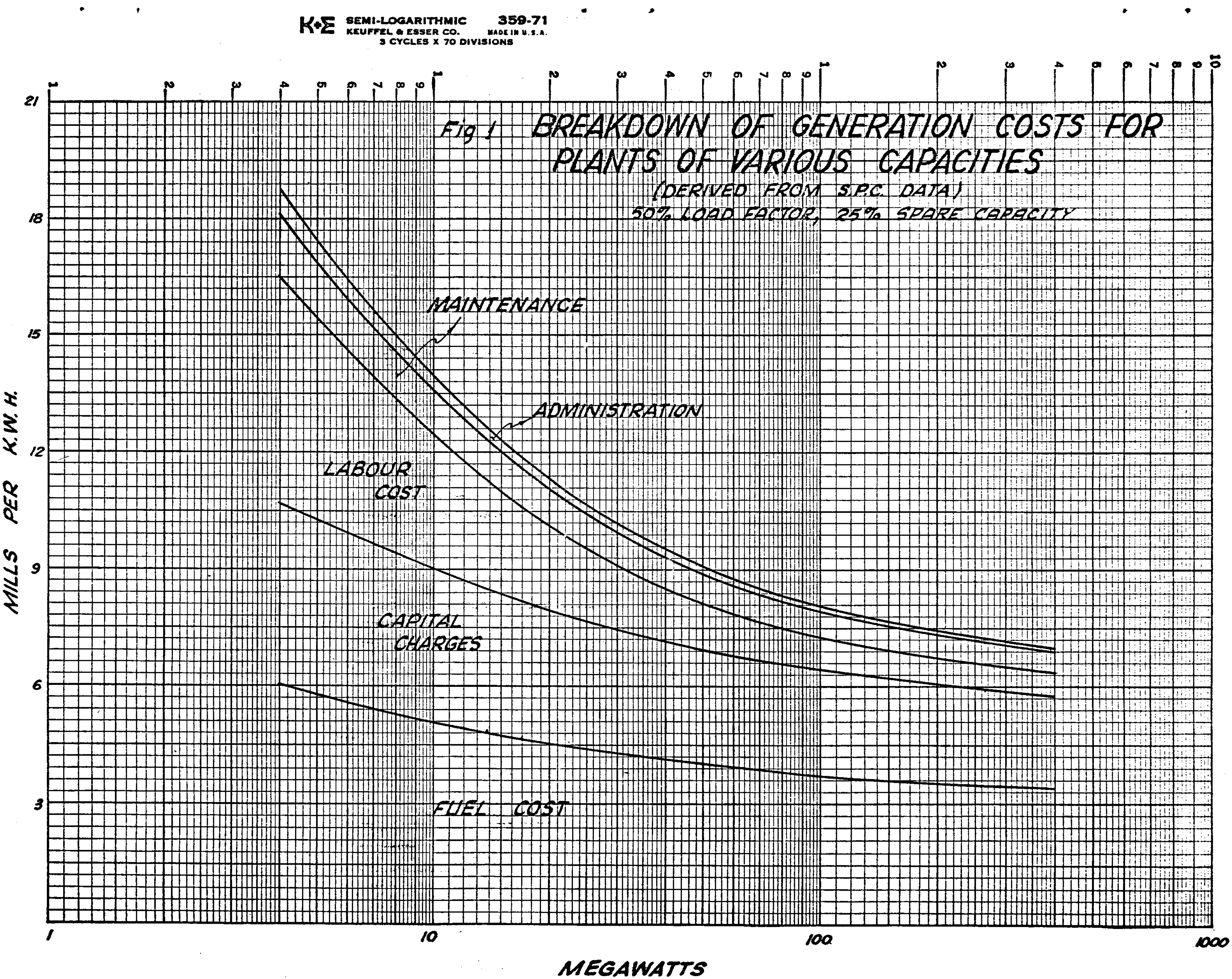
Certain general conclusions may now be deduced:

1. Where coal must be moved a considerable distance to a plant, it will almost always be more economical to place the generating plant close to the mine and transmit the power.

An exception to this would be a plant designed for stand-by and peak purposes where fuel (and freight) costs would not be significant factors.

2. Where coal and other fuels are equally available at the load centre, the competitive position of coal will almost always be improved by locating a plant at the mine and transmitting the power. This will be particularly true if the plant is designed for base load.

3. Where gas is available as a fuel, it will almost always be preferable to locate the plant at the load centre and transmit the gas. The distance over which such transmission is feasible will depend upon the spread between gathered gas prices at the field and the coal price at the load centre. The economics could generally be improved by using two fuels, gas for the base load and coal for peaks.


K+E SEMI-LOGARITHMIC 359-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
Fig 1 BREAKDOWN OF GENERATION COSTS FOR PLANTS OF VARIOUS CAPACITIES
(DERIVED FROM S.P.C. DATA)
50% LOAD FACTOR, 25% SPARE CAPACITY
MAINTENANCE
ADMINISTRATION
LABOUR COST
CAPITAL CHARGES
FUEL COST
MILLS PER K.W. H.
21
18
15
12
9
6
3
1
10
100
1000
MEGAWATTS

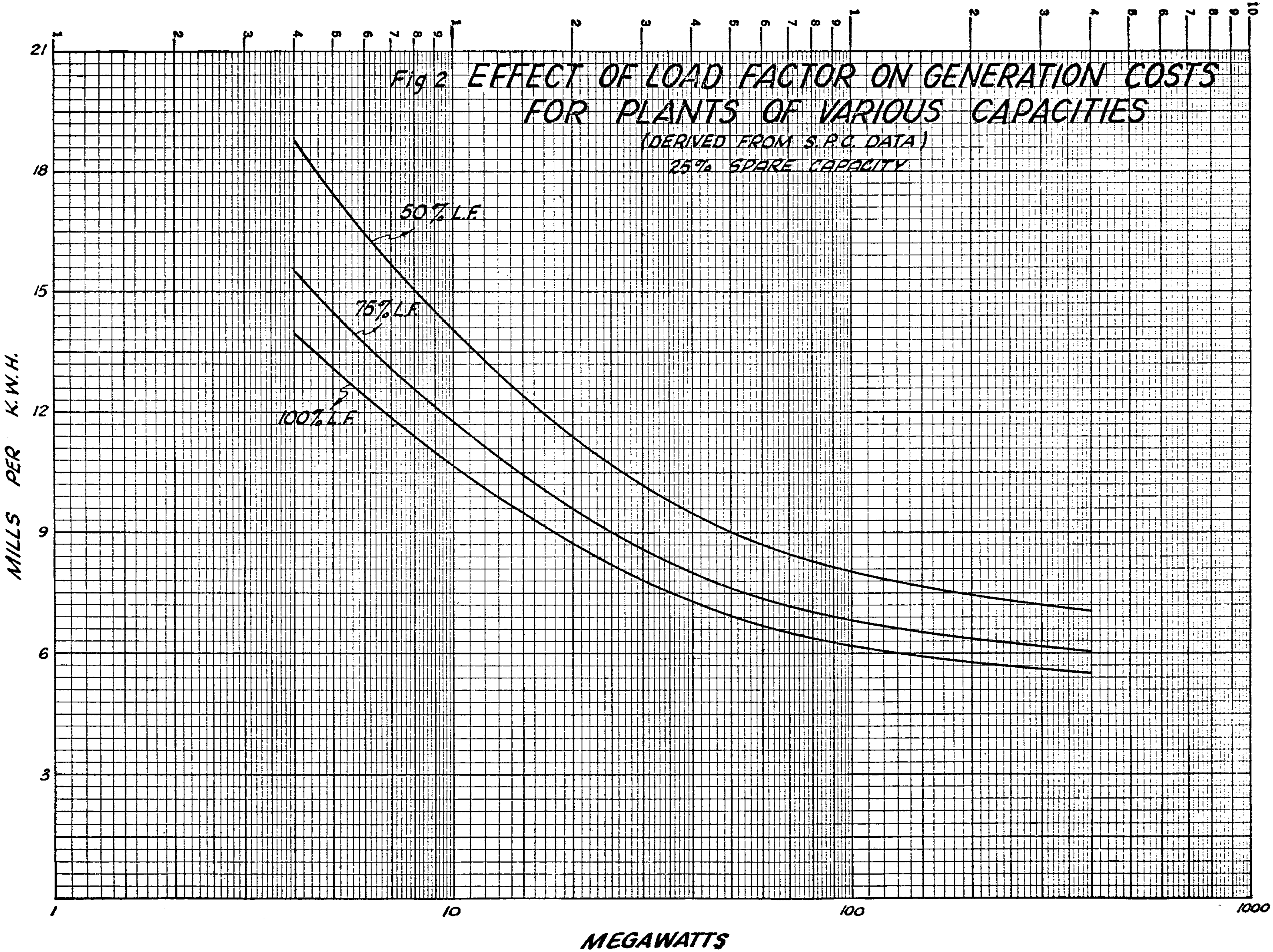
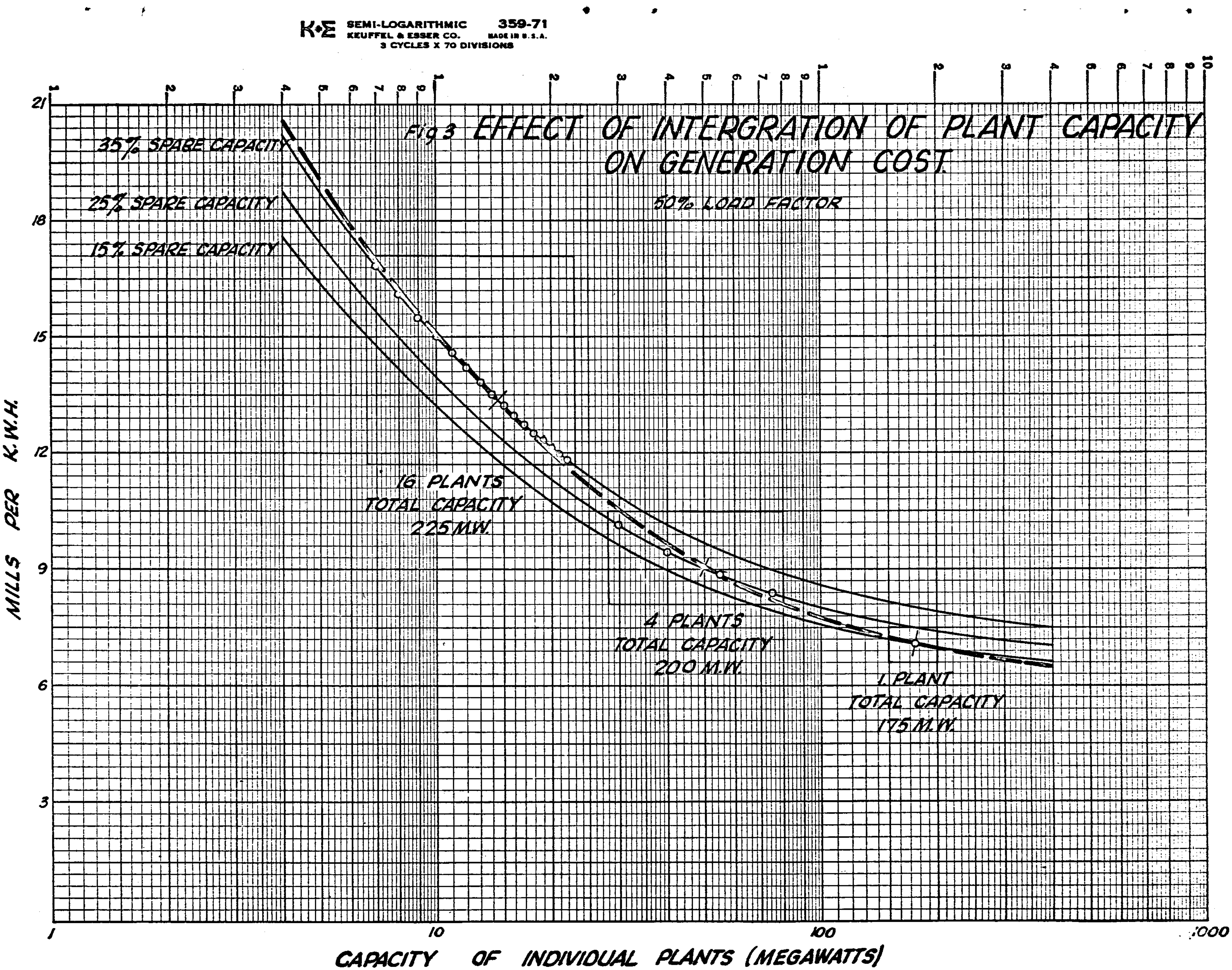


Fig 2 EFFECT OF LOAD FACTOR ON GENERATION COSTS
FOR PLANTS OF VARIOUS CAPACITIES
(DERIVED FROM S.P.C. DATA)
25% SPARE CAPACITY
50% L.F.
75% L.F.
100% L.F.
MILLS PER K.W.H.
21
18
15
12
9
6
3
1
10
100
1000
MEGAWATTS


K+E SEMI-LOGARITHMIC 359-71
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 70 DIVISIONS
Fig 3 EFFECT OF INTERGRATION OF PLANT CAPACITY ON GENERATION COST
50% LOAD FACTOR
35% SPARE CAPACITY
25% SPARE CAPACITY
15% SPARE CAPACITY
16 PLANTS TOTAL CAPACITY 225 M.W.
4 PLANTS TOTAL CAPACITY 200 M.W.
1 PLANT TOTAL CAPACITY 175 M.W.
MILLS PER K.W.H.
CAPACITY OF INDIVIDUAL PLANTS (MEGAWATTS)
21
18
15
12
9
6
3
1
10
100
1000

1. PRINCIPAL CHARACTERISTICS OF BASIC STEAM PLANTS.

(1) Plant Capacity and Peak Load (KW)	Installed Units (KW)	(3) Kwhrs Generated (27% P.F.) 1/	(4) Invested Capital $ per KW	(5) Invested Capital Total	(6) Employment Persons per MW	(7) Employment Total	(8) Plant Efficiency (Btu / Kwhr)
6,000	3 x 2,000	14,000,000	240	1,450,000	3.00	18	20,000
22,500	3 x 7,500	52,500,000	180	4,050,000	1.25	28	16,500
75,000	3 x 25,000	175,200,000	150	11,250,000	.60	45	14,000
264,000	4 x 66,000	616,700,000	135	35,650,000	.40	106	12,500

1/ Comparable with 40% Load Factor if peak demand is assessed at 2/3 of the plant capacity.

2. PRODUCTION COST DATA OF BASIC STEAM PLANTS.

(1) Plant Capacity and Peak Load (KW)	(2) Capital Charges Total, 6%	(3) Capital Charges ¢ per Kwhr	(4) Labour Cost Total ($4,500 per Person)	(5) Labour Cost ¢ Per Kwhr	(6) Fuel Cost $ Total	(7) Fuel Cost ¢ Per Kwhr	(8) Maintenance & Misc. $ Total	(9) Maintenance & Misc. ¢ Per Kwhr
6,000	87,000	.621	81,000	.579	78,400	.560	21,000	.150
22,500	243,000	.463	126,000	.240	242,550	.462	57,750	.110
75,000	675,000	.385	202,500	.116	686,800	.392	148,900	.085
264,000	2,139,000	.347	477,000	.077	2,158,450	.350	431,700	.070

(Continued)

(1) Plant Capacity and Peak Load (KW)	(10) Operating Cost $ Total	(11) Operating Cost ¢ Per Kwhr	(12) Administration % of Operating Cost	(13) Administration $ Total	(14) Generation Cost $ Total	(15) Generation Cost ¢ Per Kwhr
6,000	180,400	1.289	5.0	9,000	276,400	1.974
22,500	426,300	.812	3.5	14,900	684,200	1.303
75,000	1,038,200	.593	2.5	25,600	1,738,800	.992
264,000	3,067,150	.497	2.0	61,350	5,267,500	.854

3. FIXED AND VARIABLE COSTS OF BASIC STEAM PLANTS

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		6,000 KW Plant		22,500 KW Plant		75,000 KW Plant		264,000 KW Plant	
Cost Item	% of Cost	$ Total Cost	$ Per KW Capacity	$ Total Cost	$ Per KW Capacity	$ Total Cost	$ Per KW Capacity	$ Total Cost	$ Per KW Capacity
FIXED COST:									
Capital Charges	100	87,000	14.50	243,000	10.80	675,000	9.00	2,139,000	8.10
Labour Cost	65	52,650	8.78	81,900	3.64	131,625	1.76	310,050	1.17
Fuel Cost	5	3,920	.65	12,125	.54	34,340	.46	107,925	.41
Maintenance & Misc.	50	10,500	1.75	28,875	1.28	74,450	.99	215,850	.82
Administration	65	5,850	.97	9,685	.43	16,640	.22	39,875	.15
All Cost		159,920	26.65	375,585	16.69	932,055	12.43	2,812,700	10.65
VARIABLE COST:		$ Total Cost	¢ Per Kwhr	$ Total Cost	¢ Per Kwhr	$ Total Cost	¢ Per Kwhr	$ Total Cost	¢ Per Kwhr
Capital Charges		/	/	/	/	/	/	/	/
Labour Cost	35	28,350	.203	44,100	.084	70,875	.040	166,950	.027
Fuel Cost	95	74,480	.532	230,425	.439	652,460	.373	2,050,525	.333
Maintenance & Misc.	50	10,500	.075	28,875	.055	74,450	.042	215,850	.035
Administration	35	3,150	.022	5,215	.010	8,960	.005	21,475	.003
All Cost		116,480	.832	308,615	.588	806,745	.460	2,454,800	.398

4. FIXED COST DATA RELATED TO PLANT CAPACITY

($ per KW Peak Demand)

(1) Plant Capacity & Peak Load	(2) Capital Charges $	(3) Labour Cost $	(4) Fuel Cost $	(5) Maintenance & Misc. $	(6) Administration $	(7) Total Fixed Cost $
6,000 KW Plant						
65%	22.31	13.50	1.01	2.69	1.50	41.01
75%	19.33	11.70	.87	2.33	1.30	35.53
85%	17.06	10.32	.77	2.06	1.15	31.36
22,500 KW Plant						
65%	16.62	5.60	.83	1.97	.66	25.68
75%	14.40	4.85	.72	1.71	.57	22.25
85%	12.71	4.28	.63	1.51	.51	19.64
75,000 KW Plant						
65%	13.85	2.70	.70	1.53	.34	19.12
75%	12.00	2.34	.61	1.32	.30	16.57
85%	10.59	2.06	.54	1.17	.26	14.62
264,000 KW Plant						
65%	12.47	1.81	.63	1.26	.23	16.40
75%	10.80	1.57	.55	1.09	.20	14.21
85%	9.53	1.38	.48	.96	.18	12.53

5. COST DATA PER KWHR GENERATED

(Peak Demand 75% of Plant Capacity, 50% Load Factor Generation)

(1) Size of the Plant and Cost Items	(2) Demand Cost $ per KW	(3) Demand Cost Total $	(4) Commodity Cost ¢ per Kwhr	(5) Commodity Cost Total $	(6) All Generation Cost Total $	(7) All Generation Cost ¢ Per Kwhr
6,000 KW Plant						
Capital Charges	19.33	87,000	/	/	87,000	.441
Labour Cost	11.70	52,650	.203	39,850	92,500	.469
Fuel Cost	.87	3,920	.532	104,750	108,670	.552
Maintenance & Misc.	2.33	10,500	.075	14,750	25,250	.128
Administration	1.30	5,850	.022	4,450	10,300	.052
TOTAL COST	35.53	159,920	.832	163,800	323,720	1.642
22,500 KW Plant						
Capital Charges	14.40	243,000	/	/	243,000	.329
Labour Cost	4.85	81,900	.084	62,000	143,900	.195
Fuel Cost	.72	12,125	.439	324,050	336,175	.454
Maintenance & Misc.	1.71	28,875	.055	40,600	69,475	.094
Administration	.57	9,685	.010	7,350	17,035	.023
TOTAL COST	22.25	375,585	.588	434,000	809,585	1.095

(Continued)

5. COST DATA PER KWHR GENERATED

(Peak Demand 75% of Plant Capacity, 50% Load Factor Generation)

(1) Size of the Plant and Cost Items	(2) Demand Cost $ per KW	(3) Demand Cost Total $	(4) Commodity Cost ¢ per Kwhr	(5) Commodity Cost Total $	(6) All Generation Cost Total $	(7) All Generation Cost ¢ Per Kwhr
75,000 KW Plant						
Capital Charges	12.00	675,000	/	/	675,000	.274
Labour Cost	2.34	131,625	.040	99,650	231,275	.094
Fuel Cost	.61	34,340	.373	917,500	951,840	.386
Maintenance & Misc.	1.32	74,450	.042	104,700	179,150	.073
Administration	.30	16,640	.005	12,600	29,240	.012
TOTAL COST	16.57	932,055	.460	1,134,450	2,066,505	.839
264,000 KW Plant						
Capital Charges	10.80	2,139,000	/	/	2,139,000	.246
Labour Cost	1.57	310.050	.027	234,750	544,800	.063
Fuel Cost	.55	107,925	.333	2,883,550	2,991,475	.345
Maintenance & Misc.	1.09	215,850	.035	303,550	519,400	.060
Administration	.20	39,875	.003	30,200	70,075	.008
TOTAL COST	14.21	2,812,700	.398	3,452,050	6,264,750	.722

The Wabamun Steam Plant
Field Trip

The Wabamun steam plant was located on the shores of Lake Wabamun because of its accessibility to the large load centre in the Edmonton area, an adequate supply of condenser cooling water and a large deposit of strippable coal nearby of some 50 to 60 million tons.

The plant's first 66,000 kilowatt unit, which went into operation in October 1956, is burning gas from the Alexander gas field, 33 miles northeast of Wabamun, at the rate of some 5 billion cubic feet per year.

The existing thermal plant capacity of Alberta is 333,900 kilowatts; of this capacity 272,400 kilowatts are produced by plants burning natural gas. The use of natural gas in thermal plants on such a large scale is largely the result of natural gas reserves being developed and available in excess of the province's requirements. In all probability, as natural gas is exported, the favourable prices now prevailing will rise. By subsituting coal in thermal plants such as Wabamun, and reserving gas for those purposes for which it is best suited wherever possible, the interests of the province will best be served. At Wabamun the conversion to coal will largely depend on the availability and the well-head price for gas. Interest in the export of gas has been heightened recently, with the result that there has been a substantial increase in the well-head gas prices now being offered.

To be prepared for a possible early conversion to coal, Calgary Power Ltd., in conjunction with its consulting engineers, is carrying out detailed engineering studies of the Wabamun coal field. In 1953, an exploratory drilling program was carried out by the company to determine the extent of the Wabamun coal field and the approximate overburden/coal ratio for future open pit mining. Since then some 50 to 60 million tons of subbituminous coal under thirty to seventy feet of overburden have been proven up. Four seams aggregating over fifteen feet of mineable coal are the source of the supply. The upper three seams are visible in the Alberta Coal Ltd. pit, one mile northwest of the Wabamun plant.

Engineers are studying the layout of drainage, mining, hauling, stockpiling and crushing.

As the coal deposits are relatively close to the plant, the company does not anticipate any problem in transporting the coal to the stock pile that will be located north of the plant. Large bottom dump trucks, loaded by shovel, will haul the coal on private haul roads to the stock pile, where it will be weighed before being dumped and crushed. By a system of conveyors it will be taken from the stock pile to the bunkers located in front of the boiler in the plant. From the bunkers the coal will be fed through control scales and into pulverisers and then into the burners of the boiler.

By 1961 the Wabamun plant is scheduled to be a three-unit operation consisting of two 66,000 kilowatt units and one 150,000 kilowatt unit. The second 66,000 kilowatt unit is due to go on the line in September 1958. The extension for this unit is presently under construction on the west side of the plant. The extension for the larger unit will be constructed on the east side of the present building. This unit will probably be in operation sometime in 1961.

The ultimate use of coal in this plant is expected to be 1.5 million tons a year.

When the use of coal becomes economically advisable at Wabamun the company will likely follow conventional coal stripping methods similar to the large-scale methods used in Pennsylvania, Kentucky, etc., and closer to home, at Estevan, Saskatchewan. Large capacity excavating equipment moves the overburden from the high-wall side to the worked-out side of a long narrow pit. Offensive carbonaceous and other partings are stripped by shovel and well buried in the bottom of the pit.

Minutes of the Business Meeting

The business meeting of the 9th Dominion-Provincial Coal Research Conference opened in the conference room of the Research Council of Alberta at 8:30 p.m. on Saturday, August 31, 1957. Mr. W. A. Lang was in the chair, and Dr. N. Berkowitz acted as secretary.

Minute 1: Mr. W. E. Uren moved that the minutes of the business meeting of the 8th Dominion-Provincial Coal Research Conference, which were temporarily unavailable, be accepted as read in absentia. Mr. S. C. Mifflen seconded the motion, subject to a correction of the minutes on a matter relating to the appointment of Mr. M. Goudge to the Coal Research Committee. Motion put and agreed to.

Minute 2: In reply to a question from the chair, Mr. F. J. Harquail said that he considered the 9th Dominion-Provincial Coal Research Conference to have been the most successful he had ever attended, and that it had fulfilled its functions very well indeed. Mr. E. O. T. Simpson shared this view and added that he thought the papers to have been very instructive and of a high standard. Dr. D. S. Montgomery, speaking from the standpoint of a researcher, said that the conference provided an opportunity of securing coal operators' views and reactions to current research; it was in this that the conference could, and did, make its greatest contribution. Dr. T. E. Warren agreed, but wondered whether the title of the conference, "Coal Research Conference", was quite apt. He suggested that research organizations engaged in coal research might have separate specialist meetings. Prof. J. A. Harle also thought some change of title useful and suggested "Dominion-Provincial Coal Research and Development Conference"; this suggestion was not taken up by the meeting. Mr. S. C. Mifflen, dealing with the content rather than the title of the conference, said he shared the view that the 9th Conference had been eminently successful, but added that there was some need to get operators to advance more detailed and comprehensive suggestions for applied research. Mr. W. E. Uren stated that the coal research conferences were intended to acquaint coal operators with progress in understandable terms, and that this objective had been fully reached by the 9th Conference: he hoped the 10th Conference would be equally successful.

After some further discussion, it was moved by Mr. F. J. Harquail "that the meeting considers the coal research conferences to be of very real value and that these conferences accordingly be continued". The motion was seconded by Mr. S. C. Mifflen (on behalf of Mr. H. C. M. Gordon) and agreed to unanimously.

Minute 3: The Chairman announced that the Research Council of Alberta would be prepared to undertake the work of compiling and distributing the proceedings of the 9th Conference. This offer was accepted by the meeting. A foreword to the proceedings (summarizing the thinking of the conference, and outlining current research trends and fields in which an expanded research effort is required) will be prepared by Dr. N. Berkowitz.

Minute 4: Following a suggestion from the chair, Mr. W. E. Uren moved and Mr. M. Goudge seconded that letters of thanks be sent to the speakers who addressed the 9th Conference, to the Government of Alberta for sponsoring a banquet, and to Calgary Power Ltd. for bringing Dr. A. G. Christie to Edmonton and for arranging the trip to the Wabamun mine and power station. This motion was accepted unanimously. Mr. Lang will be responsible for implementing it.

Minute 5: Acting on a suggestion by Mr. H. H. Gardner, Mr. S. C. Mifflen proposed and Mr. W. E. Uren seconded a vote of thanks to the Chairman, Mr. W. A. Lang. Both mover and seconder referred to the excellent work done by the chairman in arranging the program of the conference and in so ably presiding over the meetings. After several individual expressions of thanks from the floor, the motion was carried by acclamation.

Minute 6: Discussions concerning the locale for the 10th Dominion-Provincial Coal Research Conference centered around the invitation by Hon. N. B. Buchanan, Minister of Lands and Mines in the New Brunswick Government, that the conference meet in New Brunswick next year. After a fairly lengthy exchange of views, in which the relative merits of New Brunswick; Halifax, N.S.; Sydney, N.S.; and Ottawa as conference centres were considered, Mr. S. C. Mifflen moved and Mr. W. Riva seconded that Hon. Buchanan's invitation be accepted and that New Brunswick be the tentative place for the 1958 conference. This motion was agreed to, subject to a final decision by the incoming Coal Research Committee. Mr. Uren will also discuss the matter further with Mr. Buchanan.

Minute 7: The chairman noted that the Coal Research Committee constitutionally consists of two members from Eastern Canada, two members from Western Canada, and a representative of the Fuels Division of the Federal Department of Mines and Technical Surveys. Mr. Uren is an ex officio member of the committee. After considerable discussion concerning the composition of the 1957-58 committee, it was decided

(i) that Mr. W. A. Lang and Mr. W. C. Whittaker shall continue to serve on the committee as the two Western representatives;

(ii) that the selection of the Eastern representatives be left to an Eastern caucus; and

(iii) that Hon. N. B. Buchanan be asked whether he wished to nominate a representative from New Brunswick.

Mr. Lang stressed the desirability of having the New Brunswick representative serve as chairman of the committee for the coming year, but several speakers, particularly Mr. F. J. Harquail, considered that no action in this direction could be taken until it was known who the New Brunswick member would be.

Minute 8: In connection with the program for the 10th Conference — a matter not actually dealt with by the meeting but left to the incoming committee — Dr. N. H. Grace suggested that a small review committee of eminent Canadian scientists unconnected with any of the coal research laboratories might usefully examine current coal research and report to the Coal Research Committee. He accordingly moved that "some thought be given to the setting up of a small committee charged with reviewing all phases of coal research in Canada and with reporting its findings and recommendations on priorities to the Coal Research Committee". This motion was not seconded and was subsequently withdrawn. Several speakers considered the establishment of such a committee to be undesirable. It was agreed, however, that Dr. Grace's suggestion be further examined by the incoming Coal Research Committee and that this committee report on their conclusions at the 10th Conference.

Minute 9: With respect to the fields in which an expansion of research was necessary, Mr. S. C. Mifflen noted that there was need for accentuated engineering research along the lines indicated in Mr. Gordon's paper to the conference. Dr. A. G. Christie supported Mr. Mifflen's views, and Mr. Gaherty added that his company (Calgary Power Ltd.), for example, would be particularly interested in research dealing with coal grindability, transport of coal in oil pipelines, and coal tar pitch for graphite production.

Minute 10: In view of the fact that members attending the business meeting were also planning to attend the Mines Ministers' Conference in Vancouver, the secretary was instructed to arrange that copies of the minutes of the business meeting of the 9th Dominion-Provincial Coal Research Conference be in the hands of Mr. W. C. Whittaker (c/o Vancouver Hotel) by September 5th.

The meeting adjourned at 10:30 p.m.