Paper Title: **"HUSKY OIL'S GAS MIGRATION RESEARCH EFFORT - AN UPDATE**

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BACKGROUND

Gas migration is defined as the leakage of gas from outside the production and/or surface casings of oil and gas wellbores (or in some cases from open hole abandonments). It can exhibit itself as gas pressure on the surface casing, gas migrating through the soil around the wellbore, or both. Figure 1 gives a simplified schematic of the problem. Gas migration has received increasing attention in recent years for a number of reasons:

1. A growing number of wells have reached, or are approaching, the end of their productive lives and will require abandonment in the near future.
2. Over the years, industry and regulators have become more cognizant the magnitude of the problem, in terms of the numbers of wells affected, the potential cost to address the problems and the technical difficulty of completely stopping the leakage.
3. Increased industry and public concern regarding the global warming phenomenon, in which methane emissions could be an important factor.

MAGNITUDE OF THE PROBLEM

A recent draft report from the Drilling and Completions Committee (DACC) Surface Casing Vent Flow Subcommittee quoted ERCB statistics which show that roughly 1 out of 20 wells in Alberta is known to have gas pressure on the surface casing. (Reference #1) While the problem in many of the wells throughout the Province is thought to be one of inadequate cementing, in the case of wells in the Lloydminster area the source of the gas and its pathway to the surface are rarely clear.

Industry groups such as the Lloydminster Area Operators Gas Migration Team (LAOGMT) and the Medicine Hat Area Shallow Gas Management Group (MHASGMG) have been established in an attempt to share knowledge, experience and expertise. Although they have not yet managed to find a solution to the gas migration problem, they have made a number of important contributions. For example, LAOGMT has made significant progress in the identification of problem wells by developing standardized testing methods which have been recognized and accepted by the ERCB. In addition, LAOGMT has supported programs under which large numbers of wells in the Lloydminster area were tested. In 1989 it sponsored a research project with the Saskatchewan Research Council which investigated the impact on plant health of methane gas in soil.(Reference #2) As well, both groups have provided an important forum for information sharing within industry as well as with the regulators.

A more recent effort in the area of surface casing vent flows was the formation of the DACC Surface Casing Vent Flow Subcommittee. (Reference #1) This committee was struck in response to a draft information letter issued by the ERCB which proposed a stringent policy that vent flows be eliminated over a 6 year period. While the committee dealt mostly with surface casing vent flows which might be attributable to inadequate cementing, some of their work overlaps into the area of gas migration, particularly with respect to the guidelines pertaining to the "seriousness" of a surface casing vent flow problem.

Based on these costs and success rates, the expected costs to eliminate gas migration are $300,000 per site overall (including open hole abandonments and cased holes) and $148,000 per site for cased holes only.

To summarize the results of Husky's work in these areas, a great deal of data had been gathered in terms of the number of wells affected (roughly half of the wells in the Lloydminster area). However, little consistent data was obtained with respect to the causes of the problem or what might be done about it. Success in re-entries and remedial workovers in existing wellbores, as well as preventative efforts in new wells, was limited and inconsistent at best. Questions which remained unanswered included:

- What is the source of the migrating gas?
- Does the gas migrate through a microannulus, through channels in the cement, through a damaged layer between the cement and competent formation rock or by some other path(s)?
- Could interwell communication of migrating gas be involved?
- Could some part of the problem be attributable to "natural sources" (e.g. swamp gas) which are using the wellbores as a conduit?
- Is there any seasonal variation of leakage rates?
- Is there any relationship between surface casing vent rates and soil gas migration rates?

More recently, Husky has entered into a research program to more systematically address the problem of gas migration from a variety of perspectives. This program is designed to look at the problem from both a technical and a business perspective and is shown schematically in Figure 2.

SEARCH FOR "BUSINESS SOLUTIONS"

On the business side, the focus is on determining the safety and environmental risks posed by gas migration from a variety of perspectives. With respect to the environmental effects, the impact on the soil is readily quantifiable (and typically quite small in terms of affected area) because of the crop damage which occurs. In terms of methane emissions and their greenhouse impact, a program has been started which encompasses an investigation of other sources of methane and measurement of surface casing vent rates as well as soil gas migration rates. Modelling to determine the potential for migrating gas to cause a safety problem by accumulating in useable groundwater horizons is also planned. If the measurements and/or modelling show that it is warranted, work will be done to assess potential technologies for methane collection and conversion to carbon dioxide. (Conversion to carbon dioxide would lower the overall greenhouse impact since methane is a much more potent greenhouse gas than is carbon dioxide, particularly over the short term.)

The first step in this process was to do a literature search of sources of methane for comparison purposes. The results of this work are shown in Table 3 which compares a number of methane sources in terms of average emission rates. (References #3 and #4)

As part of the measurement initiatives, Husky has teamed up with Novacor Research & Technology Corporation (formerly Nova Husky Research Corporation) and is pursuing an aggressive campaign to determine the rates of gas leakage from surface casing vents and soil gas migration. The surface casing vent measurements incorporate the use of rotameters of various sizes depending on the vent rate (Figure 4). Measurement of soil gas migration, on the other hand, is done through the use of flux chamber technology, something which had not been attempted before in the Canadian oil and gas industry. (Flux chamber technology has had some application in the area of measurement of emission rates of certain gases from various contaminated sites in the United States.) (Reference #5) Basically, the system consists of an enclosed chamber placed over the soil and connected to a portable gas analyzer which draws gas out of the

WHERE DO WE GO FROM HERE?

Husky is committed to working diligently on both the technical and business solutions of its gas migration research program. On the technical front, development and fine tuning of the new well gas migration prevention process is ongoing and the joint Husky/DS effort is well underway. On the business front, testing will continue in order to improve our understanding of things such as the accuracy of flux chamber measurements, seasonal variations of leakage rates and the interrelationship (if any) between surface casing vent rates and soil gas migration rates. As well, modelling will be performed to assess the risk of impacts on groundwater aquifers and techniques for containment and/or conversion of the methane will be investigated. (Work in this area will be somewhat dependent on the results in other areas.) Apart from these efforts, Husky has also begun dialogue with government and regulatory bodies to work toward regulations which require compensation levels more nearly in proportion to the level of damage. While a technical solution which totally eliminates the problem may never be possible, it is comforting to note that, based on data gathered to date, the methane leakage from the majority of "gas migration" wells does not represent a significant impact from an environmental or resource conservation perspective.

ACKNOWLEDGEMENTS

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TABLE 1 HUSKY OIL GAS MIGRATION STATISTICS

PROVINCE	WELLS TESTED	TESTED WELLS EXHIBITING GAS MIGRATION	% TESTED WELLS EXHIBITING GAS MIGRATION
ALBERTA	1300	508	39
SASKATCHEWAN	1421	739	52
TOTAL	2721	1247	46

Notes:
1) Wells exhibiting gas migration are defined as those wells having a positive surface casing vent flow or having positive soil gas readings (i.e. soil gases having detectable LEL readings using a combustible gas detector.)
2) A predominance of suspected "problem wells" have been tested biasing these figures on the high side.

TABLE 2 HUSKY OIL GAS MIGRATION REMEDIAL WORKOVERS

REMEDIAL WORKOVER TYPE	# WELLS	AVERAGE COST (K$)	SUCCESS* RATE (%)	COST PER SUCCESS* (K$)
Re-enter and case D&A wellbores	11	136	27	500
Re-enter and plug D&A wellbores	4	77	25	307
Cement squeezes on cased wellbores	6	74	50	148
Total	21	107	33	322

*Note: Success was defined as no detectable leakage shortly after the workover. Longer term success is unknown.

TABLE 3 METHANE SOURCES COMPARISON

ITEM	CH4 EMISSIONS (TONNES/YR/UNIT)	CH4 EMISSIONS (M3/D)
Gas Cooperatives (per farm supplied) (1)	0.283	1.16
Dairy Cattle (per head) (2)	0.104	0.43
Landfills (per capita) (2)	0.054	0.22
Swamps (per hectare) (2)	0.050	0.21
Beef Cattle (per head) (2)	0.039	0.16

Notes:
1) Based on estimates supplied by the County of Vermilion River Gas Cooperative
2) Based on Environment Canada's Draft Report " Canada's Greenhouse Gas Emissions, Estimates for 1990"

TABLE 4 PRELIMINARY ESTIMATED DISTRIBUTION OF GAS LEAKAGE RATES

Flowrate (m3/d)	Wells With Surface Casing* Vents Rates > Specified Rate (%)	Wells With Soil Gas Migration Rates > Specified Rate (%)
0.00	16	41
0.01	10	N/A
0.10	10	24
1.00	8	15
10.00	4	0
100.00	1	0
150.00	0	0

* Not all wells have surface casing

FIGURE 1 GAS MIGRATION SCHEMATIC

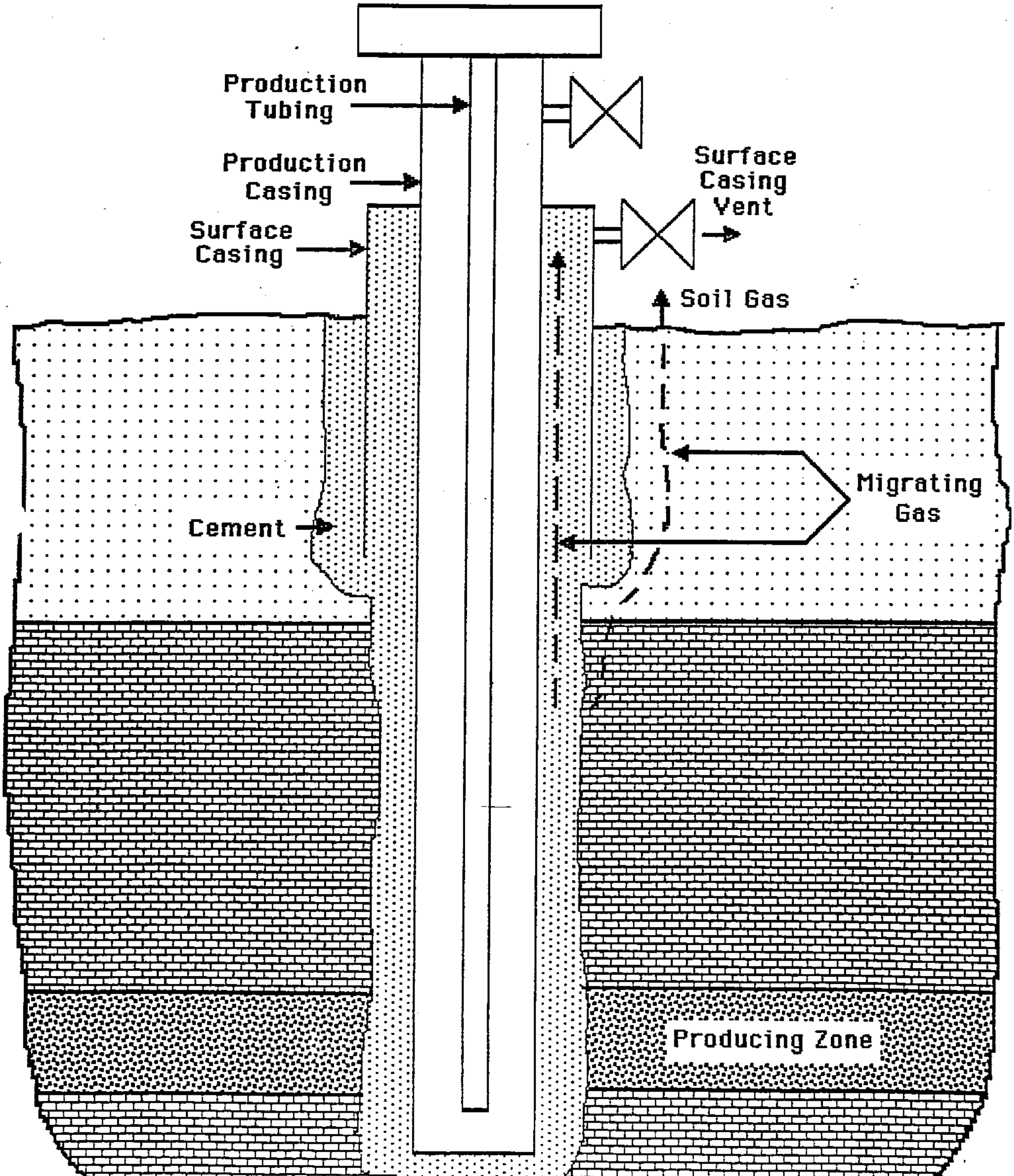


Figure 2 Gas Migration R&D Strategy

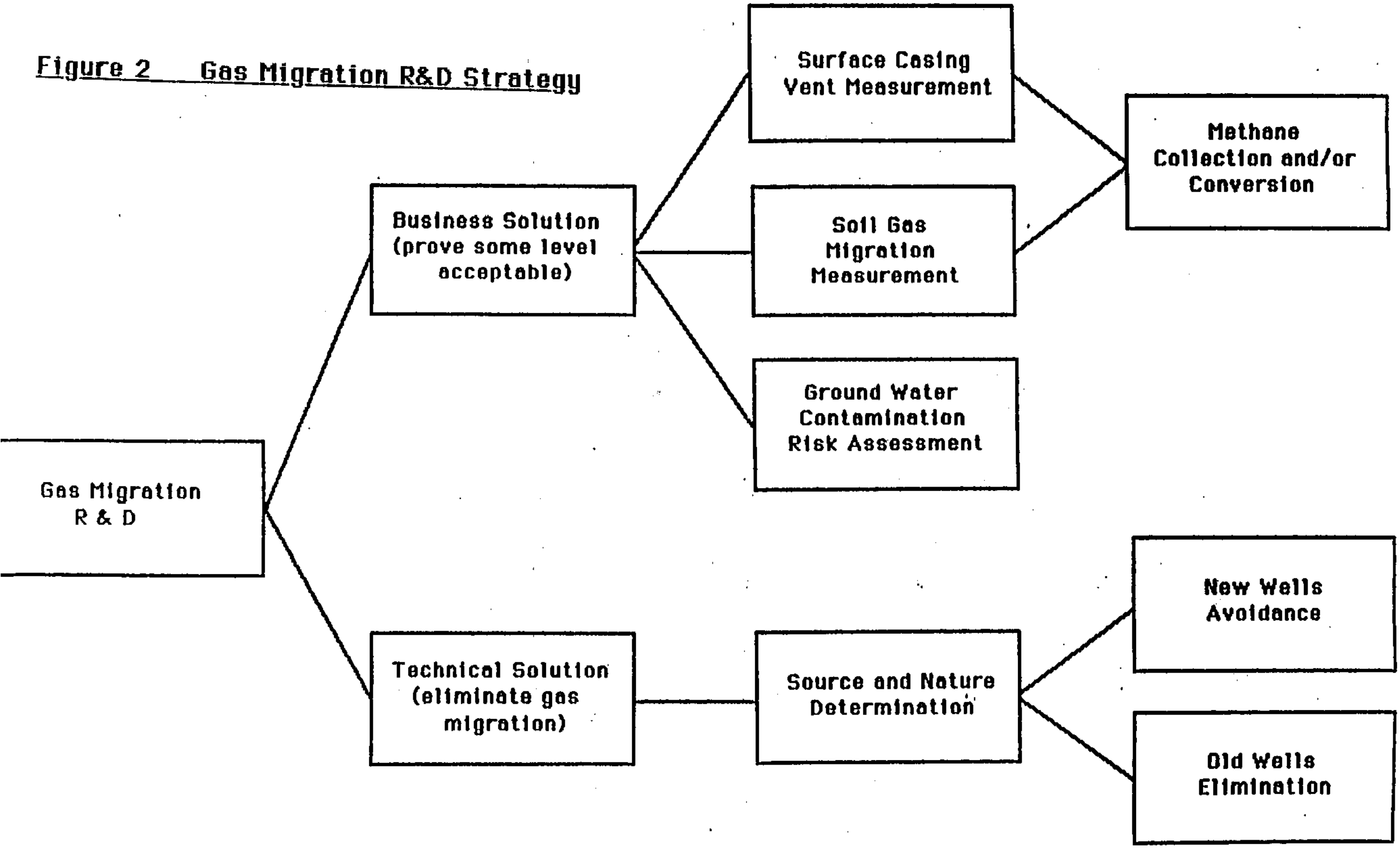
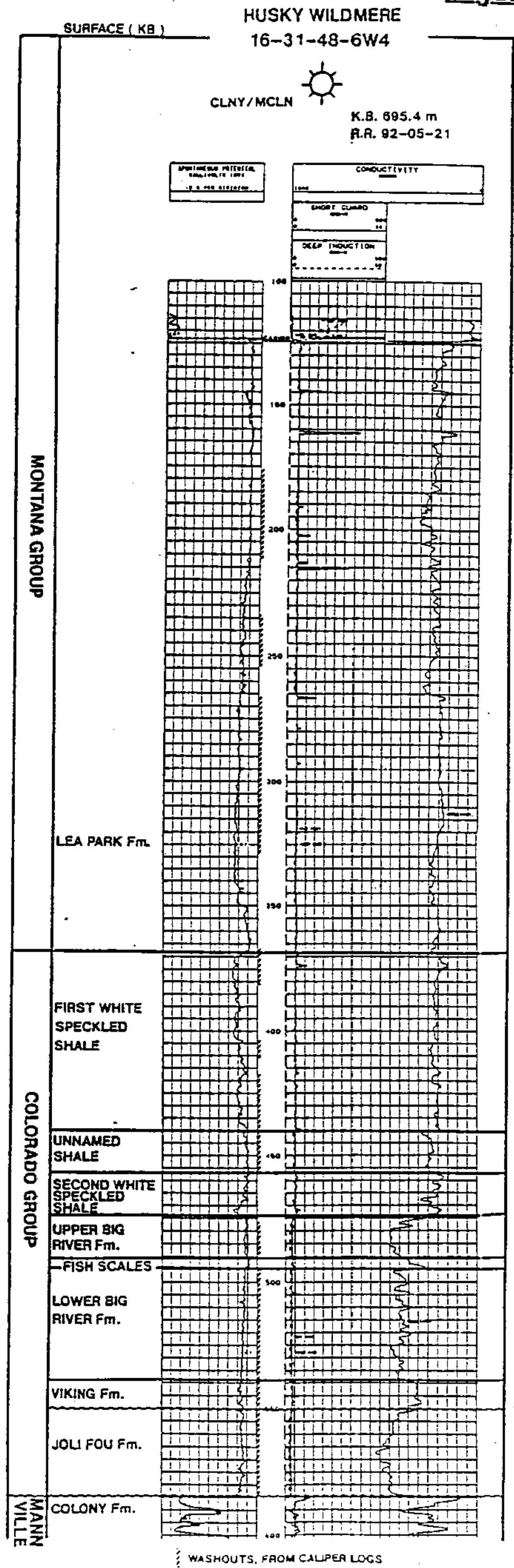


Figure 3


HUSKY WILDMERE
16-31-48-6W4
SURFACE (KB)
CLNY/MCLN
K.B. 695.4 m
R.R. 92-05-21
CONDUCTIVITY
SHORT GUARD
DEEP INDUCTION
100
150
200
250
300
350
400
450
500
MONTANA GROUP
LEA PARK Fm.
COLORADO GROUP
FIRST WHITE SPECKLED SHALE
UNNAMED SHALE
SECOND WHITE SPECKLED SHALE
UPPER BIG RIVER Fm.
FISH SCALES
LOWER BIG RIVER Fm.
VIKING Fm.
JOLI FOU Fm.
MANNVILLE
COLONY Fm.
WASHOUTS, FROM CALIPER LOGS

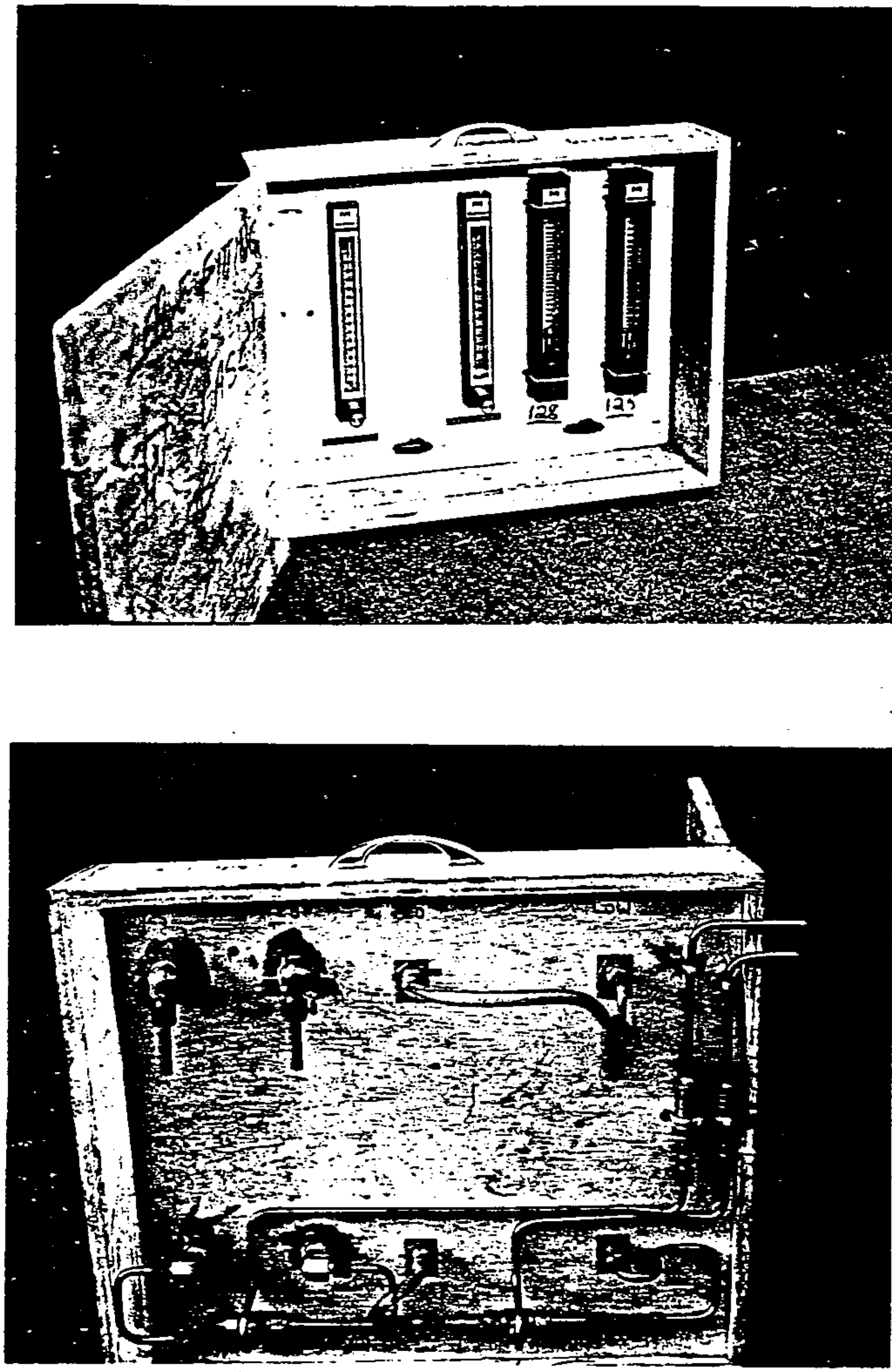


Figure 4 Front View (Top) and Rear View (Bottom) of Rotameter Instrumementation Used to Measure Surface Casing Vent Rates

FIGURE 5 FLUX CHAMBER SCHEMATIC

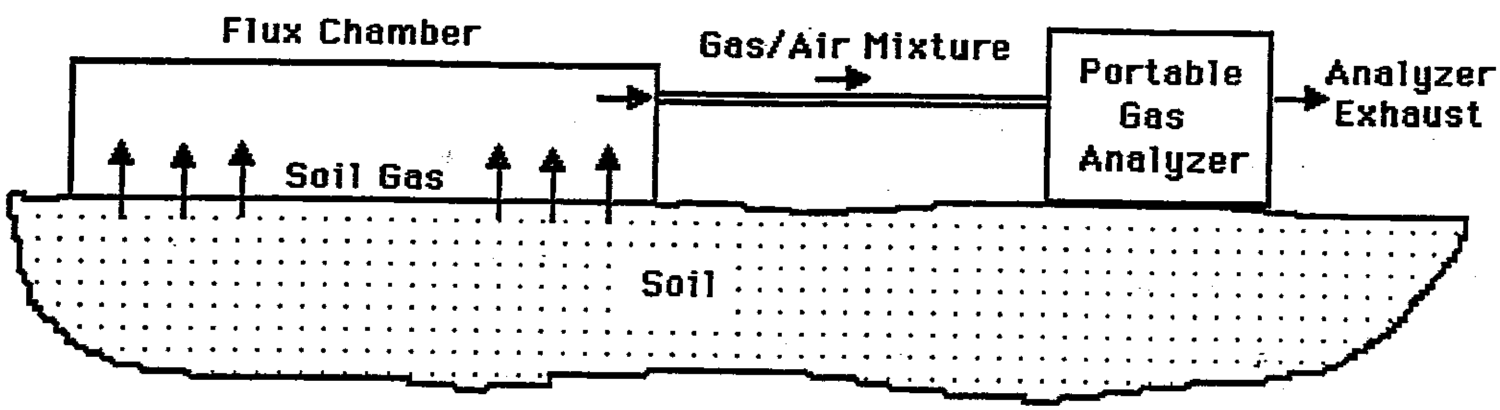
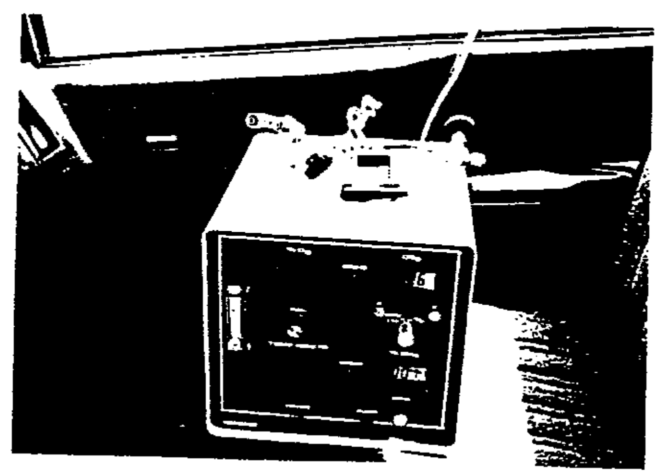


FIGURE 6 PHOTOS OF FLUX CHAMBER APPARATUS

Flux Chamber In Use



Portable Gas Analyzer