Quality control during production and application of roofing materials

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QUALITY CONTROL DURING PRODUCTION AND APPLICATION OF ROOFING MATERIALS

by H.O. Laaly

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QUALITY CONTROL DURING PRODUCTION AND APPLICATION OF ROOFING MATERIALS

H. O. LAALY
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Division of Building Research.

SUMMARY

Quality control of roofing and waterproofing membranes occurs at four distinct stages: 1) characterization of raw materials with respect to degree of purity required for an established formulation prior to production; 2) control of processing and manufacturing variables during production to permit necessary corrections before defective materials are produced; 3) testing and evaluation of finished products for conformity with the established standards or as agreed upon by the supplier and purchaser; where the latter is a large company or a government agency, compliance with a specification is usually required; 4) control and inspection of workmanship quality on the job site during the application in accordance with the architect's, engineer's or project manager's detailed job specification.

Stage 3 has already been discussed in the author's previous publications. This paper highlights some of the quality control aspects and methods that could be implemented in stages 1, 2 and 4.

Die Qualitätskontrolle von Bedachungsmaterialien während der Fabrikation und der Verarbeitung

von H.O. Laaly

ZUSAMMENFASSUNG

Die Qualitätskontrolle von Bedachungs- und Abdichtungsmaterialien ist in vier verschiedene Stufen unterteilt:

1) Kennzeichnung der Rohmaterialien in Bezug auf den Reinheitsgrad für eine vor der Fabrikation vorhandenen Formulierung.

2) Kontrolle des Herstellungsverfahrens und der Produktionsvariabeln während der Fabrikation, damit die notwendigen Korrekturen unternommen werden können, bevor zu viele fehlerhafte Produkte fabriziert worden sind.

3) Prüfung und Auswertung der Endprodukte gemäss einer Normvorschrift oder einer zwischen Fabrikanten und Käufer vereinbarten Vertragsbedingung, wobei es sich beim letzteren um einen Grosskäufer oder eine Regierungsbehörde handeln kann.

4) Kontrolle und Inspektion der Verarbeitungsqualität auf der Baustelle gemäss der spezifischen Projektvorschriften durch den Architekten, den Ingineur und den Bauleiter.

Der Verfasser hat sich mit der dritten Stufe in verschiedenen früheren Publikationen befasst. Der vorliegende Artikel behandelt an Hand einiger ausgewählter Beispiele hauptsächlich die Merkmale der Qualitätskontrolle und der Verfahren, welche in Stufen 1, 2 und 4 angewandt werden können.

CONTRÔLE DE LA QUALITÉ DURANT LA FABRICATION ET LA POSE DE MATÉRIAUX DE COUVERTURE

par H.O. Laaly

RÉSUMÉ

Le contrôle de la qualité des revêtements d'étanchéité s'effectue en quatre étapes distinctes : 1) classification des matières premières selon un degré de pureté requis pour une formulation établie avant la production ; 2) contrôle du processus de traitement et de fabrication afin d'effectuer les corrections qui s'imposent avant que trop de matériaux défectueux ne soient produits ; 3) essai et évaluation des produits finis pour vérifier s'ils sont conformes aux normes établies ou convenues entre le fournisseur et l'acheteur ; si ce dernier est une grosse entreprise ou une institution gouvernementale, la conformité à une exigence est habituellement requise ; 4) contrôle et inspection de la qualité d'exécution du travail sur le site même, en conformité avec les devis de l'architecte, de l'ingénieur ou du directeur des travaux.

L'étape 3 a déjà fait l'objet de discussions dans d'autres publications de l'auteur. Cette communication met en relief certaines méthodes de contrôle de la qualité qui pourraient être mises en application aux étapes 1, 2 et 4.

QUALITY CONTROL DURING PRODUCTION AND APPLICATION OF ROOFING MATERIALS

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SUMMARY

Quality control of roofing and waterproofing membranes occurs at four distinct stages: 1) characterization of raw materials with respect to degree of purity required for an established formulation prior to production; 2) control of processing and manufacturing variables during production to permit necessary corrections before defective materials are produced; 3) testing and evaluation of finished products for conformity with the established standards or as agreed upon by the supplier and purchaser; where the latter is a large company or a government agency, compliance with a specification is usually required; 4) control and inspection of workmanship quality on the job site during the application in accordance with the architect's, engineer's or project manager's detailed job specification.

Stage 3 has already been discussed in the author's previous publications[1,2,3]. This paper highlights some of the quality control aspects and methods that could be implemented in stages 1, 2 and 4.

INTRODUCTION

Bitumen still counts as a major raw material, used widely for roofing and waterproofing. Some 60 years ago, a technician in an asphalt testing laboratory had to chew a sample from each batch of

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air-blown asphalt to determine the degree of oxidation by the extent that it stuck to his teeth. The level of heating bitumen was controlled on the job site by visually estimating the amount of smoke and vapor emitted from the kettle and detecting, with the nose, the odor of volatile components from overheated asphalt. The fingernails of the asphalt technologist were used to determine the softening point and penetration of oxidized bitumen. Evaluating it for use in roofing and waterproofing or asphalt pavement was obviously an art, rather than a science, and had to be learned over the years. All these approaches to quality control are now, it is hoped, only faded memories from the past.

With the introduction of hundreds of new roofing materials during the past two decades, the roofing industry experienced a drastic change, not only in technology but also in the utilization of various polymeric and elastomeric-based materials and synthetic fibers for production of single-ply roofing and waterproofing membranes. This roofing revolution has necessitated a completely new quality control strategy. In order to assess the purity, homogeneity, particle size or molecular weight distribution of various components of new roofing materials, several sophisticated, highly precise instruments can be employed, not only during exploration and well drilling, but also during the refining of crude oil and the production of petrochemical intermediates and various raw materials used with them. The Encyclopedia of PVC[4] is the major source of information on quality control of PVC products from raw materials to finished products. Books by Bateman[5], Morton[6] and Stern[7] constitute the present state-of-the-art and give detailed information on raw materials and processing and testing of elastomeric materials.

While the above-mentioned literature is a significant source of knowledge on testing and properties of rubber and rubber-like materials, in practice only a few test methods are suitable for quality control testing, which must be quick, specific, economic and informative. With increasing labor costs, it is now advisable to utilize some of the modern analytical instruments, depending on the type of material and information required. Some of the techniques useful for solving more complicated problems are: infrared (IR), ultraviolet (UV), atomic absorption (AA), thermogravimetric analysis (TGA), thermomechanical analysis (TMA), X-ray diffraction (XRD), X-ray fluorescence (XRF), gas chromatography (GC), gel permeation chromatography (GPC), transmission electron microscopy (TEM) and scanning electron microscopy (SEM). In industry, R&D and quality control scientists usually cooperate closely since the objectives of both teams are identical, namely, production of high quality materials with satisfactory performance at the lowest possible cost. Consequently, both can make use of the same equipment to make its purchase possible even for small companies.

Impurities in raw materials, particle size and molecular weight distribution of the resins, and processing conditions during manufacture (such as temperature, time, moisture content) all contribute to the physical, chemical and mechanical properties of finished products and could affect the performance of the final roof drastically. Some tests are applicable to more than one stage in the production and application of new roofing materials. From a wealth of quality control procedures, only a few selected examples will be described.

Raw Materials

The degree of oxidation of blown asphalt can be assessed by its ductility, viscosity, softening point and cone penetration. However, the intensity of the carbonyl band in the IR spectrum at the 5.8 μm region can, within a few minutes, provide the same information. A combination of GC with IR and/or MS sometimes is the most powerful tool to enable prediction of polymer performance, control of resin curing time, monitoring of degradation, quality control of incoming materials and analysis of competitive products. Changes in the molecular weight distribution of polymers, such as polyvinyl chloride (PVC), polyethylene (PE), polypropylene (PP), polyvinyl acetate (PVA), styrene-butadiene-styrene (SBS), chlorinated polyethylene (CPE) and polyurethane (PU), which are often used in formulation of roofing materials, are of paramount importance with respect to the properties of the finished membranes. The degree of their homogeneity and formation of a tridimensional network in asphalt affect the following properties of modified bituminous roofing membranes: tensile strength, low temperature flexibility, static and dynamic puncturing, ability of lap jointing, melt viscosity and crack bridging capability, to name just a few.

A few examples from the published literature[8], should illustrate how GPC is a valuable technique for material characterization and quality control in the polymer industry (Fig. 1). The GPC chromatogram shows that resins A and B have different molecular weight distributions. The finished products made from these two resins may look very similar, yet differ in their melting points.

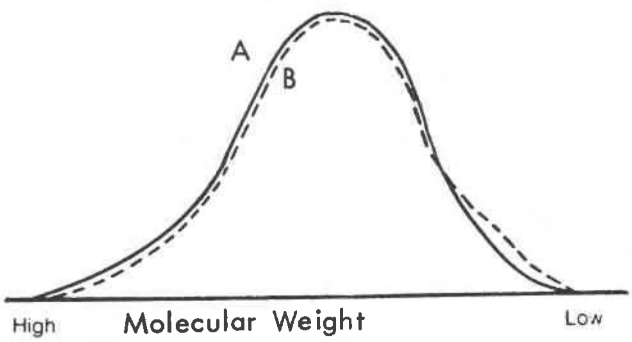

Fig. 1. Gel permeation chromatogram of resins A and B, showing molecular weight distributions[8]

Additional peaks in a chromatogram are not only indicative of impurities or additives in a resin, such as protective colloid, stabilizer, or colorant. Each peak can also be collected and identified by IR spectroscopy.

The higher the molecular weight of a resin, the higher is the strength, viscosity, required processing temperature and chemical resistance. The width of molecular weight distribution (MWD) dictates the tensile strength and also the processing behavior of the polymer (Fig. 2). Comparison of chromatograms is a kind of quality control.

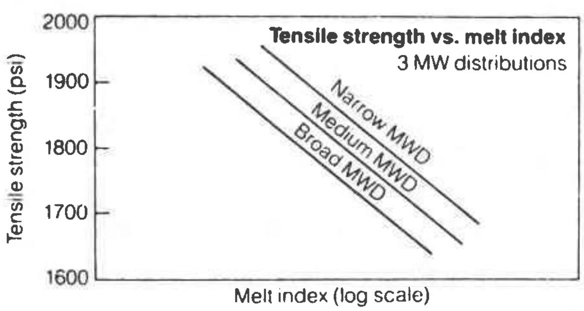

Fig. 2. Tensile strength vs melt indices[8]

The presence of unreacted monomer, low molecular weight compounds or moisture also influences the physical and processing characteristics of polymers. These entities have generally smaller molecular weight and appear near the end of the chromatogram. Using the peak height, or peak height × ½ width, their concentration can be assessed quantitatively. Sometimes calibration with internal standards is necessary.

Every component incorporated in the roofing formula requires its own specific quality control procedure. Particle size distribution of reclaimed rubber (cryogenic ground) dictates the degree of dispersion, swelling and, finally, the homogeneity of rubberized asphalt and the requirements for the level of heating and temperature during its production, since these affect the viscosity and penetration of the finished product. Synthetic rubbers, such as SBS, neoprene and butyl rubbers, have other characteristics, such as ozone resistance and iodine number, which are indicative of the degree of unsaturation.

Processing Quality Control

Degradation of polymer due to excessive processing temperature will lead to changes in its molecular weight. For example, using suitable experimental conditions and selecting the proper instrumentation variables, one can follow the stages of polyethylene oxidation, as indicated in the following chromatogram:

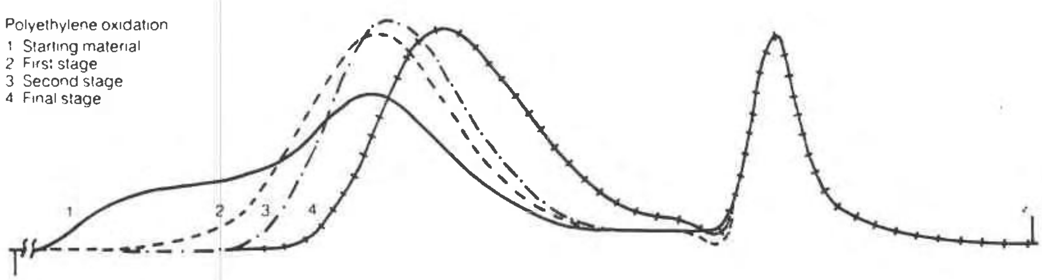

Fig. 3. Changes in molecular weight through stages of polyethylene oxidation[8]

The above chromatogram was obtained using trichlorobenzene as solvent at 135°C.[8]

Cold-applied liquid membranes must posess a certain viscosity, depending on their intended use, which could be on vertical, horizontal or sloped surfaces. In an emulsion, the surfactant must keep the product stable after at least two to three freezing and thawing cycles. Solvent-based liquid membranes must possess a reasonably fast drying time, which could vary from a few hours to a few days. As quality control, hot air oven drying at 40°C is employed. Another relatively quick quality control measure of liquid applied membranes is low-temperature flexibility (bend test) at a desired temperature. The adhesion peel test on a standardized substrate is also a very important consideration in assessing the quality of all liquid applied membranes.

Processing and quality control of prefabricated elastomeric membranes, such as ethylene-propylene dienemonomer (EPDM), poly-isobutylene (PIB), CPE, chloro-sulphonated polyethylene (CSPE), Neoprene (polychloroisoprene) and butyl rubber (whether plain or reinforced), state of curing (vulcanization) and desired flexibility of the finished membranes, vary slightly. Scorching (premature vulcanization), rate of curing (crosslinking and development of stiffness) and finally the state of optimum curing, all are stages which must be strictly controlled. Overcuring causes the material to continue to harden, the modulus to rise and tensile strength and elongation to fall. Sometimes (particularly in the case of natural rubber compounds) reversion occurs with overcuring, and modulus and tensile strength decrease. The rate at which the rubber compound is sheared or formed affects its plasticity. Processing stages (mixing, extrusion, calendering and molding) involve different levels of shear and, therefore, can be expected to affect each rubber stock differently (Fig. 4).

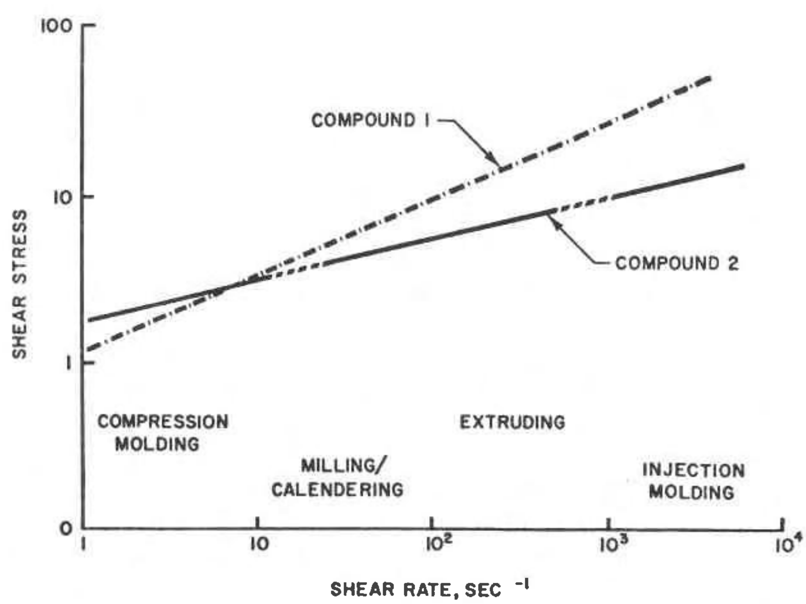

Fig. 4. Effect of shear rate on shear stress[6]

Flow resistance of compounds 1 and 2, as shown in Figure 4, varies, depending on processing. Therefore, tests to ascertain the processing characteristics of a particular stock ideally should expose the test sample to shear rates identical to those encountered in the actual process step.

The parallel plate plastometer is widely used to assess the plasticity of rubber compounds. In this device, a cylindrical preheated rubber sample, 2 cc in volume, is placed between two parallel plates and a 5 kg load is applied to it for a standard period of time, usually 3, 5 or 10 minutes. The resulting thickness of the specimen, in millimeters multiplied by one hundred, is called the "plasticity number". This method is described in detail in ASTM Method D 926. The degree of curing of rubbers is usually assessed by utilizing the Oscillating Disk Rheometer Curemeter in accordance with ASTM Method D 2084.

The use of specific indicators can often give clues to many unknown phenomena. The use of "Neocarmin" solution[9], a textile fiber indicator, with the help of a color chart, can identify many differences, such as type, surface treatment, degree of oxidation and even the morphological differences and degree of crystallinity of various resins. A UV lamp or a microscope with polarized light could be useful in quality control of raw materials and finished products.

The degree of embedment of granules on the surface of prefabricated, reinforced, modified bituminous membranes is controlled by the viscosity of the top coating, shape and size of granules and the extent of pressure applied during the calendering of the membrane. A loaded steel brush rubbing the surface of the membrane sample taken during production can give quick information about the degree of granule embedment.

Quality Control of Application (Workmanship)

Even the best membrane, if not properly applied, cannot guarantee sound roofing. For this reason, the Canadian General Standards Board Roofing Committee[10] has developed application standards for each group of materials. Every roofing project must be supervised and the inspector must be certain that all jobs are carried out as specified. Sometimes this does not happen in practice and premature failure is the result. A roofing inspector should carry with him a kit comprised of a pocket knife, suitable containers for samples, moisture detection strip, small hand saw, small hammer, pair of pliers, small hand balance, pocket calculator, camera, ruler and, finally, the job specification and drawings, along with his log book.

Preparation of roof decks or any other substrate, and exclusion of moisture in the system before and during application, are paramount. A paper indicator containing methylene blue can detect the presence of moisture.

Immediate remedial action is a requirement after the detection of faulty workmanship. There are several fast test methods available which can be carried out in the laboratory, of which three are described in this paper: granule embedment, impact and hydrostatic pressure.

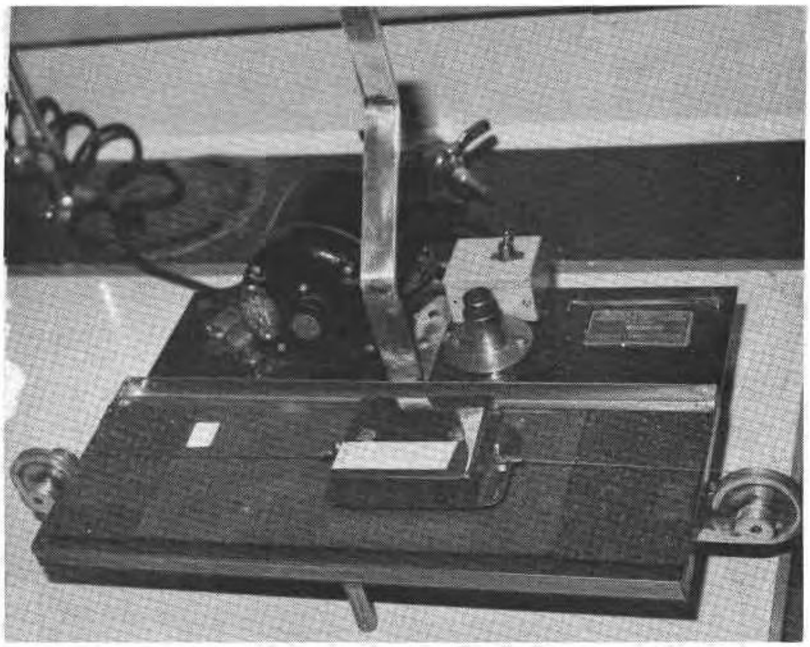

Fig. 5. Granule embedment test

A loaded, specified steel brush can be used to assess the degree of granule embedment during the manufacturing of single-ply membrane based on modified bitumen (see CGSB 37-GP-56M). The rating can measure either the weight of lost granules or percentage of exposed area after granule loss (Fig. 5).

In the dynamic puncturing test a 500-g weight is dropped on a membrane surface area of 1 cm^2 and the extent of damage is assessed (Figs. 6 and 7).

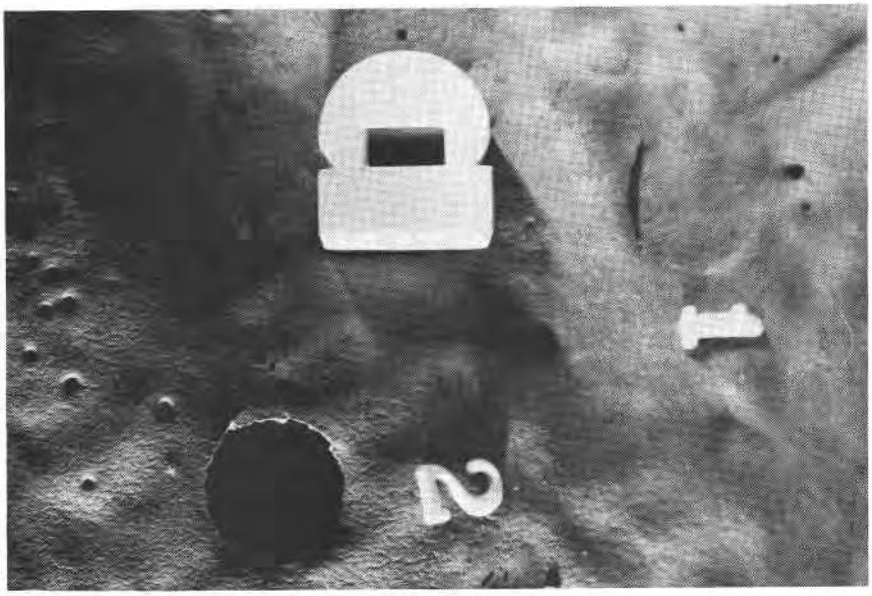

Fig. 6. Low quality coating applied on low density PU foam could not resist the impact of 500-g load from a height of 5 cm.

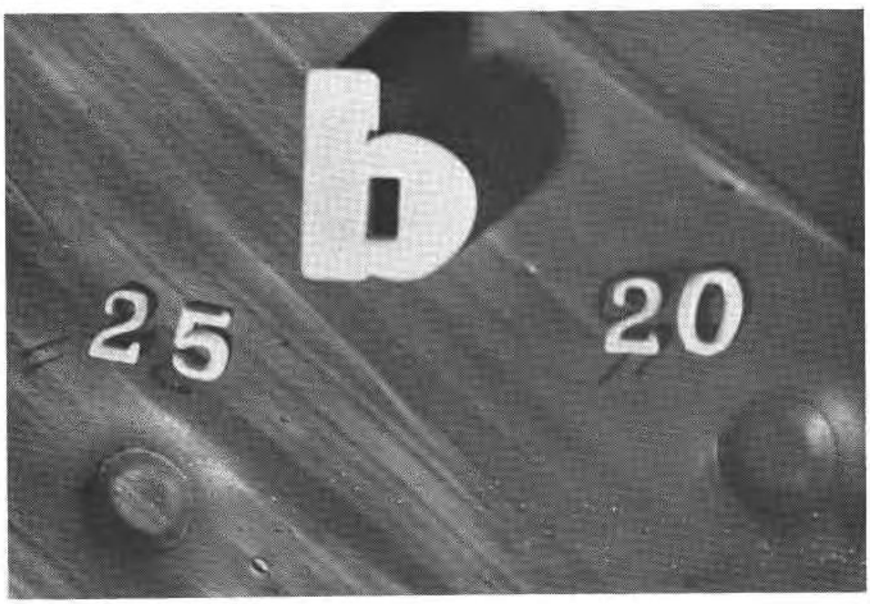

Fig. 7. A high quality liquid membrane applied on a high density PU foam was not damaged by the same test from a height of 75 cm.

A commercially available stainless steel microfiltration apparatus, capable of withstanding pressure up to 6900 Kpa could be used to test the hydrostatic pressure resistance of waterproofing membranes. However, this apparatus is too sophisticated and unnecessarily expensive for materials exposed to the low water pressures associated with buildings. Consequently, a pressure cell previously used by the Building Materials Section of DBR/NRCC was modified. The cell is made of transparent poly(methyl methacrylate), rigid enough to withstand a pressure of 21 - 28 Kpa, which is sufficient for testing waterproofing membranes. The cost is only 1/10th that of microfiltration devices.

The cell consists of a bottom and a top piece with a machined cavity about 13 mm deep and 75 mm in diameter in the center to accommodate a supporting wire mesh, a 100 mm diameter specimen, and water on top of the membrane. In the center of the bottom piece is a 7 mm depression to receive any water that passes through the membrane. The top and bottom parts are fastened together with eight 50 mm bolts, as shown on the attached drawing. A neoprene O-ring fits into grooves to hold the membrane in place and seal the cell. A hose connector for attaching the water line (preferably nylon or polyester reinforced) and a valve to maintain or release pressure are screwed into the top piece, using tape to prevent leaks.

A round 100-mm diameter specimen is cut from the membrane under test and placed on the screen support. If the sample is surfaced with mineral granules, a 7 mm wide band of silicone sealant in the form of an 82 mm ID ring is applied to the granules to make the surface of the membrane smooth where the O-ring contacts it. The cell is then assembled (Fig. 8).

A water hose is attached to the connector using a hose clamp to avoid leaks. The other end is attached to a water tap and a pressure gauge. The tap is opened and the air above the membrane replaced with water. The valve on top of the cell is then closed and the water pressure adjusted to 21 Kpa. (A water pressure regulator may be helpful.) The water tap should be closed and left for 1 hour, with occasional checks to see that the pressure is maintained. At the end of this time, the bottom of the membrane is examined through the plastic for water droplets. Determination of the presence or absence of water may be aided by disassembling the cell and placing a piece of water-test paper in contact with the underside of the membrane.

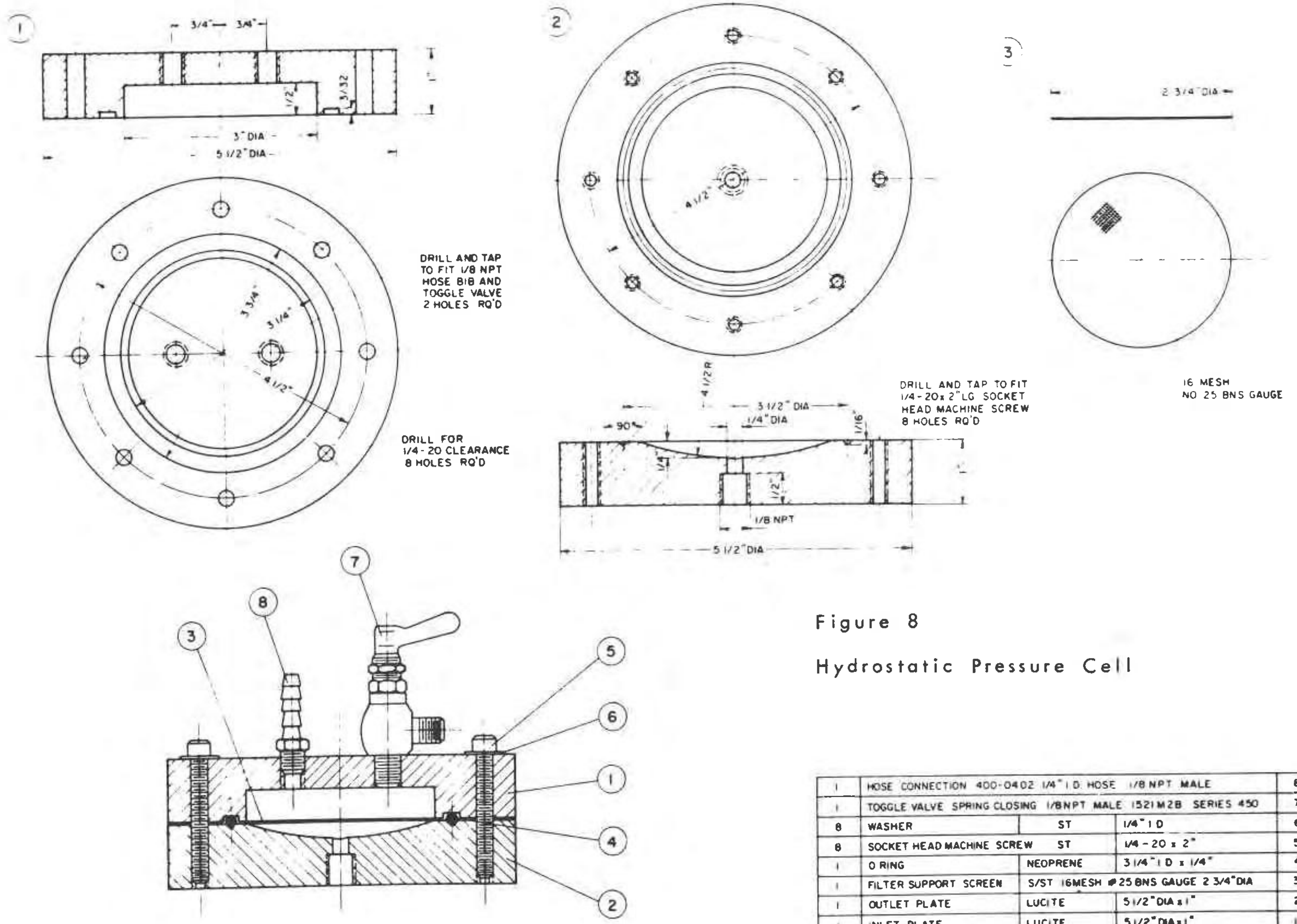

Figure 8

Hydrostatic Pressure Cell

QTY	ITEM	MAT'L	DESCRIPTION	PT NO
1	HOSE CONNECTION 400-0402 1/4" I.D. HOSE 1/8 NPT MALE			8
1	TOGGLE VALVE SPRING CLOSING 1/8NPT MALE 1521M2B SERIES 450			7
8	WASHER	ST	1/4" I.D.	6
8	SOCKET HEAD MACHINE SCREW	ST	1/4 - 20 x 2"	5
1	O RING	NEOPRENE	3 1/4" I.D. x 1/4"	4
1	FILTER SUPPORT SCREEN	S/ST 16MESH	#25 BNS GAUGE 2 3/4" DIA	3
1	OUTLET PLATE	LUCITE	5 1/2" DIA x 1"	2
1	INLET PLATE	LUCITE	5 1/2" DIA x 1"	1

The test is repeated with at least two more specimens of the membrane.

The membrane should prevent transmission of water for 1 hour at a water pressure of 21 Kpa.

CONCLUDING REMARKS

The satisfactory performance of any roofing or waterproofing project depends on proper formulation of the raw materials, and correct processing conditions to produce membranes which meet or exceed the specified values for their physical, mechanical and engineering properties, as measured by the selected test methods. The membrane must be applied according to the required application methods and job specifications. Quality control is an essential part of almost all of these stages.

Acknowledgement

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