CoA Memo. 124

THE COLLEGE OF AERONAUTICS
CRANFIELD

THE USE OF PROCESS SELECTION EXERCISES FOR THE TRAINING OF WELDING TECHNOLOGISTS

by

Dr. R. L. Apps

THE COLLEGE OF AERONAUTICS

DEPARTMENT OF MATERIALS

The use of process selection exercises for the training of welding technologists

Paper submitted to International Institute of Welding, Colloquium on Instruction in Welding

- by -

Dr. Robert Louis Apps, Senior Lecturer in Welding Technology,
The College of Aeronautics, Cranfield, Bedford.

SUMMARY

Formal lectures and laboratory experiments do not give students sufficient experience of welding processes applied to specific fabrications. A series of designs has been evolved which is capable of being fabricated by several different methods and students are required to produce fabrication procedures for each design. Suggested procedures are then discussed in an open forum in which both staff and students participate.

The use of these exercises has been found to be a useful method whereby course members can pass on their own experience to other students and in which students learn to make decisions based on available, but often incomplete, facts.

L'usage des exercises pour la sélection de procédés dans l'enseignement des technologistes de soudure

Les conférences formelles et les expériences au laboratoire ne fournirent pas aux étudiants assez d'expérience des procédés de la soudure appliqués aux fabrications spécifiques. On a évolué une série de desseins capables d'être fabriqués par plusieurs méthodes différentes et on demande aux étudiants de produire des procédés de fabrication pour chaque projet. Ensuite les étudiants et les professeurs participent à une discussion générale au sujet de ces procédés suggérés. L'usage de tels exercices a demontré qu'on y trouve une methode utile par laquelle les membres due cours peuvent faire part aux autres de leurs propres expériences et s'entrainer a prendre des decisions qui soient basés sur des faits a portée mais souvent incomplets.

Introduction

It is generally agreed[1] that the graduate welding technologist should have a knowledge of welding processes, metallurgy and design together with an understanding of inspection and other ancillary techniques. Difficulties will always exist in encompassing this range of subjects in a one year post-graduate course of study for engineers and metallurgists, and all such courses are, of necessity, something of a compromise[2,3]. However, the welding technologist must be able to correlate the subjects he has studied and to obtain the correct balance of importance between process, design and metallurgical aspects for any specific fabrication. Thus the problem facing any course in welding technology is to provide students with experience in this synthesis of interest over a limited period of time. No academic instruction can completely replace several years of practical experience but it can accelerate the acquisition of useful experience by highlighting the more significant aspects of fabrication procedure.

At Cranfield, a useful method of making students face the need of using process, design, metallurgy and inspection as part of an integrated field of study has been by the use of a series of fabrication, or process selection, exercises. In the exercises, students are given an outline design for fabrication together with information concerning the facilities available to them. They are then required to make decisions regarding joint design, processes, fabrication procedure and inspection. Solutions are submitted and marked by members of staff. Students then defend their proposals in an open forum attended by the staff and students.

The fabrication exercises have been developed over the last four years; new exercises are being added continually whilst older exercises are either modified or discarded if they do not appear to contribute to the students' understanding of welding technology. The problem in devising such exercises is to give sufficient information to make the exercises realistic whilst restricting the scale of the exercise so that an adequate answer can be prepared in a few hours. Additionally, the exercise should allow students to show some originality in design, process selection and procedure. It might be thought that actual industrial problems might offer the best type of exercise but these invariably involve large amounts of commercial information which few companies are willing to supply, and which would take a considerable time to prepare and digest. Since variety of exercises is essential with students from a wide range of industries, it is better for the staff to originate exercises from their own experience or from discussion with colleagues in industry. In several instances, papers in the technical press have given a useful starting point for an exercise (see for example, reference 4).

Programme of Exercises

Students are required to work through some 15 exercises at the rate of one or two a week. The exercises start in the Spring Term after the completion of the lecture course in welding processes.

The first exercise is a simple lightly loaded machine bed (Fig. 1) for which students are asked to select detail joint designs, welding processes and procedures. Only limited information is supplied, for instance, students are left to deduce for themselves that the loading on the structure is only very light, and many students are, at first, unhappy about the range of decisions that they must make from the limited information supplied. However, the limited information is an integral part of the exercise in that it indicates that there is rarely a unique solution to a welding problem and mirrors many practical problems where the welding engineer or technologist is required to take a decision from limited information.

In subsequent exercises the problems become more specific, being designed to emphasize certain aspects of fabrication in both heavy and light engineering. In many cases the problems lie mainly in the fields of joint design, process selection and procedure but in other exercises the student is asked to consider problems of site welding, joining dissimilar metals, inspection and post-weld heat treatment.

Students are expected to take about three hours to complete each exercise. Their solutions are then submitted to the academic staff for assessment and marking. Finally each problem is discussed in an open forum for staff and students. Generally two students are asked to submit their proposals to the forum after which a general discussion ensues. Academic staff submit a carefully considered solution towards the end of the discussion period but it is emphasized that a unique ideal solution rarely exists, since under practical conditions such variables as background experience and available labour force will have a major influence.

Specific Exercises

In a short paper it is impossible to discuss the full range of exercises that are in use. However, three specific exercises:

i.e. Pressure Vessel Nozzle (Fig. 2)
Bellows Unit in a Pipe System (Fig. 3)
Gas Turbine Combustion Tube (Fig. 4)

are briefly considered below.

(1) Pressure Vessel Nozzle

This exercise is designed to illustrate some of the problems facing the welding engineer in the pressure vessel field; the use of internal and external reinforcing pads is not the best practice but is still met with in many designs and helps to exaggerate the problems of joint design. Process selection is virtually limited to manual shielded metal arc or semi-automatic MIG/CO_2 welding but there is considerable scope in joint design (or even in altering the overall design of reinforcing pads) whilst care is needed in the welding sequences if access problems are to be avoided.

(2) Bellows Unit

The metallurgical problems of stainless to mild steel welded joints and heat treatment have to be considered in this problem. Additionally the joints in the stainless steel are specified as close butted despite the thickness and limitation on reinforcement. It is surprising how many students accept this joint design without query, although most will specify an edge preparation and will discuss the merits of various inserts. If any doubts regarding edge preparation remain after the forum, students can check their designs in the welding laboratory with the aid of a skilled welder.

(3) Combustion Tube

The specific problems of sheet metal fabrication in a context of very high quality are introduced in this exercise. Joint details are deliberately left vague so that the joint design and welding processes can be considered together. If required, students can visit the demonstration laboratories of Cranfield's Propulsion Department, which has a wide range of jet engine components on display, and discuss the requirements of combustion tubes with expert staff.

Teaching Experiences

Fabrication exercises were first introduced into the Cranfield course some four years ago. Further exercises have been added over this time and some of the original exercises modified in the light of student comments.

Initially, inexperienced students find difficulty in understanding the fabrication exercises, until they have noted the approach of the staff and other students with some industrial experience. In fact, the value of the exercises would be greatly reduced if no experienced students were available to pass their views on to students without industrial experience. It has been found that the experienced men benefit rather more from the exercises than inexperienced students, since they can evaluate and appreciate the views of other experienced students, and relate them to their own background. Additionally, the values of a man constructing to the rigorous standards of nuclear engineering are very different to those of a man in the structural steelwork industry where competition is fierce and costing exact, but both men can benefit from the views of the other. In the last session, one-year students were joined in some of the fabrication exercises, by 15 students attending a short course in welding technology. The short course students had some 100 years of fabrication experience in heavy engineering between them and the benefit to both post-graduate students and staff was considerable.

Conclusion

The value of fabrication exercises had been attested by many students, both those with and those without prior industrial experience. However, the

the co-operation of students is necessary for success. It is also necessary for several students to have industrial experience, so that they can form a nucleus for discussion.

It is also interesting to consider how these fabrication exercises could be developed, other than by addition of new exercises. The transfer of selected solutions to the welding laboratory is a possibility and could be extremely valuable. However, extension in this direction could only be at the expense of research or design projects. Visiting lecturers could be asked to discuss a particular fabrication with which they have been concerned and such an approach has been adopted at Cranfield on one or two occasions. Such discussions have proved very valuable to students but demand considerable preparation on the part of the visiting lecturer.

Finally, the writer sees no reason why such an approach should not be adopted in other fields of engineering and applied metallurgy. For example, the problems of materials selection are rarely, if ever, considered in academic courses although the problem faces many metallurgists in industry. It may be difficult to lecture upon materials selection but students could well be introduced to the approach by a series of material selection exercises.

References

1. Conference on 'The functions and education of welding engineers,' British Welding Journal 3, 159-178, 211-225, 279-297, 398-402, (1956)

2. Apps, R.L., Gourd, L.M. and Jubb, J.E.M., 'Post-graduate education in welding technology at Cranfield', Proc. Second Commonwealth Welding Conference, London (1965).

3. Borland, J.C., 'The teaching of welding at universities', ibid.

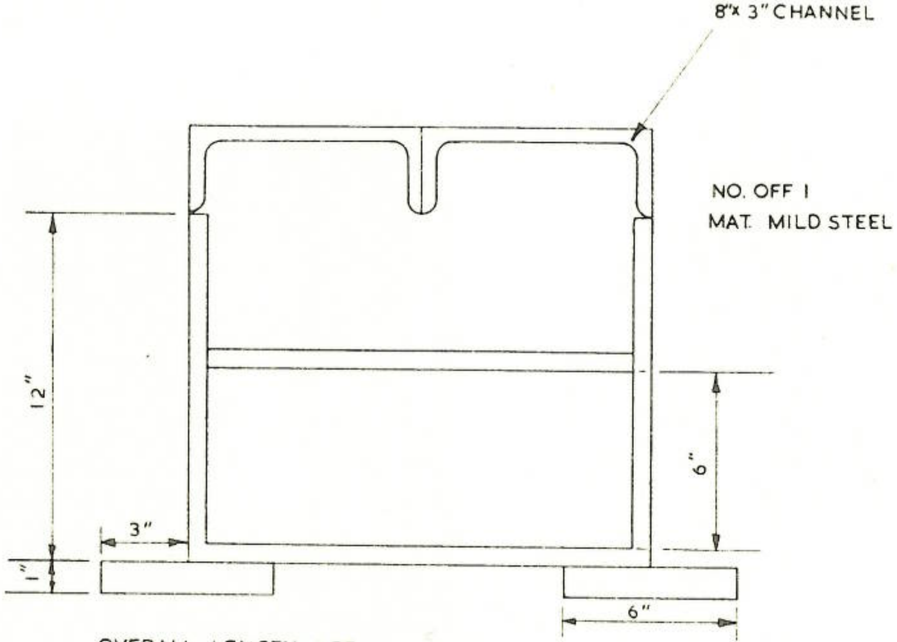
4. Beckett, H., and Lee, E.H., 'Electro-slag welding of T-butt joints', British Welding Journal, 13, 245, (1966).

Acknowledgements

The exercises described above were developed over many hours of discussion at Cranfield by Mr. J.E.M. Jubb, Mr. L.M. Gourd and the author, whose thanks are due to his colleagues. Thanks must also be given to the students of Welding Technology at Cranfield who have participated in the exercises and helped to improve them by their suggestions.

FIG. I

MACHINE BED.



OVERALL LENGTH 8FT.
ALL MATERIAL ½" EXCEPT FEET

SPECIFY THE PROCESS(ES), EDGE PREPARATIONS AND WELDING SEQUENCE TO BE USED.

TOLERANCES ON DIMENSIONS:-
DIMENSIONS ARE NOT CRITICAL

FINISH:- TOP SURFACE TO BE LEVEL
ALL OTHER SURFACES CAN BE 'AS FABRICATED'

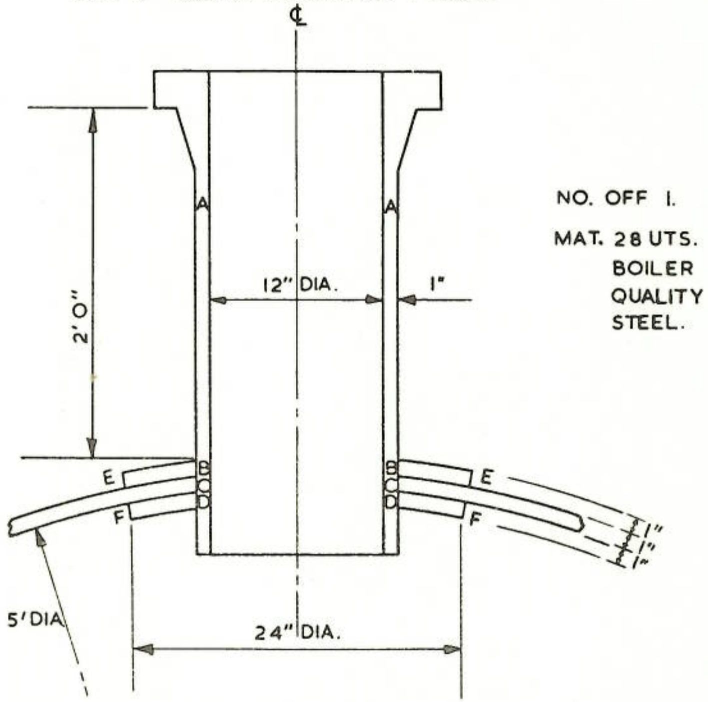
FACILITIES AVAILABLE -

(a) WELDING, OXY-ACETYLENE EQUIPMENT
METAL ARC "
SUBMERGED ARC "
M.I.G./CO_2 "

(b) PREPARATION, ETC.,
OXY-ACETYLENE CUTTING EQUIPMENT
STRAIGHT-LINE GUILLOTINE
BENDING PRESS (2" RADIUS BEND MINIMUM)
GRINDER

FIG. 2

PRESSURE VESSEL NOZZLE WITH REINFORCING PADS.



WELDS TO BE MADE AT A,B,C,D,E & F.
A,B,C & D - FULL PENETRATION WELDS.
E & F ARE 1" FILLET WELDS.
MANIPULATION AVAILABLE FOR DOWNHAND WELDING.

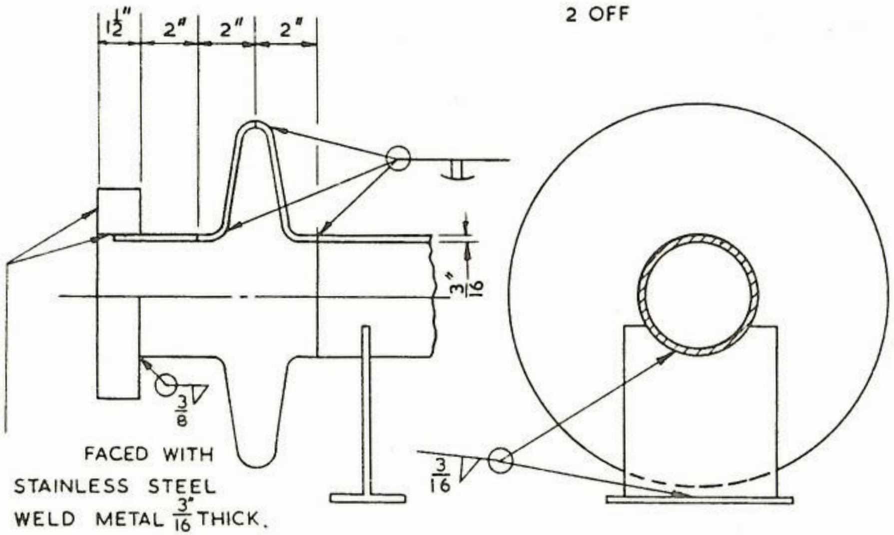
DISCUSS IN YOUR REPORT:-

1. THE TOLERANCES FOR FIT-UP.
2. APPROPRIATE WELDING PREPARATIONS.
3. THE SELECTION OF PROCESS(ES.)
4. SEQUENCE OF WELDING.

NOTE:- WELDING PROCEDURES & INSPECTION REQUIREMENTS WILL BE COVERED IN THE DISCUSSION PERIOD.

FIG. 3

BELLOWS UNIT IN FLANGED PIPE SYSTEM.

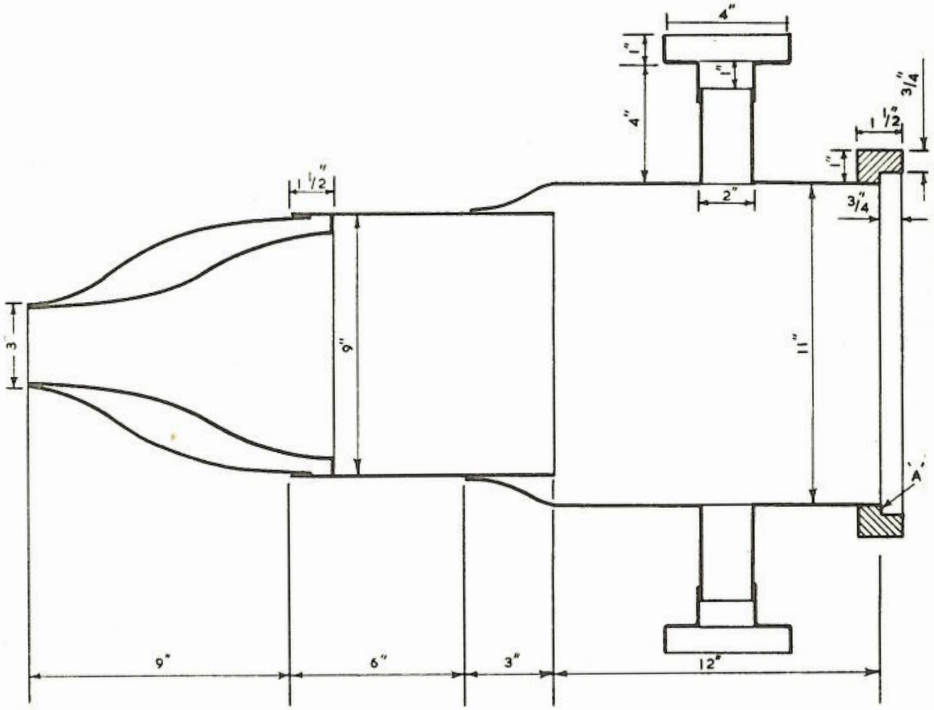


MILD STEEL FLANGE 1½" THICK.
18/8 NIOBIUM STABILIZED STAINLESS STEEL PIPING 6" DIA. BORE AND 3/16" THICK.
SUPPORT SIMILAR TO PIPING, 3/16" THICK.
THE BUTT WELDS MUST HAVE NO UNDERCUT AND THE REINFORCEMENT LIMITED TO 1/16" ON BOTH SIDES.

SPECIFY THE WELDING PROCESSES AND SEQUENCES TO BE USED AND DISCUSS APPROPRIATE INSPECTION.
IS HEAT TREATMENT ADVISABLE?

FIG. 4

COMBUSTION TUBE



MATERIAL: NIMONIC 75.
ALL MATERIAL 18 s.w.g EXCEPT AS SPECIFIED. 12 OFF
ALL DIMENSIONS IN INCHES.
FACE AT 'A' TO BE MACHINED AFTER FABRICATION.

SPECIFY WELDING PROCESSES AND SEQUENCE FOR THE FABRICATION OF THE COMBUSTION TUBE SUB ASSEMBLY.
THE PRIME REQUIREMENT IS ONE OF QUALITY. WELDS WILL BE RADIOGRAPHED WHERE POSSIBLE.