Modified Proctor/Fagerberg Method for Coal

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1 Scope

This procedure details the laboratory determination of Transportable Moisture Limit (TML) for coals up to a nominal top size of 50 mm. The procedure is based on a modification of the Proctor/Fagerberg test for general bulk materials described in Appendix 2 of the International Maritime Solid Bulk Cargoes (IMSBC) Code.

Key modifications to the original test contained in the IMSBC Code are:

- Sample preparation to facilitate the testing of 0 x 50 mm coal through reconstitution to -25 mm;
- Use of a 150 mm diameter test cell; and
- Sample compaction using a hammer equivalent to the Proctor/Fagerberg "D" energy hammer.

The Transportable Moisture Limit is the moisture content corresponding to the intersection of the 70% degree saturation curve and the test sample compaction curve.

In the case of coals where moisture freely drains from the sample such that the test sample compaction curve does not extend to or beyond 70% saturation, the test is taken to indicate a cargo where water passes through the spaces between particles and there is no increase in pore water pressure. Therefore, the cargo is not liable to liquefy (Reference: IMSBC Code s7.2.2).

The procedure commences with a drum of coal containing a sample of approximately 150 kg delivered to the testing laboratory and terminates with the laboratory reporting the test result for the coal. Details of the sample collection process are excluded from this procedure and reference should be made to the normative reference list below.

2 Normative References

The following documents are referenced in this procedure. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

AS 1152:1993, Specification for test sieves

ISO 589:2008, Hard Coal - Determination of total moisture

AS 1289.3.5.1, Methods of testing soils for engineering purposes. Method 3.5.1: Soil classification tests – Determination of the soil particle density of a soil – Standard method.

AS 4264.1, Coal – Sampling procedures

AS 4264.4, Coal and Coke – Determination of precision and bias

AS 2418, Coal and Coke – Glossary of terms

IMSBC Code (2009), International maritime solid bulk cargoes code, International Maritime Organization.

3 Definitions

For the purpose of this document, the definitions given in “AS 2418, Coal and Coke – Glossary of terms” as well as those given below apply.

3.1 Transportable Moisture Limit (TML)

The transportable moisture limit (TML) of a cargo which may liquefy means the maximum moisture content of the cargo which is considered safe for carriage in ships not complying with the special provisions of sub-section 7.3.2 of the IMSBC Code for specially constructed or fitted cargo ships.

3.2 Test Outcomes

The TML determined by this procedure is the moisture content corresponding to the intersection of the 70% degree saturation curve and the test sample compaction curve, as described in this document. This is also referred to as the PFD70 value (Proctor/Fagerberg – D energy hammer – 70% saturation).

Where moisture freely drains from the sample or test cell at a moisture content such that the test sample compaction curve does not extend to or beyond 70% saturation (as described in section 6.4), the test is taken to indicate a cargo where water passes through the spaces between particles and there is no increase in pore water pressure. Therefore, the cargo is not liable to liquefy (Reference: IMSBC Code s7.2.2).

3.3 Optimum Moisture Content (OMC)

The optimum moisture content corresponds to the maximum compaction (maximum dry density) under the specified compaction condition.

3.4 Gross Water Content or Total Moisture (W^1)

The moisture content of a sample is calculated as the mass of water divided by the total mass of solids plus water and is referred to as either the gross water content or the total moisture content. Gross water content is to be determined using the method for determining total moisture defined in the standard ISO 589.

4 Apparatus

4.1 Work Area

The work area must be located where the samples are protected from excessive temperatures, air currents and humidity variations. All phases of the material preparation and testing procedure shall be accomplished in a reasonable time to minimize moisture losses. All suitable sample containers, including plastic sample bags, shall be sealed.

4.2 Standard Sieves

Square aperture laboratory sieves of 16 and 25 mm aperture as nominated in AS 1152:1993 are required for reconstitution of the sample at 25 mm top size. A 2.36 mm sieve is required for generation of +2.36 mm and –2.36 mm fractions for particle density determination. Optionally a 2 mm sieve may be used for this purpose.

4.3 Proctor/Fagerberg apparatus

The Proctor/Fagerberg apparatus consists of a cylindrical stainless steel mould 150 mm in diameter and 120 mm high with a removable extension piece (the compaction cylinder) and a compaction tool guided by a pipe at its lower end (the compaction hammer), which is shown in Figure 1.

A schematic diagram of the Proctor/Fagerberg apparatus, including dimensions and tolerances in Table 5, is provided in Annex A.

Figure 1 — Example of Proctor/Fagerberg test apparatus, hammer and hammer guide

4.4 Compaction hammer

The required tamping pressure consistent with the D energy hammer modified for the 150 mm cell diameter is achieved by using a 337.5 g compaction hammer that allows a controlled pressure to be applied via a 75 mm diameter tamper head through a guide pipe 0.15 m in length as illustrated in Figure 1. See Table 5 for full specifications.

4.5 Drying oven

The drying oven shall be ventilated, with forced circulation of air or inert gas, typically with a stainless steel interior and capable of maintaining a temperature within the range of 105ºC ± 5ºC.

4.6 Weighing balance

The weighing balance shall be capable of weighing the sample and the container, as received, with an accuracy of better than ± 5 g.

4.7 Pycnometer

Water pycnometry equipment is used to determine the density of the full sized coal (non-crushed) in accordance with AS 1289.3.5.1. Specific equipment required is as follows:

- A conical flask or density bottle of 250 ml capacity;
- A vacuum desiccator or other vacuum equipment;
- A drying oven set to 105 to 110^{o}C;
- Balances – one with ± 0.05 g accuracy and the second with ±1 g accuracy;
- A 0 to 100^{o}C thermometer;
- A 2.36 mm sieve (as noted in section 4.2);
- A vacuum source;
- A water bath set at 60^{o}C;
- Distilled, demineralised or deionised water;
- A wash bottle containing water;
- A wire basket to hold the +2.36 mm sample;
- A container filled with water to hold the wire basket without interference;
- A scale to weigh the basket both suspended in water and drained.

4.8 Containers for hand mixing and sample preparation

Sufficient heavy-duty plastic buckets with lids of not less than 10 litres capacity are required for storage and handling.

Heavy-duty plastic bags (200 micron thick or greater) are required for storage and hand mixing of samples.

4.9 Flat Scraping Device

A thin steel scraper is required for separating the remnant sample formed in the extension piece lying above the top level of the mould. For ease of use, the scraper should have dimensions of 160 mm wide, 200 mm long and 3 to 5 mm thick.

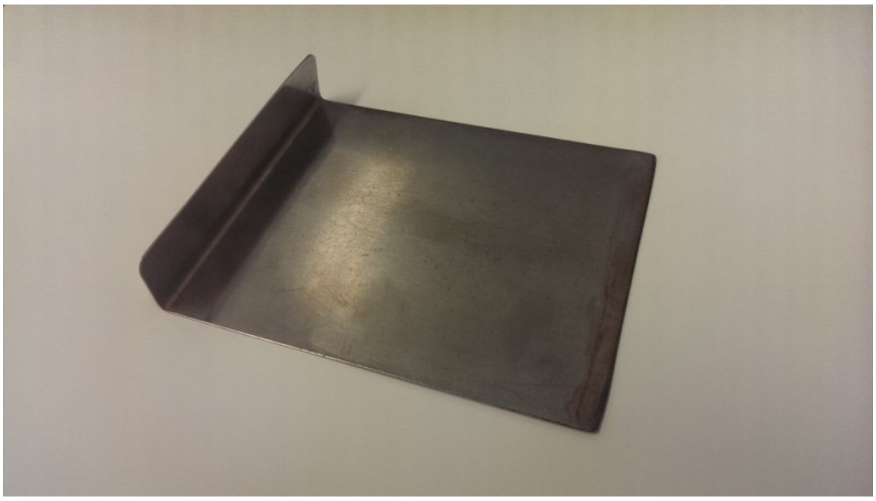

Figure 2 — Typical scraping device

4.10 Drying trays

Drying trays or pans shall have a smooth surface, be free from contamination and heat resistant, for example stainless steel or enamel. Dimensions shall be suitable to fit in the drying oven and ensure that the total sample can be contained at a loading of about 1 g/cm^2 of surface area.

4.11 Spray bottle

A suitable plastic bottle is required to add a mist spray of water to the sample.

4.12 Gloves

Heat resistant gloves are required for removal of hot trays and dishes.

4.13 Sample Divider

A suitable sample divider as specified in AS 4264.1 is required for sub-sampling the primary sample and blending the reconstituted sample for testing.

5 Sampling and Sample Preparation

5.1 General

This procedure commences with receipt of a 150 kg sample sealed in a heavy duty (200 micron thick) plastic bag and contained in a suitable (e.g. 220 litre) drum. This packaging ensures the sample does not dry prior to TML determination.

5.2 Sample preparation

Representative samples are required that have been obtained using AS 4264.1 and if required may be partially air dried or partially dried at a temperature of 40°C or less to reduce the water content to a starting point suitable for dry sieving the coal with minimal fines adhering to the oversize fraction. For this purpose, samples shall not be dried below 6% total moisture. The representative subsamples for the test shall not be fully dried, except in the case of gross water content determination.

5.2.1 Sample homogenisation and division

Take the as-received sample and divide into individual subsamples using a sample dividing apparatus as specified in AS 4264.1.

Place these subsamples into heavy-duty plastic bags.

5.2.2 Reconstituted Sample Preparation Procedure

This section outlines the sample preparation procedure required to produce a reconstituted sample as described in Table 1 and Figure 3. The reconstitution process commences where the coal is initially sieved into particle sizes larger than 25 mm and smaller than 25 mm. Coal particles in the size range of +16 mm to -25 mm size are extracted from separate subsamples and reconstituted back into the original -25 mm screened coal based on a mass equivalent to the +25 mm sized coal removed from the initial sample to provide a final reconstituted sample of sufficient mass for TML testing.

Note: As an alternative procedure, consideration is being given to allowing the full as-received sample to be screened at 2.3, 16 and 25 mm for reconstitution.

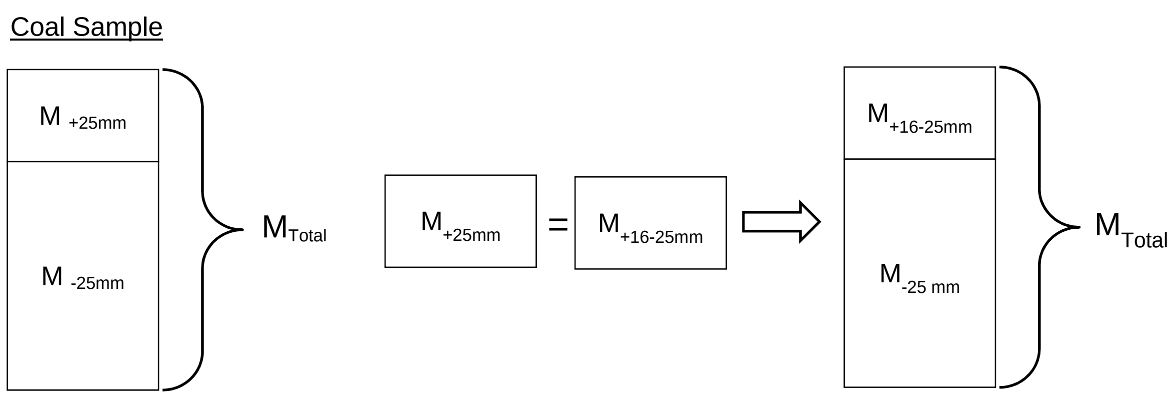

Figure 3 - Overview of sample reconstitution

Table 1 - Sample reconstitution

Step	Example
a) Generate a sample of ~25 kg which is sufficient to complete approximately 8 Proctor/Fagerberg tests.	Assumes each subsample bag contains 8 to 10 kg.
b) Screen this sample at 25 mm, ensuring minimal adhering fines on the +25 mm fraction. Weigh the +25 mm coal.	For a coal containing 20% +25 mm material, approximately 5 kg of initial sample is removed.
c) Create sufficient -25+16 mm coal by screening one or more further subsample bags of coal at 16 and 25 mm.	In the above example, 5 kg of -25+16 mm coal is required.
d) Extract an amount of -25+16 mm coal of mass equal to the mass of +25 mm removed in step b) within ±0.05 kg using a rotary sample divider or similar device, recombining sector trays as required to obtain the required mass.	5 kg in the above case.
e) Add the mass of -25+16 mm coal from step d) to the -25 mm coal from step b). Blend and divide into ~8 test portions using a rotary sample divider or similar device.	
f) Place each reconstituted test portion in heavy duty plastic bags, label and seal. **These now become the test portions used for Proctor/Fagerberg testing.**	Each bag should contain ~2.5 to 3 kg of reconstituted -25 mm coal.
g) Discard the +25 mm and -16 mm coal.	

5.2.3 As received moisture

As received moisture is to be determined on a test portion from Table 1 step e) using the method provided in ISO 589.

This moisture value provides a guide to the moisture steps required to develop the Proctor/Fagerberg compaction curve.

5.2.4 Particle density measurement

In accordance with water pycnometer standard AS 1289.3.5.1, measure the particle density on the full size range (non-crushed) coal. The solids density is used for determining the void ratio for plotting compaction curves. The recommended methodology is described below:

(a) Generate a full particle size sample of approximately 10 kg, weigh and then screen the entire contents at 2.36 mm. If a 2.36 mm screen is not available, a 2 mm screen may be substituted. Record the following:

   i. The total mass of the material;

   ii. The mass of +2.36 mm material; and

   iii. The mass of -2.36 mm material.

(b) Calculate the percentage of -2.36 mm coal in the sample.

(c) Divide the +2.36 mm coal into two test portions using sample dividing apparatus as specified in AS 4264.1 such as a rotary sample divider. Place each test portion in a heavy duty plastic bag and label.

(d) Divide the -2.36 kg coal into two test portions, place each test portion in a heavy duty plastic bag and label.

(e) Determine the particle density of the +2.36 mm fraction following the method described in Section 5.2 of AS 1289.3.5.1-2006. As noted in the standard, duplicate determinations are required.

(f) Determine the particle density of the -2.36 mm material using the method described in Section 5.1 of the above standard with the following clarifications:

   i. Use of 250 mm conical or pycnometry flasks is recommended.

   ii. From the sample bag pour 1 litre of coal into a beaker of known tare weight.

   iii. Weight the 1 litre sample and calculate the approximate bulk density of the material.

   iv. Remove a portion of the sample (nominally a mass in kilograms of 0.18 x bulk density) and place into the flask, and complete the pycnometry analysis.

   v. A water bath temperature of 60^{o}C is recommended.

(g) Calculate the particle density using the method in Section 6 of AS 1289.3.5.1.

6 Proctor/Fagerberg Test Procedure

6.1 Variables and definitions

The variables and definitions used in the determination of TML are as follows and are summarised in Table 1.

A = empty cylinder mass in grams

B = mass of cylinder with tamped test portion in grams

C = wet mass of test portion in the mould in grams = $B – A$

C_1 = wet mass of test portion removed from the mould in grams (used for moisture determination)

D_1 = dry mass of test portion removed from the mould in grams (used for moisture determination)

D = dry mass of test portion in the mould in grams

E = mass of water in the mould in grams (equivalent to volume in cm^3)

V = volume of cylinder = 2121 cm^3 or the measured value if it is not exactly 2121 cm^3

A number of the key variables are also illustrated in Figure 4.

Table 2 – Summary of variables and definitions

Variable	Unit	Symbol / value used in calculations
Mass of empty cylinder and base	g	A
Mass of cylinder, base and tamped test portion	g	B
Wet mass of test portion in the mould	g	*C* = *B* – *A*
Wet mass of test portion removed from the mould	g	C_1
Dry mass of test portion removed from the mould	g	D_1
Gross water content	%	W^1
Dry mass of test portion in the mould	g	D
Mass of water in the mould	g	E
Volume of cylinder	cm^3	V
Density of solid material	g/cm^3	d
Density of water	g/cm^3	ρ_w

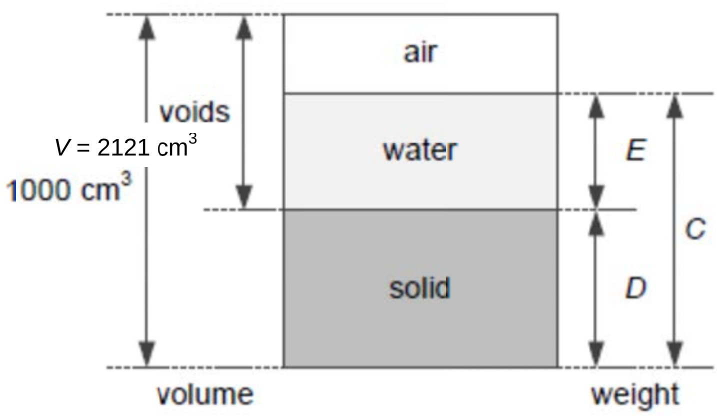

Figure 4– Illustration of key variables

6.2 Establishment of the initial compaction point

The initial compaction point is obtained using the first test portion of the reconstituted material at the initial moisture content. The test procedure is as follows:

(a) Clean the mould, collar and base plate. Inspect and clean the hammer and ensure that it moves freely in the guide tube.

(b) Determine the mass, *A*, of the empty cylinder, comprising the mould plus base plate.

(c) Assemble the mould, collar and base plate and place the assembly on a stable bench.

(d) Place approximately 500 ml (one fifth of the full 2.5 litres) of the test portion into the mould, level, and then tamp uniformly over the surface by dropping the hammer 25 times vertically through the full height of the guide pipe, moving the guide pipe to a new position after each drop. The required pattern for even compaction of each layer in the mould is shown in Figure 5.

(e) Repeat step (d) four more times so that there are 5 layers of material in the mould. Ensure that the compacted test portion with the final layer is above the top of the compaction mould whilst the extension piece is still attached.

(f) When the last layer has been tamped, remove the extension piece taking care not to disturb the compacted test portion inside. Level the compacted test portion to the top of the mould using the flat scraping device, ensuring that any large particles that may hinder levelling of the test portion are removed and replaced with material contained in the extension piece and re-level. If any holes in the surface are still observed after levelling, they should be manually filled with finer material contained in the extension piece. Care shall be taken to avoid any further compaction of the test portion.

(g) Determine the mass (*B)* of the mould and compacted coal and then calculate the mass, *C*, of the wet test portion using the equation:

$$C = B - A \quad (1)$$

(h) When the weight of the cylinder with the tamped test portion has been determined, remove the test portion from the mould, determine the mass of the wet test portion, C1, and dry the entire test portion in an oven at 105°C until constant mass is achieved. After drying, determine the weight, D1, of the dried test portion and then calculate the percentage gross water content, W^1 , as follows:

$$W^1 = (C1 - D1)/C1 \times 100 \quad \%$$

(i) Using the calculated gross water content, calculate the mass of the dry test portion in the mould after drying, *D*, using the equation:

$$D = C - C \times W^1/100 \quad (2)$$

(j) Calculate the mass, *E*, of water in the mould using the equation:

$$E = C - D \quad (3)$$

(k) Discard the used coal sample. Coal from a previously compacted test portion shall not be re-used.

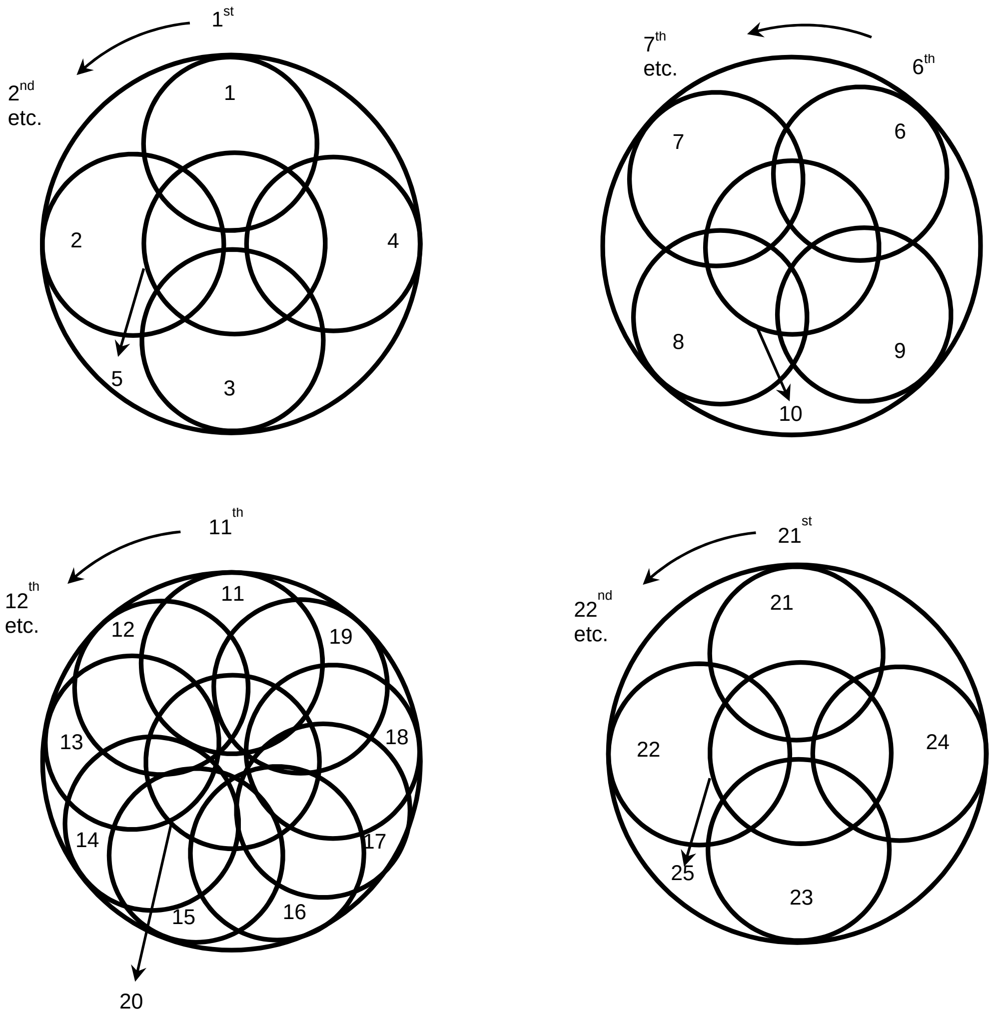

Figure 5 — Recommended compaction patterns

6.3 Establishment of complete compaction curve

The range of water contents shall be adjusted so that partially dry to almost saturated test portions are obtained.

The test procedure is as follows:

(a) For each compaction test, a predetermined amount of water is added to the test portion (~2.5 kg) in a heavy duty plastic bag. The water quantity added is that required to increase the moisture content to the target value for the next test. The water should be added as a mist spray to the surface of the individual test portions. The water at this point should be added slowly and in small quantities, as the introduction of large amounts of water may induce localised compaction behaviour.

(b) After the calculated water addition, the test portion shall then be mixed thoroughly in the plastic bag by sealing the bag and turning it over repeatedly for 5 minutes.

(c) The test portion shall then be allowed to equilibrate for a minimum of 12 hours prior to compaction testing.

(d) Repeat steps (a) to (k) from Section 6.2.

(e) Repeat the test between four and seven times using the other prepared test portions with different water contents to obtain at least 5 points on the compaction curve. The water contents should be chosen so that at least one point is wetter than the Optimum Moisture Content (OMC) or greater than a saturation of 70% to satisfactorily define the compaction curve. At least one point between the 70% and 80% degree of saturation (S) is required to effectively assess the PFD70 value. A point close to a degree of saturation (S) of 80% will also assist to accurately assessment if the OMC is greater than 70%.

6.4 Visual appearance of coal in the test cell

In order for the test to return a PFD70 value, all tests conducted at or below the PFD70 moisture value should have an even moisture distribution throughout the cell.

Two examples of tests on the same coal at different moisture contents for such a coal are shown below in Figure 6.

The photograph on the left shows a sample at a relatively low degree of saturation. Note that the coal remains in place following removal of the collar.

The right hand photograph shows a coal sample near or possibly above 70% saturation. Once again the coal remains in place following removal of the collar.

Both tests returned valid points on the compaction curve.

Figure 6 — Photographs showing valid tests for a partially saturated test portion (left) and a near fully saturated test portion (right)

Coals where water passes through the spaces between particles exhibit moisture migration within the Proctor/Fagerberg cell prior to the test portion reaching 70% saturation.

Evidence of moisture migration is from visual observation at the completion of each test as follows:

- Moisture leakage from the base of the mould is evident in Figure 7; and
- The portion above the top of the cell appears unsaturated and the test portion maintains its structure without deformation or movement.

In this case, moisture migration has occurred and hence for this coal water passes through the spaces between particles.

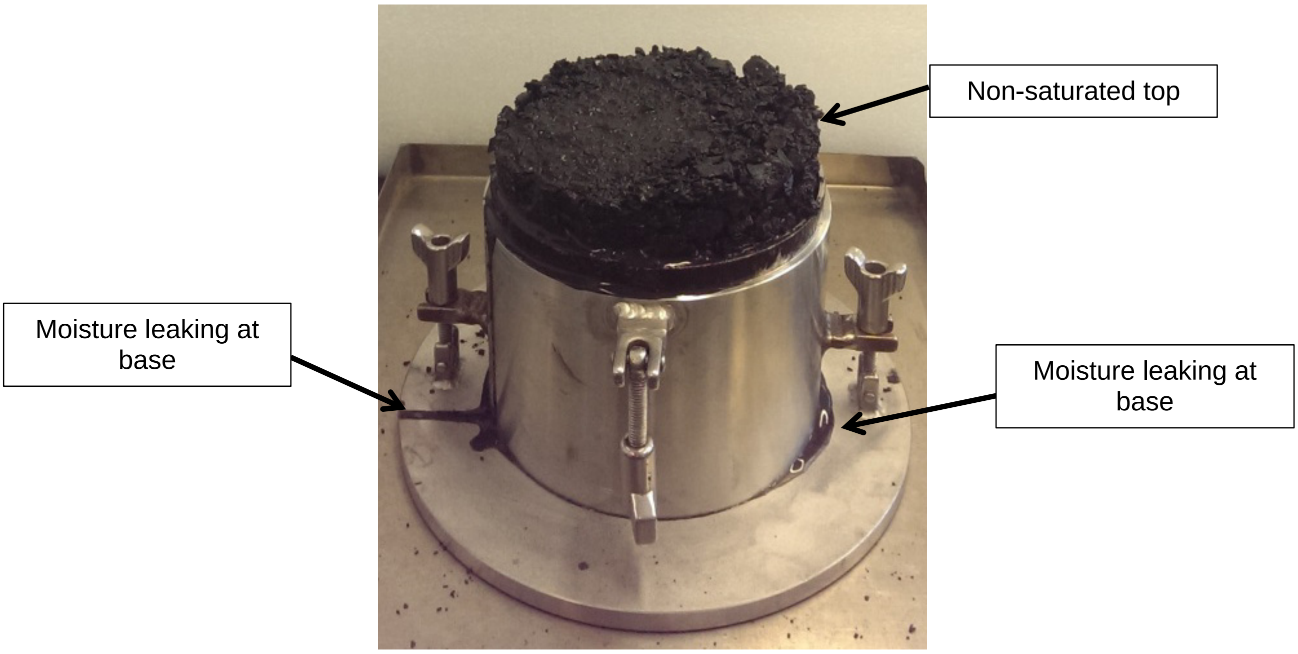

Figure 7 — Test showing water leakage from the base of the cell indicating moisture migration

6.5 Calculation of key parameters for determination of compaction curve

Carry out the following calculations for each compaction test. These are summarised in Table 2.

γ = dry bulk density, g/cm^3 (t/m^3)
= D/V

e_v = net water content (percentage by volume)
= $(E/D) \times 100 \times d/\rho_w$
where d = density of solid material, g/cm^3 (t/m^3)
ρ_w = density of water, g/cm^3 (t/m^3)

e = void ratio (volume of voids divided by volume of solids)
= $(d/\gamma) - 1$

S = degree of saturation (percentage by volume)
= e_v/e

W^1 = gross (total) water content (percentage by mass) – see 6.2 (g).

Table 3 – Key calculations for TML determination

Variable	Symbol	Calculation
Density of solid material	d	From pycnometer (see 5.2.4(g)).
Dry bulk density	γ	$\gamma = D/V$
Net water content (% by volume)	e_v	$e_v = E/D \times d/\rho_w \times 100$
Void ratio (volume voids / volume solids)	e	$e = d/\gamma - 1$
Degree of saturation (% by volume)	S	$S = e_v/e$
Gross water content (% by mass)	W^1	See 6.2 (h)

6.6 Presentation of compaction results

Record all the compaction test results in a suitable spreadsheet (such as that shown in Table 4) and from this spreadsheet create a compaction curve as shown in Figure 8 by plotting the calculated void ratio (e) for each compaction test on the Y-axis against the gross water content (W^1) plotted on the X-axis.

The straight lines in Figure 8 correspond to plots of void ratio (e) versus gross water content (W^1) at 20%, 40%, 60%, 70%, 80% and 100% degree of saturation (S). These lines are calculated at 5 values of void ratio using the formulae in Section 6.5 above.

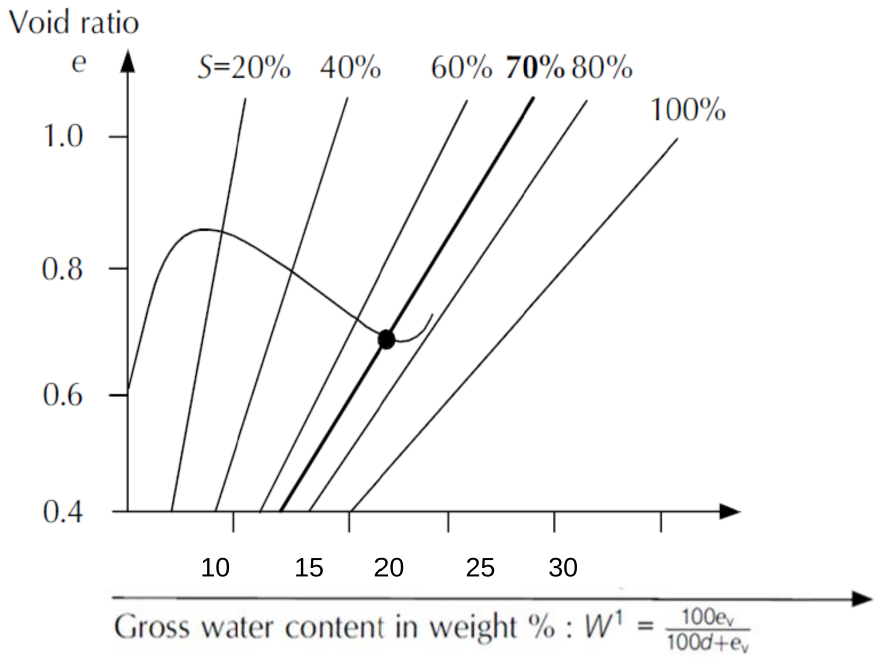

Figure 8 – Typical compaction curve

6.7 Sample compaction curve

An example of the results obtained when applying the modified Proctor/Fagerberg test to a coal sample is provided in Table 4, with the corresponding compaction curve and the 70% degree of saturation line plotted as described below.

The preferred approach to presenting the results is to plot the void ratio (*e*) against the gross water content (W^1) allowing moisture for any saturation level to be read directly from the plot as gross water content. This approach is shown in Figure 9. The saturation lines are plotted according to the equation:

$$e = W^1/(100 - W^1) \times 100 \times d / S$$

The intercept of the compaction curve with the 70% degree of saturation line in Figure 9 occurs at a gross water content of 15.4%, which is the Transportable Moisture Limit (TML). For this example, the OMC occurs at a degree of saturation of about 85%.

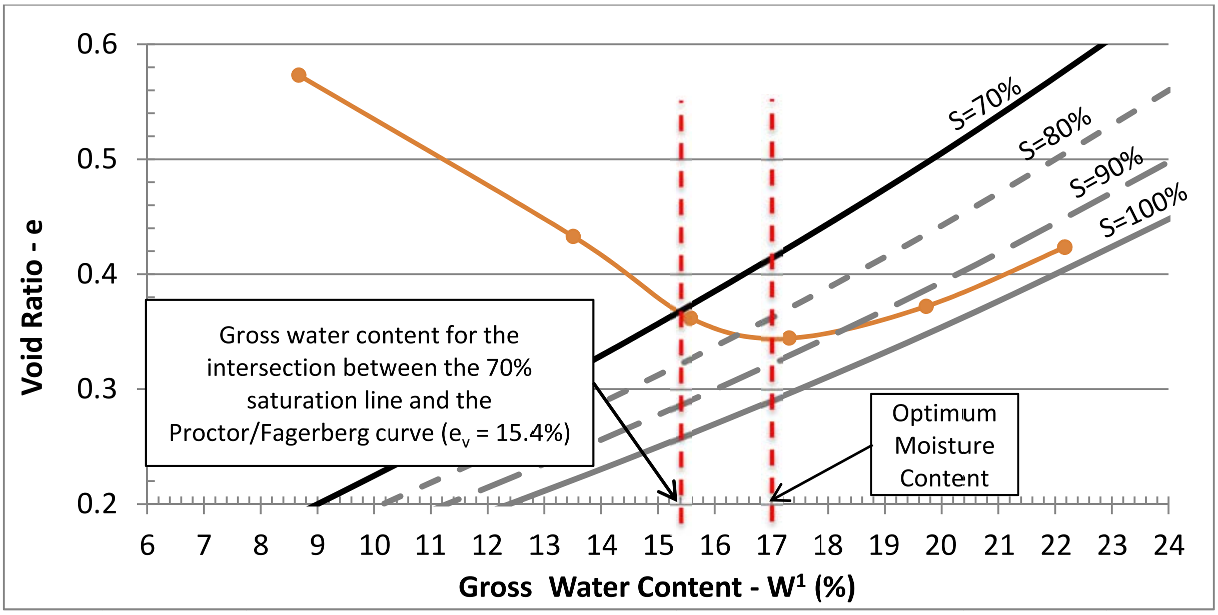

Figure 9 – Example of a measured compaction curve for void ratio versus gross water content with the 70%, 80%, 90% and 100% degree of saturation lines plotted

6.8 Determination of transportable moisture limit

6.8.1 Determination of PFD70 Moisture Content

The critical moisture content is determined from the intersection of the compaction curve and the line S = 70% degree of saturation, with the gross (total) water content (W^1) corresponding to this intersection defined as the PFD70 value. The PFD70 value is reported as the Transportable Moisture Limit.

The Optimum Moisture Content (OMC) is the gross (total) moisture content corresponding to the maximum compaction (maximum dry density and minimum e) under the specified compaction condition.

The test procedure is applicable for determination of coal TML where the degree of saturation corresponding to the OMC of the coal is at or greater than 70% saturation. Where the OMC lies below 70% saturation, this test may not be applicable for the specific coal and the PFD70 may overstate the TML. In such cases, the certificate of analysis shall state that the OMC is below 70% saturation and the shipper should consult with an appropriate authority,

6.8.2 Cases where the highest determinable point on the compaction curve lies below 70% saturation

In coals where there is visual evidence that water passes through the spaces between particles and the compaction curve does not extend to or beyond the 70% saturation line, the coal is deemed to be free draining and a TML value is not applicable. By reference to the IMSBC Code s7.2.2, such coals are cargoes where liquefaction does not occur.

7 Test Report

The test report shall include the following information:

(a) Identification of the sample;

(b) A unique reference to this document;

(c) Reference to the appropriate standard adopted for determining the density of the solids;

(d) Either:

- i) The transportable moisture limit (TML) of the sample, expressed as the gross water content as a percentage of the sample by mass; or

- ii) A statement that the test indicated that water passes through the spaces between particles at a moisture content below 70% saturation, and the coal is therefore not Group A.

(e) The solids density d in g/cm^3.

Table 4 – Example of TML determination for a coal sample using the modified Proctor/Fagerberg method

Product					Diameter of cylinder		150 mm	Laboratory temperature			25°C			Date		
Sample					Height of cylinder		120 mm	Mass of mould (***A***)			7271 g			Size fraction		
Initial gross water content (%)			5.6		Volume of cylinder		2121 ml	Initial Dry density			899 kg/m^3			Operator		
Density of solids			1416 kg/m^3		TML		15.4%							Tamper	337.5 g	
Test number	Water added	Mass of mould + sample	Tray No.	Mass of tray	Mass of wet sample + tray	Mass of dry sample + tray	Measured gross water content	Gross water content	Net water content	Void ratio	Dry density	Degree of saturation	Wet bulk density	Mass of wet sample	Mass of dry sample	Mass of water
	(ml)	(g)		(g)	(g)	(g)	(%)	(%)	(%v)		(g/cm^3)	(%)	(g/cm^3)	(g)	(g)	(g)
		B						**W**^{1}	e_V	**e**	γ	**S**		**C**	**D**	**E**
1	0.00	9360.00	T1	602.5	1656.8	1565.7	8.64	8.67	13.437	0.573	0.899	23.4	0.985	2089.0	1907.8	181.2
			T2	602.3	1643.1	1552.5	8.70									
2	150.00	9692.70	T3	630.7	1811.7	1649.6	13.73	13.51	22.097	0.433	0.988	51.1	1.142	2421.7	2094.6	327.1
			T4	882.9	2126.9	1961.6	13.29									
3	250.00	9881.60	T5	638.7	2081.4	1849.7	16.06	15.58	26.104	0.362	1.039	72.2	1.231	2610.6	2204.0	406.6
			T6	632.4	1822.6	1643.0	15.09									
4	350.00	9971.00	T7	882.2	2349.9	2095.4	17.34	17.31	29.630	0.344	1.053	86.1	1.273	2700.0	2232.5	467.5
			T8	637.9	1868.8	1656.0	17.29									
5	450.00	9996.20	T9	654.3	2013.2	1746.5	19.63	19.73	34.780	0.372	1.031	93.5	1.285	2725.2	2187.5	537.7
			T10	639.6	1999.4	1729.7	19.83									
6	550.00	9980.00	T11	885.0	2251.5	1931.6	23.41	22.17	40.311	0.423	0.994	95.2	1.277	2709.0	2108.4	600.6
			T12	883.5	2181.9	1910.1	20.93									
7																
8																
9																
10																

Note: The example above uses two drying trays for each test.

Annex A
Example of a Proctor/Fagerberg Apparatus

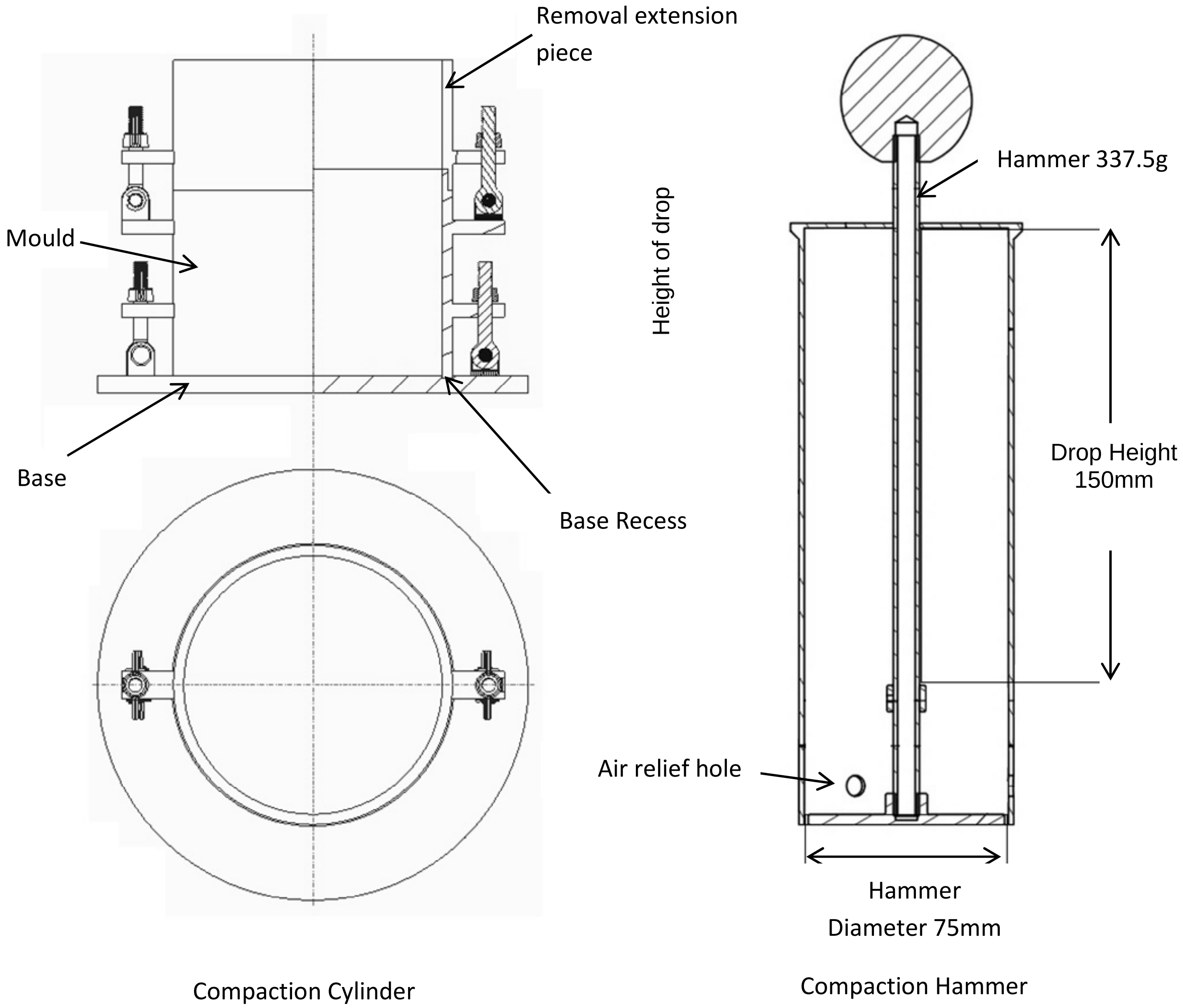

Figure A.1 – Schematic of a Proctor/Fagerberg apparatus

Table 5 – Specifications and tolerances for Proctor/Fagerberg cell and hammer

Parameter	**Units**	**Dimension**	**Tolerance**
Hammer mass	g	337.5	± 2
Hammer diameter	mm	75	± 0.2
Drop height	mm	150	± 2
Tube ID	mm	78	± 0.2
Tube OD	mm	82	± 0.2
Tube wall thickness	mm	2	± 0.2
Tube clearance	mm	1.5	± 0.2
Mould inner diameter	mm	150	± 0.5
Mould inner height	mm	120	± 1
Mould inner volume	cm^3	2121	± 18
Removable extension piece height	mm	75	± 1
Depth of recess into base to seat	mm	1	± 0.2
Gap between mould and base	mm	≤ 0.1	
Gap between mould and extension piece	mm	Easy running fit (AS 1100)	(0 to +0.1)
Clearance between mould and hammer	mm	≤ 6	