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MINES BRANCH

DEPARTMENT OF MINES

OTTAWA, CANADA

CHARACTERISTICS OF ROCK WOOL EXPERIMENTALLY PREPARED FROM ROCK AVAILABLE IN THE ST. DAVIDS-THOROLD DISTRICT, ONTARIO.

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by M. F. Goudge.*

Introductory.

In 1931 a report entitled "Raw Materials for the Manufacture of Rock Wool in the Niagara Peninsula of Ontario"[1] was issued by the Mines Branch giving the results of research on the possibilities of making rock wool from deposits of rock in the above-mentioned area. This research definitely indicated that certain large deposits were suitable for the production of rock wool, a product that up to the present has not been made in Canada. However, up to the time of publication, laboratory facilities were not available for the actual making of rock wool aside from a few fibres and thus the report was based largely on deductions drawn from a study of the characteristics exhibited by the rock while in a molten state. Shortly after the report was issued, however, facilities were made available for the production of rock wool in the laboratory, and the conclusions arrived at regarding the suitability of certain deposits were borne out by the actual making of rock wool from samples obtained from these deposits. Still later, arrangements were made with a rock wool company in the United States to make a commercial scale test on a shipment of rock from the area. This test was successful and it may now be considered as proved that, in the St. Davids-Thorold district, there are large deposits of rock suitable for the making of rock wool. Thus the basis has been laid for the establishment of a new Canadian industry to utilize a hitherto undeveloped natural resource.

Rock Used in Blowing Tests.

The samples of rock used in the blowing tests were obtained in 1931 and 1932 from the Rochester formation along the face of the Niagara escarpment in the vicinities of St.Davids and Thorold. Here the Rochester formation consists of 58 feet of dark grey, very fine-grained, argillaceous dolomite which, on exposure

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*Technologist, Mineral Resources Division.

[1] Mines Branch, Mem. Series, Rept. No. 50, (1931).

to the weather, disintegrates to a shale. The analyses[1] of the samples and the locations from which these samples were obtained are as follows:-

	1	2	3	4	5	6	7	8
Silica	22.98	24.68	25.48	27.34	26.18	26.08	24.65	24.44
Ferric oxide	2.32	2.55	2.42	2.75	2.81	2.32	2.55	3.85
Alumina	7.28	9.43	9.92	10.15	10.71	9.12	9.12	9.35
Alkalis	2.84	2.46	2.40	2.54	2.56	2.65	2.62	1.70
Calcium oxide	21.17	20.52	20.37	21.42	22.02	21.65	20.15	21.04
Magnesium oxide	12.67	11.65	10.77	8.90	8.53	10.15	12.04	10.70
Loss on ignition	30.01	28.20	27.68	26.28	26.48	27.84	28.76	27.96
	99.27	99.49	99.04	99.38	99.29	99.81	99.89	99.04

Samples 1 and 5 inclusive, consisted of sections of a drill core from a vertical drill-hole bored by Queenston Quarries, Ltd., in October, 1931, through the Rochester formation at a point near the crushing plant at the Queenston quarry. Each section represents 5 feet of rock. No. 1 is the top 5 feet, and No. 5 the section from 20 to 25 feet below the top. The core showed the Rochester formation to be 58 feet thick at this place, but the lower part of the core was not tested.

Sample 6 represents the top 20 feet of the Rochester formation exposed in a water course down the face of the escarpment at the western limit of the property of Queenston Quarries, Ltd.

Sample 7 is from the top 5 feet of the Rochester formation exposed in the floor of Walker Bros. quarry, Thorold.

Sample 8 is from the top 10 feet of the Rochester formation exposed ¼ mile west of Walker Bros. quarry in the excavation for the weir on the new Welland Canal.

Method of Making the Blowing Tests.

Six hundred grammes of the crushed sample was put in a graphite crucible and fused in an electric furnace in which temperatures up to 2650°F. could be obtained. The molten rock was poured in a steady stream ¼ inch thick into a blast of compressed air issuing from the nozzle at a maximum pressure of about 90 pounds per square inch. Wool was obtained from all the samples tested. A composite sample of the 30 feet of core from the Queenston quarry was also tested with good results.

Blowing tests were made at temperatures of 2500°, 2550° and 2650°F., and in some of the tests air pressures lower than 90 pounds per square inch were used. As a result wool of different characteristics was obtained from the same type of rock. Good re-

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[1] Analyses made by C. L. O'Brian, Division of Chemistry, Mines Branch.

sults were obtained on all the samples tested when the material was blown at a temperature of 2550°F., though the wool made from samples 4, 5 and 6 was of coarser texture and contained more shot than that made from the same samples at a temperature of 2650°F. Samples 1, 2, 3, 7 and 8 as well as the composite sample of the top 30 feet of core gave good wool when fiberized at a temperature of 2550°F. by an air blast of 90 pounds per square inch.

An insufficient number of tests has as yet been made and sufficiently high temperatures have not yet been attained in the laboratory work to warrant definite statements as to the correct temperature and pressure to use to obtain the best results with rock of a given composition, but the following general observations were made during the laboratory tests on the Canadian rock.

A short-fibred, cotton-like wool is the result of wither too high a temperature or too great a blast pressure, or of both combined.

Coarse, brittle wool, containing much shot, is the result of either too low temperature or too low blast pressure,or of both combined. This type of wool is also formed when the stream of molten material is too large in relation to the blast.

In the tests so far made, the fibres were apparently all formed within 12 feet or less of the air nozzle when the wool was being blown into an unheated room.

As was predicted in the initial report on this subject, it was found possible in the actual fiberizing tests carried on at higher temperatures than were obtainable when the first report was written, to make wool from rock in which the ratio of the weighted acidic constituents to the weighted basic constituents was less than the limit of 0.8 fixed during the preliminary work. This is particularly true of suitable rock in which the proportion of magnesia is relatively high, as it has been found that at high temperatures this constituent apparently increases the fluidity and also the viscosity range of the melts.

Characteristics of the Wool produced in the Laboratory.

All the wool that was produced is white and has a good lustre. It consists, like the various makes of rock wool and slag wool on the market, of fine, pliable, glassy fibres together with a small proportion of small, colourless, glassy pellets, or shot. Many of the shot have a fibre attached, others have none. The fibres are slightly larger at one end than the other; the thickest end of many terminates in a tiny globule of glass (shot). By blowing at different temperatures and by using different blast pressures, wool of varied fibre-length was obtained from the same rock. The following descriptions refer to two of the diverse kinds of wool— one short-fibred, the other long-fibred— it was found possible to produce under proper conditions from all of the samples tested.

The short-fibred wool consists largely of fibres less than 3/4 inch in length, though there are many as much as 3 inches long. These fibres range from 1 to 6 microns[1] in diameter, with an average of 3.5 microns. In addition to the well-defined fibres there is a considerable proportion of cotton-like material consisting of extremely short and fine fibres, which though it adds to the insulating properties, renders it difficult to "felt" the wool into a coherent blanket. Some shot are also present but they are very small, rarely exceeding 1/50 inch in diameter. This type, owing to the shortness of its fibres, is well suited to the making of granulated wool. A sample of this wool was sent to the National Research Laboratories, Ottawa, for a determination of its thermal conductivity and the results of this test are given on page 6.

In the long-fibred wool the majority of the fibres are over 3 inches long and there is a large proportion of fibres from 6 to 10 inches in length. The diameters range from 2 to 20 microns, with an average of 6.5 microns. The proportion of cotton-like material is much less than in the short-fibred type. The shot, though not numerous, are somewhat larger than those in the short-fibred wool. This long-fibred wool "felts" well into a flexible blanket and it has a much greater measure of springiness than the short-fibred type. As in all blankets made of rock wool, however, some re-inforcing material must be incorporated with it before the blanket can be handled. The length of fibre greatly exceeds that in the rock wools and slag wools being imported into Canada. Under vibration tests this type of wool stands up very well, and after a small quantity of shot and of broken fibre has been shaken out by the vibration no noticeable disintegration occurs. It would apparently be suitable for use as insulation on railway trains and ships where, at the present time, the short-fibred rock wool as now manufactured is used only to a limited extent.

All the wool produced in these tests was allowed to cool rapidly after it was blown. In view of the statement sometimes made that it is essential that the wool must be allowed to cool very slowly after it has been formed, because rapid cooling causes strains in the glassy fibres and results in a brittle wool, a great many of the fibres of all types made were examined under the polarizing microscope for evidences of strain, but none was observed, though strains were observed in some of the larger shot included in the wool. It is a well known fact that when a mass of glass is rapidly cooled, a condition of strain is developed owing to the surface solidifying and contracting upon the interior whilst it is still soft. This strained condition must be removed by a subsequent heat treatment known as annealing. However, it is most unlikely that differential cooling of any magnitude could take place in the extremely fine fibres that compose rock wool, no matter how rapidly it is cooled.

For purposes of comparison with the wool produced in the experimental work, several samples of imported rock wool and slag wool were examined. In the best types of these the fibres ranged

[1]A micron is one-thousandth of a millimetre.

from 2 to 15 microns in diameter and in length from less than ½ inch to 3 inches. There was a considerable variation in the amount of shot present, but in general the shot were of small diameter. Owing to the impossibility of separating all the shot from the fibres, no statement of the percentage by weight of shot present can be made.

Commercial Scale Test.

In order to prove conclusively that the rock found suitable by laboratory tests for the making of rock wool would also yield wool of good quality when processed in the standard equipment used at the present time in the manufacture of rock wool, arrangements were made with a company manufacturing rock wool in the United States to make a commercial scale test on a shipment of the rock, with the writer present to observe the results.

Four and a half tons of rock having an analysis similar to that of Sample No. 6 (page 2) was used in this test, which was made in March, 1933. The furnace was a water-jacketed, steel-lined, foundry cupola, 45 inches in inside diameter and 12 feet in height. Steam at a pressure of 100 pounds per square inch was used for blowing the wool. The blowing nozzle was of the V-shaped type favoured by a number of plants making rock wool and slag wool. The wool was blown into a collecting room, the floor of which was an endless conveyor which delivered the wool in blanket form to the shipping room.

The schedule of the test run was as follows:-

9.30 A.M. Lit fire in cupola.
10.45 A.M. Charged rock
10.55 A.M. First molten rock ran out tap hole.
11.10 A.M. Blowing commenced.
9.45 P.M. Test concluded.

The rock melted very easily and the stream of molten material issuing from the furnace in the early stages of the run was slightly too large and of too low a temperature to be properly atomized by the steam blast. This resulted in a pale greenish wool, which, though of marketable grade, was somewhat harsh and brittle and contained many shot. The addition of a small proportion of dolomite to the furnace charge gave a greatly improved product. Toward the end of the test when operating conditions had become stabilized, and a smaller stream at a high temperature was issuing from the furnace, a soft white wool of good fibre length and containing very little shot was obtained without the addition of the dolomite.

Characteristics of the Wool Produced in the Commercial Scale Test.

The best grade of wool produced during the commercial scale test consists of fibres from ½ to 8 microns in diameter, with the average about 4 microns. The majority of fibres exceeds

1½ inches in length and many are more than 3 inches long. There is a small proportion of cotton-like fibres. Small, colourless shot, rarely over 1/50 inch in diameter, occur both loose and attached to fibres but they are not numerous.

The average grade of wool produced during this test is composed of fibres of about the same character as those in the best grade above described, but the wool has a pale greenish tint and the shot are larger, more numerous and of a green colour. In order to find out if the presence of the shot appreciably affects the thermal conductivity of the wool a sample of this type was sent to the National Research Laboratories for a thermal conductivity test. The results as given below show that this wool is very nearly as good a thermal insulator as is the wool in which shot are not so prominent, but the shot are never desirable as they tend to break the fibres of the wool when it is being handled and also greatly increase the weight of the wool per unit bulk.

Thermal Conductivity of Rock Wool.

The low thermal conductivity of rock wool is due to the high percentage of still air enclosed between the myriads of fibres composing the wool. Tests made by adding water slowly to a glass vessel of known volume completely filled by rock wool shows that, at a density of 8 pounds per cubic foot, a rock wool of good quality contains at least 93 per cent of air. The actual percentage is probably somewhat greater owing to the fact that probably all the air was not displaced by water.

The report by Dr. C. D. Niven, National Research Laboratories, on the thermal conductivity of the samples of rock wool submitted for testing is as follows:-

Sample	No.1	No.2	No.3				No.4
	With frame	With frame	No frame	No frame	No frame	With frame	
Thickness (inches)	1.100	1.110	1.681	1.250	0.700	1.099	1.099
Duration of test (hrs.)	28	24	26	25	5	23	26
Density (lb.per cu.ft.)	7.9	10.3	5.0	6.6	11.3	7.9	8.7
Moisture (%)	0	0	3	0	0	0	0
Temperature of Cold Plate (F°)	27	27	27	27	27	27	27
Mean Temperature (F°)	54	55	54	55	54	55	53
Temperature Difference (F°)	54	55	54	56	54	56	51.5
Conductivity (B.T.U./hr/sq.ft./F°/inch)	0.230	0.248	0.240	0.242	0.248	0.242	0.28

Sample No. 1 was the short-fibred wool described on page 4.

Sample No. 2 was the wool of intermediate fibre length but containing considerable shot as described on page 6.

Sample No. 3 was a pad of rock wool containing a small amount of bonding material. This pad was made from wool produced from rock obtained from the property of Queenston Quarries, Ltd., St.Davids.

Sample No. 4 was granulated wool made from Canadian rock.

In commenting on the results of these tests Dr. Niven states that they show the quality of sample to be more important than density of packing.

The frame referred to in the tests was of wood and was 18 inches square and 1 inch thick. The sample was held in the frame by pasting a sheet of paper on top and bottom.

The above thermal conductivity tests were conducted with the rock wool at a mean temperature of 55 degrees F., and they show the material to possess remarkably good insulating properties. In common with other insulating materials the conductivity of rock wool increases with increase in temperature, but it is one of the most efficient and stable of insulating materials at temperatures less than 1000°F., and as the principal ingredient of an insulating cement it is used at temperatures up to 1200°F. Actually in many instances a good grade of wool can be used with satisfactory results at temperatures considerably higher than the above, which allow a generous margin of safety.

As loose wool and in granulated form, and in blankets, pads, bonded shapes, and as the principal ingredient of a cement it is used as a thermal insulator for all types of buildings and for a great many industrial purposes where it is not subject to excessive vibration, such as in refrigerators, cold storage plants, domestic and industrial ovens, water heaters, furnaces, boilers, hot and cold pipe lines, oil stills, tank cars, and so forth. With the development of a very long-fibred, flexible, nearly shot-free wool that does not break down under vibration, such as has been produced on an experimental scale from Canadian raw material, its field of usefulness in blanket form may be extended to insulation for ships and railway trains.

Two other major fields of usefulness for rock wool are as a material for the sound-proofing and the acoustical treatment of rooms, for which purposes it has proved eminently satisfactory. No tests have yet been made to determine the efficiency of the Canadian rock wool for these uses but, because of its similarity in essential properties, it should prove equally as suitable as that now being used.

Sound Insulation.

Rock wool is an effective insulating material against noise, and the growing demand for proper sound insulation in theatres, radio studios, hotels, hospitals, apartment houses, and office buildings opens another promising field of usefulness for this material. For purposes of sound insulation, rock wool in blanket form, in granulated form, or in wads and pads is placed within the walls, floors and ceilings of buildings where it also acts as a thermal insulator. Acoustical plasters and tiles made of rock wool are also used on the walls and ceilings with the dual object of insulating against noise and of correcting the acoustics of the room, as mentioned below. The value of rock wool as an insulating medium against noise lies in the fact that it is effective in absorbing sounds of great variety of pitch.

Acoustical Material.

A new and steadily widening market for rock wool that has developed within the past few years is in the acoustical treatment of auditoria, offices, theatres, and radio studios. Due to its good sound absorptive properties it ranks high as an acoustical material for the prevention of echo and for the reducing of excessive reverberation of sound within a room. For this purpose rock wool is used in blankets covered with flame-proofed muslin, and also as the main ingredient of acoustical plasters and tiles. Its incombustible and vermin-proof nature is a great asset in this connection because acoustical materials must be used as a facing on walls or ceiling to be effective.

Conclusion.

By both laboratory tests and commercial scale tests it has been demonstrated conclusively that a high-grade rock wool can be made from rock deposits in the St.Davids-Thorold area in the Niagara Peninsula of Ontario.

Experimental work to date has shown that four essential conditions for the production of rock wool of uniformly good quality are:

1. Material charged to the furnace must be of such composition that it will melt at a temperature between 2200°F. and 2400°F. and yield a melt possessing a relatively long viscosity range during cooling.

2. The temperature of the molten rock leaving the furnace must be such that the melt is entirely fluid or at its minimum

viscosity so that the full viscosity range will be available during the fiberizing process.

3. The process of fiberizing must be sufficiently rapid to convert all the molten rock into fibre during the very short space of time it is within its viscosity range after leaving the furnace.

4. Close control must be maintained over the furnace charge, the temperature, and the fiberizing process.

Large tonnages of rock are available in the area under discussion that fulfil the first requirement and if future work should show that a better product can be obtained by using material of somewhat different composition than that at present believed most satisfactory, there is in the same area, as pointed out in the first report, rock that contains a higher percentage of lime and magnesia, and also rock that contains a higher percentage of silica than is now desired in rock for the making of rock wool. By simply adding small proportions of one or the other of these rocks, the composition of the furnace charge can easily be made more basic or more acidic if desired.

The other essential requirements above mentioned have to do with the actual process of manufacture. It is probable that changes in the method of manufacture will be made, as the present method is wasteful of energy and also does not lend itself to very close control.

Laboratory tests have also shown that by proper control over the fiberizing process it is possible to make either short-fibred or long-fibred wool as desired.