

SAFE HANDLING OF RENEWABLE FUELS AND FUEL MIXTURES

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Contract JOR3-CT95-0032

PUBLISHABLE FINAL REPORT

January 1996 - February 1998

Research funded in part by
THE EUROPEAN COMMISSION
in the framework of the
Non Nuclear Energy Program
JOULE III

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ABSTRACT

The overall objective of this research project, funded by EC under the Joule 3 Programme, was to create new data on safety-technical characteristics of renewable fuels, wastes, low-rank coals and mixtures of these. The safety aspects of fuel storage, handling and feeding are an important issue in the development of new energy production technologies like pressurised IGCC and PFBC power production systems. Knowledge of basic handling and safety-technical characteristics of fuels and fuel mixtures is of crucial significance for the design of handling and feeding equipment, and safety systems, and for the assessment of explosion and fire hazards.

This report presents the results of a two-year study (1996 - 1997) on the spontaneous ignition behaviour and the explosibility of twelve selected fuels samples. Four woody and four herbaceous biomasses were selected together with two low-grade lignites and two biomass/lignite mixtures for this study. Thermogravimetical analyses at ambient and elevated pressure were performed to classify the fuels according to their propensity to spontaneous heating. Several safety-technical properties of the selected fuels were determined with respect to their behaviour on hot surfaces and as dust clouds. Self-ignition tests at pressures of 1 and 25 bar were carried out with several sample sizes, which facilitate the extrapolation of the self-ignition behaviour of a particular fuel to real size storage bins. Dust explosion testing was performed at initial pressures of up to 15 bar and temperatures of 150 °C to simulate pressurised drying and handling of the biomass fuels. Inerting tests with nitrogen and flue gases were carried out to determine the requirements of non-explosive conditions. Suppression tests were also performed to assess the usability of this explosion protection method for biomass fuels in elevated conditions. The results show that elevated pressure increases the tendency to spontaneous ignition of biofuels. The required safe oxygen level is much lower than the level of preventing dust explosions. Very high explosion pressures and rates of pressure rise are measured at elevated initial pressures. The required level of inertisation of dust explosions is dependent on the initial pressure and temperature. These parameters also affect the suppression of the dust explosions, making a successful suppression more demanding. The use of partly inert atmosphere led to an increasing efficiency of the explosion suppression system.

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1 OBJECTIVES

The overall objective of this research project was to create new data on safety-technical characteristics of renewable fuels, wastes, low-rank coals and mixtures of these. The safety aspects of fuel storage, handling and feeding are an important issue in the development of new energy production technologies like pressurised IGCC and PFBC power production systems. Knowledge of basic handling and safety-technical characteristics of fuels and fuel mixtures is of crucial significance to the design of handling and feeding equipment, and safety systems, and to the assessment of explosion and fire hazards.

The technical objectives of the study are:

- to characterise selected fuels and fuel mixtures by physical and chemical analyses with regard to their safety-technical characters
- to study the spontaneous ignition behaviour of these fuels and fuel mixtures and to assess the necessary preventive actions in various ambient conditions
- to determine the explosion characteristics of the most critical dusts and dust mixtures in both atmospheric conditions and at elevated pressure and temperature, being essential for the design of protective devices
- to experimentally verify explosion-prevention concepts in both ambient and elevated conditions (inertisation, suppression)
- to create a criterion based on simple analyses to assess the reactivity of the fuels with regard to their safety-technical properties.

2 TECHNICAL DESCRIPTION, RESULTS AND CONCLUSIONS

2.1 Fuels and fuel mixtures studied

Ten fuel samples and two fuel mixtures were included in the work programme. The selected samples were divided into four main groups:

Wood fuels and wood wastes: Wood dust, bark, forest residue and Spanish pine.

Agricultural residues and energy crops: Barley straw, rapeseed straw, Miscanthus and Sorghum.

Low-rank coals: German lignite and Spanish lignite.

Fuel mixtures: Mixture of wood dust and German lignite; mixture of barley straw and Spanish lignite

All fuel batches, ranging from 50 to 1 800 kg/sample, were dried and milled to a particle size below 0.2 mm to obtain reasonably homogenous samples for testing. Chemical characterisation included proximate and ultimate analyses. Extensive physical characterisation was performed by all partners, including particle size distribution, density, thermal and electrical conductivity and ignition properties.

2.2 Physical and chemical characterisation

The particle size and moisture content were the two primary properties requiring a lot of pretreatment of the samples to fit into the desired limits mentioned above. The particle size distribution was determined by normal sieving procedure by VTT, LOM, TNO and DMT, by INERIS using Malvern 2600 C laser system following the French standard NF X 11-666 and by VTT using a dry Laser beam based method. Comparison between the results of the different laboratories shows in general an acceptable deviation in mechanical sieving, considering the inhomogeneous nature of the biomasses. The Malvern and Laser beam method did, however, produce smaller D_{50} values for the fibrous biomass fuel samples. It should be noted that the form of the particles can influence the results obtained by the laser technique, especially if they are not spherical. A scanning electron microscope was used to take pictures of the various samples. It could be seen that the woody samples are very fibrous with clusters of very small particles. The agricultural dusts were somewhat fibrous whereas the lignites were more granular.

The bulk density of wood dust, barley straw and rapeseed straw dusts ranged 120-190 kg/m^3 . The other wood fuels were heavier, as were also the straws of Miscanthus and Sorghum, which have a more woody-like stem than the normal cereals. The range of bulk density of these fuels was 214-350 kg/m^3 . The bulk density of the low-grade coals and the mixtures was significantly higher, 320-677 kg/m^3 .

The compatibility of the biomasses was quite significant compared to that of coals. Light and compatible biomass fuels flow very poorly, and hence hamper the feed of the fuels into combustion and gasification reactors. The difficulties are significantly greater if a pressurised process is concerned. Tractable biomass is compacted in the course of time due to its own weight. Hence the fuels can form very stable bridging in feed bins and intermediate storage.

The chemical analyses included normal fuel properties, proximate and ultimate analyses. In addition, thermal and electrical conductivity were determined for all fuel samples.

2.3 Ignition properties

Several safety-technical properties of the selected fuels with respect to their behaviour on hot surfaces and as dust clouds were determined. The ignition sensibility of a substance can be evaluated through the determination of the following parameters:

- Minimum ignition temperature: this is the lowest temperature at which the ignition of a sample will occur. The test may be conducted using a sample in the form of a cloud (MIT_c) or a layer (MIT_l).
- Minimum ignition energy (MIE): lowest energy stored in a capacitor which upon discharge is sufficient to produce ignition of the most easily ignitable dust mixture with air under specified tests conditions.

The minimum ignition energy is used to assess the risk of ignition by various types of electrostatic discharges. For the assessment of mechanical sparks the minimum ignition temperature of the dust cloud must be known as well. The minimum ignition energy depends strongly on the initial temperature: increasing the temperature causes the minimum ignition energy to decrease. Dust properties (particle size, moisture content, etc.) can also influence the minimum ignition energy markedly. The minimum ignition energy of the

woody dusts were between 30 and 1000 mJ, of the same range as those of the lignites and the mixtures. The agricultural straws exhibited a considerably higher ignition energy of over 1000 mJ. The ignition temperature of a hot surface was for all fuel samples between 230-340 °C and the corresponding temperature of a dust cloud 400-460 °C.

2.4 Reactivity of fuel samples

The reactivity of the combustible dusts was characterised by thermal analysis using Differential Thermal Analysis (DTA) coupled with a Thermo-Gravimetric Analysis (TGA). The objective of this task was to rank the fuel samples according to their tendency to self-ignition. The tests at ambient pressure were carried out by INERIS and analyses at elevated pressure by VTT.

Based on the thermal runaway temperatures of the dusts the samples are listed by order of reactivity (by oxidation) in Figure 1. The results shown in this figure are a reactivity classification by INERIS at ambient pressure. Classification of the dust samples indicates that the low-grade coals are clearly more reactive than the biomass samples. The mixtures also show a higher reactivity than the pure biomass fuels. Increasing the pressure leads to a higher oxygen partial pressure, increasing the aggressiveness of the oxidation. This results in a higher reactivity of the sample at elevated pressures.

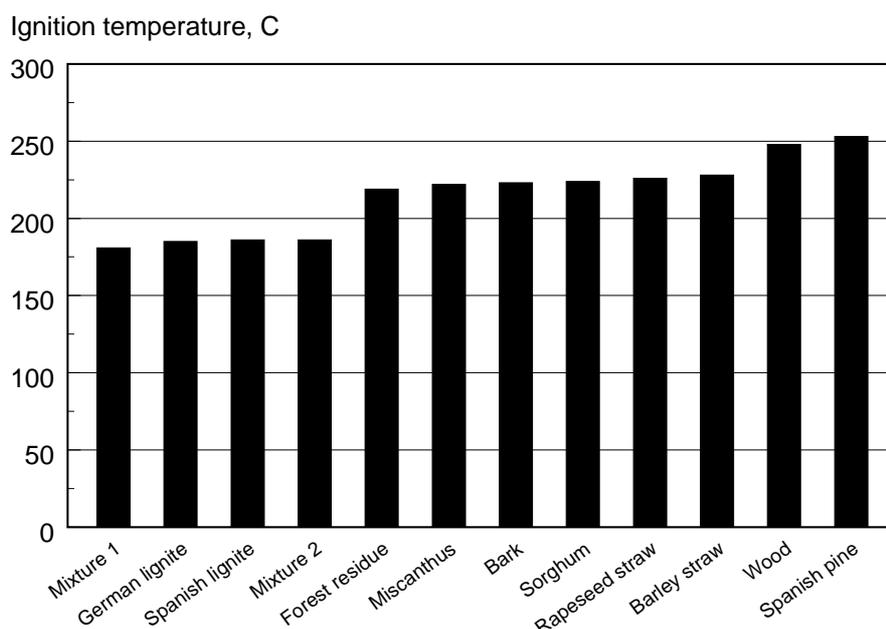


Figure 1. Reactivity classification DTA-TGA (INERIS).

2.5 Self-ignition tests

Low-temperature reactions of organic substances with atmospheric oxygen lead to self-heating. It is well-known that the self-ignition temperature of a dust deposit is a function of the size of the deposit; i.e., the self-ignition temperature falls when the size of the deposit (or storage volume) increases. Spontaneous ignition is usually studied for at least three samples of different volumes to be able to extrapolate the results for larger amounts. Employing a model for thermal explosions developed by Frank-Kamenetskii's, the self-

ignition temperature can be extrapolated to larger volumes all the way up to the industrial scale.

Self-ignition properties of the fuels were studied at normal and elevated pressure by VTT and INERIS. The extrapolated curves of the self-ignition temperature as a function of the critical diameter for three fuel samples are shown in Figure 2 at atmospheric and elevated (25 bar) pressure. The following conclusions were drawn from the study:

- The results of the self-ignition tests for the fuel samples are mainly in line with the reactivity tests carried out on DTA-TGA. The lignites are the most reactive fuels both at ambient and elevated pressure. The pure wood fuels, wood and Spanish pine, were least reactive with regard to spontaneous ignition. The wood wastes, bark and forest residue are more reactive than the agricultural straw residues. The different straws showed very similar self-ignition temperatures.
- The mixtures of lignites and biomasses were in reactivity comparable to the most reactive pure lignites.
- The elevated pressure had a significant effect on the self-ignition temperature of all fuel samples: the self-ignition temperature of the fuel fell when the pressure was elevated.

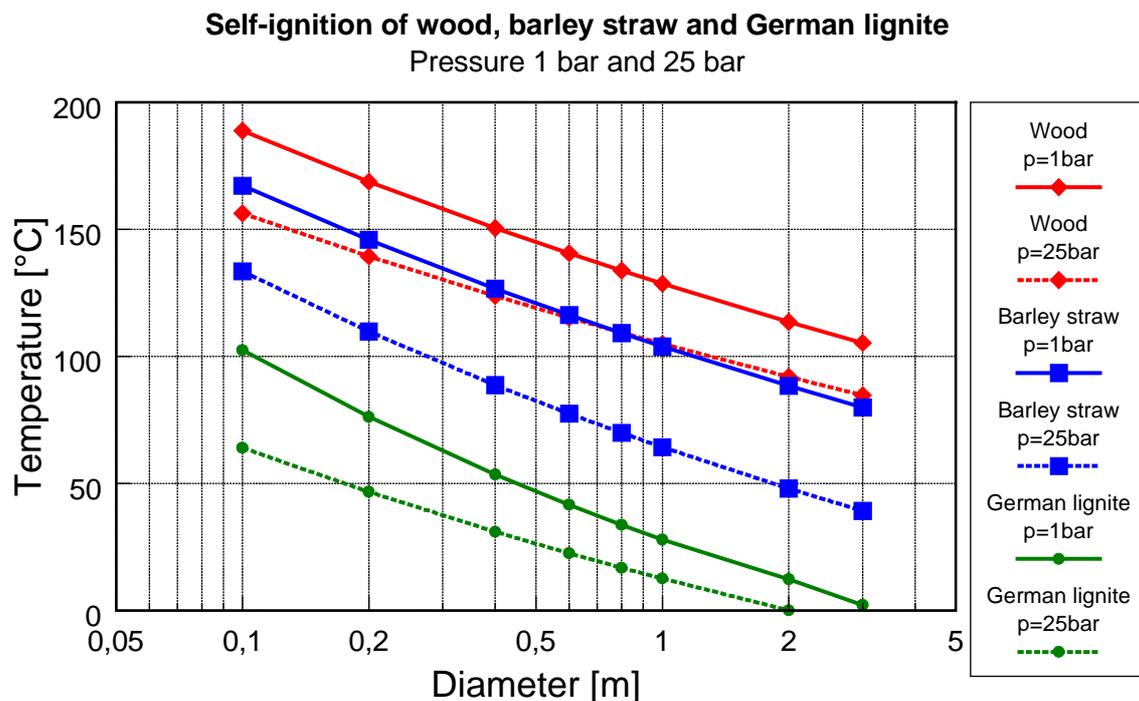


Figure 2. Self-ignition of three fuel samples in ambient and elevated pressure..

- Partial inerting, i.e., decreasing the oxygen concentration of the ambient air atmosphere, increased the self-ignition temperature, but to a rather low degree. To establish significantly safer conditions in fuel storage, an inert atmosphere with an oxygen content well below 7% is obviously required.

The time needed for self-ignition, the so-called induction time, was estimated for two fuel samples, wood and German lignite, at 25 bar pressure. The ignition time was calculated based on the fact that the heat transferring from the surroundings to the middle of the fuel bin requires a certain time. The calculations give only a very rough estimate of the induc-

tion time. For a storage bin with a 2 meter diameter induction times of appr. 25 days for the wood fuel and 60 days for the lignite were estimated.

2.6 Dust explosion tests

The knowledge of the explosions parameters at high initial pressure and temperature is fundamental for the design of safety measures at IGCC and PFBC power plants. The objective of this task was to experimentally determine the explosion indices of the selected fuels and fuel mixtures.

The explosion tests are usually performed in ambient conditions in a 1 m³ pressure vessel according to ISO 6184/1 standard procedure, or in a smaller 20 litre laboratory sphere. At high initial pressure and for “difficult” dust it is necessary to define and develop new explosion test procedures. This task included the following development work:

- development of a dispersion nozzle that makes it possible to disperse a large amount of difficult flowing dusts
- definition of the injection procedure at elevated pressure.

The tests were carried out simultaneously in the TNO 20 litre sphere and in the LOM 1 m³ vessel. **A multifactorial experimental design was used to optimise the experimental work. Conclusions were:**

- TNO was forced to disperse the dust when it was already on the bottom of the sphere. A nozzle type was designed which directed the air flow during the injection over the bottom of the sphere.
- LOM used the conventional method of introducing the dust from an external dust container. A rebound nozzle was chosen for dispersion of the dust into the explosion vessel.

Dust explosion tests were performed by four of the partners: TNO (20 litre sphere), LOM (20 litre sphere and 1 m³ vessel), DMT (1 m³ vessel) and INERIS (1 m³ vessel). The tests were performed both in normal conditions and at elevated temperature and pressure. Dust explosion parameters, maximum explosion pressure P_{max} , rate of pressure rise described by the K_{St} value, and lower oxygen concentration LOC were determined.

Figure 3 shows that a linear correlation exists between the maximum explosion pressure and the initial pressure. The maximum explosion pressure is directly proportional to the initial pressure. The results also show a fairly good conformity considering the different tests methods. Further, the explosion pressures of all fuels fall in the same order of magnitude.

An approximately linear relation also exists for the K_{St} values. There is, however, a large discrepancy in the slope of the lines for the same fuel samples. Most differences in the measured K_{St} values can probably be associated with diverse turbulence conditions inside the explosion vessel. Various turbulence levels may be ascribed to different equipment and methods, and generally to the inhomogeneous nature of the fuel samples. The influence of turbulence on the K_{St} -value and more generally the violence of the explosion phenomenon should be further investigated, especially with regard to standardisation work.

In most cases, the lower oxygen concentration LOC slightly increased with increasing initial pressure (Figure 4). The tendency is clear for wood but for the lignites and the mixture the effect of initial pressure is more irregular. Theoretically, an increase and a decrease of LOC with increasing initial pressure is possible.

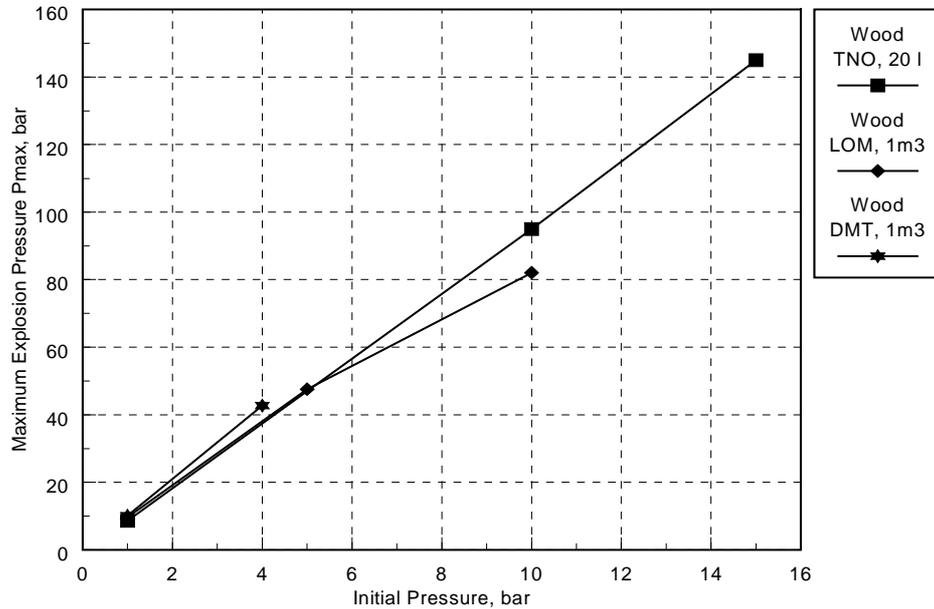


Figure 3. Maximum explosion pressure as a function of initial pressure for wood dust.

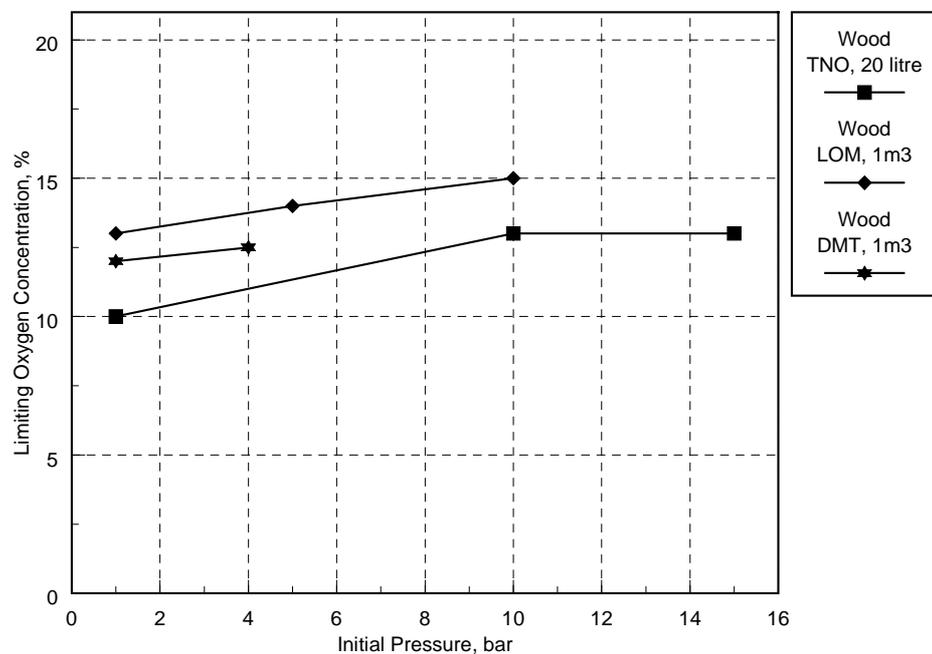


Figure 4. Lower oxygen concentration as a function of initial pressure, wood.

Most biomass gasification concepts require a dry fuel if the product gas will be utilised for power production. In many cases this means drying of the renewable fuel, and handling and feeding of the fuel at elevated temperatures. A high temperature, especially in combination

with high pressure, influences the explosion risks significantly. Due to the smaller amount of oxygen present at elevated temperatures, the maximum explosion pressure and rate of pressure rise decrease with rising initial temperature. The reduction of the explosion indices was 25 - 30% at both ambient and elevated pressure in the temperature range 20 to 150 °C.

LOC decreases with increasing initial temperature. The tests with wood and lignite dusts showed a clear decrease of the lower oxygen concentration at increasing initial temperature. For both powders tested this decrease was more or less the same, ca. 1-3 vol% for 100 °C temperature rise, Figure 5.

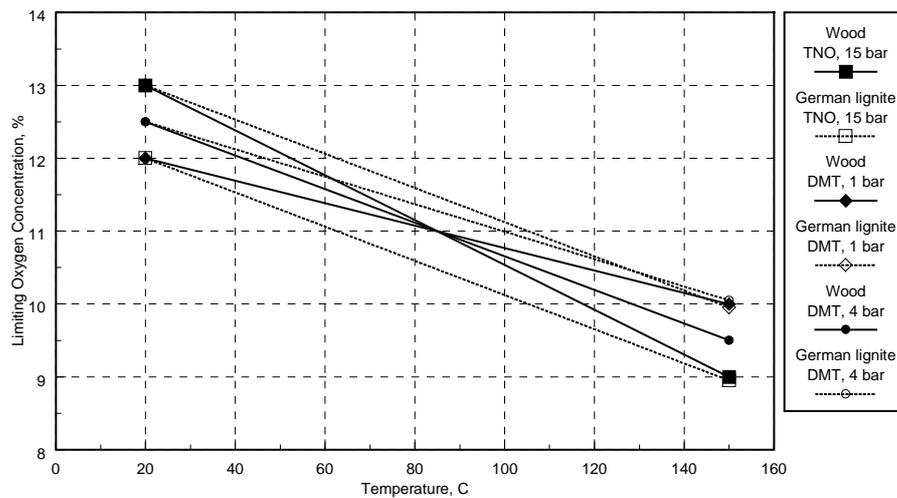


Figure 5. Lower oxygen concentration as a function of temperature, wood and German lignite.

2.7 Predictive criterion

The objective was to create a predictive criterion based on simple tests and analyses for evaluating the reactivity of the fuels and fuel mixtures with regard to their safety technical characteristics. Statistical treatment of the results was used to obtain some representative relations between some physical parameters that are accepted as indicators of the fuel reactivity and the chemical analyses of the fuels. The construction of these relations is aimed at the prediction of the theoretical reactivity of a determined fuel as a function of its chemical composition.

The ignition temperature of the fuel samples in the DTA-TGA tests was selected as a reference for the reactivity. Some significant multiple regressions were obtained for the reactivity as a function of the chemical analyses. The statistical treatment of the developed data base resulted in four significant multiple regressions with a confidence level above 95 %. The calculated indicators of the reactivity are a good tool to evaluate the reactivity of a fuel based only on chemical characteristics of this fuel, being perfectly valid to differ which

group of reactivity a fuel sample belongs to. However, the low number of data existing for each test restricts the accuracy of the calculated regressions and the number of dependent variables able to enter the fitted models. The complementation of the database with a higher number of results would offer the possibility of refining the models.

2.8 Suppression of dust explosions

Suppression systems are frequently used in industry as a measure of explosion protection. After static or dynamic pressure sensors detect an explosion, the control unit activates the outlet valves of one or more containers filled with suppressant agent. The suppressant agent is injected into the vessel and the explosion is stopped at an early stage. The reduced explosion overpressure P_{red} is far below the maximum explosion overpressure.

The suppression tests were conducted by DMT in a heatable the 1 m^3 vessel. The explosion suppression system comprised a 12.3 litre HRD container filled with monoammonium phosphate (4 kg and 8 kg) and a static pressure sensor. After detecting the explosion at the activation overpressure P_A , the suppressant was blown into the 1 m^3 vessel through two nozzles with a diameter of 1 inch. The reduced explosion overpressure P_{red} was determined in respect of the activation pressure P_A at 4 bar initial pressure and temperatures of $20\text{ }^\circ\text{C}$ and $150\text{ }^\circ\text{C}$. Wood and German lignite were used as dust samples. The results for wood dust are shown in Figure 6.

Dust explosion suppression at elevated conditions should be feasible in the above described circumstances at least for German lignite. Suppression of wood dust explosion appears more demanding, requiring lower activation pressures and probably larger amounts of suppressant. Elevated temperature, typically experienced in drying processes, hampers the use of suppression system significantly making the suppression of the dust explosion more demanding (low activation pressure). Rapid cooling of the heat energy released during the early stage of explosion is of great importance, and a high initial temperature seems to affect the efficiency of the suppressant. In these conditions a combined protection system appears feasible. Mild inertisation of the surrounding atmosphere, e.g., by reducing the oxygen concentration from 21% to 17%, in combination with suppression may be a solution for dust explosions in elevated conditions.

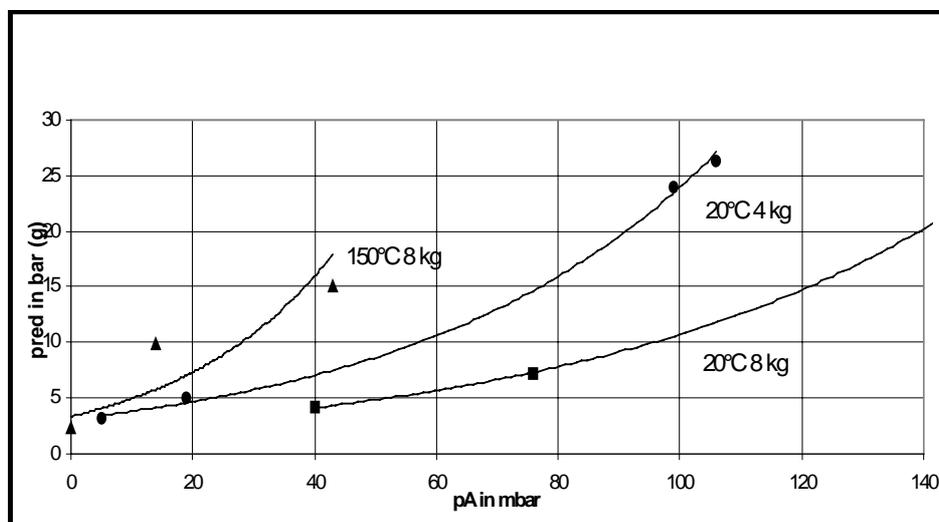


Figure 6. Explosion suppression tests with wood dust at 4 bar and 20 °C/150°C, 4 kg/8 kg monoammonium phosphate.

3 CONCLUSIONS AND RECOMMENDATIONS

Bulk density and particle size distribution are the physical properties of fuels most frequently needed for the design of feeding and handling equipment. Bulk density is dependent on particle size and should therefore be determined for a known particle size distribution. A compacted density value should be used for silos and intermediate storage bins while normal bulk density measurements are usually more adequate for the design of screws and conveying equipment. Generally low bulk densities were measured for the biomass samples involved in this study, and the compatibility of the biomasses, and the biomass/lignite mixtures, was quite significant compared to that of pure lignites.

The minimum ignition temperature of a biomass layer is between 300 and 340 °C and a little lower, 230-240 °C, for lignites. Corresponding ignition temperature of a dust cloud is higher, 400-460 °C for both biomasses and lignites. These ignition temperatures should not be confused with the self-ignition temperature of these fuels, which are considerably lower.

Thermogravimetric analysis was used to study the reactivity of the selected fuel samples. Classification of the dust samples indicates that the low-grade coals are clearly more reactive than the biomass samples. The mixtures also show a higher reactivity than the pure biomass fuels. Increasing the pressure leads to a higher oxygen partial pressure, increasing the aggressiveness of the oxidation. This results in a higher reactivity of the sample at elevated pressures. Thermoanalysis appeared to be a fast and convenient means of classifying fuels according to their reactivity. Much knowledge of fundamental fuel properties can also be extracted from these measurements. To obtain more quantitative information regarding the self-ignition behaviour of fuels by means of thermogravimetric analysis, extensive experimental work and development of the analysing methods are needed.

Low-temperature reactions of organic substances with atmospheric oxygen lead to self-heating. It is well-known that the self-ignition temperature of a dust deposit is a function of the size of the deposit; i.e., the self-ignition temperature falls when the size of the deposit (or storage volume) increases. Self-ignition can occur even in relatively thin dust layers at temperatures well below the ignition temperature on a hot surface. This must be observed, for instance, when biomass fuels are dried with hot air in low temperature bed dryers. Extended drying time and failing in removing all dust layers from the dryer might cause unexpected fires inside the dryer. These may result in violent dust explosions.

Self-ignition properties of the fuels were studied at normal and elevated pressure (1-25 bar). The results of the self-ignition tests for the fuel samples are mainly in line with the reactivity tests carried out by thermoanalysis. The lignites are the most reactive fuels both at ambient and elevated pressure. The pure wood fuels, wood and Spanish pine, were least reactive with regard to spontaneous ignition. The wood wastes, bark and forest residue are more reactive than the agricultural straw residues. The different straws showed very similar self-ignition temperatures. The mixtures of lignites and biomasses were in reactivity comparable to the most reactive pure lignites.

The elevated pressure had a significant effect on the self-ignition temperature of all fuel samples: the self-ignition temperature of the fuel fell when the pressure was elevated. Partial inerting, i.e., decreasing the oxygen concentration of the ambient air atmosphere, raised the self-ignition temperature, but to a rather low degree. To establish significantly safer conditions in fuel storage, an inert atmosphere with an oxygen content well below 7% is obviously required.

The explosion tests are usually performed in ambient conditions in a 1 m³ pressure vessel according to ISO 6184/1 standard procedure, or in a smaller 20 litre laboratory sphere. At high initial pressure and for “difficult” dust it is necessary to define and develop new explosion test procedures. The work done within this project is the first step to study the influence of dust injection methods on the severity of the explosion behaviour of biomass fuels. A multifactorial experimental design was used to optimise the experimental work. As a conclusion two different experimental approaches were adopted for the high pressure test programme. In the 20-litre sphere the dust was dispersed with a specially designed nozzle when it was already on the bottom of the sphere. Regarding the 1 m³ vessel the more conventional method of introducing the dust from an external dust container with a rebound nozzle was chosen.

Dust explosion tests were performed both in normal conditions and at elevated temperature and pressure. A linear correlation was found between the maximum explosion pressure and the initial pressure. The maximum explosion pressure is directly proportional to the initial pressure. The results also show a fairly good conformity considering the different tests methods. Further, the explosion pressures of all fuels fall in the same order of magnitude.

An approximately linear relation also exists for the rate of pressure rise, the K_{St} value. There is, however, a large discrepancy in the slope of the lines for the same fuel samples. Most differences in the measured K_{St} values can probably be associated with diverse turbulence conditions inside the explosion vessel. Various turbulence levels may be ascribed to different equipment and methods, and generally to the inhomogeneous nature of the fuel samples. With regard to development of methodology and future standardisation work in the field of explosion testing at elevated pressures the role of turbulence on the explosion indices should be investigated further. Emphasis should also be given to the development of “standard” testing for biomass fuels with a coarse and fibrous nature and low density.

In most cases, the lower oxygen concentration LOC slightly increased with increasing initial pressure. The tendency is clear for wood but for the lignites and the mixture the effect of initial pressure is more irregular. The results suggest that for most cases safe conditions can be obtained by decreasing the oxygen content of the surrounding atmosphere to a level of approximately 11-15 vol%. In practice a safety margin of 2 percentage units is usually recommended. LOC decreases, however, with increasing initial temperature. For all powders tested this decrease was more or less the same, around 2-4 vol% per 100 °C temperature rise.

The knowledge of the explosions parameters at high initial pressure and temperature is fundamental for the design of safety measures at IGCC and PFBC power plants. The dust explosion indices are essential for the design of protective measures like relief venting, inerting and explosion suppression systems. Generally very little information exists in the literature regarding explosion properties of biomass fuels and especially of explosion indices measured at elevated conditions. Therefore the knowledge created within this project

can be considered unique. Considering the typical operating pressure of IGCC gasification system of 22-25 bar, the results must be considered applicable to assessing explosion behaviour of biomass dusts at these pressures. The data created within this project facilitates a quite safe extrapolation of explosion pressures and rate of pressure rises to higher pressures. In that sense significant improvement has been achieved compared to the situation before the project. Further experimental work is, however, recommended and required to complement the current database and to develop a broader basis for the future standardisation work on explosion test methodology at elevated pressure and temperature.

On the basis of the very high explosion pressure and rate of pressure rise measured at elevated initial pressures, it is quite obvious, that designing feeding bins for total explosion containment is not feasible. Neither can relief venting be used due to the large required vent area and high reduced pressure. Inerting offers a safe alternative, but involves usually high investment and operation costs. Explosion suppression systems are frequently used in industry as a measure of explosion protection. The technology is, however, not yet commercial for pressurised systems.

Explosion suppression tests were conducted in a heatable 1 m³ vessel. The reduced explosion overpressure was determined in respect of the activation pressure at 4 bar initial pressure and temperatures of 20 °C and 150 °C. Wood and German lignite were used as dust samples. Increasing the temperature makes the suppression of the dust explosion more demanding (low activation pressure). Use of partly inert atmosphere, e.g., by reducing the oxygen concentration from 21% to 17%, led to an increased efficiency of the explosion suppression system.

The development of the explosion suppression system for high pressure applications still requires extensive experimental work. A combination of mild inert conditions with explosion suppression appears to be a feasible alternative at elevated pressures.

4 EXPLOITATION PLANS

The research within this project has produced new data on safety-technical characteristics of various biomass fuels and residues, lignites and mixtures of these. This database is the result of an extensive analyses programme and includes information on the following specific fuel properties for ten different fuels and two fuel mixtures:

- Chemical properties
- Physical properties
- Ignition properties
- Self-ignition properties
- Dust explosion properties

Generally there is very little information available in the literature regarding safety technical characteristics of renewable fuels, especially data valid for high-pressure conditions. Therefore the knowledge created within this project can be considered unique.

In addition to the technical data produced in the project significant effort has been put on the development and refining of methods and procedures for determining self-ignition properties and dust explosion indices. INERIS has built and commissioned a new pressur-

ised facility for self-ignition testing, the performance of which has been evaluated and compared to the procedures used at VTT. The first steps towards the development of high-pressure dust explosion testing and testing of “difficult” dusts have been taken in this project. New dust dispersing devices and systems have been tested as a basis for future standardisation work.

The safety aspects of fuel storage, handling and feeding are an important issue in conventional plants as well as in the development of new energy production technologies like pressurised IGCC and PFBC power production systems. Knowledge of basic handling and safety-technical characteristics of fuels and fuel mixtures is of crucial significance to the design of handling and feeding equipment, and safety systems, and to the assessment of explosion and fire hazards. In this respect the industrial branches involved in power production, like

- boiler manufacturers
- manufacturers of fuel handling systems
- energy consultants
- utility companies
- manufacturers of safety equipment

can directly benefit from the information on the safety-technical characteristics created in this project. The methodology used is of value for national and international bodies concerned with the standardisation work of test methods. Also authorities involved in safety regulation and legislation work will benefit from the knowledge created within this project.

The information on safety-technical characteristics created in the project is of fundamental nature. In this context the partners of the project have decided to declare all results as public. On approval the report will be published in VTT Publication series and disseminated according to plans set up in the technology implementation plan.