1977 Portevin Lecture
Welding, a subject for teaching and a means of teaching

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It is because I devote an important part of my time to the teaching of welding that I have chosen it as the subject of this lecture in memory of Professor Albert Portevin, a lecture which the Executive Council of the IIW did me the honour of asking me to prepare. It is also and above all because Albert Portevin was himself a teacher, my own and that of many others, that I had the idea of devoting this lecture to an activity in which he shone during his whole career, in particular at the Ecole Centrale des Arts et Manufactures, the Ecole Superieure de Fonderie and the Ecole Superieure de Soudure Autogene.

In these three schools, Albert Portevin taught metallurgy to generations of engineers and those who are still active have not forgotten the luminous clarity of his thinking which, enhanced by a remarkable literary talent, was also the hallmark of his writing. When the Ecole Superieure de Soudure Autogene opened its doors in 1930 to train the first groups of those who can today pride themselves on being the first graduate welding engineers in the world, Professor Portevin was there to welcome them and to take part in their training. From that time, he was able to adapt to the particularities of welding, his profound knowledge of the metallurgical science of the time and to anticipate the problems which were just beginning to be evident and the solutions of which he foreshadowed. I think I can say here that Albert Portevin was the founder of the metallurgy of welding and this was evident when, under the Chairmanship of Professor Geerlings, who has himself recalled this period in his own lecture (1), Commission IX of the IIW began its work.

Let it suffice to support my argument to mention here two documents: the first was published in 1933 and is now a classic. It is entitled "Les bases scientifiques de la Soudure Autogene" (The Scientific background of welding) (2). It is a veritable charter of the metallurgy of welding and it can still be usefully referred to today. The other is a file which I had from Portevin himself and which is entitled "White spots in welds". Thus were termed in 1937 what were later known as "fish eyes"; one of his young pupils had described them to him and had illustrated them by photographs of which fig. 1 is an example. On the report of his pupil Portevin wrote in his own hand "Where there are blow holes there are no "white spots", when there are "white spots" there are no blow holes. Characteristics of the defect: always more or less cup-shaped with a rounded contour—Always, in the centre, a spot, a crack, or a star".

He then wrote to his pupil "it would be interesting to see whether the halo which surrounds the defects (inclusions, cracks or blow holes) is a reality, that is to say, whether it corresponds to a reality of the metal, a difference of structure or composition, or whether it is

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Fig. 1. Photograph of a "white spot" (fish eye) on a broken tensile test specimen of weld metal produced by arc welding. R. Castro-1937-author's archives.

only an aspect, that is to say a break made in other conditions or at another time than the present break. In that case it would be in the nature of a flake". I very much doubt whether the mechanism of fish eyes has been so well described or rather foreshadowed by anyone earlier than Portevin. To conclude this reference to the past, the pupil who was then starting on his career was M. Rene Castro who later became President of the Societe Francaise de Metallurgie. Such is the vocation of the teacher who not only teaches but who also helps his pupils to explore and to think.

Coming now to the subject of this lecture I should explain briefly its title "Welding, a subject for teaching and a means of teaching". I propose to show, in the light of examples drawn from French experience, essentially that of our Institut de Soudure, that welding, when it is a subject for teaching, can at all levels constitute the pedagogical basis for a wider training, so that the teaching of welding goes far beyond its strictly professional objective. To borrow from Professor Rollason, who was in the United Kingdom another pioneer of the teaching of the metallurgy of welding, an expression for which I have not unfortunately been able to find the reference, I want to show that welding constitutes the "pretext" for a wider and deeper instruction. I wish to develop this idea by evoking successively the metallurgy of welding, the design and fabrication of welded constructions and finally professional training properly speaking, at the level of welders and welding technicians.

1. Pedagogical aspects of the teaching of the metallurgy of welding.

I have already formulated to Commission XIV of the IIW (3) the reflections which I shall develop below, reflections whose validity has been confirmed to me by later experience. This experience shows that there are at least two types of syllabus into which instruction on the metallurgy of welding can be integrated.

(a) The first type concerns the teaching of the metallurgy of welding within the framework of a specialised long term educational course including the detailed study of all aspects of welding, that is essentially the technology of the welding processes and the associated equipment, the design and fabrication of welded constructions and finally the metallurgical behaviour of welded materials and the inspection of the welds. An example is furnished by the Ecole Superieure de Soudure Autogene which in a nine month course provides instruction for welding engineers, taking as a starting point the general basic training which they have already received at their engineering schools and which leads to an engineer's diploma recognised by the state. In this type of course, work on the metallurgy of welding can be continued throughout the whole length of the course and is carried on at the same time as work on other subjects, the time devoted to it being on average two lectures per week supplemented by practical work. To put this in context, all the work on the subject (metallography, physical metallurgy and metallurgical chemistry) represents sixty lectures of 1 hour 25 minutes out of a total of 246 with, in addition, 14 lectures on the testing and inspection of welds. Naturally these lectures are supplemented by many practical periods in the metallographical and chemistry laboratories.

(b) A second way of teaching the metallurgy of welding occurs in engineering schools or departments not specialising in welding in technical universities. It may also occur in short courses, forming part of what is called in France "permanent training", that is to say teaching given to adults already practising their profession, during periods of training, the means of financing which were defined by law in 1971; in accordance with this law, undertakings are obliged to spend at present 1% of their total outlay on salaries for the training of their staffs. It is thus possible to organise short courses of one or two weeks, which deal either with welding processes and welding problems in general or which deal in more detail with a particular welding process or group of processes. In both cases, emphasis is placed on the metallurgy of welding which is presented to course members as being the study of "what the

material thinks of the operation of welding and the recollection of it which it retains".

In the case of long courses, the method initiated by A. Portevin for metallography and A. Leroy for metallurgical chemistry, a method which I have continued and developed, at present with the help of Monsieur Dadian, consists of explaining in turn, on the one hand, the essential phenomena, a knowledge of which is indispensable to the general understanding of the behaviour of materials and, on the other hand, the application of these phenomena to welding. For example, the section on solidification provides an opening on the structure of fusion welds, that on the hardening of steels leads on to hardening in welding and cold cracking; the data on solid phase precipitations leads to the welding of hardened aluminium alloys and to that of stainless steels etc. The conclusion of the course is an introduction to weldability, and to the teaching of welded fabrication, which leads the student on the recommended practices, which he will understand from the metallurgical point of view, for the welding of the principal alloys.

This approach to teaching is necessary for, at least in France, the students whom we receive, although most of them have been educated up to an engineering degree, have not a sufficient level of metallurgical knowledge to be able to tackle directly the metallurgy of welding, or, when they have received such teaching, they are in need of serious revision for they have generally been taught metallurgy in an abstract way without applying it and we have to teach them to make it part of their everyday existence so that they can use it as a basis for their thinking as welding engineers. I would venture to say that a good course in welding metallurgy should enable students to tackle later the problems posed by the welding of any new material by means of a new process.

At this point in my lecture, I return to my theme which is to show how welding becomes a means of teaching: inspired by the wish to train as welding engineers and to obtain the corresponding diploma, the pupils who come to us with a knowledge of metallurgy which is often modest leave us having acquired the taste for metallurgy and our later contacts with them show that this imprint goes far beyond their training as welding engineers and marks them for the whole of their professional career.

In the second case, that is to say, with course members who within the framework of "permanent training" follow short courses, it is not possible to initiate them into welding metallurgy by first explaining the fundamental phenomena and then their application to welding; the length of the course does not allow this. We prefer to show them in a simplified form the essential phases of the welding operation i.e. the formation of the welded zone, that is to say the chemical phenomena which occur during the operation, essentially during fusion; solidification and its aspects peculiar to welding together with their consequences; the thermal welding cycle and the solid phase transformations engendered by the operation together with their consequences.

Naturally all this is explained in the context of the thermomechanical effects of welding, that is to say in drawing the attention of pupils to the fact that the phenomena which are presented to them have their origin in the presence of stresses and strains which modify them and contribute to their consequences.

But it would be useless, dealing with adults coming from different backgrounds, whatever the level of their course, to set out the metallurgical aspects of welding without recalling the fundamental metallurgical data on which instruction is based. In this type of teaching, experience shows that it is necessary to devote to the revision of general metallurgy, which is very much appreciated by course members who always ask for more, about one quarter of the total time devoted to metallurgy. Here again, we discover how the teaching of welding leads not to narrow specialisation but to a broadening of knowledge. This remark also applies to the teaching of non-destructive testing, the physical bases of which must necessarily be explained to students who do not know them or have not put them into practice, and to the teaching of mechanical tests and the evaluation of defects on the basis of fracture mechanics, a subject still little known among engineers.

Before leaving the teaching of welding metallurgy, whether the courses be long or short, I would make two points of a pedagogical character relating, firstly, to the illustration of teaching by examples and, secondly, to the use of audiovisual methods.

To make the teaching of welding metallurgy more vivid, it must be illustrated by examples drawn from industrial practice or recent research work. Naturally an advantage is enjoyed in this respect by a teaching centre such as the Institut de Soudure which has itself an observation post constituted by a technical assistance and quality inspection department and which also has research department which can welcome students and course members to its laboratories. But one must also take care not to fall inot the trap of a method of teaching which is too, as it were, clinical and which, as in medicine,

gives students more examples of the sick and of diseases than of the healthy. Naturally one must discuss cold cracking, embrittlement, susceptibility to corrosion and other problems and mention practical cases in this context. But this must be done essentially to justify the technical solutions which make it possible to prevent such incidents and which ensure that there nevertheless exist welds which are in good shape.

We must not give our students complexes by an excessive and negative insistance on the problems raised by welding and the accidents which result from it, thus running the risk of letting them think, like Jules Romain's celebrated Doctor Knock who said that the healthy are sick people unaware of their sickness, that a weld is only good because it has not been found to be bad.

In passing, we might perhaps ask ourselves whether at least in appearance we do not share this tendency within the IIW and whether we should not try to achieve a more positive and optimistic image by producing more constructive recommendations than alarming descriptions of accidents.

The second point concerns the fact that, in the teaching of metallography, practical illustration is expensive in terms of time and money. However, closed circuit television, either direct (fig. 2) or using video tapes (fig. 3) can be of great help in illustrating quickly and effectively a metallographic lesson or demonstrating a long and costly operation, this being true not only for metallography but also for anything else. It nevertheless remains a fact that, at least within the context of a long course, the personal effort of individual observation through the microscope is indispensable and

Fig. 2 Use of live close circuit television for teaching metallography

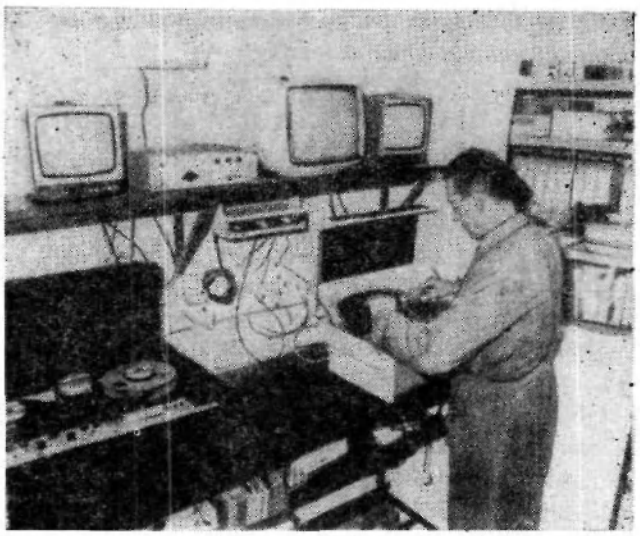

Fig. 3 Use of video tape for teaching by means of close circuit television.

a televised demonstration can only make this effort less onerous. The use of video tapes has the considerable advantage that they can be shown to classes at different levels of instruction in any circumstances, provided that the lecturer knows the films well and can adapt his commentary to his audience.

At the Institut de Soudure our experience of the use of television in teaching, firstly for metallography and then for other subjects, has been apparently satisfactory. Having regard to the technical progress achieved in photography, montage and reproduction, we are wondering if the time has not come to consider international co-operation in order to build up a sort of bank of images which would enable the load to be spread. A particular televised sequence on a given subject could without major difficulty be used in any country, since it would be easy to superimpose on the magnetic tape the original commentary translated into the language required. Perhaps Commission XIV might give preliminary consideration to this suggestion.

2. The teaching of welding design and fabrication

In the field of the design and calculation of welded constructions, as in that of their industrial realisation, we again find the teaching of welding to be "pretext" for education which goes beyond its immediate objective. To prepare design office engineers and technicians for the design and calculation of welded constructions, teaching methods have for long—too long—been based on the adaption of rivetted or cast construction, with which the student was supposed to be already familiar, to welded

construction. This method is still in evidence here and there in handbooks or collections of experiments. In my view, this method is out of date since the time has passed when welding had to find its place among other assembly processes or try to replace them. On the contrary nowadays the designer designs directly for welding and can give his imagination free rein, provided he has the necessary basis of a profound knowledge of the possibilities offered by the different welding processes, a knowledge which will protect him from the risks of impractical, dangerous or expensive designs but which will also free him from the prejeudices inherited from the classical rivetted design. It is useless to teach welded construction, that is to say the principles and the methods for the industrial production of welded constructions, to design engineers and technicians who have not a deep knowledge of the welding processes. This is evident to students, and in teaching establishments where the study of the design and calculation of welded constructions is tackled without first dealing with welding itself, students will avoid, if they have any choice in the matter, undertaking projects in welded construction.

The student must also have an adequate knowledge of the strength of materials and the ability to apply this knowledge in practice; if he has not, he must acquire it at the same time as he becomes familiar with welding. Among our welding engineer students at the Ecole

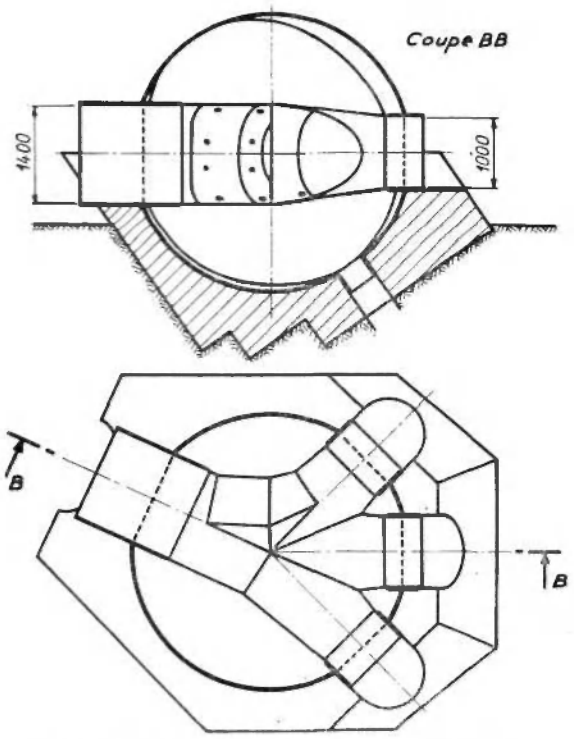

Fig. 4, Example taken from student's project. Pen stock distributors

superieure de Soudure Autogene we find that, as a result of the direction taken by their initial studies, we have simultaneously two categories of students, the first having previously received solid grounding in the strength of materials but with little knowledge of welded construction, while the second knows practically nothing of either subject. In fact, experience shows that the second category can cope perfectly well with being introduced simultaneoulsy to welded construction and to the basis of the calculation of such construction. It can even be claimed that the general and detailed study of welded structures constitutes an excellent background for an introduction to the strength of materials. It can often be noted that students without any previous instruction in the subject are more imaginative and receptive to modern solutions, going straight away for genuinely welding solutions of design problems, while some of their classmates, although initially knowing more, have difficulty in freeing themselves from the designs and methods previously taught them. As an example, fig. 4 is taken from the project of a student welding engineer and concerns a penstock distributor.

Naturally such teaching, which must be at once theoretical and practical, is necessarily supplemented by an introduction to the ways in which welded constructions fail, fatigue and brittle fracture in particular, since this influences the choice of design, the determination of fabrication procedures and the inspections to be carried out. Of course such knowledge, including fracture mechanics, is taught to many other students as well as welding engineers. But, for the latter, such instruction is not simply theoretical and without immediate and tangible application; on the contrary, welding engineers immediately see its purpose and its value and thus they have more reason to, and consequently can more easily, assimilate this knowldge.

When a construction has been designed and calculated, it must be made industrially, depending on the facilities available. Thus, the welding engineer must be prepared for what we may call welded fabrication, an activity which in professional life occupies many more welding engineers than do calculation and design. How does one teach welded fabrication, that is to say the choice of process, material and consumable, joint preparation, the ranges of prefabrication and jigging, heat treatment etc. with, at every stage, concern for what is now called quality assurance? This is a difficult problem when dealing with students whose industrial experience is restricted or non-existent. Putting aside decisions concerning, for example, edge preparation, ways of making the welds, heat treatment and positioning which can be the subject of preparatory classroom teaching,

the way of handling such subjects in order to deal with actual cases is not by means of lectures which would be boring and ineffective, particularly for an audience not yet familiar with industrial practice. It is necessary to make the students take part in exercises during which they themselves prepare, if possible in small groups in the context of a practical case, fabrication programmes which are then discussed and compared under the direction of the teacher concerned. It is during this discussion that the latter can inform the students of all the relevant elements which cannot be the subject of a theoretical lecture, such as for example, the capacity of shears, bending machines or bevelling machines, weight, bulk and transport of prefabricated sections, supply delays, possibility of erection on site, labour problems etc...in short, everything that makes up the daily life of a fabrication shop and with which students must be made familiar without being repelled when they have had no personal experience of this. It is interesting to note in this connection that students who have been sent by an undertaking where they have already been employed for some time, and who have thus some experience, participate enthusiastically in this kind of exercise and spontaneously play the role of leaders, thus perfecting their own knowledge. It is

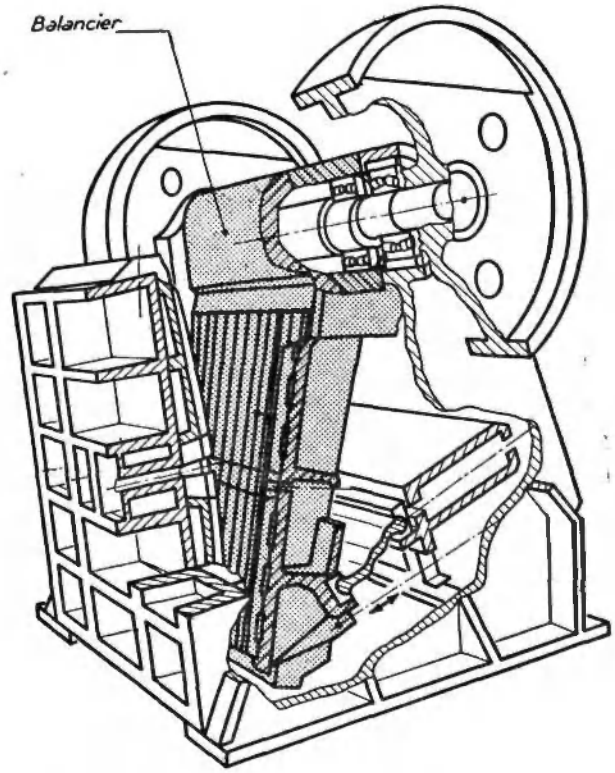

Fig. 5. Example of a fabrication procedure study: working beam of a crusher which appears dotted on the sketch.

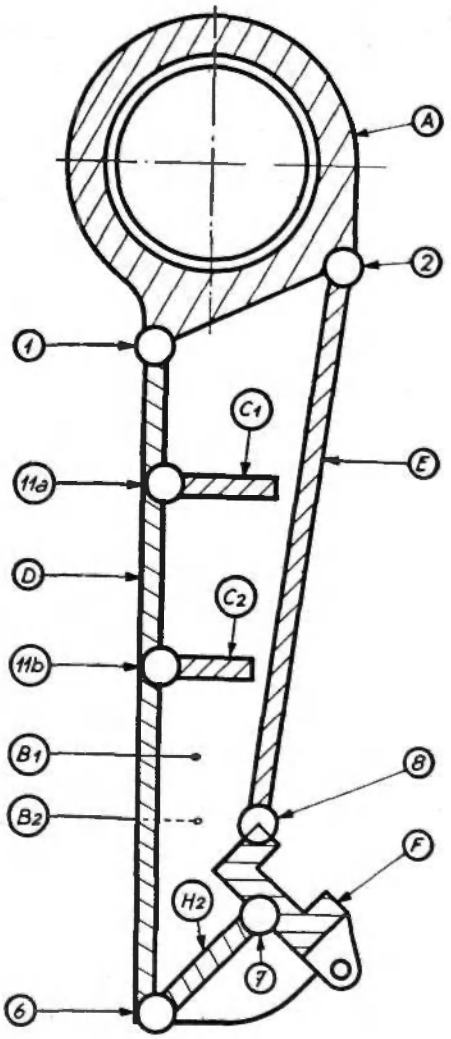

Fig. 6. Example of fabrication procedure study, part of the drawing, dimensioned but not detailed, given to students for work on the design of assemblies.

significant to see to what extent, for a given exercise in welded fabrication suggested by the teacher, a group of student engineers not yet initiated into industrial life, and a group of course members, who have already earned their stripes, react differently. As in the case of design, it may happen that the first with the naivety which is characteristic of them, propose bolder and sometimes more economical solutions then the second. Figures 5 and 6 illustrate an example of a fabrication procedure study for the working beam of a crusher. Figure 7 shows how a student is led to reply to questions put to him.

Thus, by means of welding, the teaching of which, we have already seen, serves as a foundation for the teaching of metallurgy, one can also have access to active instruction in industrial fabrication and make

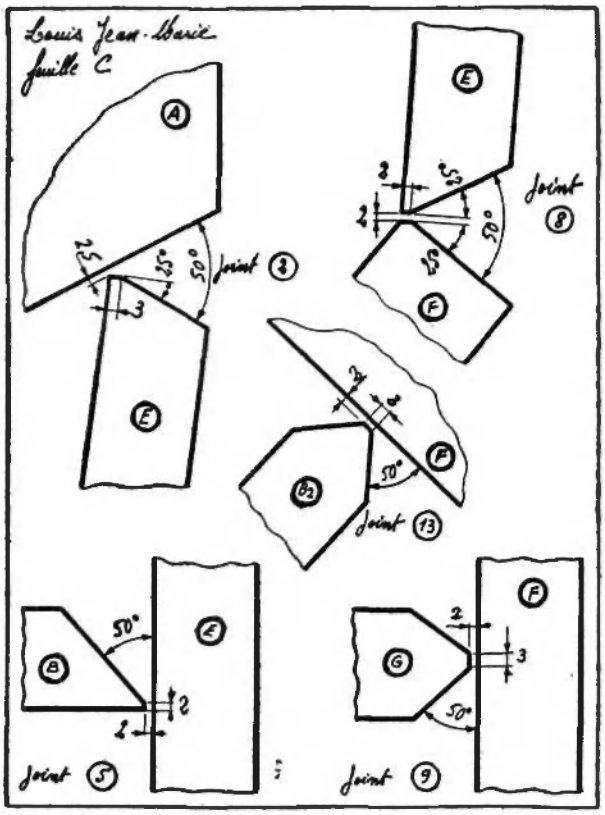

Fig. 7. Example of a fabrication procedure study: part of a study file prepared by a student.

available to industry engineers who, even before they have industrial experience, have some experience of the design and fabrication of welded constructions. Naturrally, nothing replaces industrial visits and vacation work in industry, but this method suitably prepares students for them and makes them more profitable. In fact, it makes it possible for industry to engage people who are immediately useful and this is an advantage appreciated by both sides, employers and employees.

3. The training of welders and welding technicians

It is time to pass now to the problems raised by the training of welders, that is to say in the terms of the definition accepted in France, those whose manual work determines the quality of welds made by them;

this raises the question of whether their training should go beyond the practical knowledge of the craft, all the rest that is to say the choice of processes, consumables and procedures being predetermined.

To demonstrate the size of the problem, let us consider for a moment (fig. 8), the division of welders by level and by process, taking as a basis an estimate resulting from an investigation undertaken by the Syndicat de la Chaudronnerie Tolerie du Nord de la France (4) but probably true for the whole of France, where there are about 70,000 welders. It would be interesting to see, at the level of Commission XIV of the IIW, if this is representative of the position in industrial countries in general. Since this table is expressed in percentages it is worth while to make clear its range by stating that the welding population with which it deals represents 15% to 20% of the total force of shop floor workers of the undertakings questioned, their activities being connected in whole or in part with boilermaking, ship-building and the construction of railway rolling stock. If the welders are classified in three levels in decreasing order of quality of welds and of the equipment to be fabricated, it will be noted that the total division by level (bottom line of the table) has no great variations but with a slight predominance at the lowest level. But there is a great difference between the welding processes although this evaluation does not take into account the need for welders of "nuclear quality" who are recognised as necessary for the erection and maintenance of nuclear power stations; this raises an important problem of recruitment and of further training to make possible a most stringent selection from among a large number of trained welders. It is at present estimated that 950 welders of nuclear quality will have to be trained between now and 1985. However, the experience already gained in industry shows that the selection of welders capable of reaching nuclear standards has to be made from about 10% of approved welders. It is possible from these figures to evaluate the size-even the impossibility-of the problem.

Niveau / Procédé	1	2	3	Répartition dans l'effectif total
Soudage aux gaz	17,4	18,9	63,7	13,7
Soudage manuel avec électrode enrobée	40,8	33,9	25,3	49,8
Soudage TIG	42,9	44,2	12,9	9,9
Soudage MIG-MAG	12,8	37,6	49,6	26,6
Répartition par niveau	30,4	33,8	35,8	

Fig. 8. Enquiry on welders in the north of France (SNCTTI). Division by level and by process.

Unfortunately the survey from which we have drawn the above data does not provide information on the age of welders. But it is obvious that the qualities of good eyesight, manual stability and physical and mental strength which the practice of welding requires diminish during the course of a career so that, having regard to the normal age of retirement, it is not possible to expect that a welder, during his whole working life, will be able to maintain the qualities which have earned him his qualification. There is thus a human problem, the existence of which has not escaped the organisation to which we referred above and this has led it to raise questions concerning the training of welders, not only in relation to the immediate needs of industrial fabrication and the corresponding codes, but also on the human and social level concerning the possibilities of the regarding of welders when, at the end of their careers, they have become unable to produce work of the quality implied by their initial qualifications.

Now it so happens-at least it is what happens in France but it is probable that the problem is not confined to that country-that welding is not yet considered as a job which provides a career like electronics, electricity and mechanical engineering and many other techniques which are taught in the specialised sections of technical institutions providing vocational training. Welding is most often treated as the poor relation of other disciplines and the welding section, when it exists, receives the students who have not done well enough at school to be worthy of a better fate and whom it has been impossible to attach to more highly thought of specialities. The result is that few welders are trained in normal teaching establishments or even in specialised departments immediately after they have finished their compulsory schooling. The vast majority of welders receive an essentially practical training in industry or in specialised centres providing what is called in France "permanent training". At this level, there is no time to revise and complete basic knowledge. Welders are therefore rarely able to understand the reasons for the procedures which they are made to apply and in addition they have not got the basic education which, at the end of their careers as welders, would facilitate their taking up other work.

However, welding can constitute, as well and perhaps better than the other classic industrial disciplines, the centre and basis not only of a vocational training but of an education. At the Institut de Soudure we have proof of this, through the existence-and the success-over many years of the Ecole Professionelle de Soudure which offers young people from 15-17 a syllabus spread out over 3 years centred on welding but including general education going from the French language to metallurgy by ways of physics, chemistry and mathematics; at the same time, pupils prepare for the certificates which in France provide a qualification for welding on the one hand and boiler making on the other . Initially set up to train welding personnel qualified in all processes, the Ecole Professionelle de Soudure has in an exemplary way, though on a numerically small scale, justified the intentions of its founders and indeed exceeded them, for many of its former pupils have gone beyond their initial training and continued their studies so as to gain jobs as technician engineers, engineers and even directors.

In connexion with the Ecole Professionelle de Soudure, further information would illustrate, in the context of this lecture devoted to welding as a subject for teaching and a means of teaching, the genuinely educational character of teaching centred on welding. It is possible to enter the school in the second or even the third year although the normal course lasts for three years. Each year admission takes place into the classes called "2nd special" or "3rd special"of young people who received in their general education a non-specialist training which in respect of general education is equivalent or even superior to that provided during the same time at the Ecole Professionnelle de Soudure. For various reasons these young people wish the branch out towards more practical and technological training. Experience shows that, with the help of a crash programme specially designed to introduce students to the craft of welding, the results are almost always positive. Indeed, there are many young people today who need to be practically motivated to be willing to make the effort to receive and assimilate teaching which otherwise would appear to them too theoretical and would repel them. Another experiment, the results of which are already encouraging, is at present being carried out. This consists of using the teaching of welding, within the framework of a special section of the school, as a means of catching up for boys who were either discouraged from continuing a normal school curriculum or insufficiently gifted to do so and who find in welding and its practice the motivation which encourages them to make an effort which they had previously abandoned. However the Ecole Professionelle de Soudure is still only the germ of what could become more general in technical teaching if welding finally comes to be considered as a basic industrial technique and not a succession of movements which can be learnt whenever necessary.

Conclusions

By examples borrowed from the metallurgy of welding, the design and fabrication of welded constructions and finally the training of welders, we hope to have shown that, at every level, welding can and must serve as a base for teaching syllabuses both with the objective of providing a training for a career centred on welding and also as a means of teaching contributing to an education which goes beyond the strictly technical objective. Consequently, wherever such teaching is provided at whatever level, the fruits will be gathered not only on a purely professional basis but also on a more general plane.

This having been said, I would like to return for a moment at the end of this lecture to the IIW. I shall do so first to show that its structure and the work which it is carrying out constitute, not at the level of teaching properly speaking but at that of the mutual instruction of its members, a typical illustration of my conclusion. Can anything be imagined more strictly specialised and concrete than the title "International Institute of Welding"? In considering only this title, could one guess at all the scientific disciplines which are included in its activity and all the additions to human knowledge which have resulted or which will result from the study of the technical problems raised by welding? It follows that, for the greater good of all, a very clear evolution is taking place in the composition of the national delegations which more and more are calling upon specialists. But, paradoxically, they are not all welding specialists but representatives of the scientific disciplines on which the study of welding opens. This mixture within the IIW which results in the mutual instruction of the delegates is typical of what is happening or should be happening in welding instruction and the IIW ought to be taking part in it.

In this connexion, it may be asked whether the IIW is contributing sufficiently to welding instruction and thus to education in general. My intention is not to call into question the activities of Commission XIV which is obviously the one most directly concerned and which has already raised this problem. In this respect its task is particularly difficult because of the profound differences which exist between the educational systems of the member countries. I would rather consult the Commissions as a whole, as well as the member societies of the IIW, and ask them if they are sufficiently concerned with the use of the work of the IIW in the world of teaching. Numerous documents resulting from this work are now usable and we make use of them each year at the Ecole Superieure de Soudure where the syllabuses of the various disciplines include more than thirty IIW documents which are distributed to the students. But the work of the IIW is still too little known in the world of teaching, no doubt because of insufficient circulation and effective means of collaboration between the member societies and the teachers. In addition, circulation is not helped by language difficulties which my proposal for a bank of images could help to overcome. But it must be admitted that numerous subjects which are on the agenda of the Commissions of the IIW have not yet been the subject of documents which can be used in teaching, whether at the level of engineers, technicians or even welders.

The International Institute of Welding could only gain by making an effort to place a greater part of its work within reach and at the service of teachers, for someone who has learnt something does not forget from whom he has learnt what he knows. A wider circulation of the work of the IIW would not only answer one of the aspects of the vocation of our organisation, but it would prepare for the future, specialists who believe in the IIW because they have benefited from its work.

May I, in ending this lecture and in returning to its objective, express the hope that I have at least partly reached that objective and that I have not done a disservice to the memory of him to whom I have dedicated it and who by his teaching of the metallurgy of welding, aroused the vocations of so many metallurgists and engineers.

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