THE INSTITUTE OF METALS
AT THE
TECHNION -
ISRAEL INSTITUTE OF TECHNOLOGY

Report to the
Government of Israel
and the Technion

Submitted by
D. ROSENTHAL
Metals Staff Advisor to the Technion

THE UNITED STATES OF AMERICA OPERATIONS MISSION TO ISRAEL

Tel-Aviv – August, 1958
His Excellency, The Minister of Commerce and Industry
Ministry of Commerce and Industry
Jerusalem

Excellency:

I have the honor of transmitting herewith a report: "The Institute of Metals at the Technion – Israel Institute of Metals", as prepared by Professor Daniel Rosenthal, on leave from the faculty of U.C.L.A., Los Angeles, California.

Professor Rosenthal has spent two previous tours in Israel, one of nine months and another one of two months prior to this present tour which will be completed the end of August. Professor Rosenthal is scheduled to return to Israel for two months in the summer of 1959.

His report covers three major goals which will be most beneficial to the Institute of Metals. (1) Erection of a building of about 1600 square meters to house the facilities and equipment which the USOM is providing under approved project 71-27-110. (2) Completion of the technical organization of the Institute by the setting up of a corrosion division. (3) The establishment of steady sources of income to projects to be originated or sponsored by the Government of Israel. Full details and recommendations for procedure are included in the report.

This project is a joint venture of the USOM, the Ministry of Commerce and Industry, and the Technion, for the purpose of carrying out research and consultation work in the metals industry, and in the graduate student work to provide preparation for diplomas.

I have pleasure in presenting this report, and recommend it for your earnest consideration.

Sincerely yours,

Victor H. Skiles
Acting Director
"The hand of the American people is genuinely extended in help to the newly developing countries of the world."

J.J. Haggerty
Director of the USOM
Israel

The Technical Assistance was never meant to be a one sided operation, yet cooperation between foreign and local participants is not a thing which can be set up by a decree. It is not simply a matter of choice. The level of communication that must be established transcends the ordinary barrier of languages, which hardly exists in Israel.

It is therefore a matter of deep gratification to the writer that in the present work full understanding and cooperation was achieved by the participants from the very beginning and that it has continued undisturbed ever since.

Yet the problem was by no means simple. What has begun as a limited educational assignment soon broadened into a project in which the Government, the Technion, and the industry have become deeply involved. The Institute of Metals is the result of this concerted effort.
That scarcely one year after its founding the Institute of Metals is a going and growing concern is in no small measure due to the devotion and labor of its small staff, to the Acting Director, Mr. Taub and his close associates, Dr. Minkoff and Pratt. However, the junior staff members and the rest of the personnel must not be forgotten.

The Board of Governors, under the wise and skillful chairmanship of Mr. Watson, has done a splendid job in smoothing the way for the new organization; its share of merits is by no means small, yet there would have been no Institute of Metals at all had it not been for the foresight and determination of two men: General Dori, the President of the Technion, and Mr. Taiber, the Director of Industrial Division in the Ministry of Commerce and Industry.

To all of them the writer owes a debt of deep gratitude for the unfailing support and encouragement which he found during his several visits to Israel.

The list of persons to whom the writer is so indebted would not be complete without the mention of his friend and colleague, Mr. W.J. Waylett, former Chief of Mineral Division at the USOM. His departure from Israel has deprived the Institute of a guidance which will be long remembered.
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THE PROBLEM

As goes the metal industry so goes the country is more than a saying. In countries with a predominantly industrial structure, like the U.S., metal industry has assumed—and is bound to assume for some time to come—a leading role in the national economy. Even in countries which are predominantly agricultural metal industry remains an important factor in the life of the nation. Thus in Switzerland, which is poor in natural resources but rich in skilled manpower, metal industry is the second largest after the food industry.

It is also the second largest in Israel, insofar as the number of workers is concerned. But its importance in the national economy is much smaller. This follows from Table I which shows that metal industry employs less than 1% of the total population. The corresponding figure for Switzerland is 4.3%—very close to that of the U.S., which is 5%.

A more important index for countries, which like Israel and Switzerland must depend on foreign trade for their subsistence, is the export value of the product. Finished metal products represent one third of the Swiss export, while according to Table I the contribution of metal industry to the Israel export hardly amounts to 2%. True there is a substantial increase since 1950, as attested by Table I, but this is still a far cry from the position obtained in Switzerland.
Table I

Metal Industry in Population & Export

<table>
<thead>
<tr>
<th>Year</th>
<th>Designation</th>
<th>Total Millions</th>
<th>Metal Industry Thousands</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1956</td>
<td>Population</td>
<td>1.87</td>
<td>15</td>
<td>0.8</td>
</tr>
<tr>
<td>1956</td>
<td>Export</td>
<td>187.14</td>
<td>3200</td>
<td>1.7</td>
</tr>
<tr>
<td>1950</td>
<td>Export</td>
<td>63.2</td>
<td>250</td>
<td>0.4</td>
</tr>
</tbody>
</table>


Experts both domestic and foreign are quick to point out the reasons: lack of technical "know-how", poor quality of raw materials, great diversity of manufactured goods, small annual output, absence of planning, ignorance of managerial practices, and above all indifference to good workmanship. These reasons are undoubtedly true; many others could be added, not the least of them being the influx of immigrants, with little or no vocational training, from technologically backward countries. They all pose the problem in a rather general way, too general for a concrete solution.

To put the problem on a more rational basis a proper perspective is necessary. This is provided by the comparison between the U.S. and Israel in 1953, i.e. before the initiation of the technical assistance to metal industry by the USOM.
Table 2

Labor, Engineering, and Metal Plants in 1953

<table>
<thead>
<tr>
<th>Country</th>
<th>Total Labor</th>
<th>Total Engineers</th>
<th>Metal Industry Labor</th>
<th>Metal Industry Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.A.</td>
<td>61.9 x 10^6</td>
<td>595 x 10^3 (1)</td>
<td>7.9 x 10^6</td>
<td>66.7 x 10^3</td>
</tr>
<tr>
<td>Israel</td>
<td>561 x 10^3</td>
<td>3.4 x 10^3 (2)</td>
<td>11.8 x 10^3</td>
<td>2.5 x 10^3</td>
</tr>
</tbody>
</table>

(1) extrapolated from U.S. census 1950
(2) communicated obligingly by the Association of Engineers and Architects in Israel, as of 1958

Table 3

% Distribution of Labor in Metal Plants

<table>
<thead>
<tr>
<th>Country</th>
<th>Plants with more than 20 Workers</th>
<th>Plants with less than 20 Workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.A.</td>
<td>97</td>
<td>3</td>
</tr>
<tr>
<td>Israel</td>
<td>37</td>
<td>63</td>
</tr>
</tbody>
</table>


Table 2 shows that in the U.S. there were on the average 100 workers for every engineer and close to 120 for every plant. The figures for Israel were less than 150 workers per engineer and 4.5 per plant.
Even more significant is Table 3. It is seen that while factories with less than 20 people employed only 3% of the U.S. labor, they absorbed more than 60% of labor in Israel. Now, it is not very likely that a factory with less than twenty workers can afford an engineer. Thus, not only were there fewer engineers in Israel for a given number of workers, but they were also less favorably distributed.

[Insomar as metallurgical engineers were concerned even this estimate was too optimistic. On the basis of 1953 statistics it would lead to close to 30 metallurgists in the country. In reality, the number of metallurgical engineers at that time could be easily counted on the fingers.

How this situation is related to the national output is shown in Table 4. It is seen that the relative increase of national output per capita correlates better with the growth of professional (managerial and technical) manpower than with the growth of skilled workmanship.

<table>
<thead>
<tr>
<th>Index</th>
<th>Rate</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity</td>
<td>0.2</td>
<td>actual production</td>
</tr>
<tr>
<td>Professional Population</td>
<td>0.14</td>
<td>actual professional population</td>
</tr>
<tr>
<td>Skilled Workers</td>
<td>0.04</td>
<td>actual skilled workers</td>
</tr>
</tbody>
</table>

Source: Compiled from Economic Forces in the U.S.A., l.c.
The implication for the metal industry in Israel was thus clear: to raise the export value of the finished products it was necessary to use more technology than skill, in short to bring science to the plant.

There seemed, however, to be a dilemma: on the one side there were not enough metallurgical engineers, on the other side most of the metallurgical plants could not afford one.

The Institute of Metals was offered as a way out of this dilemma. The offer was accepted, and on August 27, 1957 a foundation was laid for the establishment of an Institute of Metals at the Technion, Israel Institute of Technology. The purpose of this report is to explain the underlying reasons, to review the present situation, and to set the future goals of this new institution.

**WHAT KIND OF METALLURGISTS?**

Even before 1953 the Technion had taken the decision to establish a course in metallurgy. The implementation came only in 1954. In that year a department of metallurgy was set up in the Faculty of Chemical Engineering. The original plan called for a metallurgical curriculum on the undergraduate level. However, a closer analysis revealed that even at the rate metallurgists were being produced in the United States their annual output in Israel would hardly exceed ten for some years to come. Five appeared as a more realistic figure considering the actual

* See references at the end of the report
needs of the country. This was hardly enough to justify a whole undergraduate curriculum, or even an upper division option. More important, under the prevailing conditions, a B.Sc. graduate would not be prepared to handle responsible jobs, and metal industry would not be able to provide the necessary training for such jobs.

A different approach was therefore suggested. It consisted of the establishment of a postbaccalaureate program in a special institution, the Institute of Metals, in which instruction would be combined with service to industry. Along with the theoretical preparation, the few young men the country needs would be getting the equivalent of the on-the-job training by working as assistance on industrial problems. In this way a highly flexible and practical scheme could be evolved.

Was it feasible? To find the answer the following conditions were examined:

1. the available B.Sc. candidates,
2. the time necessary for the job,
3. the prospective industrial training, and
4. the needed research facilities.

The last two points which touch on the nature of institution rather than instruction will be considered later. Here only the first two points are examined:

1. Available B.Sc. Candidates. Obviously the most desirable type of candidates is that which has broad basic preparation both in science and engineering not burdened by too narrow a specialization
in other fields. Such preparation does not exist at present, but it conceivably might in the future when all branches of engineering recognize its importance\(^2\). The undergraduate curriculum would then become common to all of them, and the proposed scheme of special institutes could be generalized and perhaps even started before graduation.

For the present, basic common courses are limited in number and confined to the first two years of study\(^3\). An attempt to increase their number meets with considerable difficulties\(^4\).

Under the existing conditions B.Sc. candidates in mechanical and chemical engineering are better suited to the metallurgical training because their undergraduate curriculum contains an elementary course in Physical Metallurgy. However, with the adoption of the recently proposed basic courses on Materials Properties and Processing\(^5\) the choice may be broadened to other faculties and departments as well.

2. How much time is needed to do the job?

To answer this question a survey was made of the existing curricula in Metallurgy. The details are contained in Appendix "A". In applying the results to Israel it became necessary to make a distinction between Process and Physical Metallurgy.

Following a recent suggestion\(^6\) Process Metallurgy is defined as "the science and engineering of producing metals from raw materials". On the other hand, Physical Metallurgy is defined as
"the science underlying the relation between the treatment, structure and properties of metals and the engineering applications of this science, especially to fabrication and heat treatment".

Insofar as Israel metal industry in Israel is concerned only Physical Metallurgy is really important. Even with the most optimistic outlook for Process Metallurgy in Israel, the demand for specialists in this field is likely to be satisfied, for the next decade or so, with the existing personnel and the prospective candidates trained abroad. The foundry may provide a more permanent outlet for young metallurgists. However, a great deal of foundry problems border on physical metallurgy and they can be included in its curriculum.

In view of this situation there appears to be sufficient ground for concentrating on Physical rather than Process Metallurgy in setting up the program of studies at the Institute of Metals, at least in the first few years of its existence.

Accordingly a program of study leading to M.Sc. degree in Physical Metallurgy has been worked out and set up recently at the Technion. Basically it is a one year program with 17 contact hours per term and a thesis. As such it falls some twenty units short of what would have been a full undergraduate and graduate M.Sc. program in Physical Metallurgy in the States.
However, to this must be added something like four undergraduate units which the candidates already have before applying for M.Sc., and furthermore the above program does not take into account the salaried side of the student's activity as an assistant. A major portion of this activity is devoted to solution of industrial problems.

Making the necessary allowances we are justified in concluding that both the quality of the available candidates and the time put at their disposal are adequate for providing the country with competent metallurgical know-how. It now remains to examine how this knowledge can be best utilized in the plant.

**WHAT KIND OF AN INSTITUTION?**

Hardly anyone will dispute the necessity of having an Institute of Metals in Israel. How else can science be brought to the many small plants which can afford neither laboratory nor engineer, yet are in need of an expert advice? The question, however, is what kind of an Institute.

There are those who are in favor of an institution which is to be established by the industry itself to deal with current problems of production and manufacture.

Industrial institutes of this sort are not an uncommon occurrence in either Europe or the U.S. The best known example perhaps is the Portland Cement Association Research and Development Laboratories. However, they
are far from limiting their activity to current problems.

This in itself is not the main difficulty. Far more important is the fact that to support such an institution a degree of maturity and long range planning is required that can hardly be expected from the small plant owners in Israel at the present time. The situation is further complicated by government intervention in the use of raw materials. These are not natural resources of the country, but imported semi finished products which must be paid in foreign currency. And there is finally the problem of training of future metallurgists which the metal industry as a whole is neither willing nor capable of undertaking.

All this points clearly to broad national, rather than narrow private interests. The Institute of Metals as it stands now is more the creation of the government and the Technion than that of the metal industry itself. This may be deplored, especially since the establishment of the Institute was hailed and endorsed by the whole metal branch of the Manufacturers Association. Yet it should not be overrated, since a premature intervention of small contributors is likely to hinder rather than aid the activities of the Institute. Under the existing scheme the contribution of industry is strictly on the cash and carry basis. It consists of payment for services rendered directly in each particular case. It is the only practical, even though not always the most productive, way of convincing the small plant owners that they are getting their money worth.

A serious drawback of this scheme is that it puts the burden of research and development on the government and the Technion. Yet without
research and development the country can hardly hope to conquer and maintain its position on foreign markets.

The practices of the Swiss watch industry may be used as a good example to follow. Not content with the already recognized leadership on the world market it seeks constantly to beat its own records by making new and better time pieces.

Thus bringing science to the plant means really two things:

1. Meeting the existing standards at competitive prices
2. Research and development

MEETING THE STANDARDS

The simplest and most direct method of raising the quality of production is to apply the existing standards to the finished products. This is apparently the role and function of the Standard Institute in Tel Aviv which not only sets the standards, but also seeks to enforce them.

However, if a quality control is to be not only effective but also productive it must begin at the factory.

In the now universally recognized succession of operations this control must include raw materials, means and methods of fabrication, and the finished product.
a) **Raw Materials**

Unlike the primary industries like ceramics, glass, and to some extent Process Metallurgy, the Physical Metallurgy utilizes as raw materials not natural resources but semi-finished products. The diversity of their applications is such that it appears hopeless to impose standards of composition and treatment even though this is feasible since most of them are imported.

The only practicable way of exercising quality control over these materials is to devise appropriate fitness tests for each particular job.

Thus, e.g. sheet metal for deep drawing must meet a definite test of local ductility. This property, however, is a function of composition, degree of cold work, and grain size, each of which can vary depending on the other two. Therefore it would serve no useful purpose to specify only one of them, e.g. composition. Carrying out a global control test, like the Ericson bulge test, would be more meaningful. Even here the result must be interpreted in terms of the actual requirement rather than in absolute figures.

This is another way of saying that the quality control must be adapted to circumstances, a restriction which makes it quite unsuitable to the function of the Standard Institute.

It is, however, the proper function of a consultative body like the Metals Institute. To make it effective it would suffice...
that the import licensing authority require a report on a sample or samples, which could then serve as a basis for specification in ordering the item abroad.

A notable exception to this procedure is the control of foundry raw materials, which has much in common with that of primary industries. The enforcement of adequate standards of molding and fuel materials (sand, coke, limestone) would go along way toward reducing the waste of the imported pig iron. This enforcement is particularly pertinent in regard to local raw materials.

b) Means and Methods of Fabrication

The lack of adequate and reliable control equipment in the course of fabrication has been the recurrent complaint of many experts. There is very little either the Standard Institute or the Metal Institute can do about it. However, an unreliable or missing control equipment, like a pyrometer or pressure gage, also endangers the life of the personnel. This is therefore a matter for the safety engineer to look into. One of the functions of the Metal Institute should be to acquaint the safety or productivity engineers with the requirements of proper quality control in metal plants. There is no inherent difficulty in carrying out such a scheme, and these engineers, even though lacking the enforcing authority of inspectors, can perform a real service to the industry by making the proper recommendations to the management.
The know-how and methods of fabrication are the legitimate private hunting grounds of the manufacturer, and no interference here is conceivable unless on his own terms.

Insofar as the Institute of Metals is concerned such an interference takes generally the form of a curative remedy - the most obvious, but the least efficient way of serving the industry. This is because the Institute is generally called upon to intervene when the damage has already reached the stage of being beyond repair.

A typical example is that of a manufacturer of heat treated aluminum alloy shears who sought the help of the Institute to recondition a defective lot. The damage was easily traceable to overheating and as such it was irreparable. If the check of the heat treatment were made on the spot before further machining, a substantial saving in cost and labor would have resulted.

It will take no small amount of effort and time to induce the metal industry to think in terms of preventive rather than curative measures. Not until then can there be any question of research and development in the plant.

c) The Finished Product

It is not likely that the Institute of Metals will be asked to pass judgment on a finished product, except in the case of competitive bids and arbitration. This activity, even though limited, should not be underestimated, for it carries with it
a great deal of authority and responsibility. The Institute of Metals can be also of real service to the government and public agencies by advising on the quality of production of a factory which seeks importing licenses and contracts.

In summing up it can be said that meeting the standards of the factory, especially in a plant devoid of any technical staff, requires an effective, even though not continuous, intervention of the Institute of Metals.

1. The Institute can help both the government and industry by determining not only the fitness of material for a given job, but also the kind of tests which can best reveal this fitness.

2. It can advise on drafting suitable standards for local raw materials, e.g. foundry sands.

3. Control and inspection of plant equipment is not in the province of the Institute of Metals. Nevertheless, the latter can help indirectly to maintain the required fitness of this equipment by giving proper instructions to the safety or productivity engineers.

4. The most effective assistance the Institute can give the industry is unquestionably in matters affecting the know-how and methods of production. A great deal of this assistance consists of trouble shooting, but the latter will not be truly effective until and unless it is combined with sound preventive practices.
5. A limited amount of service can be performed by the Institute in evaluating the finished product both for export and domestic consumption.

In all these functions the future metallurgist working at the Institute will find ample opportunity for training and practice.

RESEARCH AND DEVELOPMENT

The type of activity which has been described must for a long time constitute the bread and butter of the Institute of Metals. However, no leadership can come from an institution which does not look ahead and prepare for the future. This is what is meant by Research and Development.

In its present state of fragmentation and disorganization the metal industry as a whole will be slow in realizing where its future interests lie. Therefore it cannot be counted on to support research projects of any kind. This support must come from various public agencies, including the government and the Technion.

Two sorts of projects must be envisaged -

a) short range, and b) long range projects.

a) Short range projects. As the name implies what is aimed at here is an answer of immediate applicability. It may be an improvement of current methods of production of the product itself, or the quality of raw materials. It may also be a study of better
preservation of existing products. This sort of research is usually referred to as development. Government and public agencies are the obvious sponsors for such projects in the absence of private contributors.

b) Long range projects. The qualification of abstract or pure is often attached to these projects meaning aloofness or remoteness from practical purposes. Yet those who use these terms, often in a derogatory sense would be hard put to name one single pure or abstract discovery that did not find its way to industry. Even the time lag which used to exist between discovery and application no longer separates these two activities. Take e.g. the discovery of semi-conductors and their counterpart the transistor, or nuclear physics and technology. In both instances discovery and applications went hand in hand.

It follows that those who get first to the source of new knowledge are also the ones most likely to be the first to reap the benefits.

Israel, a country without established tradition in the old trades, has little to lose and everything to gain by experimenting with new methods, techniques, and materials.

Such an experimentation generally takes the form of a research carried out by senior staff members anxious to maintain their scholastic standards and by their assistants in preparation for M.Sc. and Ph.D. degree. That is, most of the expense for this activity is born by the Technion. The Institute of Metals provides merely the space and equipment.
A good example of a long range project in Israel - perhaps not so long either at the rate of the present progress - is the building up of a laboratory for making of semi-conductors. These devices are apt to be in greater and greater demand as time goes on. They are destined to replace the vacuum tubes as soon as they are in full production. They represent, par excellence, an item of export in a country which has little to offer besides brains. The cost of raw material is negligible compared to the value of the finished product since most of it lies in the perfection of the purification methods. While the know-how is still scarce, it is nevertheless accessible to any metallurgist familiar with the single crystal technique.

There is finally a bonus attached to this project. It so happens that the future of high temperature technology depends critically on the ability to adapt the same single crystal technique to refractory materials.

'Short range or long range projects - they both look at the future, whereas "meeting the standards" faces the present. However, a student working at the Institute of Metals would have no difficulty in finding sufficient material for his M.Sc. and Ph.D. thesis in all of them. And he will be greatly helped by adequate and modern facilities.
ORGANIZATION

With a few modifications the present organization of the Institute of Metals follows the lines of the original proposal.

It deals with the scope, governing body, staff, building and equipment, as well as budget of the Institute.

a) Scope

The activities of the Institute have been planned to cover a broad field of metal uses, viz.:

1. Heat Treatment
2. Casting, Welding, and Allied Processes
3. Metal Forming
4. Preservation, Surface Finishing and Protection against Corrosion, and
5. Machining

Equipment and facilities for Heat Treatment are virtually completed, and work of both educational and industrial character already has been going on in this field for some time.

Activities listed under 2. and part of activities listed under 3. will be ready by the end of 1959 with the arrival of the consignment of equipment now on order or to be ordered by the USCM on the budget appropriations for 1958-1959.
Equipment for the balance of the activities in the field of metal uses will be ordered on the budget appropriations for 1959-1960, but will not be delivered until it can be housed adequately in the new building, presumably by 1961.

Only a limited amount of equipment will be ordered for Machining. This activity is already functioning in the Department of Mechanical Engineering and it will remain in the department even after its transfer to new quarters, in the vicinity of the Institute of Metals, at the Technion City. A close contact and cooperation with other activities of the Institute is being maintained through a proper representation on the Board of Governors, the policy making body of the Institute of Metals.

b) **Board of Governors**

The total representation on the Board of Governors consists of 8 members divided as follows:

1. member from Ministry of Commerce and Industry;

2. members from the Technion, including the section of Machining;

3. members from industry (2 from Manufacturers Association and 1 from Koor industries);

and 1 member from the Standard Institute.
The last mentioned representation insures close contact between
the Institute of Metals in Haifa and its sister institution in
Tel Aviv.

The Director of the Institute is an ex-officio member of the
Board.

In line with its supervising function the Board of Governors -
1. makes overall decisions regarding the administration and
activities of the Institute, including cooperation with
other agencies, e.g. in the matter of corrosion;
2. approves or modifies the budget submitted by the Director;
3. seeks sources of income and other means of financing and
promoting the activities of the Institute; and
4. takes such measures as are necessary to promote the welfare
of the Institute.

c) Staff

When in full operation the Institute will be headed by five
senior staff members, including the head of the division of
Machining. All will be holders of an academic appointment with
the Technion and each will be responsible for one of the
activities listed above. Thus education and service to industry
will be going hand in hand, instead of being opposed to each
other in a fictitious conflict between theory and practice.

Future addition to the staff will be made as need arises.
One of the members of the team will be chosen by the Technion as Director, subject to the approval by the Board of Governors. The other members will have the title of Associate Directors. They will be responsible in administrative matters to the Director who in turn will be responsible in these matters to the Board of Governors.

The team of five will constitute the executive board of the Institute. It will be assisted in its task by a staff of junior members about fifteen in number, and five or six laboratory technicians. An adequate administrative help (librarians, secretaries, receptionist-telephone operator) will be provided.

A bird's eye view of the organization is given in Flow Diagram, Table 5.

d) Relation to the Technion's Research and Development Foundation

To relieve the staff of the administrative drudgery connected with payments and accounting, the Institute of Metals has availed itself of the existing facilities of the Technion's Research and Development Foundation in all its dealings pertaining to the service to industry. This Foundation has been set up as a non-profit organization to receive, channel, and administer all outside requests for research directed to the Technion. The Foundation represents therefore a natural and economical solution for the current administrative problems of the Institute of Metals. Experience of other institutes on the campus proves that this
Table 5

FLOW DIAGRAM

Organization
of the
Institute of Metals
e) **Building and Location**

The Institute of Metals is housed temporarily in the east wing of the Aeronautical Building at the Technion City. Its final location is in the same city in the south-east corner on a plot of about 2000 sq.m. shared with the Electrotechnical Department. The building itself will provide about 1600 sq.m. floor space and will house in addition to the facilities listed under the heading: scope 1. to 4., also staff offices, library, classroom, and a conference room. Adequate provision for future expansion have been made in the building plans.

f) **Initial Cost**

This cost includes building, equipment, and building grounds. At the present state of progress only estimates are available. The cost of the building is estimated up to IL.350,000, the sum of money presently committed by the Joint Fund. When completed the equipment will amount to something like IL.220,000. Of this about 10% was acquired by the Technion, the balance is being provided by the USOM under the technical assistance program. The grounds (approaches, etc. development) will be taken care of by the Technion as a part of the overall program of improvement of the Technion City.

g) **Current Expenses**

Because of the rather slow response of the industry it will take some time before the activities of the Institute can be
developed to their full capacity. Therefore the current budget of the Institute is far from reflecting its future needs. In its transient stage it will be revised from year to year to take account of the expected growth both in research and development. The estimate of the current operating budget is appended, Table 6.

### Table 6

Estimate of the Operating Budget for July 1 1958 - June 30 1959

<table>
<thead>
<tr>
<th>Element of Cost</th>
<th>Total IL</th>
<th>Technion + J.F. 2</th>
<th>Requested from J.F.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salaries and Wages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Senior Lecturers</td>
<td>14,000</td>
<td>4,900</td>
<td></td>
</tr>
<tr>
<td>1 Lecturer</td>
<td>6,000</td>
<td>2,100</td>
<td></td>
</tr>
<tr>
<td>2 Instructors</td>
<td>9,000</td>
<td>3,150</td>
<td></td>
</tr>
<tr>
<td>3 Assistants</td>
<td>10,800</td>
<td>3,800</td>
<td></td>
</tr>
<tr>
<td>1 Technical help</td>
<td>4,000</td>
<td>1,400</td>
<td></td>
</tr>
<tr>
<td>Secretarial and Administrative help</td>
<td>7,000</td>
<td>2,450</td>
<td></td>
</tr>
<tr>
<td>Travel local</td>
<td>1,500</td>
<td>525</td>
<td></td>
</tr>
<tr>
<td>Transportation goods</td>
<td>800</td>
<td>280</td>
<td></td>
</tr>
<tr>
<td>Communications</td>
<td>1,000</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>Rent &amp; Utilities</td>
<td>5,650</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>Printing and Reproduction (+ Publicity)</td>
<td>8,000</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>Supplies and Materials (Expendible &amp; Books)</td>
<td>8,000</td>
<td>850</td>
<td></td>
</tr>
<tr>
<td>Equipment</td>
<td>750</td>
<td>260</td>
<td></td>
</tr>
<tr>
<td>U.S. Contract Technician:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allowance</td>
<td></td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>Local Travel</td>
<td></td>
<td>1,500</td>
<td></td>
</tr>
<tr>
<td>Total operating</td>
<td>76,500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total J.F.2</td>
<td></td>
<td>30,565</td>
<td></td>
</tr>
<tr>
<td>Contribution Technion</td>
<td></td>
<td>30,400</td>
<td></td>
</tr>
<tr>
<td>Service to Industry</td>
<td></td>
<td>15,535</td>
<td></td>
</tr>
<tr>
<td></td>
<td>76,500</td>
<td>76,500</td>
<td></td>
</tr>
</tbody>
</table>
It represents something like 50% of the expected normal operating budget at full capacity and the present salary scale, and 130% of the last year budget.

The Technion and the Joint Fund will contribute an equal share of about 40% to this budget; the balance is to come from services to industry. As a term for comparison the Technion contributed 50%, the Joint Fund 35%, and industry 15% to the last year budget. Thus, the progress is manifest, but there is still a long way to go before the Institute can become self-supporting. It is anticipated that the Technion will be able to maintain its contribution of 40% to the budget, even at the full operating capacity of the Institute.

**ONE YEAR OF EXISTENCE**

August marks the anniversary of the establishment of the Institute of Metals. Yet to speak of the first year of activity would be a definite misnomer. The Institute of Metals did not step down from a cloud. In many respects, both educational and professional ones, it is a continuation of former efforts. Instruction in Metallurgy has been going on already for two years at the Technion and metal industry has been served by the Department of Metallurgy within the framework of the Technion's Research and Development Foundation from its very inception. Yet, the transition to the new state of affairs is noticeable mainly by the increase of emphasis on the broader scope of activities, from
both the educational and professional point of view.

**Educational.** As a part of the educational system of the Technion the Institute of Metals belongs to the Department of Metallurgy and it participates in the academic life of the school on the same footing as other departments. This participation has taken on this year two important aspects, one on the undergraduate, the other on the graduate level.

a) **Undergraduate:** In addition to existing offerings in Physical Metallurgy for the third year study in Mechanical and Chemical Engineering, the Department of Metallurgy has set up two new courses, one on Properties the other on Processing of Materials. They were offered first on a trial basis to some 30 students of the Aeronautical Department prior to their inclusion in the new basic engineering curriculum of the Technion. This "pilot plant" experiment has provided valuable information regarding the choice of topics and laboratory exercises for the large scale operation of the coming year. It also served to prepare extensive lecture notes for the students.

b) **Graduate:** This year saw the delivery of the first two M.Sc. degrees in Physical Metallurgy on the basis of research performed entirely in the department and with the equipment set up by the USCM(9). A third thesis is about to be completed, and the first candidate for the Ph.D., has registered with the Department. In line with the new regulations of the Graduate Division and its
own policy on graduate preparation of future metallurgists, the
Department has set up a formal, one year program in Physical
Metallurgy. With this crowning achievement the planning stage
of the educational activities has been completed.

Industrial. Under the prevailing conditions most of the service to
industry was of the trouble shooting variety:— problems of urgency,
requiring immediate remedial measures. Yet, a limited amount of
research and development also was carried out, mainly in connection
with graduate work.

a) Trouble shooting. Table 7 gives an overall picture of the amount
and nature of work carried out in this category. As observed
earlier in the report the majority of work is one of the curative
nature. The metallography and heat treatment division got the
lion's share of the work. This was to be expected, since it was
also the only division nearly completely equipped. The almost
equal distribution of work between the private and public,
including cooperative, sector is interesting, but hardly
significant. One would expect more long range projects
coming from the latter group.

b) Research and development. In the absence of industrial
contributors most of the work in this category originated with
the staff itself. The list of publications(10) shows a wide
range of interest of basic as well as applied character.
c) Public service. As a part of service to industry the Institute of Metals has initiated various public activities ranging from seminars to printed news. Three seminars were staged this year, each for a different branch of metal industry: heat treatment, forming, and foundry. The success of these seminars could be measured by the steadily growing attendance from one gathering to another. There was also a growing interest in the activities of the Institute itself as gauged by the number of questions asked by the participants. In addition to these formal meetings visits of the facilities of the Institute were organized for smaller professional groups: welding, safety, and productivity engineers. The staff of the Institute was also instrumental in promoting the creation of the Israel Society of Metals and closer relations with the existing Israel Foundrymens' Association. Last, but not least, a news bulletin was founded, the first issue to coincide with the first anniversary of the Institute, to familiarize the metal industry and users with the work currently carried out in its laboratories.

The sum of activity developed by the staff of the Institute during the first year of its existence adds up to a substantial contribution to the growth of the metal industry in Israel, both to its technical manpower and know-how.
Table 7
Service to Industry
handled by the
Institute of Metals
during the period
September 1957 - July 1958

Total Number of Problems: 127
Average per month: 12.7

Distribution according to:

A. Nature of Enterprise

<table>
<thead>
<tr>
<th></th>
<th>Private</th>
<th>Public (&amp; Cooperative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>52</td>
<td>75</td>
</tr>
<tr>
<td>%</td>
<td>41</td>
<td>59</td>
</tr>
</tbody>
</table>

B. Field of Metallurgy

<table>
<thead>
<tr>
<th>Field</th>
<th>Metallography &amp; Heat Treatment</th>
<th>Foundry</th>
<th>Forming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>115</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>%</td>
<td>90</td>
<td>8</td>
<td>2</td>
</tr>
</tbody>
</table>

C. Type of Service

<table>
<thead>
<tr>
<th>Type of Service</th>
<th>Curative</th>
<th>Preventive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>80</td>
<td>47</td>
</tr>
<tr>
<td>%</td>
<td>63</td>
<td>37</td>
</tr>
</tbody>
</table>
WHAT LIES AHEAD

One year of existence is hardly enough to make predictions, let alone positive statements, about the future of the Institute of Metals. Yet in looking for trends the much longer experience of older institutes can be utilized to good advantage. The Institute of Metals is only a rising star in the already vast constellation of institutes and laboratories covering the grounds of the Technion City. There are the independent Rubber and Ceramic Institutes promoted by USOM, the locally sponsored Hydraulic, Soil Mechanics Laboratories as well as the Building Research Station of the Technions Research and Development Foundation. While nobody supposedly learns from the mistakes of the others, certain decisions and implementations can be justified by the avoidance of pitfalls which happened to others.

1. One such a pitfall is the attempt to separate research from instruction. When the country is in equal need of technical manpower and advice, when industry lacks know-how as well as facilities, to separate one from the other is to deprive both of an essential element of success. Junior staff members working for their academic degrees represent not only a dynamic, but also a continuously replenishable reservoir of technical skill. They are the future leaders of the Israel metal industry. On their grasp of the essential needs of the country and the potential value of science rests the ultimate solution of the problem of how to bring science to industry.
Yet if instruction in the Institute of Metals is inseparable from research how far should it go? Obviously, everything vital to the practicing metallurgist must be included. This condition which is necessary, might also be sufficient if instruction could be limited to the graduate level, i.e. if the undergraduate programs were broad enough to exclude the competing interests of other specialties of engineering. Such unfortunately is not the case, and short of establishing its own undergraduate curriculum the Department of Metallurgy must thrust firm roots in the existing curricula to insure sufficient supply of young candidates. This is not all. To find a fertile soil the roots must go deep enough to become an indispensable ingredient of the scientific background of any engineer regardless of its specialty. This is the reason why the Department of Metallurgy has taken the responsibility, and the Institute of Metals the task, of preparing two basic courses in Properties and Processing of Materials. The assignment is not an easy one considering that it involves anywhere from 250 to 300 students per semester, and requires laboratory as well as lecture preparation. Nevertheless it has been tackled, and the Institute of Metals stands ready to devote something like 20% of its activity to this undertaking next year. This is about half of the total time allocated to instruction. The other half will be reserved to specialization in the field of Physical Metallurgy as explained in the second section of this report. Thus, a fair distribution of time will be insured not only between instruction and service to industry, but also
between the basic and special sector of the engineering curriculum.

2. A somewhat similar parallel exists in the industrial activity of the Institute between satisfying the immediate needs and working for the future of the metal industry. The Institute of Metals has a standing obligation to impart its know-how to this industry, yet it cannot lose sight of the long range objectives. Much of the know-how is spent on corrective measures resulting from ignorance and lack of observance of accepted standards. This is a necessary and even vital task, but it cannot be wholly the responsibility of the Institute. Even if it were it could not be carried out for lack of coercion. With its present "cash and carry" policy the Institute of Metals deals only with those cases, which the manufacturer considers worth paying for, not those which stand in the way of the industrial progress of the country. Yet to adopt another policy, e.g. subscription fees for consultation, would expose the Institute to the same tribulations which other institutions have experienced in less trying circumstances. The enforcement of standards of production at the factory is a necessary prerequisite to the raising of productivity of the metal industry as a whole, but it can only be carried through as a joint venture of some enforcing government agency and the Institute of Metals.

3. From what has been said it is clear that the future of the Institute of Metals both as a self-supporting organization and a factor of industrial progress cannot lie in the activity
provided by the demands of small plant owners. Experience of similar institutions on the Technion campus shows that this activity must be supported by projects of wider scope emanating from responsible public and government agencies. The Institute of Metals can help in formulating the specific objectives for such projects. A few examples will illustrate this point.

a) There is an acknowledged need for a rational specification of imported semi-finished products in the form of bars, sheet metals, and other rolled stock in order to reduce their variety to a minimum compatible with the real requirements of metal industry.

b) There is even a greater need for establishing qualification tests for welding, especially field welding.

A systematic study of local molding sands can greatly improve the finish of castings.

d) A survey of light metal foundry facilities in the country would materially aid in the selection of plants capable of producing high quality aluminum castings for industry (aircraft, marine, transportation).

A look ahead means also aiming beyond the existing modes of production. Discovery and application of new techniques is an essential part of activity of any research institution. The Institute of Metals is planning the development of a single
crystal laboratory for semi-conducting applications. In this endeavor it is being greatly helped by the Technion which is taking positive steps toward promoting the semi-conductor technology in Israel.

5. Finally planning for the future is keeping the staff on a level of competence and alertness consistent with the advances of science and technology. A graduate program of study plays an important, but not an exclusive, role in this endeavor. The staff must also have the opportunity of visiting similar institutions abroad and acquainting itself with their activities. These contacts are particularly important in the initial stages of the development of the Institute of Metals. A trip to the U.S. of six months duration is provided for one of the staff members as a participant in the projected 1959-60 budget of the USOM under the current project 71-21-110. A continuation of this endeavor, perhaps on an exchange basis, is worthy of further study.

6. A closing comment on the future of technical assistance is in order.

In comparison with other organizations the Institute of Metals has benefitted from a rather limited technical guidance. This at least in part is due to the availability of competent staff members among the Technion's faculty. However, new fields of activity, like single crystal or refractory high temperature materials technology, are less adequately represented. The
training of additional staff members on the spot will be substantially speeded up, if expert help from abroad were available. This is not easy considering the novelty of the fields and scarcity of competent men. Perhaps, the solution should be sought in the establishment of short term visiting professorships, rather than long term technical assistance.

RECOMMENDATIONS AND CONCLUSIONS

The considerations of the previous sections can be best summarized in the form of specific recommendations:

1. The essence of the present organization of the Institute of Metals resides in the combination of instruction with service to industry. This form of organization should be maintained for the good of both functions.

2. To safeguard the existing structure of the Institute it is recommended that its future divisions be headed also by men holding an academic appointment with the Technion.

3. Participation in the undergraduate curriculum of the Technion is desirable and it is beneficial to the recruitment of candidates for the future profession of metallurgist, but all sections of the Institute should contribute fully to the graduate program in Physical Metallurgy.
4. Educational activities of the Institute of Metals should be extended to include also practising engineers in the metal industry. Seminars appear to be the proper medium for these activities.

5. Present needs of the country call for curative as well as preventive services to the metal industry. The first are the result of ignorance of standards, the second of their acceptance. Every effort should be made to tip the balance of services in favor of the latter. A stricter supervision of importing licenses could be used as a controlling factor.

6. Quality control at the factory depends on the correct functioning and reliability of plant equipment. Productivity or safety engineers should be entrusted with the task of supervision as well as education of the personnel in the correct use of this equipment, and the Institute of Metals should be consulted on the best ways of implementing the educational program.

7. Under the prevailing conditions the Institute of Metals would be leading a "hand-to-mouth" existence, if it had to depend only on the support of industry. Additional support of public and government agencies is needed to initiate short range projects aiming at the effective increase of productivity.

8. The Institute of Metals should be given every opportunity to engage in long range projects concerned with novel techniques, materials, and applications. The proper sponsoring agency for this activity, which has the obvious imprint of a research, should be the Technion itself.
9. The scientific development of the technical staff should also be fostered by a participants program in the U.S., at least in the first few years of the existence of the Institute of Metals.

10. On the spot training of staff members in new fields of activity, e.g. the semi-conductor or nuclear technology, should be given careful consideration. Short term visiting professorships tended to men of established reputation in the field might be the proper solution.

These ten recommendations are not ten commandments; rather, they are the expression of a wish and a hope.

One year is not much in human life, still less in the life of an institution, but the first year of existence is important to both. A one year infant no longer leads a purely vegetative life: there is meaning in his utterings and purpose in his action. Yet he is still helpless, still unable to stand on his feet. So is also the one year old Institute of Metals. Despite its vitality and drive it is still a frail child, in need of protection and care.

The USOM, the Government, and the Technion, like so many good fairies, stood over the cradle of the infant Institute and presented it with gifts and endowments. Yet there is always the danger that some uninvited irate fairy might cast a spell of inaction and slumber on the budding organization.

The wish and the hope is that the good fairies will continue their watchful vigil until the child is firmly planted on his feet and no longer in danger of being harmed by fairies of any kind.
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   Appendix "B"

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   On the Reorganization of Engineering Education at the Technion - Israel Institute of Technology, July 1956,
   Appendix "C"

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4. D. Rosenthal
   Basic Engineering Courses at the Technion, April 1958,
   Appendix "D"

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   Appendix "E";
   and
   Syllabus on Elements of Materials Processing by I. Minkoff (D. Rosenthal), June 1958,
   Appendix "F"


7. Program of Study leading toward M.Sc. degree in Physical Metallurgy at the Technion - Israel Institute of Technology, by Staff and D. Rosenthal, June 1958,
   Appendix "G"

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9. a) P.P. Wynblatt


b) Abraham Rozen

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10. a) A. Taub and E. Aviv


b) A. Taub


c) A. Taub

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d) A. Taub

Some observations on the mechanism of solid state graphitization in iron-carbon-silicon alloys, Foundry - accepted for publication

e) A. Taub and P. Wynblatt

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f) A. Taub

An unusual fatigue failure, Journal of the Society of Israel Engineers - accepted for publication.
A survey of Metallurgical curricula

There is probably no such thing as a "typical" metallurgical curriculum. Some institutions offer courses in metallurgy as an option of chemical engineering; others have a separate department of metallurgy; still others consider metallurgy as a part of Mineral Technology. There is also a growing tendency in the U.S. to abandon narrowly specialized curricula in favor of a broad, unified program with a goodly amount of restrictive electives.

However despite this variety three broad categories can be noted:

a. General Courses
b. Special science prerequisites
c. Special metallurgical courses

The general courses include not only mathematics, chemistry, and physics which are mostly common to all branches of engineering. They also comprise courses like Mechanics, Fluid flow and Thermodynamics, which, although adapted to the particular need of a department, are nevertheless basic to all fields of engineering.

In variance with the above category special science prerequisites are courses, like mineralogy and crystallography, which even though basic in character have a direct usefulness only in a particular branch of engineering.

* e.g. Federal Institute of Technology, Zurich, Switzerland
** e.g. M.I.T., Cambridge, Mass.
*** e.g. University of California, Berkeley, Calif.
**** e.g. University of California, Los Angeles, Calif.
**Table A-I**

Distribution of time in the undergraduate curriculum of Metallurgy among various categories of subjects - in percentage

<table>
<thead>
<tr>
<th>Institution</th>
<th>General</th>
<th>Special</th>
<th>Metallurgy</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of California Berkeley, California</td>
<td>67.5</td>
<td>7</td>
<td>25.5</td>
</tr>
<tr>
<td>Carnegie Tech., Pittsburg, Pa.</td>
<td>58</td>
<td>4</td>
<td>38</td>
</tr>
<tr>
<td>M.I.T., Cambridge, Mass.</td>
<td>65</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>E.T.H., Zurich</td>
<td>65.5</td>
<td>7</td>
<td>27.5</td>
</tr>
<tr>
<td>University of Liege, Belgium</td>
<td>54.5</td>
<td>24</td>
<td>21.5</td>
</tr>
<tr>
<td>Institute of Technology, Delft, Holland</td>
<td>51</td>
<td>18</td>
<td>31</td>
</tr>
</tbody>
</table>

Table A-I gives a sample of time distribution based on these categories for various institutions of higher learning. It is noteworthy that in this sample American institutions do not specialize more than the European ones. The general courses occupy from one half to two-third of the undergraduate curriculum.

There is, however, no distinction between Process and Physical Metallurgy in the undergraduate curricula. The split appears only on the graduate level. Nevertheless, an attempt was made in Table A-II, to make an arbitrary separation based on the content of courses.

**Table A-II**

Distribution of time between Process and Physical Metallurgy, in percentage of the total time devoted to study

<table>
<thead>
<tr>
<th>Institution</th>
<th>Process</th>
<th>Physical</th>
<th>Mining</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of California Berkeley, Calif.</td>
<td>12</td>
<td>13.5</td>
<td></td>
</tr>
<tr>
<td>Carnegie Tech., Pittsburg, Pa.</td>
<td>19</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>M.I.T., Cambridge, Mass.</td>
<td>11</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>E.T.H., Zurich</td>
<td>15</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>University of Liege, Belgium</td>
<td>14</td>
<td>6.7</td>
<td></td>
</tr>
<tr>
<td>Institute of Technology, Delft, Holland</td>
<td>13.5</td>
<td>3</td>
<td>14.5</td>
</tr>
</tbody>
</table>
From this analysis it would appear that both categories are given about equal weight. Thus, if two thirds of the curriculum is devoted to general courses, the fraction assigned to Physical Metallurgy would be something like 17%. On the basis of 200 weekly contact hours (25 per semester) a figure current in the U.S. - the number of necessary weekly contact hours for Physical Metallurgy would amount to 34.
Proposal for the Establishment
of the
Institute of Metals
at the
Technion - Israel Institute of Technology

by
Dr. D. Rosenthal
Technician USOM/SUNY
Visiting Professor of Metallurgy, Technion
Professor of Engineering UCLA (on Leave)

May 1956
SUMMARY

The need for an Institute of Metals is justified from the educational and industrial points of view. A single institution embodying both of these points is advocated with a research staff of twelve: three senior members and nine assistants devoting their time indistinctly to academic and industrial work. The Institute is conceived as an independent unit structurally and organically, but it is thought of as being linked with – and adjacent to the Department of Mechanical Engineering. The unit will occupy a floor space of about 800 sq.m. and it will house various facilities in Physical and Process Metallurgy. A rough estimate of about IL 300,000,- is given for the establishment of the Institute and its facilities. A tentative time and cost schedule has been worked out for the implementation of the present proposal covering a period of from four to five years.
The study of Metals has occupied - and is bound to occupy for some time to come - an important place in the engineering curriculum. There are two reasons for it, theoretical as well as practical. From the theoretical point of view the metal is one of the simplest solids, and its behavior and properties are the easiest to predict and understand in many respects. From the practical point of view it is still by far the most widely used structural material. The importance of metals has been recognized by the educators and planners of the engineering curriculum not only in the field of metallurgy. Mechanical Engineering, Electrical Engineering, Chemical Technology etc., devote a sizable amount of units to properties of metals and their technology. The Technion is no exception to this rule, as can be gathered from Table B-1 in which the number of contact hours assigned to metals is compared to the total number of contact hours spent by the Technion student in five of its departments. It is seen that the ratio varies anywhere from 6 to 10%, the department of Mechanical Engineering taking the lead.

In spite of the importance accorded to metals in the Technion a closer analysis of the curriculum reveals that not all aspects of this subject have been equally well developed. A large proportion of time is spent in workshop practice, and the remainder is taken up by lectures and classroom exercises. What is sorely lacking is a laboratory where the principles governing the behavior and treatment of metals can be verified experimentally or applied to practical cases. Without this experience the knowledge which the student acquires is bound to remain on a more or less trades' school level, or be at best of a vicarious character.

The need for a metallurgical laboratory has been well recognized by all experts studying the situation of the metal industry in Israel.* It has been also acknowledged by the administration and faculty of the Technion.** The emphasis, however, was in both cases on special training in Metallurgy.

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* See e.g. Metallurgy and Metal Industries in Israel by H. Bornstein, Expert appointed by the Technical Assistance Administration of the United Nations, September 1953.

** See e.g. Technion Research and Development Foundation Ltd., Report for the year 1st April, 1954 to 31st March, 1955.
Without minimizing the importance of this training – indeed as a necessary prerequisite to it – the present report recommends the establishment of a metallurgical laboratory within the framework of the under-graduate curriculum for all departments concerned with the study of metals.

The inclusion of a metallurgical laboratory in the existing undergraduate curriculum raises problems of an organizational as well as curricular nature. The present report deals only with the organizational problems. Considerations of the under-graduate and graduate curricula will be the subject of a special study.

One of the questions which must be answered is that of the required floor space. An estimate of the floor space necessary for laboratory instruction has been summarized in Table B-2. The elements for this estimate have been drawn from conditions prevailing in similar laboratories in the U.S. A figure of 250 sq.m. is thus arrived at, to which has been added about 60% for special equipment required for graduate work and experimental set ups. This brings the total of the required space for instruction to about 400 sq.m.

At this juncture, it is important to consider another, equally important function of the laboratory. This is its expected service to the metal industry.

The need for an institution which could engage in industrial research and thus help the local industry to solve some of its current metallurgical problems has been mentioned previously. The location of such an institution at the Technion appears quite natural in view of the development of the heavy industry in the Haifa Bay area. Even more important is the beneficial interaction which is bound to result between instruction and industrial experience in one single institute. And last but not least is the incentive for basic as well as industrial research which is apt to exist in an academic environment. For, to paraphrase Napoleon, it is quite true that an institute "marches" on its industrial research (as much as an army marches on its stomach) but the leadership comes only from those who depart from the beaten paths. For these very reasons it is recommended that laboratory instruction be conducted with industrial and basic research consolidated in one single institution: the Institute of Metals.

It is clear that the inclusion of the industrial research facilities will necessitate additional floor space not only to house additional equipment, like experimental foundry and steel-making laboratory, but also to provide the staff of the institute with adequate offices and a library. It is estimated in the next section that these requirements will about double the space foreseen for laboratory instruction, thus bringing it to about 800 sq.m.
In view of the rather large space requirement for metallurgical instruction and research it may be asked whether provision should not be made for the future expansion of the Institute into a department of Metallurgy*. The importance given to the study of metals in the Department of Mechanical Engineering would seem to call at least for the consideration of a division of Physical Metallurgy within this department.

The estimates made in Table B-3 show that there is little basis for such a consideration. The number of students who are likely to get a degree in Physical Metallurgy in the foreseeable future appears to be at the most nine each year. This is hardly enough to justify a special four year curriculum. The question then arises of how to provide the industry with the needed, even though small, number of metallurgists. The answer to this question lies in the training which the Institute will offer to the students who intend to specialize in the field of Metallurgy. Their number may vary anywhere from seven to ten. Some of them will be expected to carry on with graduate studies for M.S., or even Ph.D. degrees as teaching assistants or on their own, but a certain proportion may be merely Bachelors of Science getting additional experience in Metallurgy and holders of industrial fellowships or individual grants. In many cases this may be entirely sufficient for the immediate needs of the industry.

From the above consideration it follows that the Institute will perform two distinct but equally important educational functions. On the undergraduate level it will provide instruction (lecture and laboratory) in the general field of metals and their properties as needed by the various departments. It will also serve as the training center in Physical Metallurgy for those young men who desire to acquire additional experience in this field without seeking a higher degree. On the graduate level it will organize courses and direct research of students aiming at the M.S. and Ph.D. degrees. It will thus fulfill what is commonly referred to as one of the aims, or possibly the only aim, of an institution of higher learning: the dissemination and advancement of knowledge.

Like its educational counterpart the service to industry will also be of a twofold nature: 1) consultation through the dissemination of the available knowledge and experience, and 2) industrial research aimed at a solution of new or specific problems.

* The word department is used here in the sense generally meant in the U.S.: a part of the College of Engineering giving specialized undergraduate instruction.
In variance with the basic research, the industrial research endeavors to obtain answers of immediate applicability. But the two forms of research are neither incompatible nor are they unrelated. In fact, many a problem of a basic nature has developed as an outgrowth of some industrial needs. The link between the basic and industrial research will be closely maintained thanks to the particular organization of the Institute. This organization is indicated schematically in the flow diagram, Table B-4, and it is further discussed in the next section.
Organization, Planning, and Cost Estimate

Purpose

As pointed out in the previous section the creation of the Institute of Metals will accomplish a twofold purpose. It will

1. provide the Israel Institute of Technology with facilities for instruction and research in Metallurgy

2. create a center of counselling and research for the local metal industry.

This twofold purpose was outlined in the recommendation of the U.N expert, H. Bornstein as early as 1952. It has lost none of its urgency at present. On the contrary, in the face of the rapidly growing metal industry in Israel the need for the Institute seems to be even greater. It appears to be both within the province and duties of the Israel Institute of Technology to satisfy this need without delay.

Scope

The major portion of the activities at the Institute has been planned in the field of metal uses. This is known as Physical Metallurgy. Limited facilities have been provided for the study of the production of metals, or Process Metallurgy, mainly steelmaking. However, Extractive Metallurgy, which belongs more properly to Minerals Beneficiation, has not been included in these activities.

Limitations.

Mechanical Metallurgy, also called Metals Technology, forms an important part of Physical Metallurgy. The staff members of the Institute are expected to give instruction and conduct research and development in this field. However, the required laboratory facilities, which comprise a testing materials laboratory and a processing laboratory for shaping and machining of metals, are presumed to be set up in the Department of Mechanical Engineering. It is also taken for granted that members of the Institute will have free access to the above facilities for the purpose of instruction and research. On that basis only a limited number of machines for testing and processing has been included in the equipment of the Institute.

Location.

Because of the above considerations it is suggested that the Institute of Metals be located in the vicinity of the Department of Mechanical Engineering, as an autonomous unit, with its own budget and staff.

Contemplated Facilities

With this in mind the facilities of the Institute have been planned as follows:
1. Metallography
2. Heat treatment laboratory
3. Chemical analysis of metals
4. Foundry
5. Process Metallurgy (steelmaking, powder metallurgy),
   Joining processes, and Surface treatments
6. Metallurgical library and reference desk
7. X-rays and Dilatometry.

**Personal**

To head adequately all these activities a team of three
senior staff members appears necessary, with one of them
vested with the authority of a director, and the two others
acting as associate directors. For reasons stated in the
previous section and bearing on the coordination of the basic
and industrial research, all three of them must hold academic
appointments and participate actively in the instruction as
well as service to the industry. To assist them in their
educational and professional tasks provision has been made
for an adequate number of assistants, research grantees,
and graduate students. Technical and administrative help
also must be available. On this understanding the composition
of the staff may be established as follows:

a) One Director, Two Associate Directors - all holders of an
   academic appointment.

b) Nine Assistants, Research Grantees, or Graduate Students.

c) Four Laboratory Technicians (chemist, mechanic, metallur-
   gical operators).

d) Administrative help (librarian, secretaries, and a recep-
   tionist - telephone operator).

**Space Requirement**

A global estimate of the space needed for teaching and
service to industry has been made previously. It is suggested
to house all activities on the main floor, except Foundry and
Process Metallurgy, for which another floor or another loca-
tion should be provided. The assignment of the floor space
to the various activities is indicated schematically in the
accompanying sketch and it is listed below. However, a
possibility for expansion to about twice this amount should
be provided in the building plans. It is suggested that
ground space around the building be reserved for this purpose
and also foundations strong enough to support an additional
floor be foreseen. With this in mind the floor space for the
activities listed previously is as follows:

<table>
<thead>
<tr>
<th>Main Building</th>
<th>1. Metallography</th>
<th>150 sq.m.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Heat treatment</td>
<td>108 &quot; &quot;</td>
</tr>
<tr>
<td></td>
<td>3. Chemical Analysis</td>
<td>54 &quot; &quot;</td>
</tr>
<tr>
<td>Main Floor</td>
<td>4. X-rays and Dilat</td>
<td>72 &quot; &quot;</td>
</tr>
<tr>
<td></td>
<td>5. Library</td>
<td>60 &quot; &quot;</td>
</tr>
<tr>
<td></td>
<td>6. Conference Room</td>
<td>60 &quot; &quot;</td>
</tr>
</tbody>
</table>

B-7
7. Offices for
   1 Director
   2 Associate Directors
   9 Assistants
   4 Technicians
   2 Secretaries
   1 Receptionist–Telephone-Oper. . . . 100 sq.m.

8. Hallway, Entrance, etc. .......... 86 " "

Annex or Basement
9. Foundry ........................................ 75 " "
10. Process Metallurgy ...................... 75 " "

Total Annex ...................... 150 "
Grand Total ...................... 840 "

Cost Estimate

A. Building: On the basis of IL 200.– per sq.m., the building cost amounts to 840 x 200 = 168,000 IL including power line and supply of power up to 150 KW.

B. Facilities. The estimates here are only approximate. The necessary equipment has been kept down to a minimum, far below what is considered to be a normal allotment of a metallurgical laboratory in the U.S. (see e.g. the plans set up by the Pittsburgh Chapter of the American Technion Soc. 1953).

1. Metallography ...................... 40,000 IL
2. Heat treatment Lab. ...................... 40,000 IL
3. Chem. Lab. ...................... 20,000 IL
4. Foundry and Process Metallurgy ...................... 20,000 IL
5. X-rays and Dilat. ...................... 40,000 IL
6. Library ...................... 5,000 IL
7. Visual Aids ...................... 1,000 IL

Total Facilities ...................... 196,000 IL

Amount of money already spent or committed 35,000

Balance to be provided for the facilities ...................... 161,000

Grand Total ...................... 329,000
Implementation

Both from the financial and educational points of view it seems advisable to set up a certain time and cost schedule for the implementation of the proposal. For the sake of convenience the floor space requirements and the research and teaching facilities have been considered separately.

A. Floor Space

Present State.

The Metallurgical Laboratory disposes at present a floor space of about 100 sq.m. allocated in the aeronautical building. This space is sufficient to house the existing equipment and the equipment on order by the USC&M and expected to arrive sometime next September. An embryo of a research laboratory for metallographic studies and heat treatment of metals will have been thus established. However, the available floor space will not be adequate, if undergraduate laboratory also is to be included. Tentative arrangements have been made already with the Aeronautical Department to handle about thirty undergraduate students during the next academic year. It follows from Table 2 that to do this job properly more floor space is needed. It is recommended that the present floor space be at least doubled, thus bringing it up to about 200 sq.m.

Temporary Solution

The proposed increase of the floor space will enable the laboratory to satisfy not only the immediate needs of the Aeronautical Department but also the future needs of other departments, once due allowance has been made in their curricula for the laboratory exercises. The situation could thus remain in this temporary state until the building of the Institute of Metals would have been ready for occupancy, perhaps some three to four years from now.

Final Solution

The final solution calls for a special building covering a floor space of about 800 sq.m. The reasons for having the building adjacent to the Mechanical Department have been pointed out previously. Perhaps it should also be explained, why the Institute is not to be made an integral part of this department. There is first the necessity of a physical separation to prevent the transmission of vibrations from heavy mechanical equipment. There is next the psychological factor of having an institution with which the local metal industry can identify its own interests without any reservation. And there is finally the possibility of growth and development of the Institute independently of the structure and organization of the Mechanical Department.
B. Research and Teaching Facilities

Metallography and Heat Treatment

The order in which these facilities have listed previously, B-8, is also the order in which they should be implemented. The Metallography and Heat Treatment come first by reason of their immediate applicability to the instruction. They have been given an excellent start thanks to the Rothschild donation and the grant from the USOM. However, the full implementation of the program requires an additional amount of IL 40,000.- to be provided in the year 1957-1958.

Chemical Laboratory and Foundry

The Chemical Laboratory and Experimental Foundry, as well as related activities, like joining and surface treatment of metals, come second. Chemical Laboratory is a useful tool in any type of research work connected with metals, and it becomes indispensable once Foundry and Process Metallurgy get underway. A small amount of chemical equipment already exists, but with the growing demands of the basic and industrial research a standard chemical laboratory for metal analysis will be needed. The activities considered in this paragraph call for another IL 40,000.- to be included in the budget for the year 1958-1959.

Process Metallurgy and Reference Library with Visual Aids

Process Metallurgy and a Reference Library with Visual Aids, both in a limited form, have been considered as the third step in the process of building up the Institute of Metals. Process Metallurgy is not likely to have the same extent as the previously mentioned activities, and the reference library of necessity must be of a limited scope. Therefore, the expenditure connected with these activities has been set up at something like IL 41,000.- which are to be provided in the year 1959-1960.

X-ray and Dilatometry

The final step completing the establishment of the Institute of Metals will be the setting up of X-ray and dilatometric facilities. Both represent an essential part of its research activities. However, possibilities for X-ray work already exist in the Physics Department, and Dilatometry, while important, must give way to more pressing needs. The completion of the facilities of the Institute will require a last installment of IL 40,000.- to be put in the budget for the fiscal year 1960-1961.

Summary

In brief, the establishment of the Institute of Metals appears as a venture spreading over a period of about four years and carried out according to the schedule as follows:
### a. Floor Space

<table>
<thead>
<tr>
<th>Year</th>
<th>Sq.m. approx.</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>present</td>
<td>100</td>
<td>Aeronautical Building</td>
</tr>
<tr>
<td>1956 - 1959</td>
<td>200</td>
<td>Ibidem or another Building (Temporary)</td>
</tr>
<tr>
<td>1960 -</td>
<td>840</td>
<td>Institute of Metals (Permanent)</td>
</tr>
</tbody>
</table>

### b. Research and Teaching Facilities

<table>
<thead>
<tr>
<th>Facility</th>
<th>Year</th>
<th>IL. approx.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metallography and Heat Treatment</td>
<td>1957 - 1958</td>
<td>40,000</td>
</tr>
<tr>
<td>Chemical Lab and Foundry</td>
<td>1958 - 1959</td>
<td>40,000</td>
</tr>
<tr>
<td>Process Metallurgy and Library</td>
<td>1959 - 1960</td>
<td>41,000</td>
</tr>
<tr>
<td>X-rays and Dilatometry</td>
<td>1960 - 1961</td>
<td>40,000</td>
</tr>
</tbody>
</table>
### TABLE B.1

**Israel Institute of Technology**

**Existing Offerings in Properties and Processing of Metals**

<table>
<thead>
<tr>
<th>Weekly Contact House</th>
<th>(lectures, Exercises, and Laboratory–Workshop)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department</td>
<td>Division</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td>General Mechan. Engin.</td>
</tr>
<tr>
<td></td>
<td>Power and Heat</td>
</tr>
<tr>
<td></td>
<td>Production Engineering</td>
</tr>
<tr>
<td>Electrical Engineering</td>
<td>Power</td>
</tr>
<tr>
<td></td>
<td>Telecom. &amp; Electron.</td>
</tr>
<tr>
<td>Chemical Technology</td>
<td>Industr. Chem. &amp; Engin.</td>
</tr>
<tr>
<td></td>
<td>Food Techn.</td>
</tr>
<tr>
<td>Agricul. Engineering</td>
<td>Agricult. Machinery</td>
</tr>
<tr>
<td></td>
<td>Soil, Water &amp; Structures</td>
</tr>
<tr>
<td>Aeronaut. Engineering</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** 1. The total number of weekly contact hours for all terms includes workshop practice, but does not include Hebrew, Physical Training, etc., which are considered as extracurricula activities.
Note: 2. The total number of these contact hours does not correspond exactly to what is called "units required for graduation" in the U.S. For one thing, the number of weeks per term is 12 instead of 15, for another, some of the exercises are actually classroom work. However, this latter item is compensated to some extent by the exclusion of the extracurricular activities, which are counted for graduation in the U.S.

Taking the figure of 290 as the average number of weekly contact hours for the eight terms of study and using the conversion factor of 12/15 we arrive at a figure of 230 as against 200 contact hours set for graduation in the departments of engineering of most institutes in the U.S., or an excess of 15%.

3. To convert from weekly contact hours to the total number of hours the figures in Table I must be multiplied by 12. In the same fashion the units used in the U.S. must be multiplied by 15 to yield the total number of hours. On that basis the students in the U.S. spend 3000 hours on the average in the classrooms and laboratories during their four years of study, while the students in Technion devote to the same purpose about 3600 hours.
### Laboratory Facilities for Instruction in Physical Metallurgy

#### Estimate of the Floor Space

<table>
<thead>
<tr>
<th>A. Number of Students to be served:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>a.</strong> in the introductory course in the second year of study (all interested departments) first term</td>
<td>250</td>
</tr>
<tr>
<td><strong>b.</strong> in the course of Physical Metallurgy third year, second term (Mechanical Engineering)</td>
<td>90</td>
</tr>
</tbody>
</table>

Hence max. number of students per term: 250

Number of laboratory sessions per student and term in the second year course: 6

Number of available days per term $5 \times 12$: 60

Number of students to be served in one day: $250 \times 6 : 6 = 25$

Laboratory space per student including facilities for metallography and heat treatment about 10 sq.m.

Required space for metallography and heat treatment about 250 sq.m.

<table>
<thead>
<tr>
<th>B. Additional space for equipment for third year students and graduate study in Physical Metallurgy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total for instruction purposes in Physical Metallurgy</strong></td>
<td>400 sq.m.</td>
</tr>
</tbody>
</table>

* one day per week for each of the interested departments.
TABLE B.3
Estimated Annual Need of Metallurgical Engineers in Israel
based on American Conditions

<table>
<thead>
<tr>
<th>Description</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of B.S. degrees granted annually in U.S. in Metallurgy (same source as above)</td>
<td>about 700</td>
</tr>
<tr>
<td>or % of the total</td>
<td>2%</td>
</tr>
</tbody>
</table>

Estimated annual need of engineers in Israel based on American conditions:

<table>
<thead>
<tr>
<th>Description</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of populations, approx. 1.9 to 159, or 1.2%</td>
<td></td>
</tr>
<tr>
<td>Total number of Engineers</td>
<td>420</td>
</tr>
<tr>
<td>Total number of Metallurgical Engineers</td>
<td>9</td>
</tr>
</tbody>
</table>

N.B. Considering that the number of students graduating presently from Technion is about 200-220 annually, the above figure of nine must be considered as an upper limit.
TABLE B.4

FLOW DIAGRAM OF THE FUNCTIONING
of the
INSTITUTE OF METALS

INSTITUTE OF METALS

INSTRUCTION

UNDERGRADUATE STUDIES

LOWER DIVISION
(Introduction to the Study of Metals)
250 Students

UPPER DIVISION
(Physical Metallurgy)
90 Students

TRAINING OF METALLURGISTEX

GRADUATE STUDIES
(9 - 10 Assistants, Research Grantees, and Graduate Students)

SERVICE TO INDUSTRY

RESEARCH
CONSULTING

BASIC
INDUSTRIAL
THE INSTITUTE OF METALS

GROUND FLOOR:

TOTAL GROUND AREA: 650 Sq.m.

BASEMENT:

TOTAL FLOOR AREA: 850 Sq.m.
On the Reorganization of
ENGINEERING EDUCATION

at the

TECHNION - ISRAEL INSTITUTE OF TECHNOLOGY

by

Dr. D. Rosenthal

Technician USOM/SUNY
Visiting Professor of Metallurgy, Technion
Professor of Engineering UCLA (on leave)

July 1956
Foreword

The importance of a fact is measured by the return it gives - that is, by the amount of thought it enables us to economize.

H. Poincare

The present report embodies a philosophy of education and a set of principles which the Committee on Reorganization of Curriculum at the Technion has adopted, in substance if not in letter*, as a basis for its current deliberation. Without prejudice to its final decision, the Committee concurred in the idea that the content of the present report be given an early airing among the staff of the Technion. There is nothing unusual in such a procedure. It is current practice in the U.S. to seek opinions on educational problems from the whole staff, and even from students. It is hoped that the staff of the Technion will avail itself of this invitation to make its voice heard by the Committee.

The reader will find in this paper frequent references to the Report on Evaluation of Engineering Education by the American Society for Engineering Education. I hope he will not hasten to make the all too easy conclusion that here is another case of an uncritical attitude and imitation. If he reads the two documents carefully, he is bound to see that whatever similarity there is it is one of conditions rather than solutions. The changes of curriculum that are proposed here are sufficiently different to be considered as germane to the particular "climate" of Israel.

But, one may ask, why make changes at all? If Technion possesses competent and conscientious teachers - as it undoubtedly does - would not everyone of them try to adjust his teaching to the changing conditions of the technological world? Of course he would, and some probably do. But this is not the point. The danger is that by doing this singlehandedly, without regard to the whole, one is liable to make things worse instead of better. To quote a recent report**: "The proliferation of content in all fields, while a remarkable human achievement in itself, is also one of the most frightening aspects of our disturbing age."

* The suggestions which did not gain unanimous acceptance have been put in footnotes.

** Journal of Engineering Education, 46, 640 (April 1956)
The danger really is of two sorts: one of cramming and overcrowding the curriculum, the other of narrowing the specialization to the point of turning out engineers with a "one-track mind".

The first danger is already with the Technion. Even if allowance is made for the shorter length of its semesters, there is still an overall excess of contact hours of about 15% compared to an average American program. True enough, some of these hours are devoted to "recitation" on the excuse apparently that there aren't enough textbooks in Hebrew to allow for homework. I am afraid, however, there is too much propensity to "spoon-feeding" in this excuse, and for once the Technion might do well to heed also other advices than those coming from the American "textbook devotees".

The second danger is inescapable if the teacher persists in the hopeless task of catching up with the latest technological developments. I can still vividly recall my last examination in Machine Design which I almost failed because of my inability to explain the detailed functioning of the then popular Walachaert's sliding mechanism. I lost, of course, all interest in this device ever since, but so did probably everybody else including the locomotive works which were producing it.

It is hopeless to bring the student up to date on the latest technical developments not only because they are ephemeral, but also because they are too many. Clearly, a choice must be made, a choice of subjects as well as their contents.

If the Technion were solely at the service of the industry, then the choice obviously could be dictated by the immediate needs of the latter. Such a solution might be profitable to the business man, but it would be ruinous to the country. The Technion would be forming one-track minded engineers, ideally suited to the particular job, much like the seedless bananas bred by the subtropical horticulture, but as sterile and vulnerable to climatic changes as the latter.

Like in plant biology the vitality and progress of the engineering fields can be ensured only by cross fertilization. It is this more than foreseeable use that compels the mechanical engineer to study electrical theory, and the civil engineer to become interested in vibration. The collapse of Tacoma bridge in 1941 is still too fresh in the memory of the American engineers to rely on the farsightedness of the narrow specialist.

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* A.E. Morgan, Education in the Modern World: The Functions of Universities, London, 1933

** See e.g. Bruce Truscott, Red Brick University, Great Britain, 1951, p. 123 para. ff, Penguin Books

*** See e.g. D.B. Steinman, American Scientist, 42, 397 (July 1954)
A mature engineering mind while working on particular problem draws elements of solution from various engineering fields, the most fruitful ones coming often from the most remote fields. Thus, seepage of oil through porous media can be best studied by having recourse to electrical analogs, heat flow in boundary layers by means of interferometry, etc.

These "rapprochements" are not matter of chance. They are based in most cases on deep seated analogies of the governing laws. This is the main point of insisting on fundamentals in the engineering curriculum.

So much for the basic subjects. But even in the field of his particular endeavor the specialist must make a choice of what he wants the student to learn. If he is guided by immediate necessity he might do no better with his students than the professor of the Welschaert's sliding mechanism did with me. He might obtain their temporary attention, but he will not succeed in having them retain the details. Details are not the most important point.

In pages of unparalleled wisdom H. Poincare explains why this is so.

"The most interesting facts are those which can be used several time, those which have a chance of recurring. We have been fortunate enough to be born in a world where there are such facts. Suppose that instead of eighty chemical elements we had eighty millions, and that they were uniformly distributed... Then each time we picked up a new pebble there would be a strong probability that it was composed of some unknown substance. Nothing that we knew of other pebbles would tell us anything about it... In such a world there would be no science..."

In like fashion what to the student is important in a mechanism, are not its details, not even the mechanism itself, but the principles on which it is built. With their help he is able to reconstruct the details for himself, to analyze other mechanisms, and even to predict their functioning. Why? Simply, because principles have a greater chance of recurring, because they are more general. Mechanisms, whether they slide or not, are doomed to oblivion, but the principles remain. The screws of today have little in common with the prototype which Archimedes conceived, but the principle of the helical surface, which he introduced, is still valid.

* Much of the credit for introducing these analogies in engineering teaching goes to L.M.K. Boelter, Dean of Engineering, UCLA, recipient of the Lamme award for 1956.


*** Don't forget, this was written before 1912!
In the mastery of the forces of nature the engineer, like the scientist, is superior to the man-in-the-street not because he uses time saving devices, but because he is guided by thought saving principles and laws. A principle or a law, like the sayings of the sages, condenses a great deal of experience and a great deal of thought in a few lines. In the face of the frightful specialization which has invaded all fields of engineering, this is the only framework which can resist the assault of narrow training and lend stability to the engineering sciences. It is also the only one around which the consolidation of the engineering curriculum is possible.

As against narrow specialization there is admittedly the danger of broad superficiality. Both of these pitfalls can be avoided by cross-linking the engineering fields and stressing fundamentals, i.e. in final analysis, by the economy of thought "that economy of effort which, according to Mach, is the constant tendency of science" and according to Poincare "a source of beauty as well as practical advantage".*

* Ibidem. p. 23
The Report

Introduction

The considerations which follow should not be construed as a blueprint for the proposed reorganization. Rather, they are put forward as a basis for further discussion. Above all, they emphasize the general principles which should guide such a reorganization.

Philosophy of Engineering Education

The philosophy of the engineering education which underlies the present suggestions can be stated as follows:

1. preparation of the candidate for a position of leadership in the technological development and progress of the country;

2. emphasis on the science rather than art of the engineering profession.

These two principles are taken up one by one.

Preparation for Leadership

Two essential elements have been recognized in the preparation for leadership: 1) technical, and 2) social.

1. The technical preparation implies those elements of science, both pure and applied, which will enable the future engineer to keep pace with and anticipate the impending developments of technology; in other words, which will give him an increased mastery over natural resources and "forces of nature".

2. The social preparation, on the other hand, aims at developing in the future engineer an understanding of those issues and values which are involved in the distribution and utilization of these resources and forces.

Both types of preparation mean the ability of dealing with "new situations".

Note: The social element of the engineering education in the U.S., or Humanities, is believed to be instilled in the student through better acquaintance with the historical and cultural achievements of mankind.

The example of France and other West-European countries proves that secondary schools, conscious of their obligations, are quite capable of undertaking such a task. The same should be true of Israel. Therefore, the social preparation in the Technion should perhaps be devoted to more actual problems and topics, in the form of appropriate electives*.

In practice, the complexity of the engineering problems, even without their social implications, prevents a rigorously scientific approach to their solution. Yet without the scientific framework the solution is deprived of its most vital ingredient: the adaptability to changing conditions.

The science of engineering is essentially the assimilation and use of basic knowledge for the prediction of new performances. By basic we mean those elements of pure and applied science, which are the most general, therefore the least liable to change. The science of engineering also is predominantly interested in the question of why. Not so the art of engineering. The latter is essentially the knowledge and skill of current technical operations. It is based mostly on intuition, experience, and training. As such it permits often to reach a solution by pure guessing. It is specific in nature and limited in scope. Its main interest lies in the question of how.

The announced philosophy of the engineering education does not minimize the importance of the art, but it recognizes the obvious fact that institutions of higher learning are not well equipped for such a task. A suggestion for partially overcoming this shortcoming in Israel is suggested later.

Two major sectors can be distinguished in the engineering education: 1) the general and 2) the special.

The general sector contains those branches of pure and applied (engineering) science that are common to most, if not all, engineering departments. This knowledge is predicated on the long range objectives of the engineering education without regard to specialization.

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* Electives might also include remedial courses and languages.
On the other hand, the special sector aims at more immediate needs of the industry, as embodied in the various engineering professions (mechanical, civil, electrical, etc.).

The branches of pure science that are commonly agreed to be basic to the engineering education are: mathematics, physics, and chemistry. The agreement is less general on what are basic applied (engineering) sciences.

The criterion which is used here takes into account the contribution which the particular science has made to the unity of concepts and methods of the engineering endeavor.

By analogy to the three stems of the pure science the following three categories can be distinguished:

a) Tools (Graphics, Mensurations*)
b) Materials (Nature, Properties, and Processing)
c) Fields of application

Among the fields of application the Committee on Evaluation of the Engineering Education in the U.S. (A.S.E.E.)** cites:

1. Mechanics of Solids (Statics, Dynamics, Strength of Materials)
2. Fluid Mechanics
3. Thermodynamics
4. Transfer and Rate Mechanisms (heat, mass, and momentum transfer)
5. Electrical theory (circuits, fields, electronics).

* Also called Metrology

The above list is not meant to be all inclusive*. Nor does it suggest a sequence of separate courses. Rather, it exemplifies the type of basic courses which it should contain**. Nevertheless, this list represents a good starting point and it can be used as a transition from the specialized, compartmented, concept of engineering education to the more general, unified, mode of instruction.

In variance with the general sector devoted essentially to the science of engineering it is important to include here some elements of the art. Accordingly, the preparation for a particular profession will be both theoretical (lecture and laboratory) and practical (training). The theoretical part will comprise:

a) the natural sciences which are deemed to be indispensable for a better mastery of the subject, e.g. geology in civil engineering, and

b) the specifically professional courses aimed at applying all elements of the general sector to the problem of design or processing. The emphasis here should be on the methods of approach rather than detailed description, on the ability to reduce the design to its frame of reference rather than to its particular features.

* Thus, nuclear field may be considered in the near future

** The main point here is that the student who wishes to specialize in a particular field should learn not only what other fields can contribute to his professional growth, but also what his own field can contribute to other professions. This he can do best by sharing all courses in the General Sector, including those of his own field, with students of other departments. That is, all courses of the general sector should as a rule be common to most, if not all, students.

This practice does not prevent from including additional courses (or hours) in the Special Sector, as the need arises, which are devoted to the same subject but in a more detailed form.

It is hoped, however, that all departments will wish to contribute to the General Sector for the sake of others as well as their own professional growth.
The practical part, or the art of engineering, involves what is called field experience. It may be acquired in Israel in one of two ways:

a) by training in industry, e.g. in preparation for diploma, or

b) by working for the same purpose in research institutes which serve the industry, e.g. in the Institute of Metals.

Both of these activities are obviously of a post baccalaureate level. They will parallel to some extent the experience which the young engineer is apt to get in the U.S., in the first year of his industrial training.

To use a somewhat loose and trite comparison, the engineering curriculum is like a tree whose trunk is made of the basic engineering courses rooted in the fundamentals of pure sciences and branching off in various specialities at the top.

As the profession gets older the core of the engineering sciences grows in vigor and becomes more consolidated. At no time, however, does it lose contact with the pure sciences, from which it derives most of its new ideas and concepts.

There is a corresponding growth and multiplication of specialization at the top, but the sap continues to flow from the basic engineering trunk.

The gist of this comparison lies in the continuity and coordination of functions between the various parts. Each part assumes full responsibility for its share of the task, but it also coordinates its activity with that of its neighbors. Coordination does not imply subservience, anymore than specialization does not entail narrowness.

Service courses have no place in an institution of higher learning. There is no such thing as "mathematics for engineers" as far as basic principles are concerned. However, the mathematician who has to cover a vast amount of knowledge in a limited number of hours will do well to inquire into the nature of the engineering problems. He is apt to discover that most of them are of the so called boundary value kind. The conditions at the boundary are imposed by physical requirements and are not easily simplified. Enlightened by this piece of information the mathematician may wish...
to concentrate on and make more meaningful to the student those methods of analysis, e.g. Green's functions, which are particularly adapted to the nature of the problem.

Similarly engineering courses should not only use mathematics as a tool, but they should also take advantage of their power of abstraction to formulate problems and solutions in the most general way. It is only thus that the element of predictability will become manifest to the student.

What has been said about mathematics goes also for other basic sciences. Without the atomistic background of modern chemistry and physics the course on metals and their properties is little more than a hardware catalog: a dull and insipid concoction. It becomes an exciting and inspiring adventure when viewed from the vantage point of the internal architecture of solids.

The most challenging task, however, lies before the special sector of engineering in coordinating its curriculum with the broad stream of the general sector. The specialist, conscious of the immediate needs of the present, is apt to press for the particulars at the expense of the general. He is also the one the most likely to complain about the shortage of hours. Not infrequently this attitude is caused by his misunderstanding or ignorance of the ways the fundamental concepts are being taught in the general sector, concepts which he then undertakes to present in his own way.

Thus, an instructor in machine design would dwell in unnecessary length on the nature of fatigue in connection with the fatigue behavior of threaded bolts, without troubling to inquire what has been said on this subject in the earlier course of materials. Instead of wasting his time on repetition, he might have done a better and more profitable job by building on the already existing knowledge and bringing in some important details to bear on the subject.

It is only fair to add that his counterpart in the course of materials often sins in the opposite direction. A believer in the virtues of factual education he will deluge the students with tables and figures of which they have yet neither use nor appreciation.

There is a great deal to be done for a better understanding between the "theoreticians" and the "practitioners", and there is much to be blamed on both sides of the argument.
From previous considerations one would hardly expect that the time allotted to the special sector could be more than 30% of the total time devoted to the engineering courses. Is this enough for an adequate preparation for a profession? A study of one particular curriculum (Metallurgy) reveals that at present the special sector may include anywhere from 32% to 49% of all courses, depending on the institution. Similar variations are likely to be found in other curricula. The lower limit is predominant in the U.S. programs, the upper one in the European programs. However, a closer analysis of the latter e.g. Delft, Liege, shows that a large proportion of the special sector contains courses, like geology, paleontology, which not only are useful to the particular profession (Metallurgy) but also contribute to the general education of the student. The percentage of narrowly specialized courses is generally small, seldom over 30%.

In his recent report the Committee on Evaluation of Engineering Education in the U.S. has assigned about one fourth of the time to a "Sequence of Engineering Analysis, Designs, and Engineering Systems, Including the Necessary Technological Background". This long title with a host of capital letters does not suggest outright specialization, but the explanations which follow convey the feeling that it comes pretty close to it.

Whatever the meaning since the European and Israeli curricula do not have to make as much allowance for Humanities as it appears necessary in the U.S., the time allotted to specialization need not be kept at its lower limit. A figure of about 30% should provide a comfortable margin to avoid narrowness. Moreover, this figure applies only to the theoretical part, not to the training period.

<p>| Example: |</p>
<table>
<thead>
<tr>
<th>Institution:</th>
<th>Civil</th>
<th>Mechanical</th>
<th>Electrical</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.I.T.</td>
<td>30-35%</td>
<td>20-25%</td>
<td>26%</td>
</tr>
<tr>
<td>Un.of Calif.</td>
<td>18%</td>
<td>20%</td>
<td>30%</td>
</tr>
</tbody>
</table>

** ibidem, p.22
For the same reason as above, the time assigned to pure sciences in the general sector can be raised also to about 30%, instead of 25%, thus allowing more time to modern physics and mathematics than in the U.S. curricula.

This leaves about 40% for the engineering sciences electives.

Since the engineering sciences represent the core of the proposed curriculum one would expect that they should amount to more than any of the previous ones. This need not be necessarily so, if adequate consolidation is achieved, which bring unity of methods and concepts to various fields. There may, however, be some difficulty in reaching the desired result at the outset. To give enough leeway for temporary adjustments it is suggested that something like one-third of the time, or about 33%, be spent on the basic engineering sciences.

On this understanding the time allotted to various portions of the curriculum reads as follows:*  

<table>
<thead>
<tr>
<th>I. General Sector</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Pure Sciences</td>
<td>30%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Engineering Sciences</td>
<td>33%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Electives</td>
<td>7%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>70%</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>II. Special Sector</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D. Theoretical Part</td>
<td>30%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

or four years of study

III. Special Sector

E. Field experience;
Post curriculum training - one year

* More or less. There is nothing rigid in these figures
Although the above suggestions are limited to undergraduate curriculum a few remarks are in order for the sake of completeness regarding the graduate studies.

With the proposed reorganization of its undergraduate curriculum, the Technion will be in a strong position to offer a graduate program touching on the frontiers of the current knowledge. It will also be justified in emphasizing its basic nature and research. Students selected for the graduate studies are the potential reservoir of scientific manpower in Israel. They should be given every opportunity to exercise this prerogative, including the substitution of the M.S. degree for the diploma.

Under these circumstances they could continue directly for the M.S. degree after four years of study without having to spend one year on field experience.
BASIC ENGINEERING COURSES

AT THE TECHNION

by

Dr. Daniel Rosenthal

April 1958
The battle of curricula, basic versus specialized, is not only confined to the U.S. It goes on in every country concerned with the future of engineering education. It has not spared small countries, like Israel. On the contrary, in these countries the problem is more serious because, oftentimes, industry is unwilling or unable to provide the on-the-job training which vindicates a more general basic approach in the school. The author describes one phase of this battle at the Technion, Israel Institute of Technology - that which is concerned with basic engineering courses. The remedy which he suggests for the inadequacy of special training in the school may well apply to other countries.
Basic Engineering Courses at the Technion

by

Dr. Daniel Rosenthal

Being a part of a team is also the exercise of freedom.

L.M.K. Boelter

Foreword

Like many engineering schools the Technion, Israel Institute of Technology, has been long faced with the problem of modernizing its curriculum. As far back as 1952 Prof. Sydney Goldstein, the then Vice-President of the Technion, had considered and advocated the reform. At the initiative of General Y. Dori, President of the Technion, a committee headed by Prof. J. Grossman worked out a tentative proposal for the first two years of study. The present writer served on this committee, but he went a step further and submitted a plan of organization covering the whole four years of study. Much of his plan was based on the work of the Committee on Evaluation of Engineering Education.

Credit for the actual reform and implementation goes to Prof. S.B. Littauer of the Columbia University, the present Vice-President of the Technion. A first year of study common to all engineering departments has been now in operation since the fall of 1957.

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* Professor of Engineering, UCLA, USCM adviser to the Technion, Israel Institute of Technology, Haifa, Israel.

** On the Reorganization of Engineering Curriculum, July 1956, Technion, Haifa

As might be expected this measure did not raise too many objections. After all, the first year of study comprises mostly basic sciences, which have been taught in common to all engineering students in many of the existing curricula. The difficulty came when the same approach was suggested for the engineering courses in the second year of study.

As one of the proponents of the unified engineering curriculum the present writer was asked by General Dor to clarify some of the points which caused particular concern to many genuinely interested in the welfare of Israel.

The lines which follow contain a condensed and somewhat revised version of three talks* which the writer devoted to this subject.

* April 15, 20, and 21, 1958
Why Basic Courses? Let's restate our position. Why are basic engineering courses a must? Why should they be common to all faculties of engineering? There are two compelling reasons: 1) to close the growing gap between modern science and engineering; 2) to meet adequately the challenge from industry. Let's examine these reasons in detail.

Divorce from Science It has been said - not without justification - that engineering is an art as well as a science. However, insofar as institutions of higher learning are concerned it is mostly science. What the student must learn in these institutions is principally how to predict and anticipate future performances from present knowledge. Science provides him with principles, laws, and methods, it acquaints him with new discoveries out of which he is able to make new applications for what is commonly considered to be the "benefit" of mankind. This science is predominantly - though not exclusively - embodied in mathematics, physics, and chemistry. To make use of science the engineer must keep in touch with its recent advances, he must understand its working: not only its achievements but also the reasons behind these achievements.

Unfortunately, for the last quarter of a century engineering schools have failed systematically to provide him with this understanding. The graduates of today, as a rule, not only know little about modern physics and chemistry; they are far from suspecting the true reason of their success: the power of prediction that lies in the unity of the basic concepts regarding matter.

To give an example, how many engineers know that specific heat of gases can be computed from spectroscopic data, that elastic constants of solids are related to their specific heat, that these constants in turn can be used to compute the heat of sublimation? etc., etc.?

Or take e.g. the concept of lattice defects in crystal structure. How much clearer becomes the connection between the plastic and electric behaviour of semi conductors through the introduction of the concept of dislocations?

The use of the unifying concept of analogies in heat and mass flow problems is probably too well known to deserve more than a passing mention.
Purely academic preoccupations of little practical concern, one might be tempted to argue? Yet, the electrical engineer who tried in vain to increase the rigidity of relays by using special heat treated steels could have saved time and money had he learnt a bit more about the relation existing between properties and structure. And what about the enormous outlay of equipment and material - to say nothing of manpower - that went into the testing of high temperature steels of the late thirties? What has remained of this colossal effort to guide our present inquiries? Hardly more than what had already been known ten years earlier from the pioneering work of Andrade, a physicist.

A more thorough understanding of the basic scientific principles is not a luxury, it is a necessity. However, this is not enough.

To become more proficient in his own field the practicing engineer not only must lean more heavily on the basic sciences, he must also become better acquainted with the advances in other fields of engineering. The lack of familiarity with these fields makes him reluctant to accept their findings. He is uncertain of their merits, therefore unwilling to apply them. Only a unified basic approach to all engineering fields in the undergraduate curriculum can overcome his feeling of loss and mistrust when faced with a situation alien to his professional experience.

Warning from Industry

The second compelling reason for broadening the base of engineering education is what certain writers envisage as the second industrial revolution: an impending change in the physiognomy and operation of the industrial plants.

Even today big manufacturing companies, like G.E. and Bell Telephone Co., insist on broad engineering training of their recruits. This does not necessarily mean that they already have a direct need for such a training. In many cases it is merely a precaution. They prefer modelling the trainee on the company's own image and liking.

However, it is conceivable that in the future - perhaps not so remote either at the rate of the present progress - industry would have less and less use for the narrowly specialized engineer. This situation is likely to come about, according to experts, with the advent of automation. To show how, let me borrow from my own field of metallurgy.
The hardening of steel was long considered to be a delicate operation requiring the skill and know how of an expert. With the introduction of instrumentation in the plant the rule of thumb of the expert has given way to the scientific methods of the specialist. This is particularly true in the case of high speed steels whose properties and quality depend critically on the temperature of quenching and rate of cooling. Furthermore, the assembly line technology calls for a closer observance of composition and grain size, thus making another claim on the specialist.

With the advent of automation, it is however conceivable that most of the tasks that fall today on the specialist will be assigned to a machine. Such a machine would not only follow faithfully the coded instructions - more faithfully that an assembly line hand ever will - it will also adjust the temperature of quenching and rate of cooling to the composition and structure of the steel it receives. The plant engineer will simply have to program the machine to have it deliver the product within a specified range of properties, e.g. of hardness.

The advantage of automation is here quite obvious. The operation of the plant will be smoother, and the number of rejects will be smaller. The rigid adherence to norms, characteristic of the assembly line technology, will give way to flexibility and adaptation.

The quenching automation will in fact perform a function which, in the language of the communication theory, is close to the process of learning. It will not act blindly and rigidly. Rather, it will base its future performance on the nature of previously received information.

It is hard to conceive that a plant operating on such a contingent and flexible schedule, would be in the hands of narrow and rigid specialists. The climate of production will require supervision which it too must be flexible. The "know how" of the narrow specialist will have to give way to the "know how to learn" of a broader minded engineer.

If the above analysis has any semblance of truth, the proposed scheme of basic engineering curriculum will go a long way toward satisfying future needs of the industry. The essence of this scheme, it will be recalled, is not to teach facts but scientific methods. The latter are not confined to a special field; they are common to all branches of engineering. Common
engineering courses in the undergraduate curriculum will make this truth obvious to the student.

Such are our belief and our position. However, there is a price to pay and there are conditions to be met if the scheme is to succeed.

The first objection against the proposed scheme is: "Aren't we asking too high a price of the present by investing so heavily in the future? What about the immediate needs of the Israeli industry?"

The Technion has a standing obligation toward the country. It must build up its technical manpower, run its plants, develop its natural resources. How are these functions going to be discharged?

The answer is that none need to suffer because of the new program.

The common basic courses will not run through the whole four year curriculum. Courses of a more special character will take over progressively as the student nears graduation. The existing subdivision in civil, electrical, mechanical etc. engineering will also remain.

But, one might object, where is he to find time for this special preparation? Isn't the injection of common courses at the base going to cut down the necessary number of hours? Even now, there is not enough time to do the job properly!

The answer is that the inadequacy of preparation for specific engineering tasks has nothing to do with the number of hours. It lies, I am afraid, in our inability to replace practical experience by classroom demonstration. Not only is this pseudo-specialization inadequate, it is also greatly overdone.

Thus, because one or two students might become railroad or harbor engineers the whole class must take courses in Railroad Engineering or Marine Power Machinery.

Wouldn't it be more to the point and less wasteful of students' time, if this special knowledge were reserved only to those few who are actually going to be called upon to apply it?
This question raises the difficult problem of the on-the-job training in countries with low industrial potential.

It has been generally recognized, in the U.S. and elsewhere, that institutions of higher learning are not the best place for initiating the student in current engineering practices. This task has now fallen on the industry itself. A graduate from an engineering school must undergo a certain amount of training on the job before he becomes productive.

However, in Israel few establishments are either prepared or capable to train their own engineers. We are here in a dilemma.

I believe the way out of this dilemma can be found in the existing machinery of the diploma.

The diploma examination is administered in Israel one year after graduation. Its purpose is to test the ability of the graduate to apply engineering knowledge to practical problems. The candidate is generally already working in industry. However, if my information is correct, this circumstance is seldom taken into account either in the examination or in the diploma project. The former is patterned very much after the B.Sc. examinations and the latter bears every stamp of a classroom exercise. Neither represents the best way of bringing current engineering experience to the trainee.

To utilize the year of preparation for the diploma more effectively it is suggested that the project be tied more closely to the actual professional work in which the candidate is engaged. Also, the examination itself should probe his knowledge of the few specific subjects related to this work rather than the topics already covered by his B.Sc. degree.

This would require additional study on the part of the candidate and additional supervision on the part of the instructor, but it would do away with the wasteful and doubtful type of specialization, the to-whom-it-may-concern variety practiced before the graduation.

Considering the gain to the student and industry this is not too high a price to pay for the proposed reform.
Conditions for Success

Even by doing away with too much specialization on the top we may still end up with a crammed curriculum at the base unless three conditions are met:

1. coordination of subjects,
2. condensation of the content, and
3. better communication with the student.

Coordination

Even a cursory examination of the existing curricula, not only here but also abroad, will reveal unplanned repetition, or conversely lack of integration. For example, Hooker's law of elasticity and Gibbs's phase rule have a habit of cropping up in several courses. On the other hand, Properties of Materials and General Chemistry have been long cohabitating in close neighborhood, yet in complete ignorance of each other.

Such a state of affairs is unwelcome in itself, but in an unified basic curriculum it is inadmissible. It goes counter to the whole philosophy of continuity and unity on which this curriculum is built.

True, to a certain degree each discipline is self-contained and sufficient. Thus, mathematics, a branch of inductive logic, has an intrinsic value regardless of its engineering applications. However, would it detract from its dignity, if the student were also allowed to perceive its usefulness in engineering? I don't think so for a moment. Quite to the contrary. By being duly motivated he will uncover more readily the beauty as well as power of the mathematical edifice. On the other hand, the sooner is the mathematical strand woven into his thinking fabric, the more inclined he will be to use it.

These are not mere conjectures. But even if they were, there would still be good reason, it seems, to ask that instructors of closely related subjects try to coordinate and correlate their offerings.

Condensation

The broadening of the basis means not only more basic subjects in any engineering curriculum, but also more material in each of them. For example, Properties of Materials must be concerned not only with the present aspect of damage caused by corrosion, but also with its future aspect resulting from radiation. If we are not too careful, the cramming on the top will be replaced by cramming from the bottom. To avoid such a contingency the content of each course must be reexamined with a view toward making it more compact.
and concise. Greater use must be made of generalizations and abstractions. Particulars should be treated as illustrations and confined, as much as possible, to problems and home assignments.

A recent attempt at combining the mechanics of elastic, plastic, and viscous continua in one single course is a good example to follow. Similar condensation is conceivable in other subjects (e.g. a unified treatment may be attempted of acoustical, optical, and electromagnetical wave propagation).

It may be argued that there is a limit to the degree of generalization and abstraction a beginner can take. This is true enough. But let's not delude ourselves! Unless the student has learnt to reason in terms of concepts and abstractions he will not be able to practice engineering as a science. To predict is to generalize.

Mathematics has been laid at the foundation of engineering science not only as a tool, but also as a method of abstract thinking. There is too little realization of this fact among the engineering faculty, and consequently there is too much reliance on concrete teaching. It is not infrequent to find a student carrying numerical computations all the way through the problem, instead of making numerical substitutions in the final formula at the end.

We cannot hope of having the student grasp the power of unifying concepts if we let him continue in his pedestrian habits of concrete thinking.

Communication

It has been said - not without reason - that the new program puts greater demands on the learner and the teacher. One is on the receiving, the other on the dispatching side of the communication system called education. What goes into this system represents knowledge, and the problem consists of conveying more knowledge, i.e. more information, through the same channels.

Insofar as the student is concerned greater demands are made not on his time, but his ability to learn. This ability, unlike creativity, is innate in every normal human being. The role of the teacher is not to call it to life, but to stimulate it. The question is how to do it most effectively.
Two kinds of activity can be recognized in the process of learning: the gathering of information and the assessment of its value. Notes and textbooks are the proper source for the former, classrooms are on established medium for the latter.

Let this not what usually happens in practice. Instead of probing into the students' mind many a professor keeps on haranguing his audience as if it were a flock of parishioners. The result is that the students fish their knowledge in the flood of his eloquence like prospectors picking gold nuggets in a washing pan. This is not the proper way of getting at the source of information as anybody knows who has tried to piece together shreds of conversation through a faulty telephone line.

The excuse in Isreal is lack of Hebrew textbooks. This is hardly an overriding argument. Detailed notes can be prepared and assignments can be made from them in advance of the lecture. It has been done elsewhere and with marked success*. There is no reason why it should not succeed here.

The pay off is that instead of peddling facts and figures to the students the instructor can dwell longer on highlights of greater significance or go deeper into the more obscure points of the assignment. Above all he can exercise the true function of a teacher, which is the practice of the art of conversation; that art which in Socrates' dialogues has reached one of the highest levels of perfection and which more than any other device has stimulated the student's ability of learning.

There is also the professor's side of the story. His would be a sad lot, indeed, if he were to be strictly regimented by a syllabus, even one of his own making. Provided the students are held responsible for the content of the notes, there is no reason why he should not occasionally depart from the beaten paths and lecture on topics close to his heart or his field of research. There is no better way of inspiring the student than to initiate him unobtrusively into the wonderful experience of scientific discovery.

* For example, in the course of "Properties of Materials", at UCLA.
One final comment before closing. No amount of safeguards will keep the new program alive unless students and faculty alike realize that learning does not stop with the delivery of the diploma. Failure to recognize this truth will result in producing broad amateurs instead of narrow specialists - and the penalty for this sort of a fraud will be quite heavy. It is up to us to see that it does not happen.
Technion - Israel Institute of Technology
Dept. of Metallurgy

Second Year
First Semester

Syllabus on
PROPERTIES OF MATERIALS
(Lectures)

by
Hyman, Taub (Rosenthal)

April 1958
EXPLANATORY NOTES

The accompanying syllabus is merely a detailed outline of topics to be covered within a certain span of time. It does not indicate why and how the subject has been selected and what are the aims and purposes of the course. To meet possible queries regarding omissions or superfluities some explanatory remarks follow.

1. Aim of the Course: The aim of the course is to provide the student with basic knowledge enabling him to understand and anticipate the behavior of engineering materials, either existing or new, under present or future service conditions.

2. How this Aim is to be Achieved? The above aim is to be achieved:
   a) by deriving, predicting, or explaining the measurable engineering properties from the internal (atomic) structure of materials and the behavior of elementary particles, (atomic or microscopic view).
   b) by making use of basic scientific principles governing the relationship between parameters which define the state of the solid, (thermodynamic or macroscopic view).

3. Scope of the Course: The course covers solid materials in the most broad sense of the word, so that the student can acquire the feel and understanding of their unity rather than differences. (Example: Perfect solids may provide an answer to both, semi conductivity and high temperature strength).

4. What is the Student Expected to Acquire from the Course?
   The student should be able to use the above methods in determining the feasibility of materials regardless of their present uses in all engineering applications (present and future). (Example: minerals in high temperature machine design).

5. What Previous Knowledge and Skills will be Expected from the Beginner in this Course? What Tools will be Utilized?
   a) Mathematics: Graphical representation in various types of coordinates (linear, logarithmic); Vector algebra, Partial derivatives, Integration, Minimum, Maximum, Line integral.
   b) Physics: High School Physics, Mechanics, Thermodynamics (concurrent).
   c) Chemistry: Structure of Bohr atom, Periodic table, General chemistry (as per Pauling e.g.)
6. **Notes:** Mimeographic notes will be prepared covering the highlights and topics will be assigned from the notes in accordance with the schedule given below.

7. **Conduct of Class:** The schedule given below is merely a lower bound to follow so that common quizzes can be given to various sections. The instructor is free to expand any part of the course, as well as omit it in lectures, provided in the latter case students are held responsible for the content of the Notes devoted to the omitted part. It is suggested that the content of the Notes represent a passing minimum.

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**SCHEDULE**

<table>
<thead>
<tr>
<th>Part</th>
<th>Subject</th>
<th>Time appr.</th>
<th>Allotment HRS</th>
<th>Weeks of the term</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Structure of Solids</td>
<td>20</td>
<td>9</td>
<td>1 - 3</td>
</tr>
<tr>
<td>11</td>
<td>General Properties of Solids</td>
<td>25</td>
<td>12</td>
<td>4 - 7</td>
</tr>
<tr>
<td>111</td>
<td>Thermodynamics of Condensed (Solid) Unary and Binary Systems</td>
<td>15</td>
<td>6</td>
<td>8 - 9</td>
</tr>
<tr>
<td>1V</td>
<td>Metals and Alloys</td>
<td>20</td>
<td>9</td>
<td>10 - 12</td>
</tr>
<tr>
<td>1V</td>
<td>Minerals (Ceramics, Cement, Concrete)</td>
<td>11</td>
<td>5</td>
<td>13 - 14</td>
</tr>
<tr>
<td>1V</td>
<td>Molecular Materials (Synthetic and natural polymers)</td>
<td>9</td>
<td>4</td>
<td>14 - 15</td>
</tr>
</tbody>
</table>

**Total:** 100 44

Includes: Quizzes of various duration:

- **No. 1** - after 3rd week
- **No. 2** - after 7th week
- **No. 3** - after 14th week
- **No. 4** - during the 15th week.
Detailed Syllabus

Part 1 - Structure of Solids

Section 1.

Atom and grouping of atoms in solids.

1.1 Structure of atom and periodic table (brief refresher from Chemistry)

1.2 Homopolar solids (sharing of atoms)

1.3 Heteropolar (Ionic) solids

1.4 Molecular (Vander Waals) solids

Section 2.

The Crystalline State


2.2 Computation of size of unit cell.


Section 3.

Methods of Studying Crystal Structure


Part II - General Properties of Solids


Section 2. Elastic Properties. Definition. Elastic property as source of energy (watch works, Roman catapult, muscles). Young's and Shear Moduli. Their relation to atomic structure (the inverse fourth power relation). Elastic moduli and cohesion of solids (Heat of sublimation). Fundamental nature of moduli of Elasticity; (relative insensitivity to changes involving energies of less than IEV).

Section 3. Plastic Properties.


Section 4. Creep (Flow) Properties.


Section 5. Fatigue Properties

5.1 Definition. External characteristics of fatigue failure. Internal characteristics of fatigue, (localized slip, broadening of slip bands, crack initiation).


5.3 Factors affecting fatigue. (Surface conditions, geometrical form, internal flaws, corrosion). Improvement of fatigue resistance (residual stress, surface peening).

5.4 Design for fatigue. Materials and shape factor. Notch sensitivity vs. internal flaws (Example: heat treated alloys and cast iron). Fatigue vs. brittleness (minerals). Fatigue vs. creep (high temperature materials -).

Section 6. Electrical Properties


Section 7. Thermal Properties


7.3 Conductivity in insulators. Lattice vibrations. Influence of temperature (thermistors).

Section 8. Radiation Damage


Part III - Thermodynamics of Condensed (Solid) Systems

Section 1. Components and Phases.


Section 2. Atom Movement in Solids.


Section 3. Elements of Electron Bonding

The AB and AB₂ cubic structures. The anion-cation ratio. Hume-Rothery rules. Examples of application.

Part IV - Metals and Alloys


Part V - Minerals


Part VI - Molecular Materials


Section 2. Some synthetic plastics. Thermoplastics and thermosetting plastics.


Section 5. Examples of artificial and natural synthetic process. (Thermosetting and photosynthesis).
Elements of Materials Processing

Part I. Processes Involving a Change of Shape by Flow

Section 1. Analysis of Plastic Flow Process (slip in metals)

1.1 Stress-strain relationship of the flow process.
   The work of Deformation.

1.2 Limiting factors: instability (and necking), work hardening.

1.3 Production of texture.

1.4 Slip systems and continuity requirements for flow.

1.5 Influence of temperature.

Examples of Application

1.6 Analysis of Rolling: friction, force, permissible reductions, back and front tension, efficiency.

1.7 Analysis of wire drawing: die angle, friction, efficiency.

1.8 Analysis of deep drawing: efficiency, material flow (ironing), earing

1.9 Power requirements - methods of estimation

Section 2. Analysis of Viscous Flow Process (non-crystalline materials)

2.1 Stress-strain rate relationships

2.2 Influence of temperature

2.3 Comparison with plastic flow processes (viscosity)

2.4 Examples of Application. Rolling and extrusion of viscous materials (plastic, glass).
Part II. Processes Involving Fracture and Aggregation

Section 1. Conditions for fracture

1.1 Crystalline bodies
1.2 Non-crystalline bodies
1.3 Liquids

Section 2. Shaping by particle removal involving fracture - Machining.

2.1 Machining of ductile bodies
2.2 Machining of brittle bodies
2.3 Role of lubricants
2.4 Methods of particle removal

Section 3. Production of particles by fracture

3.1 Crushing
3.2 Grinding
3.3 Atomizing
3.4 Types of machinery involved

Section 4. Energy requirements for fracture as a function of -

4.1 Particle size
4.2 Surface properties
4.3 Environment

Section 5. Sizing of particles

5.1 Size classification
5.2 Methods of sizing (screening, sedimentation, chemical treatment, magnetic, filtering)
Section 6. Aggregation

6.1 Size composition (the triangular diagram: coarse, medium, and fine).

6.2 Density and size distribution.

6.3 Methods of compacting.

Section 7. Bonding

7.1 Bonding materials (clay, molten metal, cementing materials, glue)

7.2 Nature of bonding (adhesion, cohesion, diffusion)

7.3 Examples: concrete, ceramics, powder metal parts, cermets.

7.4 Pressure welding in solid state.

Part III. Processes involving joining by melting

Section 1. Local Sources of Heating

1.1 Arc
1.2 Gas flame
1.3 Exothermic

Section 2. Overall sources of heating

2.1 Furnace types
2.2 Flame

Section 3. Factors governing joining

3.1 Transfer of matter (weldability)
3.2 Heat flow
3.3 Capillarity
3.4 Fluxes
3.5 Surface condition (Preparation, etc.)
Section 4. Phenomena accompanying joining

4.1 Distortion and cracking

4.2 Thermal and residual stress

4.3 Structural changes

4.4 Chemical changes: contamination and dilution

Section 5. Analysis of some important joining processes

5.1 Welding. Temperature Distribution, Rate of cooling, Correlation with structural changes and properties.


Part IV. Processes involving shaping by a change of state

Section 1. Liquid Metals

1.1 Mass flow in molds (cast-ability)

1.2 Heat flow in molds

1.3 Metal mold reactions

1.4 Gases in metals

1.5 Shrinkage and cracking

1.6 Thermal and residual stresses

1.7 Factors affecting properties

Section 2. Ceramics

2.1 Suspensions, slips, and slurries

2.2 Molding

2.3 Drying

2.4 Firing
2.5 Glazing and enameling

2.6 Shrinkage and cracking

Section 3. Molecular Materials (Polymers)

3.1 Casting of polymers (flow temperature)

3.2 The setting and supercooling of polymers

3.3 Shrinkage and shrinkage stresses

3.4 Factors affecting properties - composition, fillers, pressure, temperature.
Laboratory Exercises:

(Tentative, subject to change)

1. Casting - Solidification Shrinkage as a function of casting analysis.
   - Influence of thermal properties of mould on solidification.

2. Welding - Determination of optimum arc welding conditions for a steel.

3. Sintering - Change of physical properties of a bronze compact as function of sintering temperature.

4, 5, 6. Visit to Factories - Iron foundry, Glass works, Ceramics factory.
Program of Study

leading towards

M.Sc. degree in Physical Metallurgy

at

The Technion – Israel Institute of Technology

prepared by

Staff of the Department of Metallurgy

and

Daniel Rosenthal
USCM adviser to the Technion
Professor of Engineering UCLA

June 1958
# Program of Study

<table>
<thead>
<tr>
<th>No.</th>
<th>Subject</th>
<th>Contact Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Metallographic Practice</td>
<td>2*</td>
</tr>
<tr>
<td>2</td>
<td>Mechanical Metallurgy</td>
<td>2*</td>
</tr>
<tr>
<td>3</td>
<td>Plasticity and Forming of Metals</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Topics in Phys. Metallurgy</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Seminar in Phys. Metallurgy</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Structure and Properties of Metals (Lecture)</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>I'd em Laboratory of Seminar</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>Thermodynamics of Metals</td>
<td>3</td>
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<tr>
<td>9</td>
<td>Solid State Physics</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>Electives</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17</td>
</tr>
<tr>
<td>11</td>
<td>Thesis</td>
<td>30 hrs. **</td>
</tr>
</tbody>
</table>

* Credit for those courses will be given to students of Mechanical Engineering who took them as elective courses in the fourth year of study.

** To be carried on also during the summer months.
Outline of Courses

In the following number in parenthesis indicates the number of contact hours and the Roman numeral indicates the term in which the course should be taken.

1. Metallographic Practice (2) II - Lecture & Laboratory

Correlation between laboratory tests and performance in practice. Relationship between properties and microstructure. Metallurgical case history.

Textbook: Kehl, Metallurgy & Metallurgical Engineering Series

2. Mechanical Metallurgy (2) I - Lecture

Griffith crack theory. Modern theories of plastic flow and fracture based on dislocations and interaction between imperfections. Anelasticity. Low and high temperature behavior.

C.S. Barrett, Structure of Metals
McGraw-Hill book Co. 1943

3. Plasticity and Forming of Metals (3) II - Lecture


Textbook: O. Hoffman & G. Sachs, Plasticity for Engineers

4. Topics in Physical Metallurgy (3) I - Lectures

Diffusion, Nucleation, Growth. Imperfect (real)
crystals. Models of crystal boundaries. Anelasticity as related to diffusion and solubility studies.


5. Seminar in Physical Metallurgy (3) II

Presentation and analysis of recent topics in the field (martensitic transformation, order-disorder, boundary phenomena, etc.)

Material based on content of Seminars sponsored and published by the American Society for Metals.

Selected texts

6. & 7. Structure and Properties of Metals (6) I, II. Lecture and Laboratory


8. Thermodynamics of Metals (3) I. Lecture


9. **Solid State Physics (6) I, II, Lecture**

   Course to be taken in the Faculty of Sciences

10. **Electives (3, 3) I, II, Lecture**

   Courses on topics connected with the subject of students' thesis work.