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# Milking Performance and Udder Health of Cows Milked Robotically and Conventionally

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**Abstract.** *Milking performance and measures of udder health were followed on two groups of about 50 cows milked either robotically or in a conventional parlor for a period of 30 weeks. Mastitis indicators were also compared. The following measurements of milking performance were recorded at every milking: milk yield, machine-on time, and electrical conductivity of udder-composite milk. Measures of udder health recorded weekly were somatic cell count of udder-composite milk and California Mastitis Test score by quarter. The robotically milked cows produced 0.5 kg (1 lb) more milk per day and averaged five minutes more milking time per day than the parlor milked cows. As a result of the greater machine-on time, the average milk flow rate of the robotically milked cows was 0.5 kg/min (1.2 lb/min) slower than the parlor milked cows. The geometric mean SCC of the robotically milked cows (158,000 cells/ml) was significantly different than for the parlor milked cows (100,000 cells/ml). There was no difference between the treatment groups in the new infection rate at either the cow or quarter level. Electrical conductivity of udder-composite milk, CMT score and udder- composite somatic cell count were correlated, although the correlation coefficient was low.*

**Keywords.** *Robot, Automatic Milking, Mastitis, Milk Yield, Milk Flow Rate Conductivity, California Mastitis Test*

## Introduction & Literature review

Past studies comparing milking performance between cows milked robotically or in a milking parlor show conflicting results. A recent Israeli study (Shoshani and Chaffer 2002) found significantly higher daily milk yield (DMY) in a robotic milking system. Other studies have found significantly less DMY (Kremer and Ordolff 1992; Wirtz et al. 2002) or no significant differences (Svennersten-Sjaunja et al. 2000, Ordolff and Artmann 2000). Ordolff and Artmann (2000) reported no significant changes in daily machine-on time (DMT) or milk flow rate (FR) when robotic milking was compared to parlor milking. These conflicting results justify further research to elucidate the factors contributing to or limiting potential benefits of robotic milking technology.

Recent research have focused on improving the sensitivity of mastitis, or abnormal milk, detection in robotic milking systems. Schemes to use deviations in electrical conductivity (EC) and daily milk yield (DMY) lack the sensitivity to be used as the sole indicators of mastitis detection (Batra and McAllister 1984; Chamings et al. 1984; Hamman and Zecconi 1998). The merits of the California Mastitis Test (CMT) in detecting mastitis have been shown (Wesen et al. 1967) and is widely used. The status of udder health in this study was quantified using changes in CMT status, EC, DMY and somatic cell count (SCC).

## Objectives

The objectives of this study were:

1. To determine if robotic milking has a significant effect on milking performance or incidence of new mastitis infections;
2. To compare the following indicators of udder health: quarter CMT score, udder-composite EC, DMY and udder-composite SCC.

## Materials & Methods

Measurements of milking performance and udder health were collected for a period of 30 weeks on 110 Holstein cows housed on either side of a 4-row, drive-through freestall barn with center feed alley. Lights were turned off in the barn for six hours at night. All cows were fed the same TMR ration. Robotically milked cows received a small amount of grain to entice them into the milking stall and keep them quite during unit attachment.

The parlor group was milked in a double-6, herringbone parlor twice daily at 12-hour intervals. The robot was a single-box system serving a single pen of cows. Cow movement in the robot pen was voluntary with forced one-way traffic. The robot group could be milked at a minimum interval of six hours (up to four times per day). The robotically milked group was inspected twice per day to ensure that each cow was milked a minimum of twice per day.

The cows used in this study were selected from the available pool of cows from the UW research herd (about 350 cows) using the following criteria:

- <200 days in milk (DIM),
- SCC <500,000 cells/ml at time of entry,
- no more than one previous monthly SCC >500,000 cells/ml

Cows admitted to the study were randomly assigned to either the robot or parlor group. The study period began by introducing 15 cows to each group. The data analyzed in this paper began on June 9$^{th}$, 2001. Cows were added in groups of 4 - 12 cows every several weeks.

Efforts were made to keep group size equal; however, some variation occurred individual cows ended their lactation. A summary of the group size during the study is given below.

Table 1. Herd size information (number of cows) over study period.

| | **Minimum** | **Mean** | **Maximum** |
|---|---|---|---|
| **Robot** | 15 | 29 | 38 |
| **Control** | 16 | 24 | 33 |

Parity and stage of lactation were recorded for each cow entering the study. Milk yield and machine-on time were recorded automatically in the parlor at every milking. Milk yield, machine-on time and udder-composite EC was recorded for robotically milked cows at each milking. Individual udder-composite SCC was measured weekly for both groups of cows. Milk samples for SCC enumeration were collected by milking staff during the morning milking for parlor cows and by an automatic sampling device for robot cows.

A weekly CMT was conducted on each quarter of all cows for both groups. CMT scores were coded as negative (CMT score negative or trace) or positive (CMT score one or greater). The number of positive quarters was then summed for each cow to obtain the number of CMT-positive quarters for each cow for each week. A variable called "new infection" was created to describe the udder health of cows during each week over the test period. A "new infection" was defined as a change in state from a CMT-negative to a CMT-positive. A minimum of one CMT-negative was needed to "reset" the new infection score back to zero.

The distribution of all response variables except SCC appeared normal. A $\log_{10}$ transform normalized the distribution of SCC. The single observations from each milking event were assembled into a daily record for each cow, where milk yields and machine-on times were summed for each day for each cow and daily averages were obtained for FR and EC for each cow.

A mixed model with autoregressive correlation was used in SAS (SAS Institute, 2001) to determine if milking method (robot or parlor) had an effect on milking performance. EC was not tested between groups, as it was only available for the robotically milked cows. The response variables DMY, DMT, FR and SCC were repeated measurements on the experimental unit of cow so the statistical analysis used a split-plot design with a subplot error of "cow" nested in "milking method". The full model tested was:

$$\text{Response} = \mu + \text{Group} + \text{Parity} + \text{DIM} + \varepsilon + \text{DIS} + (\text{Group } x \text{ DIS}) + \delta$$

Where:
Response = DMY, DMT, FR, $\text{Log}_{10}$(SCC)
$\mu$ = mean of response
Group = robot or parlor
Parity = 1 to 6
DIM = days in milk 10 to 452
$\varepsilon$ = whole plot error
DIS = number of days each cow was in the study
$\delta$ = subplot error

Backwards elimination of non-significant terms and examination of Akaike's Information Criterion was used to determine the final model.

A generalized estimating equation (GEE) was used to test for a treatment effect on the number of new infections at the quarter and cow level. This method was used due to the combination of repeated measurements of a binomial response and both categorical and continuous explanatory variables (Stokes et al.,2000). The GEE method was invoked by use of the GENMOD procedure in SAS (SAS institute, 2001). The GEE model used a binomial distribution, a type one autoregressive correlation structure and a "logit" link function since the response was binary. The repeated measurement of "new infection" on the experimental unit of cow was specified in the model. The full model tested was:

$$\text{Response} = \beta_o + \text{Group} + \text{Parity} + \text{DIM} + \text{DIS} + (\text{Group x DIS}) + \varepsilon$$

Where: $\beta_o$ = intercept
$\varepsilon$ =error

Pearson correlation coefficients were calculated between SCC and CMT score, EC, and DMY.

## Results and Discussion

A summary of the data is presented in Table 2 and weekly averages of DMY and Log10(SCC) for each treatment group are plotted in Figures 1 and 2.

Table 2. Daily record data distribution information.

| Response | Group | n | Minimum | Overall Mean | Maximum | Standard Deviation |
|---|---|---|---|---|---|---|
| **DMY[1] kg (lb)** | parlor | 3858 | 1.0 (2.2) | 29.2 (64.3) | 67.6 (149.0) | 7.8 (17.2) |
| **DMY[1] kg (lb)** | robot | 4760 | 1.0 (2.2) | 29.9 (65.9) | 69.4 (153.0) | 8.6 (18.9) |
| **DMT[2] min** | parlor | 3858 | 3.5 | 10.0 | 27.0 | 3.1 |
| **DMT[2] min** | robot | 4760 | 4.2 | 15.2 | 45.7 | 4.9 |
| **FR[3] kg/min (lb/min)** | parlor | 3858 | 0.4 (0.5) | 3.1 (6.8) | 8.2 (18.0) | 0.9 (2.0) |
| **FR[3] kg/min (lb/min)** | robot | 4760 | 0.1 (0.3) | 2.0 (4.5) | 4.3 (9.5) | 0.6 (1.3) |
| **EC[4] mS/cm** | robot | 4755 | 0.5 | 5.4 | 12.6 | 0.9 |
| **$Log_{10}$ SCC[5] (SCC 1000 cells/ml)** | parlor | 348 | 4.0 (10) | 5.0 (100) | 7.0 (10,000) | 0.6 (0.004) |
| **$Log_{10}$ SCC[5] (SCC 1000 cells/ml)** | robot | 372 | 3.7 (5) | 5.2 (158) | 6.9 (7943) | 0.5 (0.003) |

[1]DMY=Daily Milk Yield
[2]DMT=Daily Machine-on Time
[3]FR=milk Flow Rate
[4]EC=Electrical Conductivity, measured for robot group only
[5]SCC=Somatic Cell Count

It is important to note the difference in the method of measuring milking time for each milking method. In the parlor group, a button pressed by the operator immediately preceding manual cluster attachment initiates the milking time; the automatic cluster remover switchpoint was set to 0.5 kg (1 lb) per minute plus a five-second delay. Teatcups are attached individually by the robotic milking machine. The milking time robotic milking is initiated by milk flow sensed in the first quarter. Teatcups are detached when milk flow ceases in each individual quarter with the milking time ending at low flow for the last quarter.

The sample size, least square means (LSM), standard error (SE) and p-values for measurements of milking performance and SCC are presented in Table 3. LSM, also known as adjusted treatment means, were used to account for any bias in assignment of cows to treatment group.

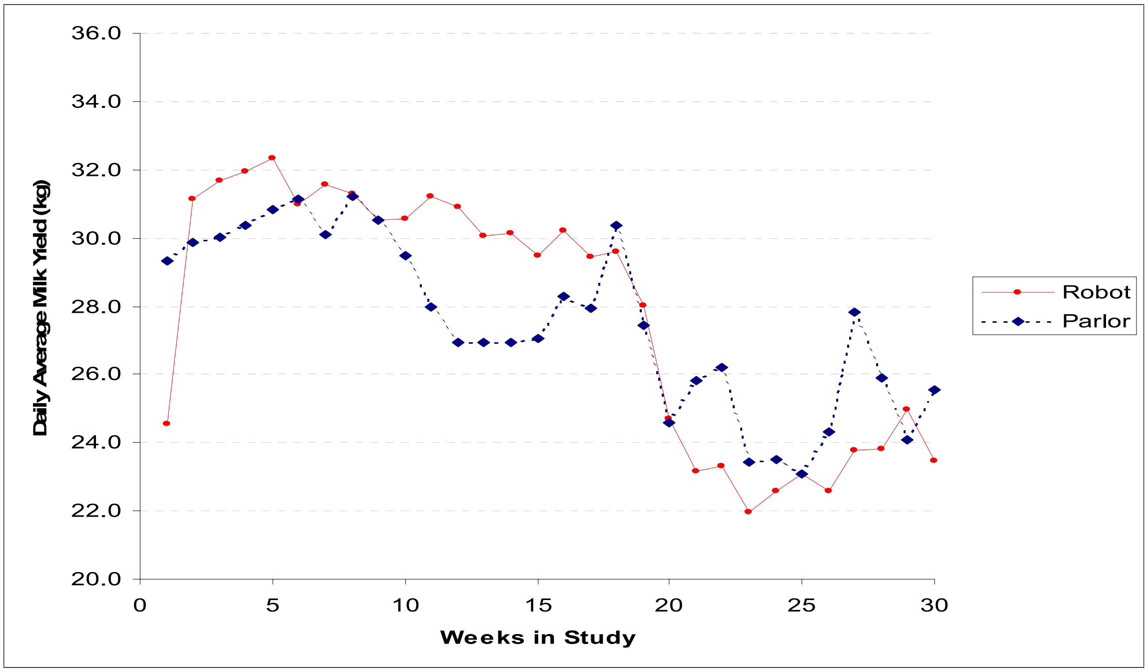


Figure 1. Daily milk yield averaged by the number of weeks each cow was in the study for each treatment group.

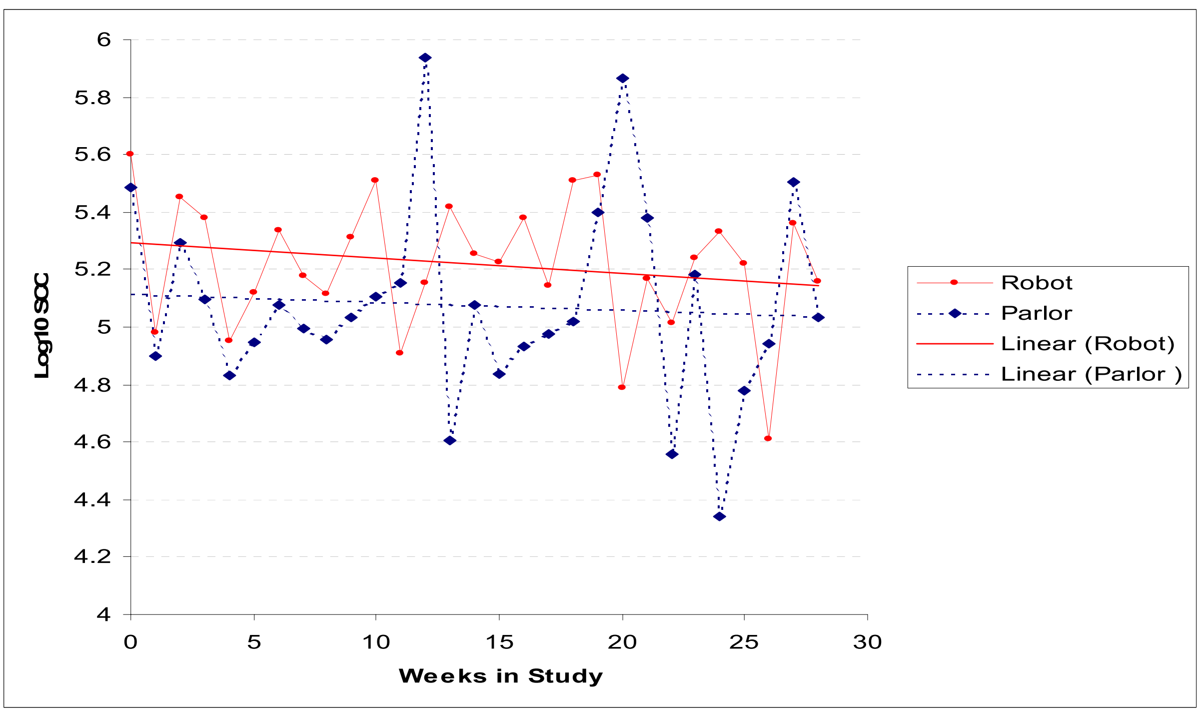


Figure 2. Somatic cell count by weeks each cow was in the study for each treatment group.

Table 3. Least square means (LSM) and for continuous response variables.

| | Robot | | | Parlor | | | |
|---|---|---|---|---|---|---|---|
| **Response** | **n** | **LSM** | **SE** | **n** | **LSM** | **SE** | **p value** |
| **DMY[1] kg (lb)** | 4705 | 29.7 (65.4) | 0.2 (0.5) | 3858 | 29.1 (64.2) | 0.2 (0.5) | 0.0306 |
| **DMT[2] min** | 4705 | 15.1 | 0.1 | 3858 | 10.0 | 0.1 | <0.0001 |
| **FR[3] kg/min (lb/min)** | 4705 | 2.0 (4.5) | 0.05 (0.1) | 3858 | 3.1 (6.8) | 0.05 (0.1) | <0.0001 |
| **$Log_{10}$ SCC (1000 cells/ml)** | 366 | 5.2 (158) | 0.03 (0.001) | 348 | 5.0 (100) | 0.03 (0.001) | <0.0001 |

[1]DMY=Daily Milk Yield
[2]DMT=Daily Machine-on Time
[3]FR=milk Flow Rate
[4]SCC=Somatic Cell Count

The final model for DMY and SCC included terms for Group, DIM and DIS. The final model for DMT and FR included terms for Group, Parity, DIM, DIS and (Group x DIS). Milking method (Group) had a statistically significant effect on DMY, DMT, FR and $Log_{10}$(SCC). The robot group was milked 2.6 times daily compared to 2 times daily for the parlor group. The robot group produced 0.5 kg (1.2 lb) more milk per day and spent 5.1 minutes more in contact with the milking machine than the parlor group. The FR of milk harvested in the robotic system was 0.5 kg/min (1.2 lb/min) slower than the conventional parlor. The SCC of the robot group was 58,000 greater than the parlor group; however, the mean SCC for both groups is in good standing.

As previously mentioned, the criteria for DMT is different between the groups. The greater DMT for the robot group may have been influenced by differences in the measurement criteria as well as delays in finding teats and attaching teat cups. Also important to note is the calculation of FR, which is simply milk yield divided by milking time for each milking, or the amount of milk harvested per unit of time. A change in FR, therefore, does not necessarily imply any physiological changes to the teat or cow. Lower FR in cows milked more frequently has also been reported by Stewart et al. (1993) due to the increased percentage of time spent in low-flow conditions.

DMY was suppressed in the robot group during the first few days of adapting to the new housing and milking system but soon recovered. The small overall gain in DMY in the robot group was probably due to increased milking frequency, although this difference is smaller than expected for a difference of 2 versus 2.6 milkings per day. It should be noted that no special provisions were made to adjust the diet for the robot group and this may have suppressed the gain in milk yield. The milking frequency of the robot group in this study (2.6/day) was similar to that observed in other studies: Wirtz et al. (2002) 2.7/day with significantly lower milk yield with robotic milking; Svennersten-Sjaunja et al., (2000) 2.4/day with no difference in milk yield; and Shoshani and Chaffer (2002), 2.8/day with significantly higher milk yield milk with a robotic system. Management factors other than milking frequency are clearly important in order to realize increase milk yield through more frequent milking with a robotic milking system.

A general decline in milk yield was observed for both groups as the study period and stage of lactation progressed. The depression in milk yield in the parlor group during weeks 10 through 15 was influenced by heat stress during the months of July and August for many of the cows in the study. It is interesting to note that the robot group did not appear to suffer as large a decrease in milk yield during this period. The robotically milked cows had a slightly higher SCC in our study. Though statistically different, neither of the average SCCs in this study, 100,000 cells/ml (parlor) and 158,000 cells/ml (robot), are cause for concern.

No significant difference between the incidences of “new infection” was found between the robot and parlor group at either the quarter or cow level. Model convergence was achieved for each response. The percentage of quarters with “new infection” over the study is presented in Figure 3. Though the treatment groups did vary slightly in percentage of “new infections” observed over time, no significant differences were found between treatment groups.

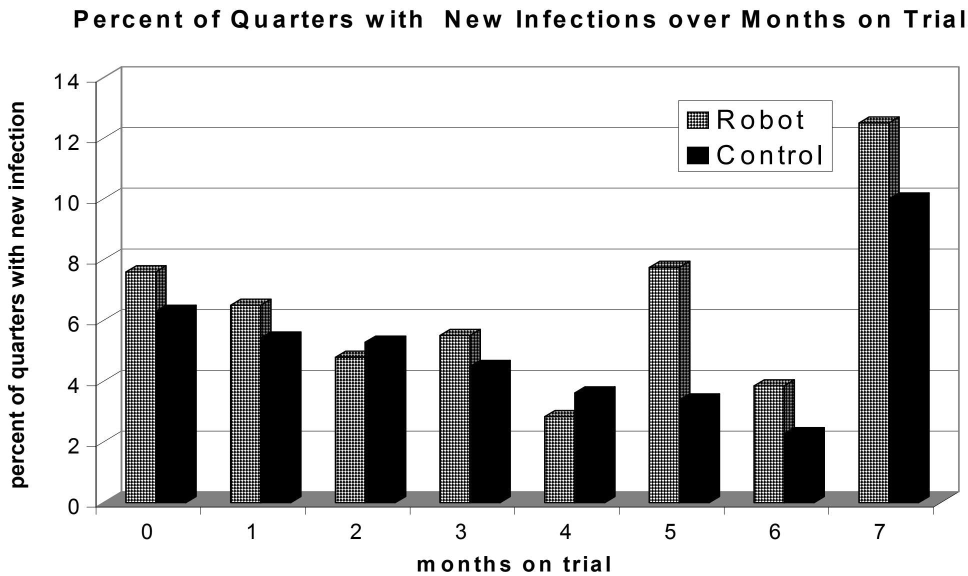


Figure 3. Percentage of quarters with new infection for each group over the study period.

Pearson correlation coefficients between composite milk SCC and three mastitis indicators: EC, DMY and number of CMT positive quarters are presented in Table 4. EC, DMY and CMT were all significantly correlated with Log10(SCC), however the correlations were low and EC had the lowest correlation.

Table 4. Pearson correlation coefficients, p-values and sample sizes for mastitis indicators.

| | **EC (n=366)** | **DMY (n=714)** | **CMT[1] (n=714)** |
|---|---|---|---|
| **correlation with $Log_{10}$(SCC)** | -0.13 | -0.20 | 0.39 |
| **p-value** | 0.0143* | <0.0001* | <0.0001* |

* Designates significance at $\alpha$=0.05 level.

[1]CMT=number of CMT-positive quarters

## Conclusions

- Cows milked with the robotic milking system produced significantly more milk per day and spent more time in contact with the milking machine per day than cows milked in a conventional parlor.
- Cows milked with the robotic milking system had a significantly higher SCC than cows milked in a parlor. However; the SCC of both groups were quite low.
- No difference in number of “new infections” as indicated by CMT score was found between the robot and parlor groups at either the quarter or cow level.
- The udder health measures of CMT score, EC and SCC were correlated but the correlation coefficient was low.

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## References

Batra, T.R. and A.J. McAllister. 1984. A comparison of mastitis detection methods in dairy cattle. *Canadian Journal of Animal Science* **64**:305-312.

Chamings, R.J., G. Murray and J.M. Booth. 1984. Use of a conductivity meter for the detection of subclinical mastitis. *Veterinary Record* **114**:243-245.

Hamann, J. and A. Zecconi. 1998. Evaluation of the electrical conductivity of milk as a mastitis indicator. *Bulletin of the International Dairy Federation No. 334*.

Kremer, J.H. and D. Ordolff. 1992. Experiences with continuous robot milking with regard to milk yield, milk composition and behavior of cows. *Proceedings of the International Symposium on Prospects for Automatic Milking.* Eds. A.H. Ipema, A.C. Lippus, J.H.M. Metz and W. Rossing. Wageningen, Netherlands, November 23-25. EAAP Publication No. 65. Pp. 253-260.

Ordolff, D. and R. Artmann. 2000. Surface temperatures of udder and teats in conventional and automatic milking systems. Robotic Milking: Proceedings of the International Symposium. Eds. H. Hogeveen and A. Meijering. Lelystad, The Netherlands, 17-19 August. pp. 301-302.

SAS Institute Incorporated. 2001. SAS Software, release 8.2. SAS Institute Incorporated, Cary, NC, USA.

Shoshani, E. and M. Chaffer. 2002. Robotic milking: a report of a field trial in Israel. *Proceedings of The First North American Conference on Robotic Milking,* March 20-22, Toronto, ON, CA. Pp. III-56-III-63.

Stewart, S., P. Billon and G.A. Mein. 1993. Predicted maximum milk flowrates in milking systems. *Proceedings of 32nd Annual Meeting of the National Mastitis Council,* Kansas City, MO.

Stokes, M., C. Davis and G. Koch. 2000. *Categorical data analysis using the SAS system*. SAS Publishing, chapter 13.4.

Svennersten-Sjaunja, K., I. Berglund and G. Pettersson. 2000. The milking process in an automatic milking system, evaluation of milk yield, teat condition and udder health. *Robotic* Milking: Proceedings of the International Symposium. Eds. H. Hogeveen and A. Meijering. Lelystad, The Netherlands, 17-19 August. Pp. 277-288.

Wesen, D.P., L.O. Luedecke and T.L. Forster. 1967. Relationship between California Mastitis Test reaction and bacteriological analysis of stripping samples. *Journal of Dairy Science* **51(5)**: 679-684.

Wirtz, N., K. Oechtering, E. Tholen and W. Trappmann. 2002. Comparison of an automatic milking system to a conventional milking parlor. *Proceedings of The First North American Conference on Robotic Milking,* March 20-22, Toronto, ON, CA. pp. III-50-III-55.