groups and/or subcommittees in the Standards
development community need underlying cohesive
technical and financial support to develop effective
standards where complex, broad, and/or long range
issues are involved. It would seem that Gas Research
Institute support for work within the American Gas
Association Laboratories would be a logical route for
research on Standards issues important to the gas
industry.

We may summarize our conclusions and
recommendations then in the following manner:

o Intrinsic design protection, rather than
  reliance on piping codes, instruction'
  materials, etc. is the preferred route for
  protection against intrusion by
  foreign objects and for protection against
  particulate contamination originating in the
  fuel supply system. With respect to
  particulate protection the priority is with
  controls intended for LP gas appliances, but
  should be a consideration with all controls.

o Protection against contaminants, now applied by
  control manufacturers solely to their own
  individual specifications, should be subject to
  a minimum consensus standard. A control valve
  should function when subject to the maximum
  loading of particulate matter passing a
  sediment trap component under specified inlet
  test conditions, or be inherently capable of
  function under the same inlet test
  conditions specified for traps where the
  integral nature of a specific design precludes
  separate component testing.

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o Funding and management resources should be
   set-up to provide appropriate technical support
   for standards development where complex, broad
   or long range issues are involved. One
   specific candidate for this support should be
   standards development in particulate control.

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4.2.3 Odorization

LP-Gases sold for fuel purposes are required to be odorized (NFPA #58) by the addition of a warning agent. The historical and current requirement is that a "distinct odor, down to a concentration in air of not over one-fifth the lower limit of flammability", be detectable. In effect, then a 0.4% by volume concentration of LP-gas in air should be detectable (California requires detectability at 0.3%). NFPA #58 is footnoted with the caveat that "it is recognized that no odorant will be completely effective as a warning agent in every circumstance".[5] A further footnote states that "experience has shown 1.0 lbs ethyl mercaptan per 10,000 gallons of liquid gas is effective. Research[14] has shown 6.4 lbs of thiophane per 10,000 gallons liquid propane will also satisfy the requirement". In actual practice odorant addition is usually in excess of this minimum, with 1.2 to 1.5 lbs. per 10,000 gallon addition typical for ethyl mercaptan. This addition of odorant to liquid gas will yield on the order of 15 to 20 parts per billion odorant concentration in air at one-fifth the lower explosive limit.

Consider the compound ethyl mercaptan, the prinicipal odorant used with propane. This material has good odorant properites provided it is not in an environment where it will be oxidized or otherwise broken down chemically. Unfortunately it is only moderately stable and tends to break down in the presence of such entities as iron oxide (rust). Its lack of stability would likely render ethyl mercaptan unacceptable if it were not for special requirements of two phase (vapor and liquid) systems to have an odorant

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with compatible phase equilibria characteristics. The
ideal system, of course, would yield equal odorant
concentrations under all delivery conditions. Ethyl
mercaptan does not approach any ideal, but represents a
utilitarian compromise. Adsorption of the odorant on
contact surfaces, a phenomenon principally associated
with new cylinders, tanks or piping (but not
exclusively so) can also act to reduce the level of
odorant at the point of delivery to the consumer.

Odorization of LP gas will typically take place at
the loading rack of the refinery or major terminal
supplier. The level of odorization may or may not be
verified by test. If a test is performed it may or may
not readily distinguish between effective odorant and
ineffective breakdown products. "Certification" (check
mark on a piece of paper) of initial odorization, not
subsequent testing is the rule as the fuel passes
through the distribution chain.

Thiophane (tetrahydrothiophene) is a cyclic
sulfide odorant valued for its resistance to oxidation.
However, it lacks a good volatility fit. It is also
more costly, but in terms of effect on total gas sales
price the cost differential should not be a substantial
factor. It is believed that only a single major LPG
supplier uses thiophane.

The issue of volatility is significant. Figure
4-7 shows vapor pressure curves for key odorants,
freezing point depressants and dimethyl sulfide, a
common breakdown product and deliberate modifier.
Tertiary Butyl Mercaptan (TBM) is the principal odorant
used in natural gas because of its good odor impact and
chemical stability (resistance to oxidation). As
commercially produced the prinicipal odorants are not

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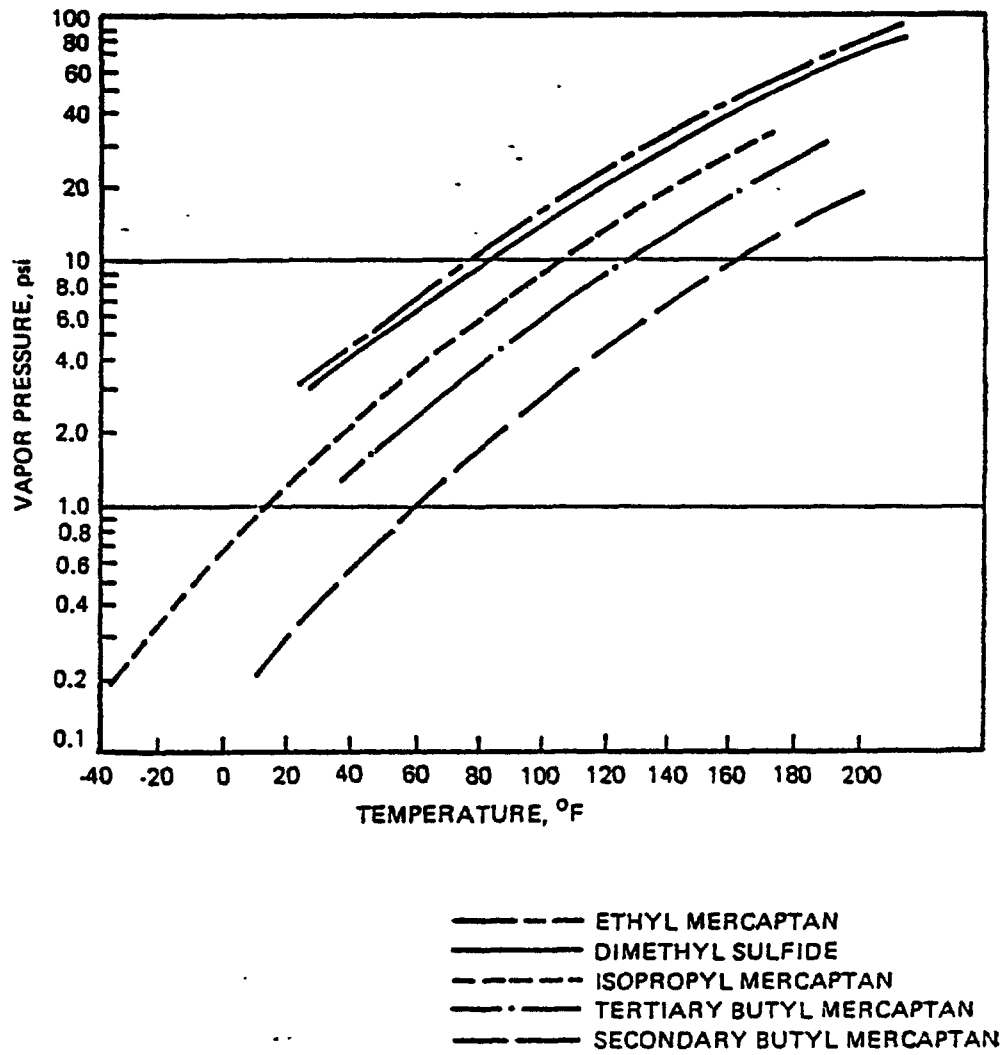
Figure 4-7   VAPOR PRESSURES VS TEMPERATURE FOR COMMON ODORANTS AND ADDITIVES

pure and therefore will have a narrow boiling range,
not a fixed boiling point. Typical distillation end
points for ethyl mercaptan, thiophane and a common 80%
TBM odorant are 98 F, 256 F and 160 F respectively.
Even the most volatile odorant, ethyl mercaptan will
have a vapor/liquid equilbrium constant in propane on
the order of 0.2 under typical conditions. The net
effect is lower concentration of odorant in the vapor
compared to the liquid, and an increasing level of
odorant in the vapor as the tank supply approaches
depletion. The lower the volatility of the odorant the
more pronounced these effects will be. The LPG
container and regulator is a simple distillation
column. The liquid LP-gas is at thermodynamic
"saturation" conditions, i.e., its boiling point for
the temperature and pressure prevailing. When a demand
for gas is created ,the vapor draw-off upsets the
equilibrium and vapor boil-off in the container begins.
Therefore mixtures will separate according to their
vapor/liquid equilbria values. Hence the ratio of
components in the liquid and the vapor will be
different and changing continuously on drawdown. Thus,
the question of substitution of odorant for LP-gas is
not as straightforward as it might seem.

The above notwithstanding, the accident/injury
picture clearly demonstrates a problem. Tests with new
containers have shown odorant disappearance in as
little as 48 hours.[15] Older containers with internal
rust or debris will also exhibit odorant fade. This is
particularly important to consider for containers which
might be empty for a period of time with the shut-off
valve open, exposing them to atmospheric air. This
would include essentially all customer owned portable
containers, and exchange cylinders. Current visual
inspection rules require no internal inspection. Hence

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the problem is unlikely to be detected before an accident occurs.

Assuming the odorant is "intact" as delivered at the residence, the presence of unburned fuel may still go undetected. Odorant in fugitive gas may be adsorbed or reacted on contact surfaces. This can include soil adsorption/reaction for in-ground sourced leaks, or adsorption on masonry walls in basements, for example. Human factor elements such as physical distraction, the variation in olfactory sense between individuals, presence of masking agents, disease or age induced degradation of the ability to smell can be important. Absence of a person to detect a leak before it becomes dangerous is a consideration.

There are obviously an array of issues dealing with odorization and the overall detection issue which we have just touched upon. Priority recommendations are found in Section 2.0.

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5.0   Equipment Considerations

5.1   Introduction

In the forthcoming discussion we will frequently refer to consensus standards which are relevant to the equipment or activity under discussion. Figure 5-1 references many of these codes in a pictorial arrangement of a residential system using an ASME stationary, aboveground tank.

Figure 5-2 provides code references for DOT (ICC) cylinders and Figure 5-3 provides similar material for a DOT portable tank.

Container spacing arrangements for residential settings are shown in Figures 5-4, 5-5, 5-6, and 5-7 for DOT cylinders, ASME aboveground tanks and ASME underground tanks, respectively.

LP-gas systems for residential purposes must be "approved" to comply with NFPA #58. This is defined as being acceptable to the "authority having jurisdiction". Irrespective of who the "authority" is, the net effect is that in most localities (but with some important exceptions) compliance with the codes and specifications referenced is achieved by utilizing components such as valves, regulators and relief devices design certified or tested by a nationally recognized laboratory such as Underwriters Laboratories (UL).

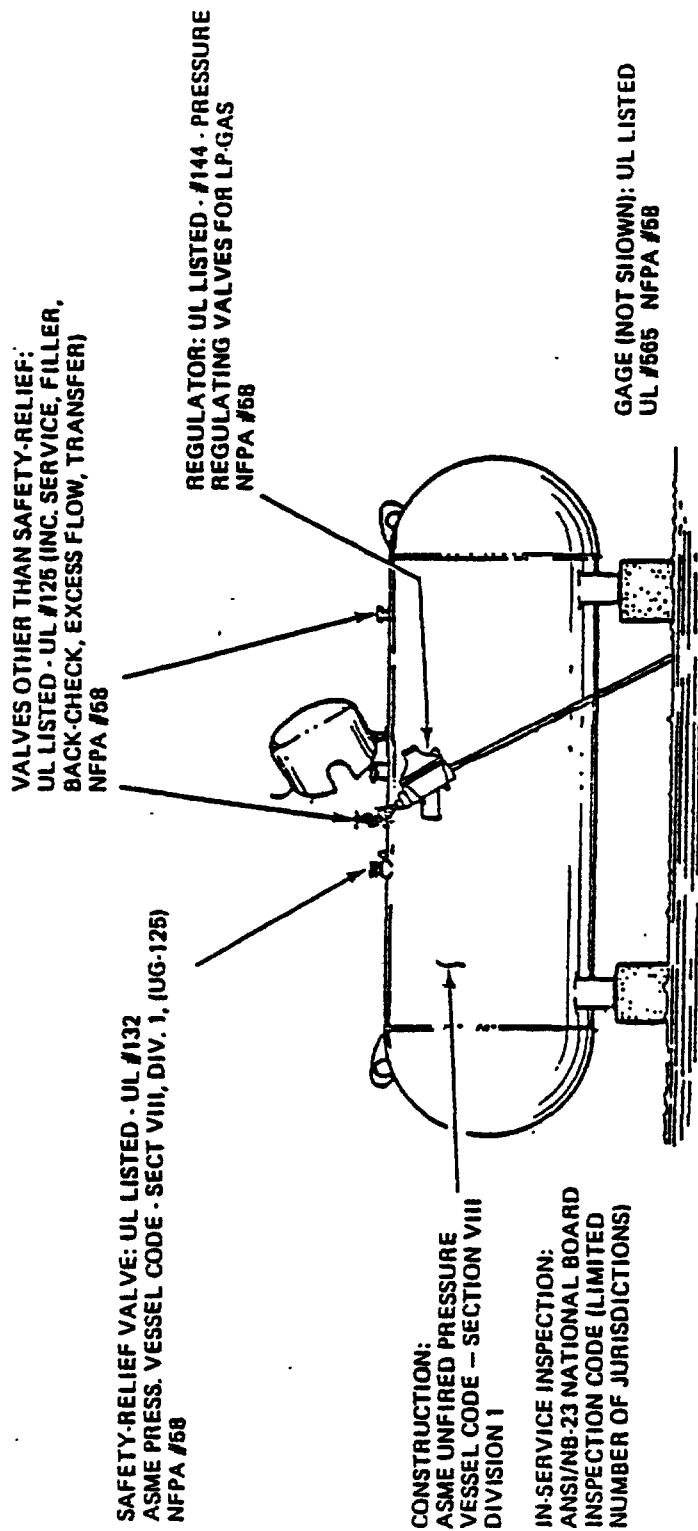### 5.2   Containers & Valves (Inc. Safety-Relief)

5.2.1   Containers

Two principal classes of containers are utilized
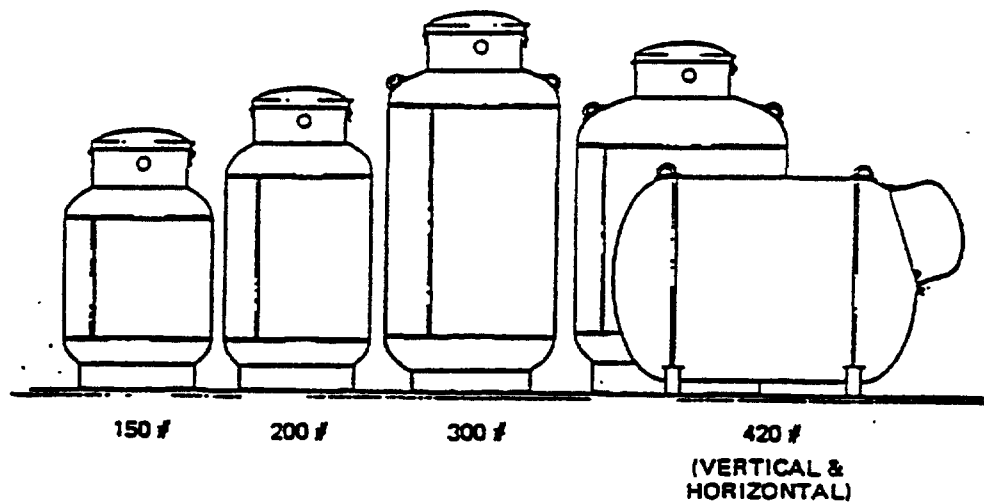
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ASME STATIONARY TANK

VALVES OTHER THAN SAFETY-RELIEF:
UL LISTED - UL #125 (INC. SERVICE, FILLER,
BACK-CHECK, EXCESS FLOW, TRANSFER)
NFPA #58

REGULATOR: UL LISTED - #144 - PRESSURE
REGULATING VALVES FOR LP-GAS
NFPA #58

GAGE (NOT SHOWN): UL LISTED
UL #565 NFPA #58

COMPLETE CONTAINER ASSEMBLIES
UL LISTED - UL #644
(ALSO INCLUDES UNITS FOR
UNDERGROUND INSTALLATION

SAFETY-RELIEF VALVE: UL LISTED - UL #132
ASME PRESS. VESSEL CODE - SECT VIII, DIV. 1, (UG-125)
NFPA #58

CONSTRUCTION:
ASME UNFIRED PRESSURE
VESSEL CODE — SECTION VIII
DIVISION 1

IN-SERVICE INSPECTION:
ANSI/NB-23 NATIONAL BOARD
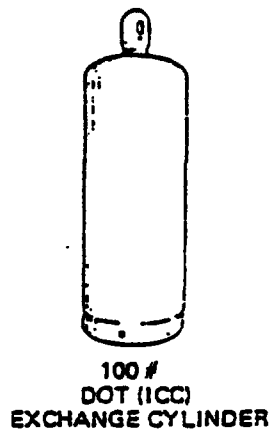INSPECTION CODE (LIMITED
NUMBER OF JURISDICTIONS)

GENERAL DESIGN, CONSTRUCTION, INSTALLATION & OPERATING
REQUIREMENTS — NFPA #58 - STANDARD FOR STORAGE AND
HANDLING OF LIQUEFIED PETROLEUM GASES

Figure 5-1 EXAMPLE CODES & STANDARDS

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150 #   200 #   300 #   420 #
(VERTICAL &
HORIZONTAL)

DOT STATIONARY CYLINDERS

100 #
DOT (ICC)
EXCHANGE CYLINDER

CYLINDER CODES

DOT CODE	CYLINDER MATERIAL	CYLINDER CONSTRUCTION	SERVICE PRESSURE (psig)
3A	Steel	Seamless	240 or 300
3AA	Steel	Seamless	240 or 300
3B	Steel	Seamless	240 or 300
4E240	Steel	2 or 3 pc., welded or brazed	240
4BA240	Alloy Steel (prescribed)	2 or 3 pc., welded or brazed	240
4BA300	Alloy Steel (prescribed)	2 or 3 pc., welded or brazed	300
4BW240	Steel (prescribed)	3 pc. welded	240
4BW300	Steel (prescribed)	3 pc. welded	300
4E240	Aluminum	2 pc. welded	240
4E300	Aluminum	2 pc. welded	300

DOT CODE	CODE OF FEDERAL REGULATIONS REFERENCE		
	SPECIFICATIONS	QUALIFICATION, MAINTENANCE & USE	LIQ. COMPRESSED GASES REGS
3A	49CFR178.36	49CFR173.1-4, 34	49CFR173.300-301, 304
3AA	49CFR178.37	"	"
3B	49CFR178.38	"	"
4B	49CFR178.50	"	"
4BA	49CFR178.51	"	"
4BW	49CFR178.61	"	"
4E	49CFR178.68	"	"

Figure 5-2   DOT/ICC CYLINDER DATA

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LIFTING LUG

DATA PLATE

DOME
OR COVER

PROTECTIVE RING

OPENINGS

SKID
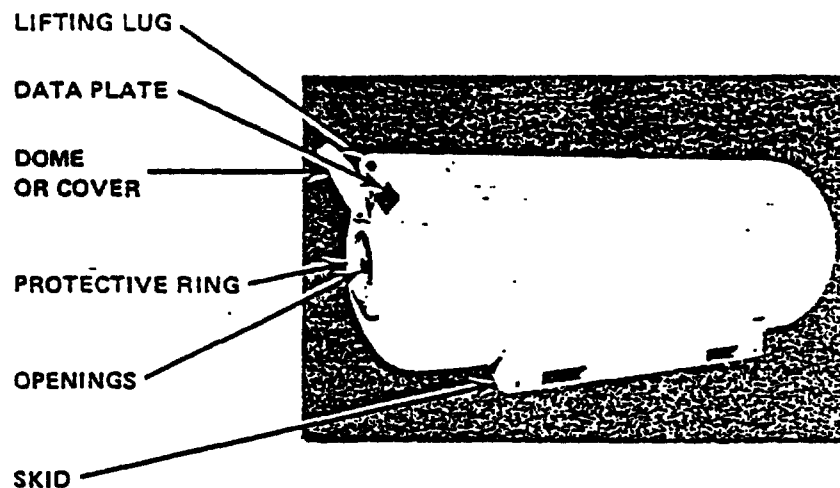
Source: National Training Aids and
Compressed Gas Association

CONSTRUCTION SPECIFICATIONS: 49CFR178.245   ASME CODE SECT VIII, DIV. 1
ASME CODE SECTION IX (WELDING)

FILLING: 49CFR173.315

PRESSURE RELIEF: 49CFR173.315 (Ref. CGA S-1.2)

Figure 5-3   DOT/ICC PORTABLE TANK (DOT51)

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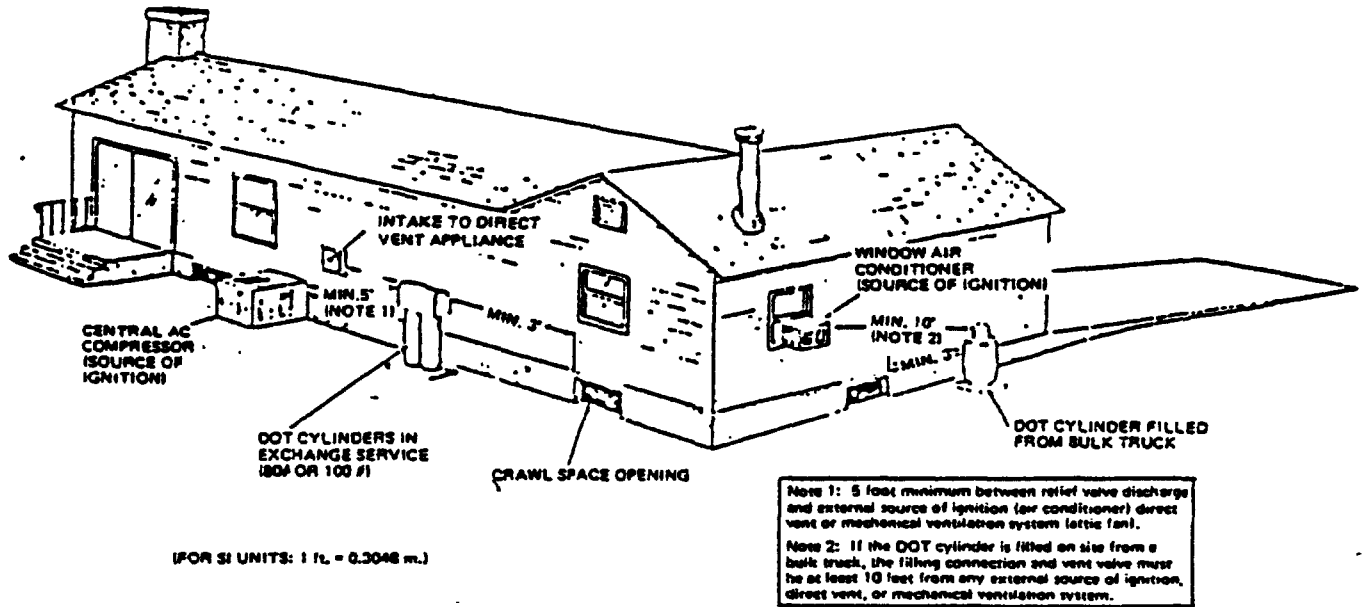
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LP-GAS CONTAINER INSTALLATION SPACING

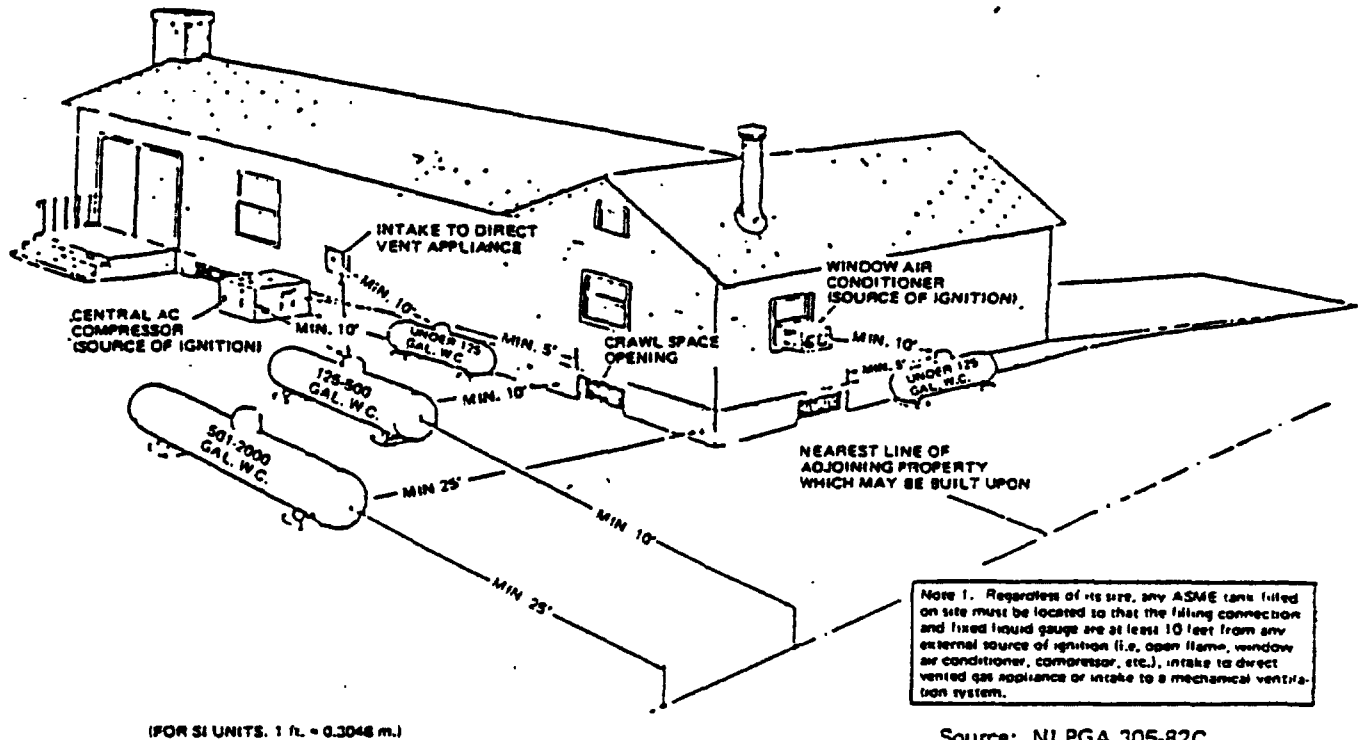INTAKE TO DIRECT
VENT APPLIANCE

WINDOW AIR
CONDITIONER
(SOURCE OF IGNITION)

MIN. 10"
(NOTE 2)

MIN. 5'
(NOTE 1)

MIN. 3'

MIN. 3'

CENTRAL AC
COMPRESSOR
(SOURCE OF
IGNITION)

DOT CYLINDERS IN
EXCHANGE SERVICE
(30# OR 100 #)

CRAWL SPACE OPENING

DOT CYLINDER FILLED
FROM BULK TRUCK

Note 1: 5 foot minimum between relief valve discharge
and external source of ignition (air conditioner) direct
vent or mechanical ventilation system (attic fan).

Note 2: If the DOT cylinder is filled on site from a
bulk truck, the filling connection and vent valve must
be at least 10 feet from any external source of ignition,
direct vent, or mechanical ventilation system.

(FOR SI UNITS: 1 ft. = 0.3048 m.)

Figure 5-4   DOT CYLINDERS

INTAKE TO DIRECT
VENT APPLIANCE

WINDOW AIR
CONDITIONER
(SOURCE OF IGNITION)

CENTRAL AC
COMPRESSOR
(SOURCE OF IGNITION)

MIN. 10'

MIN. 10'

UNDER 125
GAL. W.C.

MIN. 5'

CRAWL SPACE
OPENING

MIN. 10'

125-500
GAL. W.C.

MIN. 10'

MIN. 5'

UNDER 125
GAL. W.C.

501-2000
GAL. W.C.

MIN 25'

MIN. 10'

MIN 25'

NEAREST LINE OF
ADJOINING PROPERTY
WHICH MAY BE BUILT UPON

Note 1. Regardless of its size, any ASME tank filled
on site must be located so that the filling connection
and fixed liquid gauge are at least 10 feet from any
external source of ignition (i.e. open flame, window
air conditioner, compressor, etc.), intake to direct
vented gas appliance or intake to a mechanical ventila-
tion system.

(FOR SI UNITS: 1 ft. = 0.3048 m.)

Source: NLPGA 305-82C
Based on text of NFPA #58

Figure 5-5   ABOVEGROUND ASME TANKS

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LP-GAS CONTAINER INSTALLATION SPACING

INTAKE TO DIRECT
VENT APPLIANCE

WINDOW AIR
CONDITIONER
(SOURCE OF IGNITION)

CRAWL SPACE OPENING

MIN. 10'
(NOTE 2)

CENTRAL AC
COMPRESSOR
(SOURCE OF IGNITION)

MIN. 10'
(NOTE 2)

MIN. 10'
(NOTE 2)

CRAWL SPACE OPENING

MIN. 10'
(NOTE 2)

1000 GAL
OR LESS

MIN. 10'
(NOTE 2)

Note 1: The filling connection and vent from liquid
level gauge on tank filled at the point of installation
must be at least 10 feet from any external ignition
source, direct vent or mechanical ventilation.

Note 2: Minimum distances for underground con-
tainers shall be measured from the relief valve and
filling connection of the container except that no
part of an underground container shall be less than
10 feet from a building or line of adjoining property,
which may be built upon.

NEAREST LINE OF
ADJOINING PROPERTY
WHICH MAY BE
BUILT UPON

(FOR SI UNITS: 1 ft = 0.3048 m.)

Source: NLPGA 305-82C
Based on text of NFPA #58

Figure 5-6   UNDERGROUND ASME TANKS

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in residential applications, cylinders fabricated to
DOT specifications[7] and tanks fabricated to ASME Boiler
and Pressure Vessel Code[8] requirements. The DOT
Specification 51 Portable Tank (also ASME code
certified) is rarely found in residential applications.
Table 5-1 lists common ASME and DOT containers of
interest.

There are several distinct differences between DOT
(ICC before 1967) and ASME containers. Department of
Transportation specification containers are designed to
be transported in the filled condition. Constructional
features, such as valve protection, safety relief valve
pressure settings, etc. are predicated on the
transportation environment. Methods of filling and
percentage of fill are specifically called out in DOT
regulations (49 CFR 173) for DOT containers.
Similarly, initial inspection, certification, and one
would particularly note that important in-service
inspections are called out in Title 49.

ASME Code vessels for LP-Gas are fabricated for
two different service classifications, stationary and
mobile. Unless specifically stated the discussion in
this report deals with ASME tanks for stationary
applications. ASME Stationary tanks, unlike DOT tanks,
are not intended to be moved while loaded, and are
restricted to no more than 5% of their loading volume
with liquid product while being moved. Valve
protection, mounting and lifting accessories are not
required to be as robust as those of DOT cylinders.
Basic vessel strength is similar, however, since the
stresses from internal pressure (vapor pressure of LPG)
are high enough to be the controlling factor.

Table 5-1

COMMON DOT & ASME CONTAINERS

TYPE OF SERVICE	TYPICAL USE	PROPANE CAPACITY (in lbs.)	WATER CAPACITY (in lbs.)	COMMON DOT MFG. CODE
Stationary	Homes, Business	420	1,000	4B, 4BA, 4BW
Stationary	Homes, Business	300	715	4B, 4BA, 4BW
Stationary	Homes, Business	200	477	4B, 4BA, 4BW
Stationary	Homes, Business	150	357	4B
Exchange	Homes, Business	100	239	4B, 4BA, 4BW
Exchange	Homes, Business	60	144	4B, 4BA, 4BW
Motor Fuel	Tractor	.00	..0	4B, 4BA, 4BW
Motor Fuel	Tractor	60	...4	4B, 4BA, 4BW
Motor Fuel	Fork Lift	43.5	..04	4B, 4BA, 4BW, 4E
Motor Fuel	Fork Lift	...5	90	4B, 4BA, 4BW, 4E
Motor Fuel	Fork Lift	2.	48	4B, 4BA, 4...A, 4E
Motor Fuel	Fork Lift	4	..4	4B, 4BA, 4BW, 4E
Portable	Rec. Vehicles	40	96	4B, 4BA, 4BW, 4E
Portable	Rec. Vehicles	30	72	4B, 4BA, 4BW, 4E
Portable	Rec. Vehicles	25	59.5	4B, 4BA, 4BW
Portable	Rec. Vehicles, Grills	20	48	4B, 4BA, 4BW, 4E
Portable	Rec. Vehicles & Sm. Ind.	10	23.8	4B, 4BA, 4BW, 4E
Portable	Indoors, Trailers	5	12	4B, 4BA, 4BW, 4E
....	....	1 lb.	2.2	4.. (disposable) 4 :240 (refillable)

Note: Shaded items excluded from this study.

TYPICAL STATIONARY ASME TANKS

TYPE OF SERVICE	WATER CAPACITY (in gals.)	LP-GAS CAPACITY (in gals.)*
Domestic	100	80
Domestic	125	100
Domestic	150	120
Domestic	250	200
Domestic	325	280
Domestic	500	400
Domestic	1,000	800

*Based on propane specific gravity of 0.508 @ 60°F

Ref.: National Training Aids & Services

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Unfortunately there is no standardized nomenclature regarding pressure ratings between DOT and ASME, although ultimate design strengths are similar for ASME stationary tanks and DOT cylinders typically employed for LP service. Relief settings and hydrostatic test requirements are dissimilar. A 250 psig design pressure ASME tank and 240 psig service pressure DOT cylinder are roughly equivalent in basic design strength. However, the ASME tank will have a safety relief setting of 250 psig and the DOT cylinder will have a safety-relief setting of 375 psig.

It should not be assumed that the lower safety-relief set point for relief of internal pressure for containers of similar design strength represents the safer design. In fact, the opposite is sometimes true. The ASME code is not "commodity driven", as are the DOT specifications. For a given design rating the ASME code is directed at "saving the container" from excessive internal pressure. The hazard of releasing the contained material is not directly considered. The designer of a pressure vessel for an intrinsically dangerous, highly flammable commodity such as LP-gas, however, must have a second priority concern. That is the prevention of the release of the dangerous commodity.

In a previous section the response of LP container relief systems as a function of temperature was graphically presented. From this it would be concluded that a 250 psig ASME design container is likely to reach temperatures close to summer ambients that in significant portions of the U.S. will likely result in the release of gas through the safety relief system. Fortunately most of the more vulnerable tanks where highest risks are involved (mobile) are of 312.5 psig ASME design rating. However, this is not universally

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true. The use of 250 psig rated ASME tanks in higher
risk applications should be banned outright. On the
other hand, we see no substantial problem on a general
scale with the 250 psig rating for stationary tanks in
residential service, recognizing that there may be some
localized problem areas.

NFPA #58 has call-outs for container appurtenances
and safety device requirements for filling, withdrawal
and equalizing connections (Table 2.3.3.2 of NFPA #58)
on DOT and ASME containers. In general, back check or
excess flow valves are required to prevent uncontrolled
flow of fuel in the event of physical rupture or
break-off of connections to the tank. An important
exception is for withdrawal (service) valves on ASME
tanks. As an alternative, a restrictive orifice (5/16
in max.) between the container contents and the outlet
of the shut-off valve is permitted for containers less
than 2000 gallons water capacity. This exception opens
the door for uncontrolled releases in the event the
valve is broken off. In fact, even if an excess flow
valve is supplied, an external design is allowed,
also opening the door for uncontrolled releases with
valve break-off. The valve is vulnerable on an ASME
stationary tank since the cover strength requirements
are minimal.

The valve requirement should be changed. The
preferred requirement is a service valve with an
internal excess flow valve. An example is shown in
Figure 5-7. It is recognized that in certain
applications excess flow valves are prone to
unacceptable levels of nuisance shut-off. In cases
where such erratic performance could lead to excessive
economic loss or dangerous conditions, the alternative
would be to permit a restrictive orifice on a valve in

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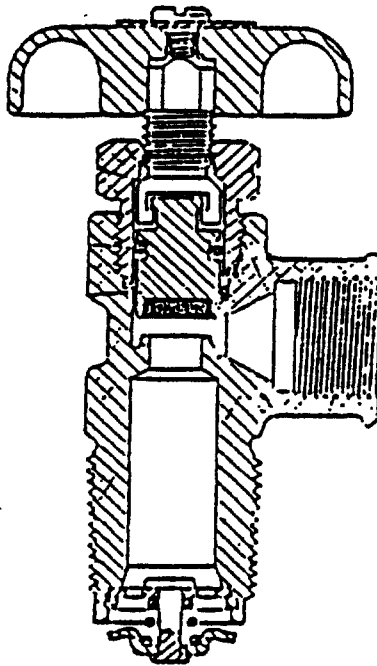
Figure 5-7 SERVICE VALVE WITH INTERNAL EXCESS FLOW CHECK VALVE

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a position not subject to break-off (such as the
threaded inlet portion).

5.2.1.1 Container Inspection

Another major difference between DOT and ASME
containers deals with in-service inspection
(re-qualification). DOT provides for mandatory
inspection, providing three alternative methods under
49CFR173 rules. NFPA #58 calls out the DOT rules and
also identifies the responsible party for
requalification of a DOT cylinder. This type of
clarity should be used as a model throughout NFPA #58.
There are no specific inspection requirements for ASME
containers in NFPA #58. Hence, spelled-out inspections
are only required if a local or state jurisdiction
requires same. Few do. NFPA #58 has a minimal general
clause only that could be construed as applicable for
ASME tanks. Where local or state jurisdictions do
require in service inspection, this is typically
undertaken by a National Board[16] certified inspector.

There is nothing so fundamentally different
between ASME and DOT containers in residential service
that one should draw no attention (unless fire damaged)
and the other have a spelled out inspection program.
We believe the correct route is to develop and adopt
formally a set of requirements for ASME tanks, as well.

Turning now to the quality of inspection for
requalification of DOT cylinders, two types of
hydrostatic testing are spelled out as acceptable to
DOT. A third inspection alternative, and by far the
most popular, is visual inspection -- external visual
inspection.

All three types of examination are predicated on establishing structural integrity of the pressure vessel. The assumption is made with respect to the visual method that external corrosion would always predominate over internal corrosion, given the normal contents were LP-gas. Even given the internal exam that is part of the overall hydrostatic test procedures, light corrosion would not be cause for rejection. Hence, none of the tests as presently conducted protect against a condition, rust, which can critically impair through chemical reaction the prinicipal warning to the consumer of leaks--the odorant added-to LP gas.

Visual examinations can be sound or essentially without value. The mechanism to provide an independent audit (not just of paperwork) to insure competence of personnel and quality of procedures is not in place, although the external inspection guides and procedures themselves are. Recommendations may be found in Section 2.0 for improving the control over inspection procedures.

5.2.2 Pressure Relief Valves

NFPA #58 requires "approved" pressure relief devices under DOT regulations for DOT specification containers and direct spring-loaded pressure relief valves conforming to UL132 or equivalent for ASME containers. Because of variations in rating method between UL and ASME, capacities have been dual stamped on relief valves. Historically there have been several problems for manufacturers due to set point tolerances, rating differences, etc. between various codes and standards. This has been resolving itself (e.g., eliminating UG-125 et. seq. from ASME code). Valve designs themselves remain basically unchanged, being spring-loaded poppet type.

A poppet design pressure relief valve opposes by spring force the load imposed on the valve by internal pressure in the container acting on the area of the valve which "sees" the contents of the container. The intrinsic design is such that when the valve begins to open a larger presented area of the valve is exposed to the gas in the container , creating a sudden increase in opening force--"popping" the valve open. Once flow is established, dynamic pressure from the flowing gas is also available tending to keep the valve open. Hence, the dynamic pressure and larger presented area of the valve means the closing pressure will be significantly lower than the opening pressure, thereby giving the safety relief system a "blowdown" characteristic. In "exercising" a relief system the rate-of-rise and rate-of-lowering in pressure can affect the initial "simmer" or start-to-discharge point, "pop" point (high rate flow established), "blow-down" and reseating pressure. Moreover

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repetitive testing will typically show a temporary
shift downward in set-point in closely spaced trials.
This shift is almost intrinsic with materials which
must be chosen for longevity and weather resistance
rather than exclusively for good hysteresis, friction
and surface compliance characteristics. There is
nothing inherently wrong with the behavioral
peculiarities described as long as they are kept in
mind. There can be a tendency to focus entirely on the
rated start-to-discharge point as indicative of
operational behavior.

Let us examine the Underwriters Laboratories
requirements regarding these performance elements as
set forth in UL 132. Table 5-2 lists the approximate
product temperatures generating a vapor pressure
sufficient to affect the start-to-discharge and re-seal
requirements per the Standard. Values are given for
ethane rich (but in specification) propane and pure
propane. In particular note the values for a standard
250 psig set-point valve on an ASME tank, versus the
same values for a DOT cylinder. A 20 plus degree
temperature shift in the one case is of little
consequence. In the lower set-point case the shift
moves from a low probability of occurrence value to a
very real probability of occurrence point. Hence our
concerns expressed earlier regarding smaller ASME
containers and the additional possibilities for
problems by air contamination. Figure 5-8 illustrates
the same information graphically with the vapor
pressure curves.

Standard UL 132 has no limits established on
popping pressures or blowdown pressures. The results
are simply recorded. It is revealing to see what these
values might be on a UL listed valve. A specific test

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Table 5-2

UL LISTED SAFETY-RELIEF VALVES
APPROXIMATE START-TO-DISCHARGE & RESEALING
TEMPERATURES FOR SELECTED CONDITIONS

UL STANDARD 132		250 psig NOM.			375 psig NOM.	
		C_3	C_2-C_3		C_3	C_2-C_3
START-TO-DISCHARGE (MIN.) PARA. 11.1	250 psig	$128^\circ F$	$112^\circ F$	375 psig	$158^\circ F$	$148^\circ F$
START-TO-DISCHARGE (MIN.) PARA. B.1 (AFTER FLOW TEST)	(85% OF 11.1)	$112^\circ F$	$100^\circ F$		$148^\circ F$	$136^\circ F$
RESEAL PARA. 11.2	(90% OF 11.1)	$118^\circ F$	$106^\circ F$		$153^\circ F$	$142^\circ F$
RESEAL PARA. B.2 (AFTER FLOW TEST)	(80% OF 11.2)	100°	$90^\circ F$		$135^\circ F$	$123^\circ F$

NO POP PRESSURE OR BLOWDOWN REQUIREMENTS

C_3 — PURE PROPANE
C_2-C_3 ~ 94.5 PROPANE/5.5 ETHANE

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VAPOR PRESSURE VS TEMPERATURE CURVE FOR PROPANE
AND PROPANE/ETHANE MIXTURE
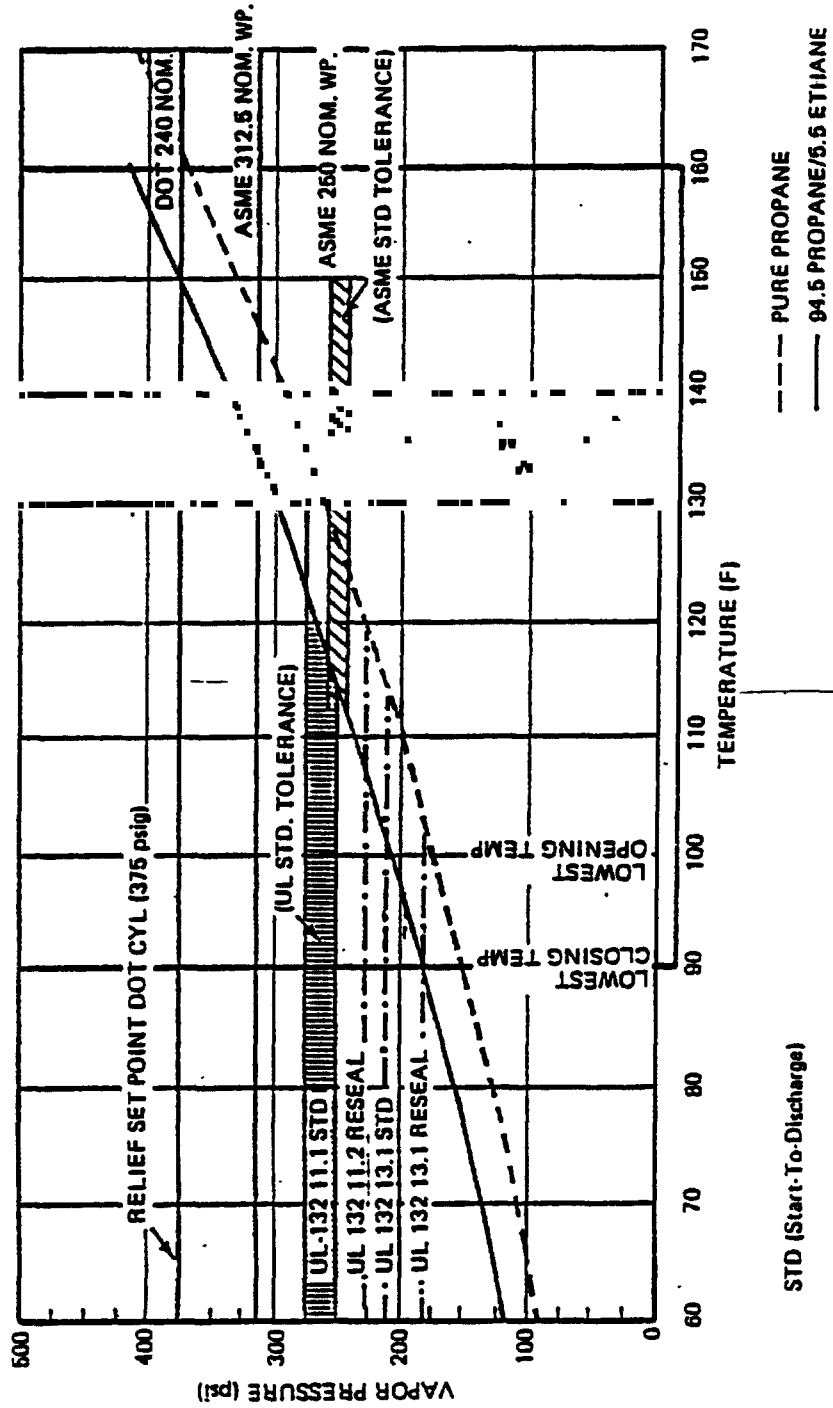
Figure 5-8   SAFETY RELIEF OPERATING PARAMETERS

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of a valve for UL132 parameters produced a
start-to-discharge pressure of 250 psig and a re-seal
pressure of 238 psig, i.e. in specification[17]. The
popping pressure was 265 psig and the blowdown pressure
was 173 psig. The latter corresponds to a product
temperature of 90. F for the ethane rich propane mix.
We believe that UL should establish specific blowdown
limits for UL132.

Compressed Gas Association (CGA) Standards provide
the requirements for flow rates on pressure relief
systems (CGA S-1.1 for DOT cylinders and CGA S-1.2 for
ASME tanks). CGA pressure relieving standards have
their ultimate genesis in John Fetterly's work for the
Bureau of Explosives in the 1920's.[18] In their present
form they reflect information published by Cummings in
1951.[19] Unfortunately much of what was derived from
this work was seriously flawed or subject to
misinterpretation with regard to its limitations.[20]
Fortunately a particularly grevious flaw, dealing with
the fire exposure area on a tank is not as critical on
tanks of the size used for residential purposes, as in
some other applications.

From CGA S-1.2 relief flow capacity for LPG
follows the formula

$$Q_a = GuA^{0.82}$$

where
    Q_a = Flow Capacity in cubic feet per
        minute of air
    Gu = 53.6 for LPG
    A = Outside Surface Area of the
        Container is square feet

Appendix "G" contains the derivation of the above
capacity equation. A more detailed analysis of LPG

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relief requirements may be found in Reference 20. In essence the capacity formula assumes a heat flux of 34,500 BTU/hr/ft^2. This corresponds to a free-burning hydrocarbon pool fire with radiant flames. Effective flux rates in experiments including larger vesels[18,20] have been measured on the order of 25,000 BTU/hr/ft^2.

There can be a tendency to become overly involved in the validity of the 34,500 Btu/h/ft^2 coefficient without realizing the full implication of the area fractional exponent. Convenient charts of A versus $A^{0.82}$ can bury the significance in routine calculation. Let us present the same information in a different manner by calculating the effective unit flux for a given tank.

$$q' \text{ effective unit flux} = \frac{H}{A}$$

Variation of Flux With Area

Let	H	q
A=1ft^2	34,500 Btu/h	34,500 Btu/h ft^2
A=120 ft^2	1.749 x 10^6 Btu/h	14,574 Btu/h ft^2
A=1000 ft^2	9.8325x 10^6 Btu/h	9,833 Btu/h ft^2

A 120 ft^2 tank would be in the 500 gallon range. It may be seen from this that the effective flux is quite low, since 25,000 Btu/hr/ft^2 is easily realized for an average flux over the entire area of the tank.

However the situation is not necessarily as bad as it seems. The real test is whether enough vapor is

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extracted before the unwetted area of the tank fails. Also since only the wetted area (area contacted by internal liquid) is effective in heat transfer we need only have the peak vapor relieving capacity for a limited time.

A safety valve is basically a pressure maintaining device, not a pressure reducing valve beyond the limited range that we have already discussed. Figure 5-9 shows the effect of temperature on steel and aluminium cylinders. Routine fires can generate 1500.F temperatures.[23] If LP is involved the temperatures in a free burning radiant fire can be in the 2000.F range[20], and similar temperatures can build up inside burning structures, certainly more then enough to cause failure of a container.

It is important that the relief valve be communicating with a vapor space. Smaller cylinders can be prone to overturn, hence the relief valve may be in liquid. The relief valve can still function, but will not be effective in extracting latent vaporization energy from the container contents.

CGA has a test for proof-testing cylinders in a fire (CGA C-14). The tests need not be retroactively performed on previously approved containers. In other words, current containers built to specifications adopted before the cylinder fire test inclusion in 49CFR173.34 do not need to be tested. As a practical matter this includes nearly all current design DOT cylinders. The test fire, severe in the sense of total heat flux, is distributed in a manner which does not represent many real case scenarios, particularly uneven heating with high flux rates to the unwetted zone likely to occur in actual situations.
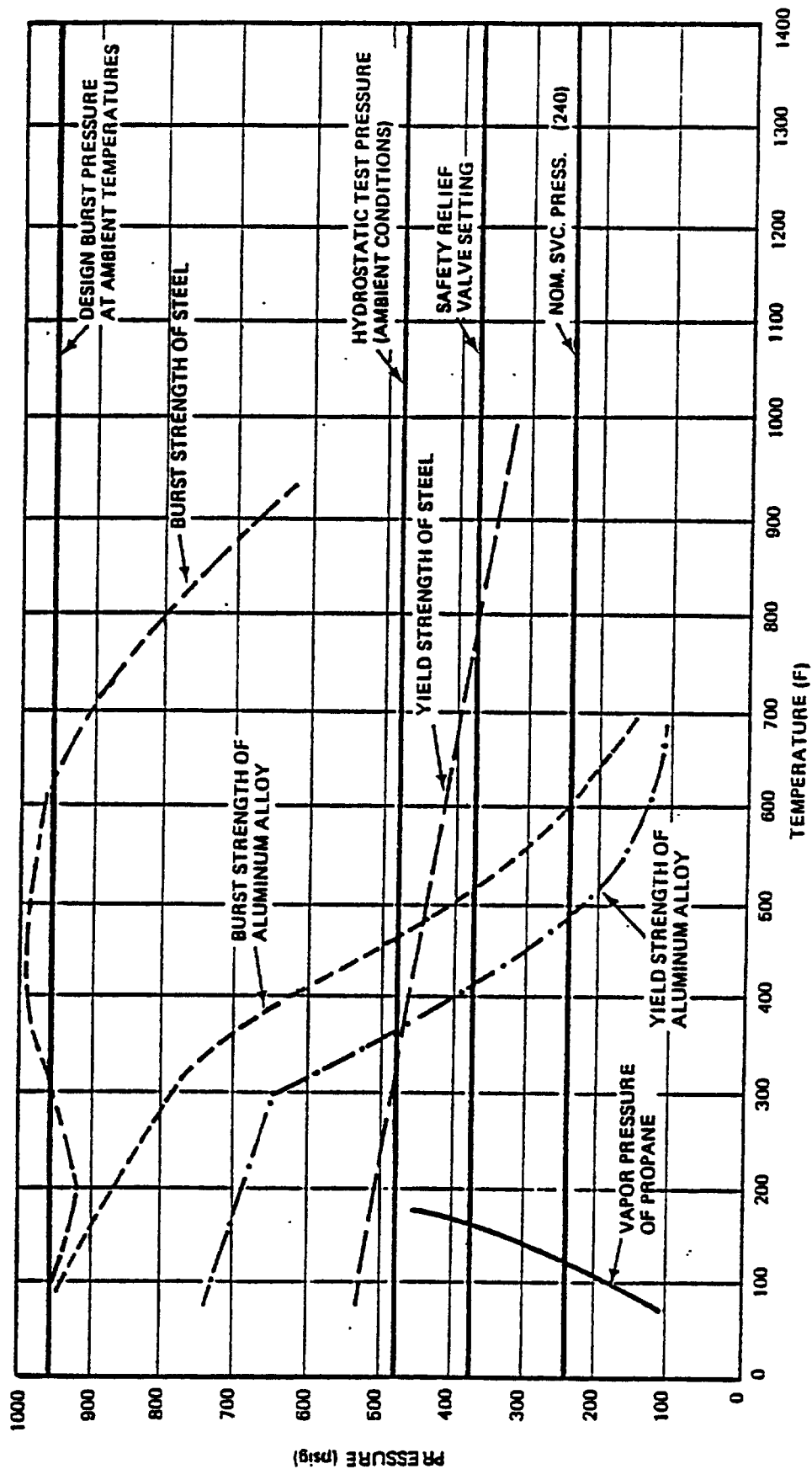
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Figure 5-9 PROPERTIES (TYPICAL) AS A FUNCTION OF TEMPERATURE — 4BA240 & 4BE240 DOT CYLINDERS

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What does all this mean? Fire exposures to above
ground tanks, such as grass fires exposing the liquid
area pose little threat with present safety relief
systems. Small cylinders (Steel) out of doors exposed
to fire will be made nearly empty by relief valve
operation, hence have little energy for violent rupture
in most cases. Aluminum cylinders are suspect in many
situations. Even with steel containers, exposure to
substantial overhead radiant heat (such as inside a
structure) or other localized heat source may cause
them to fail violently (Fig. 5-10). As a point of
interest, relief valves on 20 lb. cylinders are
generally "oversized" (factor of 2) compared to formula
derived values. This fact and the small surface area
negates a "formula" problem, but not the overall hazard
involved if the container is in a fire.

Basically, then, we cannot eliminate all major
threats irrespective of relief capacity formulas. It
is suggested that containers foreseeably to be found in
a structure, such as 20 lb. cylinders, be required to
be other than aluminum alloy (4BE specification) in
construction unless it can be demonstrated in realistic
fire scenarios to be equivalent to steel alloy
cylinders. Also, a research program into intumescent
or ablative coatings suitable for small containers
should be undertaken. Materials are already available
and in use for structural steels and larger LP vessels,
but many are not necessarily directly suitable for
small, customer owned containers.

There has been a trend away from reflective white
paint for customer owned containers, particularly 20
lb. models with portable grills. White reflective
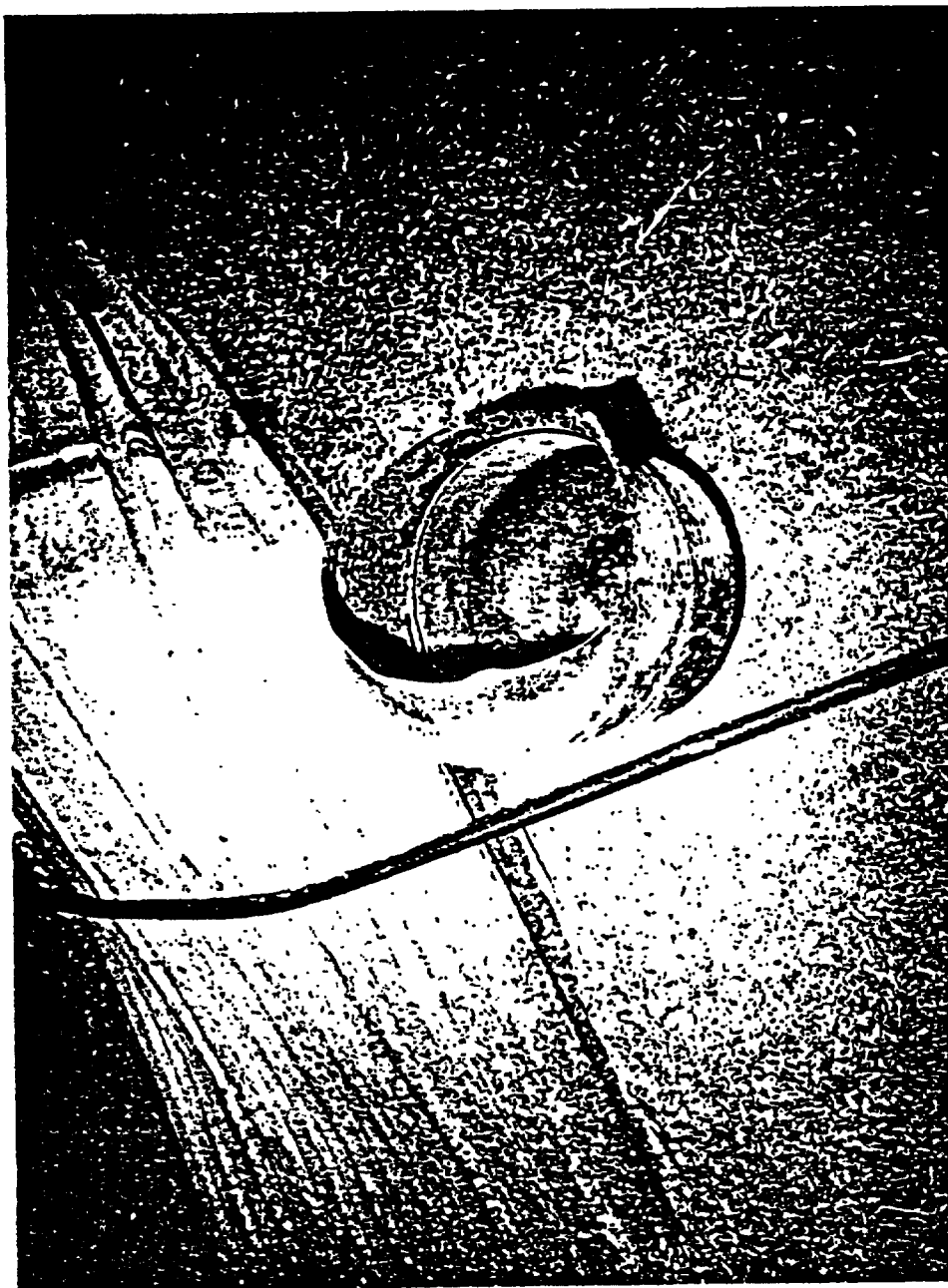paints are effective with solar exposures in keeping

Photo by Armstrong

Figure 5-10   REMAINS OF 20 LB. LP CYLINDER FOLLOWING VIOLENT RUPTURE AS
THE RESULT OF FIRE EXPOSURE

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internal pressures and liquid volume lower, a desirable
attribute. However, in the case of longer wavelength
radiant heating, such as from the burner box on a
barbecue, or in a fire, neither type of paint is
effective in substantially lowering heat transfer,
hence pressure rise. White, or other reflective paint
should be retained for portable containers. However,
no paint is a cure for overfilling or high temperature
environments.

5.3 Piping Systems

Prior discussion (Section 3.0) of priority hazards indicated no stand-out differences among choices in piping systems, fittings and connections in terms of a unified repetitive pattern of accidents. The exception was copper sulfide contamination of control valves where precautions had not been taken to preclude same. Otherwise copper systems have generally desirable properties. It also may not be practical to purchase long runs of internally lined (e.g. tinned) tubing to prevent initial copper sulfide formation. Hence, trapping to eliminate sediments or condensates regardless of cause or type is desirable.

Most accidents involving piping systems were physical damage or corrosion related, with poor installation or maintenance practices frequently in evidence. Multiple examples of poor installaion practice included improper support or lack of physical protection for exposed lines, and use of incorrect or improperly made up fittings. These type of problems are ones where a GAS Check type inspection program can be effective as an accident prevention tool.

Data involving appliance connectors was insufficient to develop whether more failures with this troublesome item occur with LP than with natural gas. Our concern is with ammonia contamination accelerating internally generated corrosion with LP systems. Hence this is an item to keep in mind for future monitoring.

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5.4 Regulators

5.4.1 Introduction

Pressure reduction and regulation of outlet gas pressure to a constant level suitable for appliance use is the critical function in an LP-gas delivery system. Pressure reduction may be accomplished in one or two stages in present systems, exclusive of any appliance regulators present. Figure 5-11 schematically illustrates one and two stage systems. Figure 5-12 is a crossectional schematic of an example final stage regulator.

UL #144 is the principal Standard covering LP regulators. NFPA #58 also has partial coverage of regulator requirements. In addition to considering a regulator as a pressure reducing and regulating valve, it must be considered as a heat transfer device, just as containers are, to understand certain physical phenomena. Vaporization of LP gases require heat. Heat not supplied through the container walls for vaporization must come from the "internal energy" of the liquefied gas. Hence, there is a pronounced cooling effect as propane vaporizes, attributable to the latent heat of vaporization of the liquid. Gaseous phase product undergoing a pressure reduction by throttling will also be cooled through adiabatic and Joule-Thompson effects of the resulting gas expansion. The greater the reduction, the more pronounced the effect. Heat transfer through the regulator and associated piping will tend to re-warm this cooled gas toward local ambient conditions. Hence, when a demand for fuel from a utilization appliance exists, we have dynamically variable temperatures through the system. These variations have performance implications.
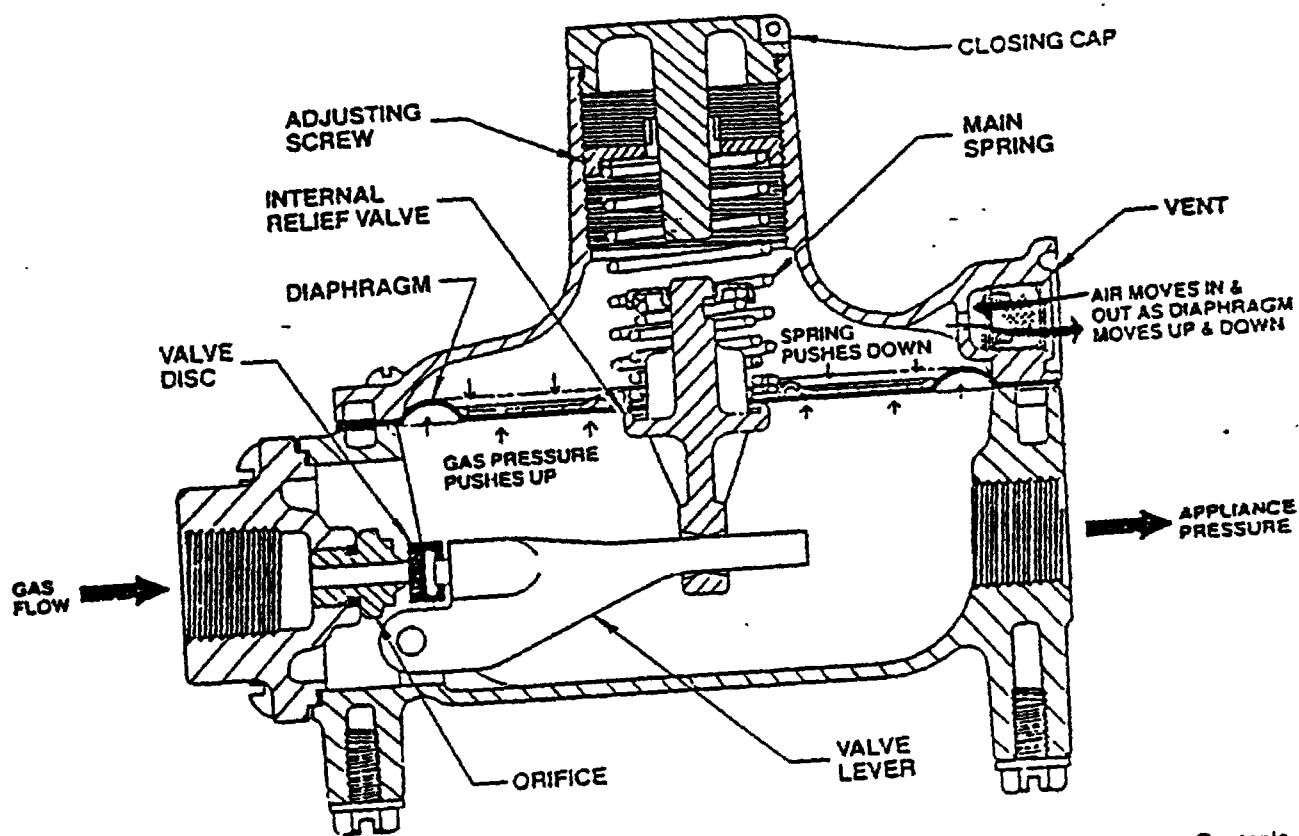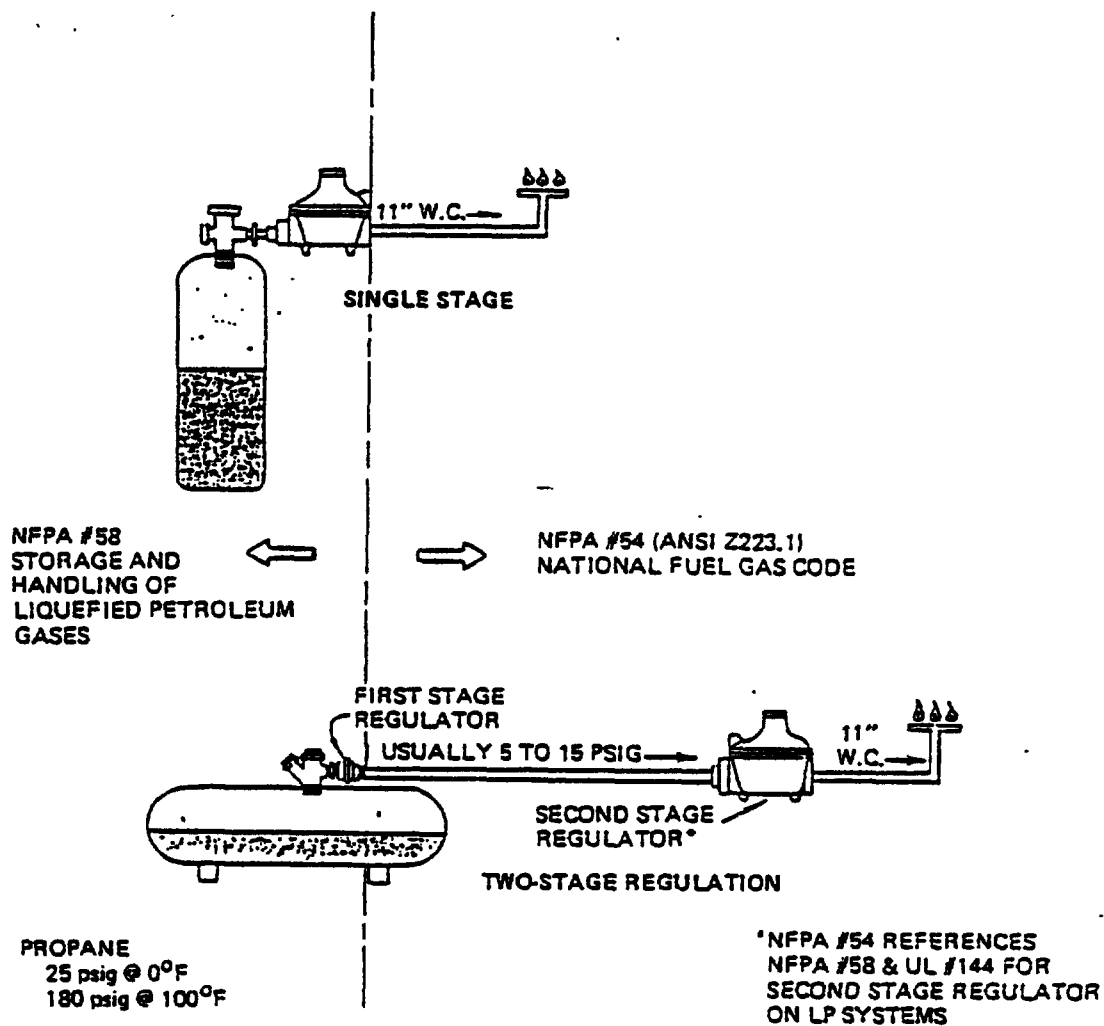
SINGLE STAGE

NFPA #58
STORAGE AND
HANDLING OF
LIQUEFIED PETROLEUM
GASES

⟸ ⟹

NFPA #54 (ANSI Z223.1)
NATIONAL FUEL GAS CODE

11" W.C.

FIRST STAGE
REGULATOR

USUALLY 5 TO 15 PSIG

11"
W.C.

SECOND STAGE
REGULATOR*

TWO-STAGE REGULATION

PROPANE
25 psig @ 0°F
180 psig @ 100°F

*NFPA #54 REFERENCES
NFPA #58 & UL #144 FOR
SECOND STAGE REGULATOR
ON LP SYSTEMS

Figure 5-11   ONE & TWO-STAGE DELIVERY SYSTEM SCHEMATICS

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CLOSING CAP

ADJUSTING SCREW

MAIN SPRING

INTERNAL RELIEF VALVE

VENT

DIAPHRAGM

AIR MOVES IN & OUT AS DIAPHRAGM MOVES UP & DOWN

VALVE DISC

SPRING PUSHES DOWN

GAS PRESSURE PUSHES UP

GAS FLOW

APPLIANCE PRESSURE

ORIFICE

VALVE LEVER

Source: Fisher Controls

Figure 5-12 PARTS OF A LP-GAS REGULATOR

The characteristics and problems which can beset
regulation systems are generally well understood. The
approaches to dealing with them, however, are far from
the point of universal agreement. Even where there is
"agreement" in the form of certain present day designs,
there are quantities of old equipment in the field and
"jury-rigged" systems which elevate the risk of an
injury accident.

5.4.2 Malfunctions-Causes & Effects

Regulator malfunctions cause incorrect delivery
pressures. The ultimate effect may be at a nuisance
level or catastrophic. The most severe effects are
usually associated with high pressures. The effects on
downstream appliance controls and recommendations for
appropriate overpressure protection levels are found in
Section 5.4.3. Low pressures are more often associated
with nuisance outages. However, with certain burner
designs and pressure conditions, potentially dangerous
effects may also be observed.

The major types of regulator malfunctions which
can cause sudden high pressure in the delivery lines
without prior warning include: (1) foreign matter
preventing the regulator disc (seat) from sealing; (2)
breaking or sticking of the relief valve mechanism
(usually caused by corrosion); (3) blocking of the
regulator vent (as by ice).

The regulator vent must remain open so air can
pass in and out as the regulator diaphragm moves. This
vent may be a small slot, hole or a larger threaded and
screened opening. The larger opening may have a "drip
lip" around it to help prevent icing if it is installed
with the opening pointed downward. Even large,

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screened vents can freeze over quickly in a freezing
rain unless protected by a hood or equipped with a drip
lip which is pointed downward. UL #144 has provisions
for freeze protection, but regulators still in the
field often lack the features or are improperly
installed negating the protection. Screens in larger
openings are essential to keep out insects. If the
screens are painted over, or clogged by debris the
regulator will malfunction.

Another regulator problem that requires
replacement or repair will always be evidenced by
abnormally high outlet pressure. This is the result of
foreign matter on the regulator seat (See Fig. 5-13).
This foreign matter may originate from scale in steel
piping, allowed to rust prior to installation, which
may show up on new installations or when systems have
been shut off, such as in summer cabins. It may also
be evidenced after a tank exchange or maintenance
activities.

Another cause of regulator malfuntion is corrosion
of the adjusting spring and relief valve spring (Figure
5-14). Condensation of moisture or corrosive
atmospheres can initiate corrosion of the metal parts.
Flooding or rain entry of improperly located or
positioned regulators can also lead to corrosion. In
the case of flooding, e.g. of improperly vented
regulators on underground tanks, harmful entry of
debris, e.g. sand & dirt may also occur. To inspect
for internal corrosion in a regulator, it is generally
necessary to shut the system down so that the adjusting
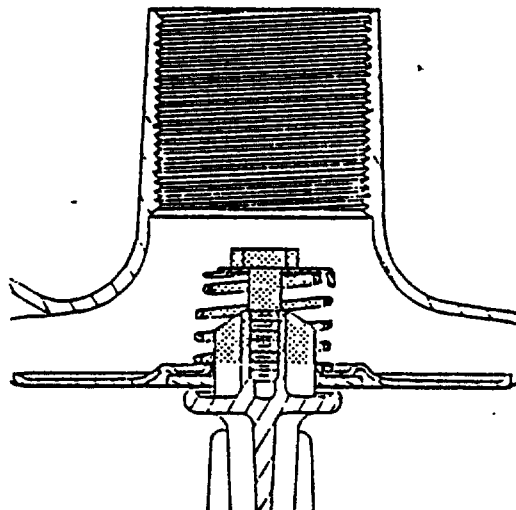screw and spring can be removed.

Other regulator problems may not occur as sudden
failures, but as gradual deterioration. These include

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SCALE, DIRT
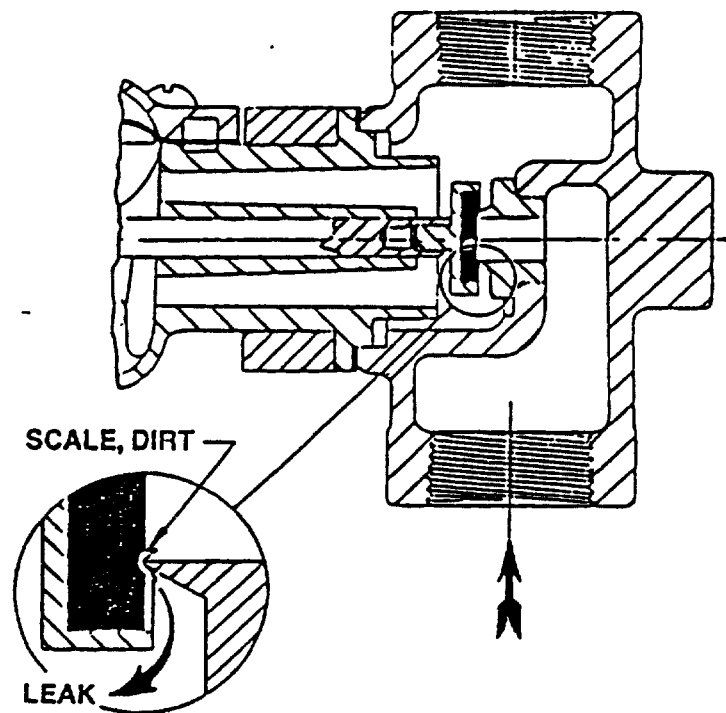
LEAK

Source: Fisher Controls

Figure 5-13 GAS LEAKAGE CAUSED BY CHIPS PREVENTING THE DISC FROM SEATING TIGHTLY ENOUGH AGAINST THE ORIFICE

Source: Fisher Controls

Figure 5-14 PUSHER POST AND INTERNAL RELIEF VALVE ASSEMBLY (SHADED AREA) VULNERABLE TO CORROSION AND STICKING

external leakage and leakage through the regulator in shut-off (lock-up) condition.

Final stage regulators are required to have an overpressure safety device. First stage regulators, at present, have such a device as an option. The provisions as given in NFPA #58-1986[5] are as follows:

2-5.8 Regulators.

2-5.8.1 Final stage regulators (excluding appliance regulators) shall be equipped with one or both of the following [see 3-2.5.2(b) for required protection from the elements which may be integral with the regulator]:

(a) A pressure relief valve on the low pressure side having a start-to-leak pressure setting within limits specified in Table 2-5.8.1.

(b) A shutoff device that shuts the gas off at the regulator inlet when the downstream pressure reaches the overpressure limits specified in Table 2-5.8.1. Such a device shall not open to permit flow of gas until it has been manually reset.

Table 2-5.8.1

Regulator Delivery Pressure in psig (kPa gauge)	Relief Valve Start-to-Leak Pressure Setting, % of Regulator Delivery Pressure	
	Minimum	Maximum
1 (7) or less	170%	300%
Above 1 (7), not over 3 (21)	140%	250%
Above 3 (21)	125%	250%

The shut-off device, alone or in combination with a "conventional" vent relief is rarely found, although several versions are in various stages of development and trial. An example of a typical vent relief system may be found in Figure 5-15. Regulators with a vent relief permit gas to flow in the outlet piping to any connected equipment, whether or not relief operation is acting to control excessive outlet pressure. A high pressure shut-off, once activated, is intended to stop the flow of gas to any connected equipment.

It is extremely important to realize that the start-to-discharge (STD) setting on the relief has

VENT

RELIEF VALVE
SPRING

GAS PRESSURE

RELIEF VALVE
SEAT

GAS PRESSURE

MAIN
SPRING
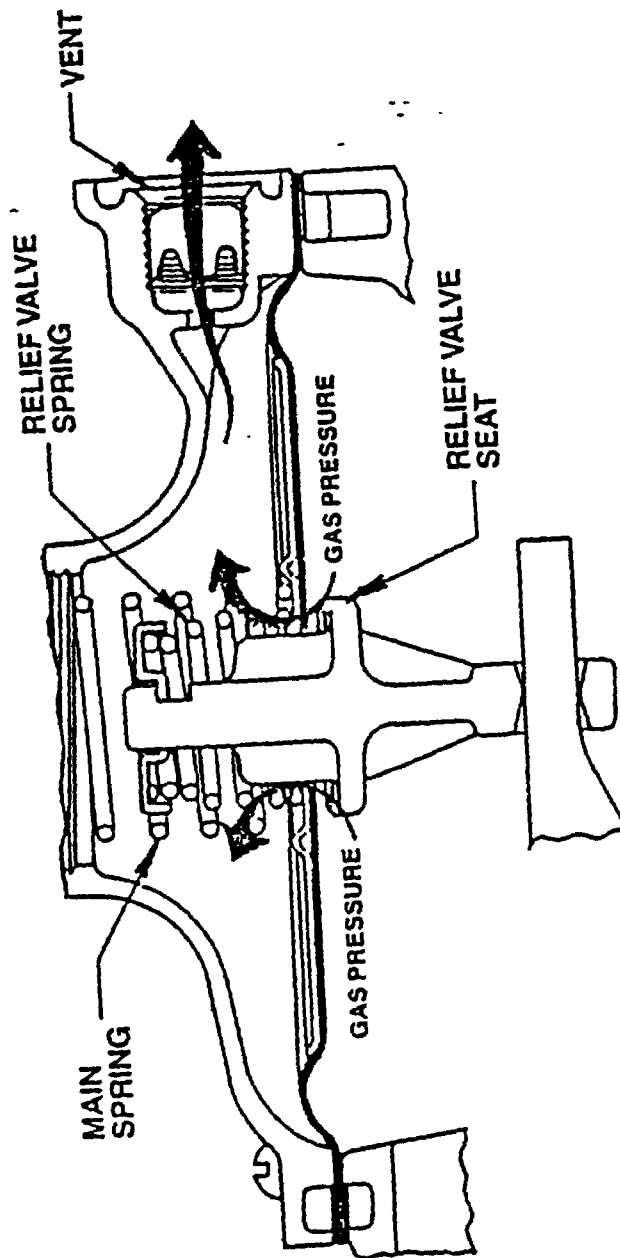
Source: Fisher Controls

Figure 5-15   INTERNAL RELIEF VALVE BEING OPENED BY EXCESSIVE GAS PRESSURE

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little to do with limiting the downstream pressure in the absence of sufficient capacity. Hence, a 300% S-T-D relief on an 11 inch water column delivery pressure regulator does not guarantee something less than 1.2 psig overpressure. UL #144 has a capacity formula and a caveat with regard to the intent. The language of the latter is as follows in the August 14, 1985 version of UL #144:[24]

> "13.3 A pressure-relief valve covered by these
> requirements is intended to reduce the risk of
> excessive buildup of downstream pressure resulting
> from seat leakage that might occur due to a
> slight imperfection at the seating area. Such a
> valve does not necessarily reduce the risk of
> excessive outlet pressure resulting from complete
> inability of the regulator to control the
> pressure." (Underlining supplied by author)

This statement would be made closer to the mark if the word "necessarily" were deleted.

Presumably the concern with providing full capacity, or large capacity relief, on larger regulators is the legitimate fear that a large amount of escaping gas from a regulator may become ignited. Unfortunately, the effect of allowing limited relief capacity is permitting a pressure build-up which will foreseeably end up in an uncontrolled release of gas into the home. Stated another way, you may move potentially explosive gas from outside to right in the living space--a poor alternative.

If one agrees that you do not want overpressure to result in an uncontrolled gas release inside the home, and further agree that a high rate release in the back

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yard is undesirable and possibly dangerous, logic would seem to lead us to the shut-off alternative. There are undoubtedly technical pitfalls in the appropriate design of an effective high pressure shut-off. That notwithstanding, the effort should be made. The most effective rendering may well include retention of a low capacity vent relief to handle the "slight imperfections" problem. Any major failure would result in the high pressure shut-off coming into play. Without the limited relief capacity, however, nuisance shut-offs would be bound to occur due to pressure build-ups under "lock-up" (no demand) conditions.

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5.4.3 Overpressure

Overpressure, as we have noted, has been identified as a causative mechanism in appliance control failures leading to accidents. The full extent of the problem may be hidden by the transient nature of some occurrences leaving a limited evidentiary trail at a fire scene, for example. It is useful to review some of the overall technical issues.

Nominal delivery pressure of LP gas to the home is approximately 11 inches w.c. (approximately 0.4 psig). Appliance regulator setting, where such regulators are applied, is typically 11 w.c. for LP gas. The inclusion or lack of an integral appliance regulator(s) with combination controls and whether or not main gas only or main gas and pilot gas regulation is supplied is entirely dependent on control age and/or product application. At the present time central furnaces must have main gas regulation and water heaters must have both main and pilot regulation. Considering the "universe" of controls in the field the majority of controls in natural gas service will have main gas regulation and the majority of LP served controls will not.

The certified pressure rating for the vast majority of appliance controls in the field is one-half pound per square inch gauge (psig). This rating pressure is of key importance in consideration of overpressure problems.

Full operational pressure ranges for controls for certification testing are 8.0 to 13.0 inches w.c. for Propane HD-5, and LP Gas. Certification tests keyed to the pressure rating of the control are applicable for leakage and structural failure. For 1/2 psig rated valves, 0.0071 standard cubic feet of air per hour (scfh) at 3/4 psig pressure for body leakage (with somewhat higher rates

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permitted through the valve) would be a typical "allowable".
Structural testing (other than a diaphragm) would be at a
minimum 2 1/2 psig. One scfh of air at 1/2 psig would be
permitted through a vent limiter for a control certified for
propane service.

. In general, standards applicable to components of a
combination control (there being no combination control
standard), do not contemplate pressure excursions outside of
the rating design multiple (five), irrespective of the
likelihood of occurrence. Also generally not addressed is
operational status and functions relationship as they affect
safety under pressure excursion conditions, even within
rating.

Control manufacturers can and often do have their own
criteria addressing concerns not covered in Standards
utilized for certification, but they are not necessarily
addressed uniformly or well by all suppliers. In order to
address the question of "what should a control take?" it is
instructive to examine what the overpressure potentials are,
and what safety elements are in place (or perhaps should be)
in the fuel supply system to limit the pressure the control
might "see" under abnormal conditions.

Considering LP gas systems, single stage regulation is
permitted in most cases. Final stage regulators are
required to have a vent relief or high pressure shut-off
under the primary consensus standard for LP gas systems (
NFPA #58). Vent capacity requirements however, under the
principal standard used for regulators (UL #144) do not
assure protection against substantial overpressure under
certain likely-to-occur conditions. LP system maximum
supply pressures are the vapor pressure of the liquefied
gas, which is a function of ambient temperature. Pressures
on the order of 200 psig are possible at 100 degrees F,

whereas pressures on the order of 60 psig at 32 degrees F
may be experienced. Historically, many overpressure
accidents in LP systems have occurred in freezing conditions
due to lack of proper regulator weather protection, or
presence of an obsolete design regulator.

Hence, 60 psig could be considered as a minimum
benchmark for LP gas systems as a likely supply side
overpressure condition. Given overpressure supply
conditions at this level, a capability to limit resulting
utilization pressure to 2 psig may be considered a
reasonable target. There are current regulators on the
market with this claimed relief capability.

It is extremely important to realize that a 2 psig
emergency limit condition valve design, and a 2 psig
"rated", i.e. at normal service conditions valve design per
current standards would not be, per se, equivalent items.
The ability of the control to function completely normally
under 2 psig pressure conditions would be an ideal,
tehnically feasible and accomplished in certain commercial
and industrial equipment. In the context of automatic
control valves for residential equipment the capability of
reaching such a ideal, at least in the near term is
unlikely. However, designs which will function normally at
1/2 psig, and limit substantially the potential for
catastrophic failure resulting in injury and/or loss in the
operating mode at pressures up to 2 psig would appear to be
feasible and reasonable.

It is quite clear an enormous amount of coordination
and cooperation among standards groups and other affected
parties must occur to delineate the guidelines for
overpressure protection throughout the fuel distribution
train. The question cannot be confined just to regulators
or just to automatic control valves for appliances. The

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general recommendations for consideration include the
following:

o   Revise fuel supply system codes such as NFPA #54 &
     #58 to require vent relief system and/or
     high-pressure (HP) shut-offs as appropriate to
     limit pressure to the inlet of controls on
     utilization equipment to 2 psig in the event of
     regulation equipment failure. HP shut-offs could be
     integral to the appliance controls, integral to the
     service regulator, or a separate device such as an
     appropriately pressure rated appliance regulator.

o   Revise the principal standard for LP Gas regulators
     (UL-144) to limit downstream overpressures from
     final stage regulators to 2 psig considering full
     capacity inlet presssures not less than 60 psig.

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5.4.4 Dew Point Curve/Condensation Effects

During the introduction to the section on
regulators we referred to the dynamic temperature
changes and two phase (liquid/gas) phenomena with LPG
delivery systems. One of the concerns is the dew point
phenomenon and problems that may arise if LP-gas vapors
condense back to a liquid in the system.

The point at which condensation is about to occur
is often called the "dew" point while the point at
which vaporization is about to occur is called the
"bubble" point. For a pure component, at a specified
pressure the dew point temperature and the bubble point
temperature are identical. By measuring the dew point
temperature at a number of different pressure
conditions one can generate a curve which relates dew
point temperature to pressure for a pure component.
This curve would be a repeatable characteristic of the
pure components. With two component systems such as a
propane and butane mix, the dew point and bubble point
become functions of composition as well as temperature
and pressure. Furthermore the mixture will exhibit a
"boiling temperature range" at a given pressure rather
then a single boiling temperature. This means that the
bubble point temperature and dew point temperature for
the mixture will not be the same points. Complete
liquid vapor equilibria for the propane butane system
was not reviewed. However the bounds of possible dew
points are established by the dew point curves for the
pure components as shown in Figure 5-16.

The vapor generated by a storage tank recently
filled with 97.5 Propane/2.5 Butane will contain less
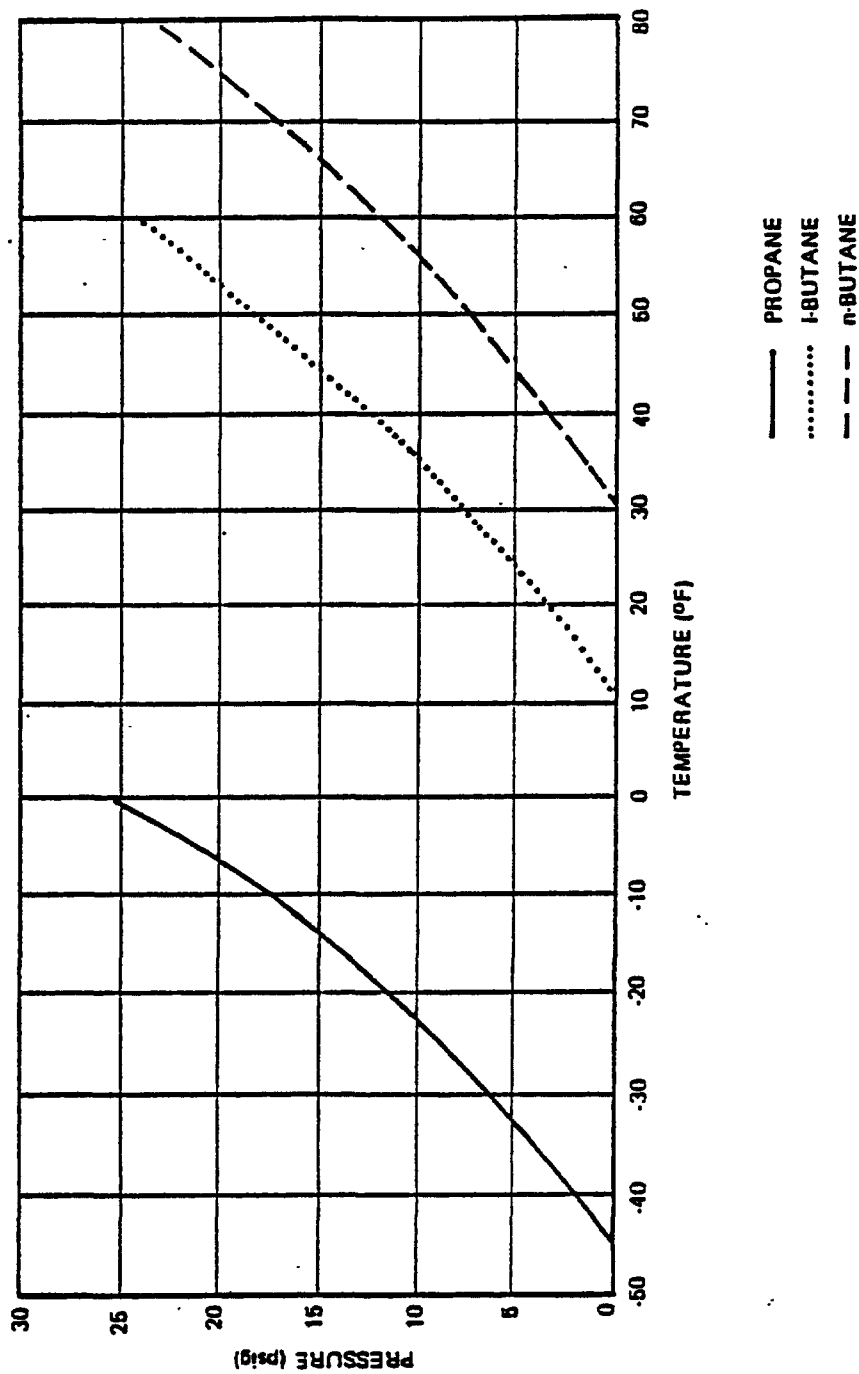than 1% butane at practical operating temperatures and

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Figure 5-16 DEW POINT VS TEMPERATURE FOR SELECTED PURE GASES

——— PROPANE
········ I-BUTANE
— — — n-BUTANE

PRESSURE (psig)

TEMPERATURE (°F)

thus we would expect dew point behavior close to that
of pure propane. As the liquid in the tank is
vaporized the remaining liquid becomes richer in butane
and therefore produces a vapor that becomes enriched
with butane. As this happens the dew point curve will
be moving toward the right in Figure 5-16. When
considering the potential hazard associated with
condensation between stages of two regulator systems
the presence of butane increases the potential for
condensation at somewhat higher temperatures then would
obtain with pure propane. From a practical standpoint
the vapor pressure temperature relationship of butane
is such that in environmental conditions of concern,
that is low temperature, the storage tank will not
generate much if any butane in the vapor. In this case
the system will behave essentially as pure propane and
the presence of butane in the system will not
contribute to a increased hazard as compared to pure
propane.

Although the presence of a small quantity of
higher boiling minor constituents is a limited concern,
there are still considerations which must be made to
reduce the likelihood of liquid formation and/or safely
handling potential overpressures resulting from
re-vaporization of trapped liquid.

In general, dual-stage regulation systems are a
superior design. In fact for permanent installations
it is our recommendation they become required.
However, too high an intermediate pressure in a two
stage system can result in condensation between stages
in low ambient temperature conditions. Referring to
Figure 5-16 for propane, and the 20 psig maximum
allowable by Standard for first stage regulators,
condensation at -5.F could occur. A 5 psig pressure

would depress the condensation point to below - 35.F.
Very clearly, regional set-point criteria should be
developed. Ten psig is a common outlet pressure
setting for first stage regulators.

A "piggy back" or integral case style design of
dual stage regulation is potentially more susceptible
to the condensation phenomena unless the specific
arrangement provides for sufficient heat gain through
the regulator body and perhaps inter-stage relief.
However, single stage regulation, with its heavy
pressure reduction is particularly susceptible to inlet
condensation. If water is a contaminant in the system
it may freeze at the regulator inlet under the certain
atmospheric conditions. With a partial blockage,
low-pressure and improper appliance burner function may
be the result.

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5.5 Concluding Remarks - Containers & Appurtenances, Valves and Regulating Equipment.

We have drummed on a fairly constant theme throughout the text of this report regarding NFPA #58 omissions, inconsistencies and the like for delineating responsibilities for accomplishing inspection requirements or lack of a requirement altogether with certain critical safety items. In other areas the requirements of NFPA #58 are well set forth. It would appear strongly desirable to set up a review task force for containers, valves (including safety-relief) and regulators to insure that the following are all adequately and systematically covered:

o Inspections Required
   o Type
   o Responsible Parties
   o Interval
   o Recordkeeping
   o Quality Audit
      - Training & Certification
      - Performance Check

Details may be better suited for safety materials of the type already rendered by NLPGA. However, the broad terms need the force of the Standard. The task group charged with this responsibility should provide rationales for not requiring that one of these provisions be covered as well as rationales for action.

5.6 Outdoor Portable Cooking Appliances

5.6.1 Introduction

We have previously indicated the priority need for addressing portable grill hazards, considered as a system problem. A major factor in barbecue grill accidents is the assembly of components whose designs are rooted in other use origins, and adapting them to an unsuitable use. In effect, this was the putting together of a number of "rights" to create a "wrong". We are speaking of the fuel cylinder, regulator and hose supply train to the appliance.

5.6.2 Technical Discussion

Figure 5-17 provides a quick reference guide to primary standards covering outdoor portable cooking appliances and components. The principal general Standard is ANSI Z21.58. A suggestion by staff support and others associated with Committee Z21 activities has been made to make good use of the efforts of the working group on a cabinet heater standard where similar concerns existed with outdoor grills. This included such issues as thermal shut-offs, special connectors (quick connect type), high pressure shut-off in lieu of a relief vent on the regulator, etc. As of this writing these proposals appear to be languishing. This study indicates they should be receiving priority attention.

A specific and repeated observation with grill accidents was the appearance of flames near the top of the cylinder. No other viable source of ignition was present save a lighted grill. The precise source of the leak was often unidentified. Where known or postulated, gas souces included leaking connections, an operating relief on the regulator, and on occasion the safety relief valve. Safety-relief valve function was usually identifiable by
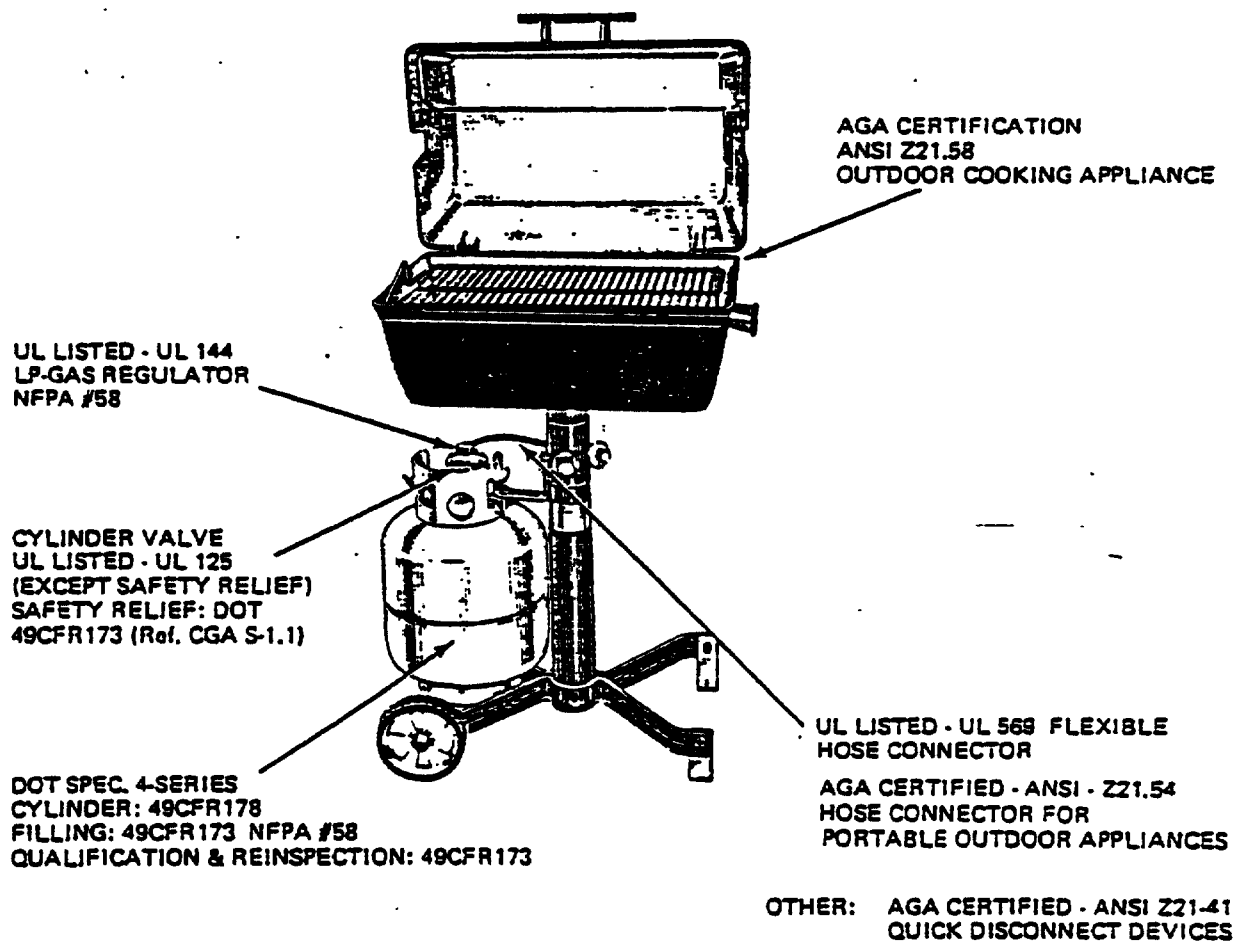
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AGA CERTIFICATION
ANSI Z21.58
OUTDOOR COOKING APPLIANCE

UL LISTED - UL 144
LP-GAS REGULATOR
NFPA #58

CYLINDER VALVE
UL LISTED - UL 125
(EXCEPT SAFETY RELIEF)
SAFETY RELIEF: DOT
49CFR173 (Ref. CGA S-1.1)

UL LISTED - UL 569 FLEXIBLE
HOSE CONNECTOR

AGA CERTIFIED - ANSI - Z21.54
HOSE CONNECTOR FOR
PORTABLE OUTDOOR APPLIANCES

DOT SPEC. 4-SERIES
CYLINDER: 49CFR178
FILLING: 49CFR173 NFPA #58
QUALIFICATION & REINSPECTION: 49CFR173

OTHER: AGA CERTIFIED - ANSI Z21-41
          QUICK DISCONNECT DEVICES

Figure 5-17 PORTABLE OUTDOOR COOKING EQUIPMENT — EXAMPLE CODES &
             STANDARDS

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description of the more spectacular flame plume.

A second feature in the accident scenarios was the rare successful intervention in stopping the flow of escaping gas. Typically, regulator melt down would occur, a rapid increase in fire intensity would ensue, and major loss would follow due to ignition of exposed structures. In general, property loss was high, but injury severity moderate. The exception involved fires in multi-family complexes where property loss and injury occurrence could both be high.

Collectively addressing this problem the following should be considered:

o   Automatic Stop-Fill Device in Cylinder
    Overfill appears to be a substantial problem
    with customer owned containers irrespective
    of end use. As shown earlier, overfill can
    lead to unwanted gas releases, which in grill
    use nearly always leads to ignition.

o   Thermally Activated Shut-Off near outlet
    of manual shut-off valve. Fire in vicinity
    of the cylinder valve may prevent manual
    shut-off by the user (or may be an unattended
    event). Automatic shut-off would prevent
    escalation of fire event to major loss from
    uncontrolled flow of gas.

o   Quick-Connect replacing POL connection
    would provide positive connection and automatic
    shut-off on disconnection at a common leak point.

o   High Pressure Shut-Off on regulator replacing
    relief vent would prevent pressure excursions

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from turning into a fire event.

o Excluding aluminum cylinders for their apparent
   lack of fire resistance, unless appropriate
   testing reveals otherwise.

We believe part of the reluctance to move on some of
these suggestions has been grounded in the understandable
fear of inviting new problems with less familiar or new
design gear. We are aware of past problems with stop-fill
devices in automotive applications, and secondary seal
problems on quick connect devices, for example. However, we
believe the ultimate safety payoff potential of these
features worthwhile to work through design and fabrication
start-up problems.

Another repetitive accident pattern observed was
failure of flexible hose connectors. Unfortunately much of
the data did not permit discrimination to actual point of
failure, such as hose/connector interface, connector itself,
or specifically the hose portion. However, thermal
influence was evident in the failure mode.

UL 569 rates hose connectors for 140.F service (no
rating marking on hose) in the absence of a request for
higher temperature certification. Radiant heat loads from a
grill burner box can create temperatures well in excess of
this value. ANSI Z21.58 does not require hose connectors or
other components of the fuel train to be checked for
temperature rise, or be temperature rated and marked for the
exposure they might see. The tests for exposure level could
be incorporated easily with existing wall and floor
temperature tests routinely performed for appliance
certification. Present standards allow a floor temperature
of 160.F to be reached in 70. F ambient conditions; okay for
a floor. The implied "acceptable" temperature levels for

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components between the grill and the floor with these floor
limits, however, could be ridiculously high, given the laws
of thermal radiation. Therefore, specific criteria and
actual temperature measurement protocols need to be
developed for the fuel train components.

The advisability of requiring high temperature
shut-offs integrated to the connector ends should be
investigated, as well.

Regulators for portable grill use should have their own
specific requirements for construction. Obviously the
overall Standard for the appliance (Z21.58) must have the
appropriate call-outs consistent with a "grill regulator".
For example, the thermal shut-off recommendation is geared
to the low melting point (m.p.) of the regulator, which very
likely is a zinc alloy die casting (m.p. approx. 800.F), or
an alluminum alloy (m.p. approx. 1100.F) vulnerable to fire
destruction. The high pressure shut-off recommendation for
the grill application should be considered independently
from the high pressure shut-off issues with general service
regulators.

The P.O.L. Connection, more formally known as a
Compressed Gas Association (CGA) #510 specification
connection is the cylinder valve standard connection.
Figure 5-18 illustrates this connection, shown here in its
"hard nose" metal to-metal seat form. A "soft" seat form
using an O-ring seal on the male connection is also
available and utilized with portable grills. Accident data
available was insufficient to be able to discern whether the
'O' Ring connection was superior for this application.
Engineering judgment would suggest that is the case because
of the ease with which metal male connection sealing
surfaces can be damaged. The soft seat POL connection,
then, would be the preferred alternative during a POL

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OUTLET   CONNECTION

.885"   .880"
7/8"   7/8"
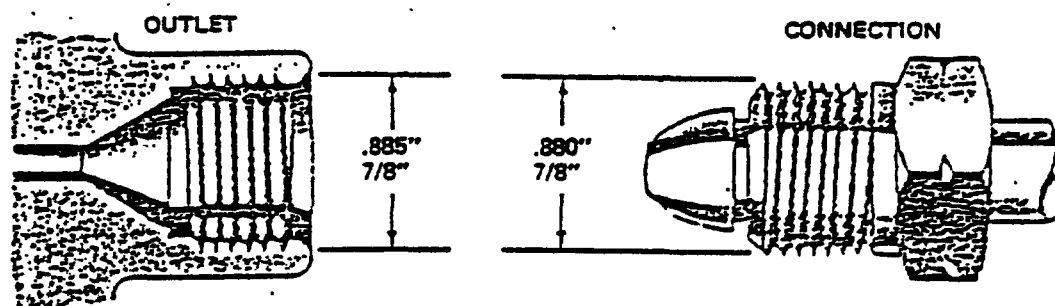
CONNECTION 510
.885"-14 LH INT. ACCEPTING A BULLET SHAPED NIPPLE

Figure 5-18   P.O.L. (CGA #510) CONNECTION

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connection phase out period. Figure 5-19 illustrates a cylinder valve with quick connect fittings and integral thermal safety.

Cylinders, usually 20 lb. DOT Specification 4BA type were involved in a number of accident sequences where the cylinder valve was accidentally opened. Though not "grill" accidents per se, the most frequent reason for the presence of the cylinder in the home environment was associated with a grill. The presence of the automatic shut-off quick connects would prevent this type of accident, although consumers should be educated to still shut the cylinder valve when the container is not in use. POL plugs should, of course be present with any POL terminated valve. Recent industry steps to promote POL plug availability and use are commendable and should continue to be emphasized.

It is useful to refer again to the bar graph of relief valve opening as a function of temperature for various fill conditions (Figure 5-20). The inclusion of an effective stop-fill device means that essentially only the three bars to the left hand side of the graph would be conditions of concern. In other words, premature safety-relief openings can largely be avoided, provided that the radiant heat loadings to the cylinder are controlled. This, as noted earlier, should become part of ANSI Z21.58.

Since the critical element for premature opening is a liquid full condition for those times when air contamination is not a factor, having filled "spare" cylinders on or around a heat producing appliance should be actively discouraged, and banned as an appliance feature. Vulnerability of filled containers, particularly with the risk of overfill present, does not justify increasing the injury and loss risk for convenience.