UNIVERSITY OF ALBERTA

MEASUREMENT OF URINE OUTPUT VOLUME: ACCURACY OF DIAPER WEIGHTS IN NEONATAL ENVIRONMENTS

BY

MIRIAM D. FOX

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS OF SCIENCE

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Mona Serenius, M.A.
Managing Editor
Acta Paediatrica Scandinavica

Dear Ms. Serenius,

I am currently a graduate nursing student at the University of Alberta (Edmonton, Alberta). In the preparation of my thesis work (Measurement of Urine Output Volume: Accuracy of Using Diaper Weights in Neonatal Environments), I am commenting on the fluid balance of the neonatal patient. Therefore, I am writing to request permission to include in my thesis an informational figure and table based on work published in Acta Paediatrica Scandinavica. The University of Alberta requires permission from the publisher to include copyrighted material because all theses are microfilmed.

I have adapted the figure found on page 50 of the article *Changes in Body Water Compartments During Growth* by B. Friis-Hansen (Volume 46, Supplement 110, 1957, pp. 1-68). I have also adapted the table found on page 725 of the article *Transepidermal Water Loss in Newborn Infants. VIII Relation to Gestational Age and Post-natal Age in Appropriate and Small for Gestational Age Infants* by K. Hammarlund, G. Sedin, and B. Stromberg (Volume 72, 1983, pp. 721-728). Please find enclosed a copy of my adaptation of this information.

Thank you for your consideration of this matter. I look forward to your response.

Sincerely,

Miriam Fox

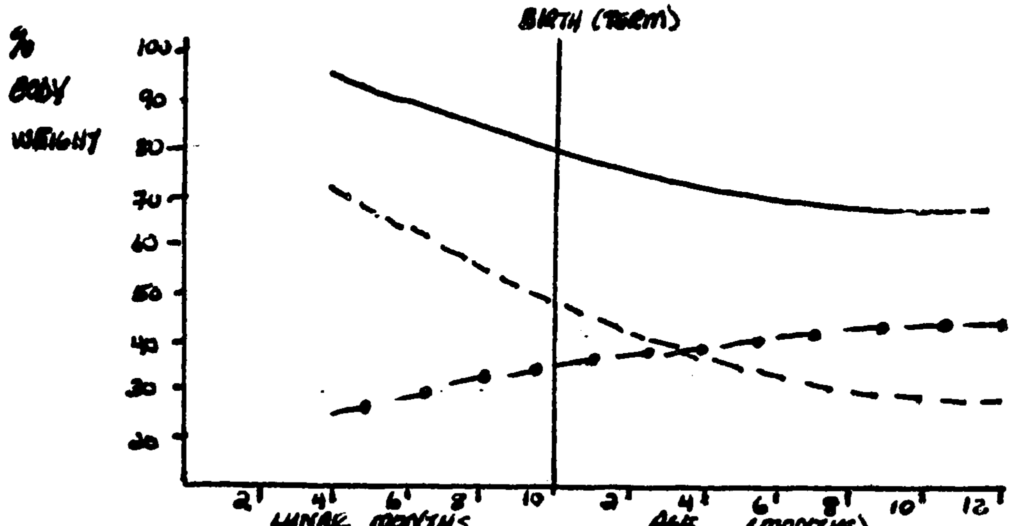
Miriam D. Fox

Permission granted
90-08-08

ADAPTED TABLE & FIGURE — MIRIAM KOX -EDMONTON

FIGURE ONE

Changes in Body Fluid of the Fetus and Infant[b]



b Modified From: "Changes in Body Water Compartments During Growth" by B. Friis-Hansen, 1957, Acta Paediatrica Scandinavica, 46, (Suppl. 110).

TABLE ONE

Mean Insensible Water Loss from the Skin of Infants Appropriate for Gestational Age at an Ambient Humidity of 50%[a]

Gestational Age (weeks)	Mean Birth Weight (kg)	IWL (g/kg/24 hours) Postnatal Age (days) <1	7	14	21	28
25-27	0.860	129	43	32	28	24
28-30	1.340	42	24	18	15	15
31-36	2.110	12	12	9	8	7
37-41	3.600	7	6	6	6	7

a Adapted From: "Transepidermal Water Loss in Newborn Infants. VIII. Relation to Gestational Age and Post-natal age in Appropriate and Small for Gestational Age Infants" by K. Hammarlund, G. Sedin, and B. Stromberg, 1983, Acta Paediatrica Scandinavica, 72, p. 725.

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THE UNDERSIGNED CERTIFY THAT THEY HAVE READ, AND RECOMMEND TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH FOR ACCEPTANCE, A THESIS ENTITLED *MEASUREMENT OF URINE OUTPUT VOLUME: ACCURACY OF DIAPER WEIGHTS IN NEONATAL ENVIRONMENTS* SUBMITTED BY *MIRIAM D. FOX* IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF NURSING.

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DATE: October 3, 1990

DEDICATION

"PUT YOUR GIFTS AT THE SERVICE OF ONE ANOTHER, EACH IN THE MEASURE HE HAS RECEIVED"

1 PETER 4:10

THIS WORK IS DEDICATED TO ALL THOSE PEOPLE WHO HAVE ASSISTED MY RESEARCH EFFORTS.

THANK YOU LOREN, MARION, KAREN M., RUTH, LOUISE, PAUL, JOHNY, ANN, KAREN B., SELLIKE, MIKE, JOHN, AND GARRY.

ABSTRACT

In the neonatal patient, urine volume is an important parameter in the determination of both renal function and fluid balance. Weighing diapers prevoiding and postvoiding has been suggested as a method to measure urine volume. However, the exchange of moisture in neonatal warming environments may influence the accuracy of this method.

In this study, the accuracy of diaper weights to reflect urine volume was tested in simulation environments with different diaper combinations. The rate of moisture exchange from diapers was determined by sequential weights of 10 samples of five diaper types in four different environments adding either 5 millilitres (ml) or 15 ml of added 0.45% saline solution (400 samples). The diaper types used were of two fibre types, disposable and cotton. These included, open cotton with burn sheeting, open cotton, closed cotton terrycloth, open superabsorbent disposable, and closed superabsorbent disposable diapers. Experimental conditions included an incubator set at 36.0°C with added humidity, an incubator set at 33.5°C, a radiant warmer set at 75% heater output, and a radiant warmer set at 50% heater output.

Multivariate analysis of variance for repeated measures demonstrated significant mean differences attributable to the effects of diaper type, environment, volume, time, and interaction effects ($p < .01$). Analysis of mean percentage differences showed that closed disposable diapers were the most accurate, exhibiting less than a 4% variation in weight in all environments. Closed terrycloth diapers showed the greatest variation for all diaper types. The samples with 5 ml of solution added showed a greater mean percentage loss than those with 15 ml added. All diaper types gained weight in the incubator set at 36.0°C with added humidity environment. All diapers lost weight in the remaining environments with the greatest change occurring in the 75% heater output radiant warmer environment.

For accurate determination of urine output volume using diaper weights, it is recommended that closed superabsorbent disposable diapers be used. Open superabsorbent disposable diapers represent the next best alternative. If cotton diapers are used, it is recommended that the diaper be checked for urine every 15 minutes.

ACKNOWLEDGEMENT

THE AUTHOR GRATEFULLY ACKNOWLEDGES THE RECEIPT OF A GRANT FROM THE NATIONAL ASSOCIATION OF NEONATAL NURSES IN SUPPORT OF HER RESEARCH.

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CHAPTER ONE

Introduction

Background and Statement of the Problem

Advances in neonatal intensive care and improved survival rates for high risk infants highlight the importance of fluid balance in this population (Oh, 1988). Fluid balance management in neonates is problematic particularly for those infants delivered at less than 30 weeks gestational age because their unique characteristics render them susceptible to fluid and electrolyte disturbances (Bell & Oh, 1979; Roy & Sinclair, 1975). Successful fluid and electrolyte management can influence the outcome of many neonatal illnesses (Bell & Oh, 1987). Investigators suggest that complications of premature birth such as impaired ventilation, patent ductus arteriosus, and bronchopulmonary dysplasia can be related to overhydration (Brown, Stark, Sosenko, Lawson & Avery, 1978; Bell, Warburton, Stonestreet & Oh, 1980; Green, Thompson, Johnson & Lock, 1983; Stevenson, 1977; Van Marter, Leviton, Allred, Pagano & Kuban, 1990). Dehydration may cause poor perfusion, acidosis, hypernatremia, and cardiovascular collapse (Williams & Oh, 1974).

The significance of urine output monitoring in the neonate is based upon fluid balance knowledge. Accurate measurement of urine is necessary to determine both renal function and fluid balance (Strauss, Zilleruelo & Freundlich, 1985). The measurement of neonatal urine output can be difficult and collection methods including catheters, perineum bags, and weighing diapers have been used. A bladder catheter may be difficult to insert in small, immature infants. Also, it is not an ideal method of urine collection over prolonged periods of time because it may predispose to infection. Plastic bags that attach to the perineum with adhesive are also used to collect urine. However, they leak frequently due to areas that have not adhered to the skin and repeated applications can result in excoriated skin. The skin of very immature infants is particularly vulnerable to adhesive damage even after one application because the bond between the adhesive and the stratum corneum may be stronger than the one between the dermis and epidermis (McManus-Kuller, 1984). Therefore, the skin may be damaged with bag removal.

Weighing diapers prevoiding and postvoiding is a method of urine output measurement that can be used for all sizes of infants for long periods of time without skin damage. It is recommended as a method of urine volume measurement in neonates by several nursing texts on fluid and electrolyte balance (Hollingsworth, 1985; Masiak & Naylor, 1985; Metheny, 1987). Weighing diapers to determine urine output is based on the principle that 1 millilitre (ml) of urine weighs 1 gram (gm). The change in postvoiding diaper weight is attributed to the urine added to the diaper by the infant.

If the moisture exchange properties of the environments neonates are nursed in are not considered, weighing diapers may be an inaccurate method of urine volume measurement. Evaporation of fluid from diapers in warming environments may decrease significantly the measured urine volume when compared to the actual urine output. In very humidified environments, measured urine volume could overestimate urine output. Fluid therapy based on these measurements could result in dehydration or overhydration. Therefore, the use of diaper weights to determine urine output accurately in different neonatal warming environments should be examined.

Purpose of the Study

The purpose of this study is to describe the relationship between urine volume, length of exposure to specific environmental conditions—incubator or radiant heater—, type of collecting diaper, and accuracy of urine volume measurement.

Research Questions

The research questions formulated to guide this study are as follows:

1. How does an incubator environment affect the accuracy of using diaper weights to determine a measured amount of 0.45% saline solution over time?
2. How does a radiant warmer environment affect the accuracy of using diaper weights to determine a measured amount of 0.45% saline solution over time?
3. How is the accuracy of using diaper weights to determine a measured amount of 0.45% saline solution affected by volume of saline on the diaper?
4. How does the type of diaper affect the accuracy of using diaper weights to determine a measured amount of 0.45% saline solution?

Urine volume is an important determinant of renal function and fluid balance.

As a result, accurate measurement of urine volume is important when planning fluid management strategies. All methods of urine measurement should be examined to establish the accuracy of measurement.

Results from this study will help to determine the accuracy of weighing diapers prevoiding and postvoiding on measuring urine volume. They will also indicate how the factors of time, diaper type, volume of urine and environmental conditions affect the accuracy of diaper weights. With this information, the neonatal nurse will have a clearer understanding of how urine volume measured with diaper weights compares with actual urine volume. This knowledge is essential to planning fluid management strategies.

CHAPTER TWO

Review of the Literature

Fluid Balance

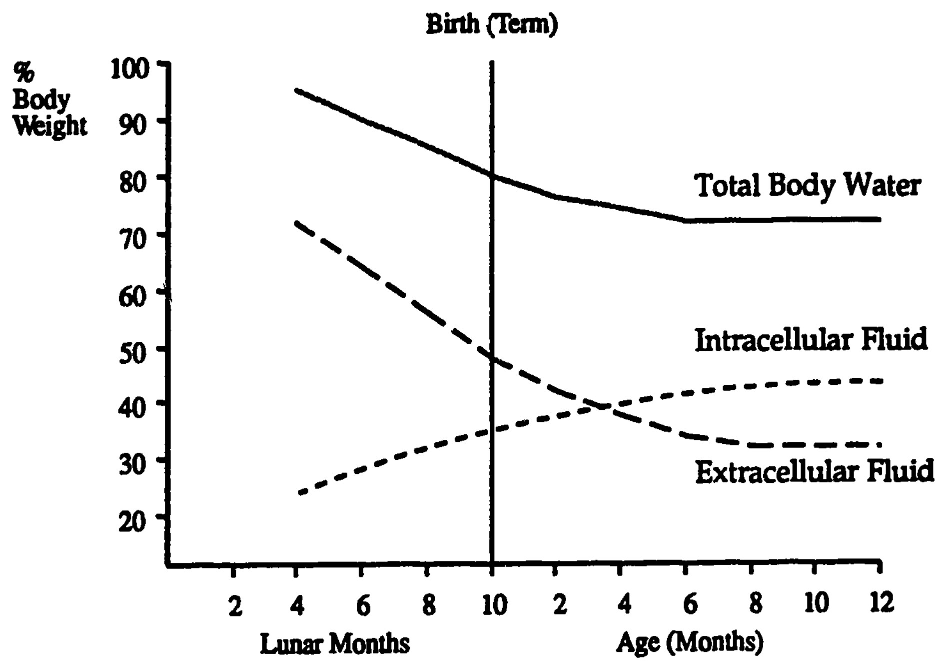
Support of fluid balance in neonatal patients is more easily achieved with an understanding of the physiological mechanisms that govern water balance and variations that can occur in sick or premature infants. With this knowledge, a nurse caring for neonates is able to identify parameters that require careful monitoring and can estimate fluid requirements and balance.

The control of fluid volume and distribution in the body is complex with various regulating factors controlling output based on body conditions and intake (Tonneson, 1986). Although this discussion focuses on water balance regulation, in reality it is inextricably tied to solute balance. The goal of neonatal fluid therapy is to replace water and electrolyte losses to maintain a normal balance of these substances (Ekblad, Kero, Takala, Korvenranta & Valimaki, 1987). For adults without unusual fluid losses, measurement of urine flow and fluid intake provides an accurate estimate of fluid balance status (Chenevey, 1987). An equation to maintain fluid balance can be written as **intake = output**. In neonates, the principles of fluid management are similar but the unique features of the neonate related to variations in body composition, insensible water loss, renal function, and neuroendocrine control of fluid balance must be considered. A review of the literature concerning these topics outlines their impact that these features have on fluid balance.

Body Fluid Distribution

Neonates have a greater percentage of fluid per body weight than adults. The water content of a term infant is estimated to be approximately 69-78% of body weight (Friis-Hansen, 1957; Widdowson, 1974) compared to 62% for an adult (Friis-Hansen, 1961). For premature infants, body water as a percentage of weight is even higher ranging from approximately 94% during the third month of gestation to approximately 86% at 26 weeks gestation, and 80% at 32 weeks gestation (Friis-Hansen, 1957; Widdowson, 1974). The partition of body water between extracellular fluid (ECF) and intracellular fluid (ICF) also varies as the fetus and newborn mature. ECF accounts for approximately 87% of body water at five months of gestation, 65% of body water at term, 30% at two months of age, and 16% at adulthood (Widdowson, 1974). While ECF volume decreases with age, ICF volume rises and represents 60% of total body water at adulthood (Friis-Hansen, 1957; 1961; Cassady & Milstead, 1971). These changes are outlined in Figure 1.

Figure 1. Percent Changes in Body Fluid of the Fetus and Infant*



*Modified From: "Changes in Body Water Compartments During Growth" by B Friis-Hansen, 1957, Acta Paediatrica Scandinavica, 46, (Suppl. 110).

A "physiologic weight loss" seen in newborns during the first week of life is largely a result of contraction of the ECF volume (ECV) (Kagan, Stanincova, Felix, Hodgman & Kalman, 1972; Nash, 1987; Shaffer, Bradt, Meade & Hall, 1987). Loss of 10% of body weight in term infants and 15% in premature infants less than 1500 grams can be anticipated (Bell & Oh, 1979; Shaffer, Quimiro, Anderson & Hall, 1987). This loss of ECV has been explained as a physiologic response to an enlarged ECV (Shaffer, Bradt & Hall, 1986; Shaffer, Bradt et al., 1987; Ross, Cowett & Oh, 1977) or a pathologic state of sodium loss secondary to renal immaturity (Sulyok, Varga, Gyory, Jobst & Csaba, 1979;

Sulyok, Nemeth, Tenyi, Csaba, Gyory, Ertl & Varga, 1979; Aperia, Broberger, Herin & Zetterstrom, 1979; Vanpee, Herin, Zetterstrom & Aperia, 1988). Shaffer and Meade (1989) examined the effect of two different sodium intakes on changes in ECV in term infants and found similar loss and sodium balance. More sodium was excreted with increased sodium intake indicating that sodium excretion is the result of sodium balance regulation rather than impaired renal tubular function.

The quantity and quality of fluid intake during this time is important since postnatal changes in body water and partition of ECF and ICF are influenced by intake of fluid and electrolytes (Kagan et al., 1972; Stonestreet, Bell, Warburton & Oh, 1983). The volume of fluid supplementation appropriate for the first four to five days of life is not clear, but it seems evident that intake should not match output during the initial week of life to allow for ECV loss (Nash, 1987; Sedin, Hammarlund & Stromberg, 1985). Consequently, the goal of fluid balance for newborns during the first week is prevention of dehydration (Strauss et al., 1985). After this period, the goal is summarized by the **intake = output** equation.

Sources of Water Loss

To determine output accurately, all sources of water loss must be considered. Typically, sources of water loss are as follows: 1. insensible water loss (IWL), 2. urine output, 3. gastrointestinal losses, and 4. sweat loss. Due to rapid growth in neonates, water necessary for the formation of new tissue mass must also be identified as a water expenditure (Bell & Oh, 1979). Therefore, zero fluid balance for the neonate becomes **intake + endogenous water production = IWL + sweat loss + gastrointestinal loss + renal loss + water for growth.** The neonate has unique physiological characteristics related to each source of water loss that result in fluid balance variations when compared to the adult model.

Insensible Water Loss. IWL is a major source of water loss for the neonate. It is the invisible, evaporative loss of water (EWL) through the skin and the airway. Loss of water from the respiratory tract typically accounts for 30% of IWL (Bell & Oh, 1979; Hey & Katz, 1969; Sulyok, Jequier & Prod'hom, 1973a). However, if an infant inspires heated, nearly saturated humidified air, this amount may be eliminated (Dery, 1973; Hey & Katz, 1969; Nash, 1987).

Studies of the IWL from the skin of neonates show that it is inversely related to gestational age (Hammarlund & Sedin, 1979; Hammarlund, Sedin & Stromberg, 1983; Maurer, Micheli, Schutz, Freymond & Jequier, 1984). Hammarlund and Sedin (1979) report that skin IWL at one day of age is 15 times greater for neonates after 25 weeks of gestation than for term infants. In a 50% humidity environment, IWL on the first day equals 129, 42, and 7 grams/kilogram/day (g/kg/day) for infants 25-27, 28-30, and 37-41 weeks, respectively (Hammarlund, Sedin & Stromberg, 1983). Increased IWL in premature infants is related to a greater surface area to body weight ratio, thinner skin, increased skin blood flow, and a larger ratio of body water to weight. By two weeks of age, preterm infants' skin develops a well formed stratum corneum resembling that of a newborn term infant (Evans & Rutter, 1986) and skin IWL falls (Hammarlund & Sedin, 1979; Maurer et al., 1984). At four weeks of age, however, the infant born at 25 weeks gestation has skin IWL twice as high as a newborn term infant (Hammarlund et al., 1983). Table 1 summarizes skin IWL for infants of different gestational and postnatal ages in an environment with 50% humidity.

Table 1

Mean Insensible Water Loss from the Skin of Infants Appropriate for Gestational Age at an Ambient Humidity of 50%*

Gestational Age (weeks)	Mean Birth Weight (kg)	IWL (g/kg/24 hours) Postnatal Age (days) <1	7	14	21	28
25-27	0.860	129	43	32	28	24
28-30	1.340	42	24	18	15	15
31-36	2.110	12	12	9	8	7
37-41	3.600	7	6	6	6	7

* Adapted From: "Transepidermal Water Loss in Newborn Infants. VIII. Relation to Gestational Age and Post-natal age in Appropriate and Small for Gestational Age Infants" by K. Hammarlund, G. Sedin, and B. Stromberg, 1983, Acta Paediatrica Scandinavica, 72, p. 725 with permission.

In the neonatal intensive care unit, premature and sick infants are placed in specialized environments in order to provide access for caretakers and to reduce thermoregulatory stress. These environments are provided typically by a radiant warmer or an incubator. The incubator encloses the infant in heated, humidified air while the radiant warmer provides heat in the form of infrared energy that is absorbed by the skin (Bell, 1983). These environments determine the IWL of an infant and are important to consider when calculating IWL.

Insensible water loss is influenced by environmental factors such as air temperature, velocity, and humidity (Hammarlund & Sedin, 1983). In low ambient humidity, IWL rises (Belgaumkar & Scott, 1975; Hammarlund & Sedin, 1979; Hey & Maurice, 1968). Investigators have noted a negative linear relationship between ambient humidity and IWL from newborns (Hammarlund, Nilsson, Oberg & Sedin, 1977; Hammarlund & Sedin, 1979; Sedin, Hammarlund, Nilsson, Stromberg & Oberg, 1985; Sulyok, Jequier & Ryser, 1972). The IWL of an infant of 25 weeks gestation will rise from 129 g/kg/day to over 200 g/kg/day when the humidity of the incubator is decreased from 50% to less than 20% (Sedin, Hammarlund & Stromberg, 1985). IWL of very small infants in incubators with forced air convection compared to incubators without forced air convection is up to 50% higher (Okken, Blijham, Franz & Bohn, 1982; Thompson, Stothers, McLellan, 1984).

Compared to an incubator environment, IWL may double under a radiant warmer (Bell, Neidich, Cashore & Oh, 1979; Bell, Weinstein & Oh, 1980; Jones, Rochefort & Baum, 1976; Williams & Oh, 1974; Wu & Hodgman, 1974). Baumgart, Engle, Fox and Polin (1981) found that IWL of infants nursed under radiant warmers correlated with body surface area, body weight and radiant power density. Smaller infants required more radiant power to keep warm which elevated their IWL. Also, net radiant power received was a determinant of IWL regardless of infant size. It has been speculated that increased skin blood flow shown by infants on radiant warmers (Oh, Yao, Hanson & Lind, 1973; Wu, Wong, Hodgman & Levan, 1974) and/or the lower absolute humidity of the environment (Bell, Weinstein & Oh, 1980) cause the increase in IWL.

Sweat Loss. Sweat is visible EWL and occurs when a body attempts to lose heat to the environment. Sweating in the neonate is present but incomplete (Foster, Hey & Katz, 1969). Although infants have a greater number of sweat glands per surface area, their response to chemical stimulation is one third that of an adult response. When neonates 35-42 weeks gestation are overheated, active sweating can be elicited (Hey & Katz, 1969; Foster et al., 1969; Rutter & Hull, 1979; Sulyok, Jequier & Prod'hom, 1973b). The set-point sweating temperature is lower with increasing gestational and postnatal ages and with vigorous muscular activity. Foster, Hey and Katz (1969) found no sweat response to thermal stimulation in any neonate less than 210 postconceptional days of age. Rutter and Hull (1979) document relatively rapid maturation of sweat production in preterm infants. A four week old neonate born at 30 weeks gestation has a greater ability to sweat than a newborn at 34 weeks gestation. Therefore, sweat loss can increase EWL 300%, from 6 ml/kg/hour (hr) to 18 ml/kg/hr, when older infants are overheated (Key & Katz, 1969: Rutter & Hull, 1979).

Renal Loss. Urine output may vary from minute to minute in the first hours of life (Strauss, Daniel, James, 1981). Although 90% of healthy term and preterm infants void in the first 24 hours, micturition may be delayed for up to 48 hours (Sherry & Kramer, 1955; Kramer & Sherry, 1957). In a more recent study, urine flow in 90% of healthy term and preterm infants less than 72 hours of age varied from 1-3 ml/kg/hr with an osmolality of 100-200 milliosmoles (mOsm)/kg and specific gravity of 1.006-1.010 (Jones, Gresham & Battaglia, 1972). A urine flow rate less than 1 ml/kg/hr for 12 hours is inadequate and defines oliguria in the neonate (Mathew, Jones, James, Bland & Groshong, 1980).

Urine volume depends on renal function and the amount of water intake available for excretion after water is lost by other routes. Low urine output in neonates most commonly arises from renal hypoperfusion following prerenal causes (Norman & Asadi, 1979). Fluid challenges may restore adequate renal perfusion and adequate urine output. However, when renal failure is established as the cause of low urine output, it is necessary to restrict fluids based on calculations of urine output and other losses. Particularly in very immature neonates, high urine output may be related to glucosuria resulting from a low glucose renal threshold and inability to use administered glucose (Bell & Oh, 1987).

The volume of urine excreted also depends on the renal solute load and the concentrating abilities of the kidney. The solute load arises from products of catabolism and the protein and electrolyte intake of the infant. During periods of growth, the solute load is decreased as solute components are incorporated in new tissue. For healthy, growing infants, the solute load arising from diets of breast milk or formula is easily excreted by the kidneys with water derived from these diets (Dreszer, 1977; Leake, 1977). When the infant is sick, however, more solute is presented to the kidney requiring water and electrolyte intake alteration to excrete waste without stress to the kidney (Dreszer, 1977; Roy & Sinclair, 1975).

Other Water Loss Considerations. Water loss in stool is estimated to be 5-10 ml/kg/day in healthy term infants on formula (Lemoh & Brooke, 1979). The amount of water loss through stool varies according to consistency of the stool, which is dependent of the type of feedings and the presence of disease.

Although water for growth is not a "loss", it should be considered when determining fluid balance. Water requirements for growth have been estimated at 10 ml/kg/day (Bell & Oh, 1987). Water produced by the oxidation of metabolic fuels balances water required for growth and these two factors may be omitted from the equation (Roy & Sinclair, 1975).

Neuroendocrine Control of Fluid Balance

The pituitary gland and the adrenal cortex are two major endocrine organs involved in the regulation of water balance (Bell & Oh, 1987). Antidiuretic hormone, arginine vasopressin (AVP) is secreted by the posterior pituitary gland under hypothalamic control to preserve water loss from the kidney during periods of increased osmolality, hypovolemia, or hypoperfusion (Leake, 1977). These functions have been listed in order of ascending importance. That is, AVP will be secreted in conditions of hypoperfusion despite adequate ECV or hyponatremia (Tonneson, 1986).

AVP production and secretion mechanisms of the pituitary gland appear to be complete in both mature and premature newborns since adaptive endocrine changes occur to restore water balance (Aperia, Herin, Lundin, Melin & Zetterstrom, 1984; Leung, McArthur, McMillan, Ko, Deacon, Parboosingh & Lederis, 1980; Rees, Brook, Shaw & Forsling, 1984). Elevated blood levels of AVP associated with hyponatremia in neonates has been attributed to a poor kidney response to AVP. Researchers have suggested that the inability to respond results from a diminished renal solute gradient and inability to concentrate urine (Svenningsen & Aronson, 1974). Recent research has led investigators to suggest that elevated AVP levels associated with late hyponatremia in premature infants are related to a hypovolemic response arising from excessive ECV loss (Sulyok, Kovacs, Lichardus, Michajlovskij, Lehotska, Nemethova, Varga & Ertl, 1985).

Aldosterone is a mineralocorticoid hormone produced and secreted by the adrenal cortex. Adrenocorticotrophic hormone, the renin-angiotensin system, and the plasma concentration of sodium and potassium regulate its synthesis (Leake, 1977). The basic feedback system is operational in all newborns but the limits of tolerance are narrow (Aperia et al., 1979; Shaffer & Meade, 1989; Siegel, Fisher & Oh, 1973; Sulyok, Nemeth et al., 1979). However, premature infants are relatively unresponsive to aldosterone as exhibited by large urinary sodium losses in the presence of high to normal levels of aldosterone (Aperia et al., 1979; Aperia et al., 1984; Sulyok, Nemeth et al., 1979).

Another hormone believed to be related to salt and water balance is plasma atrial natriuretic factor (ANF). It is secreted by the cardiac atria in response to the stretching of the myocardial wall and increases intrarenal blood flow distribution to increase the GFR. In term and preterm infants, elevated ANF concentration corresponds to the observed diuresis of ECV (Bierd, Kattwinkel, Chevalier, Rheuban, Smith, Teague, Carey & Linden, 1990; Tulassay, Seri & Rascher, 1987). Other researchers have confirmed these elevated levels but no relationship between ANF levels and parameters of salt and water balance were found (Shaffer & Meade, 1989; Ito, Marumo, Ando, Hayashi & Yamashita, 1990; Liechty, Johnson, Myerberg & Mullett, 1989).

Renal Function

The excretion of salt and water by the newborn kidney is determined by the glomerular filtration rate (GFR) and the tubular reabsorptive capacity. In comparison to the adult model, the GFR is low in all newborns regardless of gestational age (Zetterstrom, Aperia & Herin, 1985). Term infants develop a rapid increase in GFR and double the initial rate by the end of the first week of life which is most likely related to hemodynamic changes rather than kidney maturation (Aperia, Broberger, Broberger, Herin & Zetterstrom, 1983). Initial GFR is lower in premature infants less than 34 weeks gestation (Aperia, Broberger, Thodenius & Zetterstrom, 1981; Arant, 1978) and the rise in rate is much slower sometimes exhibiting no change in the first three weeks of life

(Aperia, Broberger, Elinder, Herin & Zetterstrom, 1974; Al-Dahhan, Haycock, Chantler & Stimmler, 1983).

The low GFR rate found in the premature infant may foster an assumption that lowered sodium filtration will result in sodium retention. However, inefficient tubular reabsorption of sodium results in a higher fractional sodium excretion (Oh, 1988). Several investigations show that sodium excretion in premature infants is inversely related to gestational age (Al-Dahhan et al., 1983; Aperia et al., 1979; Aperia et al., 1974; Ross, Cowett & Oh, 1977; Siegel & Oh, 1976; Sulyok, Nemeth et al., 1979; Sulyok, Varga et al., 1979). Due to decreased tubular reabsorption of sodium, premature infants are unable to initiate rapid changes to restore fluid and electrolyte balance following excessive salt or water loads and are susceptible to hyponatremia and hypernatremia. In one study, the incidence of hyponatremia paralleled the incidence of negative sodium balance which occurred in all premature infants less than 30 weeks gestational age (Al-Dahhan et al., 1983). The premature infant's capacity to absorb sodium develops so that it is similar to the capacity in a term newborn at three weeks of age (Al-Dahhan et al., 1983; Sulyok, Varga et al., 1979).

In response to acute fluid challenges, term and premature infants can demonstrate an increased GFR (Aperia et al., 1984; Daniel, James & Strauss, 1981: Leake, Zakauddin, Trygstad, Fu & Oh, 1976). Although term and premature infants demonstrate a capacity to increase GFR, free-water clearance, and urine volume in response to a fluid challenge, excretion is reduced as a percentage of the filtered load (Daniel et al., 1981; Leake et al., 1976). Therefore, a prolonged fluid challenge may result in a positive water balance and hyponatremia.

The combination of a reduced GFR, a short loop of Henle, and decreased serum urea results in an inability to concentrate urine through a wide range of values (Sujov, Kellerman, Zeltzer & Hochberg, 1984; Svenningsen, Andreasson & Lindroth, 1984). The full-term newborn infant can dilute urine to osmolalities of 30 to 50 mOsm/kg water and can concentrate urine to 700 to 800 mOsm/kg water compared to 1,200 mOsm/kg water possible for children and adults (Aperia et al., 1974; Edelmann & Barnett, 1960). The kidney of the premature infant and asphyxiated infant is limited to urine production through a narrower range of osmolality (Svenningsen et al., 1984). The capacity to concentrate urine increases rapidly in premature infants greater than 30 weeks gestation at birth so that by three weeks of age their capacity to concentrate urine is doubled (Svenningsen & Aronson, 1974). A lack of urine concentrating capacity predisposes the infant to dehydration.

Renal function may vary for infants with concurrent disease and has been examined in infants with respiratory distress syndrome (RDS). Early studies indicated that infants with RDS showed a reduced GFR and urine output (Cort, 1962; Guignard, Torrado, Mazouni & Gautier, 1976; Torrado, Guignard, Prod'hom & Gautier, 1974). Other investigations showed that if sufficient support was given to maintain a stable respiratory and circulatory status, there was no difference in renal function between healthy infants and those with RDS (Broberger & Aperia, 1978; Langman, Engle, Baumgart, Fox & Polin, 1981; Siegel et al., 1973; Tulassay, Ritvay, Bors & Buky, 1979).

Alterations in renal function may be associated with ventilatory support given to infants with respiratory problems. Artificial ventilation (AV) with positive end expiratory pressure reduces GFR and urine output in adults (Leslie, Philips, Work, Ram & Cassady, 1986). This phenomenon may result from lowered cardiac output and blood pressure associated with AV or a release of AVP, renin, or aldosterone induced by AV.

In one report, low birthweight infants receiving mechanical ventilation and continuous positive end expiratory pressure displayed no difference in urine output or sodium, potassium, and chloride balance (Leslie et al., 1986). However, other reports indicated diminished urine output, decreased serum sodium, and increased serum osmolality when levels of continuous positive airway pressure were 6 cm of water or greater (Fewell & Norton, 1980; Svenningsen et al., 1984; Tulassay, Machay, Kiszel & Varga, 1983). The mechanism causing this effect was not determined but it was speculated that it would be similar to that of the adult model. Therefore, changes in renal function associated with respiratory support should be anticipated.

For asphyxiated infants, abnormal renal functioning is attributed to reduced blood flow to the kidneys during an asphyxiating insult. The reduction in blood flow may be severe enough to cause brain or kidney injury. Hypoxic encephalopathy may result in an inappropriate secretion of AVP (Moylan, Herrin, Krishnamoorthy, Todres & Shannon, 1978; Speer, Gorman, Kaplan & Rudolph, 1984). Kidney injury may result in acute renal failure (Dauber, Krauss, Symchych & Auld, 1976). In both conditions, measurement of urine volume and estimation of other fluid losses are essential to determine of fluid requirements.

In summary, unique features of the neonate must be considered by clinicians when determining fluid management strategies to maintain fluid balance. In neonates, loss of ECF volume initially, susceptibility to EWL in neonatal warming environments, differences in renal loss of fluid, differences in neuroendocrine control of fluid balance, and differences in renal function must all be evaluated carefully when determining fluid therapy.

Measurement of Urine Output

The accuracy of the measurements obtained when diapers are weighed to determine urine volume depends upon the physical laws governing exchange of moisture. The assumption that change in diaper weight reflects the urine volume excreted by the infant may be incorrect due to the exchange of moisture in the environment. Some studies that have reported the effect of intensive care environments on the accuracy of measurements resulting from diaper/urine collection. Review of these two areas will familiarize the reader with the knowledge and concepts necessary to determine the ability of diaper weights to reflect urine output accurately.

Environmental Considerations

Hygrometry is a physical science branch which is concerned with moisture content measurement. The principles governing the exchange of moisture between urine on a diaper and the environment are derived from this science. The principles of humidity and moisture used are drawn from Harrison's (1965) discussion of humidity and moisture.

In the atmosphere, the form of moisture is water vapour. The sources of moisture are transpiration and evaporation from water and moist surfaces. The amount of water vapour in the air varies and is measured in different ways. The absolute humidity of air refers to the weight of water vapour per unit volume of air. Relative humidity is the percentage of water vapour in the air compared to the amount that could be present if the air is saturated at any given temperature. Because the saturation vapour pressure (SVP) increases with temperature, relative humidity is determined by temperature. That is, the relative humidity of air will fall when the temperature rises from 20 to 30°C if no additional moisture is available to the system to establish a new equilibrium. Also, the absolute amount of water vapour in air at 30°C with a relative humidity of 55% is greater than the amount present in air at 20°C and with a relative humidity of 55%.

Textiles and paper products such as diapers are hygroscopic materials. They exchange moisture with the environment to approach a moisture equilibrium with the ambient atmosphere by absorbing or releasing water depending on whether their moisture content is above or below equilibrium moisture. For any given level of moisture content, there is a corresponding level of atmospheric humidity at which the moisture exchange would be zero and moisture equilibrium would exist.

The equilibrium moisture content is determined by relative humidity which in turn relies upon the air temperature. Equilibrium moisture content is also determined by the temperature of the material and its unique fibre saturation point. At higher temperatures, the moisture in the material has greater kinetic energy and less additional energy is necessary for evaporation. The moisture content of the material is also dependent upon the time required for the material to absorb or lose moisture to the environment. This is a function of the humidity gradient, the type of material and the surface area exposed to the environment. In a still environment, equilibrium is established in a boundary layer between the material and the air. Air currents disturb this layer resulting in moisture exchange through a larger area.

Atmospheric moisture is in vapour form while the moisture of a wet diaper is liquid. Therefore, exchange of moisture between the diaper and the environment will also involve an exchange of heat. If the movement of moisture is from the diaper to the air, energy is required and the temperature of the air and of the diaper will drop. When the diaper absorbs moisture from the air, there will be a release of energy and the temperature of the diaper and of the air will tend to rise.

Although urine is composed primarily of water, it is a solute. The solutes in a solvent can affect the vapour pressure of the solvent by altering the forces of attraction between individual molecules and their neighbours. Therefore, the solutes in urine alter the evaporation exchange properties of water and determine a unique SVP. These properties are more affected as concentrations of solutes are increased.

Measurement Studies

Urine volume measurement with disposable diapers in a radiant heater environment and in room temperature environment has been reported by Hutton and

Schreiner (1980). After 30 minutes, EWL measured 15% under the radiant heater set at 34.5°C while only one third of the samples in room air measured greater than 10% loss. Hermansen and Buches (1988) also reported the effect of a radiant warmer on urine volume measurement for open-regular, closed-regular, and open superabsorbent disposable diapers under the conditions of room temperature, 100% and 50% radiant heater output. The greatest EWL occurred with open regular diapers exposed to 100% heater output. The least EWL occurred with closed regular diapers exposed to zero heater output. Open super-absorbent diapers showed less EWL than open regular diapers exposed to the same conditions. Ten percent water loss occurred with open regular diapers under 100%, 50%, and 0% radiant heater output within 10, 25, and 40 minutes respectively. Open super-absorbent diapers lost 10% of volume after 40 minutes under 100% heater output. Other diaper EWL did not reach 10% until almost two hours of exposure.

Two studies compared the effects of incubators with radiant warmer environments on the accuracy of volume measurement. Williams and Kanarek (1982) reported that EWL from urine collected in disposable diapers was significantly greater under a radiant heater which was set to maintain a probe on the mattress at 37°C compared to an incubator with the air temperature set at 34°C. After 30 minutes in these environments, diaper weight loss was 9% under the radiant warmer and 4% in the incubator. By 60 minutes, the weight loss increased to 18% and 7% respectively. Cooke, Werkman and Watson (1989) also compared the accuracy of weighing diapers in these two environments. Heater output was set to maintain the disposable diaper temperature at 32.8-33.9°C. They reported that diaper weight loss was a function of the time exposed to the environment but found no difference in weight loss between the two environments. Significant losses of 10% urine volume occurred in 15 minutes and the percentage of volume loss was greater for smaller volumes of urine than for larger volumes.

Hermansen and Buches (1987) reported that disposable diapers in incubators set for maximum heat and humidity increased in weight over a two hour period. Superabsorbent diapers gained an average 1.5 grams while regular diapers increased 0.4 grams. Reports of these investigations are summarized in Appendix 1.

Comparison of the investigations is difficult because of the differences in environmental conditions used for testing and in methods of reporting diaper weight loss over time. Also, the reports do not indicate the relative humidity of the incubator environment that was used. Knowledge of hygrometry determines that humidity is an essential element in moisture exchange and is vital for comparison of results. Because relative humidity is not reported, it is impossible to predict the accuracy of diaper weights in determining urine output in other incubator environments based on these study results.

Results of the studies suggest that the accuracy of diaper weights as a method of urine output measurement is reduced the longer a diaper is exposed in any environment and that diapers tend to lose more moisture in radiant environments. Despite relative humidities similar to incubator environments, the radiant warmer is drier. The absolute humidity is less due to a lower SVP which results from the lower air temperature (Bell, Weinstein & Oh, 1980).

Generally, the type of diaper studied has been limited to types of disposable diapers. Other diaper types may be used for neonatal patients and their moisture exchange characteristics may vary considerably. In the reported investigations, the diaper has been exposed completely in the study environment. Under normal conditions, an infant rests on the diaper and reduces the surface area exposed to the environment. A greater exposed surface area, such as reported in these studies, could affect moisture exchange with the environment.

CHAPTER THREE

Method

Research Design

To examine the relationship between neonatal environments, volume of urine output, type of diaper, time, and accuracy of diaper weights in measuring urine volume output a comparative, factorial design was used as a framework for the study. For the simulation trials, two volumes of 0.45% saline solution were added to five diaper combinations which were then exposed to four different environmental conditions using a radiant warmer and an incubator. Following this, repeated diaper weighing over time was undertaken to determine any gain or loss of moisture.

The two volumes of saline solution, 5 ml and 15 ml, were chosen to reflect urine outputs from one voiding of both small and large infants. Also, the percent change in diaper weight from the initial diaper weight was examined in the simulations due to the fact that significant changes could occur in one volume of saline solution and not in the other. For example, a 1.0 gm weight change in a diaper using 5 ml of saline solution would reflect a 20% loss compared to less than 7% loss for 15 ml of saline solution.

The 0.45% saline solution was used due to the difficulty of obtaining fresh specimens of neonatal urine in sufficient quantities. This saline solution also provided a standard solution which controlled for confounding results arising from variations of osmolality from different urine samples. Because the osmolality of neonatal urine is normally 100-260 mOsm/kg water (Leake, 1977), the moisture exchange properties of 0.45% saline (154 mOsm/kg water) should be similar.

Both cotton and disposable diapers were used during the study. Although other researchers have not published reports in which cotton diapers were studied, increasing concern over environmental issues may increase the use of cotton diapers in the future. Combinations of open and closed diapers were studied since some infants are not diapered in a regular fashion in order to facilitate monitoring lines and for other therapeutic considerations. Also, previous research suggested that whether a diaper was left open or closed affected moisture exchange in a radiant warmer environrment (Hermansen & Buches, 1988).

Four different environments were chosen to reflect different types that may be used in an intensive care environment. Of these four environments, two were incubator environments. One incubator environment had a greater air temperature and humidity to simulate conditions necessary for the care of extremely immature neonates. The other had a lower air temperature and humidity more typically used for premature infants. Two radiant heater environments comprised the other two study environments. Two radiant heater outputs were used to reflect the different amounts of heat necessary to keep neonates of different sizes warm.

The dependent variable in this study was the difference in weight between the actual diaper weight and the saturated diaper weight. The manipulated factors were the environmental conditions (four levels), volume of saline solution (two levels), type of diaper (five levels), and time (seven levels). Variables controlled for were infant size, diaper surface area exposed, and osmolality of added solution.

Definition of Terms

The following terms were defined as indicated below to clarify their meaning for the simulation trials:

Relative humidity - Amount of water vapour in the air compared to the amount that could be present if the air was saturated at any given temperature.

Ambient air temperature - Measurement of the amount of heat or internal energy of air in degrees Celsius (°C) by a thermometer suspended 10 centimetres (cm) above the patient mattress.

Nonservocontrol - Radiant warmer control where heater output is set and does not vary with input from a skin temperature probe.

Air velocity - Speed of air movement measured in metres per second (m/sec) 5 cm above the patient mattress.

Setting

The study was conducted in one patient area in a tertiary neonatal intensive care unit in order to standardize environmental conditions. There were two different "environmental" conditions for both incubator and radiant heater studies. For one set of conditions, the incubator (Model C-100, Air Shields, Hatboro, PA) was set for an air temperature of 33.5°C with two litres of water in the reservoir for humidity. At the end of each experimental day, the water in the reservoir was drained. Air temperature was set at 36.0° C for the other incubator environment. Humidity from water in the reservoir in the incubator at this higher temperature was augmented by the addition of humidified air from two heated cascades (Heated Bennett humidified chamber, Puritan-Bennett, Kansas City, MO) set at 46.0° C. Water in the cascade heaters was resupplied as it was depleted. Water levels varied from the full level marker on the cascade to a level one inch above this marker. The airflow supplied to the cascades was set at 15 litres per minute. Tubing from the cascade warmers supplied the humidified air to the incubator. The ends of the tubing were inserted in the left top porthole and the end tubing inlet and were directed at the incubator walls. Figure 2 illustrates the positioning of the cascade heaters and the tubing used in the simulations.

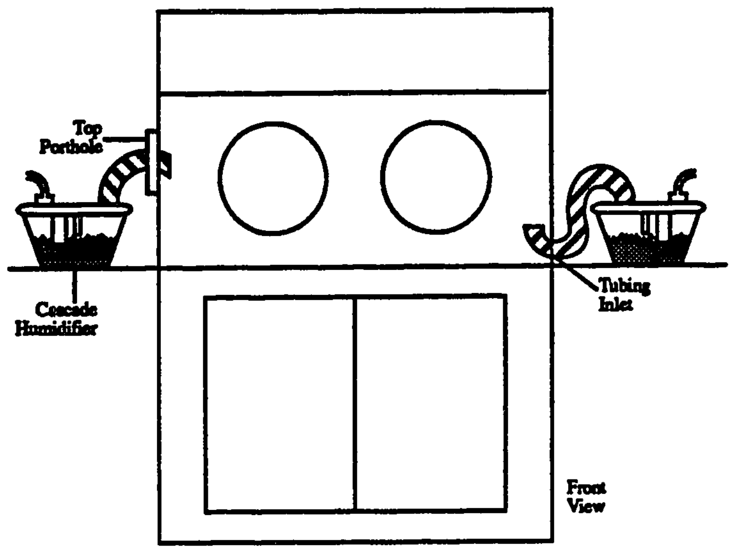
Under the radiant warmer (Ohio NC, Ohio Medical, Madison, WI), the heater output was set on nonservocontrol with the heater output set at 75% and 50% of full capacity. These outputs were determined using the following procedure. At full power on nonservocontrol the conduction angle of the sine wave measured 6.44 milliseconds (ms) instead of a full waveform of 8.33 ms for a standard 60 hertz power supply. The total area of the sine wave at full power was calculated using the integral $\int \sin(t)dt$. For use of this integral, the original time base reading had to be converted to radians and once the area calculations were obtained they were again converted from radians to time in milliseconds. The final calculations in milliseconds enabled the precise setting of the nonservocontrol knob for 50% and 75% of the full heater capacity via a digital storage oscilloscope.

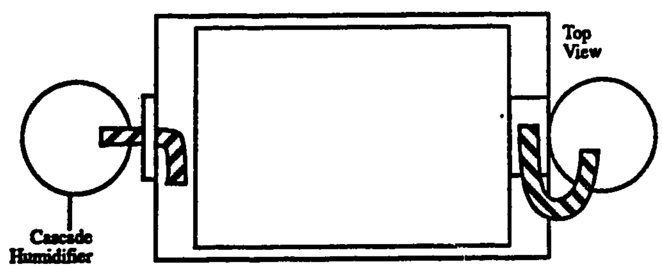
Relative humidity, air temperature, and air velocity were monitored in all "micro" environments every 20 minutes. Diaper trials started a minimum of one hour after power was supplied to the radiant warmer or the incubator so that the environment had sufficient time to stabilize. All diaper trials for the high heater output and added humidity environment were conducted first because it was found during a pilot study that conditions would remain more standardized if environments were not alternated.

Sample

The sample consisted of 10 trials of each type of diaper and two volumes of 0.45% saline solution in each of the four different environments. These combinations

Figure 2. Configuration of Cascade Humidifiers with Incubator





resulted in 400 diaper trials. The diapers that were used were as follows: cotton diaper under a piece of burn sheeting, open cotton diaper, closed cotton terrycloth diaper, open superabsorbent disposable diaper, and closed superabsorbent disposable diaper. Each diaper type was studied in each environment using 5 ml and 15 ml of 0.45% saline solution. The order of study of a particular diaper type and volume of added solution was chosen arbitrarily. Ten samples of each combination of diaper type and volume were examined before the next combination was studied. The order in which the sample groups were studied is outlined in Appendix 3.

To assess whether frequent removal of the diapers from the environment for weighing purposes would alter moisture exchange within the environment, one control group of diapers was studied. The control group consisted of 10 trials using open cotton diapers with 5 ml of added 0.45% saline solution which was left in each of the four different environments for a 90 minute period and then weighed (40 trials).

Data Collection Procedures

After each "environment" had stabilized following the guidelines outlined in the setting section, a randomly selected diaper of a particular diaper type was weighed. A known volume of 0.45% saline solution, either 5 ml or 15 ml, was added to the centre of the diaper and the diaper was reweighed. The wet diaper weight minus the dry diaper weight determined the exact amount of solution added to the diaper.

The diaper was then placed in the selected environment and weighed at 15 minute intervals over a 90 minute period. A summary of the timing protocol that was followed is found in Appendix 2. Fifteen minute intervals were selected in order to obtain a more accurate description of the change in diaper weights without excessive removal from the selected environment. A 90 minute period was chosen in order to reflect an average amount of time that may occur between diaper checks for infants nursed in these environments and who require accurate urine output measurement. This procedure was repeated until 10 trials of each of five different diaper combinations and two saline solution volumes in four different environments were tested.

For all diaper trials, a standard resuscitation doll (Infant Mannequin, Laederal, Stavange, Norway) was used to simulate a neonate to reflect more accurately the surface area exposed under actual conditions. In the closed diaper trials, the doll was "diapered" while in the open diaper trials, the doll's bottom was placed over the upper half of the diaper.

Measurement Protocols

Temperature

Air temperature was measured in the incubator with a thermistor probe (Airshield Model #68 209 80, Hatboro, PA), under the radiant warmer environment with a mercury-in-glass thermometer (Cole-Parmer Instrument, Chicago), and for cascade heated air with a mercury-in-glass thermometer (Hospilak probe #964, Lindenhurst NY). The thermistor probe was tested in a water bath for temperatures from 29-40°C with a scientific thermometer with 0.1°C graduation (Cole-Parmer Instrument, Chicago). The probe temperatures did not vary more than plus or minus 0.1°C. The mercury-in-glass thermometer for the cascade heater was also compared with the scientific mercury-in-glass thermometer in a water bath over temperatures from 29-50° C. The graduations on the cascade thermometer were in 2°C, so the readings from this thermometer were compared to the scientific thermometer when the temperature on the cascade thermometer reached a marking. At these markings, the cascade thermometer temperatures did not vary from the scientific thermometer readings more than plus or minus 0.5°C.

The thermometer and the thermistor probe were suspended 10 cm above the patient mattress in the radiant warmer and incubator environments respectively. A foil umbrella was suspended over the end of the thermometer in the radiant warmer environment to protect the end from radiant energy and falsely high readings.

Humidity

A psychrometer (Psychro-Dyne #22010, Environmental Tectonics Corp., Southampton, PA) was used to measure humidity in each environment. The psychrometer measures the "wet" and "dry" temperature of the air. The theory of wet and dry bulb thermometers is based on the evaporative cooling effect on the wet bulb. The drier the surrounding air, the more rapidly the air will evaporate. This causes the wet bulb to depress in temperature until a balance takes place between the cooling effect and the normal heat gain from the ambient condition. The psychrometric formula relates this observed temperature depression and the temperature of the dry bulb to the quantity of moisture in the air. Davis (1970) reports that the dry and wet bulb psychrometer is generally accurate to about plus or minus three percent (+/- 3%).

The psychometric formula used to calculate relative humidities from wet and dry bulb readings was the Carrier equation. This equation considers radiation and other effects (Davis, 1970).

$$e = e_w - \frac{(P - e_w)(T_{WB} - T_{DB})}{2830 - 1.44\,T_{WB}}$$

$$\text{relative humidity} = \frac{e}{e_s} \times 100$$

where e = the partial vapour pressure of the moist air

e_w = saturation vapour pressure at the temperature of the wet bulb in millimetres of mercury (mmHg)

P = barometric pressure in mmHg

T_{DB} = dry-bulb temperature, °F

T_{WB} = wet-bulb temperature, °F

e_s = saturation vapour pressure at dry-bulb temperature

The accurate measurement of the true wet and dry bulb temperatures requires adequate ventilation across the wet bulb. Adequate ventilation has been found to be 700 feet-per-minute of air flow (3.56 m/sec) (Davis, 1970). Ventilation in the psychrometer is provided by a fan powered by batteries. The speed of the air flow in the psychrometer was tested with the anemometer over a period of six hours of intermittent use (the length of time a fresh set of batteries was used). Air flow was maintained at greater than 3 m/sec which was the upper limit of the air velocity scale. The psychrometer was retested every day of the simulation.

The Psychro-Dyne was positioned for readings in the same location for both incubator environments and for both radiant warmer settings. The wick of the wet bulb was moistened with distilled water at room temperature prior to each reading. Because radiant heat affects the bulb readings, the instrument was introduced to the radiant warmer setting only immediately prior to the reading. The instrument was allowed to stabilize for two minutes prior to reading as per the operating instructions.

<u>Barometric Pressure</u>

The barometric pressures necessary for the psychrometric formula equations were obtained at the beginning of the study day from a columnar mercury barometer (Eberbach, Ann Arbor MI). Barometric pressure is determined by the expansion or contraction of the column of mercury against the scale on the column with this instrument. Barometric pressure readings from this type of instrument are accurate to plus or minus 1% (+/- 1%) (Rossini, 1974).

Air Velocity

A hot-wire, constant temperature anemometer (Omnisensor Air Velocity Meter Model #1640, TSI Incorporated, St. Paul, MN) was used to measure air velocity. The instrument measures air velocity by computing the amount of electrical power required to keep the probe at a constant temperature as units of velocity on the meter. The sensor temperature compensates for variations in ambient air temperature and for air density changes caused by temperature and pressure variations. Accuracy of the anemometer is listed at plus or minus three percent (+/- 3%).

The anemometer was newly purchased and calibrated within four weeks of purchase by the manufacturer. The accuracy of the anemometer was tested at the beginning of each testing day by placing the end in a still air space (the end of a glass cup). A discrepancy at zero flow of 0.1 m/sec or more would mean erroneous velocity readings. Although this situation did not occur, the instrument would have been recalibrated following the manufacturer's instructions. Air velocity readings were taken from a spot 5 cm above the patient mattress to measure air velocity at a distance close to the diaper surface but far enough away to allow diaper removal without disturbing the instrument. The air velocity sensor is located at the end of a wand. This wand was secured to an 120 ml glass bottle in order to maintain the same height and location for each environment for all diaper trials. The instrument was allowed to stabilize 30-60 seconds prior to reading, as per operating instructions.

Diapers

Diapers that were used are as follows: cotton diaper (Curity, Gerber), cotton terrycloth (University Linen Services, Edmonton), disposable diaper (Newborn Superabsorbent Pampers, Proctor and Gamble, Toronto, Ont), and burn sheeting (Ultracare sheeting, Zimmer, Dover OH). Cotton terrycloth diapers consist of an outside layer of cotton terrycloth material and an inside layer of cotton flannelette. In the middle of the diaper, an absorbent layer of cotton flannelette is sandwiched between the two layers.

Weights

Diaper weights were obtained using a Mettler balance scale (Model P163, Curtis Matheson Scientific, Maryland Heights, MO) with 0.001 gm graduations and reliable to 0.10 grams.

Time

The study protocol directed that diapers were to be weighed every 15 minutes and measurements of air temperature, air velocity, and relative humidity were to be done every 20 minutes. These times in minutes from Time Zero were used as narrow guidelines. That is, every attempt was made to gather data at the indicated time, but the actual time of individual readings was not recorded. A digital clock with seconds displayed was used as a time guide. Environmental readings were taken at plus or minus 15 seconds to the minute indicated from Time Zero. Diaper weights were taken at plus or minus 30 seconds to the minute indicated from Time Zero. This reflected the amount of time necessary to remove the diaper from the environment, weigh the diaper, and return it to the environment.

Assumptions

The artificial conditions created for the study require that several assumptions be outlined as follows:

1. The accuracy of urine volume measurement using diaper weights applies to diaper types used in environments similar to those used in the experiment.
2. Scales in neonatal units are precise enough to reproduce the accuracy of diaper weights obtained with a Mettler balance scale.
3. Frequent removal of the diapers from the environment for weights does not alter moisture exchange with the environment.
4. A standard resuscitation doll simulates diaper surface area exposed for term infants.
5. A 0.45% saline solution has moisture exchange properties comparable with urine typically excreted by neonates.

Pilot Study

Prior to the simulation trials, a pilot study was done to note potential problem areas. Both an open and closed superabsorbent disposable diaper were tested in each of the four environments according to the study protocol. It was noted that the relative humidity in the incubator environments was more standardized if the environments were not alternated as was proposed initially. No other change to the study protocol was necessary.

CHAPTER FOUR

Presentation of Findings

Mean weight increase/decrease was determined for each trial of diaper combinations in each environment category. Mean percentage weight increase/ decrease was determined and compared for diaper type within one setting and between settings. Data were statistically analyzed using multivariate analysis of variance for repeated measures using SPSS-x (SPSS-x 3.0, 1988). Statistical significance was set at $p < .01$. Clinical significance was determined as a mean diaper weight increase/decrease of 10%. This figure was selected as an acceptable error for the determination of urine volume in fluid therapy calculations. Fluid therapy resulting in an increase or decrease of 10% of circulating blood volume results in clinical changes in the neonate. Power of the simulation trials was determined to be .95 with an alpha of .01, a sample size of 400, and a small to medium effect size (Cohen, 1977).

Mean Diaper Weight Changes

Environmental Effect on Diaper Weight Change

To examine the effect of an incubator or radiant warmer environment on the accuracy of using diaper weight to determine 0.45% saline solution volume over time, mean percentage weight change of diaper weights over time were analyzed. Tables 2 and 3 list the calculated mean percentage weight change over time for 5 ml and 15 ml of added solution categorized according to environment type. Mean percentage weight change over time categorized by environment type and volume of added solution are further illustrated by the graphs in Appendix 4.

In the incubator set at 36.0° C with added humidity environment, all diaper types showed an overall increase in weight over 90 minutes. Cotton diapers exhibited an initial pattern of weight increase followed by a more gradual decrease in weight. For the 5 ml added volume, this weight increase peaked at 60-75 minutes while for 15 ml added volumes, the peak increase was seen at 45 minutes. Superabsorbent disposable diapers continued to increase in weight throughout the entire 90 minutes. In the incubator set at 36.0° C with added humidity environment, all diaper types with 15 ml added saline solution and closed superabsorbent disposable diapers with 5 ml added solution, did not show a 10% change in diaper weight over the 90 minute study period.

Diaper samples subjected to the remaining environments exhibited a mean

Table 2

Mean Percent Diaper Weight Change Over Time for 5 ml Added Solution by Environment

Diaper Type	n	0	15	30	45	60	75	90
		Time in Minutes						
Incubator set at 36.0°C with added humidity								
Open Cotton with Burn Sheeting	10	0	+8.8	+10.9	+12.9	+13.1	+13.4	+12.7
Open Cotton	10	0	+8.5	+12.0	+13.0	+13.4	+16.0	+12.5
Closed Terrycloth	10	0	+10.2	+13.9	+16.5	+16.7	+16.3	+14.6
Open Disposable	10	0	+4.6	+7.1	+8.7	+11.2	+12.8	+14.3
Closed Disposable	10	0	+0.6	+1.2	+1.8	+2.4	+1.8	+3.4
Incubator Set at 33.5°C								
Open Cotton with Burn Sheeting	10	0	-1.6	-4.2	-6.1	-8.9	-11.5	-13.9
Open Cotton	10	0	-3.0	-6.7	-10.5	-14.4	-18.3	-23.1
Closed Terrycloth	10	0	-2.0	-6.2	-10.9	-15.7	-20.9	-26.2
Open Disposable	10	0	-1.1	-2.1	-3.1	-4.1	-5.1	-6.2
Closed Disposable	10	0	-0.2	-0.4	-0.3	-0.7	-0.9	-1.0
Radiant Warmer Set at 75% Heater Output								
Open Cotton with Burn Sheeting	10	0	-7.8	-13.4	-19.1	-24.3	-28.6	-34.8
Open Cotton	10	0	-8.7	-14.7	-21.3	-28.0	-32.3	-39.7
Closed Terrycloth	10	0	-13.4	-25.6	-35.0	-45.1	-52.5	-60.9
Open Disposable	10	0	-4.5	-8.4	-11.2	-13.8	-16.7	-19.8
Closed Disposable	10	0	-1.0	-1.5	-2.2	-2.7	-3.3	-4.0
Radiant Warmer Set at 50% Heater Output								
Open Cotton with Burn Sheeting	10	0	-4.7	-9.3	-13.1	-17.4	-21.1	-25.0
Open Cotton	10	0	-6.3	-13.1	-18.6	-25.4	-29.6	-34.8
Closed Terrycloth	10	0	-9.8	-18.3	-26.5	-34.6	-42.5	-49.0
Open Disposable	10	0	-3.6	-5.5	-7.7	-9.8	-11.5	-13.5
Closed Disposable	10	0	-0.6	-0.9	-1.2	-1.6	-2.0	-2.4

weight loss that increased over time. Diapers under the 75% output radiant warmer showed the greatest loss, followed by those under the 50% output radiant warmer. Diapers in the incubator set at 33.5° C environment had the lowest mean weight loss percentage of these three samples. In the incubator environment, diaper weight loss was less than 10% until 45 minutes of exposure.

Volume Effect on Diaper Weight Change

The effect of added solution volume on diaper weight change was also

Table 3

Mean Percent Diaper Weight Change Over Time for 15 ml Added Solution by Environment

		Time in Minutes						
Diaper Type	n	0	15	30	45	60	75	90
Incubator set at 36.0°C with added humidity								
Open Cotton with Burn Sheeting	10	0	+1.6	+1.2	+0.6	-0.6	-1.7	-3.1
Open Cotton	10	0	+2.1	+2.1	+1.8	+1.4	+0.4	-0.6
Closed Terrycloth	10	0	+2.8	+2.5	+1.4	0.0	-1.4	-3.6
Open Disposable	10	0	+0.9	+1.4	+0.9	+2.2	+2.5	+2.6
Closed Disposable	10	0	+0.2	+0.4	+0.5	+0.6	+0.6	+0.7
Incubator Set at 33.5°C								
Open Cotton with Burn Sheeting	10	0	-0.5	-2.4	-4.6	-6.8	-9.3	-11.8
Open Cotton	10	0	-1.9	-4.4	-7.1	-12.7	-12.9	-16.2
Closed Terrycloth	10	0	-1.7	-5.1	-7.8	-10.8	-15.1	-18.2
Open Disposable	10	0	-0.6	-1.5	-1.8	-2.4	-2.9	-3.4
Closed Disposable	10	0	-0.2	-0.2	-0.3	-0.3	-0.5	-0.7
Radiant Warmer Set at 75% Heater Output								
Open Cotton with Burn Sheeting	10	0	-5.0	-9.1	-13.9	-23.4	-23.5	-28.0
Open Cotton	10	0	-5.3	-10.5	-16.5	-22.3	-26.5	-34.3
Closed Terrycloth	10	0	-7.3	-11.9	-22.0	-29.0	-35.4	-43.5
Open Disposable	10	0	-2.5	-5.0	-7.1	-9.0	-10.8	-12.7
Closed Disposable	10	0	-0.6	-1.0	-1.3	-1.7	-2.2	-2.5
Radiant Warmer Set at 50% Heater Output								
Open Cotton with Burn Sheeting	10	0	-2.8	-5.9	-9.0	-12.3	-15.0	-18.4
Open Cotton	10	0	-4.2	-8.1	-12.6	-16.6	-20.6	-24.7
Closed Terrycloth	10	0	-5.5	-9.9	-15.3	-20.8	-26.3	-32.0
Open Disposable	10	0	-2.2	-2.8	-4.7	-5.9	-7.0	-8.1
Closed Disposable	10	0	-0.3	-0.4	-0.6	-0.7	-0.9	-1.1

examined by determination of mean percentage weight change over time. Mean percentage weight change over time for 5 ml and 15 ml samples are found in Tables 2 and 3 respectively. For all diaper types and environment combinations, samples with 15 ml of 0.45% saline solution added exhibited a lower mean percentage change in diaper weight. In the incubator set at 36.0°C with added humidity environment, diaper weight change for 5 ml added solution samples was greater than 10% for four of five diaper types and ranged from an increase of 3.4% to 14.6%. For 15 ml added solution samples, however, the diaper weight changes were less than 10% for all diaper types and ranged from an increase of 2.6% to a decrease of 3.1%. Weight change for diaper samples exposed to the incubator set at 33.5° C environment with 5 ml added solution ranged from a decrease of 1% to 26.2% while the weight change for samples with 15 ml added solution ranged from a decrease of 0.7% to 18.2%. Diaper weight decrease for diaper samples exposed to the radiant warmer at 75% heater output ranged from 4% to 60.9% for 5 ml added solution samples versus 2.5% to 43.5% for 15 ml added solution samples. Diapers exposed to the radiant warmer at 50% heater output showed a weight decrease range of 2.4% to 49% for 5 ml added solution diaper samples compared to a weight decrease range of 1.1% to 32% for 15 ml added solution diaper samples.

Diaper Type Effect on Diaper Weight Change

Mean percentage weight change of diaper weights over time were analyzed to study the effect of diaper type on the accuracy of using diaper weight to determine 0.45% saline solution volume over time. Calculated mean percentage weight changes classified by diaper type and volume of added solutions are found in Tables 4 and 5. For further illustration, these weight changes have been graphed in Appendix 5.

Disposable diapers. For both 5 and 15 ml of added volumes, closed superabsorbent disposable diapers remained nearest to the weight at Time Zero. These diapers did not show a 10% change in any environment over the 90 minute study period and the largest change was a 4% loss under the 75% output radiant warmer when 5 ml of solution was originally added. Open superabsorbent disposable diapers showed the next lowest mean weight change over time. For the 15 ml added volume, percentage change was less than 10% in all environments except the 75% output radiant warmer. In that case, 10% weight loss occurred between 60 and 75 minutes of exposure. Mean percentage weight change was greater for the 5 ml volume, with greater than 10% change by 45 minutes of exposure under the 75% output radiant warmer, 60 minutes in the incubator set at 36.0° C with added humidity, and 75 minutes under the 50% output radiant warmer. The mean percentage weight change for open disposable diapers was less than 10% in the incubator set at 33.5° C.

Cotton diapers. Cotton diapers showed a greater mean percentage loss than disposable diapers from 13.9 to 60.9%. Closed terrycloth diapers exhibited the greatest change in weight. For this diaper type, significant losses occurred by 15 minutes in both radiant warmer environments and the incubator set at 33.5° C for 5 ml added solution.

Table 4

Mean Percent Diaper Weight Change Over Time for 5 ml Added Solution by Diaper Type

		Time in Minutes						
Environment	n	0	15	30	45	60	75	90
Open Cotton with Burn Sheeting								
Incubator with Humidity	10	0	+8.8	+10.9	+12.9	+13.1	+13.4	+12.7
Incubator Set at 33.5°C	10	0	-1.6	-4.2	-6.1	-8.9	-11.5	-13.9
Radiant Warmer at 75%	10	0	-7.8	-13.4	-19.1	-24.3	-28.6	-34.8
Radiant Warmer at 50%	10	0	-4.7	-9.3	-13.1	-17.4	-21.1	-25.0
Open Cotton								
Incubator with Humidity	10	0	+8.5	+12.0	+13.0	+13.4	+16.0	+12.5
Incubator Set at 33.5°C	10	0	-3.0	-6.7	-10.5	-14.4	-18.3	-23.1
Radiant Warmer at 75%	10	0	-8.7	-14.7	-21.3	-28.0	-32.3	-39.7
Radiant Warmer at 50%	10	0	-6.3	-13.1	-18.6	-25.4	-29.6	-34.8
Closed Terrycloth								
Incubator with Humidity	10	0	+10.2	+13.9	+16.5	+16.7	+16.3	+14.6
Incubator Set at 33.5°C	10	0	-2.0	-6.2	-10.9	-15.7	-20.9	-26.2
Radiant Warmer at 75%	10	0	-13.4	-25.6	-35.0	-45.1	-52.5	-60.9
Radiant Warmer at 50%	10	0	-9.8	-18.3	-26.5	-34.6	-42.5	-49.0
Open Superabsorbent Disposable								
Incubator with Humidity	10	0	+4.6	+7.1	+8.7	+11.2	+12.8	+14.3
Incubator Set at 33.5°C	10	0	-1.1	-2.1	-3.1	-4.1	-5.1	-6.2
Radiant Warmer at 75%	10	0	-4.5	-8.4	-11.2	-13.8	16.7	-19.8
Radiant Warmer at 50%	10	0	-3.6	-5.5	-7.7	-9.8	-11.5	-13.5
Closed Superabsorbent Disposable								
Incubator with Humidity	10	0	+0.6	+1.2	+1.8	+2.4	+1.8	+3.4
Incubator Set at 33.5°C	10	0	-0.2	-0.4	-0.3	-0.7	-0.9	-1.0
Radiant Warmer at 75%	10	0	-1.0	-1.5	-2.2	-2.7	-3.3	-4.0
Radiant Warmer at 50%	10	0	-0.6	-0.9	-1.2	-1.6	-0.2	-2.4

Significant losses were delayed to 30 minutes in the radiant warmer environments and 60 minutes in the incubator set at 33.5° C environment when 15 ml solution was added. Over 90 minutes, closed terrycloth diapers showed a change of almost 61% for 5 ml of added solution and 43% for 15 ml of added solution under the 75% output radiant warmer. Open cotton diapers with and without burn sheeting showed similar weight changes over time but cotton diapers without burn sheeting generally had greater total changes. Diapers with burn sheeting exhibited significant weight changes at the same

Table 5

Mean Percent Diaper Weight Change Over Time for 15 ml Added Solution by Diaper Type

		Time in Minutes						
Environment	n	0	15	30	45	60	75	90
Open Cotton with Burn Sheeting								
Incubator with Humidity	10	0	+1.6	+1.2	+0.6	-0.6	-1.7	-3.1
Incubator Set at 33.5°C	10	0	-0.5	-2.4	-4.6	-6.8	-9.3	-11.8
Radiant Warmer at 75%	10	0	-5.0	-9.1	-13.9	-23.4	-23.5	-28.0
Radiant Warmer at 50%	10	0	-2.8	-5.9	-9.0	-12.3	-15.0	-18.4
Open Cotton								
Incubator with Humidity	10	0	+2.1	+2.1	+1.8	+1.4	+0.4	-0.6
Incubator Set at 33.5°C	10	0	-1.9	-4.4	-7.1	-12.7	-12.9	-16.2
Radiant Warmer at 75%	10	0	-5.3	-10.5	-16.5	-22.3	-26.5	-34.3
Radiant Warmer at 50%	10	0	-4.2	-8.1	-12.6	-16.6	-20.6	-24.7
Closed Terrycloth								
Incubator with Humidity	10	0	+2.8	+2.5	+1.4	0.0	-1.4	-3.6
Incubator Set at 33.5°C	10	0	-1.7	-5.1	-7.8	-10.8	-15.1	-18.2
Radiant Warmer at 75%	10	0	-7.3	-11.9	-22.0	-29.0	-35.4	-43.5
Radiant Warmer at 50%	10	0	-5.5	-9.9	-15.3	-20.8	-26.3	-32.0
Open Superabsorbent Disposable								
Incubator with Humidity	10	0	+0.9	+1.4	+0.9	+2.2	+2.5	+2.6
Incubator Set at 33.5°C	10	0	-0.6	-1.5	-1.8	-2.4	-2.9	-3.4
Radiant Warmer at 75%	10	0	-2.5	-5.0	-7.1	-9.0	-10.8	-12.7
Radiant Warmer at 50%	10	0	-2.2	-2.8	-4.7	-5.9	-7.0	-8.1
Closed Superabsorbent Disposable								
Incubator with Humidity	10	0	+0.2	+0.4	+0.5	+0.6	+0.6	+0.7
Incubator Set at 33.5°C	10	0	-0.2	-0.2	-0.3	-0.3	-0.5	-0.7
Radiant Warmer at 75%	10	0	-0.6	-1.0	-1.3	-1.7	-2.2	-2.5
Radiant Warmer at 50%	10	0	-0.3	-0.4	-0.6	-0.7	-0.9	-1.1

time interval or 15 minutes later. All diaper weights showed a significant change by 30-45 minutes of exposure to environments with 5 ml added solution except the cotton with burn sheeting in the incubator set at 33.5° C environment. Significant weight changes occurred for samples with 15 ml added solution exposed to the 75% output radiant warmer at 30-45 minutes and to the 50% output radiant warmer at 45-60 minutes of exposure. As with the 5 ml added solution samples, open cotton diapers with burn sheeting added compared to those open cotton diapers without burn sheeting showed significant losses 30 minutes later. Those without the burn sheeting showed significant losses 90 minutes later.

Diaper Weight Change in Control Versus Experimental Samples

Mean percentage changes between the control and experimental samples were also calculated to determine the effect of removing diapers from the environment every 15 minutes for weighing. Control sample diapers exhibited a greater mean percentage change in diaper weights, both in the incubator set at 36.0° C with added humidity and the 75% heater output radiant warmer environments. Control samples increased 18.4% in weight in the incubator and decreased 41.6% under the radiant warmer over 90 minutes while the experimental samples increased 12.5% in the former environment and decreased 39.7% in the latter environment. The reverse was true for the remaining two environments. That is, control sample diapers exhibited a lower mean percentage change. Control sample diapers in the incubator set at 33.5° C environment and the radiant warmer at 50% environment decreased 20.5% and 29.8% respectively. In comparison, the diaper weight losses for the experimental sample diapers were 23.1% and 34.8%. Comparison of diaper mean percentage weight change for the control and experimental samples are illustrated in Figure 3.

Comparison of Factor Effects on Diaper Weight Changes

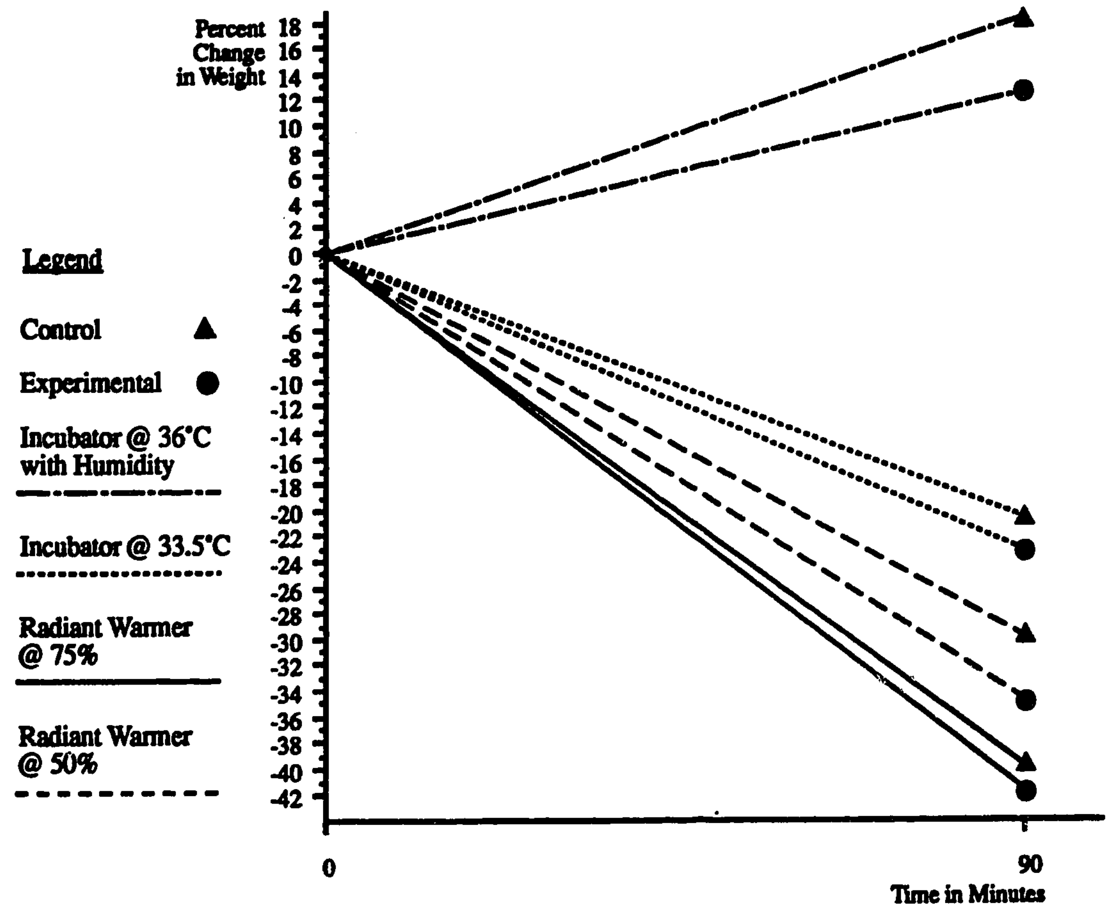
Factor Effects on Diaper Weight Change

Diaper weights were analyzed statistically using multivariate analysis of variance for repeated measures to determine how the factors of environment, volume of added solution, and diaper type affect the accuracy of using diaper weights to determine changes in a known amount of 0.45% saline solution over time.

Experimental Samples

The F-ratio (84,7822.44) calculated for the main effect of overall difference between diaper weight means was significant ($p < .01$). This value indicates that there was a difference in diaper weight means between the different samples. This overall difference in diaper weight means was analyzed with respect to the factors of environment, diaper type, volume of added solution, and time. The calculated F-ratios for these factors were 1684.75, 473.82, 16.54, and 2301.35 respectively, and were

Figure 3. Open Cotton Mean Percentage Weight Change - Control with Experimental Samples Comparison



statistically significant (p <.01). Therefore, all factors contributed to the difference in diaper weight means between the different samples.

Further analysis indicated that interactions between the factors of environment, diaper type, volume of added solution, and time also contributed to the difference in diaper weight means between the different groups. All F-ratios calculated for two-way interaction effects between factors of environment, diaper type, volume, and time were statistically significant (p <.01). The three-way interactions of environment-diaper type-time, environment-volume-time, and diaper type-volume-time also had statistically significant (p <.01) F-ratios of 43.31, 65.59, and 4.36 respectively. The F-ratio of 5.36 calculated for the interaction of the factors of environment, diaper type, volume added, and time was also statistically significant (p <.01). Therefore, there was a difference in measured mean diaper weights over time and these differences were affected by the factors of environment, diaper type, volume of added solution, and time and all possible interactions between these factors. Results of main effects and interaction effects from multivariate analysis of variance are found in Table 6.

Control Samples

A sample of 10 open cotton diapers with 5 ml added 0.45% saline solution exposed to the four environments for 90 minutes without interval weights was compared to the similar experimental sample exposed to interval weights. Multivariate analysis of variance for repeated measures indicated a significant (p <.01) change in weight overall and significant effects due to environment and time factors, and a time-environment interaction effect with F-ratios of 54,280.99, 256.49, 658.31, and 256.49 respectively. Exposure to interval diaper weighing did not show a significant effect on

Table 6

Multivariate analysis of Variance Results - Experimental Samples

Part of Model	Sum of Squares	Mean Squares	F-Ratio	Degrees Freedom Hypothesis	Degrees Freedom	Probability * p < .01
Grand Mean (GM)	2444.25	2444.25	847822.44	1.0	360.0	.0*
Environment (ENV)	14.57	4.86	1684.75	3.0	360.0	.0*
Diaper Type (DIAP)	5.46	1.37	473.82	4.0	360.0	.0*
Volume (VOL)	0.05	0.05	16.54	1.0	360.0	.6E-4*
ENV * DIAP	4.50	0.37	129.96	12.0	360.0	.0*
ENV * VOL	1.97	0.66	228.31	3.0	360.0	.0*
DIAP * VOL	0.11	0.03	9.79	4.0	360.0	.157E-6*
ENV * DIAP * VOL	0.60	0.05	17.27	12.0	360.0	.754E-13*
TIME	6.18	1.03	2301.35	6.0	2160.0	.0*
ENV * TIME	4.62	0.26	572.71	18.0	2160.0	.0*
DIAP * TIME	2.95	0.12	274.28	24.0	2160.0	.0*
VOL * TIME	0.03	0.4306E-2	9.62	6.0	2160.0	.182E-9*
ENV * DIAP * TIME	1.40	0.02	43.31	72.0	2160.0	.0*
ENV * VOL * TIME	0.53	0.03	65.59	18.0	2160.0	.7-4*
DIAP * VOL * TIME	0.05	0.1950E-2	4.36	24.0	2160.0	.422E-5*
ENV * DIAP * VOL * TIME	0.17	0.2402E-2	5.36	72.0	2160.0	.336E-5*

mean diaper weights with a calculated F-ratio of 3.53 and a probability of .06434. Interaction effects between the factors of environment and time in combination with experimental or control sample grouping were also statistically non-significant. Table 7 provides a summary table for the control group analysis of variance results. These results indicate that there was a difference in measured mean diaper weights over time for both the control and experimental samples. This difference in diaper weights was due to the factor effects of environment and time and a time-environment interaction. Whether the diaper was subjected to the control or experimental weighing intervals did not affect the mean diaper weight changes measured in the simulations.

Comparison of Factor Effects

Post hoc multiple comparisons using the Student's Newman-Keuls test were done to further describe the observed differences in mean diaper weights over time. Comparisons that would delineate every factor were not possible due to the number of cells that could be created with the test procedure. The probability value for this test is preset at $p < .05$ and could not be altered to match the significance level chosen for the multivariate analysis of variance.

Table 7

Multivariate Analysis of Variance Results - Control Samples

Part of Model	Sum of Squares	Mean Square	F-Ratio	Degrees Freedom Hypothesis	Degrees Freedom	Probability * $p < .01$
Grand Mean (GM)	129.83	129.83	54280.99	1.0	72.0	.0 *
Environment (ENV)	1.84	0.61	256.49	3.0	72.0	.239E-37 *
TYPE[b]	0.8441E-2	0.8441E-2	3.53	1.0	72.0	.06434
ENV * TYPE	0.9160E-2	0.3053E-2	1.28	3.0	72.0	.28890
TIME	1.57	1.57	658.31	1.0	72.0	.590E-37 *
ENV * TIME	1.84	0.61	256.49	3.0	72.0	.239E-37 *
TYPE * TIME	0.8441E-2	0.8441E-2	3.53	1.0	72.0	.06434
ENV * TYPE * TIME	0.9160E-2	0.3053E-2	1.28	3.0	72.0	.28890

b - Type refers to control or experimental sample

Experimental Samples

Most comparisons between diaper type and time show a significant effect ($p < .05$). These results suggest that observed diaper weight means, and therefore moisture exchange, varied according to the type of diaper and time of exposure to environmental conditions. Non-significant comparisons occurred between different diaper types at similar times reflecting similar rates of moisture exchange for some diaper types. Closed superabsorbent disposable diapers showed non-significant comparisons between all time intervals indicating small changes throughout the testing period. Results of the comparisons between time interval and diaper type are found in Table 8.

Multiple comparisons of environment type with diaper type were also done. Most comparisons revealed significant differences ($p < .05$) which indicated that diaper weight change varied between samples of diaper types exposed to different environments. There were non-significant differences between the diaper weight change for closed superabsorbent disposable diapers in the incubator set at 33.5° C and the 50% output radiant warmer environment. Open cotton with burn sheeting, open cotton, closed terrycloth, and open superabsorbent disposable diapers showed non-significant differences in the incubator environment set at 36.0° C with added humidity. Table 9 illustrates the comparisons between environment and diaper type.

Multiple comparisons between volume added and diaper type indicate significant comparisons ($p < .05$) unless the comparisons were between the same diaper type and different volumes of added solution. These comparisons suggest different diaper weight change for different diaper types and similar diaper weight change for same diaper types with different volumes of added solution. Table 10 summarizes multiple comparisons for volume of solution added and diaper type.

Multiple comparisons identifying the factors of environment type, time intervals, and volume of added solution were also done. Most comparisons were significant ($p < .05$). The results indicate that diaper weight change varied with environments, time intervals, and volume of added solution. Non-significant comparisons occurred for all Time Interval One comparisons between environment and diaper types which is expected since the mean change is zero at this time. Other random non-significant results appeared between differing volumes added, environments, and time intervals suggesting similar mean changes at different time

Table 8

Multiple Comparisons - Time Interval and Diaper Type

Diaper Type Environment Combinations	terry 7	terry 6	cotton 7	terry 5	cotton 6	c burn 7	cotton 5	terry 4	c burn 6	c burn 5	cotton 4	terry 3	c burn 4	o dis 7	cotton 3	o dis 6	c burn 3	o dis 5	terry 2	o dis 4	cotton 2	o dis 3	c burn 2	o dis 2	c dis 7	c dis 6	c dis 5	c dis 4	c dis 3	c dis 2	c burn 1	o dis 1	terry 1	cotton 1	c dis 1
terry 7																																			
terry 6	*																																		
cotton 7	*	*																																	
terry 5	*	*	*																																
cotton 6	*	*	*	*																															
c burn 7	*	*	*	*	Δ																														
cotton 5	*	*	*	*	*	*																													
terry 4	*	*	*	*	*	*	Δ																												
c burn 6	*	*	*	*	*	*	Δ	Δ																											
c burn 5	*	*	*	*	*	*	*	*	*																										
cotton 4	*	*	*	*	*	*	*	*	*	*																									
terry 3	*	*	*	*	*	*	*	*	*	*	*																								
c burn 4	*	*	*	*	*	*	*	*	*	*	*	*																							
o dis 7	*	*	*	*	*	*	*	*	*	*	*	*	Δ																						
cotton 3	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ																					
o dis 6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ																				
c burn 3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ																			
o dis 5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ																		
terry 2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ																	
o dis 4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ																
cotton 2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	*															
o dis 3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ														
c burn 2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ													
o dis 2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ												
c dis 7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ											
c dis 6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ										
c dis 5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ									
c dis 4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ								
c dis 3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ							
c dis 2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ						
c burn 1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ					
o dis 1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ				
terry 1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ			
cotton 1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ		
c dis 1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	

Legend
c burn = open cotton diaper with burn sheeting
cotton = open cotton diaper
terry = closed cotton terrycloth diaper
o dis = open superabsorbent disposable diaper
c dis = closed superabsorbant disposable diaper
1-7 = time intervals 0, 15, 30, 45, 60, 75 & 90 minutes
* = significant difference of means with Student's Newman-Keuls Test ($p \leq .05$)
Δ = non-significant Difference of means

Table 9

Multiple Comparisons - Environment and Diaper Type

	rw 75 terry	rw 50 terry	rw 75 cotton	rw 75 c burn	rw 50 cotton	rw 50 c burn	incub terry	incub cotton	rw75 o dis	rw50 o dis	incub c burn	incub o dis	rw75 c dis	rw50 c dis	incub c dis	incuH c dis	incuH o dis	incuH c burn	incuH cotton	incuH terry
rw 75 terry																				
rw 50 terry	*																			
rw 75 cotton	*	*																		
rw 75 c burn	*	*	*																	
rw 50 cotton	*	*	*	Δ																
rw 50 c burn	*	*	*	*	*															
incub terry	*	*	*	*	*	Δ														
incub cotton	*	*	*	*	*	*	Δ													
rw75 o dis	*	*	*	*	*	*	Δ	Δ												
rw50 o dis	*	*	*	*	*	*	*	*	*											
incub c burn	*	*	*	*	*	*	*	*	*	Δ										
incub o dis	*	*	*	*	*	*	*	*	*	*	*									
rw75 c dis	*	*	*	*	*	*	*	*	*	*	*	Δ								
rw50 c dis	*	*	*	*	*	*	*	*	*	*	*	*	Δ							
incub c dis	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ						
incuH c dis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*					
incuH o dis	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*				
incuH c burn	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ			
incuH cotton	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ		
incuH terry	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	

Legend
rw 75 = Radiant warmer at 75% output
rw 50 = Radiant warmer at 50% output
incub = incubator set at 33.5° C
incuH = incubator at 36.0° C with added humidity
c burn = open cotton diaper with burn sheeting
cotton = open cotton diaper
terry = closed cotton terrycloth diaper
o dis = open superabsorbent disposable diaper
c dis = closed superabsorbant disposable diaper
* = significant difference of means with Student's Newman-Keuls Test ($p \leq .05$)
Δ = non-significant Difference of means

Table 10

Multiple Comparisons - Volume of Solution and Diaper Type

	terry 5	terry 15	cotton 5	cotton 15	c burn 15	c burn 5	o dis 5	o dis 15	c dis 5	c dis 15
terry 5										
terry 15	Δ									
cotton 5	*	*								
cotton 15	*	*	Δ							
c burn 15	*	*	*	*						
c burn 5	*	*	*	*	Δ					
o dis 5	*	*	*	*	*	*				
o dis 15	*	*	*	*	*	*	Δ			
c dis 5	*	*	*	*	*	*	*	*		
c dis 15	*	*	*	*	*	*	*	*	Δ	

Legend
terry = closed cotton terrycloth diaper
cotton = open cotton diaper
c burn = open cotton diaper with burn sheeting
o dis = open superabsorbent disposable diaper
c dis = closed superabsorbant disposable diaper
5 or 15 = volume of 0.45% saline solution added
* or Δ = significant or non-significance multiple comparisons with Student's Newman-Keuls Test ($p \leq .05$)

exposures under various conditions. For diapers with 15 ml of added solution exposed to the high humidity incubator environment, comparisons at Time Intervals Two and Three are significant but are non-significant at the remaining time intervals, suggesting that only initial exposure to the environment resulted in different diaper weight change. Comparisons between environment type, time interval, and volume of solution added are identified in Table 11.

Control Samples

Post hoc multiple comparisons between environment type, control or experimental grouping, and time intervals were performed with the Student's Newman-Keuls test. Most comparisons between these factors were significant ($p < .05$). As expected, comparisons between control and experimental samples at number one or

Table 11

<u>Significant Multiple Comparisons - Environment, Diaper Type, and Time Intervals</u>

	rw 75 5-7	rw 75 5-6	rw 50 5-7	rw 75 15-7	rw 75 5-5	rw 50 5-6	rw 75 15-6	rw 50 5-5	rw 75 5-4	rw 75 15-4	rw 50 15-7	incub 5-7	rw 50 15-6	rw 50 5-4	rw 75 5-3	rw 75 15-4	incub 5-6	rw 50 15-5	incub 15-7	rw 50 5-3	incub 5-5	rw 50 15-4	incub 15-6	rw 75 15-3	rw 75 5-2	incub 15-5	incub 5-4	rw 50 15-3	rw 50 5-2	incub 15-4	rw 75 15-2	incub 5-3	rw 50 15-2	incub 15-3	incub 5-2	incub 15-2	incuH 15-7	incuH 15-1	incub 15-1	incuH 5-1	incub 5-1	rw 75 15-1	rw 50 15-1	rw 50 5-1	rw 75 5-1	incuH 15-6	incuH 15-5	incuH 15-4	incuH 15-3	incuH 15-2	incuH 5-2	incuH 5-3	incuH 5-4	incuH 5-5	incuH 5-7	incuH 5-6
rw 75 5-7																																																								
rw 75 5-6	*																																																							
rw 50 5-7	*	*																																																						
rw 75 15-7	*	*	Δ																																																					
rw 75 5-5	*	*	*	*																																																				
rw 50 5-6	*	*	*	*	*																																																			
rw 75 15-6	*	*	*	*	*	*																																																		
rw 50 5-5	*	*	*	*	*	*	*																																																	
rw 75 5-4	*	*	*	*	*	*	*	Δ																																																
rw 75 15-4	*	*	*	*	*	*	*	Δ	Δ																																															
rw 50 15-7	*	*	*	*	*	*	*	*	*	*																																														
incub 5-7	*	*	*	*	*	*	*	*	*	*	*																																													
rw 50 15-6	*	*	*	*	*	*	*	*	*	*	*	Δ																																												
rw 50 5-4	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ																																											
rw 75 5-3	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ																																										
rw 75 15-4	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ																																									
incub 5-6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ																																								
rw 50 15-5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ																																							
incub 15-7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	*																																						
rw 50 5-3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ																																					
incub 5-5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ																																				
rw 50 15-4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ																																			
incub 15-6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ																																		
rw 75 15-3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ																																	
rw 75 5-2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ																																
incub 15-5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ																															
incub 5-4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ																														
rw 50 15-3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ																													
rw 50 5-2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ																												
incub 15-4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ																											
rw 75 15-2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ																										
incub 5-3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ																									
rw 50 15-2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ																								
incub 15-3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ																							
incub 5-2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*																						
incub 15-2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ																					
incuH 15-7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ																				
incuH 15-1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ																			
incub 15-1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ																		
incuH 5-1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ																	
incub 5-1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ																
rw 75 15-1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ															
rw 50 15-1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ														
rw 50 5-1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ													
rw 75 5-1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ												
incuH 15-6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ											
incuH 15-5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ										
incuH 15-4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ	Δ									
incuH 15-3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ	*	Δ	Δ								
incuH 15-2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ	*	Δ	Δ	Δ							
incuH 5-2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*						
incuH 5-3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*					
incuH 5-4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*				
incuH 5-5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ			
incuH 5-7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ		
incuH 5-6	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	Δ	Δ	

<u>Legend</u>

rw 75 = radiant warmer at 75% heater output

rw 50 = radiant warmer at 50% heater output

incub = incubator set at 33.5°C

incuH = incubator at 36.0°C with added Humidity

number - number = volume added to diaper - time interval

time interval 1 - 7 indicates time 0, 15, 30, 60, 75, and 90 minutes respectively

* = significant difference of means with Student's Newman-Keuls Test ($p \leq .05$)

Δ = non-significant Difference of means

Time Zero were non-significant (p >.05). Multiple comparisons between the experimental and control samples under the radiant warmer at 50% heater output and in the incubator environment set at 36.0° C with added humidity showed statistically significant differences. Table 12 identifies significant and non-significant multiple

Table 12

Multiple Comparisons - Control Samples

Environment, Diaper Type, and Time Interval

		rw@ 75 CON #7	rw@ 75 EXP #7	rw@ 50 EXP #7	rw@ 50 CON #7	incubator EXP #7	incubator CON #7	incubatorH CON #1	incubatorH EXP #1	rw@ 50 CON #1	incubator CON #1	rw@ 75 CON #1	incubator EXP #1	rw@ 50 EXP #1	rw@ 75 EXP #1	incubatorH EXP #7	incubatorH CON #7
rw@ 75	CON #7																
rw@ 75	EXP #7	Δ															
rw@ 50	EXP #7	*	*														
rw@ 50	CON #7	*	*	*													
incubator	EXP #7	*	*	*	*												
incubator	CON #7	*	*	*	*	Δ											
incubatorH	CON #1	*	*	*	*	*	*										
incubatorH	EXP #1	*	*	*	*	*	*	Δ									
rw@ 50	CON #1	*	*	*	*	*	*	Δ	Δ								
incubator	CON #1	*	*	*	*	*	*	Δ	Δ	Δ							
rw@ 75	CON #1	*	*	*	*	*	*	Δ	Δ	Δ	Δ						
incubator	EXP #1	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ					
rw@ 50	EXP #1	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ				
rw@ 75	EXP #1	*	*	*	*	*	*	Δ	Δ	Δ	Δ	Δ	Δ	Δ			
incubatorH	EXP #7	*	*	*	*	*	*	*	*	*	*	*	*	*	*		
incubatorH	CON #7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	

Legend rw@ 75 = Radiant warmer at 75% output

@ 50 = Radiant warmer at 50% output

incubatorH = incubator at 36.0° C with added Humidity

EXP = Experimental Group

CON = Control Group

#1 = Time zero

#7 = Time 90 minutes

Δ = Non-significant difference of means

* = Significant Difference of means Student's Newman-Keuls test (p ≤ .05)

comparisons between environment type, control or experimental grouping, and time intervals.

Comparison of Environmental Parameters

Environmental parameters of air velocity, air temperature, and relative humidity were measured every 20 minutes during diaper trials in each of the four simulation environments. Means, standard deviations, and ranges of these parameters were determined to delineate conditions in each environment.

Experimental Samples

The incubator set at 36.0° C with added humidity measured the greatest mean relative humidity at 85.4% and greatest mean air temperature at 35.9° C. The radiant warmer set at 75% heater output measured the lowest mean relative humidity at 31.6% while under the radiant warmer at 50% heater output and in the incubator set at 33.5° C it was measured at 33.9% and 44.0% respectively. Mean air temperatures measured at 30.2° C for the high output and 28.3° C for the low output radiant warmer environments which was less than the 33.4° C measured in the low humidity incubator. In order of descending magnitude the mean air velocities measured were 0.10 m/sec, 0.064 m/sec, and 0.058 m/sec for the high output radiant warmer, low output radiant warmer, low humidity incubator, and high humidity incubator respectively. Means, standard deviations, and ranges for the environmental parameters of air velocity, air temperature, and relative humidity categorized by environment type are found in Table 13.

Control Samples

Environmental conditions for the experimental and control samples were measured and calculated in terms of means and standard deviations for air velocity, air temperature, and relative humidity in order to compare the similarity of the environments. Air velocity was similar for both control and experimental samples except for a 0.03 m/sec greater value for the experimental samples. Air temperature showed the greatest variance under the radiant warmers with the experimental samples showing a mean temperature approximately 0.05° C greater under the 75% output radiant warmer and 0.08° C under the 50% output radiant warmer environment. Measured mean relative humidities were very similar with the largest measured difference of approximately 1% under the 50% heater output radiant warmer environment. Table 14 summarizes these values.

Table 13

Environmental Parameters - Experimental Samples

Environment	Air Velocity (m/sec)			Air Temperature (°C)			Relative Humidity (%)		
	M	SD	Range	M	SD	Range	M	SD	Range
Incubator at 36.0°C with Humidity	.0297	.0158	.005 - .110	35.9496	.0588	35.5 - 36.3	85.3678	2.8564	73.9 - 92.8
Incubator at 33°C	.0577	.0228	.005 - .100	33.4238	.0266	33.2 - 33.6	44.0462	1.7303	41.0 - 51.3
Radiant Warmer at 75% Output	.1016	.0153	.040 - .195	30.2310	1.0394	27.5 - 32.1	31.5990	2.5708	20.2 - 40.8
Radiant Warmer at 50% Output	.0640	.0098	.025 - .165	28.3262	.3904	27.4 - 29.2	33.8670	2.1725	29.5 - 43.7
All Environments	.0633	.0305	.005 - .195	31.9818	2.9818	27.4 - 36.3	48.7200	21.8270	20.2 - 92.8

Table 14

Environmental Parameters - Control Samples

Environmental Means	Air Velocity (m/sec)		Air Temperature (°C)		Relative Humidity (%)	
	M	SD	M	SD	M	SD
Incubator @ 36°C Humidity						
Control	.0500	.0105	35.8780	.0466	87.6760	1.2956
Experimental	.0386	.0132	35.9300	.0380	87.6840	2.2125
Incubator @ 33.5°C						
Control	.0433	.0110	33.4360	.0263	43.9040	.0126
Experimental	.0735	.0049	33.4380	.0382	43.4280	.6394
Radiant Warmer @ 75%						
Control	.0905	.0150	29.5640	.2873	33.0000	2.5502
Experimental	.0915	.0106	30.0280	.2044	32.7920	1.7814
Radiant Warmer @ 50%						
Control	.0668	.0091	27.9500	.0999	31.7060	.6167
Experimental	.0597	.0078	28.7880	.1360	32.7480	.8657

CHAPTER FIVE

Discussion

The results of this simulation of diapering practices in a neonatal intensive care unit indicate that all of the factors tested— environment, diaper type, volume of added solution and time—affect significantly ($p < .01$) the accuracy of diaper weights in measuring urine output volume. Therefore, all of these factors must be considered in clinical situations when interpreting results from measuring urine output by weighing diapers.

Post hoc multiple comparisons using the Student's Newman-Keuls test are difficult to compare with results from the analysis of variance because the probability value of the former test was set at $p < .05$ while the latter was set at $p < .01$. This difference in probability values may have contributed to the conflicting results obtained for the significance of the factor Volume of Added Solution. Analysis of variance indicates that this factor is statistically significant while results from the multiple comparisons indicate it is not. Because of the limitations on the number of possible cells in the comparison test, comparisons involving every level of each factor identified in the simulation were not possible. A greater number of comparisons may have provided additional information for analysis.

Environment

The effect of environment on diaper weight accuracy is related to the conditions in the environment that affect moisture exchange. In this simulation, air temperature, relative humidity, and air velocity were the environmental conditions measured. The experimental design does not allow for complete delineation of the effects of individual conditions since the simulated environments varied on all factors. For the tested environments, diapers increased or decreased in weight over time according to the measured humidity. Diapers in the environment with the lowest measured relative humidity lost the most weight while diapers in the environment with the highest humidity increased in weight or lost the least amount of weight. Diapers in the environment with largest air velocity showed the greatest decrease in weight while those diapers in th environment the lowest air velocity increased in weight or had the smallest decrease in weight. Measured ambient air temperatures did not exhibit a similar relationship with diaper weight increase or decrease.

In the incubator set at 36.0°C with added humidity, the measured mean air velocity was the lowest (.0297 m/sec) while the mean relative humidity was the greatest (85.4%). These conditions would tend to limit evaporation or cause condensation resulting in all diaper combinations increasing in weight. This environment also had the highest measured mean air temperature (35.9°C) which would tend to increase evaporation in the environment by providing energy for conversion of moisture to vapour.

In this simulation, wet diapers were introduced into the environment whereas in a clinical situation, a dry diaper would be introduced and removed only when it was felt that the infant had voided. In a high humidity environment, the potential exists for the nurse to be weighing diapers that feel "wet" and yet have no urine on them. A controlled simulation in which dry diapers introduced into a high humidity environment were weighed sequentially over time is indicated to determine if an additional weight increase is probable in this more life-like situation. This information may determine that diapers should be changed periodically to limit the effect of weighing condensed water. Predicting from the results of this simulation, diapers might need to be changed as frequently as every 30 minutes to avoid more than a 10% measurement error.

In the remaining simulation environments, all diaper combinations lost weight over time in amounts directly related to the air velocity and inversely related to the relative humidity. Therefore, diaper combinations in the incubator set at 33.5°C environment showed the least weight loss because this environment measured the second highest mean relative humidity (44.0%) and second lowest mean air velocity (.0577 m/sec). Like the high humidity environment, losses were lower despite a higher measured air temperature than the radiant warmer environments.

Diaper combinations exposed to the radiant warmer at 75% heater output exhibited the greatest losses over time and this environment measured the lowest mean relative humidity (31.6%) and highest mean air velocity (.1016 m/sec). Mean ambient air temperature under the 75% heater output radiant warmer was higher than the level measured under the 50% heater output radiant warmer environment (30.2 versus 28.3°C). Day-to-day air condition variations, and a difference in air temperature resulting from radiant output levels may account for the differences in measured mean relative humidity and air velocity between the two environments.

The effects of incubator versus radiant warmer environments support the results given in two previous studies. As Hermansen and Buches (1988) reported, losses were greater for the radiant warmer environment with the greater heater output. Also, losses were greater under a radiant warmer than in an incubator as reported by William and Kanarek (1982) reported. Results from this simulation vary from those reported by Cooke, Werkman, and Watson (1989) which showed no differences in losses between an incubator and a radiant warmer environment. A lower relative humidity in the incubator used in their study may have been a factor affecting these results.

Consistent patterns of mean diaper weight change were not measured. That is, it was not possible to predict the weight change over 15 minutes based on the amount of change in the previous 15 minutes. The overall pattern was a consistent weight loss in the environments other than the incubator at 36°C added humidity. This weight loss appears almost linear over time. Cotton diaper combinations in the added humidity incubator environment increased in weight initially and then lost weight.

<u>Volume</u>

As indicated in several published studies (Cooke, Werkman & Watson, 1989; Hermansen & Buches, 1988; Williams & Kanarek, 1982), different volumes of added solution affected the mean percentage diaper weight change. All diaper combinations with 5.0 ml 0.45% saline solution added showed greater mean percentage weight changes than those samples with 15 ml added and a 10% change in diaper weight occurred more quickly for the 5 ml samples. Therefore, over time, weighing diapers was less accurate for a smaller volume of solution than for a larger volume.

<u>Diaper Type</u>

One of the main factors between diaper types that affected diaper weight change over time in the simulation environments was the fibre composition of the diapers. There were differences in weight changes if the diaper was composed of cotton or man-made material. In the incubator set at 36.0°C with added humidity, all diapers increased in weight. For cotton diaper combinations, however, a decrease in diaper weight followed the initial weight increase. A net loss of weight over time was measured for 15 ml added solution samples but not for 5 ml added solution samples. It is unknown why cotton diapers showed this change in moisture exchange with the environment over time or why the change varied for the different volumes of solution. In contrast, superabsorbent disposable diapers showed a continuous weight increase over time. These findings are supported by Hermansen and Buches (1987) who also documented that superabsorbent disposable diapers gain weight in high humidity environments.

Superabsorbent diapers showed a lower mean percentage weight change over time compared to cotton diapers. In addition, closed superabsorbent disposable diapers showed consistently smaller weight variations than did the open disposable diaper combination. Most of the studies reported in the literature studied the environmental effects on regular disposable diapers so it is difficult to compare results with this simulation. However, results given for open superabsorbent Pampers under a radiant warmer set at 50% heater output by Hermansen and Buches (1988) are very similar to the results obtained in this simulation. In both studies, open superabsorbent disposable diapers under the 50% heater output radiant warmer showed a less than 10% mean weight loss over 90 minutes. Closed superabsorbent disposable diapers in this simulation showed less of a weight loss over 90 minutes than did the closed regular disposable diapers used in the Hermansen and Buches (1988) experiment.

The diaper combination with the greatest measured weight change was the closed terrycloth combination. This finding may relate to the potentially larger surface area created on the outside of the diaper by the terry loops. Also, the wet centre may have had greater exposure to environmental conditions as it was lifted to fasten the diaper on the doll. The addition of burn sheeting on the open cotton diaper altered the moisture exchange slightly as these diaper samples showed a smaller increase or decrease in weight compared to those open cotton samples without the burn sheeting.

<u>Control Samples</u>

Comparison of control group samples with experimental samples using a two-way analysis of variance indicated that the frequent removal of the experimental diapers for sequential weights did not alter the mean weight change over time significantly ($p < .01$). Therefore, similar diaper weight changes could be expected in similar clinical environments when an infant's diaper is left in the environment for periods greater than 15 minutes. In contrast, post hoc multiple comparisons with the Student's Newman-Keuls test indicated statistically significant differences between the control and experimental groups for the 50% output radiant warmer and incubator set at 36.0°C with added humidity environments ($p < .05$). These conflicting results may relate to the differences in significance values between the two tests. Also, the overall effect determined by diaper weight changes in all four environments may have masked the changes in the two indicated environments.

Limitations of Study

The accuracy of urine volume measurement using diaper weights determined from this simulation applies only to selected diaper types used in similar environmental conditions. This limits the applicability of the results to the wide range of environmental conditions found in clinical situations. However, knowledge of how diaper weights change over time in the four environments created in the simulation can provide rough guidelines for the practitioner.

In the simulation trials, closed superabsorbent disposable diapers showed less than 4% weight change over 90 minutes and were the most accurate. This value may differ in actual clinical situations, however, since the diaper fit on the doll was snug compared to what might be achieved on a very small infant. In these cases, the clinical value should occur somewhere between the values obtained for the closed superabsorbent disposable diaper trials and those obtained for the open superabsorbent diaper trials, or between 4% and 19.8% for the greatest changes measured under the 75% heater output radiant warmer. Likewise, there is a larger surface area exposed for open diapers when small infants are placed on them which could alter the diaper weight change reported. For open diapers, though, the diapers could easily be folded to limit exposed area.

Variations in the concentration of neonates' urine in clinical situations might also result in diaper weight changes that vary from those indicated in the results of this study. Further study is necessary to determine if very dilute or concentrated urine would alter significantly diaper weight changes shown with the use of the 0.45% saline solution.

The design of the study could have been improved with continuous environmental monitoring. With this information, variations in environmental conditions would be clearer. Continuous or more frequent measurement of environmental factors would also allow factors such as relative humidity, air velocity, and air temperature to be isolated as factors in the analysis of variance instead of an overall environmental grouping.

Nursing Implications

Accurate measurement and determination of urine output using diaper weights is most important for very small immature infants. Additionally, body fluid distribution, skin evaporative water losses, and immature renal function in these infants make fluid balance critical but difficult to manage, especially in the environments designed to keep them warm. Very small immature infants tend to require high heater outputs when nursed under a radiant warmer and high air temperatures when nursed in an incubator. Also, the addition of highly humidified air to the incubator environment during the initial week of life has been recommended as a method to limit heat and water loss by these infants. These environmental conditions also affect the moisture exchange properties of the diaper environment.

Both the radiant warmer and incubator environments have the potential to limit the accuracy of diaper weights as a method of urine output measurement. Use of cotton diapers or open superabsorbent disposable diapers that are not frequently checked for urine could result in highly inaccurate calculation of urine volume. Use of this questionable figure in the determination of fluid management strategies may subject the infant to dehydration or overhydration.

Results from this study indicate that closed superabsorbent disposable diapers should be used to collect urine in those situations where precise urine output measurement for infants voiding small volumes is required since the mean percent weight change over 90 minutes was not greater than 4% in all environments. Open superabsorbent disposable diapers represent the next best alternative for precise measurements if closed ones cannot be used. However, infants should be checked for voiding every 30 minutes in the warmer incubator and radiant warmer environments and every 60 minutes in other environments. If cotton diapers are used for infants voiding small volumes of urine, diapers should be checked for urine every 15 minutes. In the opinion of the researcher, however, disturbing a sick infant every 15 minutes to check for voiding represents suboptimal nursing care. These diapers are not recommended for clinical situations requiring precise measurements.

For infants voiding larger volumes of urine in any of the simulated environments, diaper weights using closed superabsorbent disposable diapers showed mean percentage changes no greater than 2.5% over 90 minutes, thus, representing an accurate method of measuring volume. Open superabsorbent disposable diapers are a good alternative for use with this population showing less than a 10% mean percentage weight change after 60 minutes in all env[illegible]otton diaper combinations showed a mean percentage weight change [illegible]m 30-60 minutes in all environments but the incubator set at [illegible]fore, diapers should be checked for urine every 30 minutes if these diapers are used to determine urine output for infants voiding larger volumes of urine.

Increasing concern over waste management of disposable diapers has resulted in a call for increased use of nondisposable diapers. Therefore, the neonatal nurse must balance carefully the need for precise urine output measurements with environmental concerns. When accurate determination of urine volume is necessary for sick infants voiding small volumes of urine, use of disposable diapers can be justified despite the environmental cost. When less precise measurements are needed, the infant is voiding large volumes of urine, and/or the infant can be disturbed more frequently without adverse effects, use of cotton diapers for diaper weights may give adequate results and at the same time address environmental concerns.

Conclusion

Urine volume is important in the determination of renal function and fluid therapy in the neonate. It is often difficult to collect urine for urine volume measurement; therefore, comparison of prevoiding and postvoiding diaper weights has been suggested as a method to determine urine volume. However, neonatal warming environments may alter the moisture exchange in the environment resulting in inaccurate calculation of volume.

A simulation experiment using an incubator and radiant warmer in which five different diaper combinations with two volumes of added solution were placed in four different neonatal environments was conducted to determine the accuracy of diaper weights in the measurement of fluid volume. These diaper combinations were weighed at 15 minute intervals over 90 minutes to determine diaper weight changes over time.

Results of the simulation trials indicated that the accuracy of diaper weights in the determination of neonatal urine output volume is dependent upon the factors of time, environment, diaper type, and urine volume. If the neonatal nurse applies knowledge of these factors to clinical situations, it is possible for diaper weights to determine urine output accurately. If these factors are ignored, the nurse may calculate a urine output that varies significantly from the actual volume voided. The accuracy of urine losses is a significant factor in the determination of both fluid balance and renal function.

Infants voiding small volumes of urine and who are subjected to high output radiant heat or high humidity incubators require closed superabsorbent disposable diapers to determine urine volume accurately. Infants voiding larger volumes of urine or those subjected to less intense environmental conditions may have urine collected with other diaper types that are checked for urine frequently and have urine output determined accurately.

Literature Cited

Al-Dahhan, J., Haycock, G.B., Chantler, C., & Stimmler, L. (1983). Sodium homeostasis in term and preterm neonates. I Renal aspects. Archives of Disease in Childhood, 58, 335-342.

Aperia, A., Broberger, O., Broberger, U., Herin, P., & Zetterstrom, R. (1983). Glomerular tubular balance in preterm and fullterm infants. Acta Paediatrica Scandinavica, (Suppl.) 305, 70-76.

Aperia, A., Broberger, O., Elinder, G., Herin, P., & Zetterstrom, R. (1981). Postnatal development of renal function in preterm and full-term infants. Acta Paediatrica Scandinavica, 70, 183-187.

Aperia, A., Broberger, O., Herin, P., & Zetterstrom R. (1979). Sodium excretion in relation to sodium intake and aldosterone excretion in newborn pre-term and full-term infants. Acta Paediatrica Scandinavica, 68, 813-817.

Aperia, A. Borberger, O., Thodenius, K., & Zetterstrom, R. (1974). Developmental study of the renal response to an oral salt load in preterm infants. Acta Paediatrica Scandinavica, 63, 517-524.

Aperia, A., Herin, P., Lundin, S., Melin, P., & Zetterstrom, R. (1984). Regulation of renal water excretion in newborn full-term infants. Acta Paediatrica Scandinavica, 73, 717-721.

Arant, B.S. (1978). Developmental patterns of renal functional maturation compared in the human neonate. Journal of Pediatrics, 92, 705-712.

Baumgart, S., Engle, W.D., Fox, W.W., & Polin, R.A. (1981). Radiant warmer power and body size as determinants of insensible water loss in the critically ill neonate. Pediatric Research, 15, 1495-1499.

Belgaumkar, J.K., & Scott, K.E. (1975). Effects of low humidity on small premature infants in servocontrol incubators. Biology of the Neonate, 26, 337-347.

Bell, E.F. (1983). Infant incubators and radiant warmers. Early Human Development, 8, 351-375.

Bell, E.F., Neidich, G.A., Cashore, W.J., & Oh, W. (1979). Combined effect of radiant warmer and phototherapy on insensible water loss in low-birth-weight infants. Journal of Pediatrics, 94, 810-813.

Bell, E.F., & Oh, W. (1979). Fluid and electrolyte balance in very low birth weight infants. Clinics in Perinatology, 6, 139-150.

Bell, E.F., & Oh, W. (1987). Fluid and electrolyte management. In: G.B. Avery (Ed.), Neonatology: Pathophysiology and management of the newborn (3rd ed., pp. 775-794). Philadelphia: Lippincott.

Bell, E.F., Warburton, D., Stonestreet, B.S., & Oh, W. (1980). Effect of fluid administration on the development of symptomatic patent ductus arteriosus and congestive heart failure in premature infants. The New England Journal of Medicine, 302, 598-604.

Bell, E.F., Weinstein, M.R., & Oh, W. (1980). Heat balance in premature infants: Comparative effects of convectively heated incubator and radiant warmer, with and without plastic heat shield. Journal of Pediatrics, 96, 400-465.

Bierd, T.M., Kattwinkel, J., Chevalier, R.L., Rheuban, K.S., Smith, D.J., Teague, G., Carey, R.M., & Linden, J. (1990). Interrelationship of atrial natriuretic peptide, atrial volume, and renal function in premature infants. Journal of Pediatrics, 116, 753-759.

Broberger, U., & Aperia, A. (1978). Renal function in idiopathic respiratory distress syndrome. Acta Paediatrica Scandinavica, 67, 313-319.

Brown, E.R., Stark, A., Sosenko, I., Lawson, E.E., & Avery, M.E. (1978). Bronchopulmonary dysplasia: Possible relationship to pulmonary edema. Journal of Pediatrics, 92, 982-984.

Cassady, G., & Milstead, R.R. (1971). Antipyrine space studies and cell water estimates in infants of low birth weight. Pediatric Research, 5, 673-682.

Chenevey, B. (1987). Overview of fluids and electrolytes. Nursing Clinics of North America, 22, 749-759.

Cohen, J. (1977). Statistical power analysis for the behavioral sciences. New York: Academic Press.

Cooke, R.J., Werkman, S., & Watson, D. (1989). Urine output measurement in premature infants. Pediatrics, 83, 116-118.

Cort, R.L. (1962). Renal function in the respiratory distress syndrome. Acta Paediatrica Scandinavica, 51, 313-323.

Daniel, S.S., James, L.S., & Strauss, J. (1981). Response to rapid volume expansion during the postnatal period. Pediatrics, 68, 809-813.

Dauber, I.M., Krauss, A.N., Symchych, P.S., & Auld, P.A. (1976). Renal failure following perinatal anoxia. Journal of Pediatrics, 88, 851-855.

Davis, J.C. (1970). The dry and wet bulb psychrometer. In, Humidity Measurement (pp. 6-17). New York: American Society of Heating, Refrigerating and Air-conditioning Engineers.

Dery, R. (1973). Water balance of the respiratory tract during ventilation with a gas mixture saturated at body temperature. Canadian Anaesthesia Society Journal, 20, 719-727.

Dreszer, M. (1977). Fluid and electrolyte requirements in the newborn infant. Pediatric Clinics of North America, 24, 537-546.

Edelmann, C.M., & Barnett, J.L. (1960). Role of the kidney in water metabolism in young infants: Physiologic and clinical considerations. Journal of Pediatrics, 56, 154-179.

Ekblad, H., Kero, P., Takala, J., Korvenranta, H., & Valimaki, I. (1987). Water, sodium and acid-base balance in premature infants: Therapeutical aspects. Acta Paediatrica Scandinavica, 76, 47-53.

Evans, N.J., & Rutter, N. (1986). Development of the epidermis in the newborn. Biology of the Neonate, 49, 74-80.

Fewell, J.E., & Norton, J.B. (1980). Continuous positive airway pressure impairs renal function in newborn goats. Pediatric Research, 14, 1132-1134.

Foster, K.G., Hey, E.N., & Katz, G. (1969). The response of the sweat glands of the new-born baby to thermal stimuli and to intradermal acetylcholine. Journal of Physiology, 203, 13-29.

Friis-Hansen, B. (1957). Changes in body water compartments during growth. Acta Paediatrica Scandinavica, 46, (Suppl. 110), 1-68.

Friis-Hansen, B. (1961). Body water compartments in children: Changes during growth and related changes in body composition. Pediatrics, 28, 169-181.

Green, T.P., Thompson, T.R., Johnson, D.E., Lock, J.E. (1983). Diuresis and pulmonary function in premature infants with respiratory distress syndrome. Journal of Pediatrics, 103, 618-623.

Guignard, J.P., Torrado, A., Mazouni, S.M., & Gautier, E. (1976). Renal function in respiratory distress syndrome. Journal of Pediatrics, 88, 845-850.

Hammarlund, K., Nilsson, G.E., Oberg, P.A., & Sedin, G. (1977). Transepidermal water loss in newborn infants: Relation to ambient humidity and site of measurement and estimation of total transepidermal water loss. Acta Paediatrica Scandinavica, 66, 553-562.

Hammarlund, K., & Sedin, G. (1979). Transepidermal water loss in newborn infants: Relation to gestational age. Acta Paediatrica Scandinavica, 68, 795-801.

Hammarlund, K., & Sedin, G. (1983). Water evaporation and heat exchange with the environment in newborn infants. Acta Paediatrica Scandinavica, (Suppl. 305), 32-35.

Hammarlund, K., Sedin, G., & Stromberg, G. (1983). Transepidermal water loss in newborn infants: Relation to gestational age and post-natal age in appropriate and small for gestational age infants. Acta Paediatrica Scandinavica, 72, 721-728.

Harrison, L.P. (1965). Fundamental concepts and definitions relating to humidity. In: A. Wexler & W.A. Wildhack (Eds.), Humidity and moisture: Measurement and control in science and industry, Vol. III Fundamentals and standards (pp. 3-69). New York: Reinhold Publishing.

Hermansen, M.C., & Buches, M. (1988). Urine output determination from superabsorbent and regular diapers under radiant heat. Pediatrics, 81, 428-431.

Hermansen, M.C., & Buches, M. (1987). Super diapers and premature infants. Pediatrics, 79, 1056-1057.

Hey, E.N., & Katz, G. (1969). Evaporative water loss in the new-born baby. Journal of Physiology, 200, 605-619.

Hey, E.N., & Maurice, N.P. (1968). Effect of humidity on production and loss of heat in the newborn baby. Archives of Disease in Childhood, 43, 166-171.

Hollingsworth, A.O. (1985). The newborn. In: M.J. Masiak, M.D. Naylor, & L.L. Hayman (Eds.), Fluids and electrolytes through the life cycle (pp. 101-125). Norwalk, CT: Appleton-Century-Crofts.

Hutton, N.M., & Schreiner, R.L. (1980). Urine collection in the neonate: Effect of different methods on volume, specific gravity, and glucose. JOGN, 9, 165-169.

Ito, Y. Marumo, F., Ando, K., Hayashi, M, & Yamashita, F. (1990). The physiological and biological significances of human atrial natriuretic peptide in neonates. Acta Paediatrica Scandinavica, 79, 26-31.

Jones, M.D., Gresham, E.L., & Battaglia, F.C. (1972). Urinary flow rates and urea excretion rates in newborn infants. Biology of the Neonate, 21, 321-329.

Jones, R.W.A., Rochefort, M.J., & Baum, J.D. (1976). Increased insensible water loss in newborn infants nursed under radiant heaters. British Medical Journal, 2, 1347-1350.

Kagan, B.M., Stanincova, V., Felix, N.S., Hodgman, J., & Kalman, D. (1972). Body composition of premature infants: Relation to nutrition. American Journal of Clinical Nutrition, 25, 1153-1164.

Kramer, I., & Sherry, S.N. (1957). The time of passage of the first stool and urine by the premature infant. Journal of Pediatrics, 51, 373-376.

Langman, C.B., Engle, W.D., Baumgart, S., Fox, W.W., & Polin, R.A. (1981). The diuretic phase of respiratory distress syndrome and its relationship to oxygenation. Journal of Pediatrics, 98, 462-466.

Leake, R.D. (1977). Perinatal nephrobiology: A developmental perspective. Clinics in Perinatology, 4, 321-349.

Leake, R.D., Zakauddin, S., Trygstad, C.W., Fu, P., & Oh, W. (1976). The effects of large volume intravenous fluid infusion on neonatal renal function. Journal of Pediatrics, 89, 968-972.

Lemoh, J.N., & Brooke, O.G. (1979). Frequency and weight of normal stools in infancy. Archives of Disease in Childhood, 54, 719-720.

Leslie, G.I., Philips, J.B., Work, J., Ram, S., & Cassady, G. (1986). The effect of assisted ventilation on creatinine clearance and hormonal control of electrolyte balance in very low birth weight infants. Pediatric Research, 20, 447-452.

Leung, A.K.C., McArthur, R.G., McMillan, D.D., Ko, D., Deacon, J.S.R., Parboosingh, J.T., & Lederis, K.P. (1980). Circulating antidiuretic hormone during labour and in the newborn. Acta Paediatrica Scandinavica, 69, 505-510.

Liechty, E.A., Johnson, M.D., Myerberg, D.Z., & Mullett, M.D. (1989). Daily sequential changes in plasma atrial natriuretic factor concentrations in mechanically ventilated low-birth-weight-infants. Biology of the Neonate, 55, 244-250.

Masiak, M.J., & Naylor, M.D. (1985). The need: Fluids and electrolytes. In: M.J. Masiak, M.D. Naylor, & L.L. Hayman (Eds.), Fluids and electrolytes through the life cycle (pp. 1-26). Norwalk, CT: Appleton-Century-Crofts.

Mathew, O.P., Jones, A.S., James, E., Bland, H., & Groshong, T. (1980). Neonatal renal failure: Usefulness of diagnostic indices. Pediatrics, 65, 57-60.

Maurer, A., Micheli, J.L., Schutz, Y., Freymond, D., & Jequier, E. (1984). Transepidermal water loss and resting energy expenditure in preterm infants. Helvetica Paediatrica Acta, 39, 405-418.

McManus-Kuller, J. (1984). Skin development and function. Neonatal Network, 3, 18-23.

Metheny, N.M. (1987). Fluid and electrolyte balance: Nursing considerations. Philadelphia: J.B. Lippincott.

Moylan, F.M., Herrin, J.T., Krishnamoorthy, K., Todres, D., & Shannon, D.C. (1978). Inappropriate antidiuretic hormone secretion in premature infants with cerebral injury. American Journal of Diseases in Children, 132, 339-402.

Nash, M.A. (1987). Nutrition, body fluids, and acid-base homeostasis. Part 2: Provision of water and electrolytes. In: A.A. Fanaroff & R.J. Martin (Eds.), Neonatal-perinatal medicine (4th ed., pp. 460-466). St. Louis: C.V. Mosby.

Norman, M.E., & Asadi, F.K. (1979). A prospective study of acute renal failure in the newborn infant. Pediatrics, 63, 475-479.

Oh, W. (1988). Renal function and fluid therapy in high risk infants. Biology of the Neonate, 53, 230-236.

Oh, W., Yao, A.C., Hanson, J.S., & Lind, J. (1973). Peripheral circulatory response to phototherapy in newborn infants. Acta Paediatrica Scandinavica, 62, 49-54.

Okken, A., Blijham, C., Franz, W., & Bohn, E. (1982). Effects of forced convection of heated air on insensible water loss and heat loss in preterm infants in incubators. Journal of Pediatrics, 101, 108-112.

Rees, L., Brook, C.G.D., Shaw, J.C.L., & Forsling, M.L. (1984). Hyponatraemia in the first week of life in preterm infants. Part I: Arginine vasopressin secretion. Archives of Disease in Childhood, 59, 414-422.

Ross, B., Cowett, R.M., & Oh, W. (1977). Renal functions of low birth weight infants during the first two months of life. Pediatric Research, 11, 1162-1164.

Rossini, F.D. (1974). Fundamental measures and constants for science and technology. Cleveland OH: CRC Press.

Roy, R.N., & Sinclair, J.C. (1975). Hydration of the low birth-weight infant. Clinics in Perinatology, 2, 393-417.

Rutter, N., & Hull, D. (1979). Water loss from the skin of term and preterm babies. Archives of Disease in Childhood, 54, 858-868.

Sedin, G., Hammarlund, K., Stromberg, B. (1985). Water loss from the skin of preterm and full-term newborn infants. In: L. Stern, W. Oh, & B. Friis-Hansen (Eds.), Physiologic foundations of perinatal care (Vol. 2, pp.165-174). New York: Elsevier.

Sedin, G., Hammarlund, K., Nilsson, G.E., Stromberg, G., & Oberg, P.A. (1985). Measurements of transepidermal water loss in newborn infants. Clinics in Perinatology, 12, 79-99.

Shaffer, S.G., Bradt, S.K., & Hall, R.T. (1986). Postnatal changes in total body water and extracelluiar volume in the preterm infant with respiratory distress syndrome. Journal of Pediatrics, 109, 509-514.

Shaffer, S.G., Bradt, S.K., Meade, V.M., & Hall, R.T. (1987). Extracellular fluid volume changes in very low birth weight infants during first 2 postnatal months. Journal of Pediatrics, 111, 124-128.

Shaffer, S.G., & Meade, V.M. (1989). Sodium balance and extracellular volume regulation in very low birth weight infants. Journal of Pediatrics, 115, 285-290.

Shaffer, S.G., Quimiro, C.L., Anderson, J.V., & Hall, R.T. (1987). Postnatal weight changes in low birth weight infants. Pediatrics, 79, 702-705.

Sherry, S.N., & Kramer, I. (1955). The time of passage of the first stool and first urine by the newborn infant. Journal of Pediatrics, 46, 158-159.

Siegel, S.R., Fisher, D.A., & Oh, W. (1973). Renal function and serum aldosterone levels in infants with respiratory distress syndrome. Journal of Pediatrics, 83, 854-858.

Siegel, S.R., & Oh, W. (1976). Renal function as a marker of human fetal maturation. Acta Paediatrica Scandinavica, 65, 481-485.

Speer, M.E., Gorman, W.A., Kaplan, S.L., & Rudolph, A.J. (1984). Elevation of plasma concentrations of arginine vasopressin following perinatal asphyxia. Acta Paediatrica Scandinavica, 73, 610-614.

SPSS Incorporated. (1988). SPPS- 3.0 (3rd ed.). Chicago, IL: Author.

Stevenson, J.G., (1977). Fluid administration in the association of patent ductus arterious complicating respiratory distress syndrome. Journal of Pediatrics, 90, 257-261.

Stonestreet, B.S., Bell, E.F., Warburton, D., & Oh, W. (1983). Renal response in low-birth-weight neonates. American Journal of Diseases in Children, 137, 215-219.

Strauss, J., Daniel, S.S., & James, L.S. (1981). Postnatal adjustment in renal function. Pediatrics, 68, 802-808.

Strauss, J., Zilleruelo, G., & Freundlich, M. (1985). Neonatal renal functions, fluid and electrolytes in intensive care units. In: D. Vidyasagar & A.P. Sarnaik (Eds.), Neonatal and pediatric intensive care (pp. 151-161). Littleton, MA: PSG Publishing.

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Svenningsen, N.W., [illegible] (198[illegible]). [illegible] concentration during [illegible] in newborn infants. Acta Paediatrica Scandinavica, 7[illegible], [illegible]

Svenningsen, N.W., & Aronson, A.S. (1974). Postnatal development of renal concentration capacity as estimated by DDAVP-test in normal and asphyxiated neonates. Biology of the Neonate, 2[illegible], [illegible]

Thompson, M.H., Stothers, J.K., & McLellan, N.J. (1984). Weight and water loss in the neonate in natural and forced convection. Archives of Disease in Childhood, 59, 951-956.

Tomomura, A.S. (1986). Water balance and control of osmolality. In: J. Askanazi, P.M. Starker, & C. Weissman (Eds.), Fluid and electrolyte management in critical care (pp. 93-119). Toronto: Butterworths.

Torrado, A., Guignard, J.P., Prod'hom, L.S., & Gautier, E. (1974). Hypoxaemia and renal function in newborns with respiratory distress syndrome (RDS). Helvetica Paediatrica Acta, 29, 399-405.

Sujov, P., Kellerman, L., Zeltzer, & Hochberg, Z. (1984). Plasma and urine osmolality in full-term and pre-term infants. Acta Paediatrica Scandinavica, 73, 722-726.

Sulyok, E., Jequier, E., & Prod'hom, L.S. (1973a). Respiratory contribution to the thermal balance of the newborn infant under various ambient conditions. Pediatrics, 51, 641-650.

Sulyok, E., Jequier, E., & Prod'hom, L.S. (1973b). Thermal balance of the newborn infant in a heat-gaining environment. Pediatric Research, 7, 888-900.

Sulyok, E., Jequier, E., & Ryser, G. (1972). Effect of relative humidity on thermal balance of the newborn infant. Biology of the Neonate, 21, 210-218.

Sulyok, E., Kovacs, L., Lichardus, B., Michajlovskij, N., Lehotska, V., Nemethova, V., Varga, L., & Ertl, T. (1985). Late hyponatremia in premature infants: Role of aldosterone and arginine vasopressin. Journal of Pediatrics, 106, 990-994.

Sulyok, E., Nemeth, M., Tenyi, I., Csaba, I., Gyory, E., Ertl, T., & Varga, R. (1979). Postnatal development of renin-angiotensin-aldosterone system, RAAS, in relation to electolyte balance in premature infants. Pediatric Research, 13, 817-820.

Sulyok, E., Varga, F., Gyory, E., Jobst, K., & Csaba, I.F. (1979). Postnatal development of renal sodium handling in premature infants. Journal of Pediatrics, 95, 787-792.

Svenningsen, N.W., Andreasson, B., & Lindroth, M. (1984). Diuresis and urine concentration during CPAP in newborn infants. Acta Paediatrica Scandinavica, 73, 727-732.

Svenningsen, N.W., & Aronson, A.S. (1974). Postnatal development of renal concentration capacity as estimated by D DAVP-test in normal and asphyxiated neonates. Biology of the Neonate, 25, 230-241.

Thompson, M.H., Stothers, J.K., & McLellan, N.J. (1984). Weight and water loss in the neonate in natural and forced convection. Archives of Disease in Childhood, 59, 951-956.

Tonneson, A.S. (1986). Water balance and control of osmolality. In: J. Askanazi, P.M. Starker, & C. Weissman (Eds.), Fluid and electrolyte management in critical care (pp. 93-119). Toronto: Butterworths.

Torrado, A., Guignard, J.P., Prod'hom, L.S., & Gautier, E. (1974). Hypoxaemia and renal function in newborns with respiratory distress syndrome (RDS). Helvetica Paediatrica Acta, 29, 399-405.

Tulassay, T., Machay, T., Kiszel, J., & Varga, J. (1983). Effects of continuous positive airway pressure on renal function in prematures. Biology of the Neonate, 43, 152-157.

Tulassay, T., Ritvay, J., Bors, Z., & Buky, B. (1979). Alterations in creatinine clearance during respiratory distress syndrome. Biology of the Neonate, 35, 258-263.

Tulassay, T., Seri, I., & Rascher, W. (1987). Atrial natriuretic peptide and extracellular volume contraction after birth. Acta Paediatrica Scandinavica, 76, 444-446.

Van Marter, L.J., Leviton, A., Allred, E.N., Pagano, M., & Kuban, K.C. (1990). Hydration during the first days of life and the risk of bronchopulmonary dysplasia in low birth weight infants. Journal of Pediatrics, 116, 942-949.

Vanpee, M., Herin, P., Zetterstrom, R., & Aperia, A. (1988). Postnatal development of renal function in very low birthweight infants. Acta Paediatrica Scandinavica, 77, 191-197.

Widdowson, E.M. (1974). Changes in body proportions and composition during growth. In: J.Davis & J. Dobbin (Ed.) Scientific Foundation of Pediatrics (pp. 153-162). London: William Heinemann Medical Books.

Williams, P.R., & Kanarek, K.S. (1982). Urine evaporative loss and effects on specific gravity and osmolality. Journal of Pediatrics, 100, 626-628.

Williams, P.R., & Oh, W. (1974). Effects of radiant warmer on insensible water loss in newborn infants. American Journal of Diseases in Children, 128, 511-514.

Wu, P.Y.K., & Hodgman, J.E. (1974). Insensible water loss in preterm infants: Changes with postnatal development and non-ionizing radiant energy. Pediatrics, 54, 704-712.

Wu, P.Y.K., Wong, W.H., Hodgman, J.E., & Levan, N. (1974). Changes in blood flow in the skin and muscle with phototherapy. Pediatric Research, 8, 257-262.

Zetterstrom, R., Aperia, A., & Herin, P. (1985). Sodium and fluid balance in preterm newborn infants. In: L. Stern, W. Oh, & B. Friis-Hansen (Eds.), Physiologic foundations of perinatal care (Vol. 2, pp. 156-164). New York: Elsevier.

Appendix 1

Diaper Weighing/Urine Output Studies

Study	Hutton & Schreiner, 1980	Wiliams & Kanarek, 1982	Hermansen & Buches, 1987	Hermansen & Buches, 1988	Cooke, Werkman & Watson, 1989
Environment	Room temp, and radiant heater @ 34.5 C	Incubator @ 34°C, and radiant warmer with phototherapy	Incubator at maximum heat and humidity	Radiant warmer at 100% & 50 % outputs and room temp.	Radiant warmer or incubator set for dipater temp @ 32.8-33.9°C with and without heat shield
Diaper	Pamper and cotton ball with plastic wrap	Pamper	Super-absorbent and regular Pampers	Open regular and superabsorbent Pamper and closed Pamper	American disposable diaper
Fluid & Volume	2.5 or 5.0 ml of adult urine	10 ml of adult urine	No fluid added	3, 7.5, 15, 30, or 60 ml of water	1.0, 2.5, or 5.0 ml of water
Scale	Analytical balance	Triple beam balance	Not noted	Scale-Tronix Diaper Scale	Mettler balance scale
Weighing times	1, 30, 60, & 120 minutes	0, 30, 60, 120, & 180 minutes	120 minutes	5, 10, 15, 20, 30, 40, 50, 60, 75, 90, 105, & 120 minutes	15,30,45,60, & 120 minutes
Test	% volume change	% volume change	Weight change	Two-way analysis of variance with repeated measures over time	% volume change repeated measures analysis of varaince

Appendix 1 Continued

Diaper Weighing/Urine Output Studies

Study	Hutton & Schreiner, 1980	Wiliams & Kanarek, 1982	Hermansen & Buches, 1987	Hermansen & Buches, 1988	Cooke, Werkman & Watson, 1989
Change in volume by weight	Radiant warmer - Pmapers lost 15% by 30 min. Room temp- cotton <10% at 60 min & Pampers 17 % at 30 min.	Incubator loss 15% at 120 min; radiant warmer losses sig greater than incubator losses from 30 min at $p < .001$	Super Pampers gained 1.5 gms over 2 hours, while Pampers gained 0.4 gms	Statistical significant loss in weight from all types, greates from 100% output and open regular Pampers. Least in room temp and closed pamper. Open Pamper in 100% lost 10% in 15 min while room temp lost 10% after 40 min.	No effect of environment on weight change noted and data grouped. All lost weight as a function of time and loss of 5% by 15 mins. Mean % weight loss sig greater and faster for smaller volumes.

Appendix 2

Study Protocol

1. Ready "environment". Turn on equipment. Wait one hour.
2. Randomly select one diaper of study type
3. Measure environmental humidity, temperature, and air velocity
4. Weigh diaper
5. Add known volume of 0.45% saline solution
6. Weigh diaper again
7. Place diaper in selected environment, under or around doll as indicated and record time zero
8. Weigh diaper at 15 minutes from time zero
9. Record environmental humidity, temperature, and air velocity at 20 minutes from time zero
10. Weigh diaper at 30 minutes from time zero
11. Record environmental humidity, temperature, and air velocity at 40 minutes from time zero
12. Weigh diaper at 45 minutes from time zero
13. Weigh diaper and record environmental humidity, temperature, and air velocity at 60 minutes from time zero
14. Weigh diaper at 75 minutes from time zero
15. Record environmental humidity, temperature, and air velocity at 80 minutes from time zero
16. Weigh diaper at 90 minutes from time zero. One trial completed.

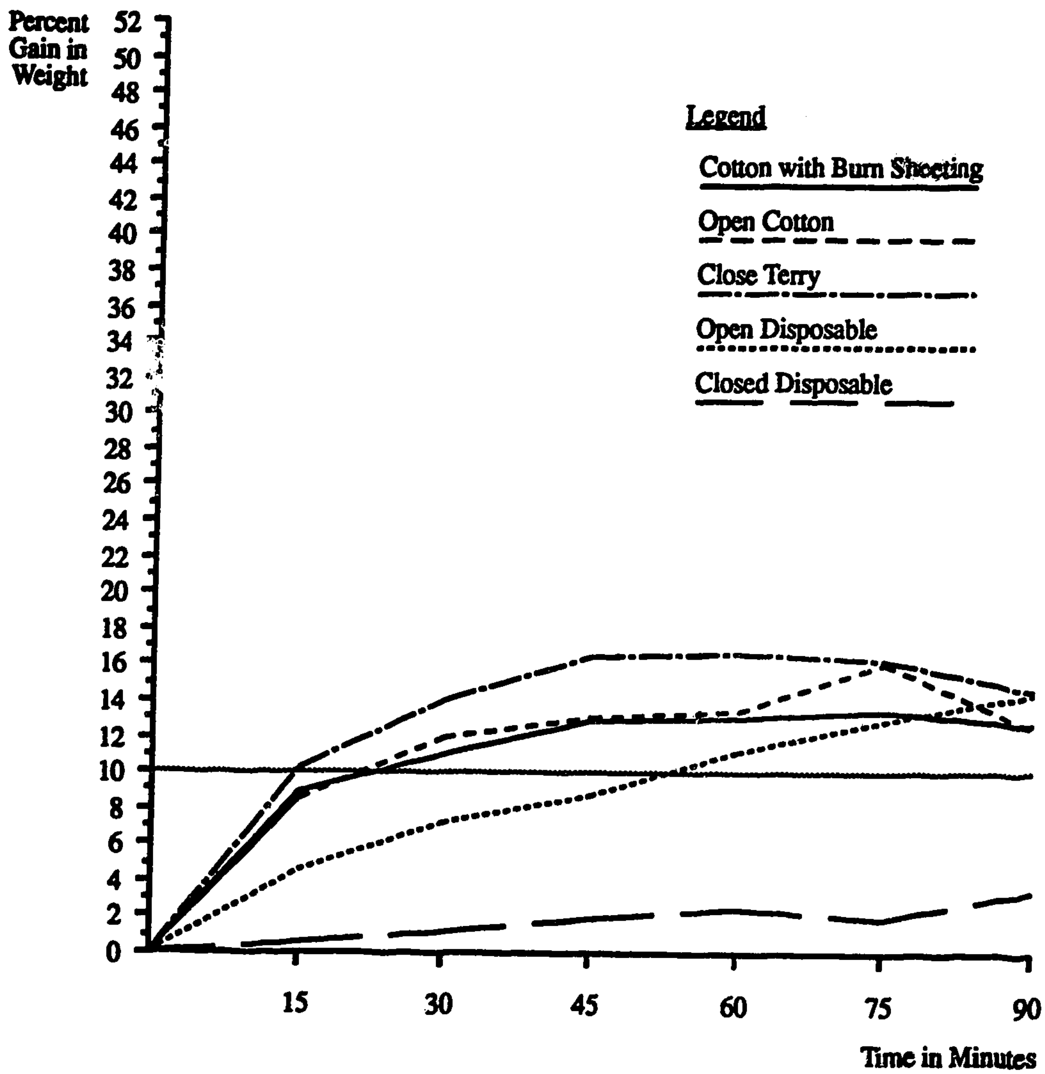
Appendix 3

Diaper Samples Testing Order

Environment	Diaper	Volume of Solution
Incubator @ 36.0° with added humidity	Open Cotton with burn sheeting	15 ml
Radiant Warmer @ 75% output	Open Cotton with burn sheeting	15 ml
Incubator @ 36.0° with added humidity	Open Cotton	15 ml
Radiant Warmer @ 75% output	Open Cotton	15 ml
Incubator @ 36.0° with added humidity	Closed Terrycloth	15 ml
Radiant Warmer @ 75% output	Closed Terrycloth	15 ml
Incubator @ 36.0° with added humidity	Open Cotton	5 ml
Radiant Warmer @ 75% output	Open Cotton	5 ml
Incubator @ 36.0° with added humidity	Open Cotton with burn sheeting	5 ml
Radiant Warmer @ 75% output	Open Cotton with burn sheeting	5 ml
Incubator @ 36.0° with added humidity	Open Disposable	15 ml
Radiant Warmer @ 75% output	Open Disposable	15 ml
Incubator @ 36.0° with added humidity	Closed Disposable	15 ml
Radiant Warmer @ 75% output	Closed Disposable	15 ml
Incubator @ 36.0° with added humidity	Closed Terrycloth	5 ml
Radiant Warmer @ 75% output	Closed Terrycloth	5 ml
Incubator @ 36.0° with added humidity	Open Disposable	5 ml
Radiant Warmer @ 75% output	Open Disposable	5 ml
Incubator @ 36.0° with added humidity	Closed Disposable	5 ml
Radiant Warmer @ 75% output	Closed Disposable	5 ml
Incubator @ 33.5°	Closed Terrycloth	15 ml
Radiant Warmer @ 50% output	Closed Terrycloth	15 ml
Incubator @ 33.5°	Closed Terrycloth	5 ml
Radiant Warmer @ 50% output	Closed Terrycloth	5 ml
Incubator @ 33.5°	Open Cotton	15 ml
Radiant Warmer @ 50% output	Open Cotton	15 ml
Incubator @ 33.5°	Open Cotton with burn sheeting	15 ml
Radiant Warmer @ 50% output	Open Cotton with burn sheeting	15 ml
Incubator @ 33.5°	Open Cotton with burn sheeting	5 ml
Radiant Warmer @ 50% output	Open Cotton with burn sheeting	5 ml
Incubator @ 33.5°	Closed Disposable	15 ml
Radiant Warmer @ 50% output	Closed Disposable	15 ml
Incubator @ 33.5°	Closed Disposable	5 ml
Radiant Warmer @ 50% output	Closed Disposable	5 ml
Incubator @ 33.5°	Open Disposable	15 ml
Radiant Warmer @ 50% output	Open Disposable	15 ml
Incubator @ 33.5°	Open Cotton	5 ml
Radiant Warmer @ 50% output	Open Cotton	5 ml
Incubator @ 33.5°	Open Disposable	5 ml
Radiant Warmer @ 50% output	Open Disposable	5 ml

Appendix 4

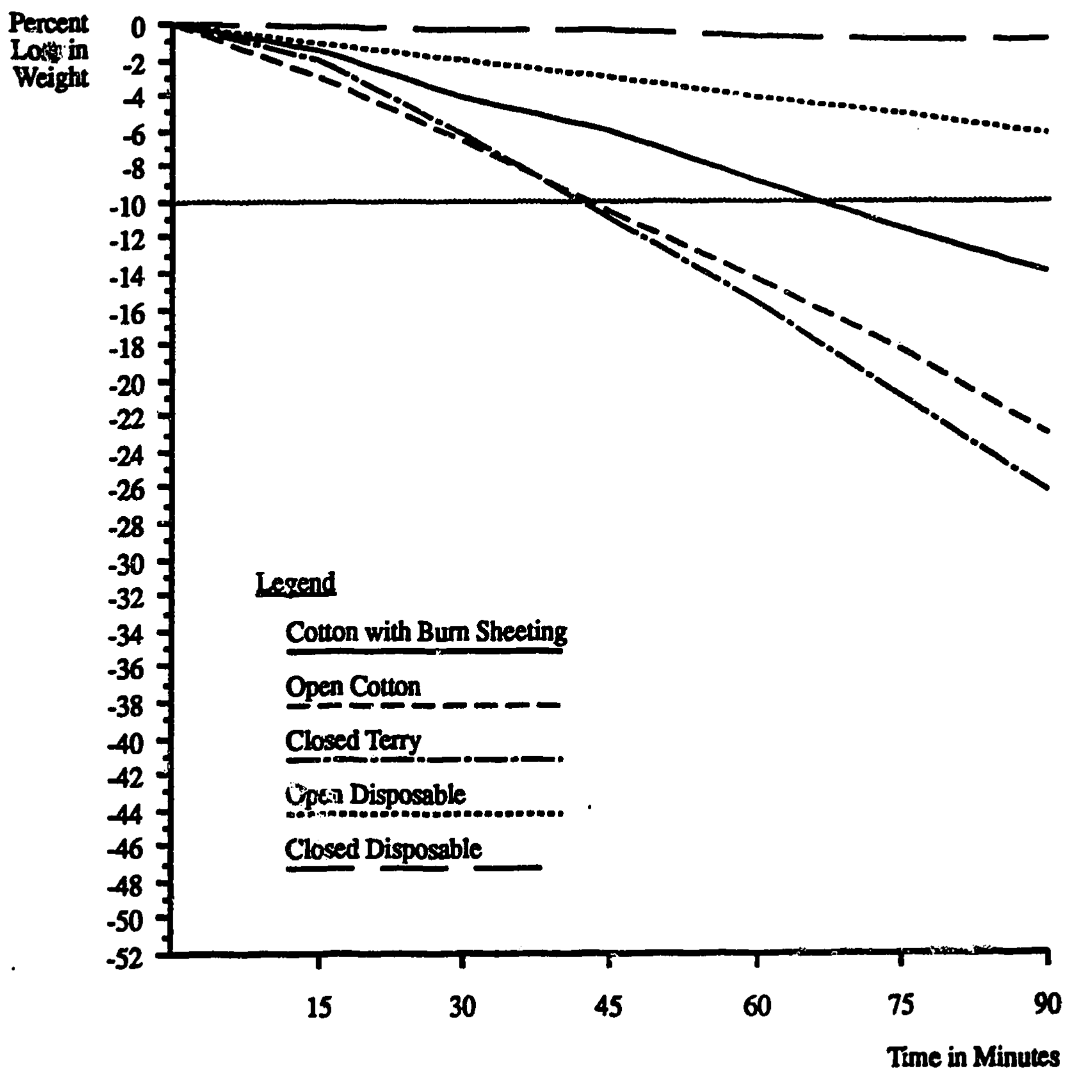
Incubator @ 36.0°C with Added Humidity 5ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec) M	Air Velocity (m/sec) SD	Air Temperature (°C) M	Air Temperature (°C) SD	Relative Humidity (%) M	Relative Humidity (%) SD
Overall Mean	.0298	.0164	35.9712	.0483	86.3512	1.7445
Cotton with burn sheeting	.0466	.0111	35.9520	.0413	87.1020	0.8306
Open cotton	.0386	.0132	35.9300	.0380	87.6840	2.2125
Closed terrycloth	.0163	.0118	35.9920	.0559	84.3760	1.0359
Open superabsorbent disposable	.0346	.0073	35.9800	.0267	86.6880	1.4993
Closed superabsorbent disposable	.0127	.0043	36.0020	.0426	85.9060	0.6187

Appendix 4

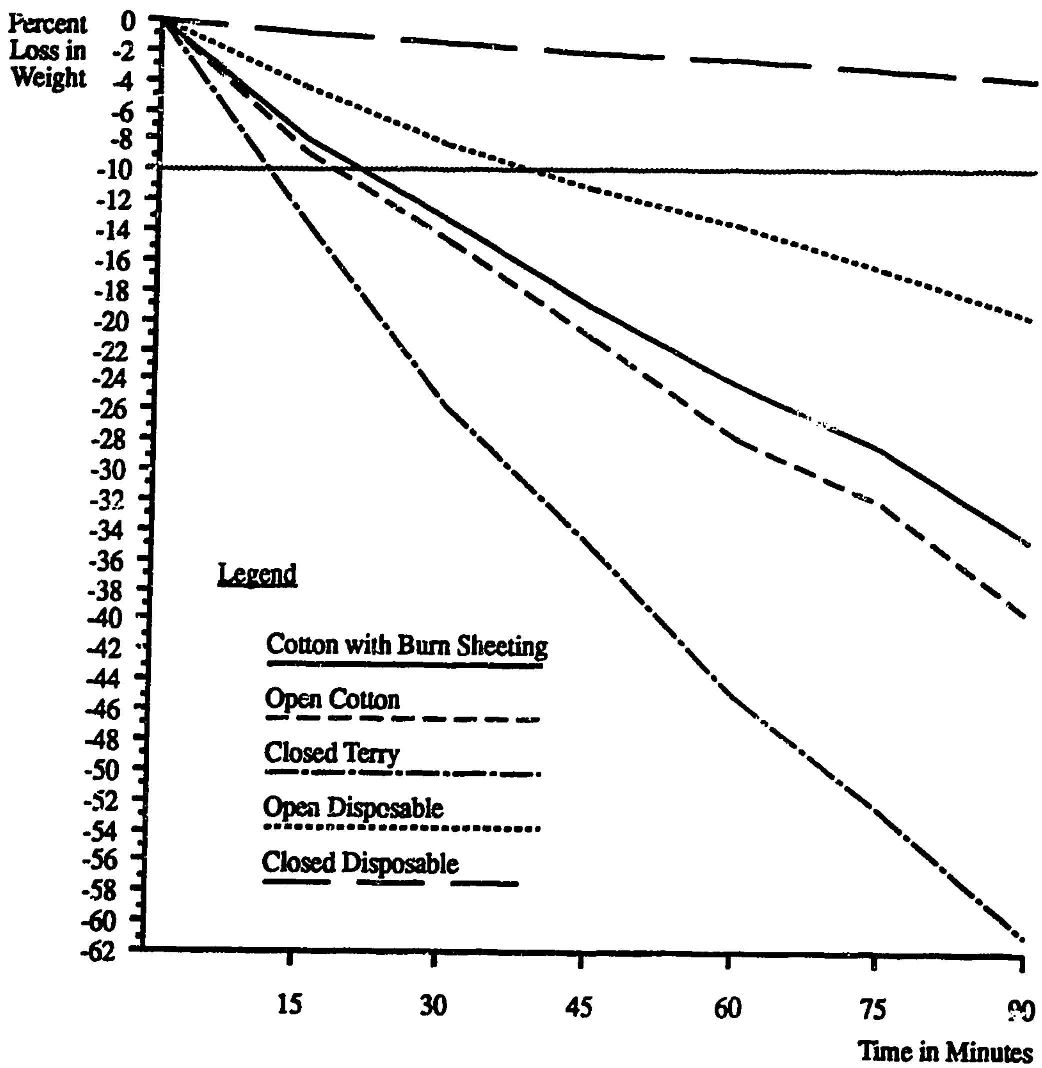
Incubator @ 33.5°C   5ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec) M	Air Velocity (m/sec) SD	Air Temperature (°C) M	Air Temperature (°C) SD	Relative Humidity (%) M	Relative Humidity (%) SD
Overall Mean	.0661	.0171	33.4280	.0256	44.0988	1.8234
Cotton with burn sheeting	.0600	.0179	33.4160	.0158	43.8420	0.1259
Open cotton	.0735	.0049	33.4380	.0382	43.4280	0.6394
Closed terrycloth	.0420	.0087	33.4160	.0184	46.9440	2.1006
Open superabsorbent disposable	.0730	.0078	33.4500	.0141	43.5860	0.2235
Closed superabsorbent disposable	.0821	.0044	33.4200	.0163	42.6940	1.0780

Appendix 4

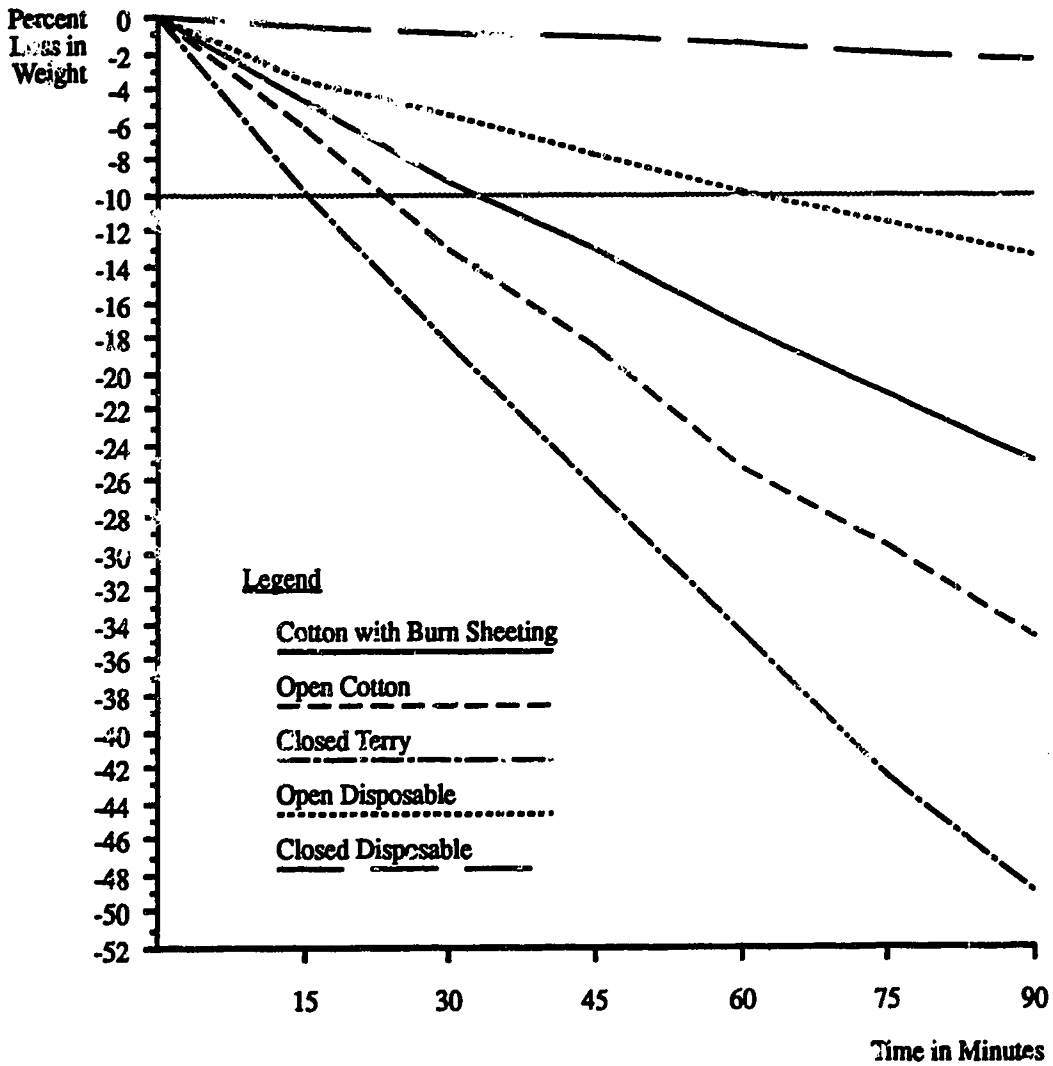
Radiant Warmer @ 75% 5ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec) M	Air Velocity (m/sec) SD	Air Temperature (°C) M	Air Temperature (°C) SD	Relative Humidity (%) M	Relative Humidity (%) SD
Overall Mean	.1051	.0127	30.7684	.6548	32.3336	2.3300
Cotton with burn sheeting	.1040	.0003	30.1880	.5734	33.5560	1.5717
Open cotton	.0915	.0106	30.0280	.2044	32.7920	1.7814
Closed terrycloth	.1044	.0086	31.2860	.2824	29.8420	1.2586
Open superabsorbent disposable	.1004	.0119	30.8800	.1320	34.9720	1.0255
Closed superabsorbent disposable	.1154	.0093	31.4600	.1998	30.5060	1.0196

Appendix 4

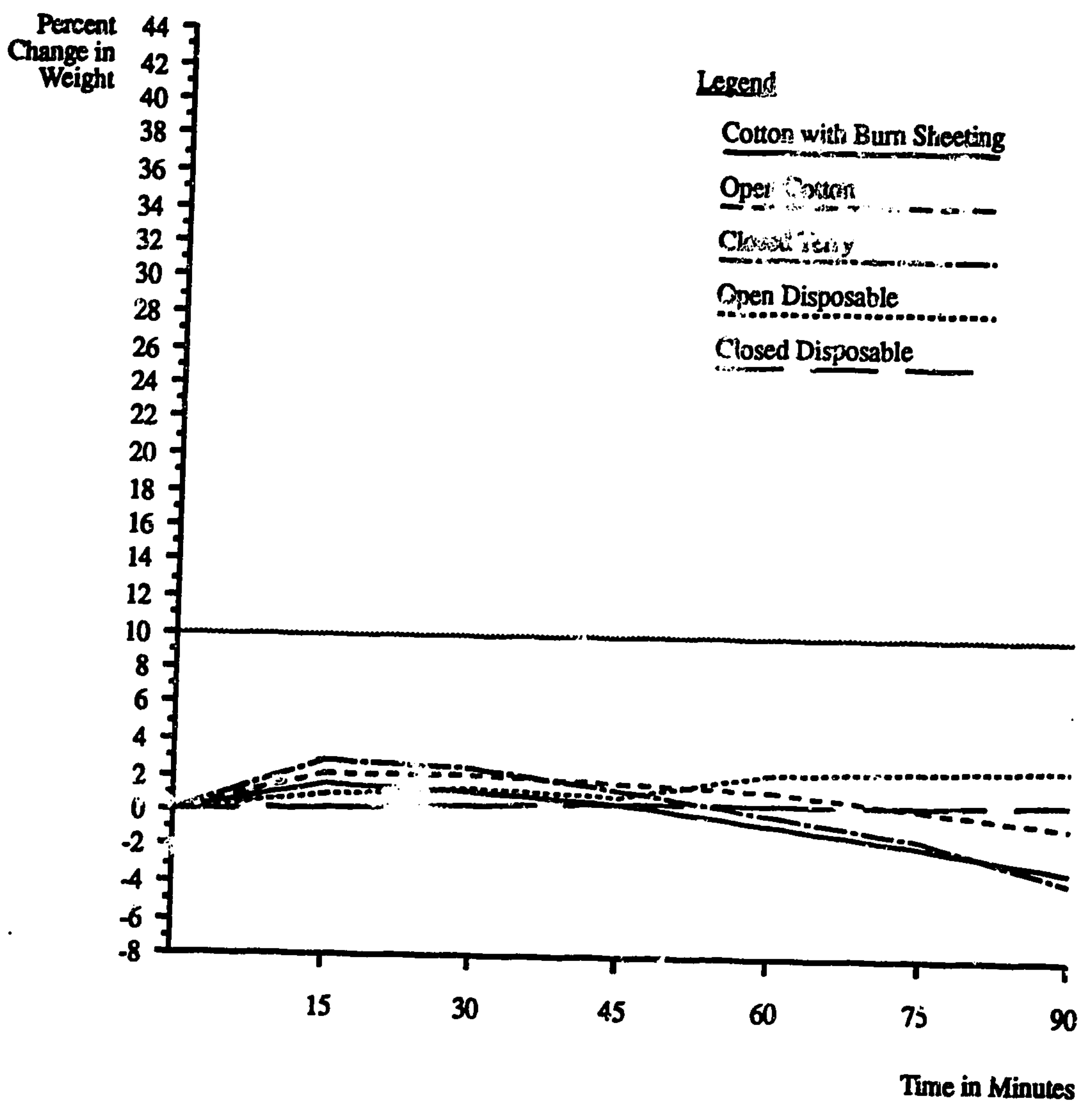
Radiant Warmer @ 50% 5ml 0.45% NaCl A...



Environmental Means (by diaper type)	Air Velocity (m/sec) M	SD	Air Temperature (°C) M	SD	Relative Humidity (%) M	SD
Overall Mean	.0637	.0096	28.4808	.2639	34.8708	2.3442
Cotton with burn sheeting	.0628	.0090	28.2820	.1109	37.2640	1.2225
Open cotton	.0597	.0078	28.7880	.1360	32.7480	0.8657
Closed terrycloth	.0728	.0081	28.2020	.1800	36.0860	2.8119
Open superabsorbent disposable	.0594	.0104	28.6980	.0769	33.8360	1.1127
Closed superabsorbent disposable	.0637	.0071	28.4340	.1418	34.4200	2.0258

Appendix 4

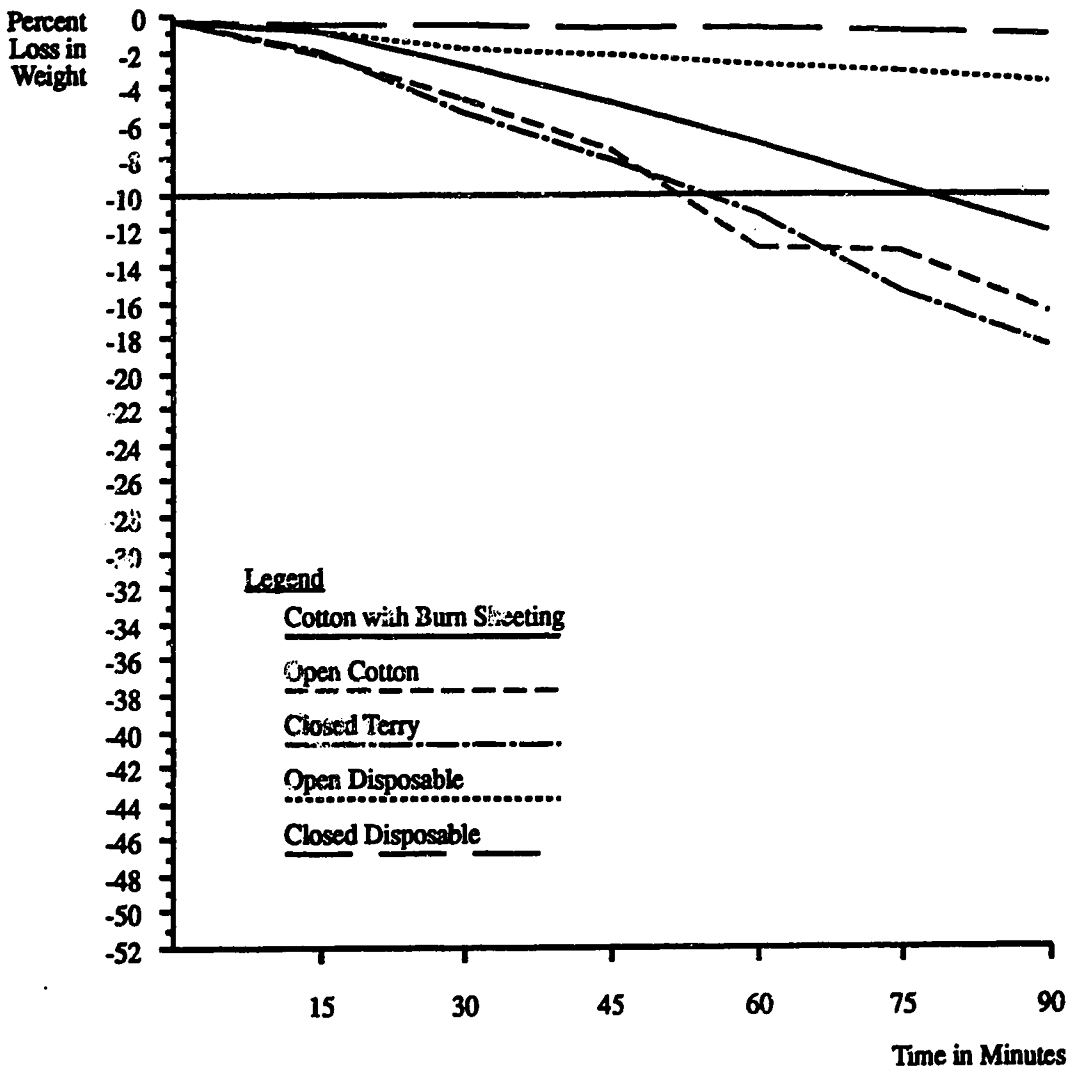
Incubator @ 36°C with Added Humidity   15ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec)		Air Temperature (°C)		Relative Humidity (%)	
	M	SD	M	SD	M	SD
Overall Mean	.0297	.0154	35.9280	.0609	84.3844	3.3864
Cotton with burn sheeting	.0199	.0099	35.9480	.0424	78.9460	1.9735
Open cotton	.0493	.0115	35.8820	.0503	88.2280	1.2034
Closed terry cloth	.0402	.0070	35.8780	.0305	85.8800	1.7916
Open superabsorbent disposable	.0162	.0080	35.9960	.0350	83.9700	0.7474
Closed superabsorbent disposable	.0228	.0061	35.9360	.0540	84.8980	1.0389

Appendix 4

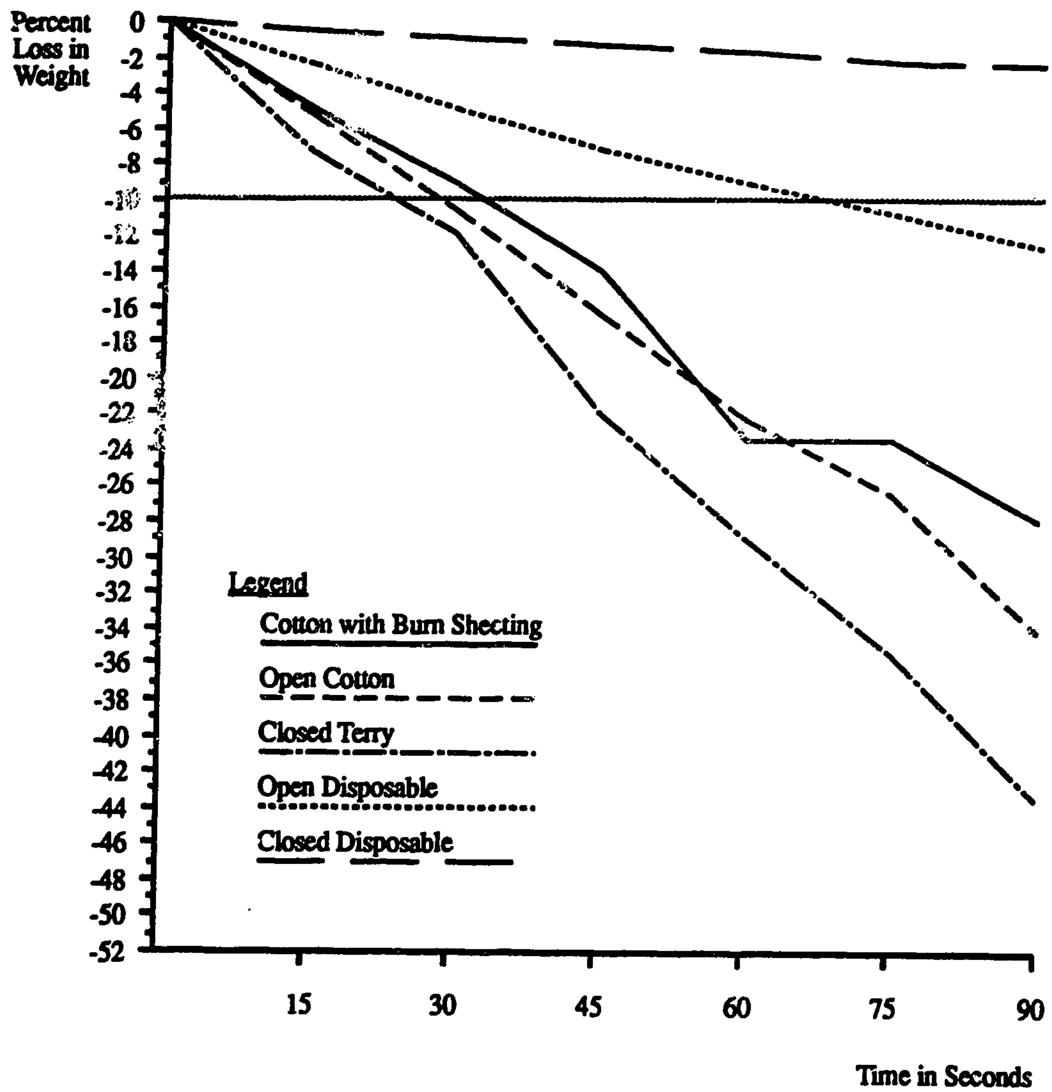
Incubator @ 33.5°C with Added Humidity   15ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec) M	Air Velocity (m/sec) SD	Air Temperature (°C) M	Air Temperature (°C) SD	Relative Humidity (%) M	Relative Humidity (%) SD
Overall Mean	.0493	.0247	33.4196	.0273	43.9936	1.6487
Cotton with burn sheeting	.0533	.0065	33.4200	.0231	43.2200	0.5527
Open cotton	.0433	.0110	33.4360	.0263	43.9040	0.0126
Closed terrycloth	.0079	.0071	33.3900	.0287	46.5940	1.6894
Open superabsorbent disposable	.0732	.0047	33.4240	.0158	43.6020	0.2963
Closed superabsorbent disposable	.0687	.0087	33.4280	.0193	42.6480	1.0877

Appendix 4

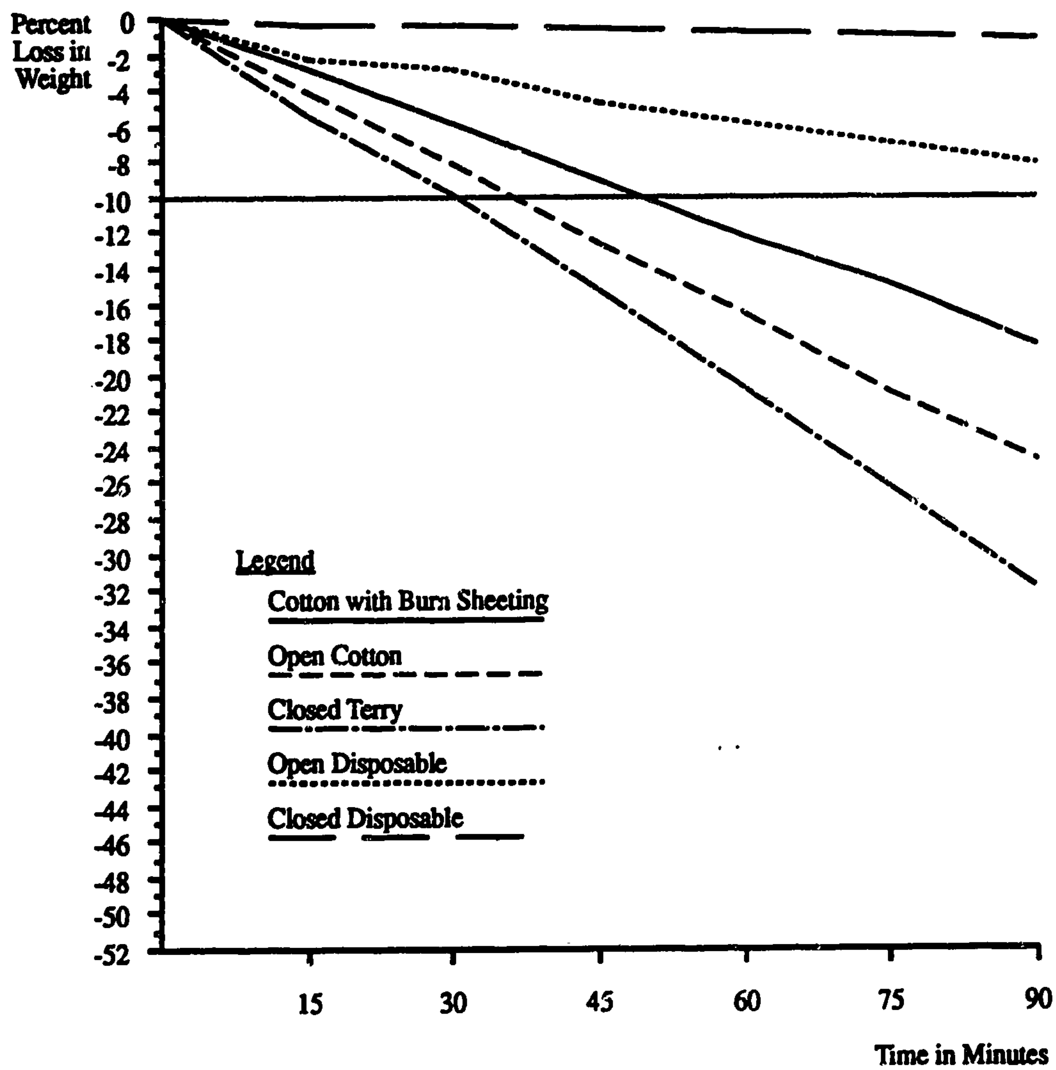
<u>Radiant Warmer @ 75%</u> <u>15ml 0.45% NaCl Added</u>



Environmental Means (by diaper type)	Air Velocity (m/sec)		Air Temperature (°C)		Relative Humidity (%)	
	M	SD	M	SD	M	SD
Overall Mean	.0981	.0170	29.6936	1.0792	30.8644	2.6120
Cotton with burn sheeting	.0871	.0096	27.9620	.0696	32.7920	0.8791
Open cotton	.0892	0140	29.5180	.4295	33.2700	2.1520
Closed terrycloth	.0921	.0138	29.5020	.1805	31.1760	1.7693
Open superabsorbent disposable	.1046	.0105	30.5460	.2685	27.7240	1.8003
Closed superabsorbent disposable	.1173	.0160	30.9400	.3267	29.3600	1.1087

Appendix 4

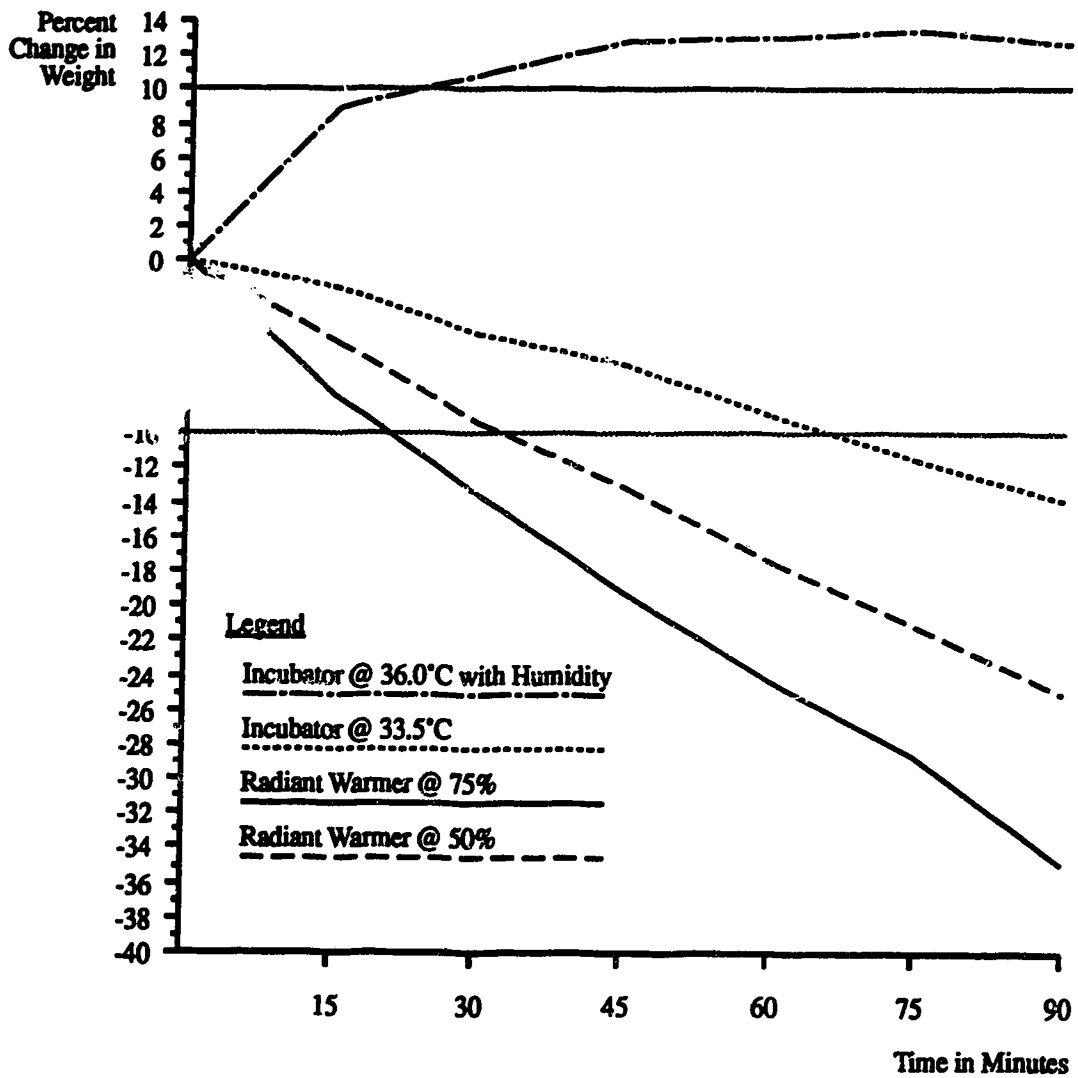
Radiant Warmer @ 50% 15ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec) M	SD	Air Temperature (°C) M	SD	Relative Humidity (%) M	SD
Overall Mean	.0643	.0100	28.1716	.4354	32.8632	1.4087
Cotton with burn sheeting	.0704	.0060	28.1700	.2195	32.7560	1.4978
Open cotton	.0666	.0091	27.9500	.0999	31.7060	0.6167
Closed terrycloth	.0519	.0065	27.5660	.1592	33.0020	1.7775
Open superabsorbent disposable	.0697	.0074	28.7280	.2352	33.4500	1.1280
Closed superabsorbent disposable	.0628	.0089	28.4440	.0692	33.4020	1.2332

Appendix 5

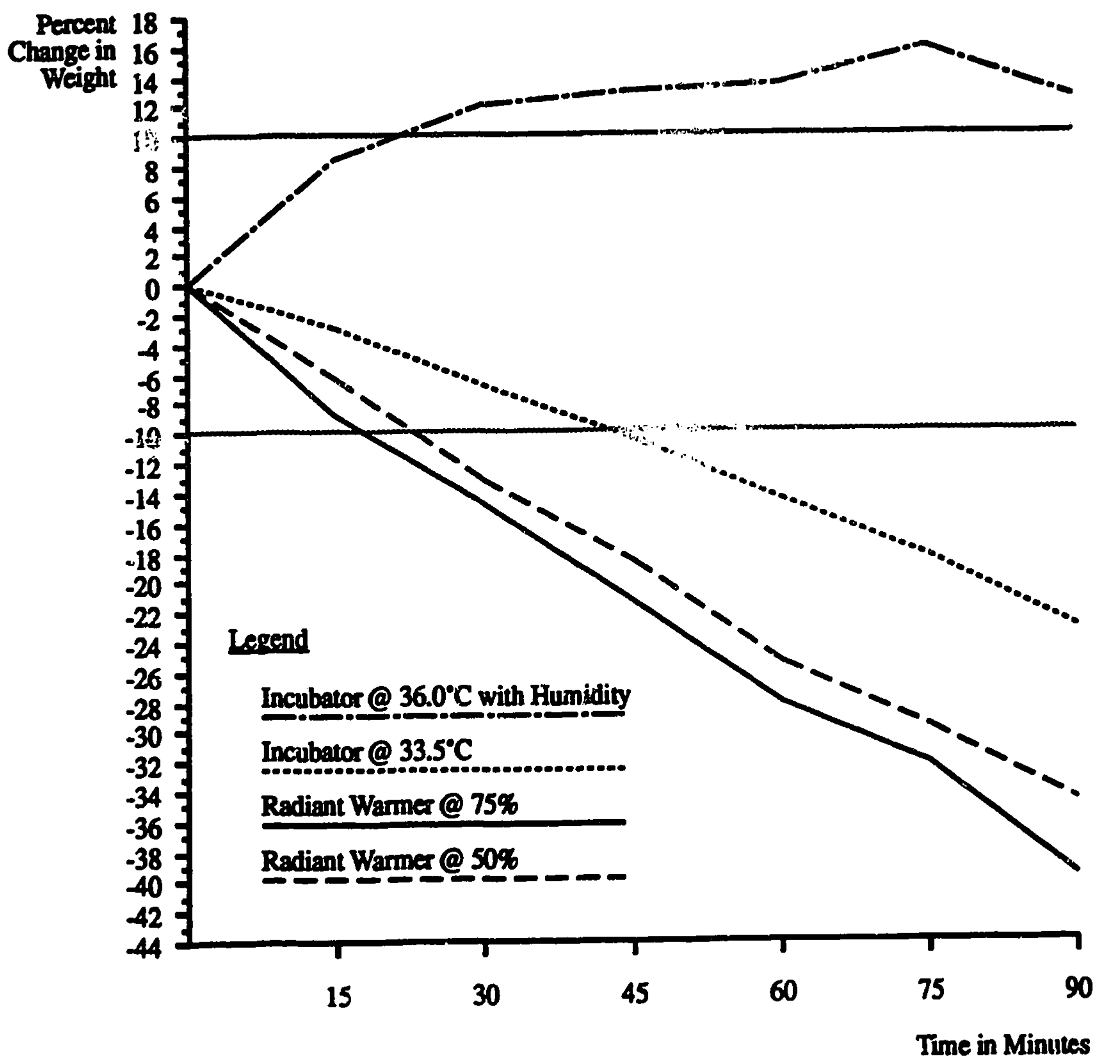
Cotton with Burn Sheeting   5ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec)		Air Temperature (°C)		Relative Humidity (%)	
	M	SD	M	SD	M	SD
Incubator @ 36.0°C w/ Humidity	.0466	.0111	35.9520	.0413	87.1020	0.8306
Incubator @ 33.5°C	.0600	.0179	33.4160	.0158	43.8420	0.1259
Radiant Warmer @ 75%	.1040	.0103	30.1880	.5734	33.5560	1.5717
Radiant Warmer @ 50%	.0628	.0090	28.2820	.1109	37.2640	1.2225

Appendix 5

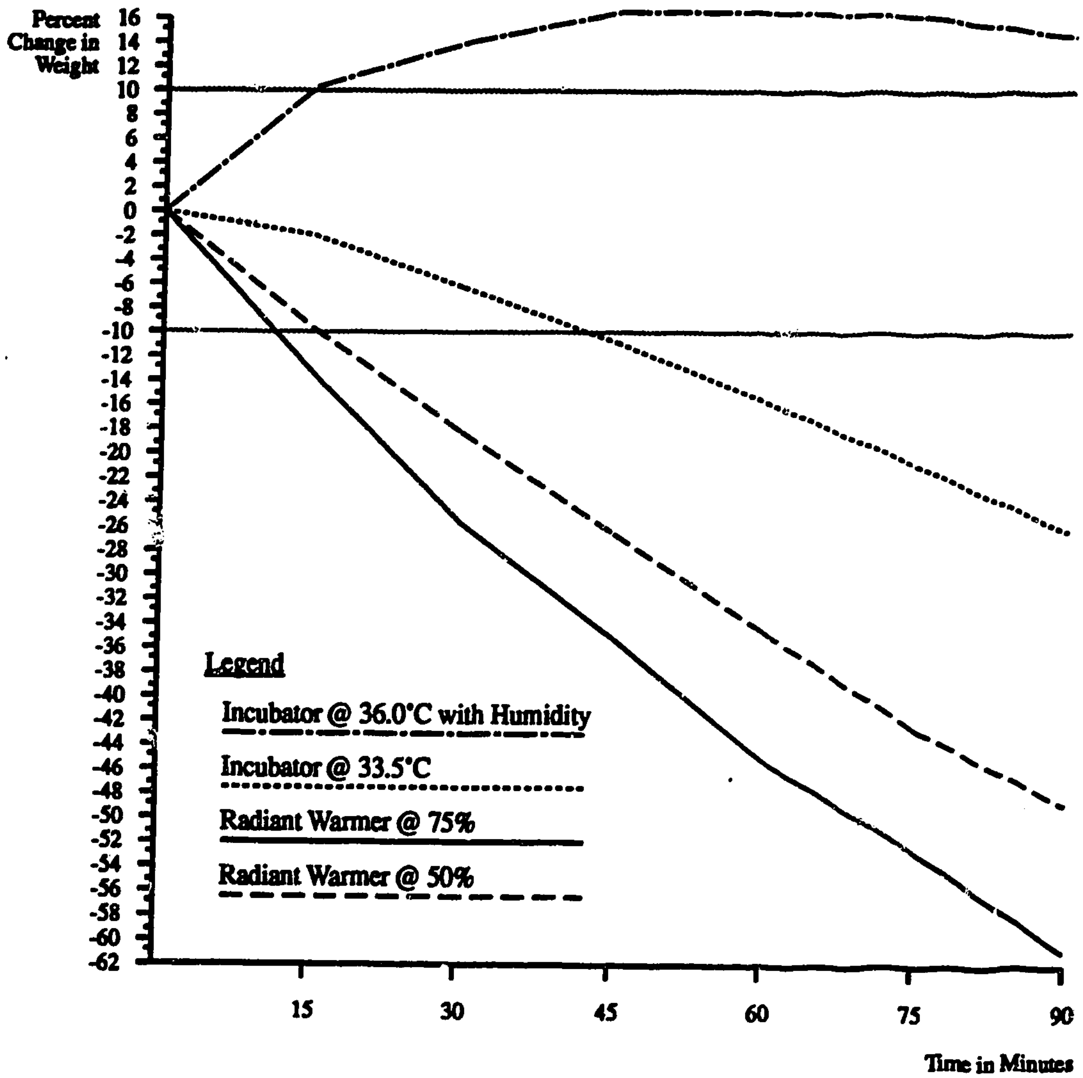
Open Cotton   5ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec)		Air Temperature (°C)		Relative Humidity (%)	
	M	SD	M	SD	M	SD
Incubator @ 36.0°C w/ Humidity	.0386	.0132	35.9360	.0380	87.6840	2.2125
Incubator @ 33.5°C	.0735	.0049	33.4380	.0382	43.4280	0.6394
Radiant Warmer @ 75%	.0915	.0106	30.0280	.2044	32.7920	1.7814
Radiant Warmer @ 50%	.0597	.0078	28.2820	.1109	37.2640	0.8657

Appendix 5

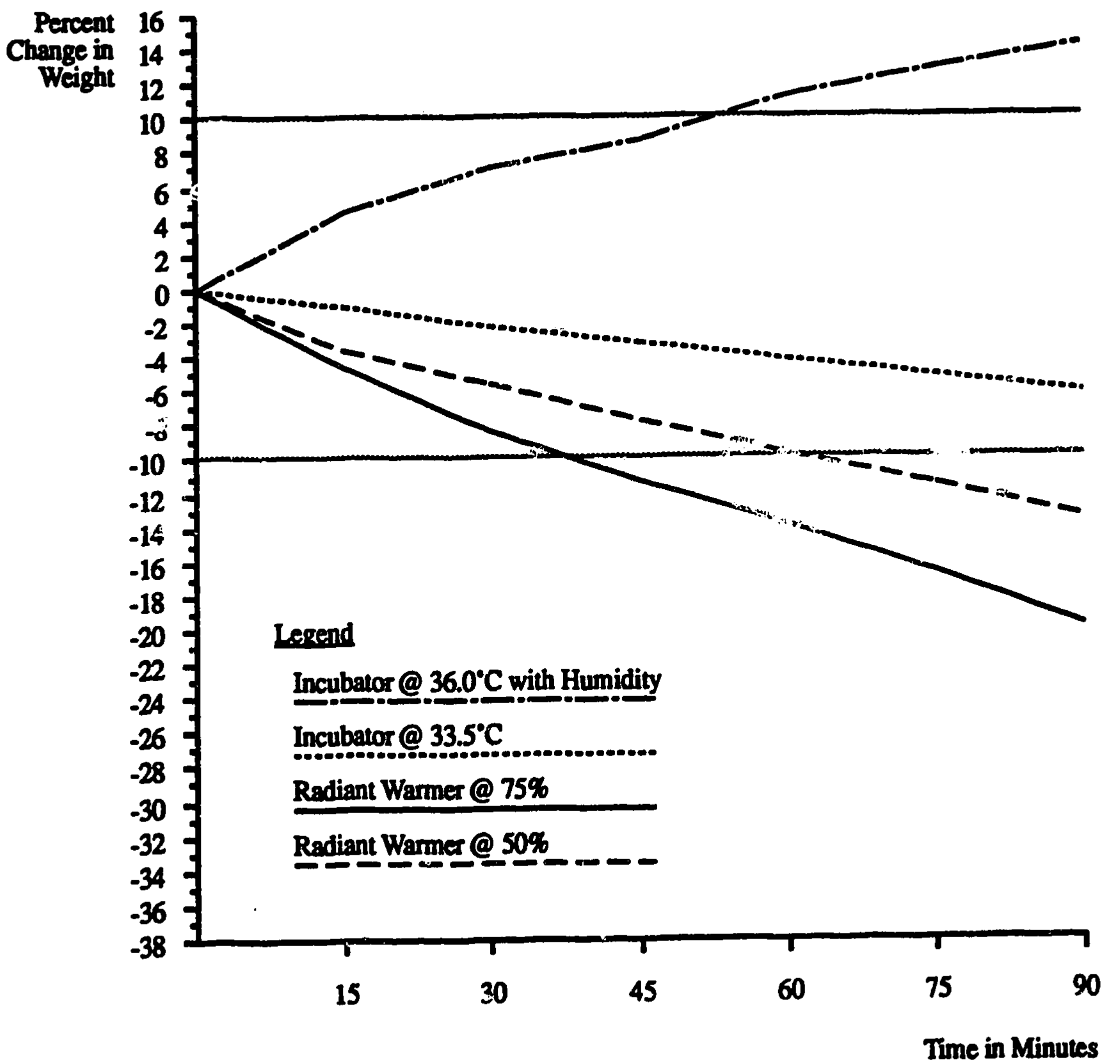
Closed Terrycloth   5ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec)		Air Temperature (°C)		Relative Humidity (%)	
	M	SD	M	SD	M	SD
Incubator @ 36.0°C w/ Humidity	.0163	.0118	35.9920	.0559	84.3460	1.0359
Incubator @ 33.5°C	.0420	.0087	33.4160	.0184	46.9440	2 1006
Radiant Warmer @ 75%	.1044	.0086	31.2860	.2824	29.8420	1.2586
Radiant Warmer @ 50%	.0728	.0081	28.2020	.1800	36.0860	2.8119

Appendix 5

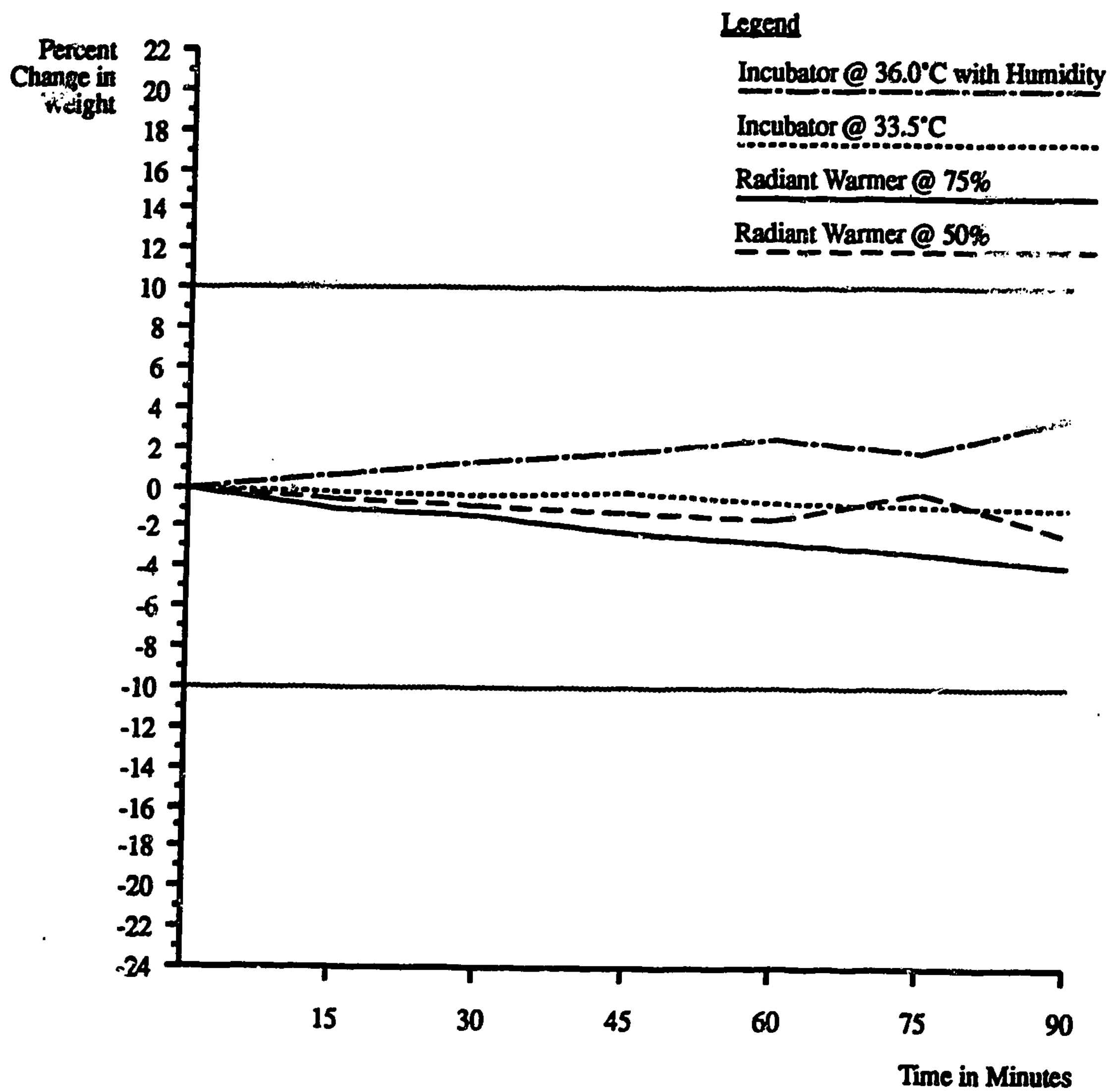
Open Superabsorbent Disposable 5ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec)		Air Temperature (°C)		Relative Humidity (%)	
	M	SD	M	SD	M	SD
Incubator @ 36.0°C w/ Humidity	.0346	.0073	35.9800	.0267	86.6880	1.4993
Incubator @ 33.5°C	.0730	.0078	33.4500	.0141	43.5860	0.2235
Radiant Warmer @ 75%	.1104	.0119	30.8800	.1320	34.9720	1.0255
Radiant Warmer @ 50%	.0594	.0104	28.6980	.0769	33.8360	1.1127

Appendix 5

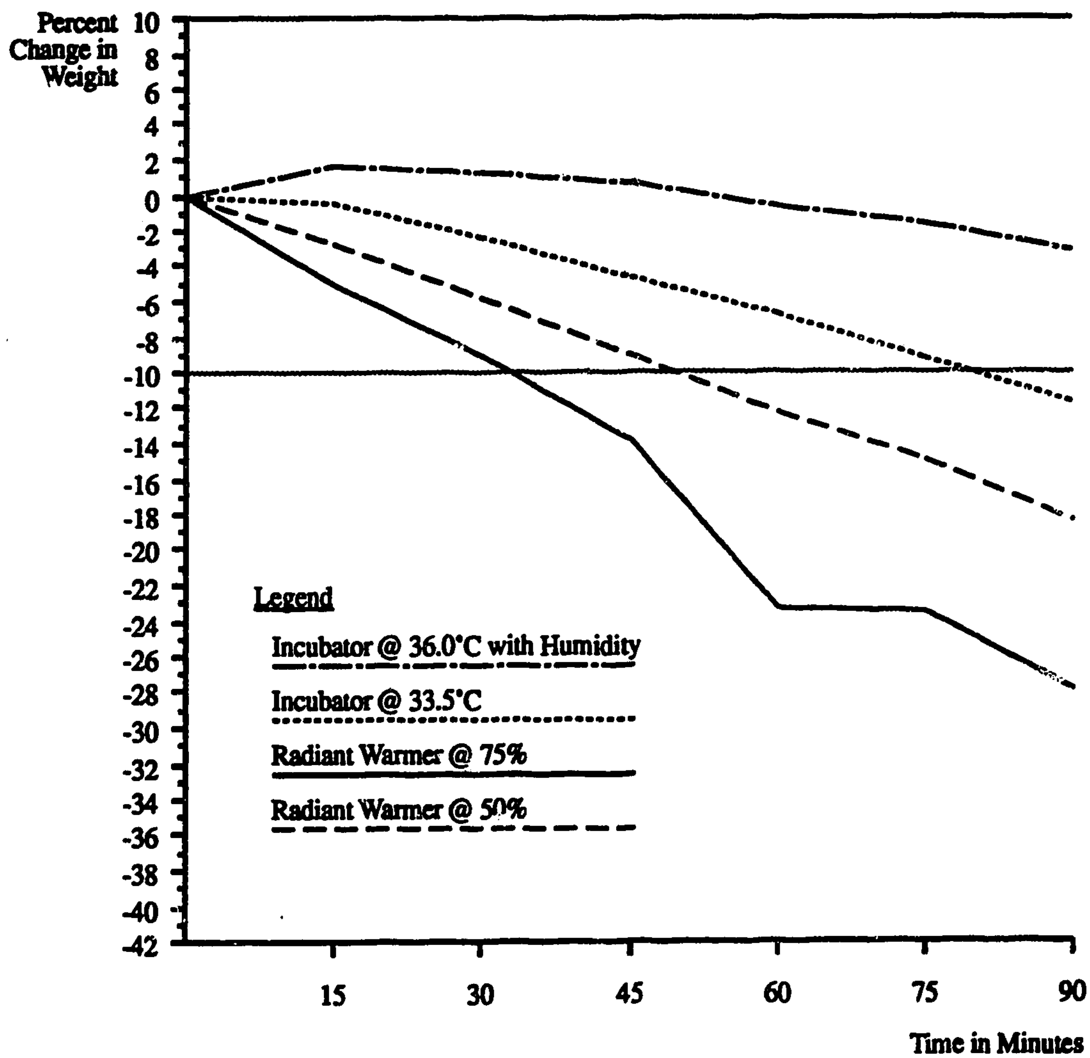
Closed Superabsorbent Disposable   5ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec) M	Air Velocity (m/sec) SD	Air Temperature (°C) M	Air Temperature (°C) SD	Relative Humidity (%) M	Relative Humidity (%) SD
Incubator @ 36.0°C w/ Humidity	.0127	.0043	36.0020	.0426	85.9060	0.6187
Incubator @ 33.5°C	.0821	.0044	33.4200	.0163	42.6940	1.0780
Radiant Warmer @ 75%	.1154	.0093	31.4600	.1998	30.5060	1.0196
Radiant Warmer @ 50%	.0637	.0071	28.4340	.1418	34.4200	2.0258

Appendix 5

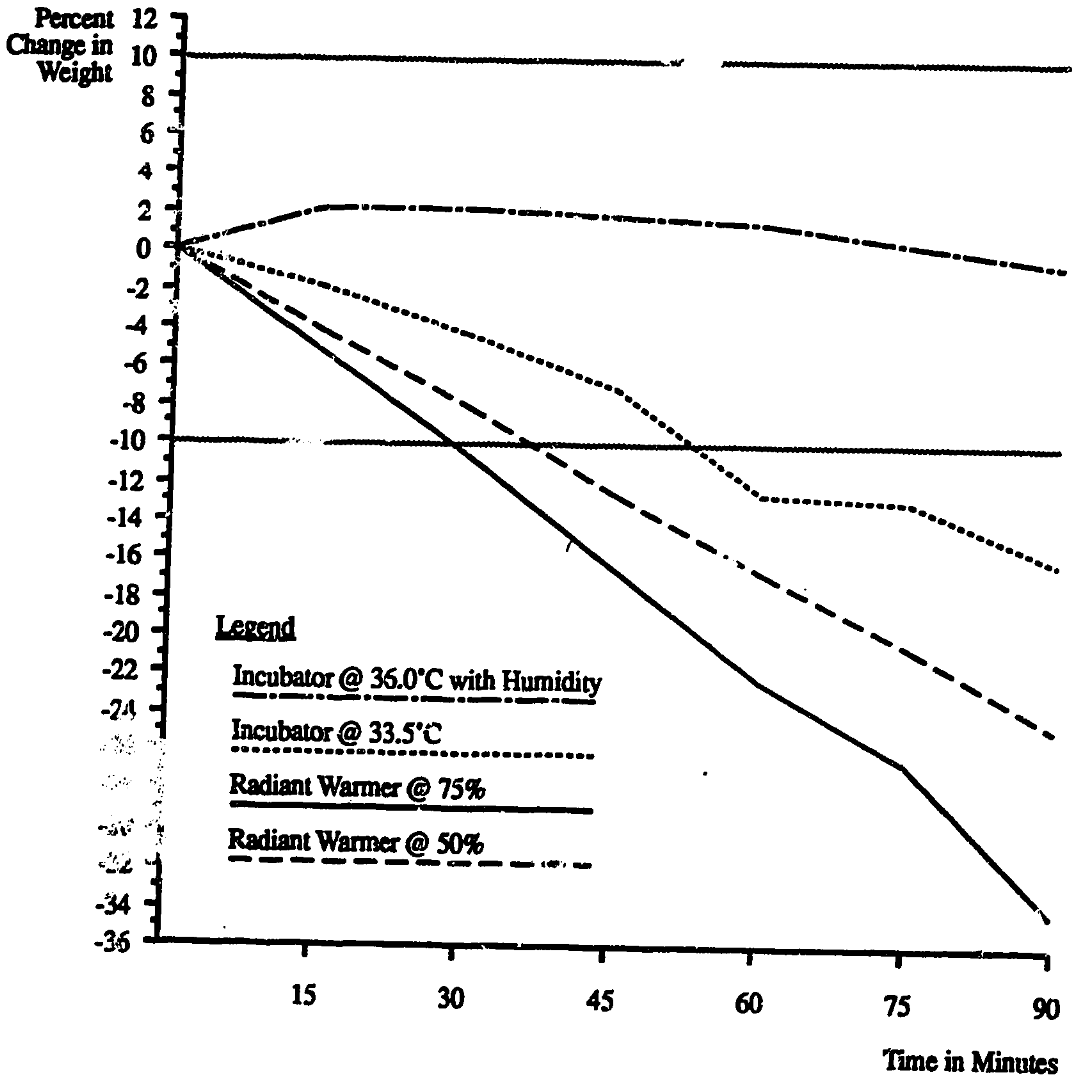
Cotton with Burn Sheeting 15ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec) M	Air Velocity (m/sec) SD	Air Temperature (°C) M	Air Temperature (°C) SD	Relative Humidity (%) M	Relative Humidity (%) SD
Incubator @ 36.0°C w/ Humidity	.0199	.0099	35.9480	.0424	78.9460	1.9735
Incubator @ 33.5°C	.0533	.0065	33.4200	.0231	43.2200	0.5527
Radiant Warmer @ 75%	.0871	.0096	27.9620	.0696	32.7920	0.8781
Radiant Warmer @ 50%	.0704	.0060	28.1700	.2195	32.7560	1.4978

Appendix 5

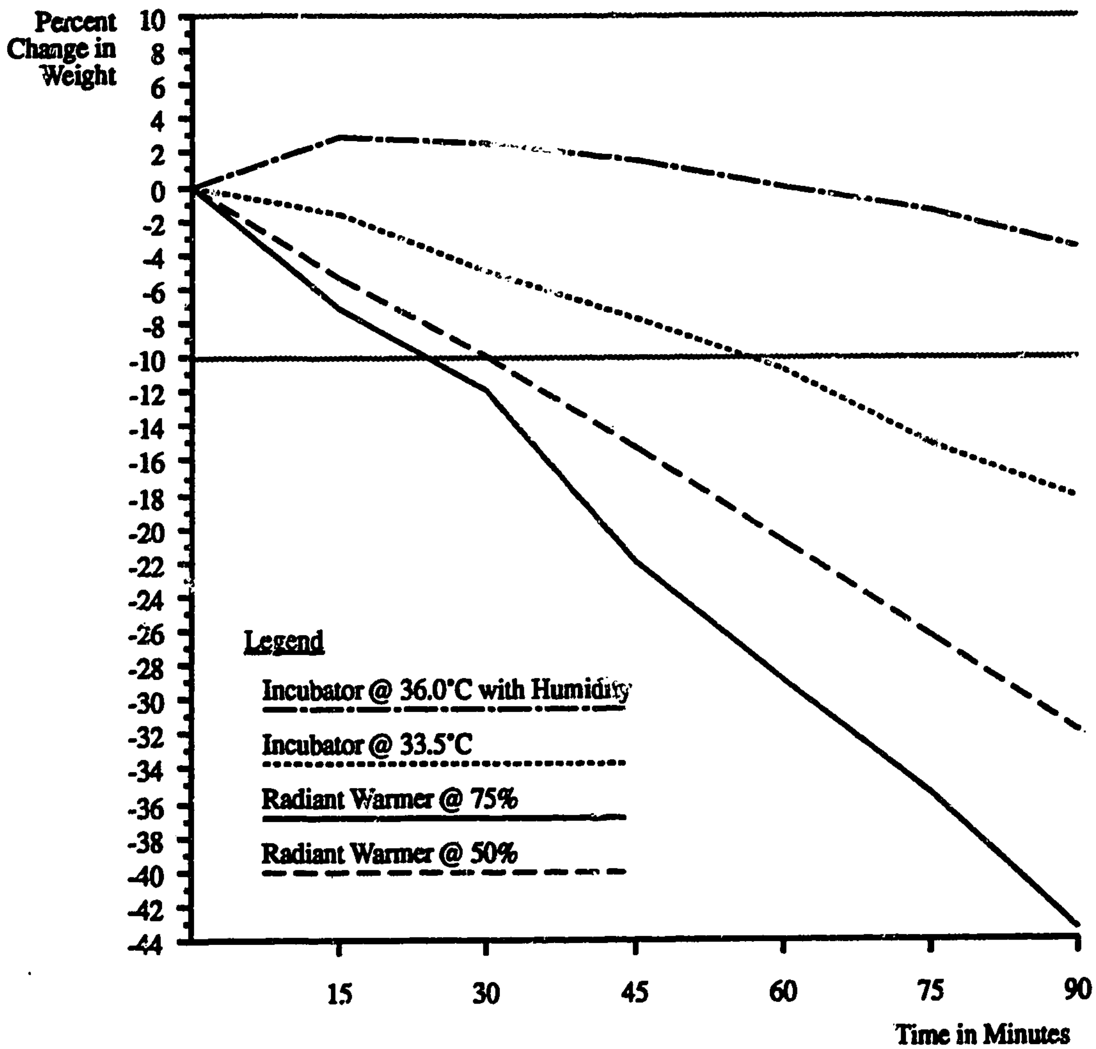
Open Cotton   15ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec) M	Air Velocity (m/sec) SD	Air Temperature (°C) M	Air Temperature (°C) SD	Relative Humidity (%) M	Relative Humidity (%) SD
Incubator @ 36.0°C w/ Humidity	.0493	.0115	35.8820	.0503	88.2280	1.2034
Incubator @ 33.5°C	.0433	.0110	33.4360	.0263	43.9040	0.0126
Radiant Warmer @ 75%	.0892	.0140	29.5180	.4295	33.2700	2.1529
Radiant Warmer @ 50%	.0666	.0091	27.9500	.0999	31.7060	0.6167

Appendix 5

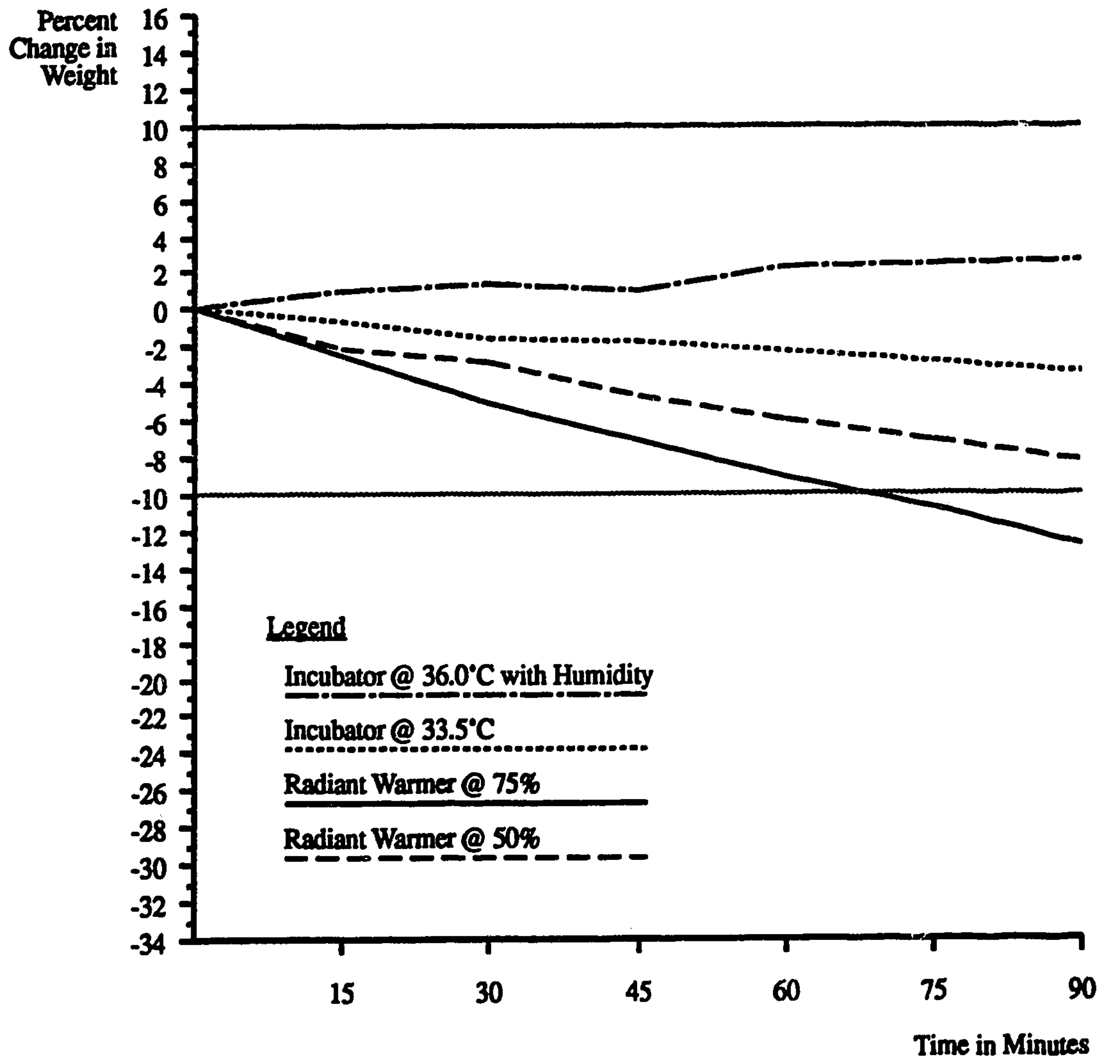
Closed Terrycloth 15ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec)		Air Temperature (°C)		Relative Humidity (%)	
	M	SD	M	SD	M	SD
Incubator @ 36.0°C w/ Humidity	.0402	.0070	35.8780	.0305	85.8800	1.7916
Incubator @ 33.5°C	.0079	.0071	33.3900	.0287	46.5940	1.6894
Radiant Warmer @ 75%	.0921	.0138	29.5020	.1805	31.1760	1.7693
Radiant Warmer @ 50%	.0519	.0065	27.5660	.1592	33.0020	1.7775

Appendix 5

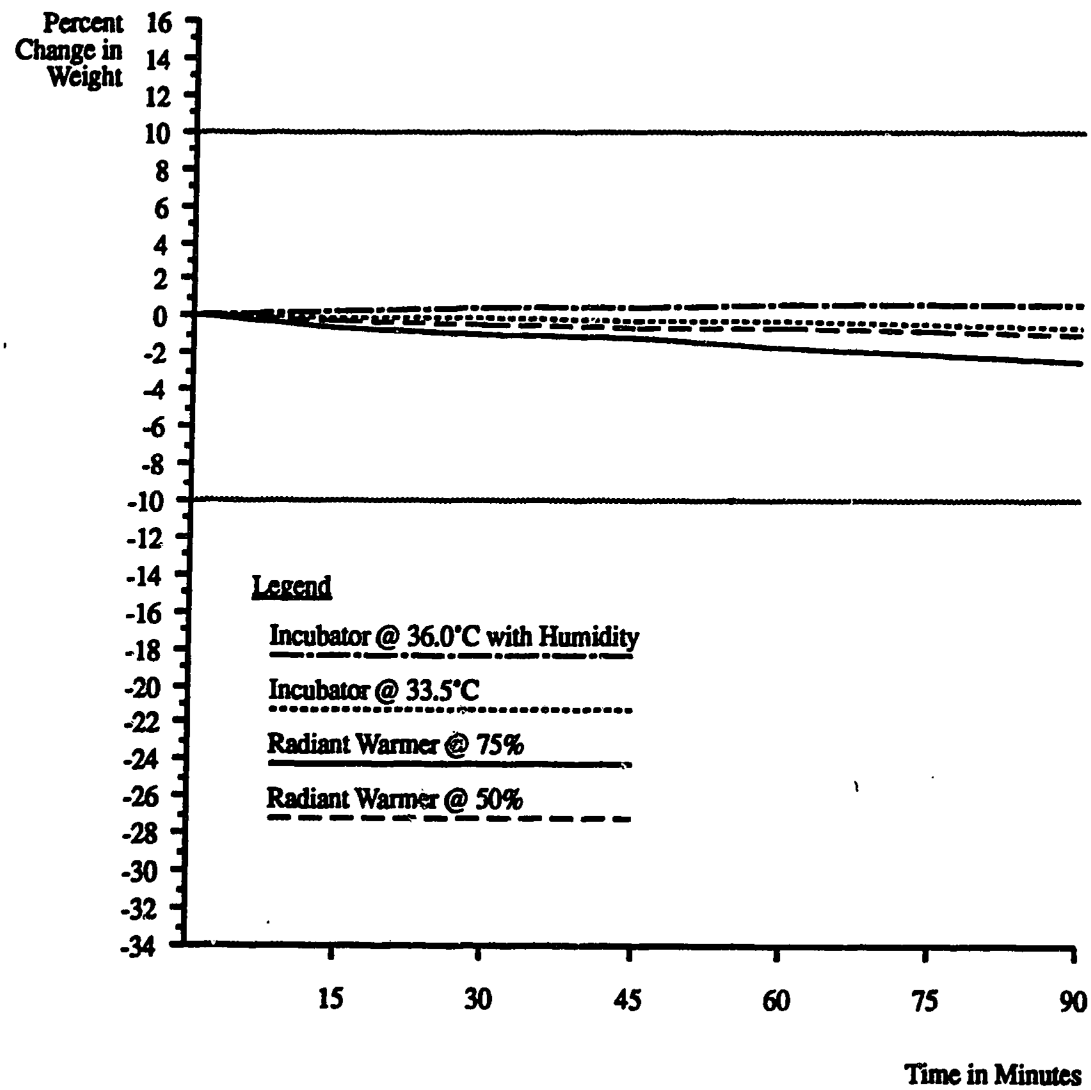
Open Superabsorbent Disposable 15ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec) M	Air Velocity (m/sec) SD	Air Temperature (°C) M	Air Temperature (°C) SD	Relative Humidity (%) M	Relative Humidity (%) SD
Incubator @ 36.0°C w/ Humidity	.0162	.0080	35.9960	.0350	83.9700	0.7474
Incubator @ 33.5°C	.0732	.0047	33.4240	.0158	43.6020	0.2963
Radiant Warmer @ 75%	.1046	.0105	30.5460	.2685	27.7240	1.8003
Radiant Warmer @ 50%	.0697	.0074	28.7280	.2352	33.4020	1.2332

Appendix 5

Closed Superabsorbent Disposable 15ml 0.45% NaCl Added



Environmental Means (by diaper type)	Air Velocity (m/sec) M	Air Velocity (m/sec) SD	Air Temperature (°C) M	Air Temperature (°C) SD	Relative Humidity (%) M	Relative Humidity (%) SD
Incubator @ 36.0°C w/ Humidity	.0228	.0061	35.9360	.0540	84.8980	1.0389
Incubator @ 33.5°C	.0687	.0087	33.4280	.0193	42.6480	1.0877
Radiant Warmer @ 75%	.1173	.0160	30.9400	.3267	29.3600	1.1087
Radiant Warmer @ 50%	.0628	.0089	28.4440	.0692	33.4020	1.2332