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FULL AND PART LOAD EFFICIENCY MEASUREMENTS FOR BOILERS

Contract MAT 1 - CT 92-0009

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1. Objectives

The objective of the project was the improvement of the test methods including the development and validation of a new concept of boiler testing to ensure a fair and realistic assessment of boiler efficiencies with a reproducibility (*) of less than 2.5%.

The concept shall take into account the energy of electric contributions to the heat balance and shall include methods for the calculation of accuracy associated with the testing.

The results of the project is to be made available to CEN.

(*) The **reproducibility (R)** is the value, below which the absolute difference between two single test results obtained with the same method on identical test material may be expected to lie within a specified probability of 95% under different conditions (different operators, different apparatus, different laboratories, and different time).

2. Résumé of the obtained results

The methods have been developed and validated. The values of reproducibility calculated from the different measurements carried out and obtained after improvements of the methods lies between 2.7 %. and 3.2 % (abs.) for full load efficiency (instead of 4.5 % before). This result is however satisfactory taking into account the fact that new uncertainty sources have been identified, and further improvements are still possible for the achievement of the initial objective. The strict application of stability criteria can lead to reproducibility value below 2.5 %.

But maybe the most important result of the project is that laboratories have decided to continue to co-operate in the future in order to improve the measurement of efficiency on boilers further.

3. Administration of the project

3.1 Partners

CO-ordinate/Contractor:
Danish Gas Technology Centre A/S (DGC), Denmark.

Contractors:
GASTEC NV, The Netherlands
Centre Technique des Industries Aerauliques et Thermiques (CETIAT), France.

Sub-contractors:
Dansk Teknologisk Institut (DTI), Denmark
British Gas plc, United Kingdom
ARGB, Belgium.

Other partners for the intercomparison:
TUV Rheinland (Germany)
Liege University (Belgium)
TNO (The Netherlands)
Italgas (Italy)
Gaz de France.

Other partners for the specific task in WPCs:
Gasunie (The Netherlands)
Grundfos (Denmark).

Other partners invited in meeting(s):
Caradon Ideal LTH (UK) Manufacturer representative
De Dietrich Thermique (France) Manufacturer representative
Hepworth Heating LTD (UK) Manufacturer representative
Repsol Butano (Spain).

3.2 Organisation

DGC was the co-ordinator of the project. The work programme consisted of eight work packages. The responsibility for and the participation in the work packages were as follows:

Work Package	Responsible	Participant
WP 1 Stability criteria	DGC	
WP 2 Influence of ambient conditions	GASTEC	DTI
WP 3 Uncertainty calculation	CETIAT	GASTEC
WP 4 Heat contribution of the pump	DGC	GASTEC, CETIAT
WP 5 Harmonisation of formulae	GASTEC	BRITISH GAS
WP 6 Influence of the calorific value	CETIAT	DGC, GASTEC
WP 7 Good laboratory practise	DGC	CETIAT, DTI, ARGB
WP 8 Intercomparison	DGC	CETIAT, GASTEC, plus up to 9 additional participants.

3.3 Time schedule

Starting date: 1 January 1993
Duration: 38 months.

4. Results obtained in each package

In order to achieve the objectives of the project the partners have jointly and severally undertaken the tasks of the work packages (WP).

The task description (from the contract) as well as the obtained results in each package are given in the following.

4.1 WP 1 stability criteria (months 1-6)

Contract specifications:
The objective of WP 1 is the development and validation of criteria which can be applied in boiler testing procedures in order to ensure that the boiler has reached thermal equilibrium prior to the testing of its efficiency. To that end DGC shall

- investigate experimentally the thermal behaviour of boilers and draw up suitable stability criteria and procedures to be followed in order to ensure that the boilers have reached thermal equilibrium
- validate the criteria and procedures developed on three types of boilers (cast iron boilers, wall-hung boilers, boilers with integrated tank)
- write a report on the tests carried out and the results of the experiments. The procedure on how to check that boilers during test have reached thermal equilibrium shall be given as well as the relevant criteria.

Results obtained:
Criteria have been developed based on the simple measurement of efficiency over periods of time of fixed length. The stability is determined by comparing the results obtained over four successive periods of time.

Two types of statistic calculations are carried out:

- the standard deviation of the obtained results
- the amplitude of variation of the obtained results (Max - Min).

The criteria have been based on the two parameters and the experiences carried out seem to prove that reasonable values have been found.

The method was validated with three types of boilers, and further analysis of the results obtained during the intercomparison (WP 8) have proven the validity of the method developed.

Details of the results obtained are given in the following report:

‘Full and Part Load Efficiency Measurements for Boilers’ WP 1 Stability criteria,
J. Schweitzer, DGC, August 1993.

4.2 WP 2 Influence of ambient conditions (months 1-6)

Contract specifications:

The objective of WP 2 is the development and validation of formulae which allow the efficiency measurements of boilers to be corrected for the influence of air temperature and humidity. To that end GASTEC with the support of DTI is to

- investigate theoretically the influence of ambient air temperature, humidity and pressure on the combustion process and the heat exchanges of boilers (convective and radiative energy losses, flue gas losses)

- develop correction formulae to be applied to efficiencies determined under non-standard conditions of air temperature and humidity in order to calculate the efficiency under standard conditions

- validate experimentally the correction formulae by performing experiments in a climatic room on the following four types of boilers: condensing boiler, balanced flue atmospheric boiler, open atmospheric boiler and boilers equipped with a forced air burner. The ranges to be covered by the experiments are for the temperature: 15^{o} to 25^{o}C, and for the humidity: 5 to 15 g/kg.

- improve the formulae where required

- write a report detailing the theoretical and experimental work undertaken together with the results of the measurements and the formulae to be used for the different kind of boilers.

Results obtained:

The test results obtained have led to the conclusion that the application of the corrections developed are reducing the influence of ambient condition. On the other hand, it was seen that repeatability can give variation due to other factors which are larger than the influence of ambient condition. This is especially true in the case of the condensing boiler tested.

The intercomparison has shown that the effect on efficiency for the test carried out was about 0.3 % (abs) for full load and 0.5 % for part load. However, for certain laboratories, where the temperature was quite high (26 ^{o} C or more), the correction is over 1 %. This confirms that these influences are far from being negligible considering the overall accuracy claimed by the laboratories (1 to 2 % at full load).

Details on the obtained results can be found in 'Full and Part Load Efficiency Measurements for Boilers' WP 2 Influence of ambient conditions, M. Koot, GASTEC, and O. Paulsen, DTI, August 1993.

4.3 WP 3 uncertainty calculation (months 7-11)

Contract specifications:
The objective of WP 3 is the development and validation of methods for the calculation of the uncertainties associated with the measurement of efficiency and standby losses. To that end CETIAT and GASTEC shall

- collect and investigate methods of uncertainty calculation in the fields which are avail able

- develop draft methods and procedures theoretically for the calculation of uncertainties associated with the measurements of
  - full load efficiency
  - part load efficiency
  - pilot flame efficiency
  - standby losses

  In each case, all relevant individual error contributions to the global error shall be taken into account and the methods and procedures for their evaluation shall be developed.

- circulate the draft to at least three laboratories in order for them to comment upon the methods and procedures proposed and to determine their viability

- improve and finalise the draft in the light of the comments received

- write a report describing the final methods and procedures and how they were derived. The report shall contain a complete set of examples.

Results obtained:
A document has been established including:

- the definitions of the statistical tools used for uncertainty calculations: variance, standard deviation, etc.
- the description of the method of uncertainty calculation (based on the knowledge of the variance of each elementary measurement which are combined together to give the overall variance)
- the adaptation of the method to the different test rigs used in European laboratories
- the list of error sources for each kind of measurement (guideline for laboratories which can investigate and determine their own figures of error sources)
- examples of uncertainty calculation.

The document was also adapted for an alternative part load measurement method, the so-called Indirect Method, recently implemented in CEN standards. The details of the method of calculation are given in the documents: 'Full and Part Load Efficiency Measurements for Boilers' WP 3 Practical guide for uncertainty calculations of full and part load efficiencies, Part one: Direct method and Part two: Indirect method, P. Claudel, CETIAT, and B. van Dongen, GASTEC, November 1993.

4.4 WP 4 Heat contribution of the pump (months 12-18)

Contract specifications:
The objective of WP 4 is the development and validation of test methods which enable the heat contribution of the pump to the boiler efficiency to be determined. To that end DGC and GASTEC shall

- develop the methods by, interalia,

- design and build a test rig in DGC's laboratory for dismounted pumps and pumps mounted on the boiler

- investigate parameters which may influence the heat contribution of the pump, such as the rotational speed of the pump, etc.

- evaluate the repeatability of the measurement using one typical pump

- validate the methods for both integrated and dismounted pumps in the laboratories of all three contractors by performing measurements using 10 typical pumps

- write a report on the work undertaken in WP 4 including:
  - the detailed description of the test rig developed, the investigations and experiments performed and their results and the value of repeatability obtained
  - the description of the validation of the methods
  - the description of the new calculation method.

Results obtained:
It has been demonstrated that the heat contribution of a pump to the water could be calculated from its heat losses by convection and radiation in the environment where it is installed.

The determining factors for the heat contribution are the water temperature and the ambient temperature (surrounding the pump).

From results obtained on pump testing, it is possible with a high accuracy to calculate the parameters which allow the prediction of the heat contribution of the pump (to water) in any situation.

A universal model based on average values of parameters measured on 10 pumps gives reasonable results regarding accuracy. By using this model, costly test of pumps during boiler type testing could be avoided.

Details are found in the report ‘Full and Part Load Efficiency Measurements for Boilers’ WP 4 Heat contribution of the pump, J Schweitzer, DGC, November 1994.

4.5 WP 5 Harmonisation of formulae (months 1-6)

Contract specifications:
The objective of WP 5 is the development of harmonised formulae for the calculation of the density of water, the enthalpy of water and of the flue gas. To that end GASTEC with the support of BRITISH GAS shall

- collect the formulae from all partners and participants in the project. The formulae are currently used by the partners and participants for the calculation of the density of water, the enthalpy of water and the enthalpy of flue gas

- calculate the above quantities for each formula and compare the results by means of graphs and tables for the following ranges:
  - water temperature: 0^o - 100^oC in steps of 5^oC
  - flue gas temperature: 0^o - 400^oC in steps of 10^oC

- establish a harmonised formula together with a justification and calculate the differences between the harmonised and each of the old formulae

- write a report giving all essential information.

Results obtained:
For water, values below 10^oC and above 90^oC have not been included because they are not relevant to the test work. When considering flue gas enthalpy, only the major constituents - CO_2, N_2, O_2 and H_2O - need to be considered.

Participants were asked to submit formulae - together with the relevant units and measurement conditions - for these parameters. Some submitted methods for calculating flue loss and other formulae relating to the specific heat of water.

From the data received, harmonised formulae were proposed.

See details in the report ‘Full and Part Load Efficiency Measurements for Boilers’ WP 5 Harmonisation of formulae, L.W. Eastell, British Gas, December 1994.

4.6 WP 6 Influence of the Calorific Value (months 16-20)

Contract specifications:
The objective of WP 6 is the development of a formula which allows the efficiency measurements of boilers to be corrected for the influence of the calorific value of the flue gas. To that end, CETIAT, DGC and GASTEC shall

- collect from the laboratories concerned the results of preliminary tests which they have already carried out and from all participating laboratories information on the characteristics of the gases which are currently being used in boiler efficiency tests

- collect from all participating laboratories information on the characteristics of gases cur rently being used in boiler efficiency tests which are required to calculate their calorific values

- calculate the calorific values of the above gases and determine the range to be investigated

- prepare gases of different composition to cover the range of the calorific value to be investigated

- develop the correction formula

- write a report detailing the results of the survey, of the theoretical and experimental work undertaken together with the results of the measurements and the proposed correction formula together with a description of how it was derived.

Results obtained:
In the study, two approaches to the possible influence of the calorific value on boiler efficiency were made.

The first one consisting of theoretical calculation including the flow rate of combustion products, the flame temperature and their influence on the process of heat exchange led to the conclusion that no measurable influence shall be expected.

The second part consists in a practical approach where tests of a suitable number of boilers supplied with gases with different calorific values are carried out.

Tests have been carried out at two laboratories (GASTEC and CETIAT) with as well G25 and G20 and with different types of boilers. The results obtained compare very well and confirm the results obtained by theoretical calculation.

See details on the project results in report 'Full and Part Load Efficiency Measurements for Boilers' WP 6 Influence of the calorific value on boiler efficiency, P. Claudel, CETIAT, and M. Koot, GASTEC, April 1994.

4.7 WP 7 Good Laboratory Practise (months 16-20)

Contract specifications:
The objective of WP 7 is the development of a document on improved Good Laboratory Practise. To that end DGC and CETIAT with the support of DTI and ARGB shall

- collect from the participants the procedures for boiler efficiency testing which they currently apply

- investigate further the results of the previous BCR intercomparison in the field and identify weaknesses in the currently applied procedures

- based upon the results of the investigation and on the results of WPs 1-6 of this project, develop improved or new procedures to solve the problems identified

- draft a document on Good Laboratory Practise

- experimentally apply the Good Laboratory Practise and improve and finalise the draft in the light of the results.

Results obtained:
The method developed on the basis of the above indicated points have been tested in real condition of testing and improved.

During the intercomparison test further control of the method has been carried out. The general opinion of laboratories about the use of the GLP is very positive. However, new improvement directions were found during this last phase:

- The application of the method is not always simple or comprehensive enough, especially concerning the correction of ambient conditions, which have led to different interpretations. The translation of the method in a “standard” is necessary to avoid any confusion or misunderstanding of the method. A simple computer program can also be developed in order to facilitate the introduction to the use of the method. The fist action will be carried out in the coming months and the second action shall be discussed before possible further development.

- The practical calculation of the uncertainties has demonstrated that the method is clear and quite easy to use. However, misinterpretations are still possible. It would be necessary to detail the determination of the individual uncertainties much more.

See details on the project results in report ‘Full and Part Load Efficiency Measurements for Boilers’ WP 7 Good Laboratory Practise, J. Schweitzer, DGC, November 1994.

4.8 WP 8 intercomparison (months 21-36)

Contract specifications:
The objectives of WP 8 is the determination of the reproducibility of efficiency measurements between European laboratories involved in boiler efficiency measurements when applying the procedures developed in this project and the demonstration that it has been reduced to no more than 2.5%. With the assistance of the partners DGC shall therefore organise participation in an intercomparison of boiler efficiency testing for up to 12 laboratories within the Member States of the European Community. This shall include

- the preparation of detailed intercomparison guidelines

- the construction of a boiler suitable to be used as travelling standard

- the performance of a comprehensive initial acceptance testing of the boiler and the

performance of measurements in accordance with the agreed guidelines at the beginning and at the end of the intercomparison

- the collation and analysis of the intercomparison results of all participants and the preparation of a synthesis report.

Results obtained:
The reproducibility obtained after improvements of the methods lies between 2.7 %. and 3.2 % (abs.) for full load efficiency. This result is however satisfactory taking into account the fact that new uncertainty sources have been identified, and further improvement are still possible for the achievement of the initial objective. This also consists of a clear improvement of the previous state of the art (4.5 %).

The different phases described have been carried out. The result of 2.5 % has not been reached. The reproducibility measured lies between 2.7 % and 3,2 %, which is however satisfactory, considering that the strict application of stability criteria clearly improves the above results.

The analysis of the test results indicates directions to improve the reproducibility further and the laboratories have decided to join their forces for that purpose.

It shall be mentioned that a heavy lime deposit on the internal surface of the heat exchanger during the test was the reason for some troubles in the intercomparison.

As a result, experimental results had to be corrected (the “lime effect “ was measured and the results could so be corrected).

The laboratories have however decided to organise (after finalisation of this contract) a new test in order to get a more accurate figure especially at part load.

See details on the project results in report ‘Full and Part Load Efficiency Measurements for Boilers’ WP 8 Intercomparison Test of an Atmospheric Gas Boiler, J. Schweitzer, DGC, February 1996.

5. New direction for future improvements in measurement

5.1 Introduction

After a first round robin test (or intercomparison), organised in 1990-1991 [13] the causes creating bad reproducibility were classified as follows:

1. The methodology description in the test standard was insufficient.

2. The method of the test standard was not detailed enough in order to get a sufficient reproducibility.

3. The procedures used (test procedures, internal quality assurance: calibration, etc.) were not equivalent or satisfactory.

4. Some significant factors were not taken into account in the results (e.g. influence of ambient temperature on test results etc.).

The points 1, 2 and 4 have been improved very much during the project.

5.2 Origin of residual uncertainties

An exercise on the values obtained in the intercomparison had consisted in checking if the difference measured between the laboratory is systematic or not. The individual values of efficiency have been compared to the average value obtained.

It appears that in the large majority of the cases the differences obtained are systematic: when a laboratory has higher value for one test, this will also be true for the other tests.

The repeatability (calculated on the basis of the results of the intercomparison test) is giving a certain idea of the influence of **random errors**. The **systematic errors** are not taken into account in the repeatability.

Considering the good experimental value obtained of repeatability and that the overall accuracy of measurement is due to both systematic and random errors it can also be said that the main influence is probably systematic errors (permanent drift on meters, etc.).

5.3 Is accuracy given by laboratory realistic ?

It also appears that when carrying the calculation of uncertainty laboratories are too optimistic and do not take into account all error sources: the uncertainty given lies between 1.0 and 2 % and in some cases it seems underestimated because the values given is in contradiction with the differences measured between laboratories.

This means that at least some laboratories are too optimistic. At full load a common uncertainty of +/- 1.5 % would be able to explain the difference measured .

5.4 Residual uncertainty: the sources

In the following, the differences obtained between the laboratories are examined and explanations are given on the reasons, which cause that the results differ from one laboratory to another.

5.4.1 Reproducibility of the boiler performances

The constancy of boiler performances is certainly one of the points which will contribute in the random error measured.

Another point, which would be interesting to look at, is the variation on boiler performances due to fabrication tolerances.

5.4.2 Instruments

Measurement instruments each have their own accuracy which is not always known depending on whether the instrument manufacturers have or have not given information. When the information is given, it can happen that it is not always reliable. Sometimes it is possible to get information on measurement appliances from specific research results aiming at investigating the appliance characteristics. Some independent certification test results are also sometimes available. Most of the time the laboratories also have some opinion based on instrument performance. This opinion is generally based on the experience by using the instrument (e.g. drift between two calibrations, etc.).

An important piece of work has been done by all partners to investigate the accuracy of each individual measurement, taking into account the different uncertainty sources (calibration, corrections, drift, resolution, etc.). But the estimation of the different error sources is made on the basis of either existing data (e.g. measurement of drift with temperature, etc.) or approximation / estimation. In this last case, a future exchange of information between the partners would be profitable to get more accurate figures.

As the errors are mostly systematic, it could be expected that there is drift on instruments. However, when considering the information given by the different laboratories, drift is in some of the cases very low. This can be due to the fact that laboratories underestimate drift or other systematic errors.

Among the known weak points are the water and gas flow meter.

5.4.3 Calibrations

The calibration procedures are part of the quality system which is set up individually by each of the laboratories. There might be some differences between the laboratories due to that fact only.

It can be seen from the description given by all partners that the frequency of calibration for flow meters is e.g. rather different and can be more than 4 years for some partners.

The analysis of the results given shows that in general the drift between two calibrators is not always given (not known ?) When it is given it appears to be an important source of uncertainty.

In general there would be a need to harmonize some parts of the quality systems used throughout Europe.

5.4.4 Test Procedures

The test procedures have been subject to improvements, and the procedure developed has been implemented in the GLP document used by all the partners for the test of the boiler of

the intercomparison. Further improvement might still be possible especially when laboratories

have investigated their own accuracy and detected the weak points.

5.5 Conclusion

The following conclusion could be given from the research carried out:

* Gas wobbe index has no influence on efficiency.
* Ambient temperature and pressure generally lead as an average to 0.3 to 0.5 % corrections on efficiency respectively at full load and part load.
* Uncertainty can strongly be reduced thanks to stability criteria.
* The GLP document also includes several requirements, which helps to obtain a better accuracy and reproducibility:
  - a harmonized method of calculation of efficiency.
  - a detailed calculation method for the determination of accuracy.

Many participants recognize the benefits of the discussions we have had several times on specific measurement problems and the fact that the meetings constituted are a very good platform for technical information exchange between testing laboratories. Therefore, it could be an advantage to maintain regular contact between laboratories on measurement issues to exchange information and improve the accuracy further.

6. ORGANIZATION FOR FURTHER IMPROVEMENTS

6.1 Network of laboratories

The laboratories have seen the possibility to improve the measurement accuracy further and have decided on a free basis to create a network/group of partners where measurements problems shall be discussed and where the experience with different problems shall be shared.

The main features of this network would be the following:

- Mutual information on laboratory measurements questions.
- Permanent updating of GLP document (also taking into account new procedures for part load testing).

- Organisation of further reference boiler test.
- Specific task, (e.g. practical determination of individual uncertainty source or uncertainties when testing condensing boilers).

In order to have effective work, the scope has been defined as “Testing Related to Efficiency Directive” and therefore only boilers are considered. However, items like emissions, or possibly results obtained on other appliances (when relevant) could be discussed in the group as well as information on other ongoing projects will be given.

Laboratories performing tests on domestic boilers are mainly concerned by the network. The partners of this “BCR” project on efficiency will all be invited. It is however necessary to restrict the number of participants in order to have efficient work in the group. Therefore only “external” participants, who would have some active participation and real contribution to the group, will be invited.

The meeting frequency would be about one two-day meeting per year depending on the items to be discussed.

6.2 Intercomparison: Other interested parts

Several laboratories have expressed their interest in participating in a future intercomparison. Those are:

a) Repsol Butano.
b) Manufacturers (AFECI).
c) Other laboratories, which are CSTC (Belgium)
INTEGRA (Italy)
IKE, Stuttgart (Germany)
CTIF (France).

In addition a letter to notified bodies (GADAC) has been sent to inform of the possibility that a new intercomparison could be organised.

6.3 Supplementary intercomparison test

In order to confirm the result presently obtained a new intercomparison test will be initiated in March 1996.

DGC will prepare the necessary documents and will collect the results during the test.

Only 2 tests (one full and one part load) will have to be carried out.

6.4 Reference boiler

The reference boiler was proposed as a way to control the measurement of the laboratories in the future. Comparing with the intercomparison test for this boiler, the results are known by the laboratories and used for the control purpose.

The boiler used in the first intercomparison test has been chosen as the reference boiler. CETIAT shall be in charge of the annual check of the boiler as well as the administration of the boiler circulation. It was suggested that after the new intercomparison, the laboratories will regularly test the reference boiler at a frequency to be determined. Other laboratories/manufacturers shall also be allowed to use the boiler at a cost to be determined. The participants shall have a priority on the test and shall pay a fee corresponding to CETIAT costs for the maintenance administration.

7. Future use of the results. Conferences. Paper.

The following actions have been undertaken in order to make the results of the above project available to CEN, and additionally in order to implement the obtained results in future test procedures of laboratories.

7.1 Implementation of the results

Fejl! Ukendt argument for parameter.. At the beginning of the project, the most relevant technical committees were informed,

namely: TC57 fuel oil boilers and TC 109 gas-fired boilers, of the technical content of the project.

Fejl! Ukendt argument for parameter.. Two liaison persons in charge of the information exchange between the two CEN committees and the project participants were appointed and have regularly informed the committees of the progress of the project.

Fejl! Ukendt argument for parameter.. A synthesis of the results of the research has been implemented in a 'Good Laboratory Practice' document which has been written to as high a degree as possible in a format used by CEN. In addition to this, the proposed new testing procedures have been tested by laboratories performing the intercomparison, and each of the laboratories was asked to answer a questionnaire to evaluate the opinions of the laboratories regarding integration of the new testing procedures in type testing procedures.

Fejl! Ukendt argument for parameter.. At the completion of the project, a detailed presentation of all the obtained results together with the main partners of the project will be proposed to each TC.

7.2 Future use of the GLP document

Some results have already been implemented in a CEN document (see annex) without any preliminary agreement with CEN !

It will be the responsibility of each participant to distribute the GLP to the national organisations, which could have an interest for the document. These are:

- Notified bodies
- Standardisation committees
- Accreditation organisations
- Manufacturers
- Etc.

Also, at the European level the co-ordinator will contact the European associations and organisations as CEN, GADAC, AFECI, UEC, etc.

It will be proposed to the CEN committees (boiler only) that we organise a presentation (1 or 2 hours) on the results obtained in the project and especially on the GLP. For that purpose the partners involved in the different packages will be asked about their contribution (2 or 3 per-

sons each time). CEN 109 and CEN 57 are the two committees, who are mostly concerned and who will be contacted.

7.3 Conferences

The results of the project have been presented at the BCR Conference in Brussels in December 1994, where a poster on the project was presented among all other BCR projects.

For the next IGU (International Gas Union) conference a paper has been proposed. The paper has in principle been accepted. Finally, at a conference on measurements in Norway in 1996 it has also been planned to present of the results.

8. CONCLUSION

The **reproducibility** at full load lies between 2.7 and 3.2 %. The application of the stability criteria and other new procedures shows that there is an improvement of reproducibility. Furthermore, it is possible to improve the figure obtained further.

The main errors are systematic. Once identified it is certainly possible to reduce those errors further (e.g. drift on meter by more frequent calibrations).

Some procedures from the GLP document should be more clearly described in order to avoid some interpretation problems, which could occur with the present version.

A harmonization of the calibration procedures (including the frequency) at EU level would be useful. This could also be extended to other procedures of quality control.

Having solved the problems mentioned, the next question will be: how can the reproducibility of measurements be controlled in the future ?

The possibility of repeating the test every year or every second year with a "calibrated reference boiler" has been studied. This "calibrated boiler" to be used for control of the test rigs could lead to improvement of the new procedures.

In order to check the validation of the corrections the laboratories have decided to repeat an intercomparison test.

Furthermore the laboratories have decided to continue their collaboration in order to organize the above mentioned activities and to improve the interlaboratory reproducibility further on the basis of the conclusions obtained.

ANNEX

Copy of Annex A of CEN. pr EN 677.

ANNEX

QUESTIONNAIRE ON GLP

To be returned with test report

The reason for the survey is to get an idea of which part/s of the document might need improvement to ensure a better use of the method proposed.

The questionnaire consists of a set of questions on the different parts of the method (stability, uncertainty, pump, etc.).

Finally, your opinion on the whole document would be appreciated.

QUESTIONNAIRE ON GLP

ANONYMOUS SURVEY

To be sent with test report

1 Correction of efficiency (influence of ambient temperature, etc.)

Do you think that the application of the GLP document is

- ☐ easy
- ☐ not very difficult
- ☐ difficult
- ☐ very difficult
- ☐ no opinion yet

For type testing, do you think that the procedures shall be kept

- ☐ optional
- ☐ mandatory
- ☐ no opinion yet

Do you think that the procedures of the GLP document are

- ☐ too expensive to incorporate (investment)
- ☐ too expensive to use (for type testing)
- ☐ a reasonable investment
- ☐ reasonable in use costwise
- ☐ no opinion yet

Do you think that the global testing time with the new procedures will be

- ☐ shorter (e.g. no need to check test, higher reliability, instability etc.)
- ☐ same duration or similar
- ☐ longer
- ☐ no opinion yet

2 Stability criteria
3 Uncertainty calculation
4 Pump correction
5 Use of harmonised formula
6 Other procedures of the GLP document