FMP 1791

Technical Information

N-Methylpyrrolidone Handling and Storage

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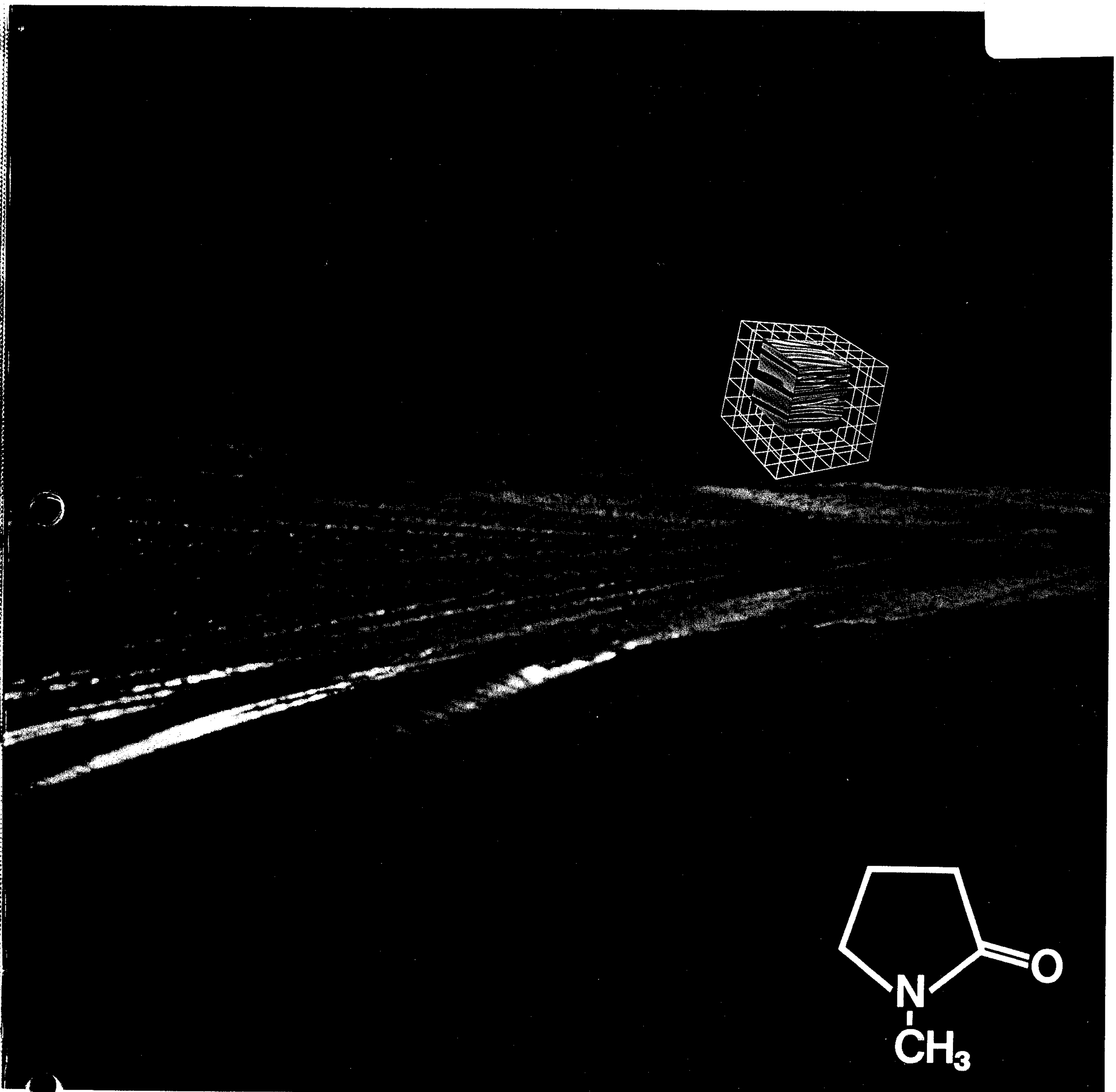

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I. Introduction

N-Methylpyrrolidone (NMP) is a highly polar, aprotic, general-purpose organic solvent. NMP is a colorless low viscosity liquid with a faint amine odor. It is miscible in all proportions with water and conventional organic solvents.

This brochure presents basic information on appropriate precautions for the safe handling and storage of NMP. Additional information on physical properties, applications and toxicology are contained in the NMP technical booklet available from BASF Corporation.

II. Handling Precautions

A. FIRE

NMP is considered a combustible material in bulk containers (larger than 55 gallons) by the U.S. Department of Transportation (DOT) because it has a flash point of 91°C (195.8°F). When ignited, NMP will sustain a fire. Handling facilities and equipment should be designed to minimize the probability of fire and should be provided with proper fire-fighting equipment. All types of fire extinguishers are effective against NMP fires. However, the dry chemical extinguisher (1) is recommended because it takes less skill to operate. Firefighters should be equipped with self-contained breathing apparatus and turn-out gear.

Water makes an effective fire extinguishing material for NMP since it is miscible in water unlike many organic solvents. Alcohol-based foam is also recommended. Early review of these precautions with the appropriate local fire fighting organization is recommended for all bulk storage locations.

Bulk storage tanks should be marked with the National Fire Protection Association (NFPA) fire hazard diamond symbol as set forth in National Fire Code Standard 704. The recommended hazard values for NMP given in the 1984 National Fire Code Guide 325M are: Fire—1; Health (under fire conditions)—2; Reactivity—0.

NATIONAL
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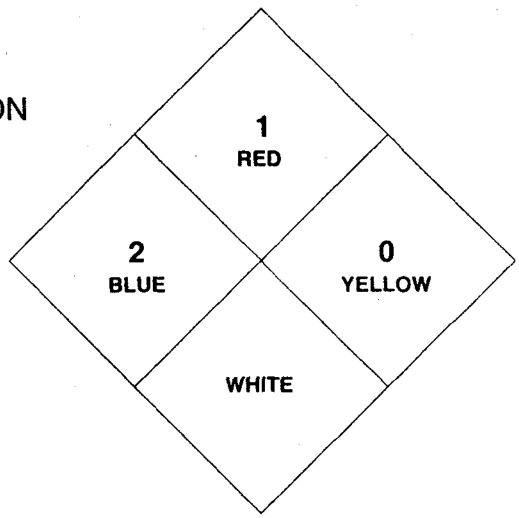

B. SAFETY PRECAUTIONS

Applicable codes which cover the storage and handling of NMP include:

1. OSHA 1910.106 (Occupational Safety and Health Administration)
2. NFPA No. 30 (National Fire Prevention Association)
3. NEC Code Article 500 (National Electrical Code)

In addition to the above, all applicable federal, state and local ordinances, the requirements of underwriters and insurance companies and the rules of good safety practices should be followed carefully.

C. PERSONAL PROTECTION AND FIRST AID

Because NMP is an eye irritant, chemical splash goggles (2) (3) should be worn when handling it. If NMP enters the eye, flush with water for at least 15 minutes, and consult a physician.

Gloves of butyl rubber (4) and FEP Teflon (5) provide the best resistance to NMP. Gloves should be rinsed following use and discarded. Butyl rubber aprons (6) may be used for splash protection, however, the PVC coatings found on much protective clothing rapidly dissolve in NMP. (Detailed information on protective clothing available in a separate technical report.)

If contact does occur, the affected area should be flushed thoroughly with water to prevent skin irritation. As a precautionary measure, remoisturize the skin with a protective ointment.

If NMP is swallowed, drink plenty of water to dilute it, force vomiting and consult a physician.

Overexposure to NMP vapors can bring about nausea, headache or dizziness. Assist—or carry—the person to the fresh air, aid in breathing if needed and consult a physician.

D. SAMPLE STORAGE

NMP samples are safely stored in clear glass bottles or steel cans with sufficient vapor space to allow for thermal expansion. Bottles should be stored in a controlled temperature environment. Polyethylene cap liners will prevent the breaking down of painted or resin coated caps or liners. Electronic grade samples should be stored in high density polyethylene bottles to avoid leaching of elemental components from glass.

E. WASTE DISPOSAL

NMP is classified as a combustible liquid. Waste NMP should be stored in approved safety-type disposal cans that are properly labeled as to their contents and hazard. NMP is highly biodegradable and may be effectively treated in an industrial wastewater treatment facility of the proper size using activated sludge technology. Similarly, regional municipal wastewater plants can often handle the normal daily discharge from NMP processing facilities. Nevertheless, disposal of NMP by these routes should not be started until approval has been obtained from responsible operators of the treatment facility.

Measures should be adopted to avoid any spills and leakage of NMP. Spills should be contained for subsequent recovery or disposal. Polyethylene or steel containers will handle many NMP wastes. Where possible, biotreatment is recommended. Additional information on the biodegradability and aquatic toxicity of NMP is given in Appendix D. Incineration in a licensed facility is also recommended. When an absorbent has been used to contain an NMP spill, it may be incinerated or buried in a licensed landfill.

III. Equipment

A. TANKS

NMP can be handled in carbon steel, stainless steel or nickel equipment. Aluminum is suitable for NMP service at ambient temperatures, only. Storage at ambient temperatures will not affect NMP. Cool storage conditions and light paint on aboveground tanks decrease evaporative losses.

Either vertical or horizontal tanks are suitable for bulk storage and may be located indoors, outdoors or underground. Location of the tank should be in a protected area and in compliance with governmental regulations and engineering practice regarding storage of bulk liquids. The tank should be 1.5 times larger than the maximum normal amount received to avoid running out of solvent.

Above ground tanks should be equipped with top and side manways. Provisions should be made for a 2-inch diameter, or larger, flanged bottom outlet as well as top connections for fill pipe, level gauge, emergency vent and a conservation vent. Dry nitrogen blanketing of storage tanks is the preferred method of moisture control. The dry nitrogen blanket is maintained at a slightly positive pressure by regulating valves so that all air is excluded. This will minimize rusting of the tank interior which may cause discoloration of the NMP. A typical unloading and storage arrangement is shown in Figure 1.

Underground storage tanks require similar connections. These tanks are more difficult to install and make it hard to detect leaks. New regulations will require monitoring ground water contamination from underground storage tanks. An outside protective coating of coal-tar epoxy or a bituminous coating is recommended. Special provision for complete tank drainage prior to cleanout is necessary in case of contamination.

Tank foundations should be in accordance with accepted engineering practices and codes. Diking of the storage area is recommended to control the spread of NMP in case of overfilling, line breaks or ruptures.

B. PIPING

Storage tanks should be equipped with a fill dip pipe that extends to within 4 inches of the bottom to prevent static electricity charges from forming. The dip pipe should be provided with a gas bleed hole near the top of the dip pipe to act as a siphon break.

ASTM A53 seamless pipe with gasketed flanges is preferred. Polytetrafluorethylene (PTFE) machined or envelope-type gaskets are suitable up to 500°F (260°C) depending on manufacturer's recommendation. Flexitallic® type gaskets should be used at higher temperatures. However, schedule 80 pipe with 3000-lb. screwed forged fittings, assembled without pipe dope and back welded, is also acceptable. All non-backwelded, screwed connections should be sealed with a PTFE thread sealant (8). For corrosion protection, underground piping should be welded and coated with asphalt or wrapped in plastic adhesive tape.

Flanged 150 psi rated carbon steel gate valves (9) (10) are recommended. Carbon steel ball valves (12) may also be used. Avoid brass or bronze valves. A wedge ring of PTFE or Kalrez® is preferred for valve stem packing.

C. HOSES

Stainless steel metal-braided hoses (13) have proved satisfactory for handling NMP. For special applications PTFE or polyethylene metal-braided hoses may also be used.

D. PUMPS

Centrifugal or positive displacement pumps are satisfactory for use with NMP. For clean solvent services, canned motor pumps (14) have been used, providing a leak-free environment from the pump.

E. PRESSURE AND VACUUM RELIEF

Storage tanks should have a pressure-vacuum relief vent to prevent the buildup of pressure as NMP is charged into and withdrawn from the tanks. A conversion-type safety vent is advisable (15). A properly-sized emergency venting device is recommended (16) to prevent injury to personnel or damage to the tank if a fire occurs.

F. TESTING

The bulk storage system, tanks and piping should be hydrostatically tested for leaks before introducing NMP. Remove all water from the system after testing and dry, prior to charging with NMP.

G. GROUND REQUIREMENTS

Each part of the NMP bulk handling system—tanks, pumps, hoses, platforms, tank cars and tank trucks—should be electrically grounded to a ground rod or other approved grounding system. This helps avoid static electricity buildup during solvent pumping operations. Wire jumpers should be installed at swing joints and other locations to provide an unbroken low-resistance ground circuit. Recommended ground resistances are shown in the following table:

SERVICE	MAX ALLOW. RESISTANCE, OHMS	GROUNDING
Motors—Hazardous Areas	3	Grounding wire in conduit with circuit connectors
Tanks and Vessels	2-5	Cable to establish ground
Pipelines With Flammables	2-5	Driven rods, cables
Tank Cars and Rails	2-5	Driven rods, cables

Adequate grounding is required for drum-loading stations, including both the drums and conveyor. The minimum size for grounding cable should be AWG No. 4.

H. NON-METALLIC MATERIALS

Several rigid plastics—UHMW polythylene, polytetrafluorethylene, nylon 6/6 and acetal copolymer—were tested by partial immersion in NMP at 49°C (120°F) for 6 weeks. All samples showed less than one percent weight gain and dimensional stability within one percent.

Several elastomers were also tested by partial immersion in NMP at 49°C (120°F) for 6 weeks. Silicone rubber and butyl rubber showed the best weight and dimensional stability. Mechanical properties tested before immersion and after drying are shown in Table 2.

Although not tested in our laboratories, Kalrez® has given good field service with NMP.

Whether the above materials will prove satisfactory for any given application depends on many factors such as the temperatures, pressure and purity of the NMP being handled as well as the processing and application of the materials. Therefore, the above report of test results should be used only as a starting point for selecting materials to be tested in specific application trials.

If it is necessary to clean or repair an NMP storage tank, all traces of the solvent, both liquid and vapor, should be removed from the whole system including the pumps, piping and associated equipment. First, the solvent is drained, then the entire system is rinsed thoroughly by filling with water and draining several times.

After the last water is drained, the entire system is purged with air. Before performing maintenance that is likely to produce sparks (welding, wire brushing, etc.) the atmosphere in the tank and in its immediate vicinity should be checked with an explosimeter (16) to make sure there are no explosive mixtures present.

Cleaning the tank from the outside is preferred. But if it is necessary to enter the tank the following additional precautions should be taken:

1. All piping to the tank is to be disconnected or capped.
2. A positive flow of fresh air is to be provided to the tank.
3. Tank oxygen content is to be tested prior to entry and monitored (18) while personnel are inside the tank.
4. Tank atmosphere is to be rechecked with an explosimeter (17) for explosive mixtures.
5. The man entering the tank is to have a safety rope and wrist straps attached. The other end of the rope is to be constantly tended by a man outside the tank who will keep the man inside the tank under observation at all times. Adequate additional personnel should be nearby if assistance is required to withdraw the man from the tank.

The interior of the tank can be cleaned by brushing down the side walls from top to bottom and removing all debris. As an aid to cleaning, either trisodium phosphate or sodium carbonate can be used in concentrations of 0.5 lbs per gallon of water. Chemical goggles (2) (3) and gloves (4) should be worn during this procedure. The cleaning solution can be flushed out with water.

Before bringing the system back on stream, it should be hydrostatically tested with water. Upon completion of the test, displace the water with nitrogen, and dry the tank.

V. Equipment Suppliers

The following represents a list of manufacturers whose products are compatible for use in NMP service. This list is not meant to be all inclusive, nor does it imply an unqualified recommendation or endorsement by BASF Corporation. There are undoubtedly other products of similar types which may be equal or better suited for this purpose.

REFERENCE NO.	VENDOR	TYPE OF SERVICE	EXAMPLE
(1)	The Ansul Company Stanton St. Marinette, WI 54143 (715) 735-7411	Dry Chemical fire extinguishers	"Purple K" potassium-bicarbonate base dry chemical
(2)	American Optical Corp. Safety Products Div. Southbridge, MA 01550 (617) 765-9711	Splash goggles	Universal
(3)	Clarkdale, Inc. RFD #4, Hillside Ave. Londonderry, NH (603) 434-1600	Splash goggles	Type 710B splash goggles
(4)	North Hand Protection Co. Siebe North, Inc. 4090 Azalea Drive P.O. Box 70729 Charleston, SC 29405 (803) 554-0660	Gloves	Butyl rubber gloves
(5)	Clean Room Products, Inc. 56 Penataquit Ave. Bay Shore, NY 11706 (516) 588-7000	Gloves	FEP Teflon gloves
(6)	Record Industrial Co. P.O. Box 407 1020 Eighth Ave. King of Prussia, PA 19406 (215) 337-2500	Protective clothing	Butyl rubber aprons
(7)	Carboline 350 Hanley Industrial Ct. St. Louis, MO 63144 (314) 644-1000	Finish coatings	Inorganic zinc Primer—carbo Zinc II Carboline 190 HB
(8)	Permacel U.S. Route 1 New Brunswick, NJ (201) 524-5000	Pipe thread lubricant and sealer	Ribbon dope PTFE type—model P412
(9)	Pacific Valves, Inc. 3201 Walnut Avenue Long Beach, CA 90801 (213) 426-2531	Gate valves over 3"	Model 150-2

REFERENCE NO.	VENDOR	TYPE OF SERVICE	EXAMPLE
(10)	Henry Vogt Machine Co. P.O. Box 1918 Louisville, KY 40201 (502) 634-1511	Gate valves ½–2″	Forged steel gate valve model 353
(11)	Alemite Pump Co. (Standard Supply and Hardware, Inc.) P.O. Box 73941 Baton Rouge, LA 70807 (504) 356-5211	Pneumatic driven pump for drum unloading	Model 7861B-304SS Dip Pipe, Teflon internals, 9 GPM capacity with 100 psi air
(12)	Marpac Division of Mark Controls Corp. 1900 Dempster St. Evanston, IL 60204 (312) 647-1500	Ball valves	Carbon steel model CS-C470TT
(13)	Goodall Rubber Co. P.O. Box 8237 Trenton, NJ 08650 (609) 587-4000	Hoses	Metal-braided stainless steel hoses
(14)	Lawrence Pump & Engine Co. 300 Canal St. Lawrence, MA 01842 (617) 685-5145	Canned motor pumps	A1 Series canned centrifugal pump
(15)	The Protectoseal Co. 225 W. Forest Ave. Bensenville, IL 60106 (312) 595-0800	Conservation vent with flame arrester	Series No. 830
(16)	Groth Equipment Corp. P.O. Box 15293 1202 Hahlo Houston, TX 77020 (713) 675-6151	Emergency vents	
(17)	Mine Safety Appliances 230 N. Braddock Ave. Pittsburgh, PA 15208 (412) 273-5000	Explosimeters	Explosimeter model 2A, P/N-89220
(18)	Mine Safety Appliances 230 N. Braddock Ave. Pittsburgh, PA 15208 (412) 273-5000	Oxygen analyzers	Portable oxygen indicator model E, P/N-77600

Assay of NMP by Gas Chromatography

This method is used to determine the assay of NMP by means of a gas chromatographic analysis.

The following labware and reagents are required for this method of determination:

1. One gas chromatograph equipped with a FID detector.
2. One 2m glass column (ID 2mm)
3. 15% carbowax 20M + 3% KOH on Chromosorb P/DMCS column packing
4. One 10 microliter syringe

The procedure for the determination of the assay of NMP is as follows:

1. Gas chromatograph conditions:

Initial temperature	150°C
Final temperature	220°C
Initial hold	1 minute
Final hold	10 minutes
Rate	16°C/minute
Carrier Gas (Helium)	1.8 liters/hour

2. Allow the Gas Chromatograph to reach equilibrium
3. Inject 2 microliters of sample
4. Components sequence:

	Relative Retention Time
GBL*	0.56
NMP	1.00

Titration of Aqueous Methylamine Solutions

This method is used to determine the amine content of aqueous solutions by means of titration with 1 N hydrochloric acid.

The following labware and reagents are required for this method of determination:

1. 1 N Hydrocholoric Acid
2. One Erlenmeyer flask (250 mls.)
3. Methyl red indicator
4. One burette (50 mls.) with 1/10 ml. scale divisions

* GBL is the BASF abbreviation for Gamma Butyrolactone.

The procedure for the determination of the methylamine content is as follows:

1. Dilute 20.0 mls. of 1 N HCL with about 20 mls. of water in an Erlenmeyer flask
2. Weigh in 1-2g of the solution to be tested
3. Add several drops of methyl red indicator
4. Titrate with 1 N HCL until the color changes from yellow to red
5. The amount of methylamine is calculated from the following:

$$\% \text{ Amine} = \frac{(\text{Initial mls. HCL} + \text{Consumption of HCL}) \times 3.106}{\text{weight of sample}}$$

Additional analytical methods available on request.

I. INTRODUCTION

Biodegradation refers to the biological (usually bacteria) catalyzed breakdown of organic chemicals. When dissolved oxygen is present as it typically is in a biologically healthy stream or river, the end products are carbon dioxide and water. In practice, complete oxidation is rare. More commonly, a partial breakdown occurs resulting in the formation of CO_2, H_2O, and metabolites.

Most chemicals will cause environmental damage if released untreated. The damage can take many forms depending on the chemical involved. Direct toxic effects may take the form of:

a. poisoning of aquatic species through short single dose exposure (acute toxicity)

b. poisoning of aquatic species due to persistent non-degraded toxicants (chronic toxicity)

c. poisoning of higher members of the food chain through bioaccumulation in aquatic species

Indirect toxic effects may take the form of:

a. oxygen demand overloading causing dissolved oxygen levels in the water to be depleted below levels needed by typical species of fish

b. high algal growth rates resulting in lake eutrophication

Prevention of future damage requires minimizing both the amount and toxicity of those wastewater discharges.

The need for treatment of chemicals prior to their release is obvious. In turn, this makes the need for a means of predicting the degree of treatment obvious. However, considering the wide range of circumstances that could be applicable, the form of the measurements needed to make these predictions is far from obvious. Our measurement, biodegradability, is not an absolute intrinsic property. Its value, and the method involved in determining that value, is dependent on the anticipated conditions which have necessitated the treatment. For example, a chemical which might be inadvertently released to a receiving water (a spill) would have different properties of interest than a chemical intentionally released to a wastewater treatment plant (aquatic toxicity vs. BOD). Similarly, the levels of treatment required and the ultimate efficiency of treatment achieved would differ as would the tests required to measure them.

II. MEASURES OF BIODEGRADABILITY

Biodegradability is a function of the type and amount of bacteria available, the structure of the chemical being treated, various environmental factors (oxygen, pH, etc.), and the contact time. Different treatment situations will involve different combinations of the above. Thus, it is understandable that many different types of tests exist.

Primary biodegradability was an early test method established to measure the loss of a particular property of interest (surface tension or foaming). This test used high concentrations of acclimated bacteria. Contact times are on the order of one day. Since only a small structural change is required in the test chemical to cause loss of a physical property, this type of test generally gives very extensive biodegradability even though most of the molecular makeup of that chemical remains untouched. For this reason, this type of test has fallen out of use.

The familiar BOD (Biological Oxygen Demand) test is an example of a respirometric (oxygen consumption) measurement of biodegradability. By measuring oxygen consumption, these tests provide a better indication of the extent of degradation of the chemical structure than does loss of a property of the chemical. These tests are often reported as percentages of theoretically complete oxidation (ThOD); accordingly, the biodegradability values are generally lower even though the extent of treatment may often be greater. This type of test varies in the conditions under which it is run, however, it is generally run with low concentrations of bacteria which may or may not be acclimated (adapted to the chemical) and contact times on the order of 1-5 days. The BOD test is the most commonly used test to describe wastewater treatment plant performance.

A third general type of test takes the respirometric test a step further by increasing the contact time to 30 days or longer (virtually insuring that the bacteria are acclimated). The objective of this test is to measure the ultimate biodegradability (greatest possible extent of degradation). This testing simulates the environmental fate of chemicals in a receiving water. The biodegradability values are usually higher than the shorter term BOD type tests.

Biodegradability can also be measured by monitoring other properties or descriptions of the test chemical. Chemical Oxygen Demand (COD) measures (for practical purposes) the complete oxidation of a chemical to CO_2 and H_2O. Thus, biodegradability measured by COD is generally lower than by any other test. The ratio of the BOD to COD gives the percentage of the molecule that can be biologically oxidized. A value of 0.3 or greater is considered good.

Total Organic Carbon (TOC) is sometimes used to describe a molecule. Values of biodegradability obtained by monitoring this parameter generally lie between BOD and COD values.

Obviously, it is essential that the test conditions be specified when citing biodegradability numbers. When comparing values from different sources it is vital to insure that the values are describing the same test.

III. MEASURES OF AQUATIC TOXICITY

The harmful effect of a chemical released into a receiving water is dependent on its concentration in that water. All chemicals are toxic if their concentration is high enough. Therefore, it is necessary to determine a "safe" concentration. The tests for doing this generally use various forms of aquatic life as indicators of toxicity. The values reported usually show the chemical concentration at which 50% of the test organisms would be expected to die. The common term for this is the LD-50. Because the life forms used in this testing vary greatly in their sensitivity to chemicals, the tests results also vary greatly. Again, it is important to specify the conditions used in the test and to make sure that conditions are identical when comparing values. In general, LD-50 values <10 ppm are considered toxic. Values between 10 and 100 ppm are somewhat toxic and values >100 ppm are "non-toxic."

IV. NMP BIODEGRADABILITY

River die-away tests were conducted by Chow & Ng (1). These tests simulate the fate of a compound in a receiving water. Using an initial concentration of 100 ppm NMP, they found 95% removal as measured by specific compound analysis and 45% removal as measured by COD. These determinations were conducted after two weeks exposure. The low COD removal compared to the specific compound removal indicates a high degree of molecular modification (probably nitrogen-carbonyl bond splitting) and a lesser amount of mineralization (conversion to CO_2 and H_2O). Thus, while the compound was no longer present as NMP, the compound was still present as modified fragments.

An additional test by the same people using a semi-continuous activated sludge system acclimated for five days showed 7 day biodegradability of 95% by specific analysis.

In similar tests, Matsui (2) used a semi-continuous system to measure TOC, COD, and specific compound (by GC) removals. These results all showed >92% removal (regardless of the parameter being measured) within 24 hours starting with concentrations ranging from 92 ppm to 210 ppm NMP.

Rowe and Tullos (3) studied biodegradability of NMP in acclimated and unacclimated, static and continuous flow, laboratory activated sludge systems. The tests were run at 300 and 1000 ppm of NMP; the continuous cells had an 18-hour hydraulic residence time. The results indicate that NMP was largely degraded (more than 98 percent destruction with 90 percent TOC reduction in the continuous cells), and that significant acclimation is easily achieved (more than 75 percent TOC reduction in 24 hours in unacclimated static tests).

Respirometric tests provided by BASF show a BOD-5 (acclimated) of 1.2 wt/wt. Compared to the Theoretical Oxygen Demand (ThOD = COD) of 2.18, this gives a BOD/COD ratio of 0.55 which is quite biodegradable.

As an indication of the impact of NMP on an activated sludge treatment system, the *Handbook of Environmental Data* (3) lists a no-effect level (LD-0) for NMP using the bacterium Pseudomonas as 5 g/1. This demonstrates that NMP is non-toxic to treatment systems even at fairly high concentrations. BASF AG tests indicate that activated sludge wastewater treatment systems will continue to function efficiently at NMP concentrations at least as high as 2000 ppm.

BOD tests conducted by BASF show that using unacclimated bacteria, NMP is biodegradable (BOD-5 = 0.76). However, acclimation significantly increased the biodegradability; BOD-5 = 1.15 wt/wt. Long term BOD tests show substantial biodegradability BOD-20 = 1.2 wt/wt.

All of the above tests show that in acclimated systems or systems that could acclimate during the normal contact time (as in the case of a spill to a receiving water), NMP is readily biodegradable. There are indications that in unacclimated, short contact time systems (single dose exposure in municipal treatment plants) NMP would not be significantly degraded.

V. AQUATIC TOXICITY

GAF data for various species of fish list the LC-50 as ranging from 832-3048 ppm. Even the lowest value is well within the "non-toxic" range.

VI. CONCLUSIONS

NMP is nearly non-toxic to most aquatic life and can be readily degraded by typical wastewater treatment plant organisms. It is, accordingly, an advantageous solvent to use whenever any possibility of discharge with an aqueous stream exists.

REFERENCES

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(2) "Activated Sludge Degradability of Organic Substances in the Waste Water of the Kashima Petroleum and Petrochemical Industrial Complex in Japan," S. Matsui, T. Murakimi, T. Sasaki, Y. Hirose, and Y. Iguma, *Progress in Water Technology, Vol. 7,* Nos. 3/4, pp. 645-659 (1975).

(3) "Lube Solvents No Threat to Waste Treatment," E. H. Rowe and L. F. Tullos, Jr., *Hydrocarbon Processing, 59,* pp. 63-65 (October 1980).

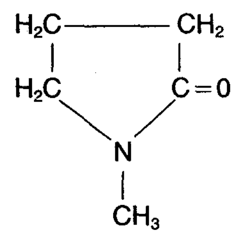
(4) *Handbook of Environmental Data on Organic Chemicals.* 2nd Ed., Karel Verschueren, Van Nostrand, Reinhold Co., N.Y. 1983, p. 873.

TABLE 1

n-METHYLPYRROLIDONE
PHYSICAL PROPERTY DATA

FORMULA: C_5H_9NO

STRUCTURE:



	CGS	ENGLISH	SI
MOLECULAR WEIGHT:	99.1	99.1	99.1
DENSITY – LIQUID (20°C)	1.03 gm/cc	64.3 lb/ft^3	1,030 kg/m^3
(40°C)	1.02 gm/cc	63.6 lb/ft^3	1,020 kg/m^3
(60°C)	0.99 gm/cc	61.8 lb/ft^3	990 kg/m^3
BOILING POINT (760 mm Hg)	203°C	397°F	476°K
FREEZING POINT (760 mm Hg)	−23.5°C	−10.3°F	249.6°K
VISCOSITY (20°C)	1.7 cp	4.11 lb/ft-hr	1.7 mPa-s
(50°C)	1.0 cp	2.41 lb/ft-hr	1.0 mPa-s
(80°C)	0.9 cp	2.17 lb/ft-hr	0.9 mPa-s
HEAT OF VAPORIZATION (100°C)	122 cal/g	219 Btu/lb	510 kJ/kg
SPECIFIC HEAT – LIQUID (0°C)	0.401 cal/g-°C	0.401 Btu/lb-°F	1.68 kJ/kg-°K
(50°C)	0.465 cal/g-°C	0.465 Btu/lb-°F	1.89 kJ/kg-°K
(100°C)	0.502 cal/g-°C	0.502 Btu/lb-°F	2.10 kJ/kg-°K
SPECIFIC HEAT – VAPOR (25°C)	0.301 cal/g-°C	0.301 Btu/lb-°F	1.26 kJ/kg-°K
VAPOR PRESSURE – (40°C)	1.0 Torr	0.02 psi	133 Pa
(60°C)	3.5 Torr	0.07 psi	465 Pa
(80°C)	9.5 Torr	0.19 psi	1270 Pa
REFRACTIVE INDEX	1.4700	1.4700	1.4700
HEAT OF COMBUSTION	7.29 kcal/g	13,100 Btu/lb	30,500 kJ/kg

TABLE 1 (Continued)

	CGS	ENGLISH	SI
FLASH POINT (ASTM-D 93-72)	91°C	196°F	364°K
IGNITION TEMP. (ASTM-D 286-58 T)	270°C	518°F	543°K
FLAMMABLE LIMITS IN AIR			
UPPER	9.5 vol %	9.5 vol %	9.5 vol %
LOWER	1.3 vol %	1.3 vol %	1.3 vol %
THERMAL CONDUCTIVITY (25°C)	1.63 W/cm-°C	1.13 Btu-in/ft.^{2} hr°F	0.163 W/m°K
HANSEN SOLUBILITY parameters:			
δd	8.8 $(cal/cm^3)^{\frac{1}{2}}$		18.0 $(J/cm^3)^{\frac{1}{2}}$
δp	6.0 $(cal/cm^3)^{\frac{1}{2}}$		12.3 $(J/cm^3)^{\frac{1}{2}}$
δh	3.5 $(cal/cm^3)^{\frac{1}{2}}$		7.2 $(J/cm^3)^{\frac{1}{2}}$
δo	11.2 $(cal/cm^3)^{\frac{1}{2}}$		22.9 $(J/cm^3)^{\frac{1}{2}}$

KAURI-BUTANOL VALUE
(ASTM D1133-83) > 300

Additional physical properties can be found in the NMP Technical Booklet available from BASF Corporation.

TABLE II

ELASTOMER MECHANICAL PROPERTIES

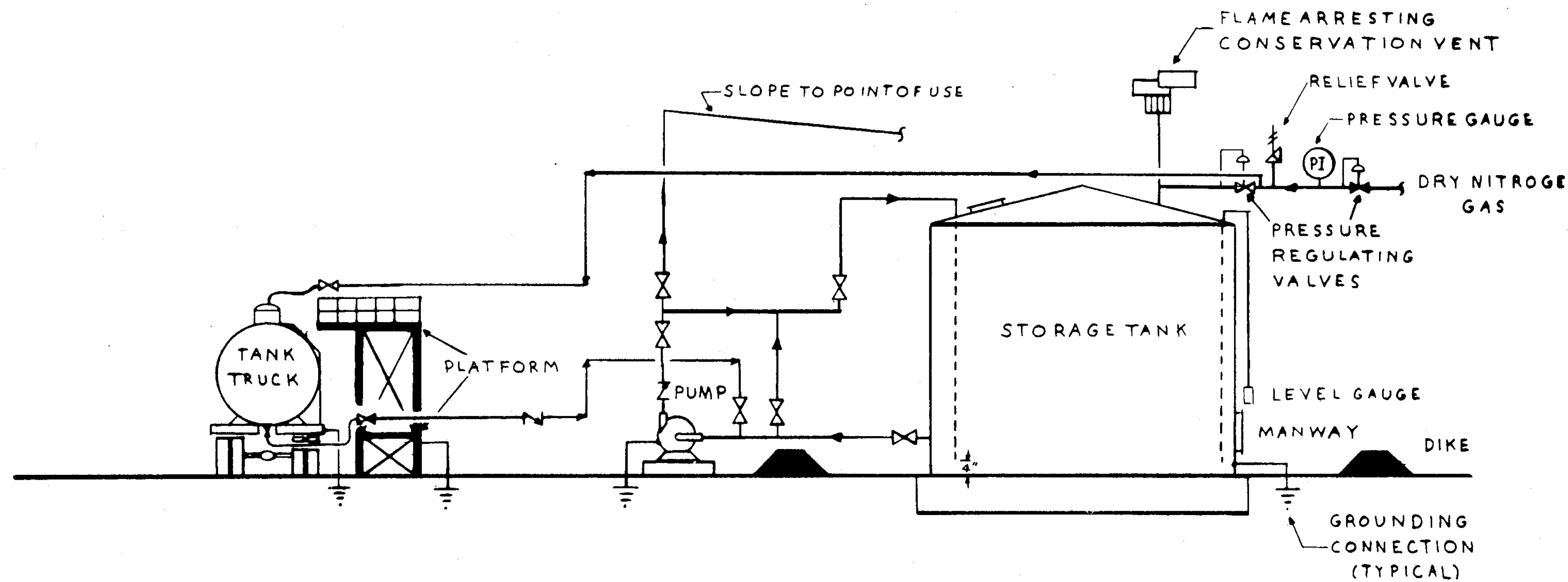
Results of Material Resistance to NMP
(6 Weeks Immersion @ 120°F)

MATERIAL	INITIAL WT. (G)	FINAL WT. (G)	Δ WEIGHT	% Δ WEIGHT	DIMENSION BEFORE (CM)	DIMENSION AFTER (CM)	TOTAL LOSS	TOTAL GAIN
1) CELCON®	95.8334	96.7680	0.9346	0.98	3.0 × 11.5 × 1.93	3.0 × 11.5 × 1.56	—	0.026
2) TEFLON®	16.8372	16.8394	0.0022	0.013	3.2 × 10.1 × 0.241	3.2 × 10.1 × 0.241	—	—
3) NYLON (ROD)	15.8448	15.9256	0.0808	0.51	1.3 × 10.2 × 1.300	1.3 × 10.2 × 1.290	0.01	—
4) TIVAR®	28.9250	29.1876	0.2626	0.91	2.6 × 10.2 × 1.204	2.6 × 10.3 × 1.209	—	— × 0.1 × 0.005
5) NYLON (SHEET)	31.0453	31.1811	0.1358	0.44	3.6 × 10.5 × 0.711	3.6 × 10.5 × 0.714	—	0.1 × — × 0.003
6) PVC	17.3684	—	—	—	3.5 × 11.7 × 0.301	—	—	—
7) EPDM	13.5350	12.4198	−1.1152	−8.2	3.8 × 10.2 × 0.331	3.6 × 9.8 × 0.309	0.2 × 0.4 × 0.022	—
8) NEOPRENE (R-30)	17.7365	23.5720	6.8355	39.0	4.0 × 10.4 × 0.354	—	—	—
NEOPRENE (R-30)	17.7365	18.2105	0.4740	2.7	4.0 × 10.4 × 0.354	3.9 × 10.4 × 0.324	0.1 × — × 0.03	—
9) GUM RUBBER	27.2070	31.9650	4.7580	17.5	4.0 × 10.3 × 0.683	4.3 × 10.3 × 0.719	—	0.3 × 0.5 × 0.036
10) NEOPRENE (R-41)	8.2889	9.1755	0.8866	10.7	3.9 × 10.1 × 0.165	—	—	—
NEOPRENE (R-41)	8.2889	7.1048	−1.1841	−14.3	—	3.6 × 9.5 × 0.160	0.3 × 0.6 × 0.005	—
11) BUTYL RUBBER	39.1515	40.8792	1.7277	4.4	4.4 × 10.2 × 0.640	4.4 × 10.3 × 0.665	—	— × 0.1 × 0.025
12) MYLAR®	0.6565	0.7224	0.0659	10.0	3.9 × 10.1 × 0.013	3.8 × 10.2 × 0.013	—	—
13) VITON®	12.2540	25.5317	13.2777	108.0	4.0 × 10.3 × 0.162	—	—	—
VITON®	12.2540	14.2267	1.9727	16.1	4.0 × 10.3 × 0.162	4.4 × 11.0 × 0.134	—	0.4 × 0.7 × 0.03
14) HYPALON®	9.0964	10.3928	1.2964	14.3	3.9 × 10.2 × 0.170	—	—	—
HYPALON®	9.0964	8.2690	−0.8274	−9.1	3.9 × 10.2 × 0.170	3.7 × 9.8 × 0.167	0.2 × 0.4 × 0.003	—
15) SILICONE	8.1632	8.2814	0.1182	1.45	4.2 × 10.3 × 0.158	4.2 × 10.3 × 0.157	0.001	—

Detailed information is available in a separate technical report.

NOTES:

1. THIS SKETCH IS FOR REFERENCE ONLY AND IS NOT INTENDED TO BE USED FOR DESIGN OR INSTALLATION.



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	CHIEF ENGR.		

TITLE

STORAGE AND HANDLING SYSTEM SCHEMATIC DIAGRAM

LOCATION	CLASSIFICATION

BASF Corporation

APPR. NO.	
PROJ. NO.	
JOB NO	
SCALE	

DRAWING NUMBER	REV.
FIGURE 1	0