HAZARD AREA ANALYSIS

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Hazard Area Analysis can be carrried out
using either generalised guidelines or
substance/condition specific treatments.
A brief outline is given of one company's
change from a qualatative to a
quantitative attitude, together with some
details of the techniques involved.

Keywords - Hazard, area, analysis, zone, classification.

The concept of Hazard Area Analysis has always been
based upon the likelihood of an incident. This in
turn being governed by:

a) the probability of a flammable atmosphere
and
b) the likelihood of an ignition source.

The more likely a flammable atmosphere the more
stringent the controls imposed on the electrical
equipment.

The use of the terms likelihood and probability
could be taken as implying a quantitative approach.
It is, however, only relatively recently that
quantitative arguments have played a significant
part in Hazard Area Analysis.

It is my intention to give a brief outline of the
development of Hazard Area Analysis within
Associated Octel. The main feature being that of a
change from an industry based generalised approach
to one that incorporates quantitative and
generalised features. Both of which can be
related, very specifically, to our particular
circumstances.

The results of the change in approach can perhaps
best be seen by looking at the effects on a Hazard
Area drawing for a particular Works. The

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flammable materials handled included methyl
chloride, dichloroethane, and lead alkyls.

The original means of analysis was carried out
relatively simply by the application of the
Institute of Petroleum system (ref 1.). This
defined three classifications based on subjective
assessment of the likelihood of a flammable
atmosphere.

Division 0 - continuous

Division 1 - likely at any time

Division 2 - under abnormal conditions & rapidly
             dispersed

It also gave generalised guidelines for the extent
of any Hazard Area, which took little obvious
account of the properties of the materials
involved.

Most if not all of our classification for the
Works fell into clause 1.4.2. as ventilation, for
historical reasons a problem. This then generated
Zone 1 areas within and 50 feet around all of the
buildings that handled flammable materials.

The I.P. approach would have certainly been easy to
use. However in 1969 Associated Octel began, with
others, to feel that some attempt should be made to
develop an approach which allowed specific account
to be taken of the individual materials and their
conditions of use.

It was generally felt that whilst the actual
equipment used, within the various Hazard Areas,
had become scientifically based and precise the
actual analysis of those areas was very imprecise.
The main areas of concern related to the
application of generalised guidelines were;

a) were some areas over-classified resulting in the
   specification of costly equipment.

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b) were some areas under-classified resulting in
   the use of equipment that could prove hazardous.

Work was then commenced to try and establish
appropriate quantitative approaches for;

i) calculation of Hazard Area extent

ii) calculation for Hazard Area Classification

HAZARD AREA EXTENT

The quantification of extent falls into three main
parts;

1. Leak rate calculation

2. Source strength calculation

3. Dispersion calculations

The techniques used in these calculations have been
developed within industry and so only a brief
description will be given here.   Further
details can be obtained from reference 2.

Leak Rate Calculation

There are two basic types of leaks, gas and liquid
that need concern the Hazard Area Analyst.
Materials stored as liquids under pressure above
their normal boiling points can flash and choke the
flow from large holes. However in general the
types of leaks concerned with in this type of work
are small and will therefore not result in flashing
flow situations.

The basic flow of an incompressible liquid through
an orifice is given by

$$G = Cd.A.[2(P1-P2)p]^{0.5}$$

where G = flow kg/s
      A = cross sectional area of leak m^2
      p = density kg/m^3
      $P1$ = upstream press. N/m^2

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$P2$ = downstream press. N/m^2
Cd = discharge coefficient

This can be modified to take account of liquid head and pressure.

For a gas

$G = Cd.A.p_2.\{(2P1/p_1)(k/(k-1)[1-(P2/P1)^{(k-1)/k}]\}^{0.5}$

where k = ratio of specific heats

Source Strength Calculation

In some circumstances this can simply be the results of leak rate calculations, ie for a gas or where it can be assumed that any liquefied gas release will immedeatly vapourise. For other materials account will have to be taken of;

a) evaporation from pools for liquids with boiling points above ambient.

b) flash evaporation both on emission and from ground contact for materials with boiling points below ambient.

From reference 3, the evaporation rates for non boiling fluids, are given by :

$m'' = 2E^{-3}.u^{0.78}.r^{-0.11}.\dfrac{M.P_t}{R.T.p}.Ln(1+\dfrac{P_w}{P_t-P_w}).Pi.r^2.60^2$

where;

m'' = evaporation rate (m^3/hr)
u = wind speed (m/s)
r = pool radius (m)
M = mean molecular weight
R = gas constant = 8300 $(J/kg.mol\ ^{\circ}K)$
T = fluid temperature $(^{\circ}K)$
P_t = total pressure (atmospheric) = 10^5 (Pa.)
P_w = vapour pressure of fluid at temperature T (Pa.)
p = density of vapour = $\dfrac{M.273}{22.4\ x\ T}$ (kg/m^3)

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For leaks that flash on emission

$V = G.F_{vap}$

where V = flow vapourised kg/s
G = flow from orifice kg/s
F_{vap} = fraction vapourised = $(Ti - Tb)s/L$
Ti = initial temp.
Tb = boiling temp.
s = Av. specific heat of liquid
L = Av. latent heat of liquid

Dispersion Calculations

The nature of the release could dictate the type of treatment involved. A relatively high pressure leak of gas will disperse as a jet, entraining air into itself through the turbulence promoted by the momentum of the material itself Emissions with little momentum, such as evaporating liquids will be subject to atmospheric dispersion, with air entrainment created by atmospheric turbulence.

If a jet were to hit an object and lose its momentum then it too becomes subject to atmospheric dispersion. In most situations in Hazard Area work the approach can be taken to always use atmospheric dispersion as jet dispersion cannot always be guaranteed

Atmospheric dispersion

$Ds = [36.8 \ Q/(u.Cl)]^{0.552}$

where Ds = distance traveled m
Q = escape rate m^3/s
u = wind speed m/s
Cl = lower flammable limit %vol

As a result of using the above quantification it is now possible, given a potential hole size, the properties of the material and their conditions of use, to determine the extent of Hazard Area extent.

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HAZARD AREA CLASSIFICATION

The I.P. code and B.S.5345 (ref 4) define the three areas used in Hazard Area classification in qualitative terms. How have these been incorporated into a quantitative approach ?.

The whole area of classification revolves around the expected frequency of an incident which can be expressed as;

$$I = i.a$$

where i = frequency of ignition source
      a = probability of a flammable atmosphere

"I" must be a constant which then dictates that "i" must decrease as "a" increases.

Around 1971 it was felt that "i" was relatively well established for the electrical equipment used within each Hazard Area. This then enabled values of "a" to be proposed which if expressed as hours per year allowed time limits to be applied for each Hazard classification.

After much deliberation the qualitative definitions used by some sectors of the Chemical Industry, including Associated Octel where changed to;

Zone 0 = Flammable atmosphere present for greater than 1000 hours/year

Zone 1 = Flammable atmospheres present for less than 1000 hours/year but greater than 10 hours/year

Zone 2 = Flammable atmospheres present for less than 10 hours/year

There were variations on this theme one of which, a lower limit for Zone 2 of greater than 0.01 hours/year, was eventually adopted by Associated Octel.

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Flammable Atmosphere Duration

Having provided ourselves with quantitive definitions for Hazard Area classification, how did we go about comparing the performance of our [Plant equipment against these definitions.

The duration of a flammable atmosphere can be expressed in the general form of;

$$T = Td + Ti + Tr + Tc + Te$$

where Td = time to detected a flammable atmosphere
Ti = time to isolate a source
Tr = time to remove source
Tc = time to disperse a flammable atmosphere
Te = duration of other flammable atmospheres from other sources

This can be re-written as;

$$T = F (tv/2 + ti + tr + tc) + Te$$

where F = frequency of leak within an area
tv = average time between visits to the area
ti = average time to isolate a leak
tr = average time to remove a source of flammable atmosphere
tc = average time on each occasion to disperse the flammable atmosphere

This is all general, the specific circumstances of any situation can mean that certain terms may be amalgamated or ignored.

For example;

tv may be large but other means may result in a short detection time, area monitoring, smell, noise, process monitoring etc.

tr for a liquid may be sizable due to evaporation times but for a gas could be very small.

tc will often become significant if the particular

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location prevented the effective dispersion, such
as in a poorly ventilated area.

**Frequency, Duration and Release Rate Determination
in Practice**

Sources of flammable atmospheres can fall into two
basic groups, voluntary and involuntary.

Voluntary releases can take the form of process and
maintenance vents, sampling, disconnections etc.
Examination of the Plants design and method of
working can enable frequency, duration and release
rates to be estimated.

Involuntary releases are totally unintentional but
can occur through equipment of human failures.
These types of releases are the most difficult to
quantitify as their frequency, size and duration
are relatively unknown. There are several methods
that can be used in an attempt to establish the
required data.

Examination of Plant records such as maintenance
records, foremans logs, monthly reports incident
reports etc, can give invaluable data related to
the frequency and scale of leaks. This however
takes up a lot of resources due to the sheer volume
of paperwork one has to get through to establish a
large enough sample for realistic results.

Within Associated Octel the re-assessment of all
its Works areas was considered sufficiently
important enough that the time required was
considered justifiable.

There are still situations, however, were
appropriate in-house data is just not available.
In such circumstances a semi-quantitative approach
is adopted.

There are few published sources of failure data,
ICI in 1976 published (ref. 5) a collection of
data amassed from their own and others experiences.
This for its time was and still is an extremely
useful piece of work. Some of this data has been

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adapted by Associated Octel for use in Hazard Area analysis.

As an example. small flanges failures are defined as 3mm in diameter and occur with a frequency of 0.005/year. The ratio of large holes to the total number of holes depends on a factor called a severity fraction which in turn is related to the working pressure to design pressure ratio. The closer this ratio is to unity then the more likely large holes will occur. The size of the large holes will be dependant upon the pipe diameter, number of bolts used and the gasket thickness. Complete loss of a joint is unlikely and experience indicates that the potential upper limit of joint loss will be that between two adjacent bolts.

References 6 & 7 have also be useful sources of failure data.

EXAMPLE OF HAZARD AREA CLASSIFICATION CALCULATIONS

1. Pipework system

A system that contained 350m of pipe, 54 valves and 229 flange joints experienced 16 pipe leaks, 2 flange leaks and 8 valve leaks over a period of two years.

This information can be converted to the following failure rates;

pipeline leaks = 16/(350 x 2) = 0.023 per m/yr

flange leaks = 2/(229 x 2) = 0.0044 per joint/yr

valve leaks = 8/(54 x 2) = 0.075 per valve/yr

2. Leak rate

Properties of material and conditions of use

Material = Methyl Chloride
Boiling point = -24 deg.C
Storage press = 35 psig
Pipe line 50mm diam with 4 bolts

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Large hole limited to 10mm equivalent diameter

Design pressure = 210 psig

Working to design pressure ratio = 35/210 = 0.167

Severity fraction for 0.167 = 0.002

Frequency of large holes = 4.4 x 10-3 x 2 x 10-3
                         = 8.8 x 10-6 per joint/yr

Assume 3mm hole and an ambient temperature ·of 10 deg.C

Liquid leak rate using standard equations

small leak = 0.01 kg/s

large leak = 1 kg/s

Leak source

small leak assume all evaporates = 0.01 kg/s

large leak = max evaporation on contact with ground
           = 2 kg/s

followed by

           = evaporation from cooled ground
           = 1 kg/s

Dispersion

Using atmospheric dispersion

distance to LEL; small leak = 3m
                 large leak = 15m initially
                              reducing to 10m

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Duration of Flammable Atmosphere

Plant visited once per hour so average time to detection = $0.5 \times 1 = 0.5$ hours

Time to isolate = 10 minutes

Time to stop source = 1 min

Number of flanges in overlapping area = 50

Duration of flammable atmosphere

small leak = $50 \times 4.4 \times 10^{-3}$ $(0.5 + 0.17 + 0.02)$
$= 0.15$ hours/year - zone 2

large leak = $50 \times 8.8 \times 10^{-6}$ $(0.5 + 0.17 + 0.02)$
$= 3 \times 10^{-4}$ hours/year - safe area

Final assessment from flange leaks = 3m zone 2

DISCUSSION

This brief example thus illustrates some of the simple but time consuming procedure called for in the application of a quantitative method.

Going back to the Classification area shown previously, the reasons for the changes can perhaps now be explained.

1. The major change is that most of the Zone 2 areas have been reclassified as Zone 1. This has come about by consideration of the types of leaks that could occur and how long any flammable atmosphere could last.

for example, the type of equipment and its layout used in the main buildings resulted in relatively infrequent leak sources of a minor range.

2. The Classifications now reflect the activities of the areas concerned.

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for example, loading/offloading points, the methods used can result in spills or emissions which can be appropriately highlighted.

Another spin-off from the development of this type of approach is through the appreciation of the many influencing factors. Hazard Areas for proposed plants can be outlined at an early stage. Consideration of the materials to be handled, the conditions of use, the type of plant and its layout, enables preliminary Hazard Area analysis to indicate the type of electrical equipment likely to be required with a new plant.

It is important to note, especially with a quantitative approach, the limitations of Hazard Areas. They control the type of electrical equipment to be used. It is common practice in some places to use Hazard Areas as influencing factors in other activities to be carried out in that area. Hazard Areas indicate the some potential for flammable atmosphere they do not cover all circumstances.

It is quite possible using a lower limit for Zone 2 that some areas handling flammable material will result in classification as safe areas. For example a long stretch of pipe in the open with no valves and limited flanges. Leaks from lines & flanges would no overlap and be so rare as not to result in hazard area classification. This does not indicate that maintenance activities can be allowed to take place without precaution. All works activities should be judged on their own merits taking into account of and not be dictated by the presence or otherwise of Hazard Areas.

It is hoped that this brief outline of some of the considerations taken into account on Hazard Area analysis at Associated Octel has enabled some appreciation of the benefits that could be gained, despite the time consuming aspect of such an approach.

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