A STUDY OF THE INTERCHANGEABILITY OF GAS DETECTOR TUBES AND PUMPS

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INTRODUCTION

CHEMICAL INDICATOR TUBES PROVIDE A RAPID AND ECONOMICAL METHOD FOR DETERMINING GASEOUS CONTAMINANT CONCENTRATIONS IN AIR. HOWEVER, VARIABILITY IN THE RESULTS HAS OFTEN BEEN EXCESSIVELY LARGE. THE GENERAL PROBLEM ENCOUNTERED WITH THEIR WIDE-SPREAD USE IS WELL STATED IN AN EXCERPT FROM THE AUGUST 9, 1965, REPORT OF THE JOINT AMERICAN CONFERENCE OF GOVERNMENT INDUSTRIAL HYGIENISTS - AMERICAN INDUSTRIAL HYGIENE ASSOCIATION COMMITTEE ON DIRECT-READING GAS DETECTING TUBE SYSTEMS:

"THE JOINT COMMITTEE ON DIRECT-READING GAS DETECTING TUBE SYSTEMS OF THE ACGIH-AIHA RECOGNIZES THAT SUCH DEVICES ARE WIDELY USED BY INDUSTRIAL HYGIENISTS AND BY OTHERS, AND THAT THEIR USE IS, IN FACT, DESIRABLE IN INDUSTRIAL HYGIENE ACTIVITIES. IT HAS ALSO BEEN APPARENT THAT A GREAT DEAL OF THE USAGE OF THESE DEVICES HAS BEEN BY INDIVIDUALS UNFAMILIAR WITH THE LIMITATIONS OF THE SYSTEM AND THAT UNWARRANTED INTERPRETATIONS OF ANALYSES OF THE WORKROOM ATMOSPHERE BASED UPON THESE TUBES HAVE BEEN MADE. THEREFORE, ERRORS IN USE OF SUCH TUBE DETECTORS HAVE BEEN DUE TO THE LACK OF KNOWLEDGE OF THE USER AND BY THE VARIATIONS IN PERFORMANCE INHERENT IN THE TUBES THEMSELVES."

WITH THE CONTINUALLY INCREASING USE OF GAS DETECTOR TUBES, THE VALIDITY OF THE RESULTS OBTAINED BY USING ONE MANUFACTURER'S DETECTOR TUBES WITH ANOTHER MANUFACTURER'S SAMPLING PUMP HAS SO OFTEN BEEN QUESTIONED THAT THE NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH) OF THE UNITED STATES PUBLIC HEALTH SERVICE UNDERTOOK A PERFORMANCE STUDY OF THE INTERCHANGEABILITY OF GAS DETECTOR TUBES AND PUMPS. SINCE THERE IS CURRENTLY A WIDE VARIETY OF CONTAMINANTS THAT CAN BE QUANTITATIVELY MEASURED WITH

GAS DETECTOR TUBES AND SINCE TIME DID NOT PERMIT USE OF ALL OF THEM, CARBON MONOXIDE WAS SELECTED AS THE CONTAMINANT TO BE USED IN THE STUDY. FURTHERMORE, THE CARBON MONOXIDE GAS DETECTOR TUBE IS THE MOST FREQUENTLY USED GAS DETECTOR TUBE TODAY.

GAS DETECTOR TUBES AND PUMPS EVALUATED *

CURRENTLY, EACH DETECTOR TUBE MANUFACTURER SUPPLIES A SPECIFIC SAMPLING PUMP TO BE USED WITH ITS DETECTOR TUBES, AND NO MANUFACTURER MARKETS EITHER SAMPLING PUMPS OR GAS DETECTOR TUBES WHICH IT CLAIMS ARE WIDELY COMPATIBLE WITH THOSE OF OTHER MANUFACTURERS. THE SAMPLING PUMPS USED IN THIS STUDY ARE REPRESENTATIVE OF THE FOUR BASIC TYPES OF SAMPLING PUMPS USED WITH GAS DETECTOR TUBES: (1) BELLOWS PUMPS, (2) DIAPHRAGM PUMPS, (3) PLUNGER PUMPS, AND (4) RUBBER BALL PUMPS.

THE FOLLOWING MANUFACTURERS' SAMPLING PUMPS AND CARBON MONOXIDE LENGTH-OF-STAIN DETECTOR TUBES WERE USED IN THE STUDY:

(1) SAMPLING PUMPS

BACHARACH UNIVERSAL GAS SAMPLER, PART NUMBER 19-7016
DRAGER MULTI GAS DETECTOR, MODEL 21/32
KITAGAWA MODEL 400 PRECISION GAS DETECTOR
MSA UNIVERSAL SAMPLING PUMP, PART NUMBER 83499
SAF-CO CARBON MONOXIDE INDICATOR METER
SCOTT/GASTEC ANALYZER, PART NUMBER 8501

(2) DETECTOR TUBES **

BACHARACH CARBON MONOXIDE DETECTOR TUBE, PART NUMBER 19-0195
DRAGER CARBON MONOXIDE 5/C DETECTOR TUBE
KITAGAWA CATALOGUE NUMBER 100 CARBON MONOXIDE DETECTOR TUBE
MSA CARBON MONOXIDE DETECTOR TUBE, PART NUMBER 91229
SCOTT/GASTEC CARBON MONOXIDE DETECTOR TUBE, CATALOGUE NO. 8525

*USE OF BRAND NAMES IS FOR INFORMATION ONLY AND DOES NOT IMPLY ENDORSEMENT BY NIOSH.

**NO SAF-CO CARBON MONOXIDE DETECTOR TUBE WAS USED IN THE STUDY SINCE SAF-CO MAKES ONLY A COLOR-INTENSITY CARBON MONOXIDE DETECTOR TUBE, AND THE TUBES BEING EVALUATED WERE LENGTH-OF-STAIN CARBON MONOXIDE DETECTOR TUBES.

In the fall of 1971, NIOSH purchased approximately one hundred (100) of each of the above specified detector tubes from each of the respective manufacturers under specifications that each set of tubes from a given manufacturer be from the same batch in order to eliminate possible batch variations. The sampling pumps used in the study were obtained from various NIOSH groups.

Due to the different types of data needed to evaluate the interchangeability of gas detector tubes and pumps, the study was divided into three parts: (1) analysis of the suction pressure versus elapsed time for each manufacturer's pump with the various carbon monoxide detector tubes, (2) analysis of the flow rate versus elapsed time for each manufacturer's pump with the various carbon monoxide detector tubes, and (3) analysis of the tube readings obtained by actually interchanging each manufacturer's carbon monoxide detector tube with each manufacturer's gas sampling pump.

ANALYSIS OF SUCTION PRESSURE VERSUS ELAPSED TIME

In order to monitor the suction pressure versus the elapsed time for each manufacturer's pump with the various carbon monoxide tubes, a pressure-sensitive recording instrument was loaned to NIOSH by Dragerwerk, A. G., of Lubeck, Germany. The instrument (Schematic 1) consisted basically of a thin metal diaphragm triggered by a solenoid value with a marker arm attached to the outer edge of the diaphragm. The deflection of the marker arm on the recording chart was directly proportional to the suction pressure of the sampling pump. Before the data was taken for this section, the deflection in chart units was calibrated with a mercury manometer and a vacuum pump so that the deflection could be read directly in suction pressure units of inches of mercury.

After the above testing system had been calibrated, each manufacturer's pump was tested with (1) a standard resistance tube, (2) its specific CO tube, and (3) the various other manufacturers' CO tubes. The test air suction volume in each case was that produced from one complete pump stroke of the different manufacturers' pumps being used. Once each set of data was collected, it was plotted on standard coordinate graph paper with the X-axis representing "Elapsed time (sec)" and the Y-axis representing "Suction Pressure (in. Hg)." The resulting curves are shown in Graph 1 thru Graph 15. Since the suction pressure was continuously measured at the point where the suction pump and the gas detector tube connect and since the resistance on the upstream side of the gas detector tubes remained constant, the various graphs can be directly compared in order to observe the different suction behavior of the various pumps in the study. As can be seen from the

CURVES, THE CURVE OF A SPECIFIC MANUFACTURER'S CO DETECTOR TUBE USED WITH ANOTHER MANUFACTURER'S SAMPLING PUMP CAN NEVER BE EXACTLY SUPERIMPOSED UPON THE CURVE GENERATED FROM USING THE SPECIFIC MANUFACTURER'S CO DETECTOR TUBE WITH ITS DESIGNATED PUMP. ALTHOUGH IN SEVERAL CASES THE CURVES ARE QUITE SIMILAR, IT WILL BE NOTICED THAT EITHER THE SUCTION PRESSURE OR ELAPSED TIME (OF EACH PUMP STROKE) IS DIFFERENT. ALSO, IT IS INTERESTING TO NOTE THAT THE INSTANTANEOUS SUCTION PRESSURE OF THE VARIOUS MANUFACTURERS' SAMPLING PUMPS WITH THEIR RESPECTIVE CO GAS DETECTOR TUBES VARIED FROM A LOW OF .15 INCHES HG ASSOCIATED WITH THE BACHARACH SAMPLING PUMP AND CO DETECTOR TUBE TO A HIGH OF 8.1 INCHES HG ASSOCIATED WITH THE GASTEC SAMPLING PUMP AND CO DETECTOR TUBE. WE CAN, THEREFORE, SEE FROM THE ABOVE GRAPHS THAT EACH MANUFACTURER'S PUMP AND CO GAS DETECTOR TUBE DOES HAVE DIFFERENT SUCTION CHARACTERISTICS DUE TO THE VARIOUS DIFFERENCES INHERENT IN EACH PUMP AND TUBE DESIGN EVEN THOUGH THE SINGLE STROKE GROSS SAMPLING VOLUME OF MOST OF THE PUMPS STUDIED WAS THE SAME.

ANALYSIS OF FLOW RATE VERSUS ELAPSED TIME

THE FLOW RATE VERSUS ELAPSED TIME FOR EACH MANUFACTURER'S PUMP WITH THE VARIOUS CO GAS DETECTOR TUBES WAS CONTINUOUSLY MEASURED AND RECORDED BY A CGS DATAMETRIC MODEL 900-2836 CONSTANT TEMPERATURE HOT-WIRE ANEMOMETER WITH AN ATTACHED HEWLETT-PACKARD MODEL 680 STRIP CHART RECORDER. THE ANEMOMETER WAS FIRST CALIBRATED USING THE SUGGESTED PROCEDURE DESCRIBED IN THE CGS MANUAL, AND IN TURN, A BASE VOLTAGE WAS ESTABLISHED. THEN A BUBBLE METER WAS CONNECTED UPSTREAM OF THE HOT-WIRE ANEMOMETER PROBE, AND A VACUUM PUMP CONTROLLED WITH A MICROMETER VALVE WAS CONNECTED IN SERIES WITH THE BUBBLE METER. BY ADJUSTING THE MICROMETER VALVE, IT WAS POSSIBLE TO CONTROL THE AIR FLOW RATE ACROSS THE PROBE SENSOR. VARIOUS AIR FLOW RATES WERE REPEATEDLY GENERATED, AND SUBSEQUENTLY, A CALIBRATION CURVE OF THE HOT-WIRE ANEMOMETER DIFFERENTIAL VOLTAGE (FLOW RATE VOLTAGE MINUS BASE VOLTAGE) VERSUS AIR FLOW RATE (CC) WAS PLOTTED. THE RESULTING CALIBRATION CURVES CAN BE SEEN IN GRAPHS 16 AND 17. IT WAS NECESSARY TO PLOT TWO DIFFERENT CURVES (ONE FOR USE ABOVE 350 CC/MIN. AND ONE FOR USE BELOW 350 CC/MIN.), FOR THE INDIVIDUAL DATA POINTS FIT THE EQUATION OF A STRAIGHT LINE UP TO THE VOLTAGE POINT CORRESPONDING TO 350 CC/MIN. AND FIT THE EQUATION OF A POWER CURVE AFTER THE VOLTAGE POINT CORRESPONDING TO 350 CC/MIN. IT WAS THOUGHT THAT THIS POINT MIGHT BE THE TRANSITION POINT BETWEEN LAMINAR AND TURBULENT FLOW. HOWEVER, A REYNOLDS NUMBER WAS CALCULATED AND FOUND TO BE WELL WITHIN THE LAMINAR FLOW REGION. THE HOT-WIRE ANEMOMETER PROBE SENSOR WAS RECALIBRATED AND ESSENTIALLY THE SAME POINTS WERE AGAIN PLOTTED. THEREFORE, THE EXISTENCE OF THESE TWO DIFFERENT CURVES WITH A TRANSITION POINT AT 350 CC/MIN. MUST BE ATTRIBUTED TO THE VARIANCES INHERENT IN THE TESTING SYSTEM. ALSO, SINCE EACH PROBE FILAMENT

HAD ITS OWN CHARACTERISTIC RESISTANCE, IT WAS MANDATORY THAT ALL THE TEST DATA BE TAKEN WITH THE SAME FILAMENT IN PLACE IN ORDER TO ASSURE THE VALIDITY OF THE RESULTS.

AFTER THE HOT-WIRE ANEMOMETER WITH THE ATTACHED STRIP CHART RECORDER HAD BEEN CALIBRATED AND THE RESULTING CALIBRATION CHARTS HAD BEEN GRAPHED, EACH MANUFACTURER'S PUMP WAS TESTED WITH (1) A STANDARD RESISTANCE TUBE, (2) ITS SPECIFIC CO TUBE, AND (3) THE VARIOUS OTHER MANUFACTURERS' CO GAS DETECTOR TUBES. ONCE AGAIN, THE TEST AIR SUCTION VOLUME USED IN THE STUDY WAS THAT PRODUCED FROM ONE COMPLETE PUMP STROKE OF THE DIFFERENT MANUFACTURERS' PUMPS BEING USED IN THE STUDY. ONCE EACH SET OF DATA WAS COLLECTED, IT WAS PLOTTED ON STANDARD COORDINATE GRAPH PAPER WITH THE X-AXIS REPRESENTING "ELAPSED TIME (SEC)" AND THE Y-AXIS REPRESENTING "AIR FLOW RATE (CC/MIN.)". THE RESULTING CURVES ARE SHOWN IN GRAPH 18 THRU GRAPH 29.

THE INTEGRAL OF THE AREA UNDER EACH CURVE SHOULD BE EQUAL TO THE VOLUME SAMPLED WITH EACH SAMPLING PUMP AND GAS DETECTOR TUBE COMBINATION. HOWEVER, SINCE THE CALCULATED VOLUMES DO DIFFER IN MANY CASES FROM THE ACTUAL VOLUMES SAMPLED, THESE DISCREPANCIES MUST AGAIN BE ATTRIBUTED TO VARIANCES INHERENT IN THE TESTING SYSTEM. SINCE THE FLOW RATE WAS CONTINUOUSLY MEASURED AT THE INLET TO THE CO GAS DETECTOR TUBE AND SINCE THE RESISTANCE AT THIS POINT REMAINED CONSTANT, THE VARIOUS GRAPHS CAN BE DIRECTLY COMPARED IN ORDER TO OBSERVE THE DIFFERENT FLOW RATE CHARACTERISTICS OF THE VARIOUS SAMPLING PUMP AND GAS DETECTOR TUBE COMBINATIONS. OF THE SIX MANUFACTURERS' PUMPS USED IN THE STUDY, THE MSA PUMP, THE KITAGAWA PUMP, THE BACHARACH PUMP, AND THE SAF-CO PUMP HAVE FOUR ORIFICES, ONE ORIFICE, TWO ADJUSTABLE ORIFICES, AND ONE ADJUSTABLE ORIFICE, RESPECTIVELY, WHILE

THE DRAGER AND GASTEC PUMPS HAVE NO ORIFICES. AGAIN AS IN THE GRAPHS OF SUCTION PRESSURE VERSUS ELAPSED TIME, ALTHOUGH THE CURVES ARE QUITE SIMILAR AND ALMOST SUPERIMPOSEABLE IN SEVERAL CASES, IT WILL AGAIN BE NOTICED THAT EITHER THE FLOW RATE OR ELAPSED TIME (OF EACH PUMP STROKE) IS SLIGHTLY DIFFERENT. HOWEVER, THE CURVES WHICH ARE THE MOST SIMILAR ARE THOSE FOR THE PUMPS WITH ORIFICES. APPARENTLY THE CONTROLLING FLOW RESISTANCE IN THOSE CASES WAS THE INHERENT RESISTANCE IN THE SAMPLING PUMPS RATHER THAN THAT IN THE GAS DETECTOR TUBES. THE INSTANTANEOUS FLOW RATE (SUCTION) OF THE VARIOUS MANUFACTURERS' SAMPLING PUMPS WITH THEIR RESPECTIVE CO GAS DETECTOR TUBES VARIED FROM A LOW OF 15 CC/MIN WITH THE BACHARACH PUMP WITH ORIFICE A AND THE BACHARACH CO DETECTOR TUBE TO A HIGH OF 850 CC/MIN. WITH THE DRAGER PUMP AND CO DETECTOR TUBE.

IT CAN, THEREFORE, BE SEEN THAT IT IS NOT SUFFICIENT TO PULL THE SAME VOLUME OF AIR THROUGH EACH MANUFACTURER'S CO GAS DETECTOR TUBE WITH THE SAME PUMP, FOR THE FLOW RATE IS INHERENTLY AFFECTED BY THE INTERNAL SUCTION PROPERTIES (RESISTANCE) OF THE PUMP BEING USED. FURTHERMORE, IT HAS ALSO BEEN SHOWN IN AN EARLIER STUDY REPORTED BY KURT LEICHNITZ IN 1971 THAT EVEN IF THE PUMP STROKE TIME IS HELD CONSTANT, THE FLOW RATE CHARACTERISTICS OF THE PUMPS WITH THE VARIOUS CO GAS DETECTOR TUBES WILL STILL DEPEND UPON THE SUCTION CHARACTERISTICS OF THE INDIVIDUAL PUMP AND THE RESISTANCE BUILT INTO EACH GAS DETECTOR TUBE AND SAMPLING PUMP.

ACTUAL INTERCHANGE OF EACH MANUFACTURER'S CARBON MONOXIDE DETECTOR TUBE WITH EACH MANUFACTURER'S GAS SAMPLING PUMP

THE FINAL SECTION OF THIS STUDY INVOLVED THE ACTUAL INTERCHANGE OF THE VARIOUS MANUFACTURERS' CO GAS DETECTOR TUBES WITH EACH MANUFACTURER'S SAMPLING PUMP. HOWEVER, THE SAF-CO SAMPLING PUMP AND CO GAS DETECTOR TUBE WERE NOT USED IN THIS PHASE OF THE STUDY SINCE SAF-CO ONLY MAKES A COLOR INTENSITY DETECTOR TUBE. AS STATED EARLIER IN THE PAPER, NIOSH PURCHASED APPROXIMATELY ONE HUNDRED OF EACH OF THE PREVIOUSLY LISTED MANUFACTURERS' DETECTOR TUBES UNDER THE SPECIFICATIONS THAT EACH SET BE FROM A SINGLE BATCH. CARBON MONOXIDE WAS SELECTED AS THE CONTAMINANT TO BE USED IN THIS PHASE OF THE STUDY, AND A CERTIFIED CYLINDER OF 100 ± 1 PPM CARBON MONOXIDE GAS WAS ORDERED FROM MATHESON GAS PRODUCTS. THE CARBON MONOXIDE CONCENTRATION WAS CONFIRMED BY NIOSH'S PHYSICAL AND CHEMICAL ANALYSIS BRANCH IN CINCINNATI, OHIO.

IN ORDER TO TEST THE VARIOUS COMBINATIONS OF PUMPS AND DETECTOR TUBES, A BASIC GAS MANIFOLD SYSTEM WAS CONNECTED TO THE CARBON MONOXIDE CYLINDER. TEN CARBON MONOXIDE TUBES OF EACH OF THE DIFFERENT MANUFACTURERS WERE TESTED WITH THE SAMPLING PUMPS OF THE VARIOUS MANUFACTURERS. EACH DETECTOR TUBE'S LENGTH OF STAIN AND CORRESPONDING CONCENTRATION WAS DETERMINED BY THREE INDIVIDUAL, QUALIFIED TUBE READERS, AND THEIR READINGS WERE AVERAGED TO OBTAIN A SINGLE READING. THE SPECIFIC INSTRUCTIONS GIVEN BY A MANUFACTURER FOR USING ITS PUMP AND DETECTOR TUBE COMBINATION WERE FOLLOWED WHEN ITS DETECTOR TUBE WAS USED WITH THE OTHER MANUFACTURERS' SAMPLING PUMPS. IT SHOULD BE NOTED THAT THE SAMPLE VOLUME DESIGNATED BY A MANUFACTURER FOR USE WITH ITS PUMP AND CO DETECTOR TUBE COMBINATION WAS THE SAME VOLUME USED FOR ITS DETECTOR TUBE AND THE VARIOUS OTHER MANUFACTURERS' PUMPS COMBINATIONS. THE ONLY EXCEPTION TO THE ABOVE

STATEMENT OCCURRED IN THE USE OF THE BACHARACH CO DETECTOR TUBE WITH THE NON-BACHARACH PUMPS. IN THIS CASE THE 112 CC SAMPLE VOLUME USED WITH THE BACHARACH PUMP COULD NOT BE DUPLICATED WITH THE OTHER PUMPS. INSTEAD A SAMPLE VOLUME OF 100 CC HAD TO BE USED. THE EFFECTS OF THIS VARIANCE WILL BE DISCUSSED SHORTLY. THE RESULTS OF THIS FINAL PHASE OF THE STUDY ARE PRESENTED IN TABLE 1 THROUGH TABLE 5. EACH TABLE HAS THE DATA TABULATED IN THE FOLLOWING FOUR CATEGORIES: (1) THE PUMP TYPE USED WITH THE SPECIFIC CO GAS DETECTOR TUBE, (2) THE AVERAGE CO GAS DETECTOR TUBE READING ($\bar{x}$), (3) THE STANDARD DEVIATION OF THE TEN DIFFERENT TUBE READINGS USED TO CALCULATE $\bar{x}$, AND (4) THE % DEVIATION FROM THE SPECIFIED USE VALUE - THE SPECIFIED USE VALUE BEING DEFINED AS THE $\bar{x}$ CALCULATED FROM CORRECTLY USING A MANUFACTURER'S CO GAS DETECTOR TUBE WITH ITS SAMPLING PUMP.

TABLE 1 SUMMARIZES THE DATA ACCUMULATED FROM USING THE BACHARACH CO INDICATOR TUBE NO. 19-0195 WITH THE VARIOUS PUMPS IN THE STUDY. PER THE BACHARACH INSTRUCTIONS, ITS CO DETECTOR TUBE WAS USED WITH ITS PUMP WITH ORIFICE A AND THE 16 CC SAMPLE FITTING IN PLACE, AND SEVEN (7) PUMP STROKES (112 CC) WERE TAKEN. THE CO CONCENTRATION DETERMINED WITH THE BACHARACH PUMP AND DETECTOR TUBE AVERAGED 81.5 PPM VERSUS THE CERTIFIED 100-PPM VALUE. AS CAN BE SEEN FROM THE TABLE, NO OTHER COMBINATION OF BACHARACH CO DETECTOR TUBE USED WITH ANOTHER MANUFACTURER'S SAMPLING PUMP PRODUCED RESULTS SIMILAR TO EITHER THE 81.5 PPM VALUE OR EVEN THE 100 PPM VALUE. IN FACT, THE NEXT CLOSEST COMBINATION, THE BACHARACH CO INDICATOR TUBE WITH THE KITAGAWA SAMPLING PUMP, PRODUCED RESULTS 92.5% GREATER THAN THE SPECIFIED USE VALUE (81.5 PPM). FURTHERMORE, SINCE ONLY A 100 CC SAMPLING VOLUME WAS USED WITH THE NON-BACHARACH PUMPS, THE RESULTING CONCENTRATIONS OF THE BACHARACH CO TUBES USED WITH THE OTHER MANUFACTURERS' PUMPS WERE ACTUALLY LOWER THAN THEIR TRUE VALUES.

TABLE 2 SUMMARIZES THE DATA TABULATED FROM USING THE DRAGER CO 5/C INDICATOR TUBE WITH THE FIVE PUMPS BEING USED IN THIS PHASE OF THE STUDY. PER THE DRAGER INSTRUCTIONS, A SAMPLING VOLUME OF 100 CC WAS USED WITH ITS DETECTOR TUBE. THE CO CONCENTRATION MEASURED WITH THE DRAGER PUMP AND DETECTOR TUBE AVERAGED 96 PPM VERSUS THE CERTIFIED 100 PPM VALUE. THE OTHER COMBINATIONS OF PUMPS AND DRAGER CO DETECTOR TUBE YIELDED AVERAGE CONCENTRATIONS THAT RANGED FROM 20.7% HIGHER TO 33.6% LOWER THAN THE 96 PPM CO CONCENTRATION MEASURED WITH THE DRAGER CO DETECTOR TUBE AND SUCTION PUMP. IT WOULD BE EXPECTED THAT THESE RESULTS WOULD SPAN SUCH A NARROW RANGE, FOR THE DRAGER SAMPLING PUMP HAS NO ORIFICE, AND THE AIR FLOW RATE WOULD BE TOTALLY A FUNCTION OF THE RESISTANCE INHERENT IN DRAGER 5/C CO DETECTOR TUBE. OBVIOUSLY, THE MAGNITUDE OF THIS RESISTANCE IS THE CONTROLLING FLOW RATE FACTOR WHEN THE DRAGER CO DETECTOR TUBE IS USED WITH OTHER MANUFACTURERS' SAMPLING PUMPS, AND THESE RESULTS SHOULD BE USED ONLY ON A QUALITATIVE BASIS.

TABLE 3 SUMMARIZES THE DATA TABULATED FROM USING THE GASTEC CO INDICATOR TUBE NO. 8525 WITH THE FIVE PUMPS BEING USED IN THIS PHASE OF THE STUDY. PER THE GASTEC INSTRUCTIONS, A SAMPLING VOLUME OF 100 CC WAS ALSO USED WITH ITS DETECTOR TUBE. THE CO CONCENTRATION MEASURED WITH THE GASTEC PUMP AND DETECTOR TUBE AVERAGED 109.1 PPM VERSUS THE CERTIFIED 100 PPM VALUE. THE OTHER VARIOUS COMBINATIONS OF SAMPLING PUMPS AND GASTEC CO DETECTOR TUBE, PRODUCED CONCENTRATIONS THAT DEVIATED FROM +4.7% TO -42.5% OF THE SPECIFIED USE VALUE. AGAIN, THE ABOVE RANGE OF RESULTS WOULD BE EXPECTED, FOR THE AIR FLOW RATE IS DEPENDENT UPON THE RESISTANCE INHERENT IN THE GASTEC NO. 8525 CO DETECTOR TUBE.

ALTHOUGH SEVERAL OF THE GASTEC CO DETECTOR TUBE AND NON-GASTEC SAMPLING PUMP COMBINATIONS PRODUCE RESULTS SIMILAR TO THOSE PRODUCED WITH THE GASTEC CO DETECTOR TUBE AND SAMPLING PUMP, THESE RESULTS SHOULD AGAIN BE USED SOLELY FOR QUALITATIVE RATHER THAN QUANTITATIVE PURPOSES.

TABLE 4 SUMMARIZES THE DATA TABULATED FROM USING THE KITAGAWA CO INDICATOR TUBE NO. 100 WITH THE FIVE PUMPS OF THE DIFFERENT MANUFACTURERS. PER THE KITAGAWA INSTRUCTIONS, A SAMPLING VOLUME OF 100 CC WAS USED WITH ITS DETECTOR TUBE. THE CO CONCENTRATION ANALYZED WITH THE KITAGAWA PUMP AND DETECTOR TUBE AVERAGED 100.1 PPM VERSUS THE CERTIFIED 100 PPM VALUE. THE OTHER VARIOUS COMBINATIONS OF SAMPLING PUMPS AND GASTEC CO DETECTOR TUBES YIELDED CONCENTRATIONS THAT DEVIATED FROM +90% TO -37.7% OF THE SPECIFIED USE VALUE. AS THE DATA INDICATE, ONLY ONE COMBINATION OF A KITAGAWA CO GAS DETECTOR TUBE WITH A NON-KITAGAWA PUMP PRODUCED RESULTS CLOSER THAN 12% TO THE VALUE PRODUCED WITH THE KITAGAWA PUMP AND DETECTOR TUBE.

TABLE 5 TABULATES THE DATA RECORDED USING THE MSA CO INDICATOR TUBE NO. 91229 WITH THE FIVE PUMPS OF THE DIFFERENT MANUFACTURERS IN THE STUDY. PER THE MSA INSTRUCTIONS, ITS CO DETECTOR TUBE WAS USED WITH THEIR PUMP WITH ORIFICE #1 IN PLACE AND WITH A SAMPLE VOLUME OF 100 CC. THE CO CONCENTRATION MEASURED WITH THE MSA PUMP AND DETECTOR TUBE AVERAGED 153.7 PPM VERSUS THE CERTIFIED 100 PPM VALUE. THE OTHER COMBINATIONS OF PUMPS AND MSA CO GAS DETECTOR TUBES YIELDED AVERAGE CONCENTRATIONS THAT RANGED FROM +240.6% TO -26.9% OF THE SPECIFIED USE VALUE (153.7 PPM). AS THE DATA INDICATE, ONLY ONE COMBINATION OF A MSA CO GAS DETECTOR TUBE WITH A NON-MSA PUMP PRODUCED RESULTS CLOSER THAN 10% TO THE VALUE MEASURED WITH THE MSA PUMP AND DETECTOR TUBE. IT IS THEREFORE, AGAIN RECOMMENDED THAT THESE RESULTS BE USED ONLY AS A QUALITATIVE RATHER THAN A QUANTITATIVE MEASUREMENT.

CONCLUSION AND A FEW PERTINENT COMMENTS

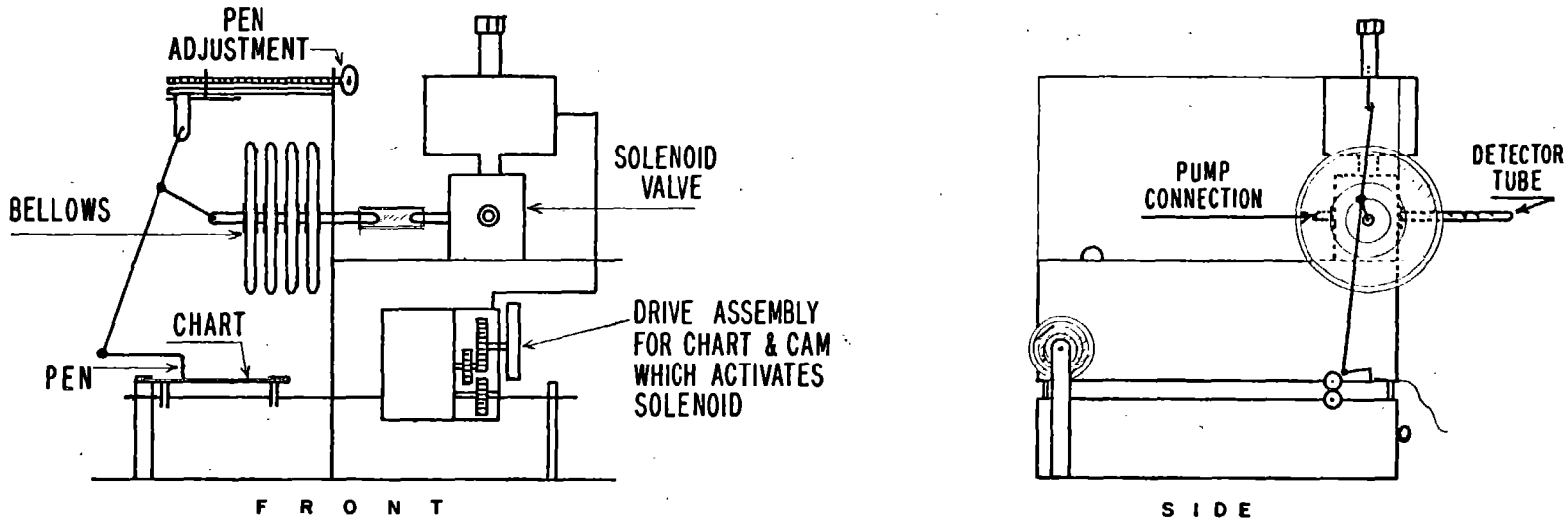
IT CAN BE SEEN FROM THE PREVIOUS GRAPHS AND TABLES THAT THE INTERCHANGE OF VARIOUS MANUFACTURERS' GAS DETECTOR TUBES WITH VARIOUS MANUFACTURERS' SAMPLING PUMPS CAN INTRODUCE SYSTEMATIC ANALYSIS ERRORS. EACH MANUFACTURERS' CO GAS DETECTOR TUBE IS CALIBRATED FOR A FIXED SAMPLING VOLUME AND AIR FLOW RATE DICTATED BY ITS SAMPLING PUMP. TO CONNECT ITS CO GAS DETECTOR TUBE TO ANOTHER MANUFACTURER'S SAMPLING PUMP WILL MORE OFTEN THAN NOT YIELD PURELY QUALITATIVE RESULTS. THESE SYSTEMATIC ERRORS ADDED TO CURRENT ERRORS ALREADY INHERENT IN EACH SAMPLING PUMP AND DETECTOR TUBE WOULD INCREASE THE TOTAL ERROR TO THE POINT THAT THE QUANTATIVE NATURE OF THE SAMPLING PUMP AND GAS DETECTOR TUBES WOULD BE REDUCED TO A QUALITATIVE LEVEL, AND THIS MODIFICATION IS NOT IN THE BEST INTERESTS OF THE USER. ALTHOUGH THIS STUDY INVOLVED ONLY CARBON MONOXIDE AS A CONTAMINANT, IT INDICATES THAT A MANUFACTURER'S GAS DETECTOR TUBE AND SAMPLING PUMP SHOULD BE REGARDED AS A SINGLE UNIT AND ACCORDINGLY, SHOULD NOT BE INTERCHANGED WITH OTHER MANUFACTURER'S SAMPLING PUMPS AND GAS DETECTOR TUBES. ALSO, NIOSH WILL BE CERTIFYING A MANUFACTURER'S GAS DETECTOR TUBE AND SAMPLING PUMP TO BE USED AS A UNIT, AND THEREFORE, TO USE EACH SYSTEM MOST EFFECTIVELY, THE GAS DETECTOR TUBE AND SAMPLING PUMP OF A SPECIFIC MANUFACTURER SHOULD NOT BE INTERCHANGED WITH THOSE OF ANOTHER MANUFACTURER UNLESS QUALITATIVE RESULTS ARE DESIRED.

REFERENCES

1. Buchwald, H. "The Determination of Atmospheric Contaminants With Portable Indicator Kits." Transactions of the Association of Industrial Medical Offeicers, Vol. 15, July 1965, No. 3, pp. 100-102

2. Leichnitz, Kurt "Effect of the Suction Behaviour of Different Pumps on the Indication of Detector Tubes." Drager Review, No. 24, March 1971, pp. 13-21.

3. Morgenstern, Arthur S.; Ash, Robert M.; and Lynch, Jeremiah R. "The Evaluation of Gas Detector Tube Systems: I. Carbon Monoxide." AIHA Journal, Vol. 31, Sept. - Oct. 1970, pp. 630-632



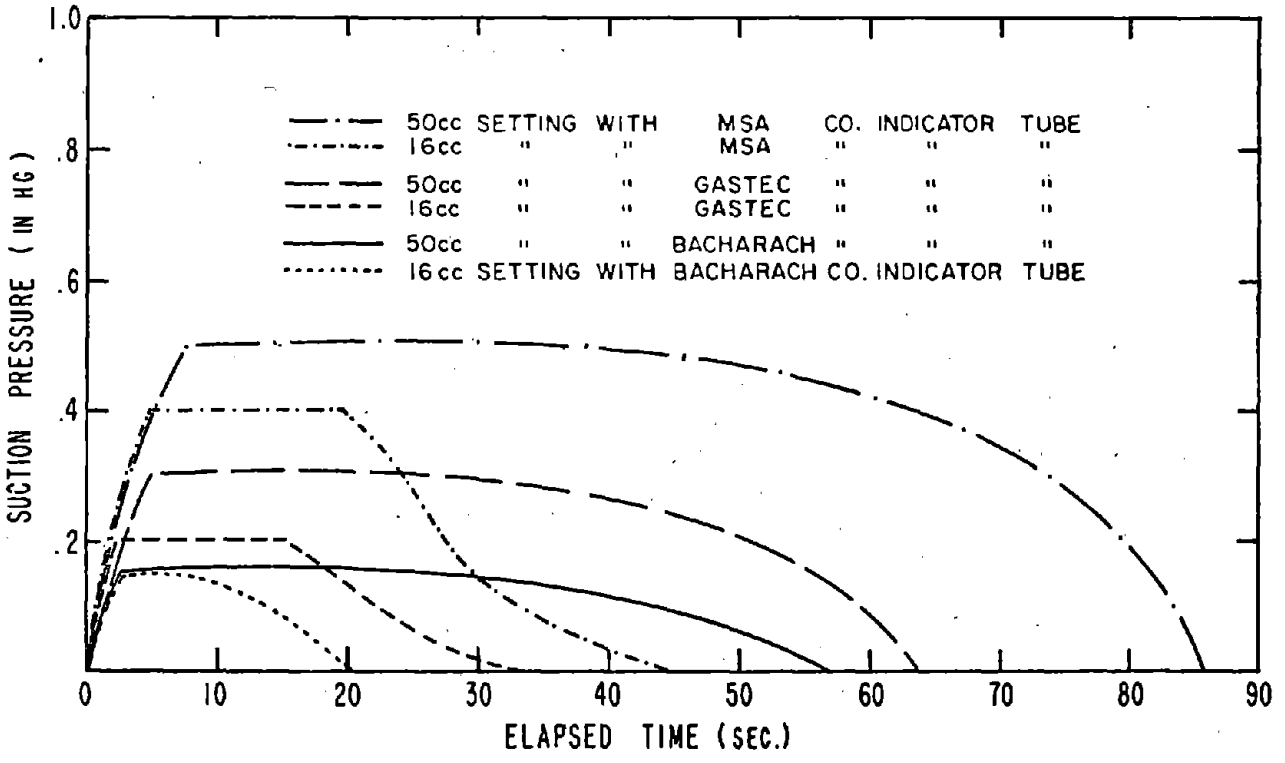
DRAGER CO. PRESSURE SENSING & RECORDING INSTRUMENT — SCHEMATIC. CHART SPEED: 5.75" / MIN.

DIMENSIONS: 9.5" WIDE X 10" LONG 10" HIGH (TOP OF SOLENOID)

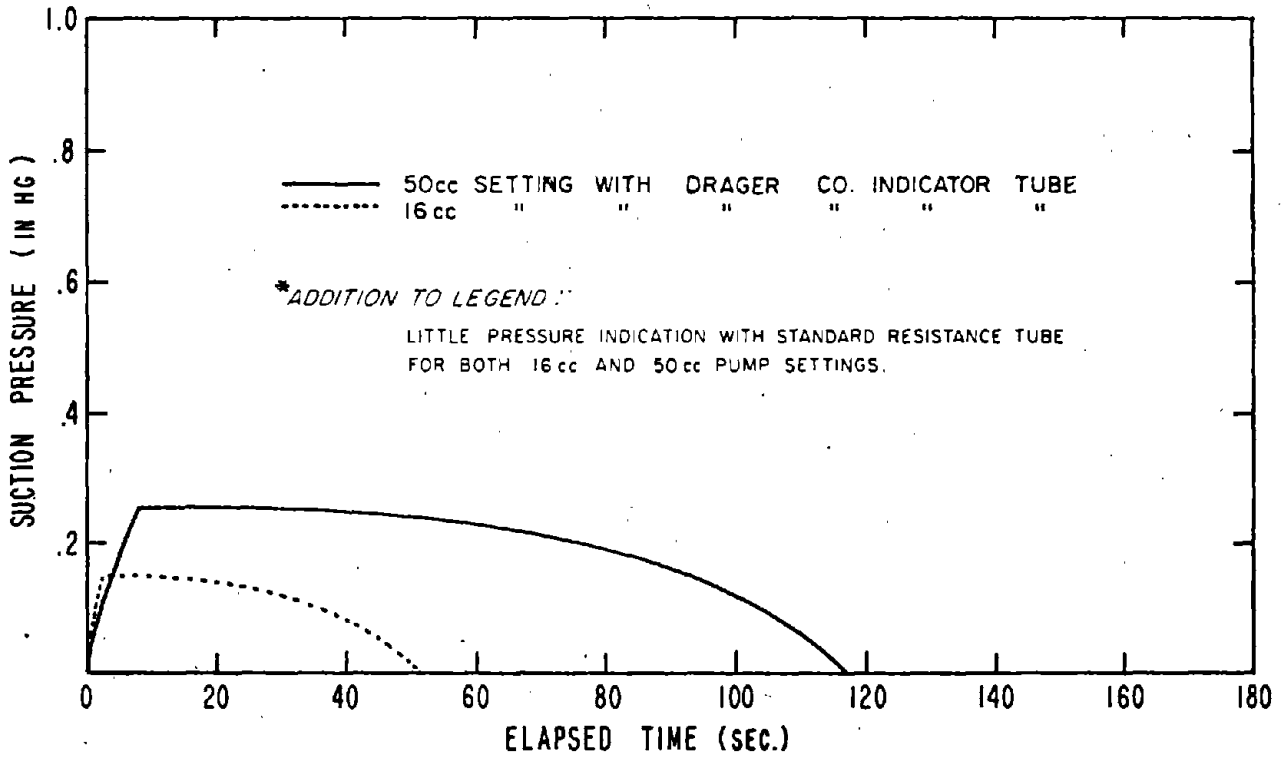
SCHEMATIC 1

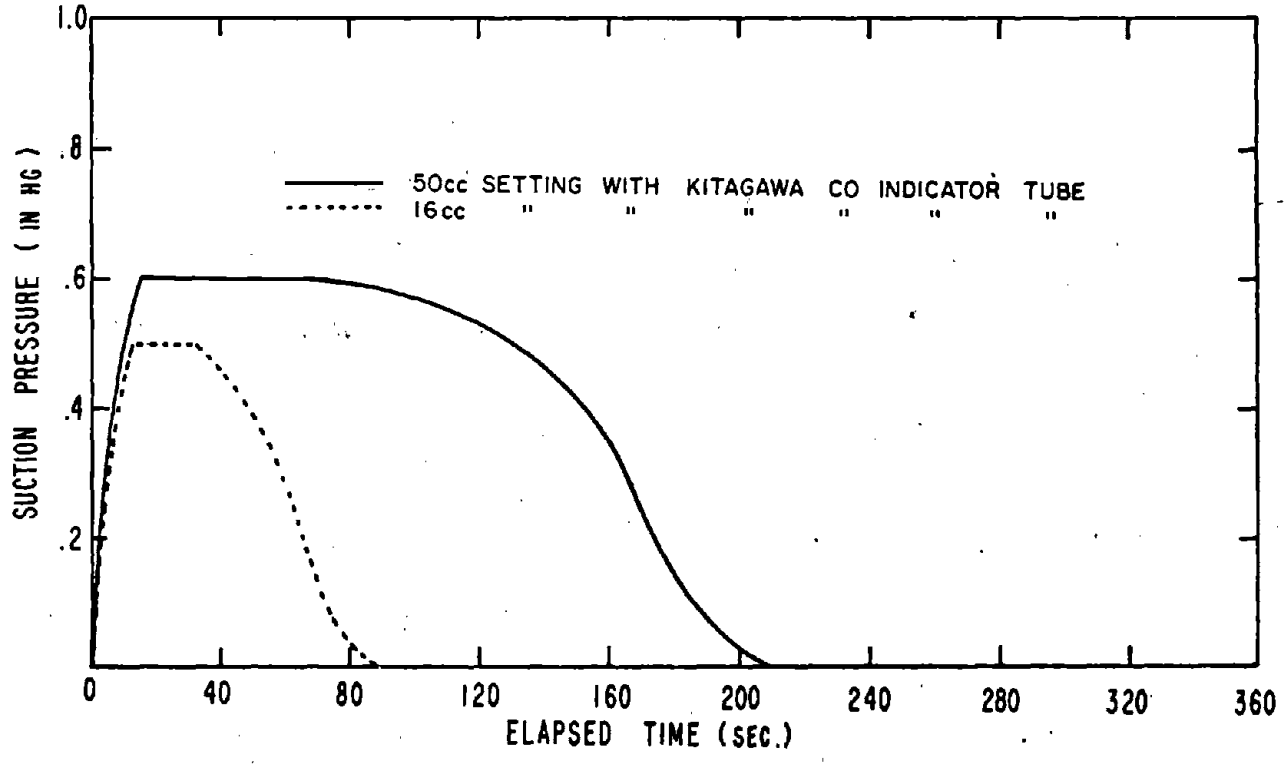
GRAPH 1.

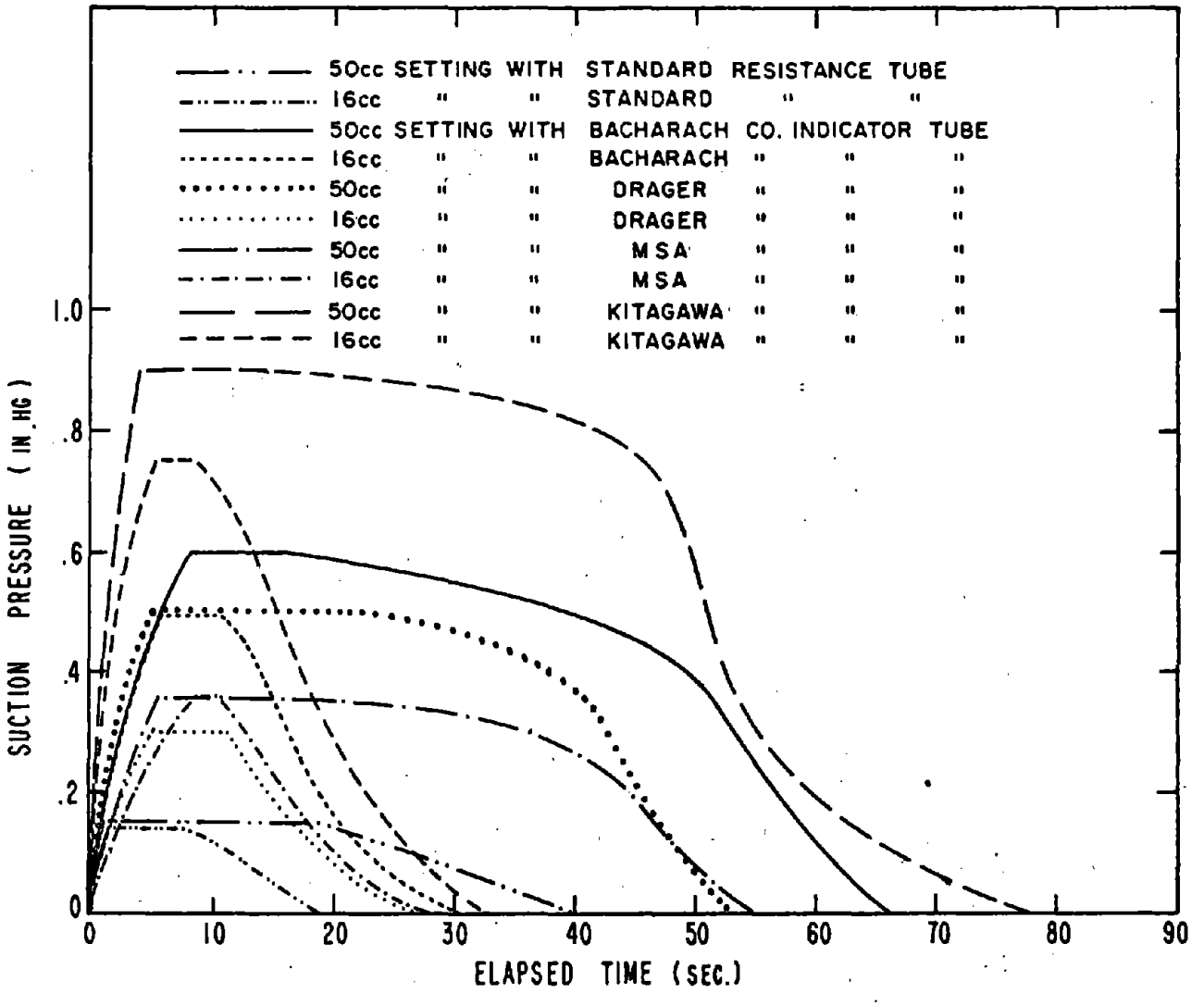
GRAPH OF SUCTION PRESSURE
VS.
ELAPSED TIME FOR BACHARACH PUMP
WITH ORIFICE "A"



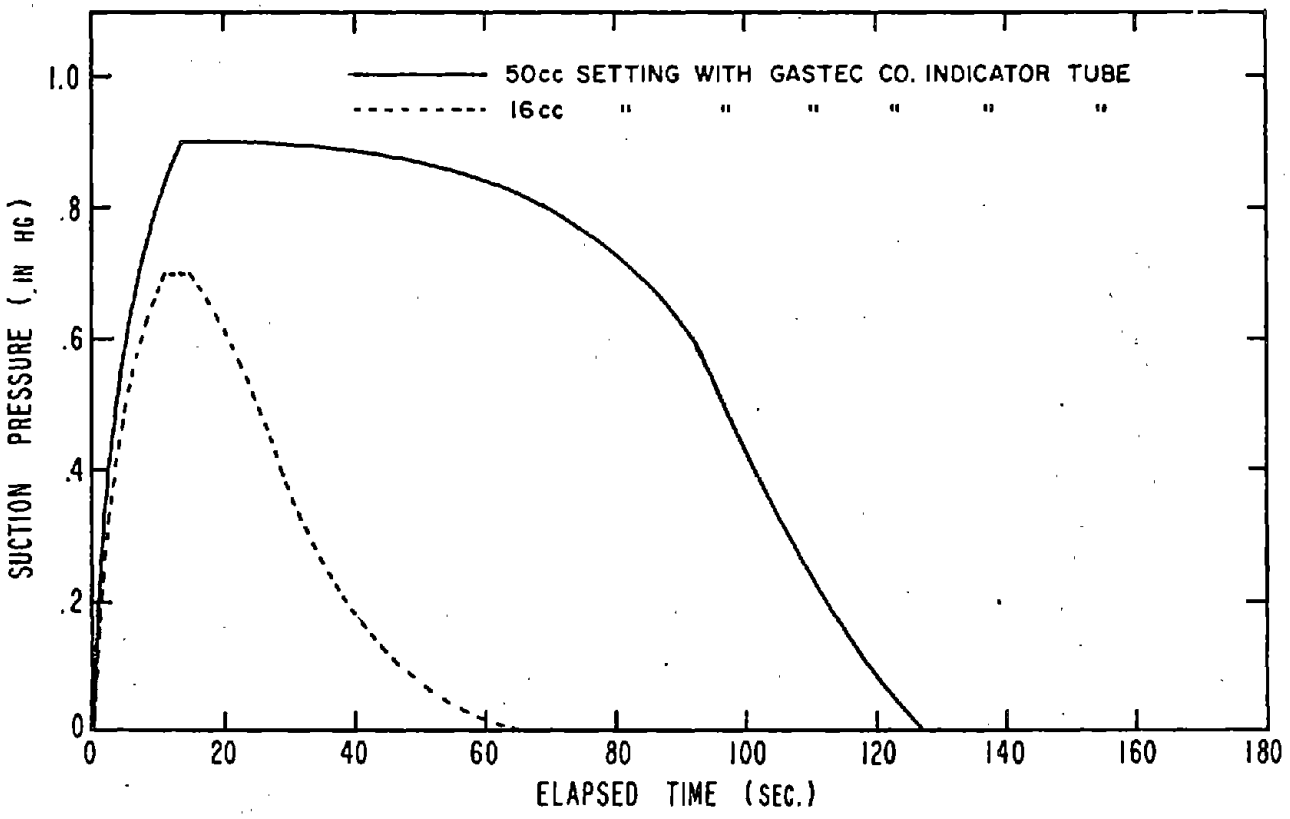
GRAPH 2. GRAPH OF SUCTION PRESSURE VS. ELAPSED TIME FOR BACHARACH PUMP WITH ORIFICE "A"



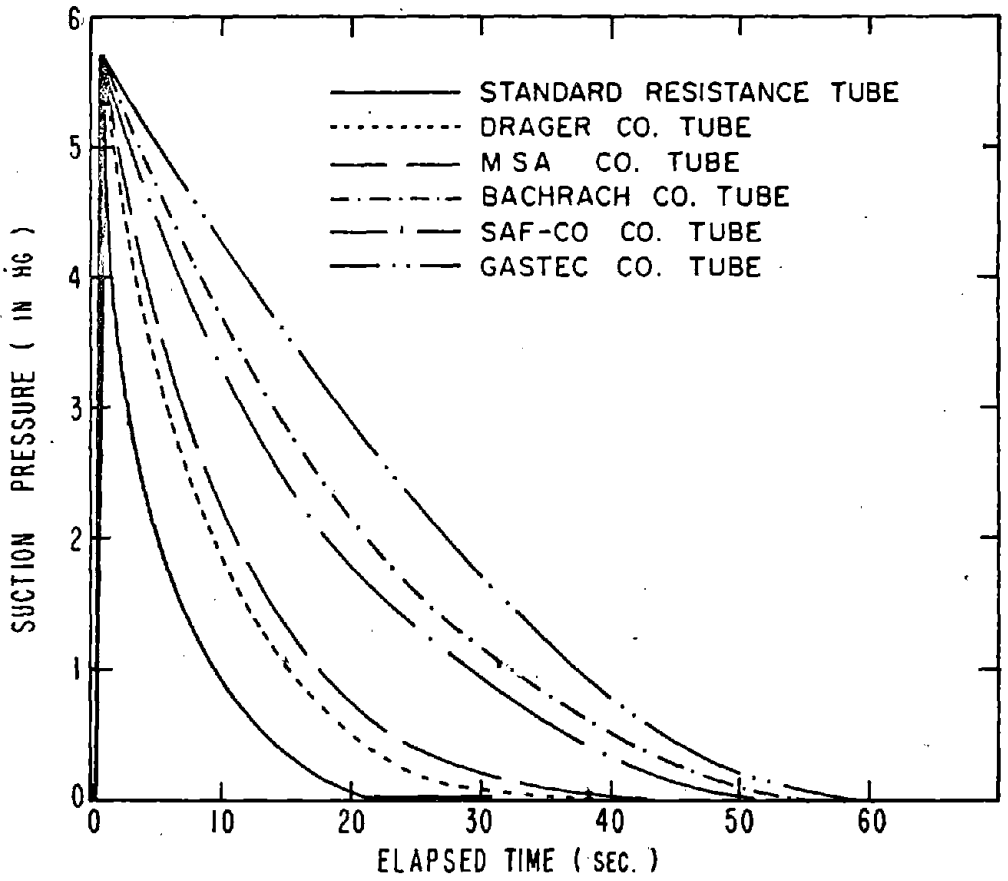




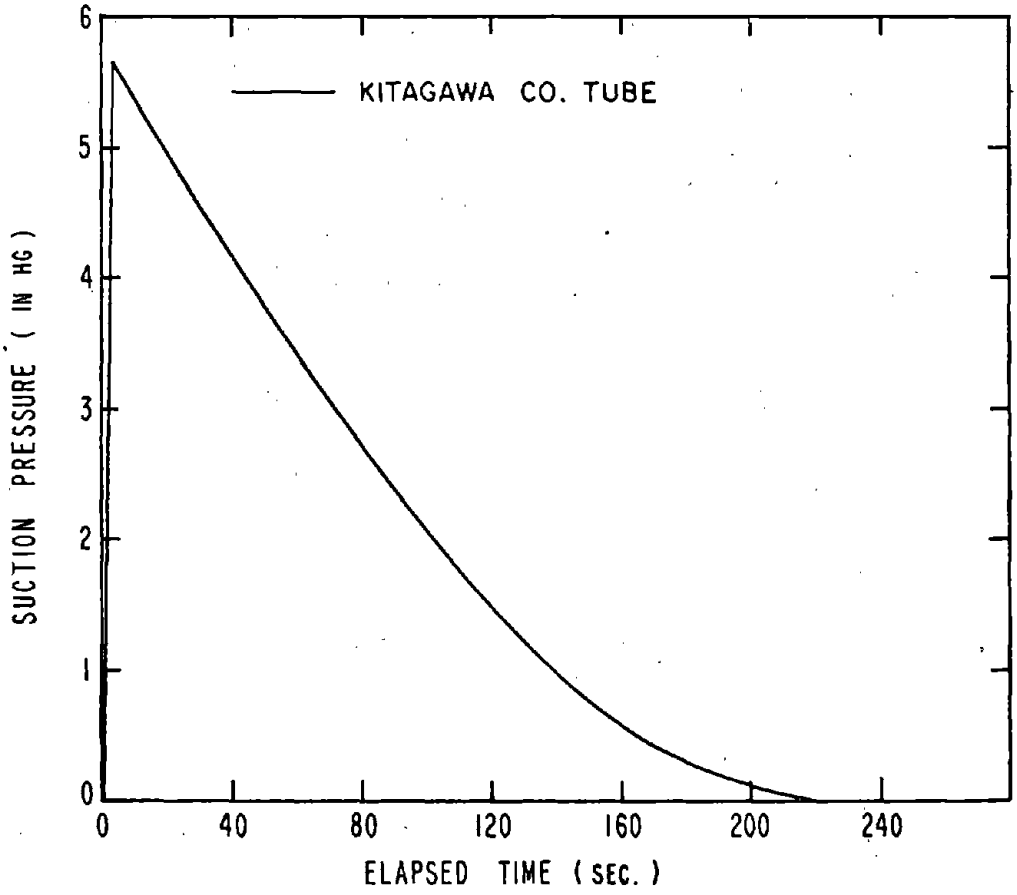
GRAPH 3. GRAPH OF SUCTION PRESSURE VS. ELAPSED TIME FOR BACHARACH PUMP WITH ORIFICE "B"



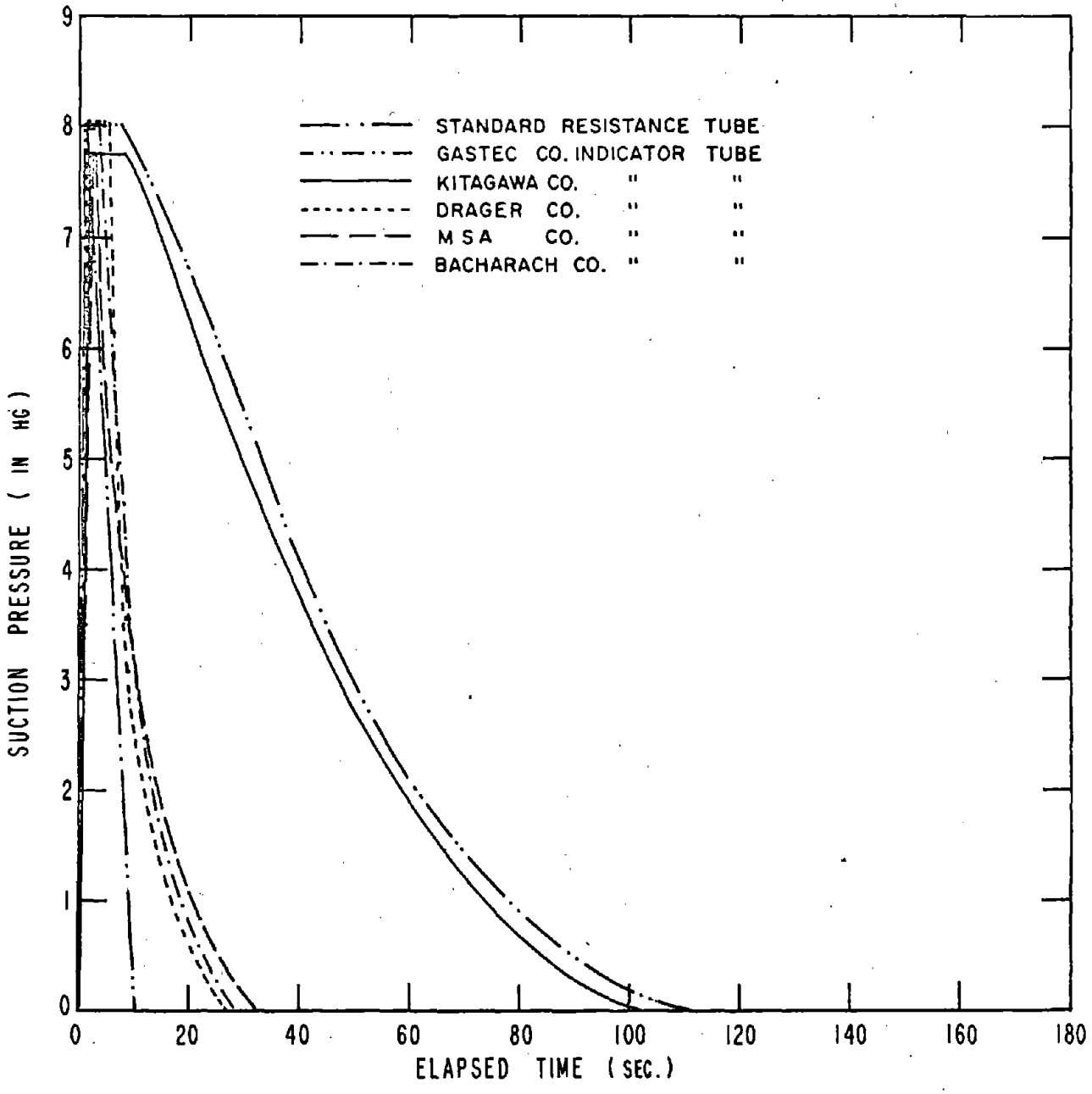
GRAPH 4. GRAPH OF SUCTION PRESSURE VS. ELAPSED TIME FOR BACHARACH PUMP WITH ORIFICE "B"



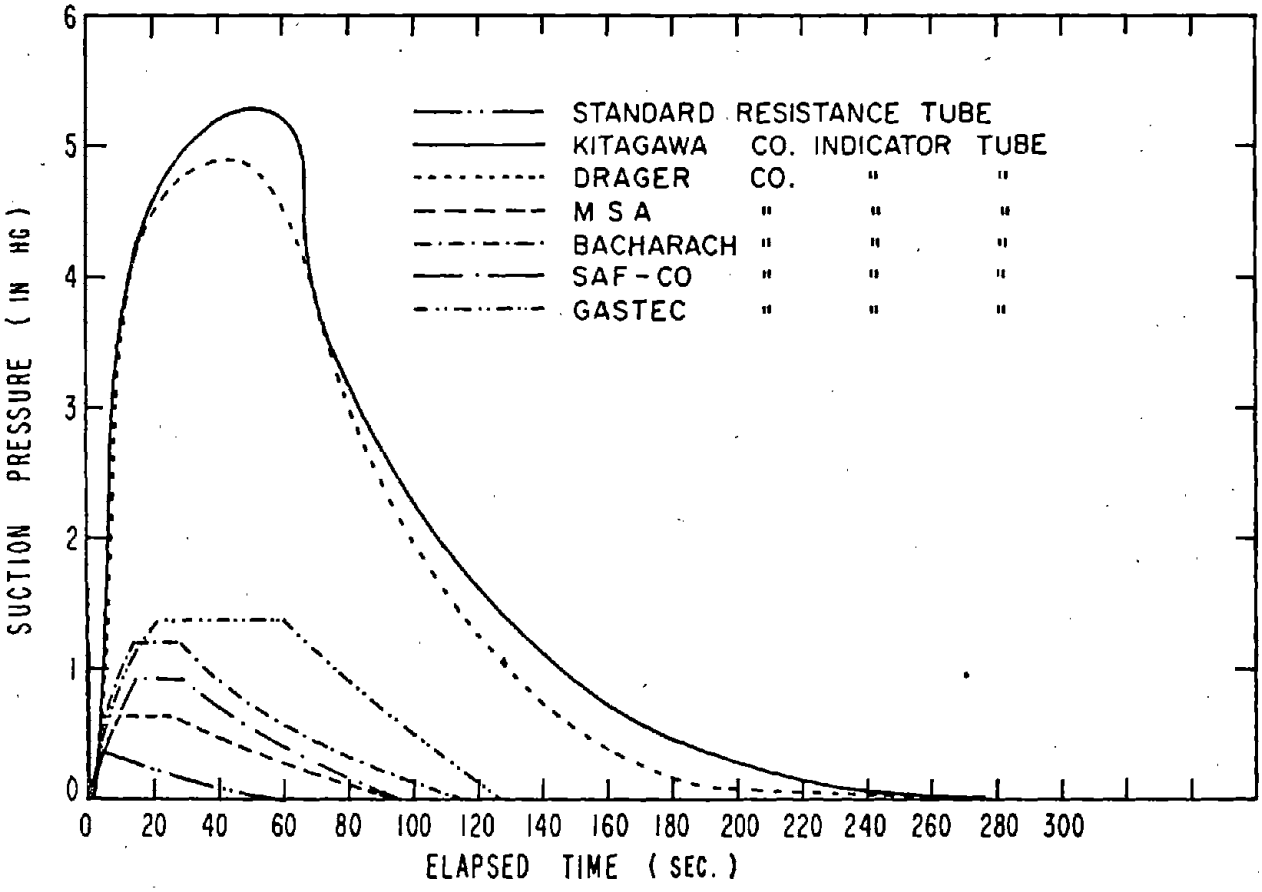
GRAPH 5. GRAPH OF SUCTION PRESSURE VS. ELAPSED TIME FOR DRAGER PUMP.



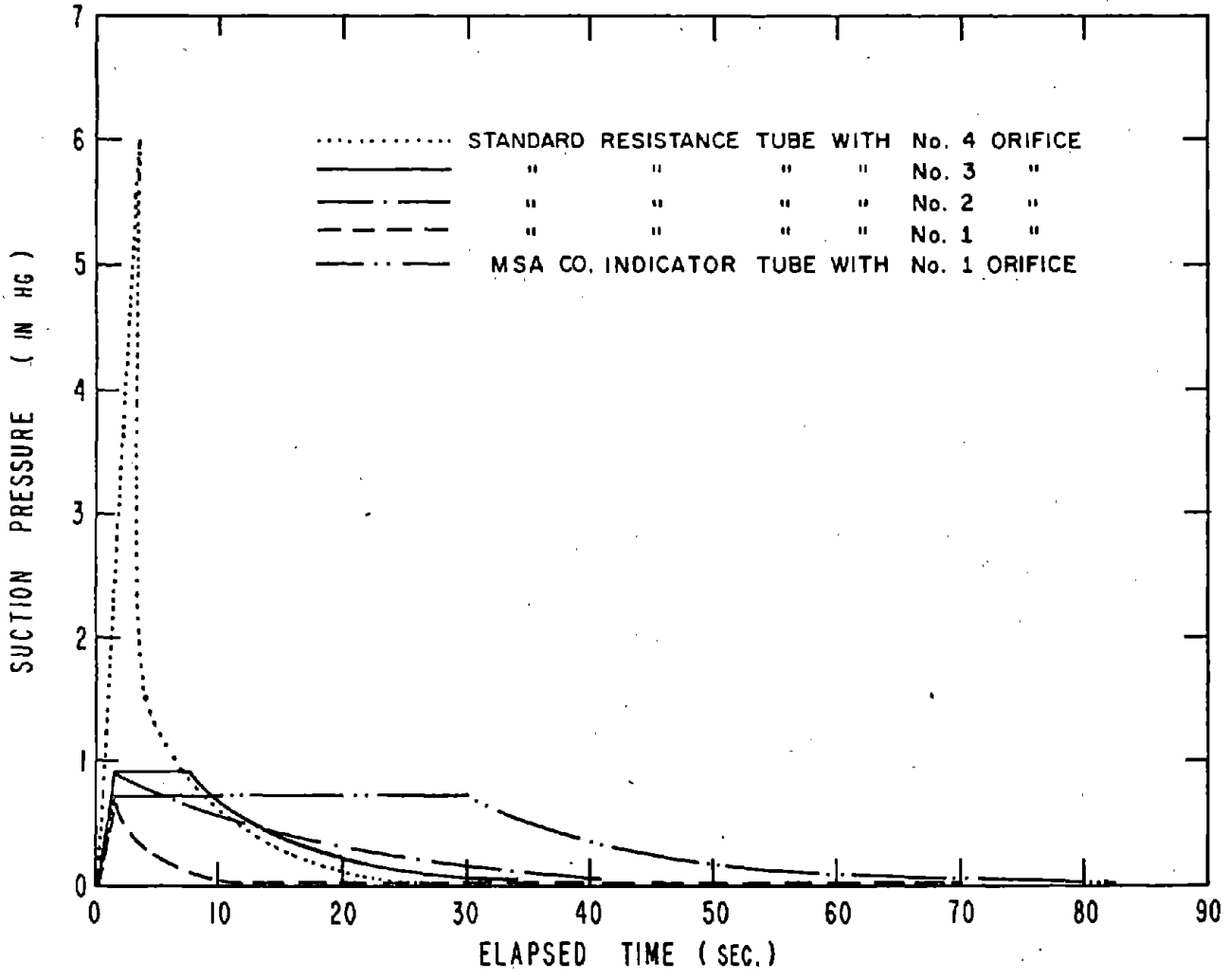
GRAPH 6. GRAPH OF SUCTION PRESSURE VS. ELAPSED TIME FOR DRAGER PUMP.



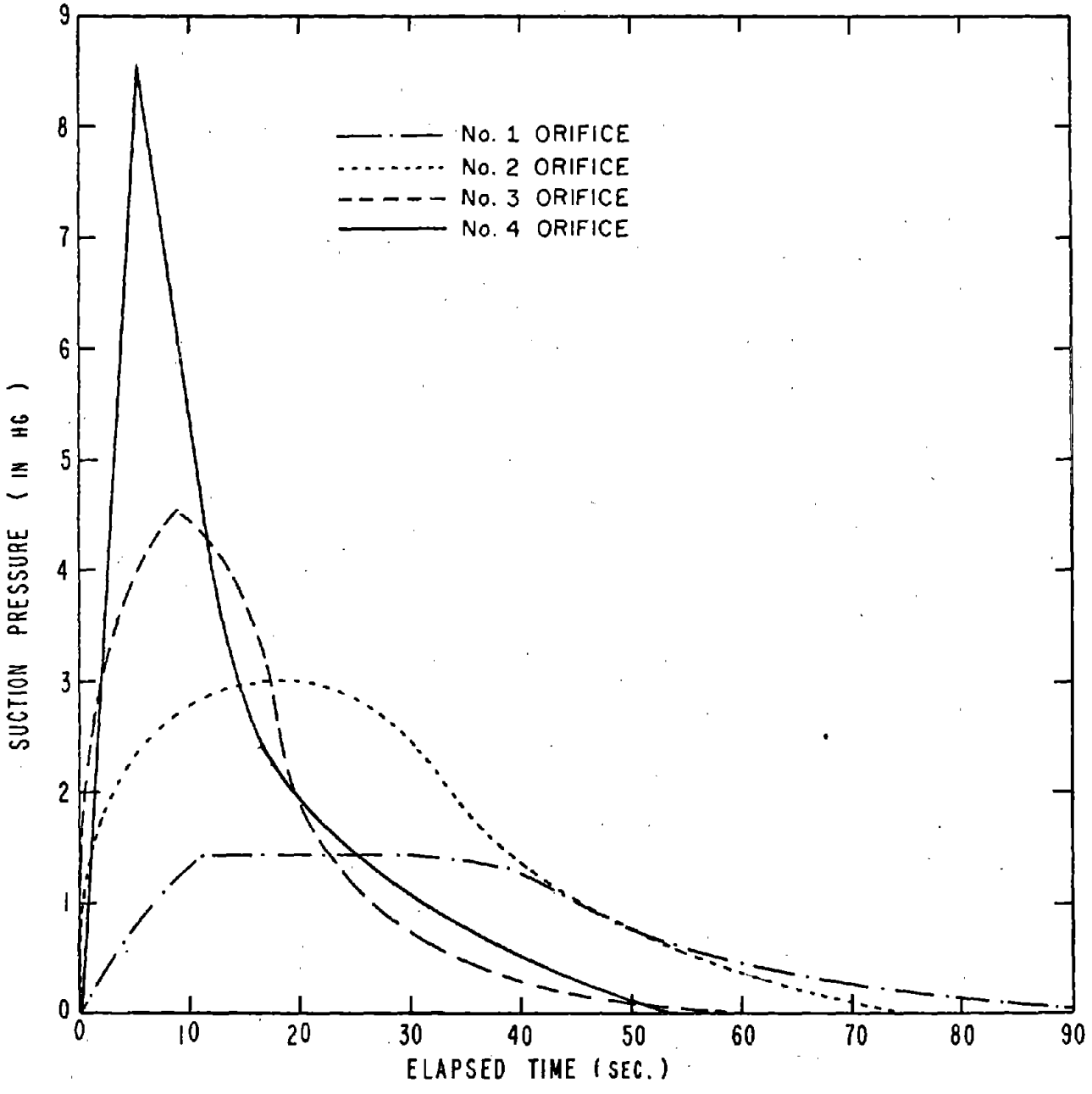
GRAPH 7. GRAPH OF SUCTION PRESSURE VS. ELAPSED TIME FOR GASTEC PUMP.



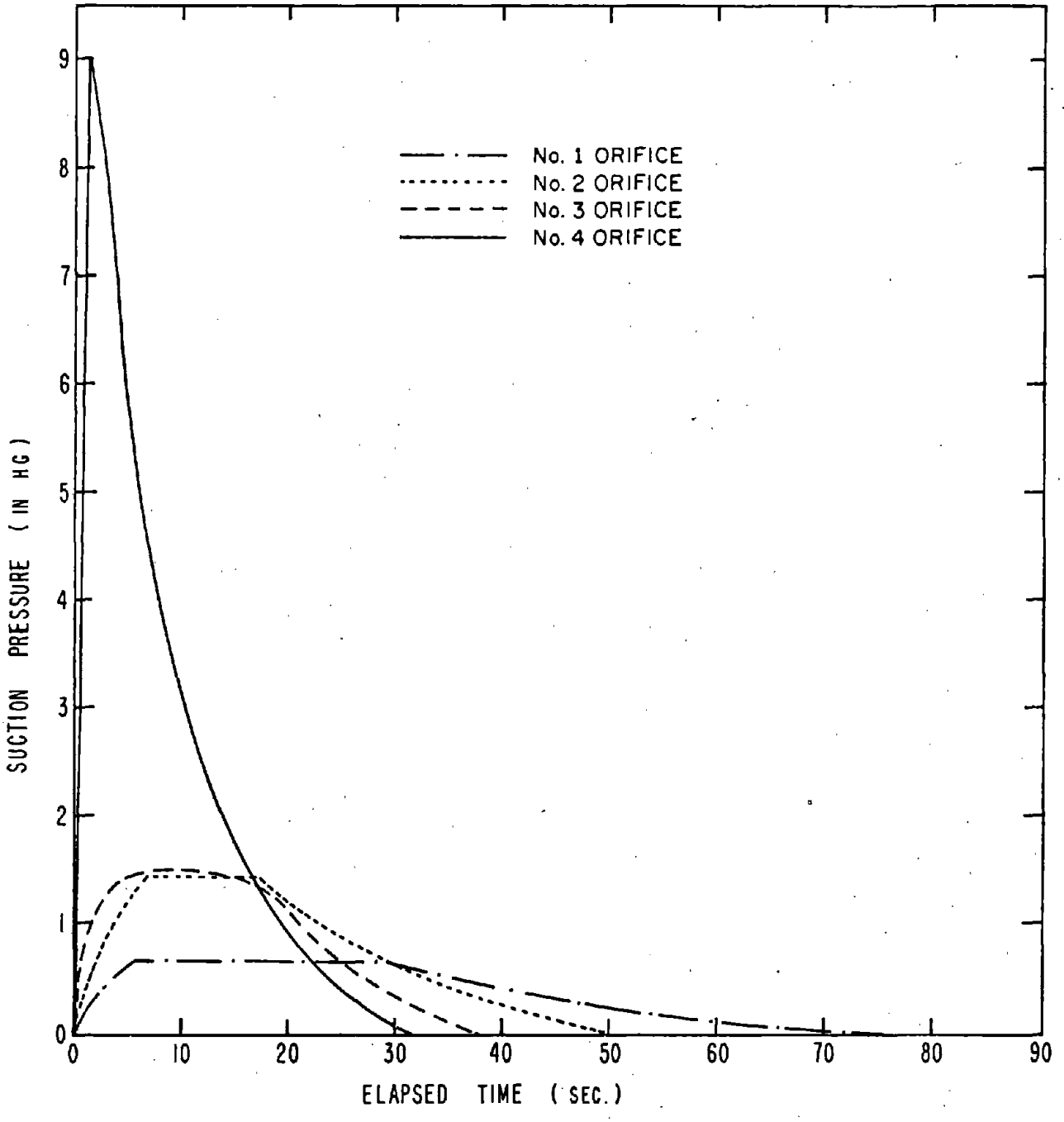
GRAPH 8. GRAPH OF SUCTION PRESSURE VS. ELAPSED TIME FOR KITAGAWA PUMP.



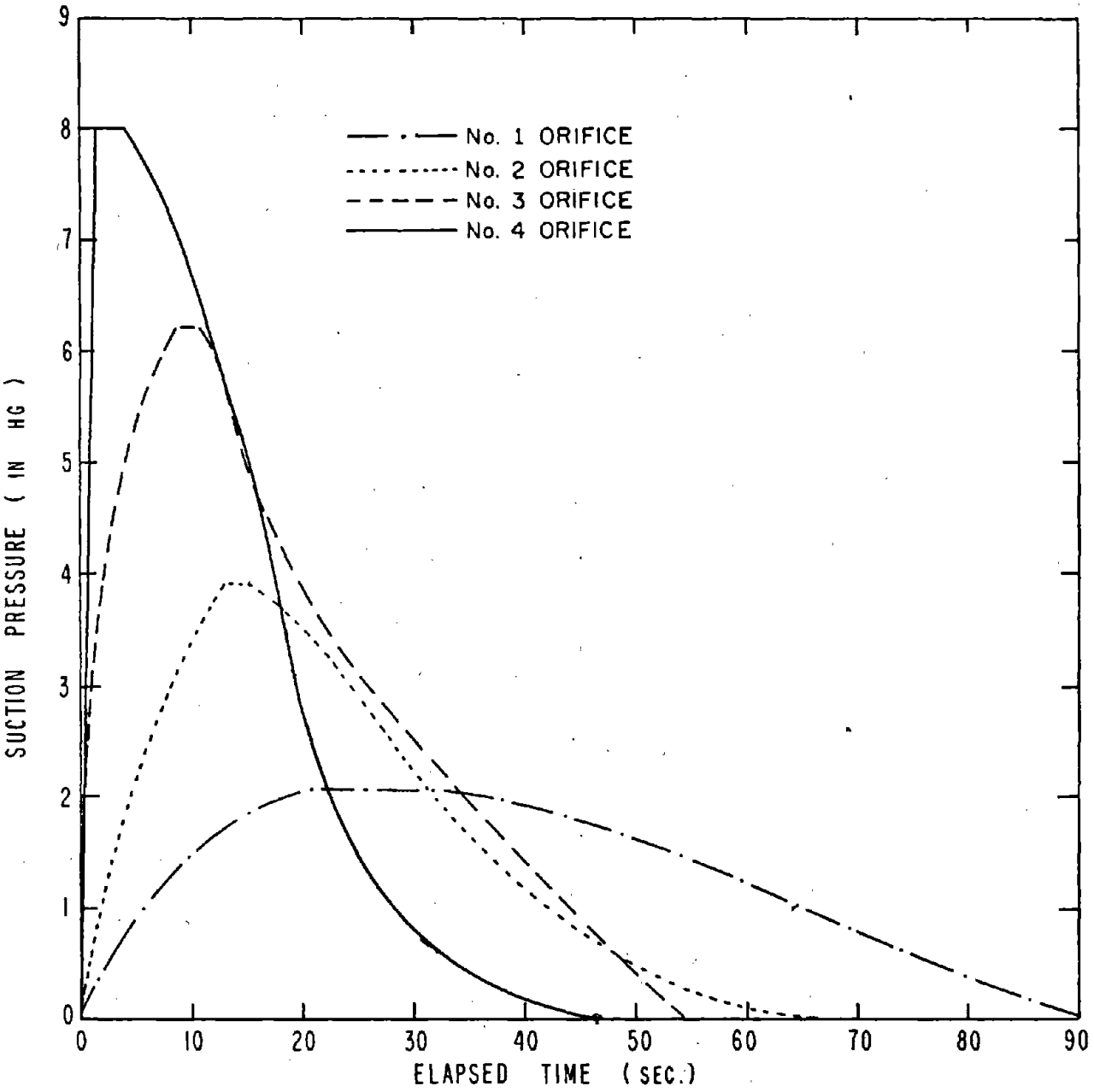
GRAPH 9. GRAPH OF SUCTION PRESSURE VS. ELAPSED TIME FOR MSA PUMP WITH STANDARD RESISTANCE TUBE AND MSA CO. INDICATOR TUBE.



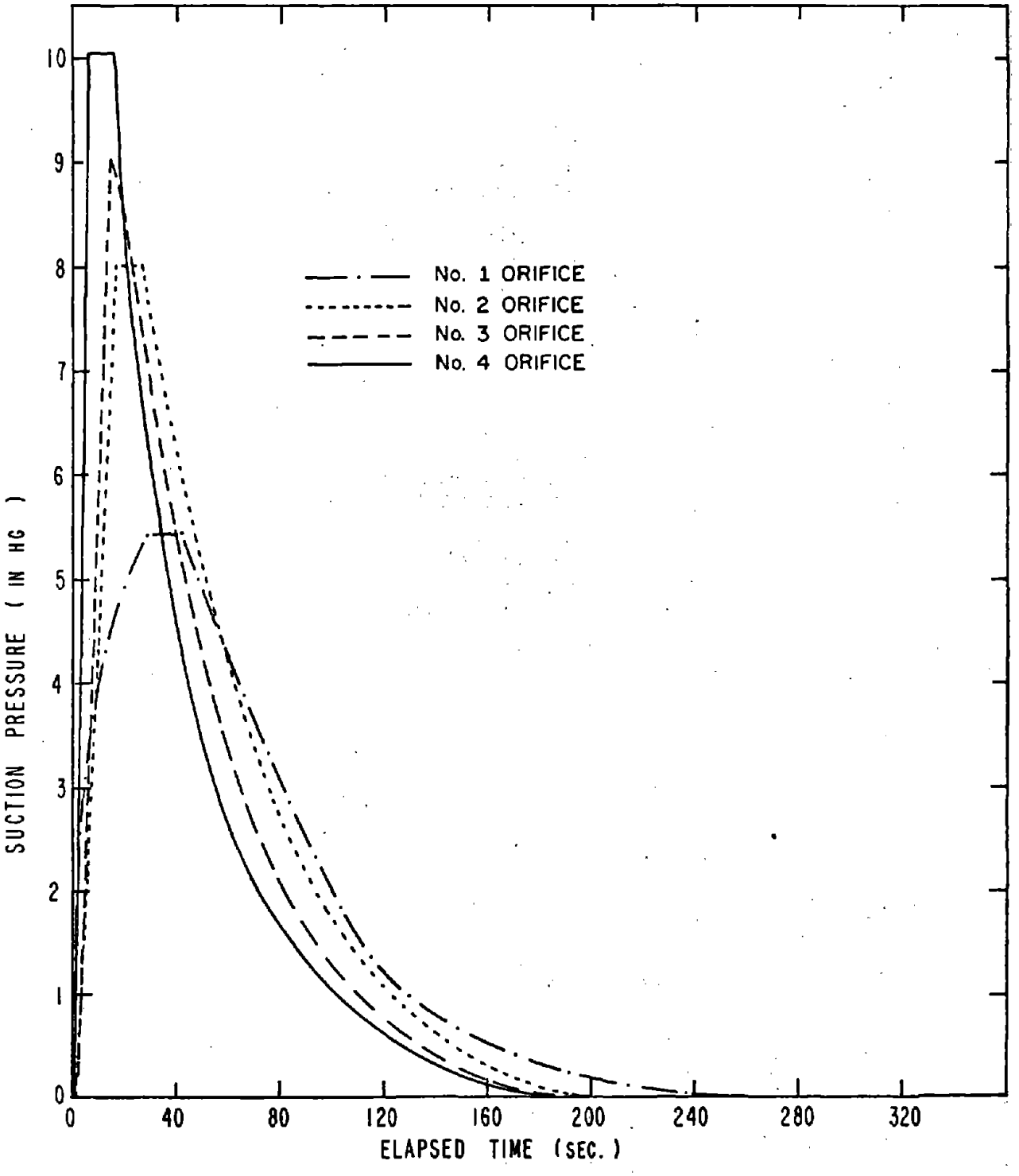
GRAPH 10. GRAPH OF SUCTION PRESSURE VS. ELAPSED TIME FOR M S A PUMP AND BACHARACH CO. INDICATOR TUBE.



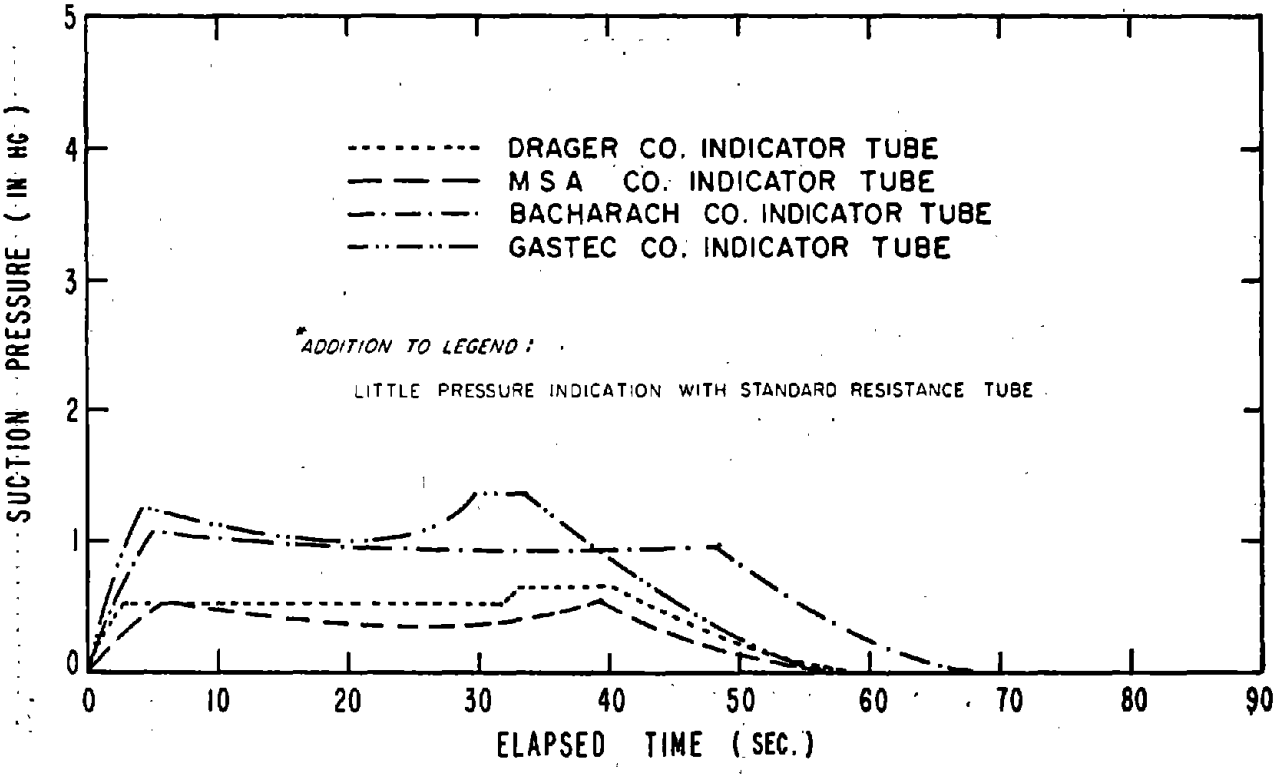
GRAPH II. GRAPH OF SUCTION PRESSURE VS. ELAPSED TIME FOR M S A PUMP AND DRAGER CO. INDICATOR TUBE.



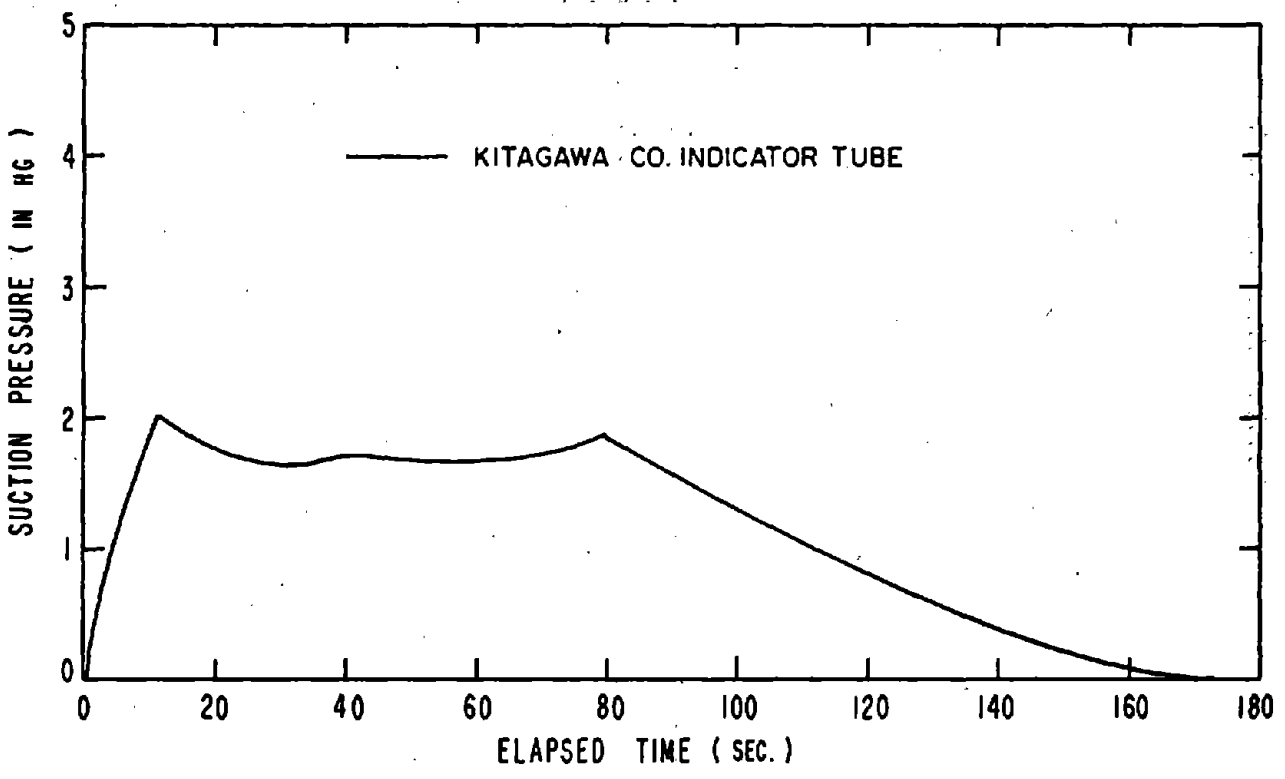
GRAPH 12. GRAPH OF SUCTION PRESSURE VS. ELAPSED TIME FOR M S A PUMP AND GASTEC CO. INDICATOR TUBE.



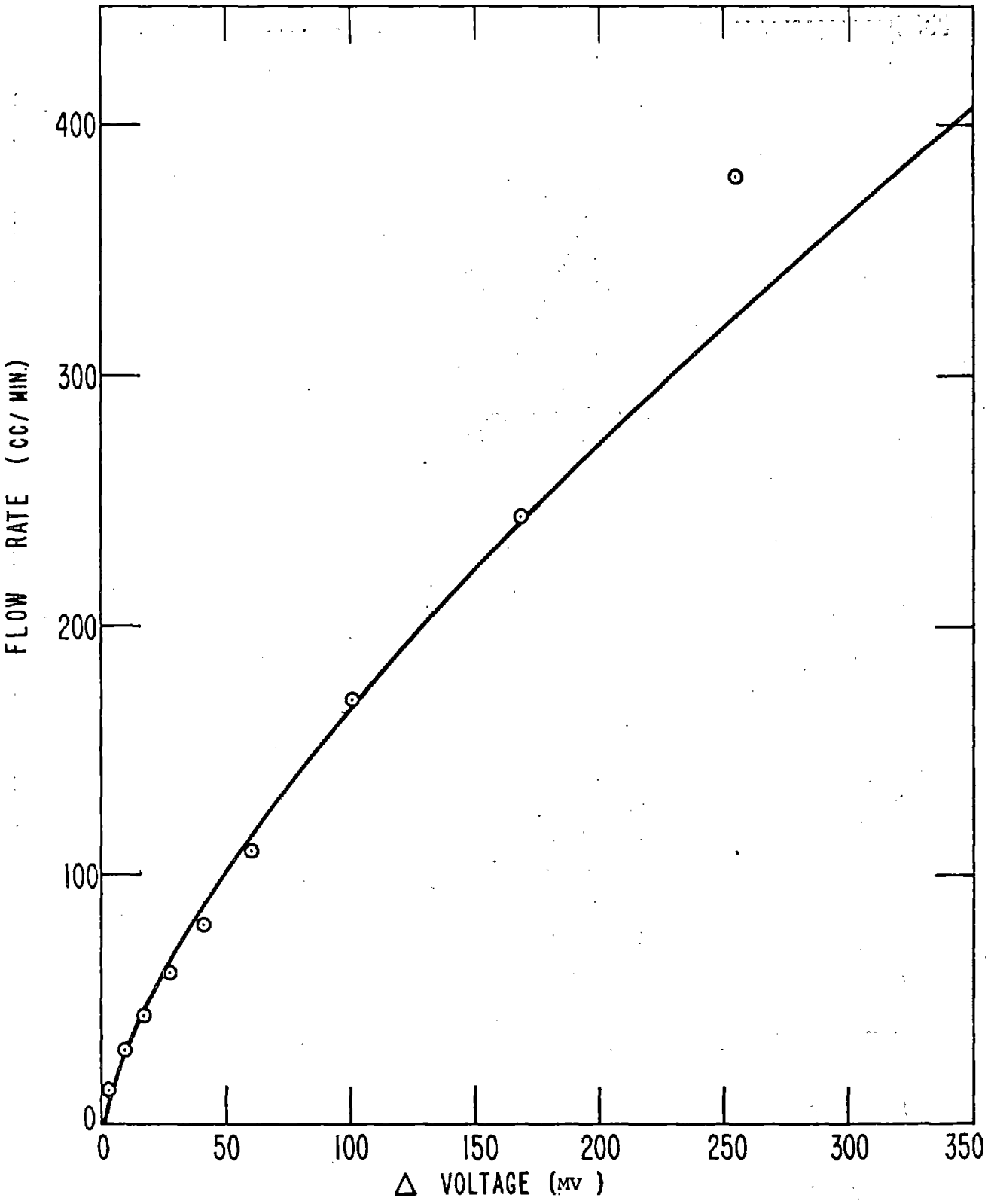
GRAPH 13. GRAPH OF SUCTION PRESSURE VS. ELAPSED TIME FOR MSA PUMP AND KITAGAWA CO. INDICATOR TUBE.



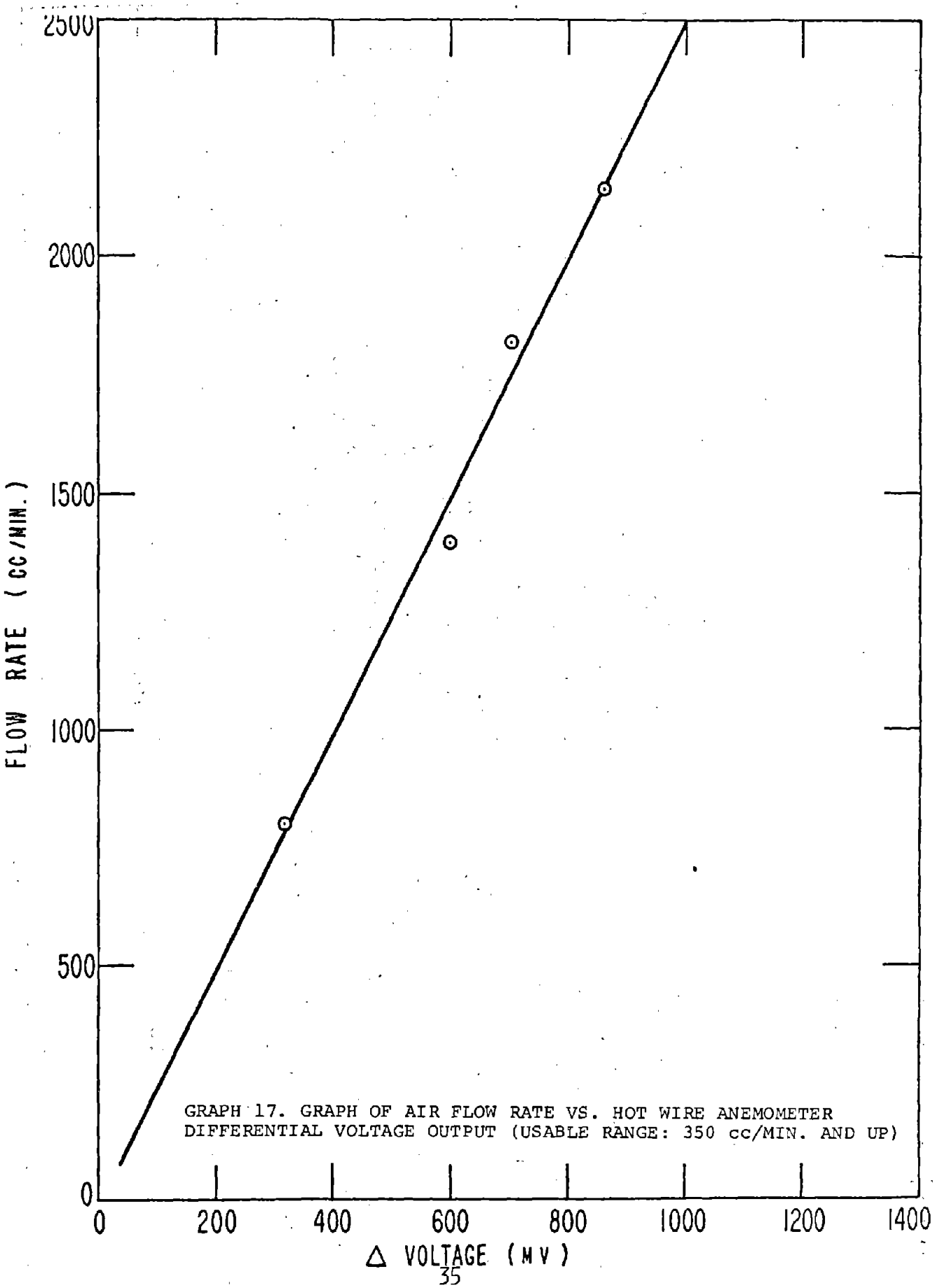
GRAPH 14. GRAPH OF SUCTION PRESSURE VS. ELAPSED TIME FOR SAF-CO PUMP.



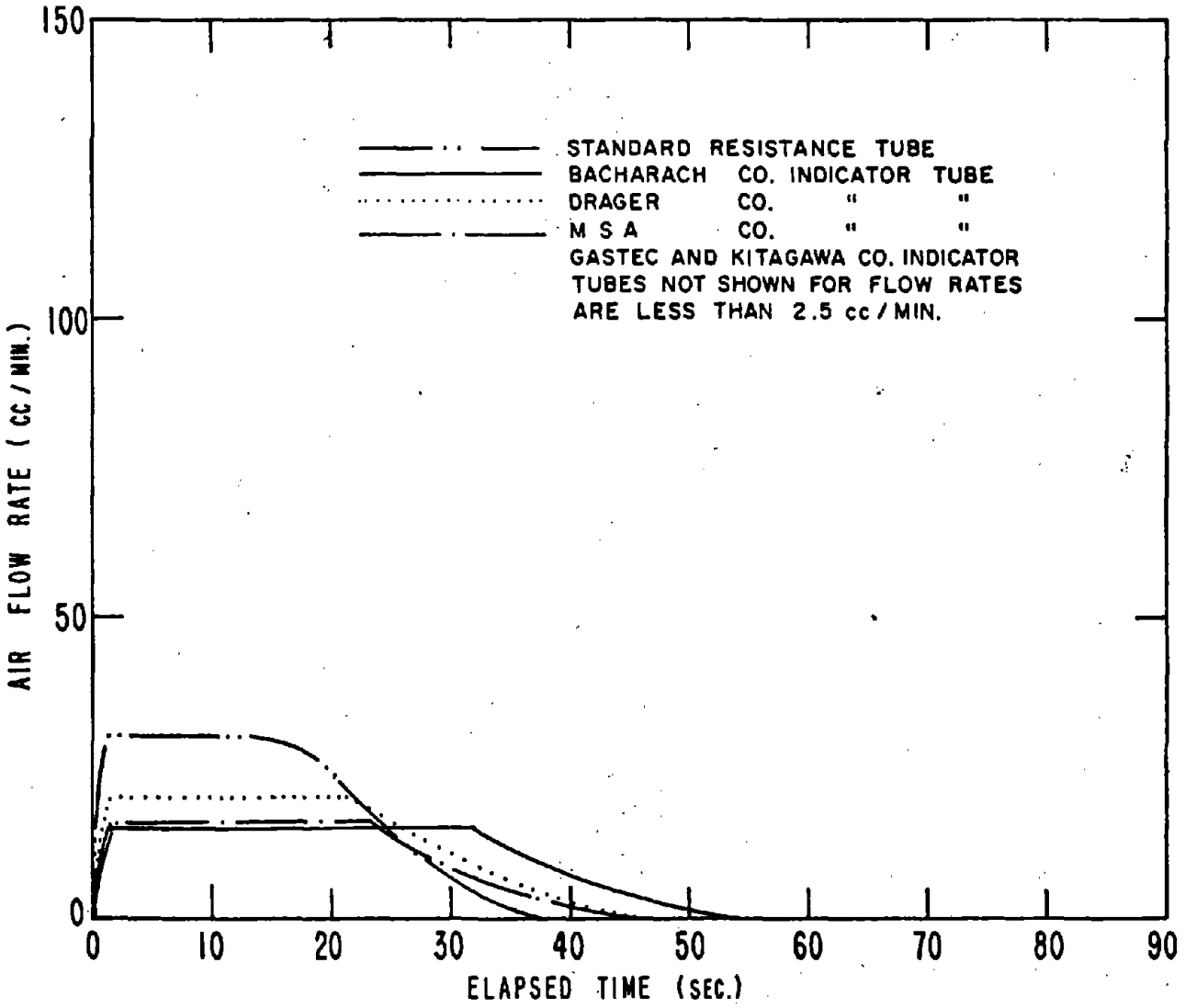
GRAPH 15. GRAPH OF SUCTION PRESSURE VS. ELAPSED TIME FOR SAF-CO PUMP.



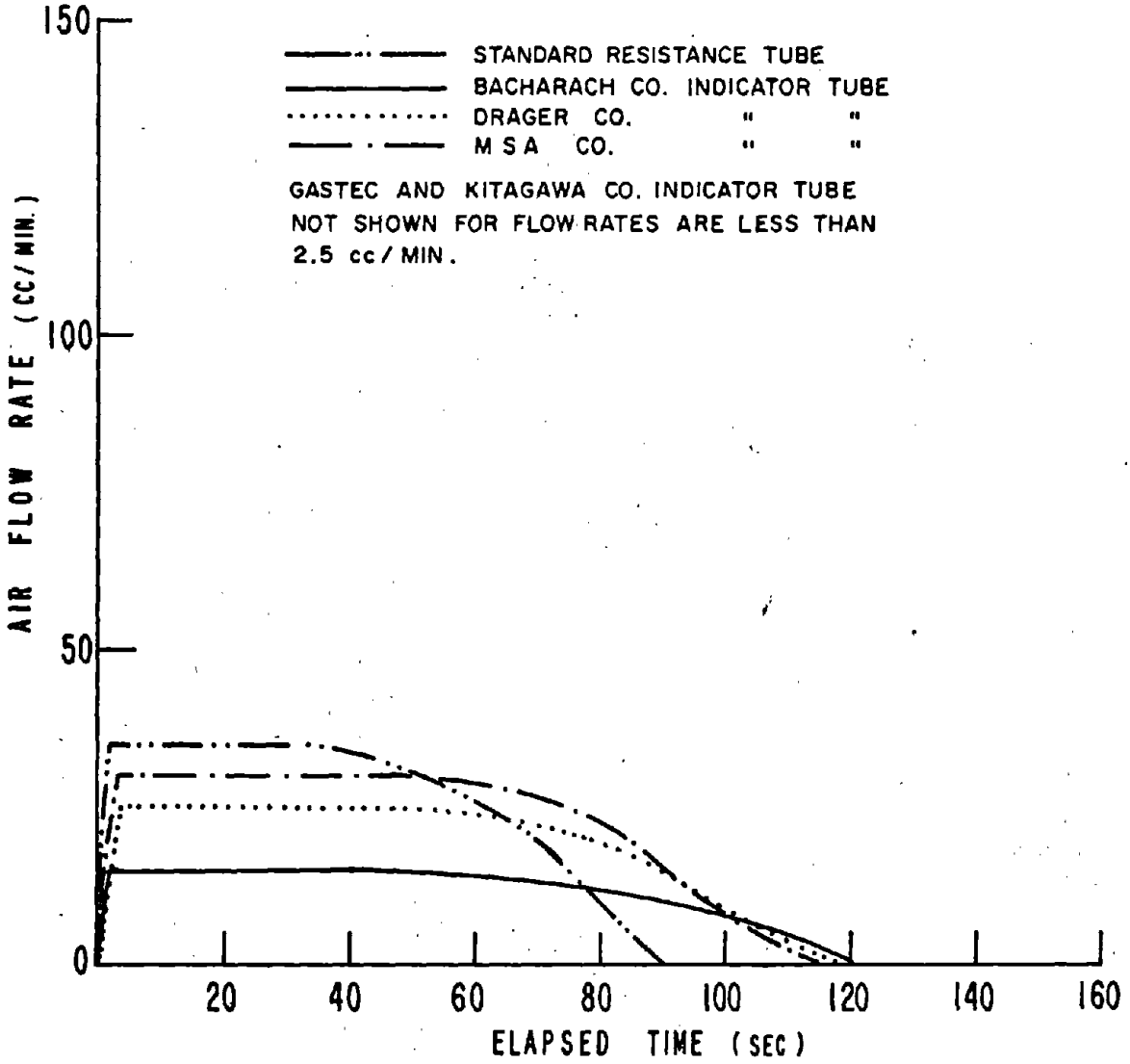
GRAPH 16. GRAPH OF AIR FLOW RATE VS. HOT WIRE ANEMOMETER DIFFERENTIAL VOLTAGE OUTPUT (USABLE RANGE: 0-350 cc/MIN)



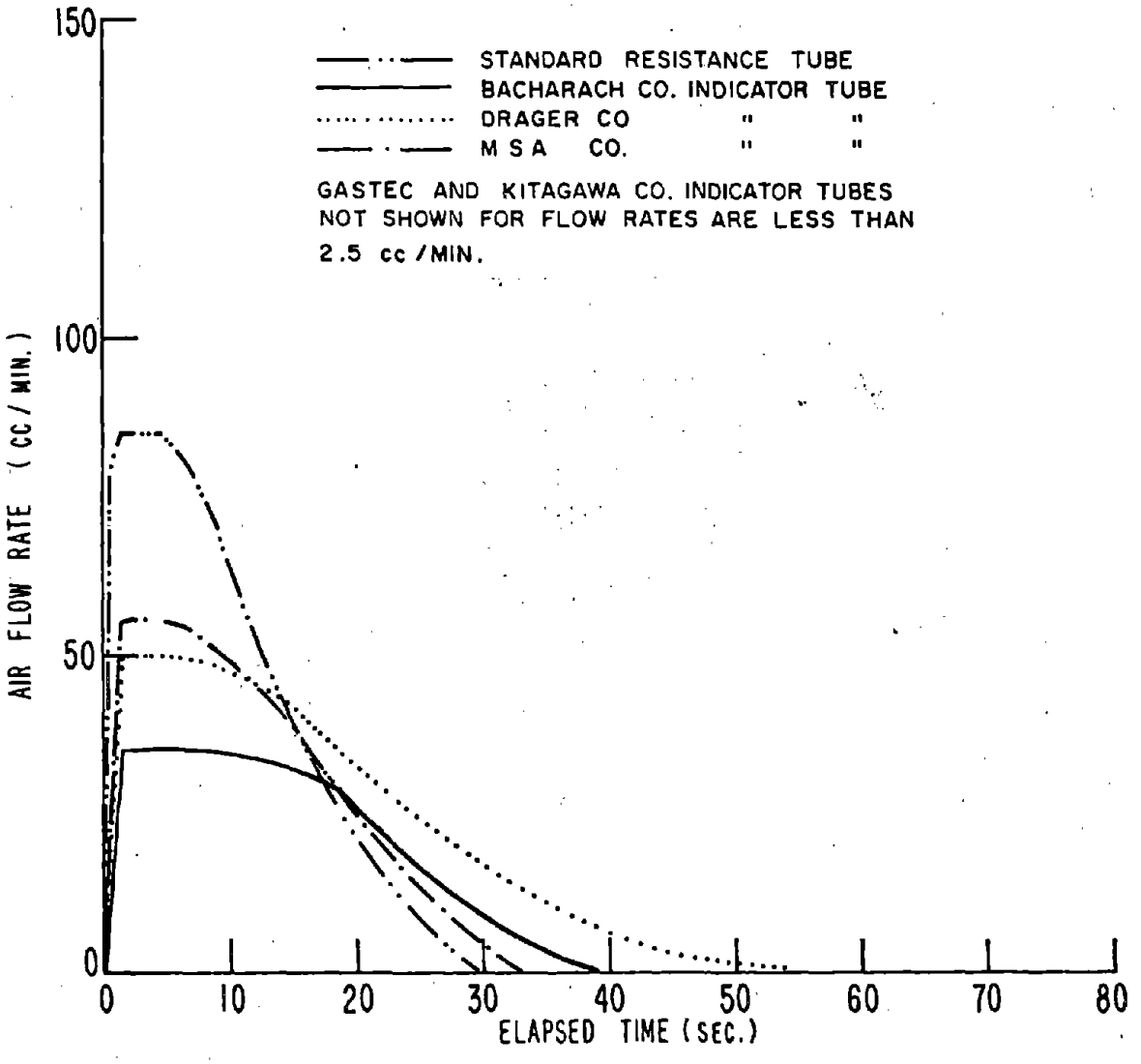
GRAPH 17. GRAPH OF AIR FLOW RATE VS. HOT WIRE ANEMOMETER DIFFERENTIAL VOLTAGE OUTPUT (USABLE RANGE: 350 cc/MIN. AND UP)



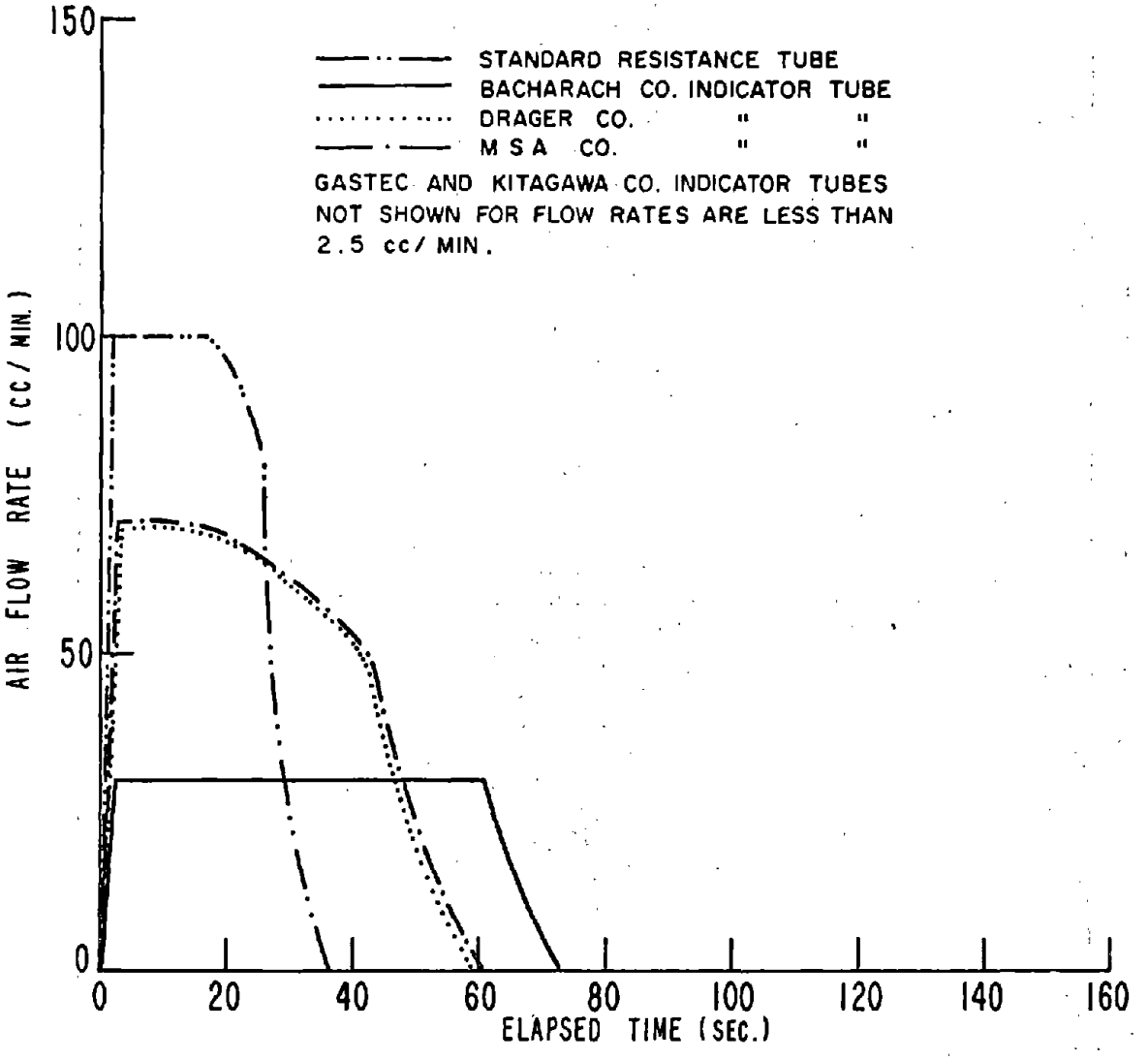
GRAPH 18. GRAPH OF AIR FLOW RATE VS. ELAPSED TIME FOR BACHARACH PUMP WITH ORIFICE "A" AND 16 cc SETTING.



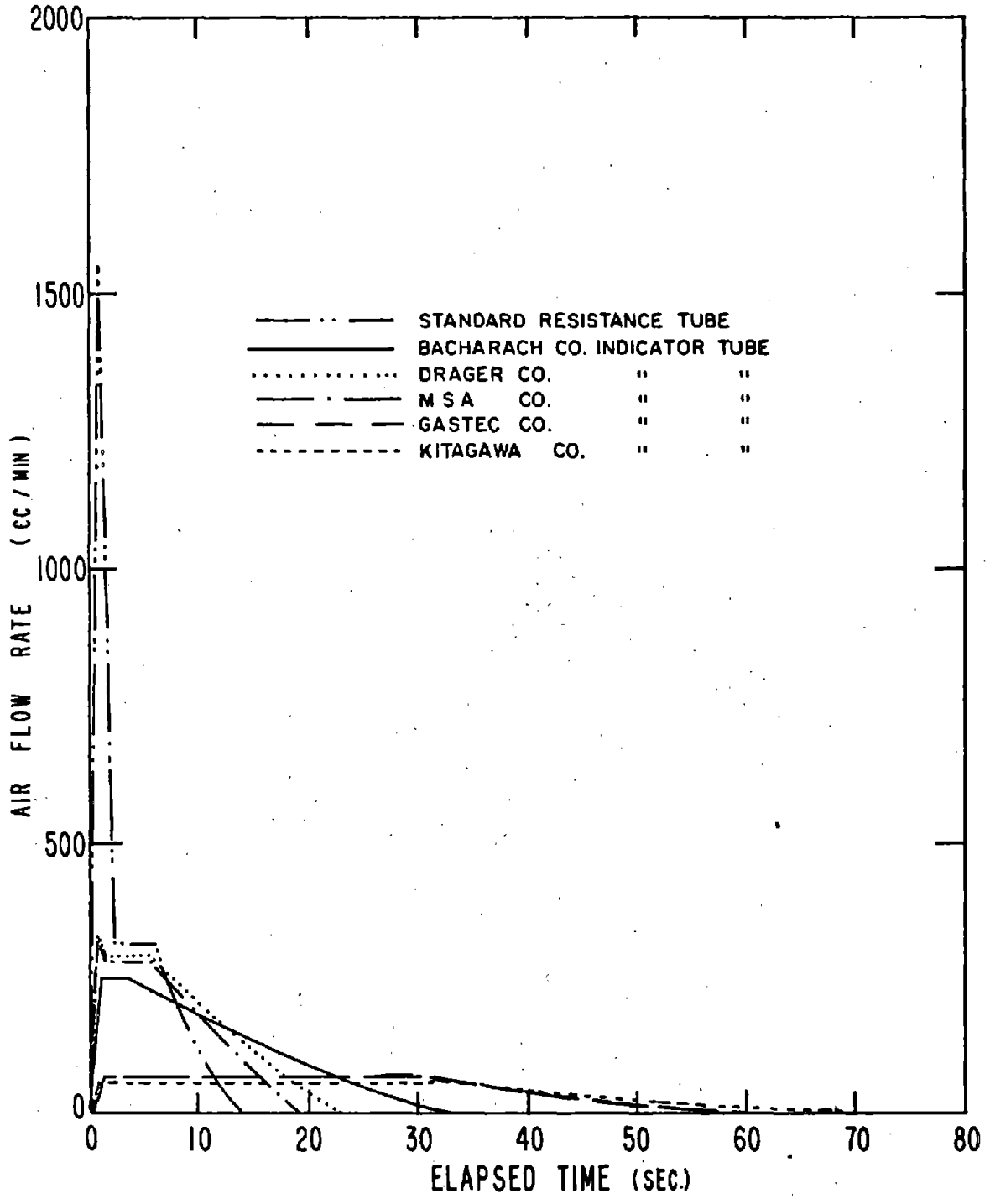
GRAPH 19. GRAPH OF AIR FLOW RATE VS. ELAPSED TIME FOR BACHARACH PUMP WITH ORIFICE "A" AND 50 cc SETTING.



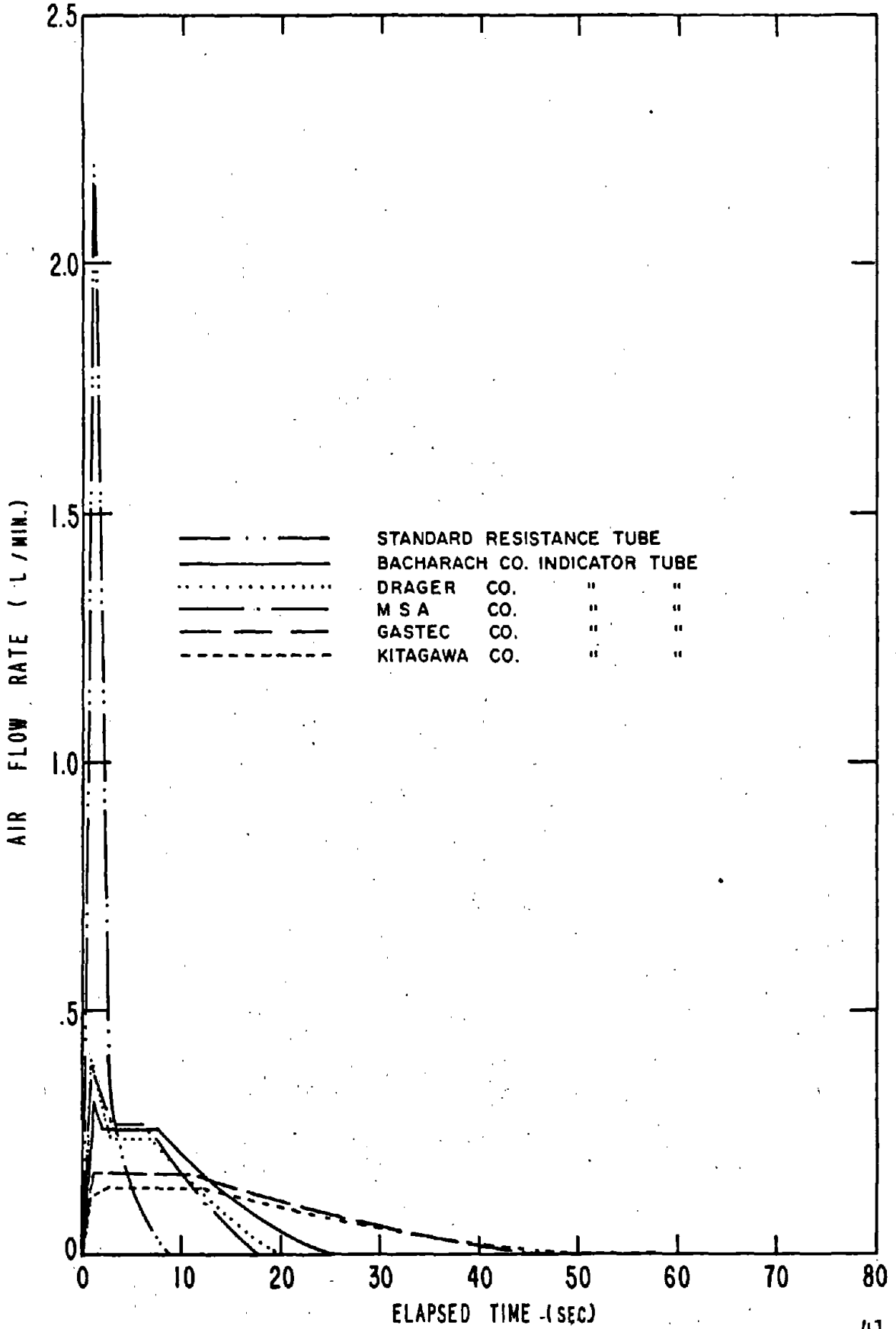
GRAPH 20. GRAPH OF AIR FLOW RATE VS. ELAPSED TIME FOR BACHARACH PUMP WITH ORIFICE "B" AND 16 cc SETTING.



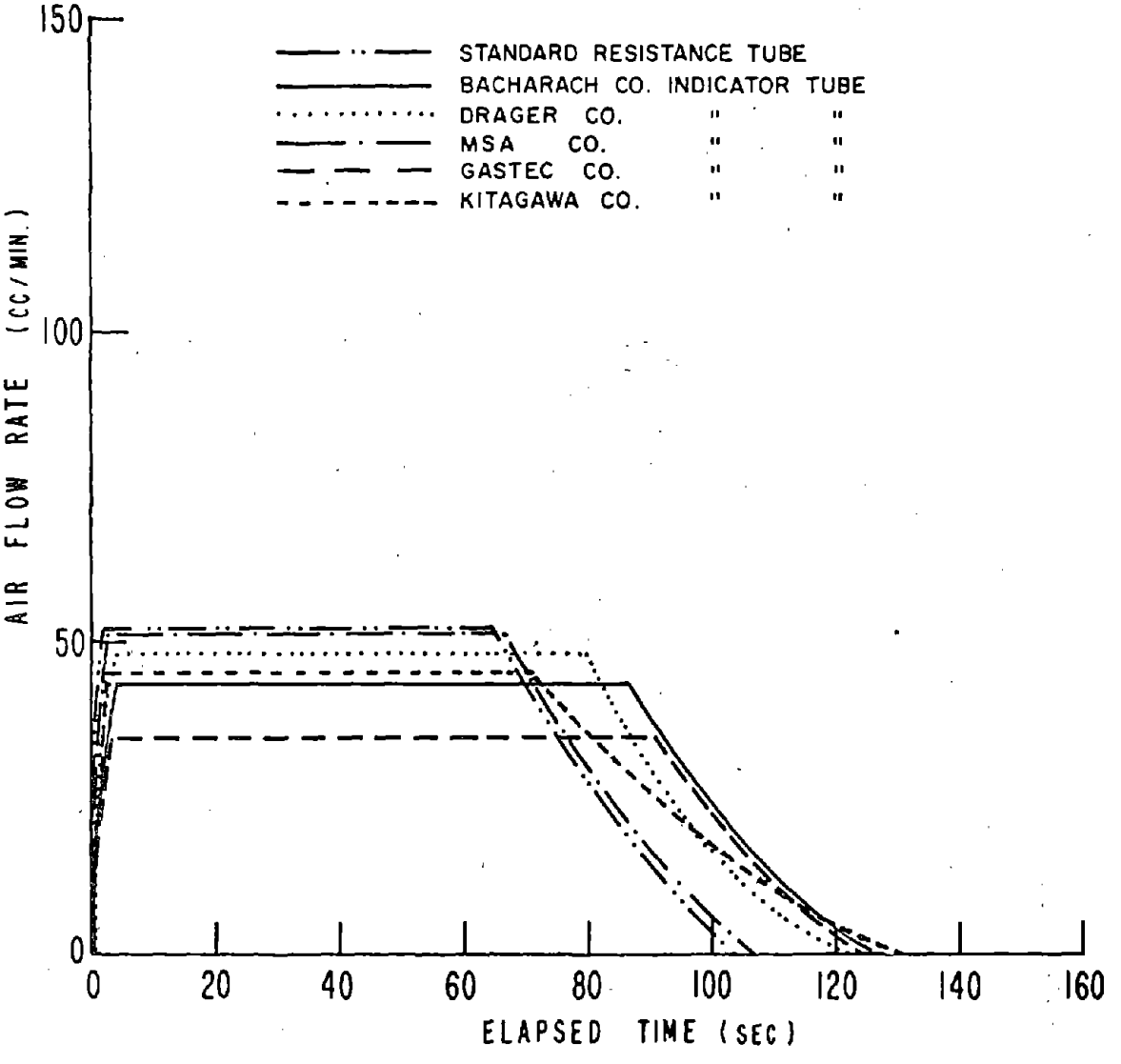
GRAPH 21. GRAPH OF AIR FLOW RATE VS. ELAPSED TIME FOR BACHARACH PUMP WITH ORIFICE "B" AND 50 cc SETTING.



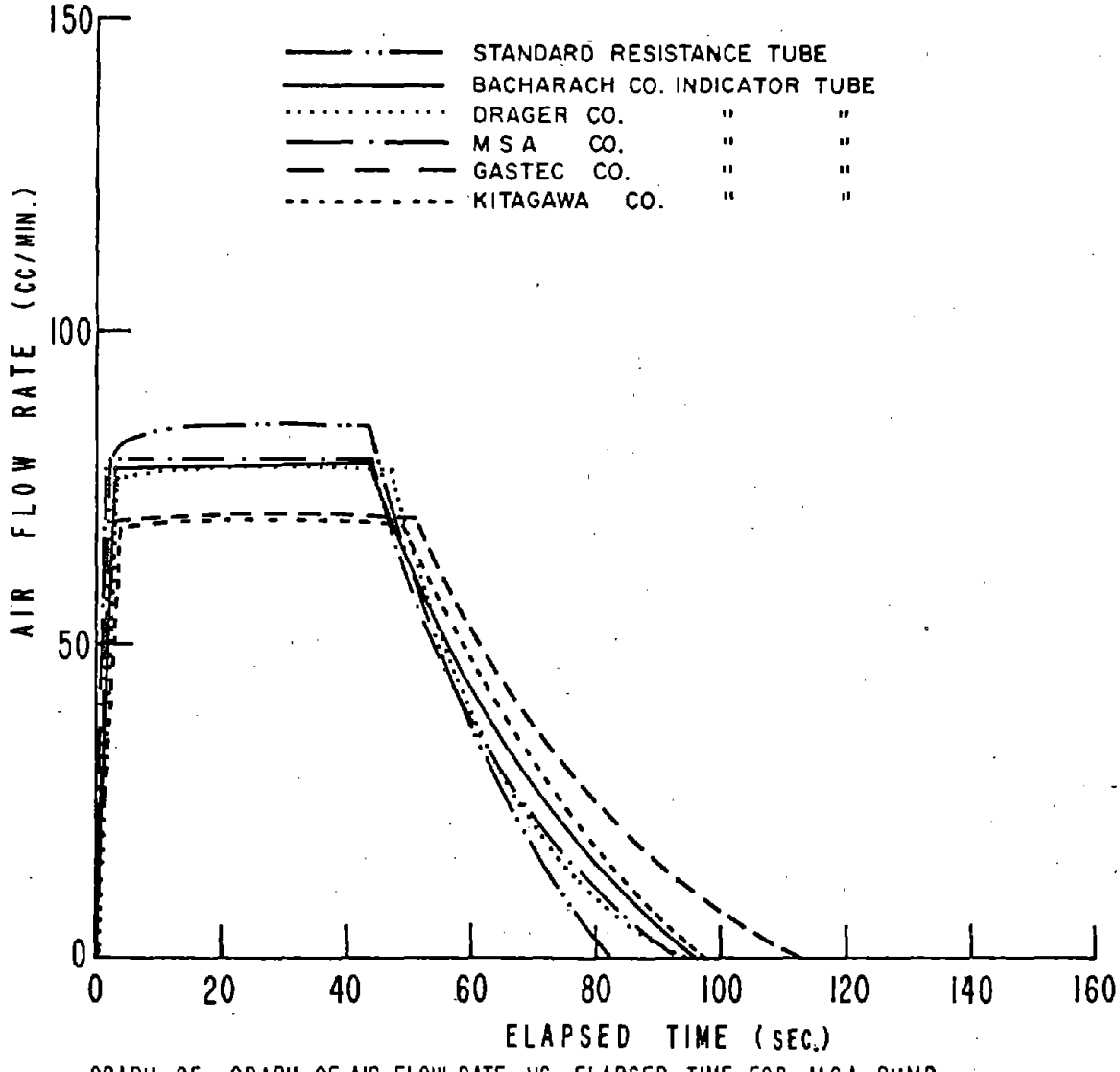
GRAPH 22. GRAPH OF AIR FLOW RATE VS. ELAPSED TIME FOR DRAGER PUMP.



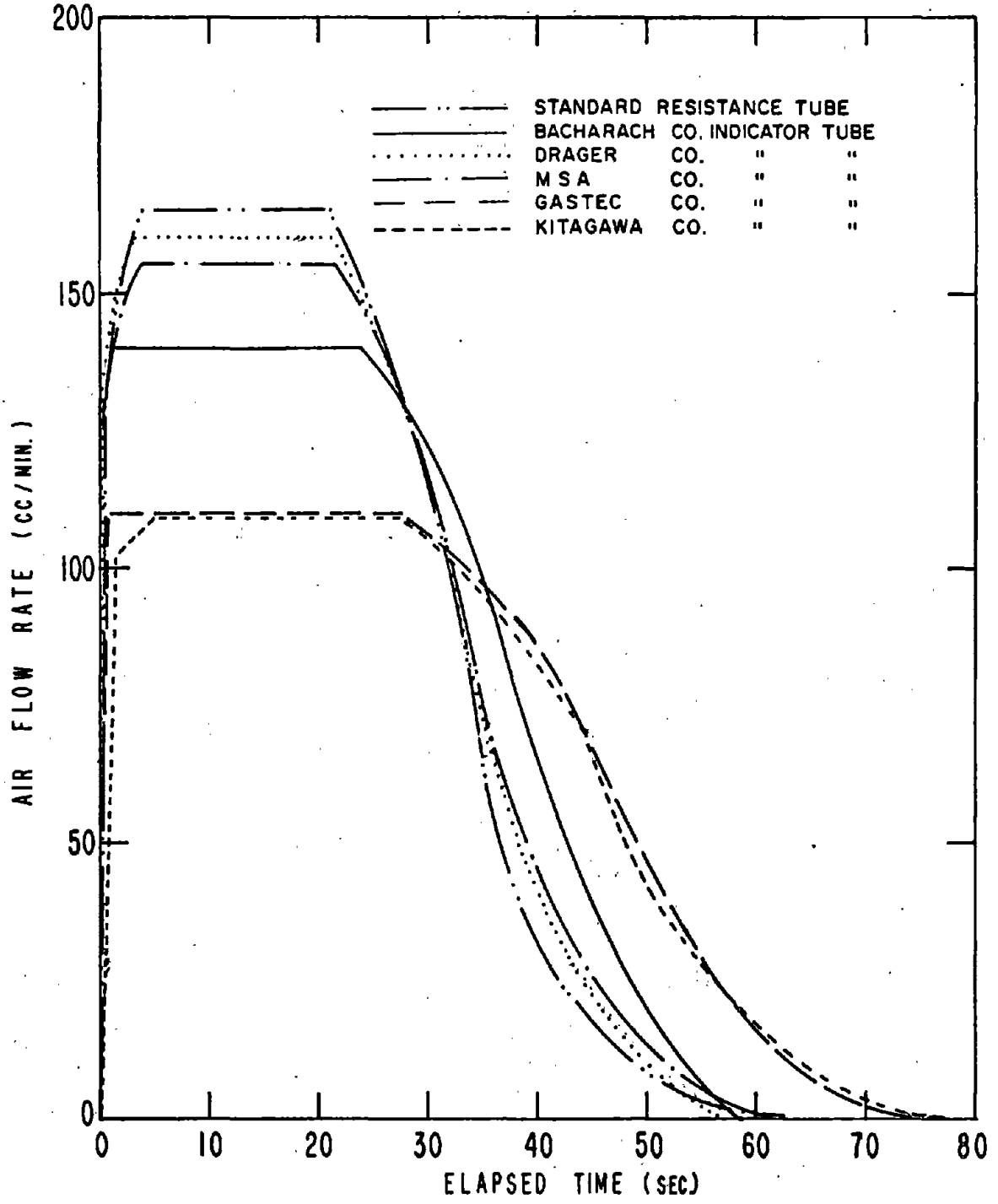
GRAPH 23. GRAPH OF AIR FLOW RATE VS. ELAPSED TIME FOR GASTEC PUMP.



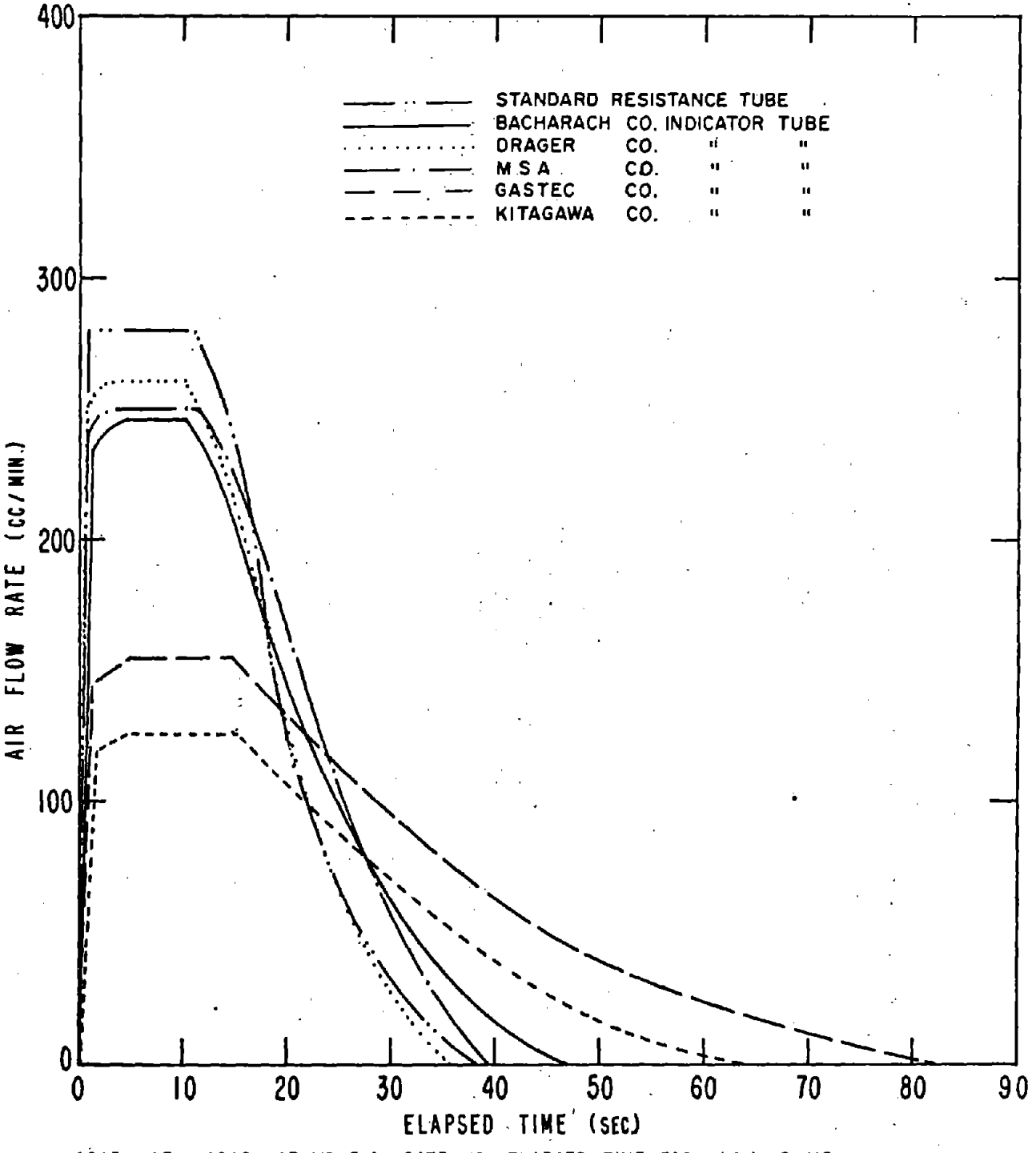
GRAPH 24. GRAPH OF AIR FLOW RATE VS. ELAPSED TIME FOR KITAGAWA PUMP.



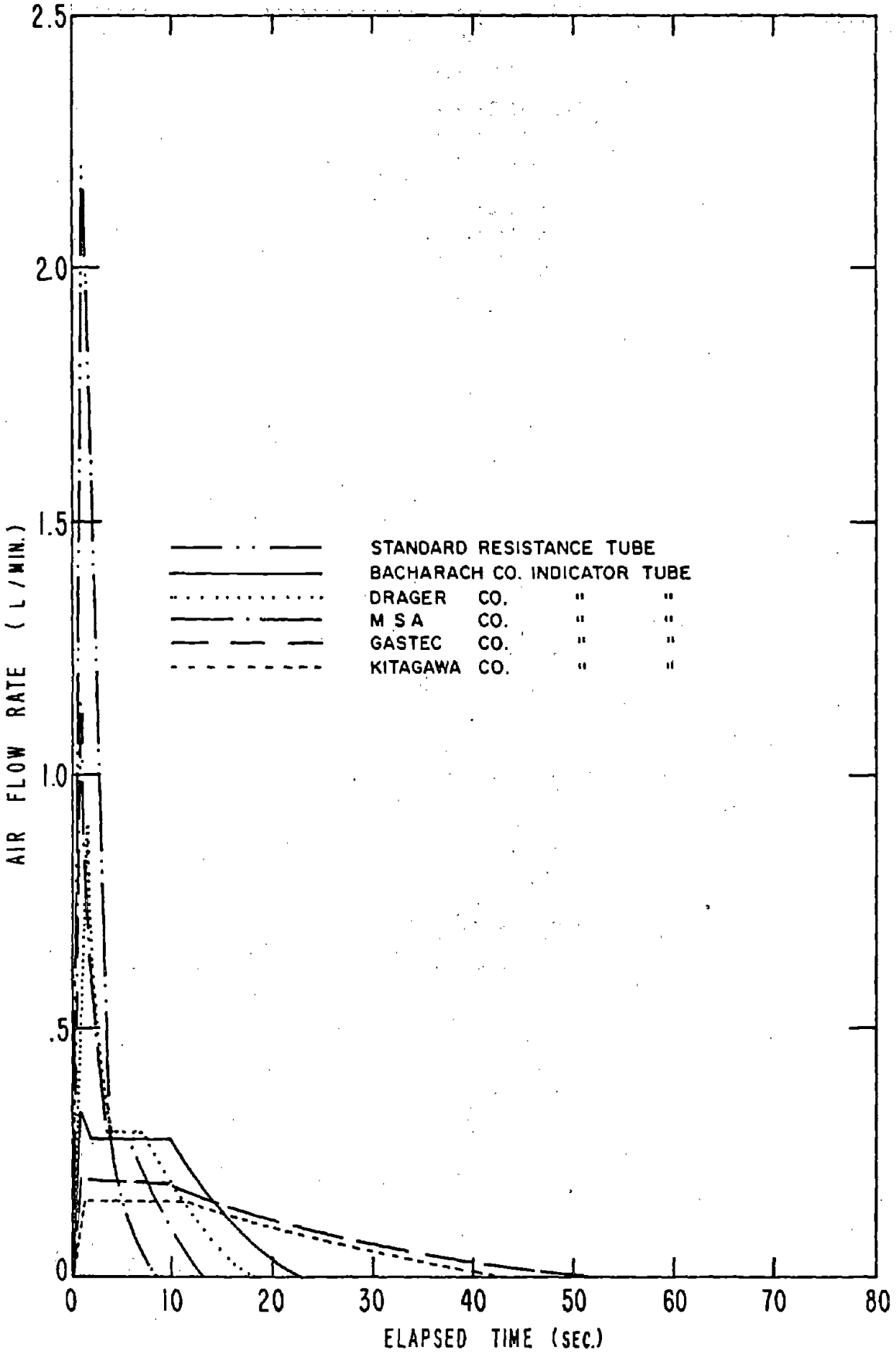
GRAPH 25. GRAPH OF AIR FLOW RATE VS. ELAPSED TIME FOR MSA PUMP WITH ORIFICE No.1.



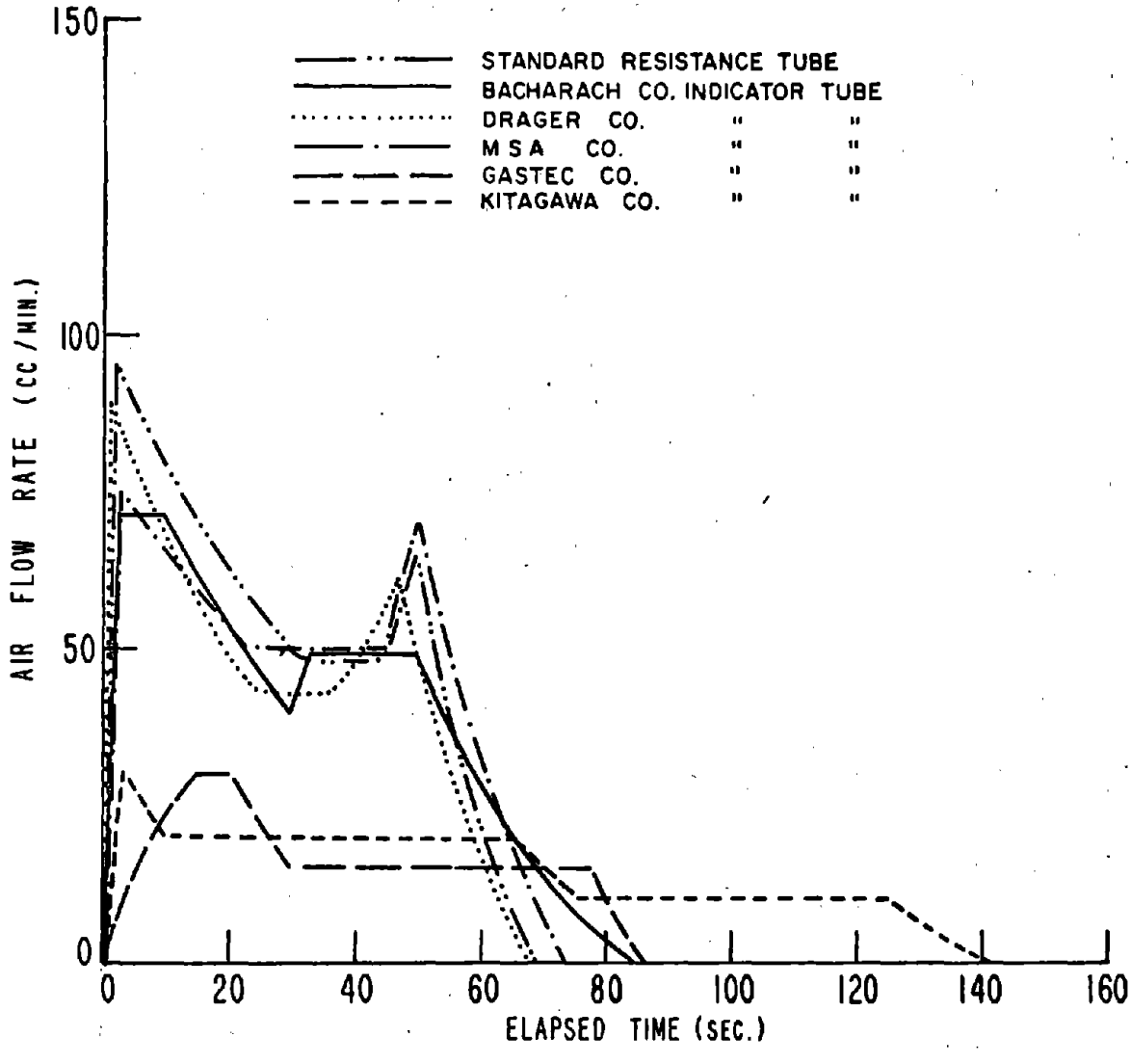
GRAPH 26 GRAPH OF AIR FLOW RATE VS. ELAPSED TIME FOR M S A PUMP WITH ORIFICE No. 2.



GRAPH 27. GRAPH OF AIR FLOW RATE VS. ELAPSED TIME FOR M S A PUMP WITH ORIFICE No. 3.



GRAPH 28. GRAPH OF AIR FLOW RATE VS. ELAPSED TIME FOR M.S.A PUMP WITH ORIFICE No.4.



GRAPH 29. GRAPH OF AIR FLOW RATE VS. ELAPSED TIME FOR SAF-CO PUMP.

TABLE 1.

TUBE TYPE: BACHARACH CO., No. 19-0195, LOT No. 482, EXP. DATE : 9 / 73
CONTAMINANT : CO
COCENTRATION : 100 PPM - 112 CC VOLUME — ORIFICE A SUGGESTED BY MFG.

PUMP TYPE	$\bar{X}$ *CONCENTRATION*	*S*	*% DEVIATION FROM SPECIFIED USE VALUE*
BACHARACH-ORIFICE "A"	81.5	5.4	———
DRAGER	261.7	19.4	+ 221.1
MSA-ORIFICE No. 1	235.3	6.7	+ 188.7
MSA-ORIFICE No. 2	299.7	0.9	+ 267.7
MSA-ORIFICE No. 3	300.0	0.0	+ 268.1
MSA-ORIFICE No. 4	300.0	0.0	+ 268.1
KITAGAWA	156.9	21.2	+ 92.5
GASTEC	285.7	22.9	+ 250.5

TABLE 2.

TUBE TYPE: DRAGER CO. 5/C , LOT No. 404181 , EXP.DATE : 9/73

CONTAMINANT: CO

CONCENTRATION: 100 PPM - 100 CC VOLUME

PUMP TYPE	$\bar{x}$ *CONCENTRATION*	*S*	*% DEVIATION FROM SPECIFIED USE VALVE*
DRAGER	96.0	3.3	——
MSA-ORIFICE No.1	64.5	11.3	-32.9
MSA-ORIFICE No.2	78.5	4.9	-19.3
MSA-ORIFICE No.3	87.5	4.9	- 8.9
MSA-ORIFICE No.4	115.8	3.7	+20.6
KITAGAWA	63.8	3.3	-33.6
BACHARACH-ORIFICE "A"	65.4	4.0	-31.9
GASTEC	115.9	7.6	+20.7

TABLE 3.

TUBE TYPE : GASTEC CO., CAT. No. 8525 , LOT No. 10515 , EXP. DATE : 10/72

CONTAMINANT : CO

CONCENTRATION : 100 PPM – 100 CC VOLUME

PUMP TYPE	$\bar{x}$ *CONCENTRATION*	*S*	*% DEVIATION FROM SPECIFIED USE VALVE*
GASTEC	109.1	8.5	———
DRAGER	97.7	4.7	– 10.5
MSA-ORIFICE No. 1	101.4	5.2	– 7.1
MSA-ORIFICE No. 2	103.5	4.3	– 5.2
MSA-ORIFICE No. 3	112.3	11.7	+ 2.9
MSA-ORIFICE No. 4	114.3	7.2	+ 4.7
BACARACH-ORIFICE "A"	62.5	14.0	– 42.8
KITAGAWA	92.8	10.6	– 15.0

TABLE 4.

TUBE TYPE : KITAGAWA CO. No. 100 , LOT No.1720100 (54-TUBES) No.1590070 (26-TUBES), EXP. DATE : 9/72

CONTAMINANT : CO

CONCENTRATION : 100 PPM - 100 CC VOLUME

PUMP TYPE	$\bar{X}$ *CONCENTRATION*	*S*	*% DEVIATION FROM SPECIFIED USE VALVE*
KITAGAWA	100.1	26.8	———
MSA-ORIFICE No. 1	132.0	28.8	+ 31.9
MSA-ORIFICE No. 2	123.7	43.0	+ 23.6
MSA-ORIFICE No. 3	154.2	31.1	+ 53.9
MSA-ORIFICE No. 4	190.2	9.5	+ 90.0
DRAGER	88.8	9.4	− 11.3
BACHARACH-ORIFICE "A"	62.4	16.2	− 37.7
GASTEC	184.0	30.8	+ 83.8

TABLE 5.

TUBE TYPE : M S A CO. PART No. 91229, LOT No. 135, EXP. DATE: 1/74

CONTAMINANT : CO

CONCENTRATION : 100 PPM - 100 CC VOLUME — ORIFICE No.1 SUGGESTED BY MFG.

PUMP TYPE	$\bar{x}$ *CONCENTRATION*	*S*	*% DEVIATION FROM SPECIFIED USE VALVE*
MSA-ORIFICE No.1	153.7	24.8	——
MSA-ORIFICE No.2	213.2	27.1	+ 38.7
MSA-ORIFICE No.3	339.6	22.2	+120.9
MSA-ORIFICE No.4	523.6	72.8	+240.6
DRAGER	244.0	36.6	+ 58.8
KITAGAWA	135.0	7.2	− 12.2
BACHARACH-ORIFICE "A"	112.4	11.8	− 26.9
GASTEC	168.8	71.2	+ 9.8

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